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Saturation of zonal flow via eigenmodes of tertiary instability

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The profiles of zonal flow, density, and turbulence intensity are found to form static patterns [1] in numerical simulations of the modified Hasegawa-Wakatani (mWH) model [2], resembling the formation of E×B staircases and profile corrugations in global gyrokinetic simulations of turbulence transport [3]. Several reduced models were proposed previously to explain the formation of such profiles, with examples given in Ref. [4–6].

The two-dimensional density and potential in the nonlinear stage show identifiable eigenmodes created by the potential well formed by the zonal flow, indicating their role in the almost-collisionless saturation of zonal flow. They are dubbed as the eigenmodes of tertiary instability (or in fact the primary drift-wave instability modified by zonal flow) by Zhu *et al*. [7] and were found to determine the nonlinear threshold of turbulent transport, i.e. the Dimit shift.

In this work, we solve for the tertiary eigenmode given a static profile of zonal flow and density. We then construct a quasi-linear theory to evolve the zonal flow and density profile. It was found to reproduce the correct shape of the zonal flow and density phasing, providing insights into the saturation of zonal flow and the formation of E×B staircases.

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