Multi-Scale and Multi-Step: Zonal Shearing Patters in Drift-ETG Turbulence

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Understanding and predicting the spatial scale of zonal flow shear is of great interest in confinement physics, since zonal shear scale ultimately determines the degree of breaking of gyro-Bohm scaling. Inhomogeneous (potential vorticity) mixing along with feedback of shearing effects on turbulence excitation act to induce zonal modulations which trigger the formation of zonal flow and density gradient *staircase* structures. Such staircases are the highly nonlinear end-state of the initial modulational instability which triggers ZF amplification. Staircase formation by inhomogeneous mixing is an inexorable consequence of the nonlinear gradient dependencies of the fluxes[1,2] (heat, particles, vorticity) and not limited to regimes accessible in certain types of simulations[3]. Staircases can condense to form barriers.

In this paper, we report on studies of zonal flow morphology in multi-scale turbulence systems. We have developed a reduced model in which:

i.) (larger scale) drift waves and (smaller scale) ETG modes coexist and compete for the free energy in $\nabla T_e$, driven by the heat flux $Q$.

ii.) independent but coupled turbulence potential enstrophy populations are evolved, as a function of radius and time. The radial scales of these two populations are disparate. The populations each couple to $\nabla T_e$ and to zonal potential, albeit on different scales. The populations interact with each other via DW spectrum induced stochastic straining[4].

iii.) zonal structures on drift and ETG scales.

Preliminary results indicate that the two populations tend toward spatial competition, i.e. ETG's are excited in steep $\nabla T_e$ regions between 'steps' in the drift wave staircase. Such excitation naturally triggers the formation of a small scale staircase within the steep $\nabla T_e$ zones of the larger one. Theoretical work focuses on the question of representing the small $\rightarrow$ large scale couplings of the respective population fields.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences program under Award Number DE-FG02-04ER54738.

(1) A. Ashourvan and P.H. Diamond, Phys. Rev. E 94, 51202(R), (2016).
(2) A. Ashourvan and P.H. Diamond, PoP 24(1), 012305 (2017).
(3) G. Dif-Pradalier, et al., Phys. Rev. Lett. 114, 085004 (2015).
(4) C. Holland and P.H. Diamond, PoP 11, 10431 (2004).