5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Global $\boldsymbol{E \times B}$ pattern formation in tokamak plasmas resembles the traffic-jam

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The $\boldsymbol{E \times B}$ staircase-like pattern formation is found to resemble the traffic jam in the first principle gyrokinetic numerical experiments of tokamak fusion plasmas[1-3]. Simulations demonstrate the finite response time of individual particle's transport to the mean flux analogous to the driver's adaptation time to the steady-state traffic speed, as shown in Fig. 1. The response time decreases as the mean flux rises, and staircase-like patterns are more arduous to develop with higher ambient flux, as shown in Fig. 2. Staircase-like corrugations in the particle flux cause staircases in the density profile after a finite time delay. A feedback loop is verified to sustain the staircases formation, and $\boldsymbol{E \times B}$ flow staircases shearing plays a key role. The numerical experiments support a previous heuristic model[4,5] of zonal flow staircase generation.

References
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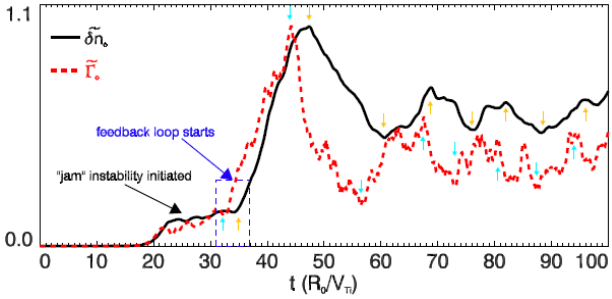

Figure 1: Time evolution of staircase intensity of electron particle flux $\widetilde{\Gamma_e}$ and electron density fluctuation $\widetilde{\delta n_e}$.

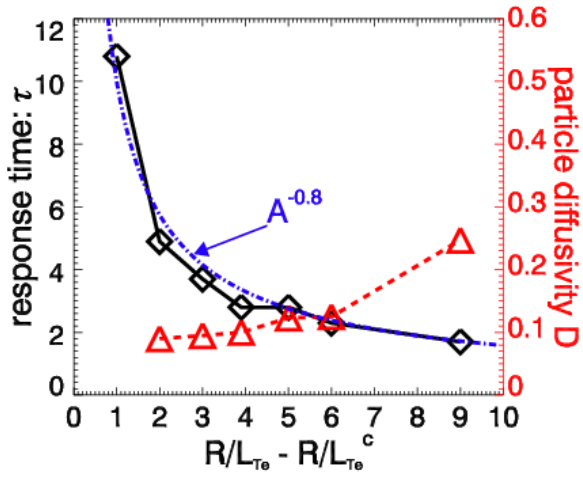

Figure 2: Response time τ (black-solid) and particle flux diffusivity D (red-dash) as a function of $R/L_{Te} - R/L_{Te}^c$. Here R/L_{Te}^c is the linear critical electron temperature gradient. The response time fits a power law scaling $\tau \sim A^{-0.8}$ well.