How Phase Patterns Define Zonal Flow Structure and Avalanche Scale

Z.B. Guo and P.H. Diamond

CMTFO and CASS, University of California, San Diego, La Jolla, CA 92093-0424 USA

We present a novel mechanism for multi-scale interaction, namely phase pattern formation. The physics of the outer scale of the avalanche distribution remains uncertain. Calculation of the zonal flow pattern structure is necessary to predict it. We show that toroidicity can mediate phase couplings of drift waves at different rational surfaces, so that a *global* phase dynamics is induced. It is then the roughening of the global phase profile that induces the inhomogeneity of the turbulent Reynolds stress, and hence drives the ZF. The roughness of the global phase profile can drive a ZF from zero, which is different from the conventional modulational instability paradigms where a seed ZF is required. The evolution equation of the global phase is obtained by taking continuous limit of the phase 'lattice' in the initial stage. The global phase equation is reduced to an Edwards-Wilkinson equation. The PDF of the spatial spectrum of the phase profile (corresponding to the spatial spectrum of the ZF) is obtained by assuming white noise. In the later stage, the phase-detuning effect of ZF shear is incorporated into the phase evolution equation. Thus, that a new feedback loop, focused on ZF-phase, is uncovered. In the steady state, the phase equation determines the *intrinsic spatial structure* of the ZF. The 'shock layer' solution of the global phase profile corresponds to a strong ZF shear layer with its width determined by the safety factor profile, turbulence intensity, etc. We discuss the relation of phase pattern induced ZF structure to the outer scale of avalanching and thus, ultimately, to the degree of Gyro-Bohm breaking. Both ITG and ETG zonal flows are discussed.

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