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Self consistent theory of zonal flows in ion temperature gradient turbulence

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Abstract

Sheared poloidal flows of plasma are known to damp ion temperature gradient driven turbulence in tokamaks. The mechanism for the nonlinearly generated part of the poloidal flow, zonal flows, is less known. Therefore a self-consistent theory of nonlinearly excited zonal flows amidst complex background of ion temperature gradient (ITG) turbulence is presented. Starting with a reactive fluid model, Weiland model, utilizing Taniutis reductive perturbation method a set of coupled nonlinear equations is obtained. The nonlinear equations has a form resembling Zakharov equations. The equations represent dynamical evolution of nonlinearly excited zonal flows and potential fluctuations of ITG turbulence. The zonal flows and ITG turbulence fluctuations are shown to couple through the nonlinearities. For Cyclone Base Case parameters, it is shown that zonal flows are resonantly excited through terms originating from the nonlinearity in the ion energy equation. Using a gyro-Landau fluid model the effect of closure of the fluid hierarchy on the resonant excitation of zonal flows is investigated. It is thereby concluded that even though different fluid models have similar values of the thresholds and growthrates, defining the transport in quasilinear models, the mechanism generating zonal flows is sensitive to the closure of the fluid hierarchy.

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