Bifurcation analysis of the Dimits shift: Conceptual issues and resolutions*

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Abstract

It is well established that the Dimits upshift[1] is due to the suppression of drift-wave fluctuations by zonal flows.[2] However, systematic calculation of the width of the nonlinearly stable regime as a function of control parameter (background temperature gradient) presents some conceptual challenges. To illustrate the difficulties, a simple fluid model of ion-temperature-gradient-driven turbulence[3] is studied with the aid of systematic bifurcation analysis. The presence of very weakly damped zonal modes in the eigenspectrum is a complicating feature that precludes simple application of cookbook formulas for local bifurcations and construction of the center manifold. An alternate procedure is described and used to obtain a model system of coupled amplitudes for drift waves, zonal flows, and sidebands. The presence of a stable fixed point for finite distance above linear threshold is identified with the Dimits-shift regime. Further complications include the necessity for multiple-scale analysis to deal with a near-continuum of modes that become unstable nearly simultaneously. The method is related to the reductive-perturbation approach employed by Weiland and coworkers,[4,5] but differs fundamentally in its treatment of the sidebands.

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