§15. Nonlinear Competition between Zonal Flows and Geodesic Acoustic Modes

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It has been known that the zonal flows (ZFs) and geodesic acoustic modes (GAMs) are destabilized by microscopic fluctuations in the range of drift wave frequencies [1]. The rates, at which ZFs and GAMs are driven by background microscopic turbulence, have been derived [1,2]. The nonlinear saturation of the Reynolds stress, when the ZFs have finite amplitude, was also derived [3]. That is, when the induced flow has finite amplitude, the drift wave spectrum is deformed so that the energy input from turbulence to the flow is suppressed. This result was derived by renormalizing the higher order kinetic of quasiparticle response. Under the presence of ZFs and GAMs, the deformation of drift wave spectrum causes the modification of the driving rates of ZFs and GAMs. Thus, the nonlinear competition between ZFs and GAMs occurs. The turbulent transport is strongly affected by the inclusion of zonal flows. Thus, the competition between ZFs and GAMs must be taken into account, in order to analyze the turbulent transport in toroidal plasmas.

In order to study the competition between the ZFs and GAMs, the effect of the return flow along the magnetic field line must be taken into account. The coupling of the poloidal flow to the parallel flow enhances the effective inertia of plasma [4]. For ZFs, one has an enhancement factor for the effective inertia $1+2q^2$ (in the plateau regime). The back interaction of the ZFs and GAMs on drift wave turbulence closes the set of coupled equations, which determines the level of turbulence and turbulent transport. The self-consistent solution of the microscopic fluctuations, ZFs and GAMs is obtained. The competition between ZFs and GAMs is summarized in the parameter space of the damping rates [5].

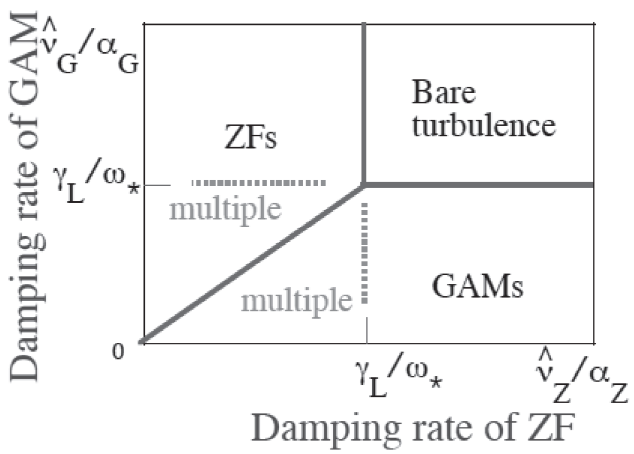
In a normalized form, a set of the energy balance equations are given for drift waves, zonal flows and GAMs as

$$\gamma_L \hat{\phi}^2 - \omega_* \hat{\phi}^3 - \hat{\nu}_Z Z - \hat{\nu}_G G = 0 ,$$

and

$$\hat{\nu}_Z Z = \frac{\alpha_Z \hat{\phi}}{1 + h\dfrac{Z+G}{\hat{\phi}^2}} Z , \quad \hat{\nu}_G G = \frac{\alpha_G \hat{\phi}}{1 + h\dfrac{Z+G}{\hat{\phi}^2}} G ,$$

where $\hat{\phi}^2 = \left(k_\perp^2 L_n / k_\theta\right)^2 \left| e\tilde{\phi}/T \right|^2$ is the normalized fluctuation, $Z = \left(U_Z/\omega_*\right)^2$ and $G = \left(U_G/\omega_*\right)^2$ are normalized vorticity, nonlinear decorrelation rate $\Delta\omega_k \simeq \omega_* \hat{\phi}$, α_Z and α_G are coupling coefficients, and damping rates $\hat{\nu}_G = \left(1 + q^{-2}/2\right)\nu_G$, $\hat{\nu}_Z = \left(1 + 2q^2\right)\nu_Z$. (See [3] for explanation of coefficients.) Competition between ZFs and GAMs is possible to occur in the region $\hat{\nu}_Z/\alpha_Z < \gamma_L/\omega_*$ and $\hat{\nu}_G/\alpha_G < \gamma_L/\omega_*$. One has $2q^2 \nu_Z < \nu_G$ for preferential excitation of zonal flows. Domains of ZFs and GAMs are summarized in the figure.



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