Fluctuation-Induced Bistability: A Model of Heat Flux Hysteresis and Avalanching in Confined Plasmas

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We propose a theory-based model which explains the observation of heat flux hysteresis in the absence of a transport barrier. This study also strikes at the fundamental question of `what is an avalanche?'. Subject to the conventional hypothesis that there exists a critical temperature gradient for the excitation of the turbulence, we show that multiscale coupling between mesoscopic and microscopic fluctuations can induced bistability of the local turbulence intensity and system state bifurcation. For the subcritical scenario, i.e., the temperature gradient below its linear threshold, if the intensity of the mesoscale temperature gradient exceeds a certain threshold, the system transitions from a metastable `laminar' state to an absolutely stable excited state. Correspondingly, the effective thermal conductivity jumps from a value close to the neoclassical value to an anomalous value. By reducing the external drive, the excited state returns to the laminar one. Therefore, it is the bistability of the turbulence intensity that induces the heat flux hysteresis. The scaling of the hysteresis strength is obtained. Incorporating turbulent viscosity effect, a stable front of turbulence intensity is formed. This front connects the excited-- and laminar states, and propagates as an avalanche. We also derive the probability distribution function of intensity pulses. Hysteresis and turbulence intensity avalanche speed are estimated in a unified theoretical framework.