Turbulent impurity transport simulations in stellarators

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Keeping a low concentration of impurities in the plasma, in order to avoid intolerable fuel dilution and radiation levels, is necessary for accessing high performance scenarios in present day experiments and making thermonuclear fusion feasible at reactor scale. It is therefore crucial to quantitatively understand impurity transport in the plasma. Although the transport of impurities in stellarators is often dominated by neoclassical mechanisms, the first experimental campaigns of Wendelstein 7-X (W7-X) have shown that impurity transport in this device can only be explained by a strong turbulent component. The calculation of turbulent transport requires to solve the gyrokinetic system of equations, which, for the three-dimensional geometry of stellarators, implies a high computational cost, in particular when several species with disparate masses are accounted for. Furthermore, stellarator-specific codes, more complex than their tokamak counterparts, are needed. Therefore, it has not been until recently that multispecies nonlinear gyrokinetic simulations have been available for large stellarators, like LHD or W7-X (see [1] and [2], respectively).

In this talk, the turbulent transport of impurities in stellarators is comprehensively studied with the recently developed δf gyrokinetic code stella [3]. For W7-X, the results show that ordinary diffusion carries the largest fraction of the total turbulent impurity transport, and its size is compatible with experimental observations. Thermo-diffusion is practically negligible and the convection in the absence of impurity pressure gradients can be radially inwards or outwards, depending on the type of turbulence. Interestingly, both the diffusion and the convection coefficients are strongly reduced when the density gradient of main ions and electrons increases (see fig. 1 and also reference [4]), which may explain the steep impurity density gradients reported in pellet-fueled W7-X high performance scenarios [5]. Comparing different stellarator configurations, namely, W7-X, TJ-II, NCSX and LHD, it is also found that the size of the normalized turbulent diffusion and convection are comparable across the first three of them, with appreciably lower transport coefficients for LHD. Apart from these results, obtained at trace impurity concentration, the role that non-trace impurities have on the bulk turbulence is also addressed. In particular, we will study the effect of impurity injection on the reduction of the heat fluxes.

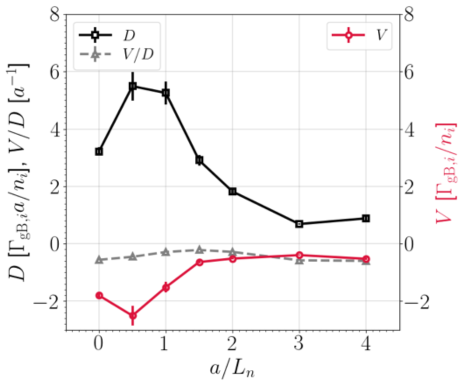

Fig. 1: for W7-X, normalized diffusion (D) and convection (V) coefficients for Fe^{16+} as a function of the main ion density gradient and for a normalized ion temperature gradient of $a/L_{Ti}=4$.

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