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Stochastic prey-predator theory of the L-H transition in fusion plasmas -- time-dependent statistical analysis and information theory

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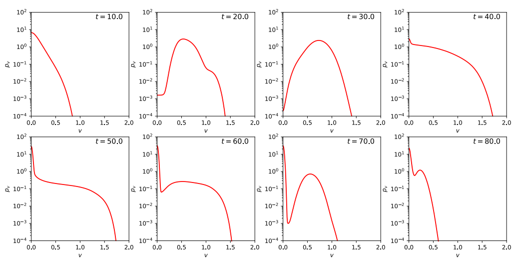
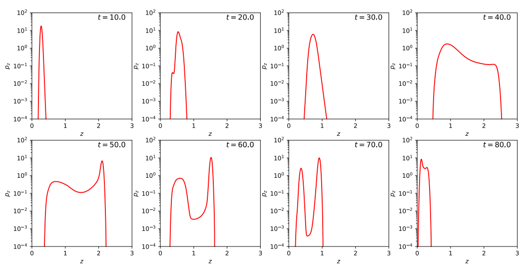
The L-H transition is a novel phenomenon involving the sudden improvement in the plasma confinement when an input power threshold is reached. Notably, the transition is accompanied by the regulation between turbulence and sheared poloidal flows with certain causal relationship between this regulation and the L-H transition. Here, the poloidal flows are distinguished into means flows (driven by the background pressure gradient) and zonal flows (driven by turbulence). The qualitative behaviour of the L-H transition was previously predicted using a deterministic, prey-predator-type model for the amplitudes of turbulence, zonal flow shear, mean flow shear and the ion density gradient [1].

In this talk, we present new results from a stochastic L-H transition model by extending [1] to include stochastic noise terms in the dynamical equations for the turbulence, zonal flow shear and density gradient. Previously the stationary solution of the density gradient was used [2]. The noise terms capture the effects of physics on much smaller temporal scales than the evolution of low frequency drift-like turbulence and large scale zonal and mean flows. The inclusion of noise in the equation for the density gradient is primarily for numerical reasons.

We show how a time dependent probability density function (PDF) for the turbulence, zonal flow shear and density gradient evolves in time and provide new insight into the L-H transition that was impossible through the deterministic model. In particular, we show that the PDF is often strongly non-Gaussian and thus the mean value and other moments are of limited use. In addition, we also discuss the utility of information geometry [3] and other statistical measures in elucidating dynamic hysteresis associated with the L-H transition and its backward, H-L transition. Figure 1 shows snapshots of 1-D marginal PDFs for a linearly increasing and then decreasing input power.

[1] E. Kim *et al*, Phys. Rev. Lett. **90**, 185006 (2003).
[2] R. Hollerbach *et al*, Physics of Plasmas **27**, 102301 (2020).
[3] E. Kim, J. Stat. Mech. 093406 (2021).





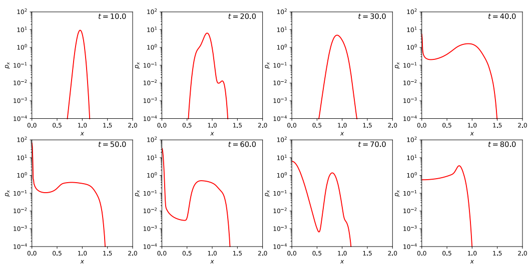


Figure 1: Snapshots of the 1-D marginal PDFs for each variable: (top right) zonal flow shear, (bottom left) ion density gradient, (bottom right) turbulence.