NONLOCAL BEHAVIOR OF TURBULENCE IN THE PRESENCE OF POLOIDALLY LOCALIZED HEAT SOURCE

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Recent research using GYSELA, the global full-F gyrokinetic code, has shown that time-modulated heat source can be utilized to analyze non-local transport events, such as turbulence spreading and avalanche-like transport [1]. Figure 1 a) shows that the phase of time-modulated heat source has correlation with diffusive and avalanche-like transport. To understand the correlation between the heat source and turbulence spreading in detail, we estimate the propagation speeds of heat and turbulence pulse, with respect to the frequency of time-modulated heat source. From Figure 1 b), we can see that propagation speed of turbulence is faster than that of heat pulse, regardless of the frequency. It is natural, since the timescale of the period of source is in the order of transport timescale. Also, we observed that the propagation speed has linear dependency on the frequency. According to previous works on heat pulse, the propagation speed is known to be proportional to the square root of the frequency and turbulence intensity [2]. However, our estimation can be justified since turbulence driven by time-modulated heat source is proportional to the frequency.

We extend this research to study the effects of poloidally localized, time-modulated heat source on turbulence. Recent analytic study reveals that a poloidally inhomogeneous heat source can trigger different types of geodesic acoustic mode (GAM) [3]. In the case of heating at low field side, there's heat source-driven geodesic acoustic mode, referred to as Q-GAM. Whereas, heating at high field side can excite the E-GAM. So, we analyze the behavior of GAM with respect to poloidally asymmetric heat source, and possible effects on poloidal asymmetry of turbulence, and $E \times B$ shear layer.

In this synopsis, we introduce the simulation results when there is upper and lower heat source, respectively. The simulations on Ion Temperature Gradient-driven (ITG) turbulence have been performed in the presence of poloidally localized heat sources placed at upside and downside of toroidal geometry. Note that simulation has been performed in concentric circular geometry and localized heat source has been implemented after plasma relaxed to near-marginality. Each localized heat source is activated at $1.5 \times 10^5 \omega_c^{-1}$ and deactivated at $1.9 \times 10^5 \omega_c^{-1}$, aiming to induce source-driven nonlocal transport.

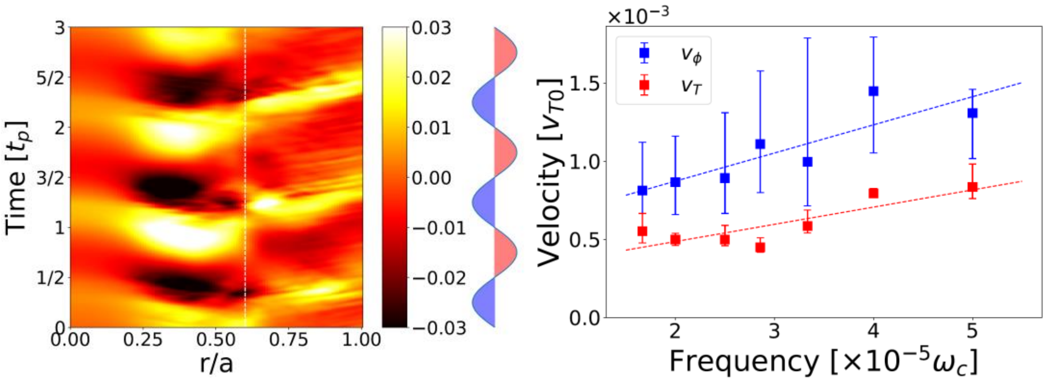

Figure 1 a) (Left Figure) Time evolution of the perturbed temperature in the presence of time-modulated heat source. Here, $t_p = 4.0 \times 10^4 \omega_c^{-1}$ is the period of time-modulated heat source. Sinusoidal graphs on the R.H.S. is the amplitude of heat source in time. b) (Right figure) Propagation speed of heat and turbulence with respect to the frequency of modulated heat source $f = 1/t_p$.

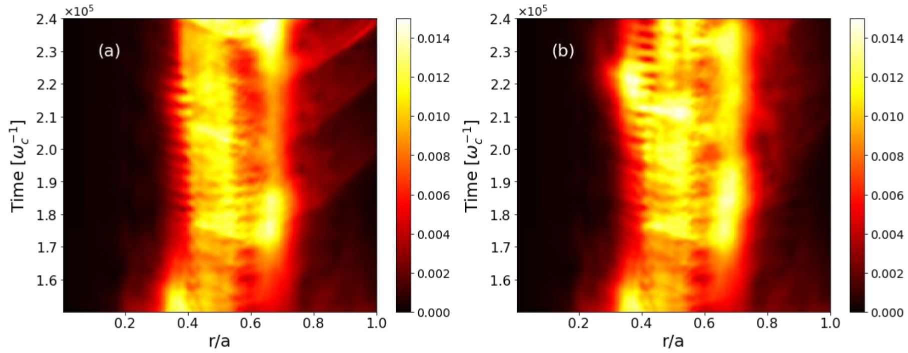

Figure 2 Time evolution of flux surface averaged turbulent fluctuations, $|\phi| = \sum_{m,n\neq 0} |\phi_{mn}|$. Here, heat source is located at (a) upside, and (b) downside, respectively.

Figures 2 and 3 illustrate time evolutions of electrostatic fluctuations, $|\phi| = \sum_{m,n\neq 0} |\phi_{mn}|$, and $E \times B$ shearing rate, $|\omega_{E\times B}|$, in the presence of heat source on upside or downside, respectively. Regarding electrostatic fluctuations, upper heating shows stronger propagation toward the edge, whereas lower heating demonstrates more pronounced propagation toward the core. This difference can be explained by behavior of $E \times B$ shear layer. Specifically, for upper heating, the void region in the $E \times B$ shear layer exhibits stronger propagation toward the edge, closely related with turbulence propagation. Conversely, in lower heating scenario, this void is less pronounced. However, at $t \sim 2.2 \times 10^5 \omega_c^{-1}$, a momentary weakening of the $E \times B$ shear layer at $r/a \sim 0.4$ is observed, coinciding precisely with the propagation of turbulence towards the core. These observations demonstrate that the up-down asymmetry of the heat source can affect $E \times B$ shear layer and nonlocal transport even in concentric circular geometry.

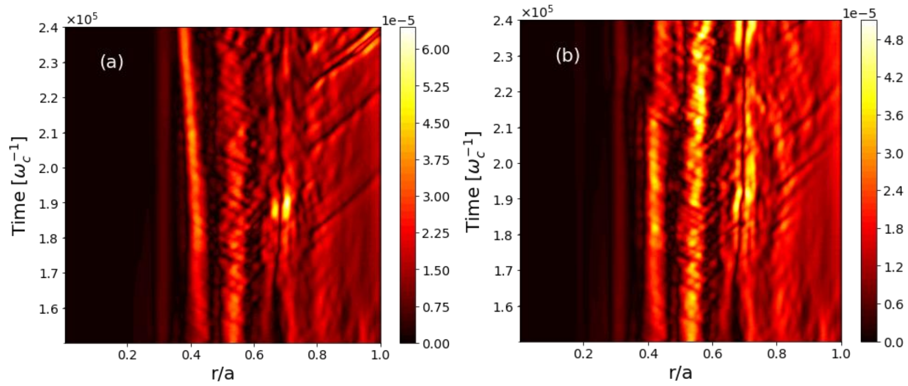

Figure 3 Time evolution of $E \times B$ shearing rate, $|\omega_{E\times B}|$. Here, heat source is located at (a) upside, and (b) downside, respectively.

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