TEMPERATURE RELAXATION PROCESSES IN TURBULENT INHOMOGENEOUS PLASMA WITH UPPER HYBRID PUMP

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In this report, we present the influence of parametric instability in a magnetized inhomogeneous plasma on the properties of high-frequency (HF) plasma with pump. Consider the electron-ion inhomogeneous plasma in an external magnetic field $B_{0\bar{z}}$. The plasma is subjected to an HF pump field, which is directed perpendicularly to $\bar{B}_0$. For a long wavelength ($k_0 = 0$) pump wave, we can write $\bar{E}(t) = E_0\bar{y}\cos\omega_0 t$. Study the case when the pump wave frequency ω_0 is close to the upper-hybrid frequency

$$\omega_{\mathrm{UH}} = \Omega_e\left(1 + \frac{\omega_{\mathrm{pe}}^2\sin^2\theta}{2\Omega_e^2}\right) \tag{1}$$

The expression (1) is valid in a strongly magnetized plasma for the case $\omega_{\mathrm{pe}} \ll \Omega_e$. The damping rate of the upper-hybrid wave $\gamma_{\mathrm{UH}} \approx \nu_{\mathrm{ei}}$.

The frequency and the damping rate of the electron drift wave are

$$\omega_D \approx -\frac{k_{\perp}\alpha T_e}{m_e\Omega_e} \quad , \tag{2}$$

(where $\alpha = n_0^{-1}\,\mathrm{d}n_0/\mathrm{d}y$ is the parameter characterizing the plasma density inhomogeneity)

$$\gamma_D = -\left(\frac{\pi}{2}\right)^{1/2}\omega_D\left[\frac{-\omega_D k_x^2\rho_i^2(1+T_e/T_i)}{2k_{\mathrm{II}}v_{T_e}} + \frac{T_e}{T_i}\frac{\omega_D(1+T_iT_e}{2k_{\mathrm{II}}v_{T_i}}\exp\left(-\frac{\omega_{\mathrm{De}}^2}{2k_{\mathrm{II}}^2v_{\mathrm{II}}^2}\right)\right] \ . \tag{3}$$

Consider the case when the second (ion) term in (3) is dominant. Note that the scale size of the density gradient $L = 1/\alpha$ must satisfy the condition of weak inhomogeneity $\lambda \ll L$, where $\lambda = 2\pi/\ k_{\perp}$ is the wavelength of drift plasma oscillations.

For the obtaining the relaxation time between the electron and ion temperature τ_{ei} we use the formula [1,2]

$$\frac{1}{\tau_{\mathrm{ei}}} = -\frac{W_i}{\frac{3}{2}n_eT_e} \quad , \tag{4}$$

where W_i is the power density for the plasma ion component.

Present the power density W_i in the form [3]

$$W_i = \int\frac{d\bar{k}}{(2\pi)^3}\int\frac{d\omega}{2\pi} < \delta\bar{E}\delta\bar{E} >_{\omega,\bar{k}} \frac{1}{4\pi}\omega\,\mathrm{Im}\chi_i^o \tag{5}$$

where $< \delta\bar{E}\delta\bar{E} >_{\omega,\bar{k}}$ is the spectral density fluctuations of the electric field.

Investigate the relaxation process when the parametric decay of the pump wave into upper-hybrid and electron-drift waves occurs

$$\omega_0 = \omega_{\mathrm{UH}} + \omega_D \quad . \tag{6}$$

Note that ω_0 must be slightly above ω_{UH} because $\omega_D \ll \omega_0, \omega_{\mathrm{UH}}$. The threshold for such instability is [4]

$$E_{\mathrm{th}}^2 = \frac{8\omega_0^2B_0^2}{k^2c^2}(\mathrm{qr_{De}})^2\frac{\omega_{\mathrm{pe}}^2}{\Omega_e^2}\frac{\nu_{\mathrm{ei}}}{\Omega_e}\frac{\gamma_D}{\omega_D} \quad . \tag{7}$$

In the region above the instability threshold the plasma becomes turbulent. Using the nonlinear stabilization mechanism that leads to saturation of the fluctuation level [4] we obtain the expression for $< \delta\bar{E}\delta\bar{E} >_{\omega,\bar{k}}$.

Taking into account (5) and using (4) we find

$$\frac{1}{\tau_{\mathrm{ei}}} \approx \frac{1}{32}\frac{e^2}{m_eT_e\omega_0^4}\frac{E_0^4}{B_0^2}\frac{(\mathrm{kc})^2}{(\mathrm{kr_{De}})^2}\frac{\Omega_e^2}{\omega_{\mathrm{pe}}^2}\frac{\Omega_e}{\nu_{\mathrm{ei}}}\frac{\omega_D}{\gamma_D}(\gamma_D\gamma_{\mathrm{UH}})^{1/2} \quad . \tag{8}$$

We see from (8) that the inverse relaxation time grows with increasing density gradient and pump wave intensity. Note also the sharp dependence $1/\tau_{\mathrm{ei}} \sim \omega_0^{-4}$.

Comparing (8) with the $\frac{1}{\tau_{\mathrm{ei}}^0}$ in a magnetized homogeneous plasma without pump [5] we find

$$\frac{1}{\tau_{\text{ei}}}\Big/\frac{1}{\tau_{\text{ei}}^{0}} \approx \frac{\pi^{3/2}}{9}\frac{n_e r_{\text{De}}^3}{\ln(\frac{\Omega_e}{\omega_{\text{pe}}})\ln(\frac{m_i}{m_e})}(\frac{m_i}{m_e})^{1/2}\frac{\mu^2}{(\text{kr}_{\text{De}})^2}(\frac{v_E}{v_{\text{Te}}})^2\frac{\Omega_e^2}{\omega_{\text{pe}}^2}\frac{\Omega_e}{\nu_{\text{ei}}}\frac{\omega_D}{\gamma_D}\frac{(\gamma_D\gamma_{\text{UH}})^{1/2}}{\omega_{\text{pi}}} \tag{9}$$

where $\mu = \frac{\text{kE}_0 c}{\omega_0 B_0}$, $v_e = \text{eE}_0/m_e\,\omega_0$. For hot plasma parameters: $n_e r_{\text{De}}^3 \approx 10^8, \mu \approx 5\times 10^{-2}, v_E/v_{\text{Te}} \approx 10^{-4}, \text{kr}_{\text{De}} \approx 10^{-1}, T_e \approx 1\text{keV}, B_0 = 50\text{kH}$ we have

$$\frac{1}{\tau_{\text{ei}}}\Big/\frac{1}{\tau_{\text{ei}}^{0}} \sim 10^4 - 10^5$$

Thus, the presence of parametric instability in a magnetized inhomogeneous plasma leads to a significant growth of HF plasma heating.

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