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Fast response of turbulence and heat pulses to thermal perturbations

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Plasma transport cannot be explained by local models alone, and the effects of non-local transport must be taken into account. In particular, avalanche phenomena and turbulence spreading have been recognized as causes of non-local transport. However, observations of these phenomena are limited due to measurement limitations, and both experimental and theoretical understanding of these phenomena are inadequate. This study reports the new findings of turbulence and heat propagation phenomena that cannot be explained by the existing avalanche and turbulence spreading models in the Large Helical Device (LHD) experiments.

In order to induce large observable turbulence spreading phenomena, a collapse of the electron internal transport barrier (e-ITB) is targeted. In the LHD, both turbulence and thermal pulses are generated near the foot of the e-ITB and propagate to the peripheral region faster than the diffusion time when thermal avalanche phenomena accompany the e-ITB collapse. The propagation velocity of the turbulence pulses is about 10 km/s, which is faster than the propagation velocity of the heat pulse of about 1.5 km/s [1]. Existing models predict that both heat and turbulence propagate at about 1 km/s, but the turbulence pulse propagates more than an order of magnitude faster than predicted. Although the simultaneous propagation of the turbulence and heat pulses has been reported in a number of experiments, it is thought that the phenomenon observed in the LHD is due to a different mechanism.

The modulated electron cyclotron heating (ECH) experiments, in which the induced time width of the heat pulse was varied by changing the time width of the ECH, were performed to systematically study the effects of the time scale of the turbulence and heat pulses on their propagation velocity (See Figs. 1(a)(b)). As shown in Fig. 1(c), the results showed that the propagation velocity of the heat and turbulence pulses is faster at shorter pulse widths. The smaller the timescale of the thermal pulse, the larger the deviation between the velocity of the turbulent pulse and the thermal pulse, with the turbulent pulse being much faster than the thermal pulse. This result indicates the existence of a phenomenon that cannot be explained by existing models in which heat and turbulence propagate simultaneously, and provides essential insight into the physical mechanism of non-local transport.

References

[1] N. Kenmochi *et al.*, Scientific Reports **12**, 6979 (2022)

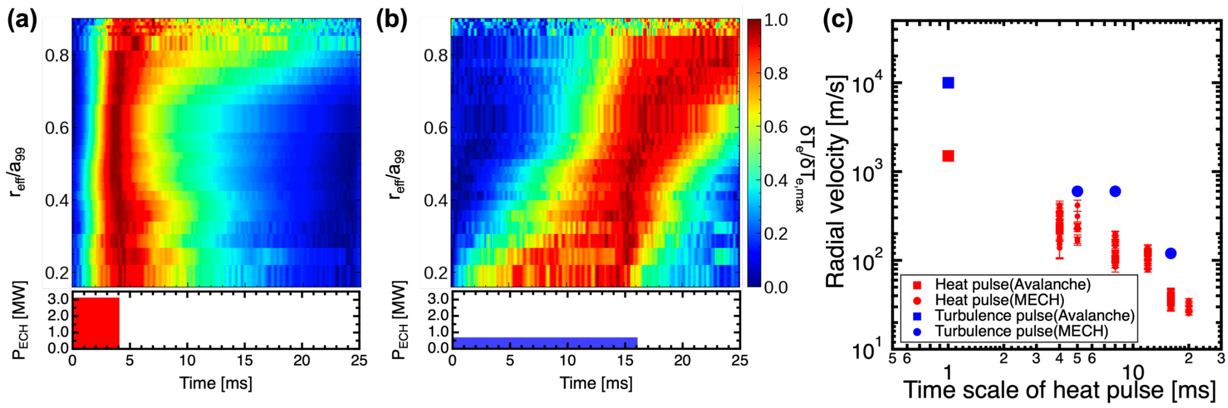

Figure 1. (a)(b) The time evolution of the electron temperature (T_e) profiles measured by ECE with the variation normalized between 0 and 1. The time evolutions of ECH injection powers are shown at the bottom of the figures. The pulse widths of ECH in (a) and (b) are 4 ms and 16 ms, respectively. (c)The relationship of radial propagation velocity of turbulence (blue) and heat (red) pulses to the time scale of heat pulses.