Mechanism for turbulence proliferation in transitional shear flows

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Wall-bounded turbulent shear flows are known to be space-time intermittent at low Reynolds number, with characteristic long-lived isolated turbulent structures (puffs in pipe flow or bands in planar shear flows). At some critical Reynolds number, these isolated structures either decay to the absorbing laminar state, or proliferate via a self-replicating process known as splitting. It is now established that the laminar-turbulent transition is a second-order phase transition, whose critical point corresponds to the balance between decay and splitting of puffs or bands.

While the decay of turbulence has been thoroughly characterised by the presence of an underlying saddle point, or edge state[1 2], it is only recently that a description of turbulent proliferation was proposed from the viewpoint of dynamical systems[3].

In this talk, we wish to test this dynamical mechanism using DNS of plane Couette flow in a one-dimensionalised setup. We will use ideas from stochastic calculus[4] and introduce the concept of *probabilistic edge state*, from which there is an equal probability for a band to self-replicate or return to a single band, as presented in Fig. 1. Our results support a two-step mechanism: an initial expansion, followed by the nucleation of a quasi-laminar gap, after which the system relaxes to a two-band state.

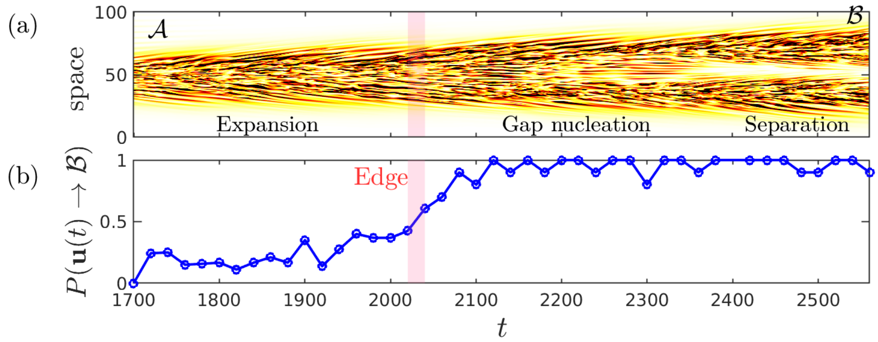

Figure 1: (a) Self-replication of one localized turbulent band (state $\mathcal{A}$) into two (state $\mathcal{B}$), in plane Couette flow ($Re = 330$). (b) Corresponding *committor function* (probability to reach $\mathcal{B}$ directly at a given time t). The 0.5 probability defines a probabilistic edge state, which is crossed during the expansion phase.

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[1] Duguet, Willis and Kerswell, *J. Fluid Mech.* **613**, 255–274 (2008).
[2] Paranjape, Duguet and Hof, *J. Fluid Mech.* **897**, A7 (2020).
[3] Frishman and Grafke, *Proc. Royal Soc. A* **478**, 20220218 (2022).
[4] Weinan and Vanden-Eijnden, *Annu. Rev. Phys. Chem.* **61**, 391–420 (2010).