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Zonal Field Generation by Toroidal Alfven Eigenmode

ZHIXUAN WANG, University of California, Irvine

Zonal fields (zonal flow and zonal current) have been shown to spontaneously generate and regulate microturbulence. The generation of zonal fields by Alfven eigenmodes has attracted intense attention recently. Global hybrid-MHD and local gyrokinetic simulations of toroidal Alfven eigenmode (TAE) indeed find zonal flow generation by mode coupling. However, a nonlinear gyrokinetic theory finds spontaneous generation of zonal fields by TAE modulational instability, arguing the need for kinetic simulations in realistic geometry. Here we use gyrokinetic toroidal code (GTC) to study the TAE in DIII-D discharge #142111 near 525ms by using experimental geometry. Global linear simulation finds a strongly unstable TAE driven by energetic particles (EP) for the dominant toroidal mode (n=4). The radial position of EP-driven TAE peaks at and moves with the location of the strongest EP pressure gradients as EP profile moves outward radially. Experimental data confirms the fast outward drift of the TAE eigenfunction, which is found to be caused by EP non-perturbative contribution. Global GTC nonlinear simulation finds that zonal fields are driven by TAE mode coupling such that the growth rate of zonal fields is twice of the TAE growth rate. Revisiting the nonlinear simulation model reveals a missing nonlinear term, which proves to be especially important for the zonal current. Although zonal current has little effect on the TAE saturation, zonal flow significantly reduces the TAE saturation amplitude.