Estimation of local turbulence and energy transport in the edge of magnetic confinement devices

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We propose an approach for analyzing edge plasma turbulence, through plasma density fluctuations, as a locally stationary process with power law spectral densities. We divide the data into segments over which the process is essentially stationary and then use the wavelet scale spectra to estimate the parameters of the power law, which are the scale factor and the exponent. These parameters vary from segment to segment, with variation in part due to the non-stationarity of the data and part due to the estimation errors that depend on the length of the segments. In this approach, segmentation effects due to estimation errors are removed by filtering.and the method is based on an exhaustive search for an optimal segmentation.

We also estimate an effective local range, that is, the set of scales over which the process can be modelled by a power law. In particular, we are interested in quantifying fluctuations about the Kolmogorov law and in analyzing them in detail. To illustrate the meaning of this approach, consider Navier-Stokes equations, for which the following scaling relations hold:

$$r \to \lambda r, \qquad u \to \lambda^h u, \qquad t \to \lambda^{1-h} t.$$

According to the Kolmogorov law, $h = 1/3$ if no fluctuations in h are present. However, according to the multifractal model of turbulence, each fluctuation h at scale r is weighted with a probability distribution

$$P_h(r) \sim r^{3-D(h)},$$

where $D(h)$ is the singularity spectrum. The quantity $D(h)$ is the source of fluctuations in $h = 1/3$ and its estimation enables precise estimation of local power law parameters.

Our results in the analysis of edge density fluctuations in the **TORE SUPRA** and **PISCES** devices indicate that the fluctuations have multifractal statistics i.e. the scaling behavior of the absolute moments is described by a nonlinear function with non-trivial self-similarity properties. The proposed method is used to efficiently quantify the differences in the multifractal properties of the density fluctuations in the toroidal and linear devices, and to estimate their effect on the energy transport. An ultimate goal of this research is a complete study of the effects of the heterogeneity in local power law model on energy transport, diffusion and turbulence properties in the edge of the magnetic confinement devices.