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Turbulent transport of impurity ions with hollow density profiles in tokamak devices

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Hollow density profiles (HDPs) of impurity ions widely observed in advanced tokamaks and helical devices indicate that steep temperature gradients of main ions and electrons are beneficial for the sustainment of HDPs of impurity ions. However, the underlying physical mechanism for sustaining such profiles remains unsolved. Such profiles are desirable for present experiments and future fusion reactors due to preventing impurity accumulation in the core, reducing the heat load on the divertor, and improving confinement. This talk reports systematic theoretical and experimental investigations of the sustaining mechanisms of hollow impurity ion density profiles. It proposes that the dominant role of impurity mode (IM) in the transport of impurity ions with HDPs, and the temperature gradient screening effects on turbulent transport as the mechanism for the sustainment of HDPs of impurity ions. A comparison with the impurity injection experiment in HL-2A was performed and reasonable agreement has been observed. Reduction of the peaking factor of impurity density profiles caused by the increase of electron density gradient observed in the experiment is evidenced in turn with theory. It is important shows that the IM produces significant heat transport even when the temperature profiles are relatively flat. We find the temperature ratio effects, T_e/T_i (τ_i) and T_e/T_z (τ_z), are quite opposite on linear instability but are similar in quasilinear particle and heat transport. These results suggest that IM may cause damage to fusion energy gaining in future fusion devices, which are accompanied by high temperature ratios (τ_z and τ_i). Based on our simulation and experiment investigation, it is shown that I-mode characterized by a low electron density gradient and steep temperature gradient is expected to be favorable for sustaining HDPs of impurity ions. Furthermore, mitigation of edge localized mode and improvement of confinement have also been found in HL-2A when impurity ions are injected into the edge.

References

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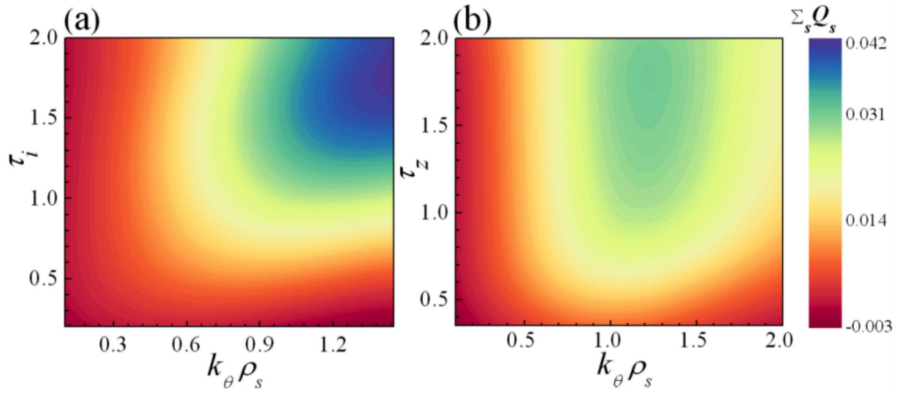

Figure 1 Contour plots of the normalized total heat fluxes of various elementary particles, (a) for IMs with C^{6+} in the two-dimensional plane of (τ_i, $k_\theta\rho_s$) for τ_z=1 (b) and (τ_z, $k_\theta\rho_s$) for τ_i=1, respectively.