Fully electromagnetic gyrokinetic eigenmode analysis of high-beta shaped plasmas

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Abstract

A new, more efficient method to compute unstable linear gyrokinetic eigenvalues and eigenvectors has been developed for drift-wave analysis of plasmas with arbitrary flux surface shape, including both transverse and compressional magnetic perturbations. In high-beta, strongly shaped plasmas like in the National Spherical Torus Experiment (NSTX) [M. Ono *et al.*, Nucl. Fusion **40**, 557 (2000)] , numerous branches of closely-spaced unstable eigenmodes exist. These modes are difficult and time-consuming to adequately resolve with existing linear initial-value solvers, which are further limited to the most unstable eigenmode. The new method is based on an eigenvalue approach and is an extension of the GYRO code [J. Candy and R.E. Waltz, J. Comput. Phys. **186**, 545 (2003)], reusing the existing discretization schemes in both real and velocity space. Unlike recent methods, which use an iterative solver to compute eigenvalues of the relatively large gyrokinetic response matrix, the present scheme computes the zeros of the much smaller dielectric matrix using a direct method. In the present work, the new eigensolver is applied to gyrokinetic stability analysis of a high-beta, NSTX-like plasma. We illustrate the smooth transformation from ion-temperature-gradient (ITG)-like to kinetic-ballooning (KBM)-like modes, and the formation of hybrid ITG/KBM modes, and further demonstrate the existence of high-k Alfvénic drift-wave "cascades" for which the most unstable mode is a higher excited state along the field line. A new compressional electron drift wave, which is driven by a combination of strong beta and pressure gradient, is also identified for the first time. Overall, we find that accurate calculation of stability boundaries and growth rates cannot in general ignore the compressional component, $\delta B_{\parallel}$, of the perturbation.

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