Intrinsic instabilities in X-Point geometry: a tool to understand and predict the Scrape Off Layer transport in standard and advanced divertors

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Next generation tokamaks will have to operate under the stringent constraint posed by the interaction between plasma and solid surfaces. Current experimental extrapolations for the Scrape Off Layer (SOL) width in ITER predict a 1mm thickness at the outer midplane (in inter-ELM phase at low collisionality) [1]. Such sharp gradients might induce instabilities in the SOL, which could induce perpendicular turbulent transport and a consequent flattening of the SOL profiles.

In this work, we study intrinsic SOL instabilities (i.e. driven by the SOL gradients) using a flute formalism which incorporates the appropriate sheath boundary conditions at the target [2]. The linear growth rate of the modes, their structure and the associated diffusion coefficient are obtained. The latter is estimated using a simple γ/k^2 approach for the fastest growing mode. The model used includes curvature and sheath drives, finite Larmor radius effects, resistivity and partial line tying at the target. The magnetic geometry is obtained using current carrying wires, representing the plasma current and the divertor coils, and naturally generates X-point geometry and magnetic shear effects.

We find that a mode, highly localized in the outer divertor leg, appears when the SOL gradients are increased beyond a certain threshold, which leads to an enhanced transport below the X-point.

Our calculation also offers a comparison between standard and advanced divertor configurations (Snowflake and Super-X) [3,4]. Importantly, the spatial variation of the perpendicular wave number is such that the estimated diffusion coefficient, in the low collisionality regime, is roughly twice as large for the advanced configurations than for the Single Null geometry in the upstream region, while it is much smaller in the divertor leg, i.e. beyond the X-point. This effect is due to the inclusion of realistic X-point geometry, the strong magnetic shear of which determines the reduction of the turbulent structures and of the transport associated with them. As the SOL width is directly related to the anomalous perpendicular transport, our results could indicate how different magnetic geometries affect the wetted area at the divertor.

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