Impact of avalanche type of transport on the profile formation in toroidal plasmas

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The self-organized criticality (SOC) has been stimulating concepts in various complex systems [1]. An avalanche is a bursty relaxation process in SOC, often described in a sand-pile model shown in Fig. 1. The avalanche can propagate over long distance, sequentially driving transport in neighboring areas through local critical excitations. Due to its nature, it contributes to rigidity in the global profile, which is significantly impact on the pattern formation in the system.

In toroidal laboratory plasmas, cross-field transport, which determines radial pressure profiles, is dominated by turbulence. The system is rich in nonlinear phenomena, exhibiting a variety of local and global bifurcations and transitions. One of the particular interests is the formation of a transport barrier from a stiffness state (Fig. 2). The stiffness is characterized by the gradient scale length of pressure profiles remaining constant over a wide radial region. The pressure profile hardly changes against the power of heating source nor heating locations. In contrast, a transport barrier represents a departure from this stiffness state, where the pressure gradient increases in a specific radial region. Especially, a transport barrier located in the core is referred to as an internal transport barrier (ITB).

Studies of stiffness and ITBs have been linked to the modeling of core plasma turbulence. A conventional approach is the quasi-linear model, where turbulence intensity and transport fluxes are expressed in local parameters. However, experimental observations show that transport dynamics can occur globally [2]. Based on these observations, the concept of avalanching transport has been formulated in magnetically confined plasmas and widely observed in numerical simulations [3]. Recently, the observation of the interaction between avalanches and pattern formations are increased in experiments. In this talk, we especially focus on the experimental studies of avalanches on the formation of the stiffness and the ITB.

The main content of this talk will cover three topics: (i) Stiffness formation in JT-60U tokamak, (ii) ITB formation in JT-60U, and (iii) non-stiff profile formation in Helitoron J stellarator/heliotron. The first two topics will focus on how avalanching transport affects stiffness [6] and ITB formation [7]. We estimated the partial components of avalanche-driven heat flux, and thus we can discuss its impact qualitatively. The third topic will address profile formation in stellarators/heliotrons [8], which typically lack stiffness. In these devices, the gradient scale length decreases monotonically towards the core, indicating reduced confinement as temperature increases. For complemental understandings, we will compare the results from stellarators/heliotrons with those from tokamaks [9].

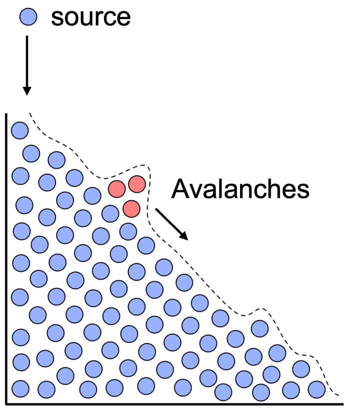

Figure 1. Schematics of avalanches in sand-pile model.

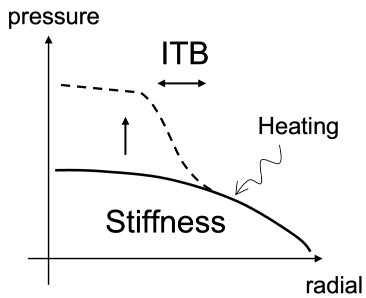

Figure 2. Schematics of ITB and stiffness in toroidal plasmas. Stiff profiles are insensitive to the external heating.

References

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