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KNOSOS, a fast neoclassical code for three-dimensional magnetic configurations: validation and optimization studies

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An accurate calculation of radial neoclassical transport is important for both tokamaks and stellarators. In tokamaks, deviations of the magnetic field from axisymmetry (caused, for example, by ripple due to the finite number of coils or by resonant magnetic perturbations) can result in significant neoclassical damping of the toroidal rotation. In stellarators, their intrinsically three-dimensional configurations lead to specific neoclassical transport regimes that produce radial energy transport comparable, and often larger, than its turbulent counterpart. Although typically less demanding than gyrokinetic codes, the computational cost of neoclassical simulations is crucial for a thorough characterization of transport in three-dimensional configurations, especially at low plasma collisionalities.

In this talk we present KNOSOS (KiNetic Orbit-averaging SOlver for Stellarators), a freely-available open-source code [1,2] that provides a fast computation of low collisionality neoclassical transport in three-dimensional magnetic confinement devices by rigorously solving the radially local bounce-averaged drift kinetic equation. Apart from its remarkable speed, KNOSOS includes physics often neglected in neoclassical codes, such as the effect of the component of the magnetic drift that is tangent to magnetic surfaces and the component of the electrostatic potential that varies on the magnetic surface.

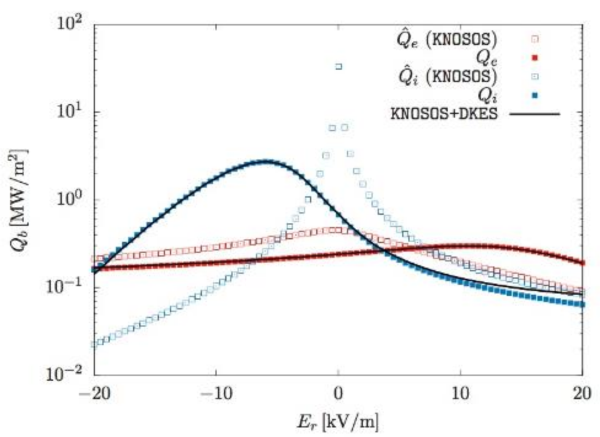

Figure 1: Radial energy flux as a function of the radial electric field for an LHD plasma calculated with (full squares) and without (open squares) tangential magnetic drift. Blue corresponds to ions and red to electrons.

In the first part of the talk, by characterizing plasmas of several devices, we show that, where applicable, KNOSOS reproduces the results of standard neoclassical codes, being orders of magnitude faster [2]. The examples provided include the solution of the ambipolarity and quasineutrality equations, since both the radial electric field and the variation of the electrostatic potential on the flux-surface may have a strong impact on the radial transport of impurities. To date, these equations could only be solved consistently at a large computational cost. Experimental validation studies will be reported [3,4].

In the second part of the talk we illustrate how, by retaining the effect of the component of the magnetic drift that is tangent to magnetic surfaces, KNOSOS can describe the superbana-plateau transport regime of stellarators and non-axisymmetric tokamaks. We also explain that KNOSOS keeps the dependence of the tangential magnetic drift on the magnetic shear: it is known to be relevant for the calculation of the neoclassical toroidal viscosity in tokamaks with broken axisymmetry [5], and could affect energy transport in heliotron-type stellarators, whose configuration is characterized by a strong magnetic shear. An example is shown in figure 1.

We end by outlining several planned applications of KNOSOS for stellarator and tokamaks, including neoclassical analyses in Wendelstein 7-X, LHD and ASDEX Upgrade, and optimization studies of heliotron-type devices [6].

References

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