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Local and global analysis of symmetry breaking for ITG and BAE modes

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The mode structure symmetry breaking such as flux surface averaged parallel wavenumber $\langle k_{||} \rangle$ and poloidal angle $\langle \theta \rangle$ is important for estimating the momentum transport due to its connection to the corresponding off-diagonal component [1]. It is also a key concept to demonstrate the non-perturbative effect of energetic particles on Alfvén eigenmodes and to study the interaction between low frequency Alfvén eigenmodes and thermal/energetic particles [2]. In this work, the symmetry breaking of the 2D structure of the Ion Temperature Gradient (ITG) mode and Beta-induced Alfvén Eigenmode (BAE) is studied based on local and global analysis. The Mode Structure Decomposition (MSD) approach [3] is developed with the complex envelope phase variation (θ_k) [4] and global effects taken into account. The results are compared to ORB5, GKW for ITG and XHMGC for BAE.

For the ITG problem, a theoretical method for the calculation of parallel mode structure has been developed [4,5]. It is shown that the radial symmetry breaking is intimately coupled to the parallel symmetry breaking [5]. For local simulations, in addition to the "tilting angle" ($\mathrm{Re}\{\theta_k\}$), the intensity gradient described by $\mathrm{Im}\{\theta_k\}$ affects the local eigenvalue and the symmetry breaking. "Global-oriented local simulations" are suggested where global corrections are taken into account in the local model and its importance for the study of turbulent momentum transport is discussed.

For the BAE problem, the wave-packet calculation technique for weakly coupled poloidal harmonics is proposed to demonstrate the BAE mode structure symmetry breaking, with the non-perturbative effect of the energetic particles (EPs) included. The theoretical global analysis identifies the essence of "boomerang" structures with/without asymmetric tails in poloidal plane as well as the radial and parallel symmetry breaking. The agreement between the wave-packet calculation and XHMGC is achieved. Global effects and non-perturbative EP response are important ingredients for the symmetry breaking and their effects on EP transport as well as the implications to experimental observations are discussed.

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