Dynamics and statistics of a self-organized electron temperature corrugation in KSTAR tokamak plasmas

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In many fusion plasma simulations, it has been found that turbulent transport is dominated by non-diffusive avalanche transport events [1]. Avalanches are a near ballistic heat flux propagation event whose spatial scale follows the system size, i.e. the minor radius for tokamak plasmas. Avalanche-like transport events have been observed also in plasma experiments and their critical behavior has been demonstrated [2,3]. Being a dominant transport process, avalanche events can lead to Bohm or worse than Bohm confinement scaling unless they are limited by the shear flow. Fortunately, in some regime close to the marginal stability, the avalanche events are found to coexist with global self-organized shear flow layers, or transport barriers, with the meso-scale steps [4]. Through the regulation of avalanche events by the shear flow layers, a staircase-like pressure profile corrugation appears and the gyro-Bohm confinement scaling can be recovered [5].

Recently, intensive simulation studies have been conducted to understand the characteristics of the self-organized shear flow layers (also known as the E x B staircase) as well as their relation with the avalanche transport events [5]. Meanwhile, the experimental researches have been mostly limited to demonstrating existence of global shear flow layers in tokamak plasmas. For example, it was manifested in the self-organization of a staircase-like pressure profile corrugation [3,6,7] or in the radial variation of turbulence correlation length [7,8,9]. In this work, dynamics and statistics of the self-organized temperature corrugation in KSTAR tokamak plasmas have been further analyzed to advance our understanding on its characteristics and the relation with the avalanche-like events [10]. For dynamics, a previous long-range measurement of electron temperature corrugation was revisited. The initial formation process of a global temperature corrugation shows that its seed perturbation propagates with the anomalously fast speed. Also, two-way transformations from low-k (k = 1/(radial tread width of a staircase-like corrugation)) to high-k and from high-k to low-k are observed. For statistics, a series of controlled experiment was conducted to obtain probability distributions of the lifetime, the power, and the radial tread width of the corrugation. The distributions have a long tail, representing an intermittent behavior in the regime of analyzed plasmas. In particular, the probability distribution of the radial tread width of corrugations near the large avalanche-like event follows the Frechet distribution [5]. In addition, direct interaction between the avalanche-like transport event and the self-organized temperature corrugation is observed. The avalanche heat flux propagation seems to be jammed with the formation of the temperature corrugation [11], and the corrugation is eventually destructed with the avalanche heat accumulation. Both growth and destruction of the temperature corrugation are strongly influenced by the avalanche event. This observation provides insights into self-organization of a coherent structure out of turbulent fluctuation bath, which is one of the most fundamental problems to understand a complex system.

Although the corrugation (or the shear flow layers) observed in KSTAR plasmas is an intermittent structure, its operational regime is close to the stationary internal transport barrier regime in KSTAR [12]. Future work would include investigation on the relation between the stability of meso-scale shear flow layers and the macroscopic internal transport barrier.

References

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