On the Structure of the Zonal Shear Layer Field and its Implication for Multi-scale Interactions

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Several fundamental problems in core transport remain unresolved. One of these is quantifying the degree of gyro-Bohm breaking. Another is to explain the strength of turbulence and transport in 'No Man's Land'. Both problems raise questions of apparent non-locality, both in space and in scale. In particular recent simulations[1] suggest that multi-scale interaction of longer wavelength drift-ITG modes with shorter wavelength ETG modes may be crucial to a satisfactory accounting for both electron and ion heat fluxes. One aspect of the long-short interaction is the effect of shearing and straining of the 'shorts' by the 'longs', both by drift-ITG driven zonal flows and the modes themselves[2]. *Thus, understanding the strength and the profile of the zonal flow shearing field is an essential part of the multi-scale problem.*

Here we discuss new theoretical results on the structure of the zonal flow shear profile for a simple model of drift-wave turbulence, with density, vorticity and turbulent potential enstrophy as variables. We present a study of the multi-scale interactions of shear layers which develop from an E×B staircase[3]. Formation of the staircase structures is due to the inhomogeneous mixing of generalized potential vorticity (PV) resulting in the sharpening of density and vorticity gradients in some regions and weakening them in others. Inhomogeneous mixing of PV is implemented via a nonlinear Rhines scale dependent mixing length, which is the crucial element of this model in closing the feedback on PV gradient by reducing the turbulent diffusivity. *The staircase structure develops from the initial modulation and separates the flow shear into mesoscale 'jumps', which are regions of locally steep gradients, and 'steps', which are regions of gradient flattening. The jumps merge and migrate, leading to the development of macroscale profile structures from mesoscale elements.* This process is shown in Fig.1. We emphasize that initial shear layer locations do not correspond directly to the final profile structure. We present extensive studies of bifurcation physics of the global state, including results on

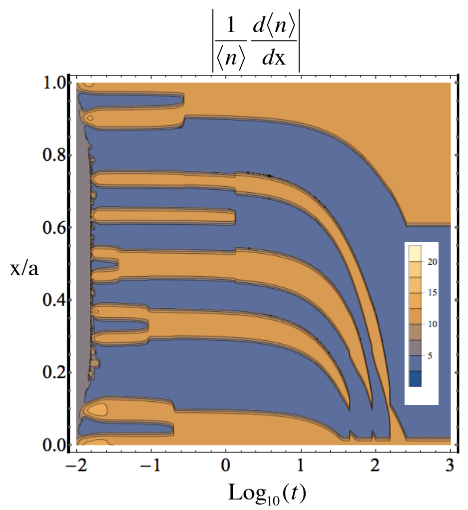

Figure 1: Contour plot of the time evolution of $|d \log \langle n\rangle / dx|$ along the plasma radius. Horizontal axis is the log of time, and the vertical axis shows the scaled radial location.

the global flux-gradient relations (flux landscapes) predicted by the model. Furthermore, we demonstrate that depending on the sources and boundary conditions, either an edge region of improved confinement, or a macro edge step with strong turbulence can form. This suggests that the profile self-organization is a global process, though one describable by a local, but nonlinear model.

The implication of this dynamics for multi-scale interaction problem is that the condensate of zonal structures will necessarily then modulate the ETG field. An edge condensate of steps implies strong ETG activity in 'No Man's Land', while an edge condensate of jumps implies an edge barrier. Ongoing work is concerned with extending the reduced model to incorporate multi-scale effects by adding an additional population of 'shorts'.

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