§16. Characteristics of Turbulent Transport in Flux-driven L-mode Plasmas

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L-mode transport exhibiting profile stiffness is the basis in understanding fusion plasmas while the mechanism including the transport scaling has not been fully resolved. A transition from Bohm to gyro-Bohm scaling with respect to a/ρ_i has been observed in gradient-driven ITG simulations while not confirmed in flux-driven global ones [1-3]. Here, we elucidate the overall picture of the L-mode transport dominated by the ITG turbulence using GKNET incorporated with statistical analyses [4].

ITG turbulence and ExB dynamics: Figure 1 shows the evolution of (a) heat flux Q_{tub} and radial electric field E_r for P_{in} = 16MW with the plasma of a/ρ_i = 150 and $\nu_* = 0.0656$. The transport is classified into three regions, (I) heating region, (II) source/sink free region, (III) sink region. The temperature is found to be self-organized exhibiting an exponential function form while the scale length L_T is changed at $r \sim r_*$ indicating the weak transport barrier formation.

In region (I), quasi-periodic radially localized avalanches are observed in the heat flux Q_{turb} due to the ITG mode. The radial electric field E_r is excited in both boundaries of the mode as zonal flow and propagates outward with the heat flux accompanied by the zonal pressure. The quasi-periodic occurrence of the events regulated by the external heat input is found to produce quasi-steady $E \times B$ flow layer at two radial locations, $r_a \sim 10\rho_i$ and $r_b \sim 40\rho_i$.

In region (II), the radially extended ballooning modes which range from meso ($\sim \sqrt{L_T\rho_i}$) to macro ($\sim L_T$) scale are excited intermittently due to the instantaneous phase alignment of potential vortices. The zonal flow and pressure produced at the inside boundary of the ballooning mode coincides with the $E \times B$ flow layer at $r_b \sim 40\rho_i$, suggesting that the inner boundary of the ballooning mode is connected to the heating edge, i.e. $r \sim r_b$, while outer boundary $r \sim r_c$ is undetermined. It is noted that $r_c - r_b$ corresponds to the radial correlation length of the ballooning mode, i.e. $\ell_c \sim r_b - r_c$. If ℓ_c is almost same for successively produced ballooning modes, the quasi-steady $E \times B$ staircase is produced at outer boundary of the mode, i.e. $r \sim r_c$. In Fig.1(b), the $E \times B$ staircase located $r \sim r_c$ exhibits dynamical evolution toward outside so that $\ell_c \sim r_b - r_c$ becomes wider. This suggests that turbulent spreading takes place.

Statistical analyses: Figure 2 shows the heat flux distribution $Q(r,\theta)$ in the phase of (a) quasi-steady state and (b) burst. Using the data, we investigated the PDF for the eddy size S providing the heat flux Q, i.e. $P(S)$. The power law dependence $P \propto S^{-1}$ is obtained up to $S \sim 100\rho_i^2$ for case (a) and $S \sim 200\rho_i^2$ for case (b) while damped quickly beyond them. The results indicates that the heat flux driven by the eddies with $S < 100\rho_i^2$ provide the base transport. However, a hump appears in the burst case (b) around $S \sim 600\rho_i^2$ which corresponds to the radially extended ballooning modes shown in Fig.2 (b).

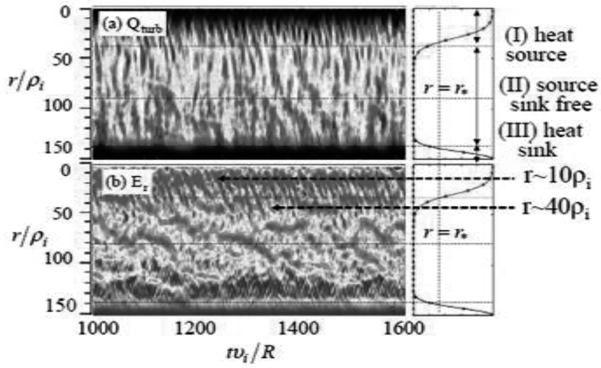

Fig.1. Spatio-temporal evolutions of normalized (a) heat flux, (b) radial electric field in the case of P_{in}=16MW.

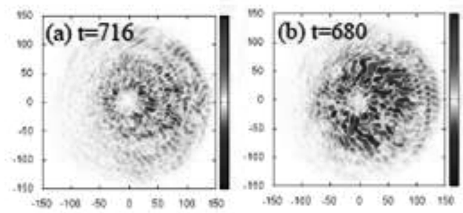

Fig.2: Q(r,θ) at steady state phase (a) and burst phase(b).

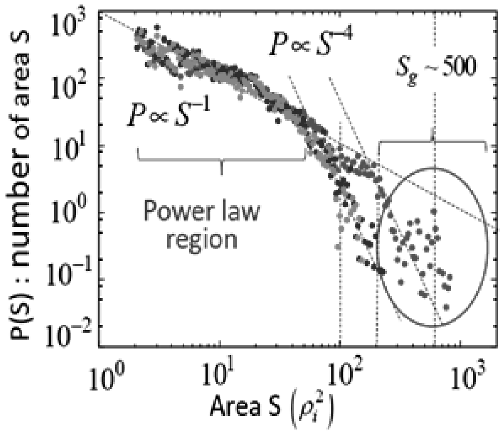

Fig.3: Heat flux size PDF for Fig.2 (a) (blue) and (b) (read).

We have investigated the Hurst exponent H using the heat flux data. The value is found to increase from center ($H \sim 0.57$) toward edge ($H \sim 0.8$), suggesting that the whole plasma exhibits long range correlation while the degree increase toward edge.

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