*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-5.187 (2004)*

Comparisons of anomalous and neoclassical contributions to core particle transport in tokamak discharges

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The need for a more detailed description of the anomalous transport of different particle species in reactor grade plasmas has driven the development of an extended version of the Weiland transport model [1] for ITG, TE and impurity modes to provide separate descriptions of each of the hydrogen isotopes, helium ash and multiple charge states impurities within a single description. The Extended Drift Wave Model (EDWM) incorporates an arbitrary number of ion species in a multi-fluid description, an extended wavelength spectrum and has been completely rewritten as a self contained Fortran 95 module.

This paper sets out to briefly describe initial results of the EDWM with respect to DT particle transport, compare some of the results with standard neoclassical theory and to introduce the DEA code (Density Evolution Assessor), a semi-predictive particle transport code that has been developed in parallel with the EDWM.

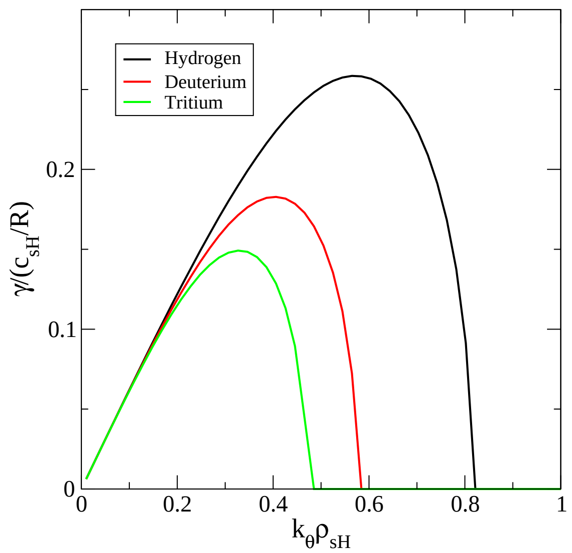

Figure 1. Growth rates as a function of $k_\theta\rho_{sH}$ for H, D and T each. R/Ln = 2, Te/Ti=1 and R/LT = 3.75

The need for an extended wavelength spectrum when treating multiple hydrogen species is demonstrated in Figure 1., where the peak of the normalized ITG growth rate as a function of the hydrogen $k_\theta\rho_{sH}$ is shown. An electrostatic version of the model with no parallel physics or collisions was used to obtain these results. Only the ITG mode is excited for the range of parameters (R/Ln = 2, R/Lt = 3.75 and Te/Ti = 1). To cover the peaks in cases when H, D and T are mixed we need to replace the effective correlation length used in [2] with a sampling of the actual spectra. For cases where the ITG mode provides the dominant contribution to the transport and for similar density length scales for the hydrogenic species, the ITG growth rate (γ) and particle flux (Γ) can be shown to scale as $\gamma \propto 1/\sqrt{M_i^{eff}}$ and $\Gamma \propto \sqrt{M_i^{eff}}$ respectively. Figure 2 shows that the frequently used assumption that deuterium and tritium particle fluxes and diffusivities are similar does not hold when the corresponding density scale-lengths are different.

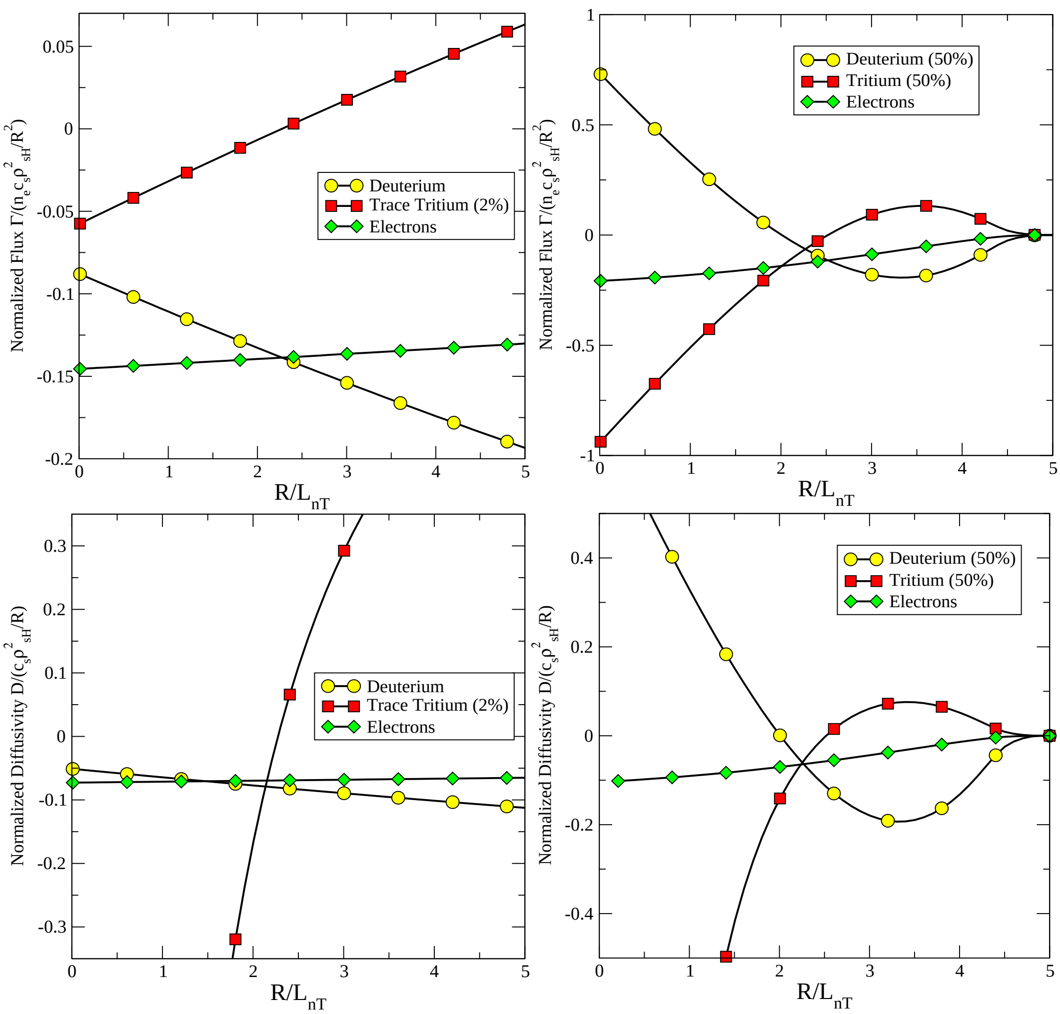

Figure 2. Deuterium, tritium and electron particle fluxes (top) and diffusivities (bottom) as a function of tritium density scalelength (R/LnT) for left) a 2% trace tritium case and right) a 50/50 DT mix. Fixed shape background plasma with Te/Ti=1, R/Ln=2 and R/Lt=3.75, for all specie, fraction of trapped electron = 0.4.

We note that the sign of the inferred effective diffusivities are such that the system tries to equilibrate the density scale-lengths between the species as noted in non-linear GS2 simulations [3]. For the trace tritium case, the influence of the varying tritium density scale-length on the growth rate is very weak. The difference in shape between the trace tritium case and equal mix cases is due to the comparatively stronger influence of the gradients for the 50/50 DT mix. The main feature, i.e., the difference in sign between the deuterium and tritium fluxes follows from the ambipolarity condition built into the linear dispersion solver. These results were obtained with a reduced set of physics options available in the model. Using the full physics version (collisions, electromagnetic effects in a weak ballooning formulation etc) does not appear to qualitatively change the results presented. Limited sampling suggests that driving an additional TE mode or introducing an impurity species into the calculations does not significantly change the DT transport properties either. An interpretative analysis comparing the particle fluxes calculated from a comprehensive neoclassical model (NCLASS) [4] and EDWM is shown below. The calculations are based on an ELMy JET H-mode (#37718 at t=53.8s) taken from the International Profile database [5, 6]. At the analysis time point, an ITG and a TE mode is excited in the gradient region (ρ > 0.2). Inner core profiles are too flat to drive any drift wave transport and neoclassical transport dominates. Figure 3 shows density and temperature profiles and deuterium particle fluxes together with ITG and TE mode growth rates and real frequencies. A clear particle pinch is observed through the combination of the Ware pinch and a TEM driven pinch. To examine the dynamic interplay between different transport mechanisms a semi-predictive particle transport code, DEA (Density Evolution Assessor), has been constructed and initial results are presented here.

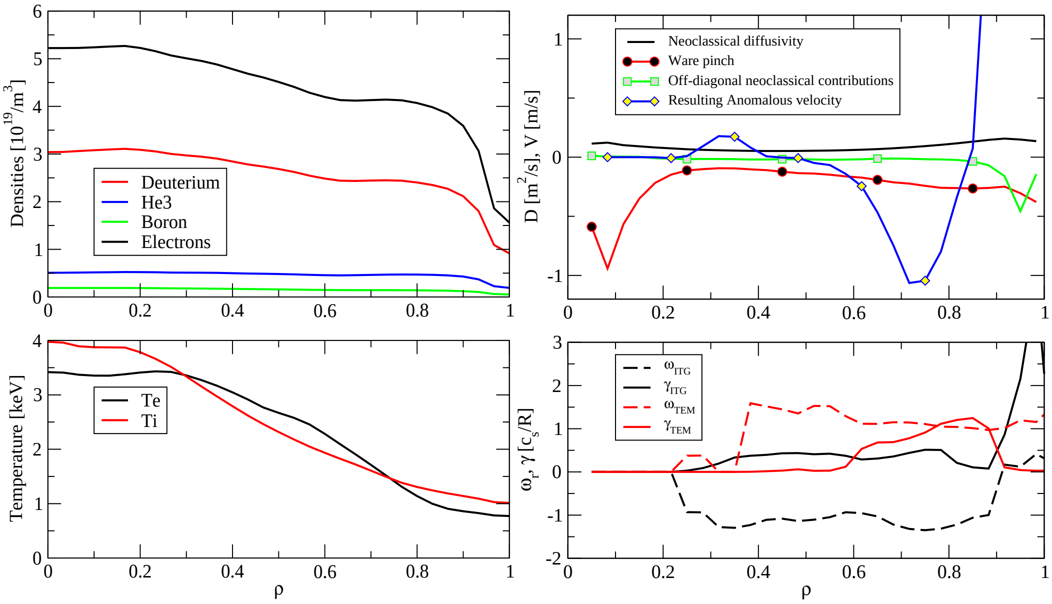

Figure 3. (Left Panel) Temperature and density profiles from JET 37718. (Right Panel) Comparison of neoclassical and anomalous contributions to the D transport.

Simulations, using the conditions shown in Figure 3 as starting conditions (using only a wall particle contribution source), show an initial core peaking due to the neoclassical Ware pinch. This peaking tendency saturates through an outward flux from a kinetic ballooning mode that grows up with increased peaking together with an ITG type mode (labelled Imp. ITG in the figure). To a lesser extent a reduction of the Ware pinch through non-inductive effects is also visible. The TE driven pinch in the outer core broadens initially in the simulations and as density becomes steeper the pinch is reduced and eventually changes direction.

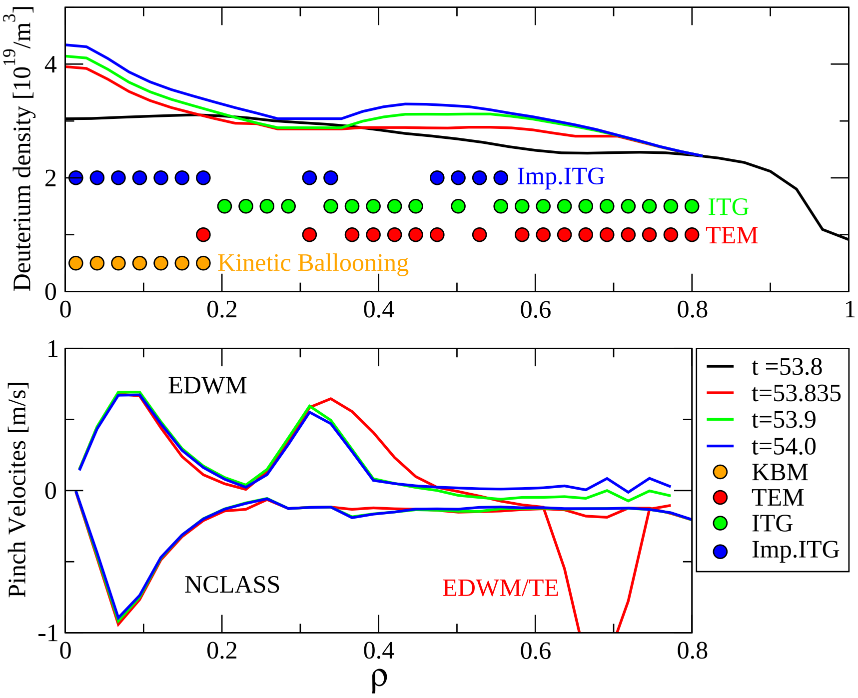

Figure 4. DEA simulation: Initial time evolution of 37718, (NB sources turned off).
(Top:) Peaking of deuterium profiles with indication of excited modes.
(Bottom:) Net neoclassical and anomalous particle flows at different times..

In summary, the extended drift wave model (EDWM) for multiple ion species has been introduced together with the semi-predictive particle transport code, DEA. Initial studies shows that deuterium and tritium diffusivities may be different and that a combination of neoclassical and anomalous particle pinch flows may be needed to describe particle peaking.

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