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Global nonlinear gyrokinetic treatment of Alfvénic instabilities in ITER

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ITER will be the first tokamak with a significant population of alpha particles, which will bring a number of challenges as compared with current machines. One of these is the resonant interaction of the energetic alpha particles with magnetohydrodynamic (MHD) waves, most notably the instabilities of Alfvén eigenmodes (AEs), e.g. the toroidal Alfvén eigenmodes (TAE). These instabilities have the potential to redistribute the alpha particles in particular, and therefore these instabilities should be understood and modelled.

We present the first applications of a global nonlinear electromagnetic gyrokinetic code to the problem of TAEs in ITER. This work addresses the issues of Alfvén eigenmodes in the ITER 15 MA scenario [1], a scenario previously modelled extensively (see reference [2] and references therein), including results from linear gyrokinetic, nonlinear perturbative hybrid-gyrokinetic, nonlinear nonperturbative MHD-hybrid, and local gyrokinetic models. However, previously, it was not possible to simultaneously retain kinetic, nonperturbative, and global effects – known to be important to TAEs in ITER, due to the difficulties of the large size and plasma beta in ITER for global electromagnetic gyrokinetics.

The results presented were obtained using the ORB5 code [3], a global electromagnetic particle-in-cell (PIC) code using spectrally filtered finite elements for the representation of the fields, and considers all species kinetically, using the so-called "pullback scheme" [4] to mitigate the cancellation problem and help to overcome the aforementioned difficulties.

The presented results first show the linear instabilities, including the effects of the realistic electron mass and the transition between global and localized eigenmodes. This is extended to show the saturation of single modes due to retention of the wave-particle nonlinearity, and finally we show the enhanced saturation amplitudes and alpha particle redistribution in the presence of multiple modes – an effect broadly consistent with previous hybrid modelling [5].

An example of the nonlinear behaviour is shown in Figure 1, where one can see that the nonlinear perturbed field is peaked at larger radius than the linear mode structure. This behaviour is only observed when multiple modes are present and is associated with the enhanced saturation and the local flattening.

The consequences of these results, their limitations and the outlook will be discussed.

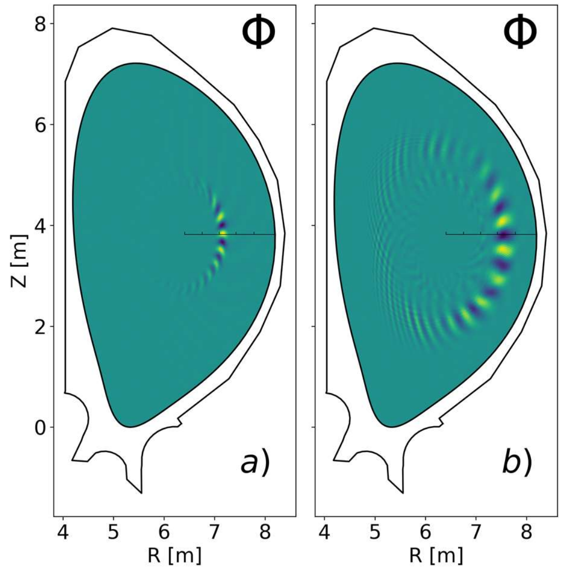

Figure 1: Poloidal cross section of the electrostatic potential in a multi-mode simulation of TAEs in the linear phase (a) and the nonlinear phase after saturation (b).

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