Nonlinear Upshift of the TEM Critical Density Gradient and other TEM Developments

D. R. Ernst and M. Hoffman
Plasma Science and Fusion Center, Mass. Inst. of Technology, Cambridge, MA, USA
Email: dernst@psfc.mit.edu

Initial nonlinear simulations of TEM turbulence[1] with GS2 found a nonlinear upshift of the TEM critical density gradient, similar to the Dimits shift of critical ion temperature gradient in ITG turbulence. We have since shown the upshift increases strongly with collisionality,[2] consistent with the strong damping of TEMs by detrapping, and the relatively weak collisional damping of zonal flows. The role of secondary instability[3] is evident in the creation of zonal flow dominated states in the upshift regime. During single bursts of particle flux, the growth rate of the potential is approximately proportional to the amplitude of the dominant primary mode. We are now investigating parametric scalings of the upshift.

In contrast with our TEM work, which has focused on density gradient driven cases with $T_i = T_e$ and significant collisionality, a second study,[4] with strong electron temperature gradients and $T_e = 3T_i$, found that zonal flows have little effect on the turbulent saturation level. We have carried out a series of nonlinear simulations in both regimes, based on Cyclone parameters, to address this apparent discrepancy.[5] We found that the presence of the electron temperature gradient drives fine scale spatial structure, which reduces the effect of zonal flows relative to our original case. A simultaneous study[6] has also linked the importance of zonal flows to the electron temperature gradient. We have further developed a stability diagram clarifying the roles of resonant and non-resonant TEMs, based on 2,000 simulations.

After developing a synthetic phase contrast imaging diagnostic for GS2, we obtained close agreement between the measured wavelength spectra of density fluctuations, and simulations of TEM turbulence, in an Alcator C-Mod ITB plasma.[2] TEMs are predicted to dominate the spectrum in ITB cases,[1] and measured and simulated fluxes agree. The ITB serves to localize the chordal PCI measurement, amounting to a direct observation of TEM turbulence in a tokamak plasma. Supp. by U. S. DoE contracts DE-FG02-91ER-54109, DE-FC02-99ER54512, and DoE NUF Program.

[1] D. R. Ernst *et al.*, Phys. Plasmas **11**(5) (2004) 2637.

[2] D. R. Ernst *et al.*, in Proc. 21st IAEA Fusion Energy Conference, Chengdu, China, 2006, IAEA-CN-149/TH/1-3. (http://www-pub.iaea.org/MTCD/Meetings/FEC2006/th_1-3.pdf)

[3] B. N. Rogers, W. Dorland, M. Kotschenreuther, *Phys. Rev. Lett.* **85**(25) 5336 (2000).

[4] T. Dannert *et al.*, Phys. Plasmas **12** 072309 (2005).

[5] M. Hoffman and D. R. Ernst, Bull. Am. Phys. Soc. (2007).

[6] J. Lang, Y. Chen, and S. Parker, *Phys. Plasmas* **14**, 082315 (2007)