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Quantifying Self-Organization in Magnetically Confined Fusion Plasmas

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Plasma self-organization is the frontier research area in plasma physics and its understanding is extremely important for the construction of innovative fusion configurations. Emergence, an outcome of self-organization, implies the appearance of certain large scale structures, forms or patterns, formed from a large number of simple interactions of smaller parts of the system. Motivated by these requirements, we have developed a framework (mathematical and computational), which, at the same time, makes choice of the optimal wavelet for analysis of data, enables optimal prediction of the dynamics, quantifies stages of self-organization and removes the effects of noise, when required [1]. It also includes the role of scales in the process. A spatiotemporal data of the gyrokinetic Vlasov simulation results for the ion temperature gradient turbulence, where the standard and the inward-shifted configurations of the Large helical Device are considered in this study. Although fluctuations of the electrostatic potential for zonal flows exhibit spatiotemporal chaos in both configurations, we show that self-organization is different in the two cases. Specifically, we show that complexity is more intense in the standard configuration, however the increase in time of complexity is higher in the inward-shifted configuration implying faster relaxation. These results are shown to be consistent with the results of the analysis of the spatiotemporal chaotic dynamics in the two configurations. We illustrate how this method may be used to test various confinement configurations in order to achieve the optimal self-organization under given circumstances. We also analyze the ion-saturation current measurements of three different confinement regimes, namely the L-mode, the H-mode and the dithering H-mode, in the scrape-off layer of several devices. We show how self-organization in each of the regimes may be compared and also how changes in configuration may be predicted. Finally, we discuss the versatility of the method and other potential uses in the realm of fusion plasmas.

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