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Dynamics between energetic particles driven instabilities, lower frequency flow and turbulence on EAST

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The interactions between instabilities associated with energy redistribution result in a variety of operating characteristics that are highly self-organized in magnetically confined plasma[1]. The multi-scale interaction between energetic particles (EPs) driven instabilities and turbulence is a topic of general concern in burning plasma, which is relevant for the EPs confinement and abnormal energy transport. While zonal flow could act as a mediator of the cross-scale interactions[2,3]. The designed experiments were dedicated in EAST to study the dynamics between turbulence and TAEs, turbulence and fishbone instabilities.

The enhancement of lower frequency poloidal plasma flow (LFF) and suppression of turbulence is observed with CO_2 laser collective Thomson scattering (CTS) diagnostic when the fishbone instabilities are excited in experiments, shown in figure 1. TGLF simulation indicate the suppressed turbulence could be TEM and ETG turbulence, and simulations with M3D-K code indicate that fishbone instability can enhance the local radial electric field with mode number n=0. The validation of experiments and simulations suggests that the fishbone instability can accelerate the lower frequency poloidal plasma flow, suppress turbulence, and improve the confinement.

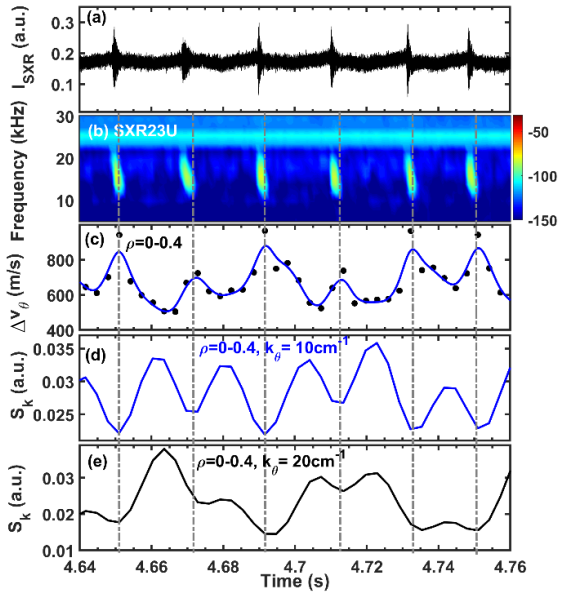

Figure 1. Time evolutions of (a) soft X-ray, (b) fishbone instabilities detected with soft X-ray, (c) plasma core poloidal rotation velocity, the core region turbulence intensity (d) at k_θ = 10 cm^{-1} and (e) at k_θ = 20 cm^{-1}.

Besides, by carefully mitigating TAE amplitude to a non-zero level with RMPs, turbulence suppression and LFF generation are also observed. After RMP rapidly reduces the TAEs amplitude four times. Turbulence suppression and the LFF generation are observed in the experiments (figure 2). Similar experiments show that energetic particles (EPs) may act as a mediator of the cross-scale interactions and are beneficial for turbulence suppression and lower frequency poloidal plasma flow generation. Besides the synchronous couplings of turbulence and TAEs, TAEs and lower frequency poloidal plasma flow are observed. The dynamics between turbulence and TAEs provides an idea for synchronous control of TAEs and turbulence, and the resulting EPs confinement improvement and plasma stored energy increase are favorable for plasma performance.

The work experimentally advances the research of the multi-scale physics between turbulence and TAEs, turbulence and fishbone instabilities, and provides an idea for simultaneous control of turbulence and TAEs. This work was supported by the Strategic Priority Research Program of Chinese Academy of Sciences (Grant No. XDB0790101), the National Natural Science Foundation of China (Grant Nos. 12305254), Science Foundation of Institute of Plasma Physics (Grant Nos.DSJJ-2024-07).

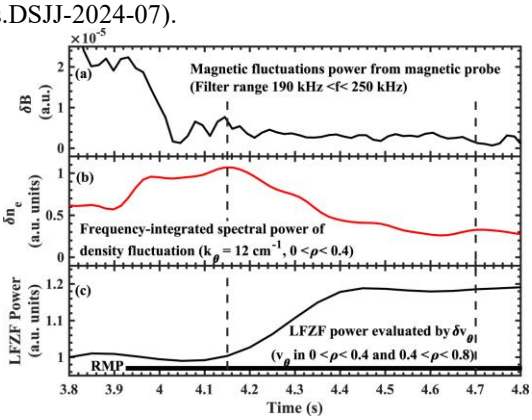

Figure 2. TAEs mitigation experiments under RMP at 3.9s. (a) Time evolution of the integrated TAEs amplitude in the frequency range 180 kHz < f < 280 kHz. (b) Evolution of frequency-integrated spectral power of density fluctuations with k_θ = 12 cm^{-1} in plasma core ρ = 0–0.4. (c) Evolution of LFF power that evaluated by poloidal velocity fluctuation.

References

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