7th Asia-Pacific Conference on Plasma Physics, 12-17 November 2023

Information Geometry Analysis of H-mode Transitions

Y. Andrew[1], T. Ashton-Key[1], J. Dunsmore[1,2], H.J. Farre-Kaga[1,3], E. Kim[4]
1. Blackett Laboratory, Imperial College London
2. Department of Physics, University of Warwick
3. Cavendish Laboratory, University of Cambridge
4. Fluid and Complex System Research Centre, Coventry University

e-mail: y.andrew@imperial.ac.uk

As the energy input to magnetically confined fusion (MCF) tokamak plasmas increases, the system undergoes a phase transition to a highly organized state with improved particle and energy confinement, the H-mode. At the transition to H-mode the plasma turbulent energy transport within the narrow edge region, typically a few cm wide, is observed to dramatically reduce with concurrent development of steep (sheared) rotation and pressure gradients. This bifurcation event is critical for MCF development as an energy source because it is only through such improved plasma confinement that a net electric fusion reactor could be conceived of at a viable operational scale. Understanding the plasma conditions and causal dynamics that permit access to and controlled exit from H-mode therefore continues to be a high priority, and active area of physics research for tokamaks across the world [1].

Since the timescales for the plasma low to high, L-H, and reverse transitions [2] are so short, conventional data analysis and modelling approaches based on mean values or variance provide limited insight to the complex dynamics of these plasma phase changes. A novel approach to unravelling the trigger mechanisms and variable interactions of the H-mode self-organisation, is to envisage them as time-dependent stochastic processes with high frequency plasma fluctuations and non-gaussian distributions [3]. Time-dependent probability density functions (PDFs) of key experimental variables can be constructed using sliding time-windows of sufficiently small-scale to investigate statistical intermittent events in edge plasma turbulence and flows, with higher order PDF cumulants such as, kurtosis. The analysis can be further extended by comparing the evolution of the PDFs over time and determing their associated statistical states using the dimensionless diagnostic of information length [3]. During H-mode transitions, the edge plasma perpendicular velocity PDFs are shown to develop strong right tails, which indicate turbulence-suppressing local plasma flows. Such features and other subtle plasma turbulence behaviour are explored using geometric methodology to elucidate of the dynamic H-mode phase transitions and stochastic processes.

This presentation gives an overview of how information geometry can be used to mark or predict the onset of L-H transitions, support theories of predator-prey self-regulation between turbulence and observed local plasma flows and understand differences in H-mode power threshold.

References

[1] L. Schmitz *et al* 2022 *Nucl. Fusion* **62** 126050.

[2] Y Andrew et al 2023 Phil. Trans. A **381**, ISSN: 1364-503X.

[3] E Kim and R Hollerbach 2020 Phys. Rev. Research **2** 023077.