Stochastic Dynamics of
Fusion Low-to-High Confinement Mode (L-H) Transition

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The Low-to-High confinement (L-H) transition is one of the most important plasma bifurcations whose understanding is critical for accessing the ideal operation regime in magnetically confined fusion plasmas. At the same time, a growing number of experiments and simulations reveal ample evidence for strongly non-equilibrium characteristics of fusion plasmas (e.g., avalanches, intermittency), questioning a naïve picture of bifurcation in a deterministic system based on a mean-field type theory. Furthermore, turbulence characteristics in Low confinement (L) mode are very variable, often with highly time-varying RMS values of fluctuating electron density and turbulence velocity. To address this, we present a timely new turbulence statistical analysis method [1-4] to elucidate how plasma statistical properties change over the L-H transition. Stochastic noises produce random trajectories of turbulence, zonal flows, and mean flows, leading to the L-H transition occurring at different times and uncertainty in power threshold Qc above which the L-H transition occurs. Different power ramping scheduling and initial conditions also contribute to the uncertainty in Qc. Self-regulation and causal relations (which are essential for unravelling plasma interaction) are well captured by information geometry [4] in comparison with other popular methods (e.g., transfer entropy). We propose a novel probabilistic theory of the L-H transition and power loss. Some of the theoretical findings are supported from the L-H transition experimental data analysis [5]. Implications for understanding other advanced operation scenarios are further discussed.

References

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