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Ion composition effects on neoclassical transport in density pedestals

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Orbit-width scale profile variations, as found in tokamak pedestals, qualitatively change the nature of neoclassical transport, as the radial fluxes no longer can be expressed by Fick's law-like relations that relate the local fluxes to local gradients. Instead, the profile values at nearby flux-surfaces are needed to calculate the fluxes on a given surface – the transport is said to be radially global. The fluxes nevertheless tend to decorrelate over distances longer than an orbit-width, which has implications for impure plasmas or isotope mixtures, as the different species will have different correlation lengths, but are coupled through collisions.

We study such effects in density pedestals using the global δf drift-kinetic solver PERFECT [1]. We focus on sharp density and electrostatic potential variations, with weak temperature T and pseudo-density $\eta = n e^{Ze\Phi/T}$ variations, as this allows the problem to be linearized around a flux-surface Maxwell-Boltzmann distribution, and thus provides a simple context for the study of global effects. We find that global effects tend to reduce the heat flux by about 10 – 20%, depending on the pedestal profile and isotope. The convective contribution to the ion heat flux can be comparable to the conductive one for sharp electron profiles. In the middle of the pedestal in local simulations, both contributions vary linearly with the local logarithmic density gradient, while in global simulations they become less sensitive to that parameter for sharper pedestals. The global fluxes have qualitatively different poloidal structure, as these fluxes are no longer divergence free on flux-surfaces, which allows complicated radial-poloidal flow patterns to emerge, as illustrated in Figure 1.

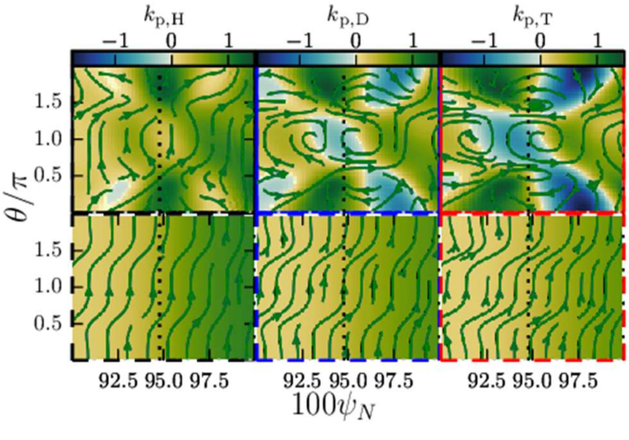

Figure 1: *Streamline plot of radial-poloidal fluxes superimposed over poloidal flow coefficients, from local (top row) and global (bottom row) simulations, for H, D and T isotopes (columns 1, 2 and 3). The flow coefficients are defined to be flux-functions in the local limit, but can even change signs in the global simulations, as is found here. Note that the flow structures extend from the pedestal top (black dotted line) into the core, for a distance that scales with the orbit width.*

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References

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