First principles modelling of Magneto Hydro Dynamic instabilities and their control in magnetic fusion devices using HPC techniques

Presented by Marina Becoulet

Atomic Energy Commission, Institute for Magnetic Fusion Research, CEA/ IRFM, Cadarache, 13108, St. Paul-lez-Durance, France.

The main goal of ITER project is the demonstration of the feasibility of future clean energy source based on the nuclear fusion in magnetically confined plasma. In the era of ITER construction fusion plasma theory and modelling provide not only deep understanding of a specific phenomenon but play a crucial role in solving urgent issues and taking modelling-based design decisions for active plasma control mandatory in ITER. The most demanding of HPC resources first principles fusion plasma modelling relies on fluid models, such as Magneto Hydro Dynamics (MHD), when applicable, or more and more often on kinetic models. The challenge stems from the complexity of the 3D magnetic topology, large difference in time scales from Alfvenic (10^{-7}s) to confinement time (hundreds of s) and large difference in space scales of micro-instabilities (mm) to the machine size (few meters) and most importantly from the strongly non-linear nature of plasma instabilities which needed to be avoided or controlled. The overview of the recent non-linear MHD modelling results of Edge Localized Modes (ELMs) and their control by Resonant Magnetic Perturbations (RMPs) in ITER (Fig.1) will be presented after the validation of the model in the existing machines. In particular, it will be shown that the non-linear, multi-harmonics approach, realistic tokamak geometry with the X-point and the Scrape-Off-Layer (SOL), optimized spectrum of RMP coils, toroidal rotation and bi-fluid diamagnetic effects implemented in JOREK code [1], represent a minimum model which permitted to reproduce ELMs suppression by RMPs in AUG [2], KSTAR[3] and ITER.

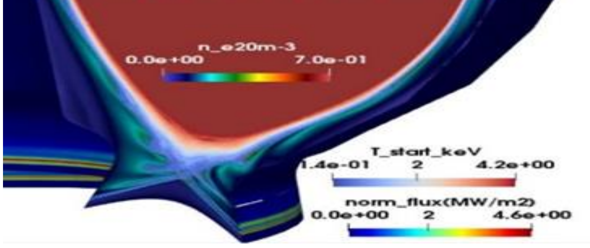

Fig.1. Density, magnetic topology (Poincare plot) and divertor heat flux in ELM suppressed stage by RMPs N=3, 60kAt in ITER.

References :

[1] G T A Huysmans et al Plasma Phys Control Fusion 51 (2009) 124012
[2] F Orain et al Phys. Plasmas 26(2019), 042503
[3] S K Kim et al Nucl. Fusion 60(2020), 026009