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Predicting Cross-Scale Self-Organization in Turbulent Magnetically Confined Plasmas

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Recently, we have developed a comprehensive mathematical and computational framework for the analysis and quantification of self-organization [1]. Application of this method may resolve some of the important issues of fusion plasmas such as prediction of changes in the pattern formation and transport properties, to name a few. We assume that the system self-organizes if its complexity (related to statistical prediction) increases with time.

The experimental data consists of the ion-saturation current measurements performed by a moveable Langmuir probe located at the outboard mid-plane on the MAST device. Several different confinement regimes in MAST are analyzed: high-density L-Modes, Dithering H-Modes with heating power close to the threshold for L-H transition with intermittent edge localized modes (ELMs) and H-Modes with ELMs present. We show how the method is used for predicting the occurrence of the particular Mode and we discuss the possible applications of this method for other issues relevant for fusion plasmas. Also, we illustrate how the method is used to predict ELM bursts in the edge plasma, in time and in the spatial location.

We further apply this framework in order to predict different bifurcations and dynamic regimes in the model of Stimulated Raman scattering (SRS) in plasma [3], a paradigm of three-wave interaction of great importance for inertial confinement fusion. This three-wave interaction is related to a nonlinear coupling of intense laser light (pump) to the electron plasma wave (EPW) and the scattered light, shifted in wavenumber and frequency. SRS belongs to a family of underdense plasma instabilities which can have a detrimental effect on efficiency of laser energy deposition into a fusion target. This particular SRS model has a very rich spatiotemporal dynamics and exhibits a paradigm of transition to spatiotemporal chaos via quasiperiodic and intermittent stages. We show that our self-organization framework predicts with great accuracy, pattern changes in time and space and occurrence of new dynamic regimes. In addition, the method quantifies each self-organizing state enabling precise characterization of self-organization process under change of different parameters of the system.

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