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The avalanche-like electron heat transport events and their regulation by the shear flow structure

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Non-diffusive avalanche-like electron heat transport events are observed in the L-mode and the weak ITB core plasmas in KSTAR [1]. Avalanches are a mechanism suggested to understand the non-diffusive characteristics of anomalous plasma transport [2]. While they are frequently observed as a dominant transport process in many simulations, they have been rarely identified in experiments [3,4]. In KSTAR, the transport events which have characteristics of avalanches are observed clearly in the period without strong MHD instabilities by which the small fluctuations can be buried.

Analysis of the observed events found that they have characteristics of avalanches expected from the self-organized criticality (SOC) theory [5]. The events are identified by a pair creation of void ($\delta T_e < 0$) and bump ($\delta T_e > 0$) of the electron temperature propagating fast in opposite direction from the avalanche initiation location $R = R_{av}$ (see Fig. 1). The flux is invariant under the dual transformations of $x \to -x$ ($x = R - R_{av}$) and $\delta T_e \to -\delta T_e$, implying the joint reflection symmetry [6]. The propagation speed is ~100 m/s which is a fraction of the diamagnetic velocity and much faster than the diffusive transport. They have various perturbation amplitudes (δT_e), radial scales, and periods. The large event whose bump propagates down to the plasma boundary is indicated by black arrows in Fig. 1, and the smaller events whose heat pulses propagate over the limited range are highlighted by gray color in Fig. 1. The radial scale seems to be correlated with the perturbation amplitude. The power spectrum of δT_e which is a proxy of the avalanche size PDF exhibits a power-law behavior as shown in Fig. 2(a). The correlation between the radial scale and δT_e implies the spatial criticality of the events. On the other hand, the power-law spectrum reflects the power-law behavior of the correlation function, indicating the long memory effect (, or the temporal criticality) of the T_e time series in the avalanching region. The Hurst exponent of the T_e time series is also found to be large $H > 0.5$ as shown in Fig. 2(b). These aspects of the observed events are consistent with characteristics of avalanches in the SOC system [7].

In addition, a fine 2D T_e measurement in KSTAR found that the avalanche-like events can be regulated by the shear flow layers as expected in the recent nonlinear gyrokinetic simulations [8,9]. The subtle shear flow layers were identified by the radial corrugation of the 2D T_e profile as shown in Fig. 3. The measured width of the corrugation is around $45\rho_i$ where ρ_i is the ion Larmor radius. When this structure exists, the radial scale of the avalanche-like events is limited in the mesoscale (~$45\rho_i$). The dynamics of the T_e profile corrugation, or the shear flow layers, is complicated and the corrugation with the opposite polarity is also observed. More researches including the cross validation with the numerical simulation will be important.

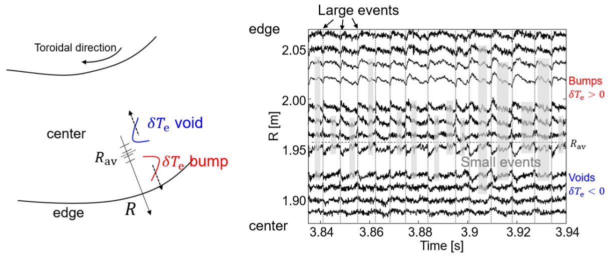

Fig. 1. Spatio-temporal measurements of voids and bumps of the avalanche-like events

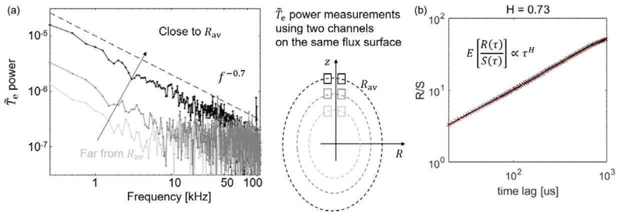

Fig. 2. (a): The power spectrum of δT_e. (b): The Hurst exponent measurement using the R/S method.

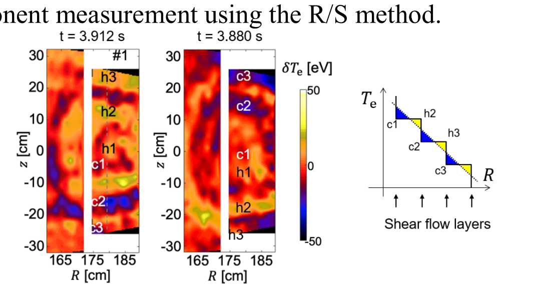

Fig. 3. The T_e profile corrugation (shear flow layers) with different polarity.

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