EUROfusion

# Gyrokinetic simulations of transport in pellet fuelled discharges at JET

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**See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia*

## Introduction

- Pellet injection is the likely fuelling method of reactor grade plasmas.
  - Will temporarily perturb density and temperature profiles and change key dimensionless parameters such as $a/L_n$, $a/L_T$, $\nu_{ei}^*$, and plasma $\beta$ affecting transport properties.
- L-mode pellet injection experiments were performed during 2014 hydrogen campaign.
  - Diagnostic set-up optimized to measure post pellet evolution of density profiles.
  - Accurate equilibrium reconstruction and Gaussian process regression[1] fits of the kinetic profiles were performed as basis for gyrokinetic analysis.
- Following microstability analysis of MAST pellet fuelled discharge where stabilization of all modes was found in negative $a/L_n$ region[2].

## Discharge parameters

- The discharge 87847 is analysed at several radial positions around the pellet ablation density peak.
- $B = 1.7\,\mathrm{T}$, $I_p = 1.75\,\mathrm{MA}$ and $P_{ICRH} = 3.45\,\mathrm{MW}$, $T_i = T_e$ and $n_i = n_e$ is assumed.
  - Focus on time point with the largest density peak, $t = 0.0042\,\mathrm{s}$ after the pellet injection.
  - Results compared to intra pellet time point with relaxed profiles at $t = 0.032\,\mathrm{s}$ after pellet.

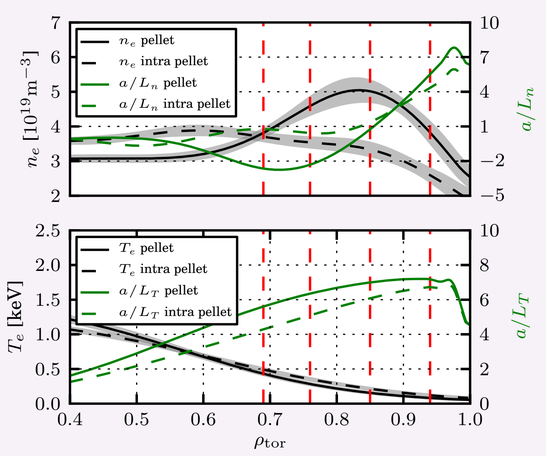


Figure 1: Profiles of density and temperature. Dashed lines indicate radial positions of the NL analysis.

| $\rho_{tor}$ | $t$ [s after pellet] | $n$ [$10^{19}$/m$^3$] | $T$ [keV] | $a/L_T$ | $a/L_n$ | $\nu_{ei}$ [c$_s$/a] | $\beta$ [%] | $q$ | $\hat{s}$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.69 | 0.0042 | 3.81 | 0.43 | 5.60 | -2.64 | 1.39 | 0.20 | 1.61 | 1.32 |
| 0.69 | 0.034 | 3.69 | 0.49 | 4.29 | 0.77 | 1.05 | 0.22 | 1.60 | 1.34 |
| 0.76 | 0.0042 | 4.59 | 0.28 | 6.35 | -2.32 | 3.73 | 0.16 | 1.86 | 1.64 |
| 0.76 | 0.034 | 3.54 | 0.35 | 5.11 | 0.42 | 1.89 | 0.15 | 1.85 | 1.66 |
| 0.85 | 0.0042 | 5.01 | 0.15 | 7.00 | 0.74 | 13.00 | 0.10 | 2.30 | 2.20 |
| 0.85 | 0.034 | 3.34 | 0.21 | 6.08 | 1.36 | 4.74 | 0.09 | 2.30 | 2.22 |
| 0.94 | 0.0042 | 3.83 | 0.08 | 7.16 | 5.50 | 34.44 | 0.04 | 3.01 | 3.42 |
| 0.94 | 0.034 | 2.60 | 0.12 | 6.71 | 4.33 | 11.36 | 0.04 | 3.01 | 3.43 |

Table 1: Discharge parameters

## GENE simulations setup

- Both linear and nonlinear simulations of ITG/TE mode turbulence performed using the gyrokinetic code GENE[3] in a flux tube domain.
- Including finite $\beta$ effects and collisions in realistic geometry.
- Fast particles and rotation are not expected to play important role in this low-$\beta$, ICRH heated discharge and are not included.
- For nonlinear GENE simulations, simulation domain in the perpendicular plane of $L_y \sim 125 - 250\rho_s$ and $L_x \sim 110 - 240\rho_s$ with a typical resolution of $[n_x, n_{k_y}, n_z, n_{v_\parallel}, n_\mu] = [144, 48, 32, 64, 16]$.
- Collisionless simulations included in order to connect results to more reactor relevant conditions.

## Linear results

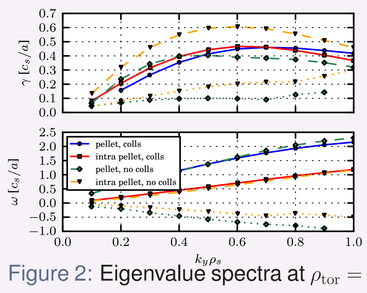


Figure 2: Eigenvalue spectra at $\rho_{tor} = 0.69$, subdominant modes dotted.

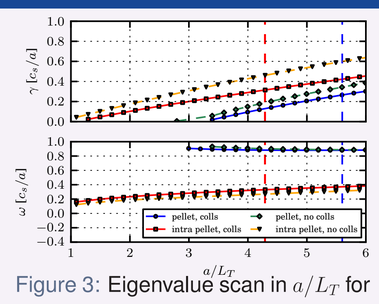


Figure 3: Eigenvalue scan in $a/L_T$ for $\rho_{tor} = 0.69$ and $k_y\rho_s = 0.3$.

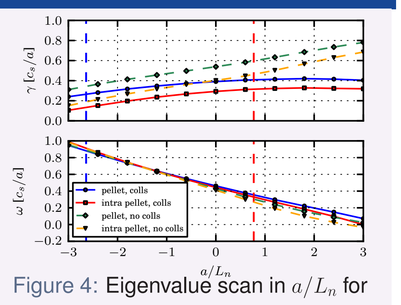


Figure 4: Eigenvalue scan in $a/L_n$ for $\rho_{tor} = 0.69$ and $k_y\rho_s = 0.3$.

- Eigenvalue spectra dominated by ITG mode for $k_y\rho_s < 1.0$ and $\rho_{tor} < 0.95$.
- With collisions the normalised growth rates are slightly reduced in the pellet case in the negative $a/L_n$ region.
  - Negative $a/L_n$ stabilising but partially undone by increase in $a/L_T$.
- In the collisionless case the stabilisation at the pellet time point is more pronounced.
- Subdominant TE-mode with reduced growth rates appears at pellet time point without collisions, collisions stabilise it.

## Nonlinear results

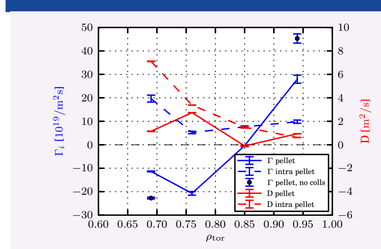


Figure 5: Particle fluxes and effective diffusion coefficients.

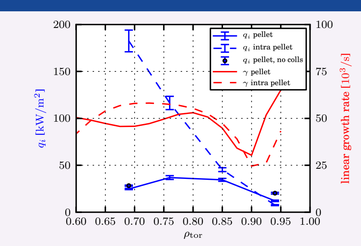


Figure 6: Ion heat fluxes, linear growthrates at $k_y\rho_s = 0.3$ also shown.

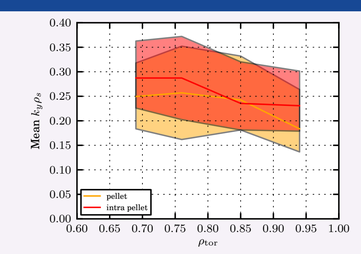


Figure 7: Mean $k_y\rho_s$ of the ion particle flux

- Particle flux inwards in negative $a/L_n$ region, changes sign on the outside of the pellet ablation peak.
  - Similar magnitude on each side of the pellet ablation peak.
  - In negative $a/L_n$ region diffusion coefficients are lower after the pellet than at intra-pellet time.
- The outward heat fluxes are greatly reduced in negative $a/L_n$ radial range compared to intra pellet case.
- Collisionless simulations at $\rho_{tor} = 0.69$ and $\rho_{tor} = 0.94$ exhibit larger particle fluxes than collisional case in unchanged direction.
- Poloidal flux spectra remain similar at both time points.

## Conclusions

- ITG mode growth rates slightly reduced in negative $a/L_n$ radial range.
- Outward heat fluxes and diffusion coefficients reduced on inside of the peak compared to intra pellet time point.
- Particle fluxes on each side of the peak were of similar magnitudes and in opposed directions, suggesting a symmetric evolution of post-pellet density profiles.

## Acknowledgements and references

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[1] MA Chilenski, M Greenwald, Y Marzouk, NT Howard, AE White, JE Rice, and JR Walk. *Nuclear Fusion*, 55(2):023012, 2015.

[2] L Garzotti, J Figueiredo, CM Roach, M Valovič, D Dickinson, G Naylor, M Romanelli, R Scannell, G Szepesi, MAST Team, et al. *Plasma Physics and Controlled Fusion*, 56(3):035004, 2014.

[3] http://genecode.org/.

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