A model of interchange turbulent transport across separatrix with sheared flows

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Low to high confinement mode transitions feature steepening of edge gradients, impacting both energy confinement and power exhaust (decrease of the heat flux channel width λ_q). It relates to the reduction by local sheared flows of transport across flux surfaces near the separatrix.

The central paradigm of the present model consists in an extension of isolated filament models toward absolute prediction of turbulence spectra for density and potential. This is done in the framework of geometrically simplified 2D interchange equations [1], that showed to correctly describe SOL widths and filament properties in circular plasma geometry [2]. In addition, background sheared flows are included in the spectral model via the generation of mode anisotropy (radial wave number) compensated by an interchange recall force. Over all, the spectral model gives access to comprehensive ruling laws for density and potential spectra, plus all consequent transport observables.

The model is fully verified against a broad set of flux driven turbulent simulations. Confrontation against observations from the TJ-K stellarator showed that poloidal spectra for electron density and potential, measured in a standard plasma scenario over the full poloidal section, are quantitatively predicted. Second, the model was confronted to a large database of fluctuation levels, poloidal correlation lengths and density decay lengths measured in the SOL of Tore Supra, with overall satisfaction [3]. The model is currently implemented in a 1D-profile solver for density, pressure and momentum, in order to assess role of self-consistent sheared flows on transport across separatrix. Preliminary results on energy confinement time and SOL widths show parametric dependencies in qualitative agreement with experimental scaling laws. The magnetic configuration (upper or lower X-point) is also found to affect the edge rotation in agreement with experimental findings, because of magnetic shear. Moreover, the parametrisation of the model should allow for inclusion of specific physics effects such as shaping (triangularity, elongation), parallel resistivity and divertor regimes.

[1] Y. Sarazin et al., Physics of Plasmas (1998)
[2] N. Fedorczak et al., Contribution to Plasma Physics (2018)
[3] M. Peret et al., Nuclear Fusion (2021)