Impact of fast particles and nonlocal effects on turbulent transport in plasmas with hollow density profiles

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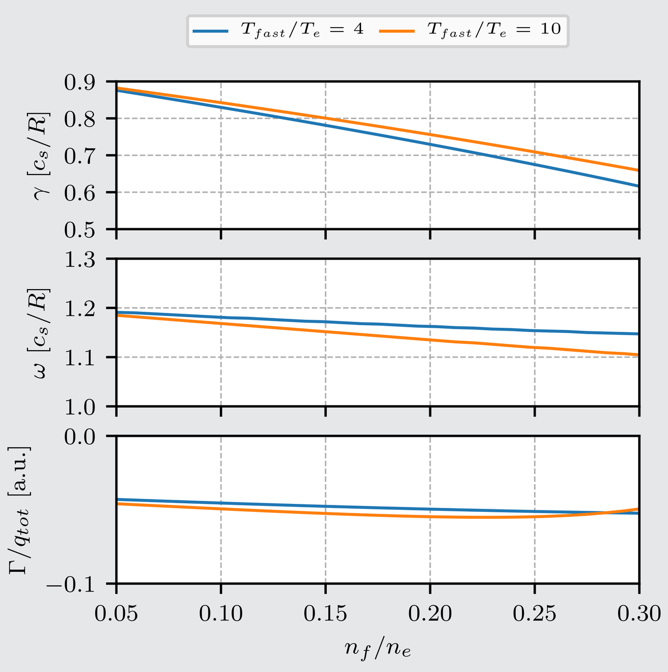
Introduction

- Pellet fuelling and L/H transitions can lead to **hollow** density profiles.
- The positive density gradient (negative $R/L_n = -\frac{1}{n}\frac{\partial n}{\partial r}$) can stabilise turbulence or change the relation between diffusive and convective fluxes.[1]
- The presence of a fast particle species can modify this interplay.
- If the positive gradient region is narrow, so that the gradient varies fast, nonlocal effects can play a role.
- Results of gyrokinetic and fluid models are compared for a CBC-like system.[2]

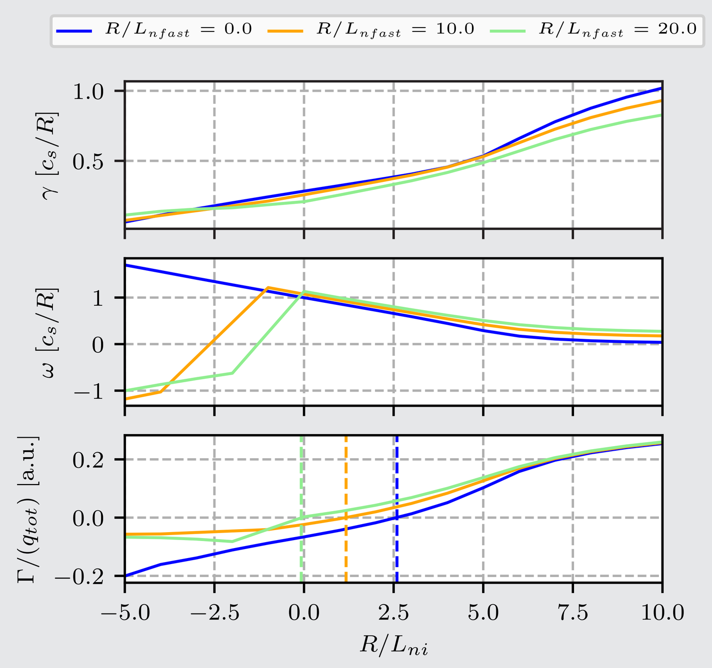
Fast particle effects

Fast particles (FP) can stabilise ITG through a number of effects: dilution, Shafranov shift, electromagnetic stabilisation through suprathermal pressure gradients. [3]

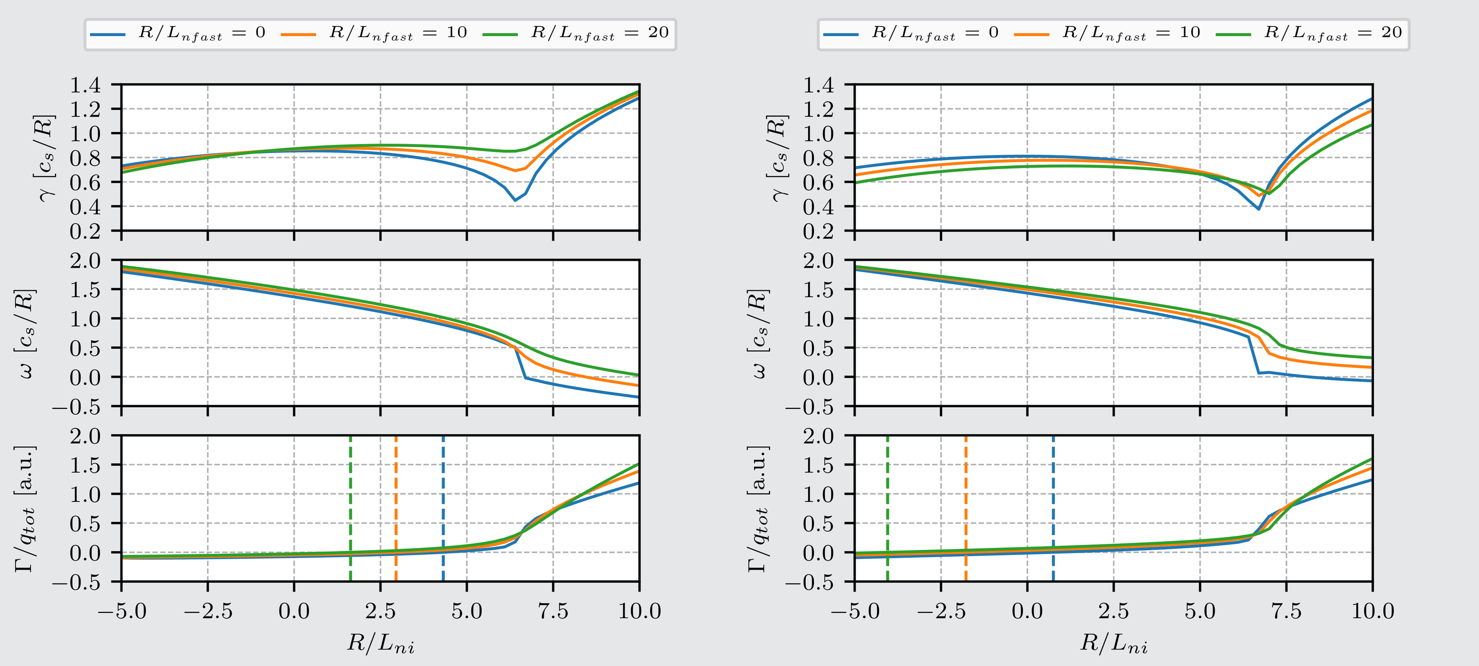
- FP are modelled with Maxwellian background distribution here.
- To enforce quasineutrality: electron density gradient is adapted
- $k_\perp \rho = 0.3$



EDWM: Dependency on the fast particle fraction



Linear GENE: Dependency on $R/L_{n,fast}$ with $\beta = 0.5\%$



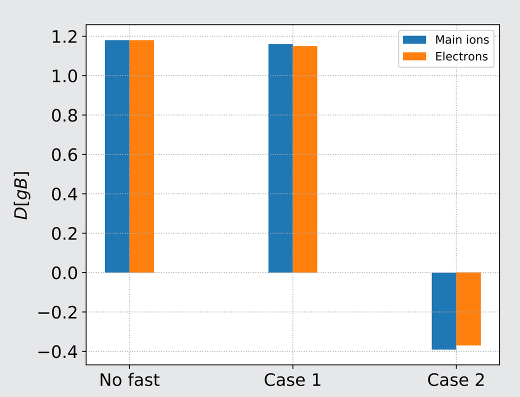
(a) $\beta = 0$ (b) $\beta = 0.5\%$

EDWM: Dependency on $R/L_{n,fast}$

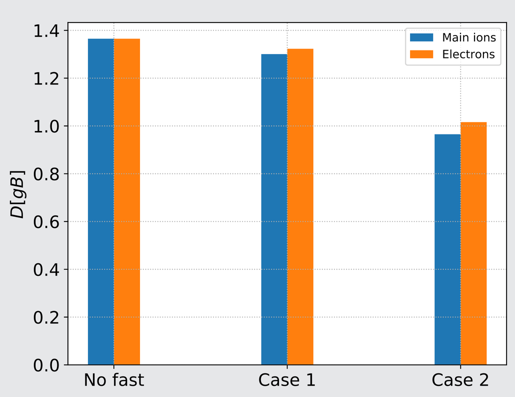
- Fast particles stabilize turbulent modes with increasing fraction.
- For $\beta = 0.5\%$ FP stabilisation dependency on $R/L_{n,fast}$ reverses.
- Finite β and fast particles both decrease the inward particle flux in a negative R/L_n region.
- This can be qualitatively observed both in EDWM and GENE.

Diffusivity predictions: ($T_{fast}/T_e = 10$, $\beta = 0.5\%$)

	$\frac{R}{L_{n,fast}}$	$\frac{R}{L_{n,i}}$	$\frac{R}{L_{n,e}}$
Case 1	0	-2.78	-2.5
Case 2	15	-2.5	-0.75
No fast		-2.5	-2.5



EDWM



Nonlinear GENE

- No strong impact of fast particles in case 1
- Case 2: ITG stabilisation due to pressure gradient, even outward (up ∇n) particle flux with EDWM
- EDWM and GENE only disagree for case 2, still right tendency

Simulation setup

Gyrokinetic model:

- GENE code[4] which solves the nonlinear gyrokinetic equation on a fixed grid in 5D phase space.
- Arbitrary number of gyrokinetic species
- Electromagnetic effects and collisions can be included
- Local (flux-tube) and radially global simulations

Fluid model:

- Extended version of Weiland drift wave model (EDWM)[5]
- Arbitrary number of ion-species in multi-fluid description

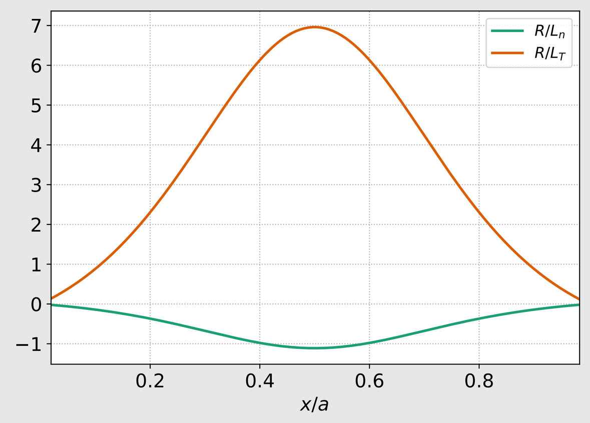
Cyclone base case (CBC):

- $q = 1.4, \hat{s} = 0.8, B_0 = 3.1\text{T}, \epsilon = 0.18, R = 1.65\text{m}, T_e = T_i = 2.85\text{keV}, R/L_T = 6.96, n_e = n_i = 3.5 \cdot 10^{19}\text{m}^{-3}$

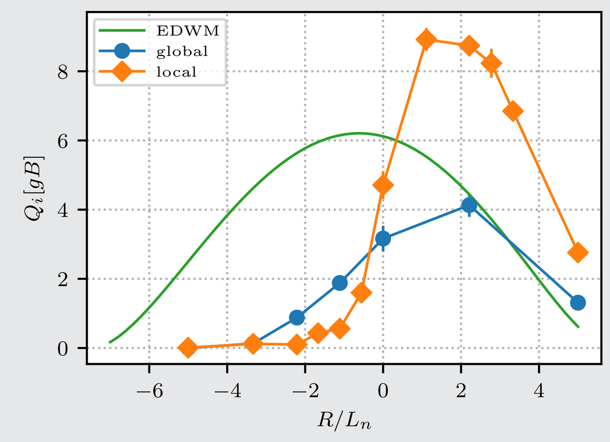
Finite ρ_* effects

Comparing EDWM and global ($\rho_* = 1/300$) and local GENE simulations:

- Adiabatic electrons, i.e. only ITG turbulence
- Physical parameters at $x = 0.5a$ correspond to CBC
- Profiles of $R/L_n, R/L_T$ have Gaussian-like shape
- Monotonically increasing q profile

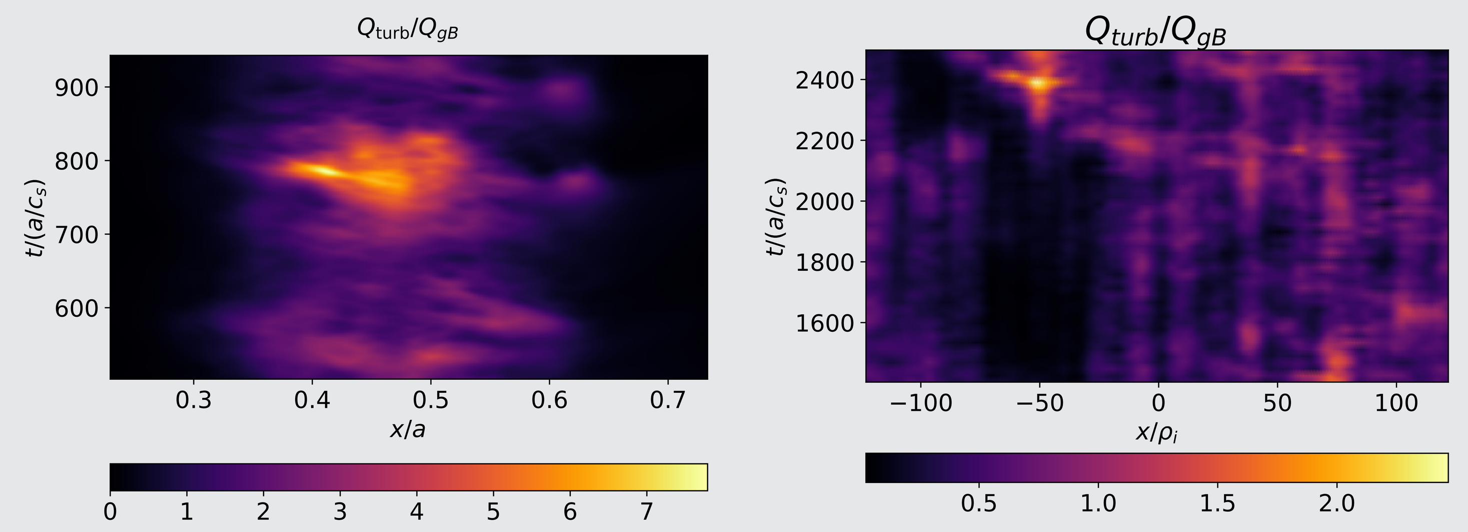


Radial profiles of gradients



Time and radially averaged heat flux

- EDWM reproduces only qualitative dependence of Q on R/L_n, based on $k_\perp \rho = 0.2$
- Positive R/L_n: Less heat flux in global simulations (expected, see e.g. [6])
- Negative R/L_n: Weaker turbulence suppression for global modes



(a) global (b) local

Temporal-radial behaviour for $R/L_n = -1.1$

- More coherent structures (avalanches) in global simulation
  $\Rightarrow$ Turbulence spreading

Conclusions

- High β and fast particles might be detrimental for pellet fuelling.
- Nonlocal effects can have unusual consequences: higher heat transport.

References and Acknowledgements

[1] Daniel Tegnered, Michael Oberparleiter, et al. In: *PPCF* (2017). accepted.
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[4] http://genecode.org/.
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[6] J Candy, RE Waltz, and W Dorland. In: *PoP* 11.5 (2004), pp. L25–L28.

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