Role of small-scale turbulence and multi-scale interactions in electron heat transport in 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

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JET L-mode plasmas with Ion Cyclotron Resonance Heating (ICRH) electron heating with and without significant ion heating by Neutral Beam Injection (NBI) are studied with gyrokinetic simulations performed with the GENE code in the local limit [1]. The simulations cover both the electron and the ion scales and take into account also the multi-scale interactions.

In the ion scale simulations, where the dominant modes are the Trapped Electron Modes (TEM) and the Ion Temperature Gradient (ITG) modes, despite the numerous confidence tests on the main parameters (such as R/L_{Te}, R/L_{Ti}, R/L_{in}, s), it was impossible to reproduce the electron heat fluxes and especially the electron stiffness found experimentally. Furthermore, both higher electron stiffness and lower values of R/L_{Te} are observed in plasmas with significant NBI heating than in plasmas with pure ICRH heating, for the same normalized electron heat flux [2]. This could not be reproduced in the simulations.

A possible explanation of the missing electron heat fluxes and of the difference between the discharges with and without NBI heating was found in the Electron Temperature Gradient (ETG) modes. In recent works, these modes and their interaction with ion scale modes are found to be responsible of a large amount of the heat flux in certain regimes [3-5]. Linear gyrokinetic simulations indicate that ETG modes are unstable in all the JET plasmas considered and that, due to the differences in \( \tau = \frac{Z_{eff} T_e}{T_i} \), the ETG threshold in the discharges with NBI heating is lowered [6], confirming the possibility of a greater influence of ETGs in plasmas with \( T_e < T_i \). Nonlinear simulations on electron scales were performed using the external flow shear as the mechanism that leads to a saturation of the ETG streamers. Using a simple addition of the fluxes due to TEM/ITG and due to ETG, the experimental electron and ion heat fluxes could be reproduced quite well. Also, in the discharges with only ICRH heating, the electron stiffness was reproduced [6].

Motivated by these results, a first multi-scale simulation was started using the experimental parameters, two kinetic species, real ions/electrons mass ratio, and Miller geometry. This simulation will allow to study how the instabilities on different scales interact and how the nonlinear transfer of energy between different scales in the system takes place, and to have a direct comparison between theory and experiment.

“This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.”