§26. Fluctuation Level of Turbulence in the L-mode Plasma of Tokamaks

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Determination of the level of fluctuations level and the their characteristic scale length is the key problem for the toroidal plasma confinement research. Conventional argument for the saturation of fluctuation is based on the picture that the linear growth rate γ^L balances with nonlinear damping, Dk^2, where k is the wave number [1]. This picture provides the view that the most (linearly) unstable mode dictates the turbulence nature. The experimental observation, however, does not support this prediction. We proposed a new approach for the turbulence and transport [2]. It is shown that the anomalous transport can cause nonlinear instabilities in toroidal plasmas. The balance between the nonlinear stabilization determines the stationary turbulence.

The typical mode number of the mode, which is most strongly driven by the nonlinear interactions, is given as

$$k_\perp = h(s)/\delta\sqrt{\alpha}$$

where $\alpha = -q^2R\beta'$ denotes the normalized pressure gradient ($\beta=\mu_0 n_i(T_e+T_i)/B^2$, q is the safety factor), and δ is the collisionless skin depth, c/ω_p. The coefficient h(s) is about 0.1 for the parameter of $s\approx1$, and $h(s)\approx1$ for small shear case ($s=r(dq/dr)/q$). The fluctuation level is also given as

$$\frac{e\tilde{\varphi}}{T} \approx \frac{q^2}{f(s,\alpha)}(-R\beta')^{3/2}\,\delta^2\,\frac{v_{Ap}}{a}\,\frac{eB}{T}$$

where v_{Ap} is the poloidal Alfven velocity $\tau_{Ap} = a\sqrt{\mu_0 m_i n_i}\,/\,B_p$, B_p is the poloidal magnetic field Br/qR. The function f denotes the influence of the magnetic shear and the Shafranov shift. This term f is fitted as $0.4\sqrt{s}$ in the strong shear limit, and approximated as

$$f(s,\alpha) = (1+2\alpha-2s)\sqrt{\{2+6(s-\alpha)^2/(1+2\alpha-2s)\}}$$

in the weak/negative shear limit.

The result shows the parameter dependence as well as the spatial profile of the fluctuation level. The fluctuation level is a strong increasing function of the pressure gradient. The density dependence shows that, the level is decreasing by increasing if the density is increased, assuming that the pressure gradient is unchanged. It is also shown that the relative fluctuation amplitude is larger near edge.

The fluctuation and transport is in the regime of the strong turbulence and the relation

$$\frac{e\tilde{\varphi}}{T} \approx \frac{eB}{T}\chi$$

holds. The difference of the fluctuation amplitude between core and edge is more prominent than that of the transport coefficients by the dependence of 1/T.

References

1) Kadomtsev B B: in *Plasma Turbulence* (Academic press, New York, 1065),
2) Itoh K, Itoh S-I and Fukuyama A: Phys. Rev. Lett. **69** (1992) 1050.