6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Global electromagnetic gyrokinetic simulations of Energetic Particle driven instabilities in ITER and ASDEX Upgrade

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Nonlinear global gyrokinetic treatment of electromagnetic instabilities proved almost impossible for a long time. This work reports on how breakthroughs in global models have allowed results of energetic particle (EP) - Alfvénic instability interactions, previously plagued by the difficulties of the multiscale nature of global modes in realistic plasma betas such as kinetic effects and large ion/electron mass ratio.

A large challenge facing burning plasmas such as ITER will be how to deal with the large population of alpha particles born from fusion reactions. Instabilities such as Alfvén Eigenmodes (AEs) may be driven unstable by 3.5 MeV alpha particles. The amplitude of these perturbations must be predicted, to estimate if alpha particle transport and losses are expected. Dedicated experiments [1] at ASDEX Upgrade (AUG) were performed with a scenario tailored to increase the ratio of the EP to bulk plasma pressure to be closer to a burning plasma, a valuable resource for validating modelling tools. In order to put AEs on the same footing as other perturbations, for example the EP-driven Geodesic Acoustic Mode (EGAM) seen in the AUG experiments, or turbulence, our goal is to model everything in a consistent framework, global electromagnetic gyrokinetics. Reduced models, such as MHD-kinetic hybrid models need higher fidelity results such as these for validation. Recent work [2] has improved the ability of particle-in-cell codes to move to high beta, allowing simulations of large scale global instabilities in realistic plasmas such as ITER [3], EP-turbulence interaction [4], and high-β turbulence [5].

In this work, we present progress that has been made on modelling EP-driven AEs and other instabilities using the gyrokinetic code ORB5 [6], first global nonlinear simulations of AUG scenarios with realistic EP distribution functions, and modelling of two ITER scenarios: Q=10 at 15 MA baseline [7], Pre-fusion Power Operation (PFPO) [8]. For the AUG scenario, we elaborate on the studied interaction of Alfvénic instabilities and EGAMs [9], reporting on the extension of ORB5 by coupling with RABBIT [10] to consider realistic Neutral Beam (NBI) distribution functions. We compare the EGAM growth for cases varying off-axis NBI beam angles. For the ITER 15MA Q=10 scenario, we show predictions that thresholds to enhanced nonlinear alpha particle transport regimes may be within a factor of 2. By considering realistic distribution function for the alpha particles, which is found to increase the drive, we report on predictions of AE growth at nominal EP density with a realistic isotope mix. Finally, we report on the PFPO phase of ITER, a hydrogen plasma with NBI EPs. We look at EP-driven low-n global AEs, medium-n localized AEs, and we also find that higher-n BAEs/AITGs can be driven by the bulk plasma gradients even in the absence of EPs. For this case, also electromagnetic simulations of microturbulence instabilities were performed, driven by the background plasma.

References

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