Causality detection and turbulence in fusion plasmas

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This work explores the potential of an information-theoretical causality detection method for unraveling the relation between fluctuating variables in complex nonlinear systems: the ‘Transfer Entropy’, capable of effectively distinguishing between driving and responding variables [1]. The method is tested on some simple though nonlinear models, and guidelines for the choice of analysis parameters are established [2].

Using this method, measurements from the edge region of magnetically confined fusion plasmas are analyzed. The selected data bear relevance to the all-important spontaneous confinement transitions often observed in fusion plasmas, fundamental for the design of an economically attractive fusion reactor.

Measurements from a poloidally distributed set of Langmuir probes at TJ-K allow the simultaneous measurement of plasma potential, ion saturation current and turbulent particle flux. It is shown how the mean (Zonal Flow) potential interacts with the turbulent amplitude and flux, revealing the existence of two interaction timescales: one associated with turbulence regulation by the Zonal Flow potential, and one tentatively identified with the back-reaction of transport on the mean potential.

At TJ-II, several types of confinement transition are studied using the method: in ECRH heated plasmas, a transition associated with a change of neoclassical root as the mean density is raised or lowered and a transition achieved by applying external biasing; and in NBI heated plasmas, L–H transitions. Diagnostics used include Langmuir probes and Doppler reflectometry. It is shown how the present method is capable of clarifying the interaction between fluctuating quantities such as the turbulence amplitude, turbulent flux, poloidal rotation velocity and Zonal Flow amplitude.

References