§35. Characterization of Local Turbulence in Magnetic Confinement Devices

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Plasma edge turbulence, known for a long time to be intermittent in the scrape-off layer, is in focus of intense current research efforts aimed at understanding plasma confinement and dynamics of turbulent transport in magnetic fusion devices which represent important issues related to the control of confined plasma. Turbulence studies of the scrape-off layer (SOL) have revealed that intermittency in this region is caused by large-scale coherent structures with high radial velocity designated as blobs (or avaloids). A natural route for understanding turbulence and intermittency in the edge region of confinement devices and related transport properties is to search for universal properties and differences between dynamics of different systems and regimes. The first studies performed in this direction have concentrated on search for long-range dependence properties of plasma density fluctuations as well as on their eventual self-similar properties [1-2]. Self-similar processes have been attractive models to describe scaling of plasma fluctuations due to the fact that they are well documented and mathematically well-defined. In addition they are relatively simple and parsimonious [2], and each of their properties are controlled by the one unique parameter, H, known as the Hurst parameter. It was soon realized that in spite of observed self-similarity for several confinement devices, over the mesoscale range of time scales [2], i.e. scales between 10 times the turbulence decorrelation time and plasma confinement time, different scaling laws exist in different time scale ranges. Hence, it became clear that self-similar processes might not be adequate to model the case of extremely complex plasma turbulence fluctuations. Existence of long-range correlations, noticed in several magnetic confinement devices, suggested that scaling models with a single parameter are appropriate at large scales but at small scales, characteristic for intermittency, more parameters are needed. As a consequence, a need for multifractal analysis, an extension of monofractal analysis which is based on self-similarity concept, was recognized relatively recently. In spite of that, only few studies [3], were devoted to the multifractal analysis of plasma fluctuations and more importantly a multifractal analysis tools used were hardly adequate to recognize subtle differences in various confinement devices and hence deviations from universal characteristics.

In this work, multifractal tools have been employed in order to test the universality [4] of the edge turbulence properties in various magnetic confinement devices. It was shown that Large Deviation Spectra (LDS) could represent a powerful tool enabling advanced insight into the multifractal processes and provide information that is sensitive to the data and hence to the confinement device in which the date were generated. Details of the calculation of LDS can be found elsewhere [4-5]. The important feature of LDS is that departure from a pure bell-shape and concavity indicates a presence of more multiplicative laws underlying the cascade process. Complemented by an analysis of local turbulence based on the fractional Brownian motion and wavelet scaling properties it was shown that turbulence properties are different in the MAST device and the Tore Supra tokamak, suggesting that new studies involving different devices and possibly extensions of existing methods for the analysis should be undertaken. Shapes of LDS (versus Hoelder exponent) can suggest different energy transport mechanisms in the two devices (figs. 1 & 2) while the local analysis reveals a multiscaling character of the processes in the Tore Supra device in contrast to the genuine multifractal processes in the MAST device. In the light of results presented here the call for a careful interpretation of the universal characteristics of edge turbulence data is evident. In addition, differences over local temporal records of turbulence data for various devices show how important is local modeling based on the fractional Brownian motion and wavelet scale spectra for constructing e.g. accurate synthetic random medium for simulation of wave propagation in turbulent plasma.

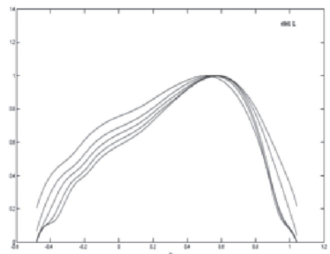

Fig. 1 LDS for MAST L-mode signal 6861 for five different scales $\Delta t = 2^3, 2^4, 2^5, 2^6$ and 2^7

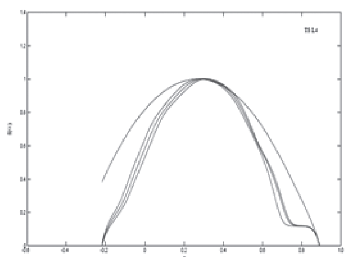

Fig. 2 LDS for Tore Supra L-mode L4 for five scales is the most symmetric with practically no lumping measures

References
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