Turbulence simulations of interchange motions and intermittent transport in TCV scrape-off layer plasmas

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It has long been known that the scrape-off layer (SOL) plasma of magnetic confinement experiments is strongly turbulent with relative fluctuation levels in the plasma density being of order unity. Estimates from probe measurements indicate that the radial turbulent transport of particles and heat may overcome parallel losses to the divertor region, thereby causing significant plasma–wall interactions and possibly underlying the density limit [1].

Recent two-dimensional imaging techniques further indicate that the turbulent transport is associated with magnetic field-aligned structures with a blob-like shape in the plane perpendicular to the magnetic field [2]. A new paradigm is thus emerging, whereby SOL turbulence is intermittent and the anomalous transport is caused by radial advection of such filamentary structures. This indirectly implies that SOL turbulence is non-local in the sense that the fluctuations are not driven by local SOL profile gradients [3]. The radial structure advection is however due to large-scale convective motions due to unfavorable magnetic curvature in the SOL [4].

Here we present results from interchange turbulence simulations which employ a simple description of the closed and open magnetic field line regions [5]. When comparing the simulation results with measurements in the TCV SOL [6], excellent agreement is found for the radial variation of statistical distributions and temporal correlations both for the particle density and the turbulent particle flux. This includes the functional shape of probability distributions, which are strongly skewed and flattened due to the abundance of positive bursts in the time series, and the conditionally averaged waveforms, which have a steep front and a trailing wake in the SOL. Some results will also be presented for variations of the turbulence statistics with the average plasma density. Finally, estimates of the turbulent particle flux in the experiments is compared with similar estimates and exact calculations from turbulence simulations.

The non-linear interchange dynamics due to unfavorable magnetic curvature hence provides the basis for understanding the nature of the anomalous SOL transport, reconciling numerous experimental observations including radial structure advection, large fluctuation levels, skewed and flattened probability distributions and asymmetric conditional waveforms [1–6]. This eventually results in broad plasma profiles which are thought to be the cause of high levels of main chamber plasma–wall interactions.

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