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Gyrokinetic investigation of the nonlinear interaction of Alfvénic modes and turbulence

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Alfvénic modes (AMs) are macroscopic (i.e. extending for a sensible part of the radial domain) plasma oscillations which are commonly excited by energetic particles (EPs) in tokamak plasmas. EPs, i.e. suprathermal ions, are generated by means of external heating mechanisms, or as a product of nuclear reactions. AMs are known to produce radial particle transport of the EP species, and therefore can modify the heating of the plasma [1]. Turbulence, on the other hand, is historically known to produce radial particle and heat transport of the thermal species in tokamak plasmas. Recently, a strong interaction of turbulence and EPs has been observed experimentally (see for example Ref. [2, 3]) and also studied by means of theoretical analyses [1, 4, 5] as well as local (i.e. flux-tube) numerical simulations (see for example Ref. [6, 7]).

In this work, we investigate the nonlinear dynamics of AMs and turbulence by means of selfconsistent global gyrokinetic simulations. The particle-in-cell code ORB5 [8] is used. The nonlinear interaction of AMs with each of three species of the plasma – thermal ions, thermal electrons, energetic ions – is investigated. Thermal ions and EPs are treated as gyrokinetic, and thermal electrons are treated as drift-kinetic. The interaction of low frequency AMs, like beta-induced Alfvén Eigenmodes (BAE), with the thermal species, and especially with the thermal electrons, is found to be important to determine the saturation level, which is lower if the kinetic electron dynamics is neglected [9]. The excitation of zonal flows by AMs is also investigated, and the zonal flow saturation level is also lower if the kinetic electron dynamics is neglected [9]. Finally, the heat flux of each species, carried by the AMs and by turbulence, is compared and the consequent relaxation of the profiles is described.

As main results, we find that the BAE excited by the EPs can carry substantial heat fluxes of ions and electrons, and it is capable of flattening their temperature profiles (see for example the ion temperature profile in Fig. 1). At the same time, the energy entering the system at the large scales (global BAE) is responsible of an increase of the heat fluxes especially at the toroidal mode numbers corresponding to the BAE and its harmonics.

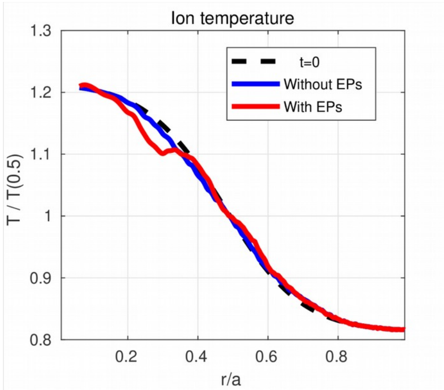

Fig. 1. Ion temperature profile at the beginning of the simulation (dashed line), at the time of the turbulence saturation in the absence of EPs (blue continuous line) and in the presence of EPs (red continuous line). Note the flattening of the temperature around the radial location of the BAE, in the simulation with EPs.

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