

Impurity transport driven by electrostatic turbulence in tokamak plasmas

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Impurity transport driven by electrostatic turbulence is analyzed in weakly-collisional tokamak plasmas using a semi-analytical model based on a boundary-layer solution of the gyrokinetic equation. The model does not rely on expansions in the smallness of the magnetic drift frequencies, and includes collisions modelled by a Lorentz operator. By assuming large aspect-ratio, low beta, toroidal symmetry, circular cross section and weak collisionality, and assuming a ballooning eigenfunction for the electrostatic potential as in [1,2], analytical expressions for the perturbed density responses can be derived and used to calculate the stability boundaries, mode frequencies, growth rates and the quasilinear particle fluxes. Parametric dependencies of the above quantities with respect to impurity charge, effective charge Z_{eff} , impurity density scale length L_{nz} , and collisionality have been determined and compared with quasilinear gyrokinetic simulations with GYRO resulting in very good agreement. Our results indicate that for moderate or high impurity charge number, the eigenfrequency and stability boundary are very weakly affected by the increasing impurity charge for constant Z_{eff} and are approximately equal to the corresponding quantities in a pure plasma. For lower Z , especially for helium or carbon dilutions, the effect of impurities influences the eigenfrequency and thus the stability boundary significantly. If the mode is far from marginal stability, the effect of increasing Z and Z_{eff} affects the growth rates and mode frequencies only weakly. The normalized impurity flux is reduced with increasing Z if Z_{eff} is constant, due to the reducing impurity fraction $n_z/n_e \sim 1/Z^2$, and it is increased with increasing Z_{eff} if Z is constant. Collisions do not affect the mode frequencies, growth rates and impurity fluxes significantly. The eigenfrequencies and growth rates depend moderately on L_{nz} , and the impurity flux changes sign at a certain fixed value of L_{nz} . An analytical approximate expression for the zero-flux impurity density gradient is derived and used to discuss its parametric dependencies.

References

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