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Zonal Flow and Zonal Density Saturation Mechanisms for Trapped Electron Mode Turbulence

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Mode coupling theory and gyrokinetic turbulence simulation is used to study the nonlinear saturation mechanisms of collisionless trapped electron mode (CTEM) turbulence. Turbulence simulations find that the importance of zonal flow is parameter sensitive, but is well characterized by the ExB shearing rate formula. The importance of zonal flow is found to be sensitive to temperature ratio, magnetic shear and electron temperature gradient. For parameter regimes where zonal flow is unimportant, zonal density (a purely radial density perturbation) is generated and is found to be the dominant saturation mechanism. In fact, CTEM turbulence saturates at physically reasonable levels with or without zonal flow. This is in stark contrast to ion temperature gradient driven turbulence where the zonal flow has an order of magnitude effect on the saturation level. A toroidal mode coupling theory is developed that agrees very well with simulation in the initial nonlinear saturation phase (before fully developed turbulence ensues). The theory predicts nonlinear generation of the zonal density and then the feedback and nonlinear saturation of the unstable mode. Inverse energy cascade is also observed in CTEM turbulence and reported here.