Intermittent fluctuations in the scrape-off layer of fusion plasmas

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The scrape-off layer region of magnetically confined plasmas is a non-equilibrium system with order unity relative fluctuation level of plasma parameters, broad radial profiles and finite particle density and pressure at the main chamber wall. This may have numerous detrimental effects on future fusion power reactors, including enhanced erosion of wall material, auxiliary heating and plasma control by electromagnetic waves, control of divertor detachment and exhaust mitigation, and the empirical density disruption limit.

Experimental measurements have demonstrated that the fluctuations in the scrape-off layer are due to radially outwards motion of blob-like plasma filaments. These structures are formed in the vicinity of the last closed magnetic flux surface at the outboard mid-plane region. They are elongated along the magnetic field lines and localized in the plane perpendicular to the magnetic field. The average profiles and their fluctuations are determined by the blob size, velocity, amplitude and frequency of occurrence. In order to predict the role of turbulence and fluctuations in the boundary region, it is thus necessary to clarify the relation between these quantities, their statistical distributions and their dependence on plasma and device parameters.

Recently, the fluctuations have been shown to possess universal statistical properties across plasma parameters, confinement regimes and devices. This includes the shape of large-amplitude fluctuations, their probability distribution function, frequency power spectral density and rate of level crossings. The intermittent fluctuations are well described as a super-position of uncorrelated pulses with fixed shape, describing the presence of broad profiles and predicting threshold phenomena such as sputtering. This provides a unique tool for modelling the fluctuations, comparison across devices and verification of turbulence simulation codes.

This presentation will give a review of recent progress on turbulence and fluctuation-induced transport in the scrape-off layer of fusion plasmas, comprising experimental measurements, modelling and numerical simulations. Particular emphasis will be given to the role of turbulence and fluctuations for plasma exhaust and plasma-wall interactions. Suggestions for future research and development within theory and experiments will be given.