Saturation Level of ETG Turbulence

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Goals and motivation

- Goal: Investigate a new saturation level determined by a balance with Landau damping.
- Motivation: In non-linear gyrokinetic simulations large thermal transport levels, beyond mixing length estimates, have been observed for a long time Dorland 2000, Jenko 2000, 2002 ….

Outline

1. Derive ETG model for frequency and growth rate
2. Derive linear GAM frequency.
3. Use e.g. WKE or mode-coupling to derive the growth rate of the GAM.

$$\Omega_q^2 = \frac{5}{3}\frac{c_e^2}{R^2}\left(2 + \frac{1}{q^2}\frac{1}{1+\beta_e/(2q_r^2)}\right)$$

The dispersion relation can be solved perturbatively using $\Omega_q = \Omega_0 + i\gamma_q$ and we find in the electrostatic limit

$$\frac{\gamma_q}{c_e/L_n} \approx \frac{1}{2}\frac{q_r^2\rho_e^2 k_\theta \rho_e}{\sqrt{\varepsilon_n \eta_e}}\frac{1}{1+1/2q^2}\left|\phi_k \frac{L_n}{\rho_e}\right|^2$$

Saturation Mechanism

A predator – prey model is used to find a new saturation level stemming from a balance With the Landau damping.

$$\frac{\partial N_k}{\partial t} = \gamma_k N_k - \Delta\omega N_k^2 - \gamma_1 U_G N_k$$

$$\frac{\partial U_G}{\partial t} = \gamma_q U_G - \gamma_L U_G - \upsilon^* U_G$$

$$N_k = \frac{L_n^2}{\rho_e^2}\left|\phi_k\right|^2 \text{ and}$$

$$U_G = \left\langle \frac{e\phi_G^{(0)}}{T_e}\frac{L_n}{\rho_e}\sin\theta \right\rangle$$

$$\left|\frac{e\phi_k}{T_e}\frac{L_n}{\rho_e}\right|^2 \approx \frac{2L_n}{qR}\left(1+\frac{1}{2q^2}\right)\sqrt{\varepsilon_n\eta_e}\left(\frac{4}{3}\sqrt{\frac{2}{\pi}}+\upsilon^*\right)\left(\frac{k_y}{q_x}\right)^2\left(\frac{1}{k_y\rho_e}\right)^3$$

$$\left|\frac{e\phi_k}{T_e}\frac{L_n}{\rho_e}\right| \approx 30-40$$

L_n=0.05, q=3.0, R=4, ε_n=0.025, $1/q_x = (2\rho_e L_T)$^(1/3), $k_y \rho_e$ =0.3 and k_y/q_x = 4.