§5. On Influences of Long-Range Fluctuations on Transport in Large Helical Device Plasmas

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The competing effects of the long-range fluctuation, which has been found on LHD [1], on thef net turbulent transport are discussed. The transport, which is driven directly by this mode, is evaluated. Then, the associated reduction of fluctuations in the range of drift wave turbulence is analyzed, by employing the predator prey model. The transport driven by microscopic turbulence is reduced by the appearance of long-range fluctuations. Comparing these two competing processes, the condition is derived for the net transport to be reduced by the appearance of this long-range fluctuation. In addition, the experimental observations of microscopic fluctuations are discussed. The reduction of high-frequency fluctuations occurs in conjunction with the long-range fluctuations.

Theory

Back interaction of the long-range fluctuations to drift wave turbulence is evaluated by use of predator-prey model for drift wave intensity W and that of long-range fluctuation S (where both are normalized to the kinetic energy density associated with the diamagnetic drift velocity):

$$\frac{d}{dt} W = \hat{\gamma}_L W - \hat{\omega}_2 W^2 - \alpha S W, \qquad (1)$$

where the growth rate γ_L, the nonlinear damping rate ω_2, and time-derivative are normalized ($\hat{\gamma}_L = \gamma_L/\omega_*$ and $\hat{\omega}_2 = \omega_2/\omega_*$). The coefficients $\hat{\gamma}_L$, $\hat{\omega}_2$, and α are considered to be of the order unity. See, e.g., [2, 3]. From Eq.(1), the reduction of transport by drift wave turbulence is computed. The condition, that the reduction in the transport by drift waves is larger than the additional transport by the long-range fluctuation, is derived as

$$\frac{\hat{\gamma}_L}{\alpha} < \frac{\gamma_{\mathrm{dec}}}{\gamma_{\mathrm{dec,\,drift}}} \left\{ 1 + \left(\frac{2\pi r}{\lambda_r} \right)^2 \right\}, \qquad (2)$$

where γ_{dec} and $\gamma_{\mathrm{dec,\,drift}}$ are the decorrelation rates of long-range fluctuations and drift waves, respectively, and λ_r is the radial wavelength of the long correlation mode. By using the estimate near the stability boundary [2, 4] $\alpha \simeq \omega_*/\gamma_L$, the inequality relation (2) is given as

$$\left(\frac{\gamma_L}{\omega_*} \right)^2 < \frac{\gamma_{\mathrm{dec}}}{\gamma_{\mathrm{dec,drift}}} \left\{ 1 + \left(\frac{2\pi r}{\lambda_r} \right)^2 \right\}. \qquad (3)$$

The RHS of inequality relation (3) has been evaluated to be of the order of $1/10$ in the experiment. Away from the marginal stability, the long-range fluctuation as a whole enhances the transport for the present parameters.

Experiments

Temporal evolutions of squared intensity of microscopic turbulence and long-range fluctuation, $I_d(t)$ and $I_l(t)$, are deduced from fluctuation signals. The cut-off frequency for high-pass filter is as 50 kHz. In order to understand the quantitative influence of long-range fluctuations on microscopic fluctuations, statistical analysis is performed The figure 1 illustrates the Lissajous plot of two signals, $I_l(t)$ and $I_d(t)$. The Gauss least square fitting is shown by solid line. The least square fitting provides that

$$\frac{I_d(t)}{\langle I_d \rangle} = 1.068(\pm 0.016) - 0.068(\pm 0.014) \frac{I_l(t)}{\langle I_l \rangle} \qquad (4)$$

where $\langle I_d \rangle$ and $\langle I_l \rangle$ are the time averages of $I_d(t)$ and $I_l(t)$. That is, about 6~7% reduction of background fluctuations is observed associated with the long-range fluctuations in this discharge.

It is statistically admissible that the smaller value of $I_d(t)$ is associated with the larger value of $I_l(t)$. This result confirms, qualitatively, theoretical considerations.

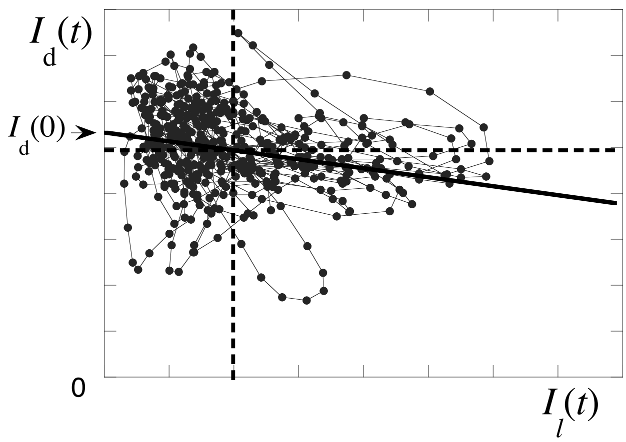

Figure 1: The Lissajous plot of two signals, $I_l(t)$ and $I_d(t)$. Both $I_l(t)$ and $I_d(t)$ are given in arbitrary units, and dotted lines show the mean values. Solid line indicates the least-square fitting.

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