Turbulent transport close to marginal instability:

role of the source driving the system out of equilibrium

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When modeling plasma turbulent transport different approaches are pursued. One the one hand, flux driven approaches are based on the idea that no scale separation can be assumed in a turbulent system. The system is then driven out of equilibrium by a localized source term favoring inhomogeneous turbulent patterns such as avalanches. On the other hand, gradient driven approaches rely on the idea that the back-reaction of fluctuations on the mean profiles is not a critical ingredient for turbulence self-organization and saturation. The two main advantages of this approach are its reduced numerical cost, and its apparent efficiency for the analysis of experimental data, since the experimental profiles can then be used as input parameters. The driving force for the latter systems is distributed in the whole volume and more homogeneous turbulent patterns can be expected.

Although both approaches can lead to quite different results, a quantitative estimate of their differences is still lacking. This work aims at studying the impact of the type of forcing on a key aspect of turbulence, namely the transition from stability to turbulence and the self-organization of different systems close to criticality.

We start with a minimum model of turbulent systems embedded in the TOKAM2D code that models the interchange instability. We analyze two cases, *flux (FD) and gradient driven (GD)*. Changing the ratio between two parameters, the g-term (g is an averaged curvature drive) and the density gradient length ($L_n = -n/\partial_x n$), we can step the system from a stable state, i.e. below the linear threshold, where the perturbations are dumped diffusively, to a turbulent state, running through different intermediate states.

In the GD approach we can isolate a parameter region, just above the linear threshold ($g/L_n = 0.4\mathrm{E}-5$) in which a decrease of Ln yields a drop of the radial turbulent flux. Such flux collapse can be explained by coupling the interchange instability (that linearly grows with g/L_n and is maximum for small values of k_r) and the Kelvin Helmholtz (KH) instability (that grows from a developed nonlinear state and depends on the magnitude of the linear perturbation). Such interaction leads to a predator–prey mechanism: the linear perturbation (streamers), coupled with the non-linearly unstable mode, generates the zonal flows. Acting as weak transport barriers, these flows reduce the perturbation amplitude and stabilize the non-linear mode. This dynamical pattern takes place periodically and a good agreement is found between numerical and analytical results. Further increasing g/L_n also increases the number of linearly unstable modes until, for g/L_n larger than $0.6\mathrm{E}-5$, the interchange instability becomes dominant and the system is fully turbulent.

The same mechanism is then studied for the FD simulation in which only g-term can be modified, while the density profile is self-defined by the system. In this case, and close to the threshold, the system exhibits similarities with the mechanism described by the GD system. The system self-organizes, creating small transport barriers. These impact the density gradient and do not disappear periodically. The new degree of freedom on the density profile makes the transition to turbulence more complicated and less simple to characterize. New diagnostics are used to compare and better quantify the differences between the two transitions: statistical analysis are performed in order to study the impact of the driving on the fluctuating terms, while the transport at large scale is compared using a coarse graining procedure.