Radial Localization of Alfven Eigenmodes and Zonal Field Generation
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GTC gyrokinetic particle simulations of DIII-D tokamak find a radial localization of the toroidal Alfven eigenmode (TAE) due to the non-perturbative energetic particle (EP) contribution \cite{1}. The EP-driven TAE has a radial mode width much smaller than that predicted by the MHD code NOVA \cite{2}. The TAE radial position peaks at and moves with the location of the strongest EP pressure gradients. Experimental data confirms that the eigenfunction drifts quickly outward in the radial direction. The EP contribution also breaks the radial symmetry of the ballooning mode structure and induces a dependence of the TAE frequency on the toroidal mode number, in excellent agreement with the experimental measurements. Our studies show that accurate prediction of the AE growth rate requires non-perturbative, self-consistent simulations to calculate the true mode structures.

GTC nonlinear simulation of the TAE in DIII-D finds that zonal fields are driven by TAE mode coupling (passive generation), rather than the modulational instability. The growth rate of the zonal fields is twice that of the TAE growth rate, consistent with earlier MHD-gyrokinetic hybrid simulations. The effects of the zonal fields on the TAE nonlinear saturation are weak. Furthermore, GTC nonlinear simulations of beta-induced Alfven eigenmode (BAE) show that the mode frequency has a fast chirping associated with the oscillation of the mode amplitude \cite{3}. Localized zonal fields with a negative value around the mode rational surface are generated by BAE. In the weakly driven case, the zonal fields with a strong geodesic acoustic mode (GAM) component have weak effects on the BAE evolution. In the strongly driven case, the zonal fields are dominated by a more significant zero frequency component and have stronger effects on the BAE dynamics \cite{4}.

Electron cyclotron heating (ECH) suppression is one of the few known control mechanisms available for Alfven instabilities. GTC and TAEFL simulation of two recent DIII-D reversed shear discharges in which ECH significantly altered the unstable NBI driven AE spectrum has been carried out. In these discharges, ECH injected near $q_{\text{min}}$ was found to suppress reversed shear Alfven eigenmode (RSAE) activity with primarily weak TAE remaining, and ECH near the magnetic axis was found to enhance RSAE activity. Simulations show a qualitatively similar behavior, \textit{i.e.}, a shift to lower amplitude (weakly growing) TAE when ECH injection shifts from the axis to the $q_{\text{min}}$ location. Simulations find that the dominant contribution to the change of the stability is the modified EP profile.

References: