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Effects of impurities on drift wave based particle transport and comparison with neoclassical impurity particle transport

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INTRODUCTION

Drift wave based descriptions of energy confinement in tokamaks have developed over the last decades towards a standard model for anomalous ion energy transport in the gradient region of the plasma. This holds true mainly for the main ion species although combined descriptions of ITG, TEM and in some cases ETG modes provide reasonable estimates also for the electron transport channel [1, 2, 3]. These models have traditionally been used much less for studies of particle transport. A new implementation of the Weiland model is extending the original formulation to contain an arbitrary number of ion species [4].

Initial work with the extended version of the implementation (EDWM) [5] showed that the deuterium and tritium can have different characteristics in going from tritium trace levels to a 50-50 mix of DT. The composition of the plasma has an impact also on the stability of the main ion drift wave descriptions and detailed results on the linear stability of DT plasma in presence of impurities will be discussed in the second section of this short paper.

The relative importance of neoclassical and anomalous particle transport depends on the charge number of the species being studied as well as the detailed relation between the shape and magnitude of the different density and temperature profiles under investigation. The different scaling with charge number in drift wave based and neoclassical models tend to favour a stronger component of neoclassical transport for higher Z impurities. However, profile effects may obscure the simple scalings in that the drive terms for the anomalous transport in particular may be reduced or that the balance between temperature and density scale length may lead to a comparatively larger influence of the thermo-diffusion component over the Ware pinch (in neoclassical modelling) or curvature driven pinch in the anomalous case. The detailed balance between the two descriptions will be discussed and comparisons made with the NCLASS [6] model.

INFLUENCE OF IMPURITIES ON THE DT PARTICLE TRANSPORT

The EDWM model can be exercised in different ways incorporating different levels of physics sophistication. In order to highlight the underlying physics effects the scans on impurity effects were done using a reduced set of physics options available in the model. In particular, this baseline test model runs are done using an electrostatic model in the local limit with no $k_{//}$ effects but assuming a population of deeply trapped particle treated as a fluid species.

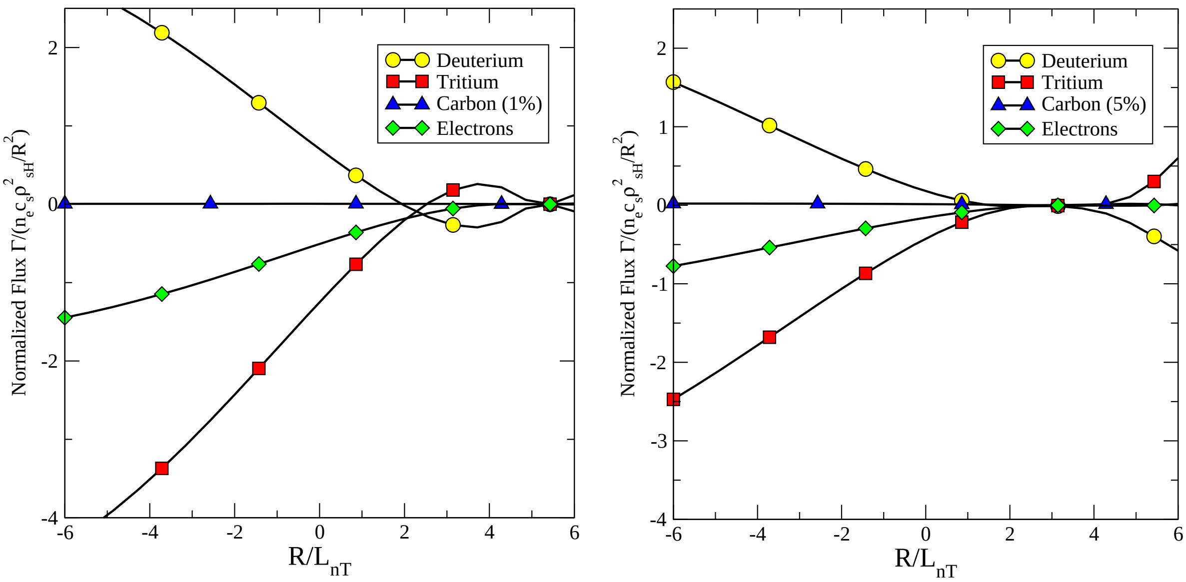

Figure 1 Stabilizing influence of different levels of carbon on deuterium and tritium transport. The left graph has 1% Carbon and the graph on the right has 5% carbon. Normalized transport levels calculated from quasi-linear estimates form the baseline version fo the EDWM model are shown as a function of a varying tritium gradient. Base parameters are R/LT = 3.75, R/Ln $_{D,C}$ = 2., Te/Ti = 1.0, f_t = 0.4. R/Lne is calculated from ambipolarity

We note that as R/Ln_T for the tritium becomes large in magnitude the transport becomes more or less completely determined by the deuterium component (which here remains fixed at R/Ln_D = 2) and a linear dependence of the tritium particle flux and the tritium gradient is established. This can be seen in figure 1. for large negative R/Ln_T. Although not shown explicitly in the figure continuing towards large positive R/Ln_T will yield the same linear dependence. In the intermediate region where the D and T transport is closely linked and the asymmetry in the D and T particle fluxes remain as described in [5] and the tendency to equilibrate the density scale-lengths between species is not destroyed by the presence of an impurity species. The main effect apparent from the presence of the impurity species, here taken to be Carbon, is a stabilizing trend with increased dilution of the main ions. For less peaked or inverted carbon profiles both the deuterium and the tritium particle transport tend to increase, see fig 2. The presence of an excited impurity ITG mode for large impurity fractions only marginally affects the DT fluxes.

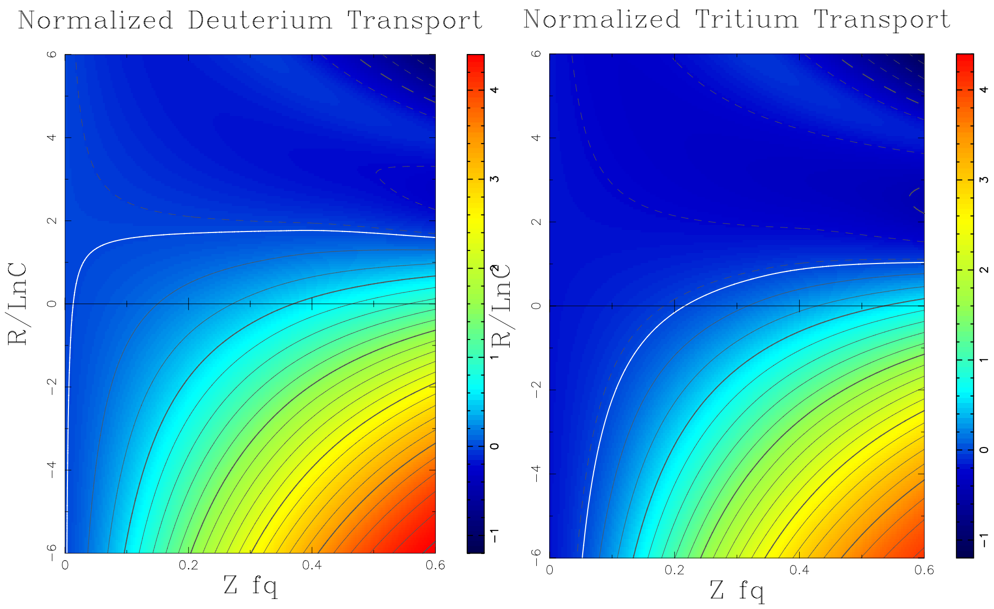

Figure 2. Variation of the impurity (Carbon) content and the scalelength around the nominal condition as presented in Figure 1. $R/Ln_D = R/Ln_T = 2$, otherwise same parameters as given in Fig. 1.

COMPARISON OF ANOMALOUS AND NEOCLASSICAL PARTICLE FLUXES

In general profile effects are important for both neoclassical transport properties (sign and magnitude of thermodiffusion and other non-diagonal effects are sensitive to relative gradient scalelengths between different species and ITG/TEM transport is non-linearly driven by gradients. In the trace particle limit the anomalous gradient response becomes linear and estimates of the relative importance of the two competing mechanisms simplifies in principle. Here we use perturbative D and V estimation techniques in the DEA code [5] to compare interpretative fluxes from neoclassical and anomalous estimates. The slope of the response is proportional to the diffusivity, the intersection with the y-axis represents the pinch velocity and the intersection with the x-axis is the local peaking factor –VR/D. As seen in figure 3 the Z-dependence is as expected, however the D are similar in magnitude (left panel). Increasing the background ion temperature gradients by 25% strongly increases the anomalous component of the diffusivity. A reduction of the gradient scale by 25% reduces both D and V to neoclassical values and often the anomalous pinch can reach neoclassical values for only small profile variations. In general it is found that the magnitude of V can be very similar for the ITG/TEM model and the full off-diagonal neoclassical pinch. For non-trace species the situation is more complex, pinch terms are often competing leading to a net effect that are of the same magnitude as the Ware pinch. In both cases the detailed dependence of the off-diagonal terms on the gradients may provide transport contributions comparable to ITG/TEM particle transport contributions.

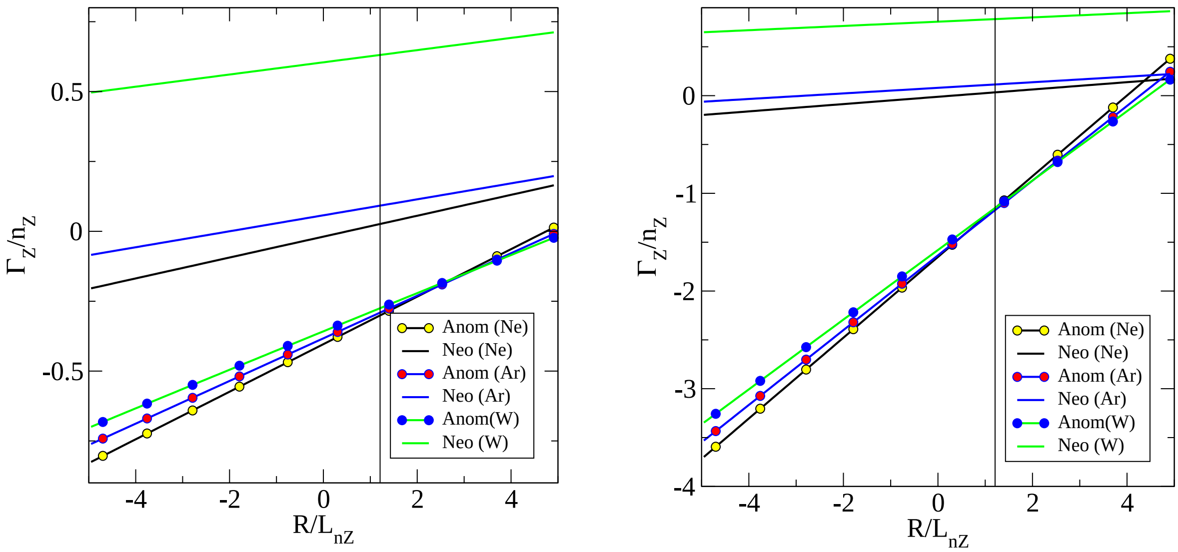

Figure 3. Comparison between neoclassical and neoclassical fluxes for three different trace impurities in a DIII-D type discharge. Anomalous estimate is calculated using the full physics version of the EDWM. Nominal values in the left panel with data from DIII-D #98775 at t=1.52s but with Carbon replacing the Neon profile and introducing Ne, Ar and W as small trace impurities as a fraction of the electron density. In the right panel same data but with R/Lti increased by 25%.

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