Tracking the edge of chaos in a boundary-layer flow

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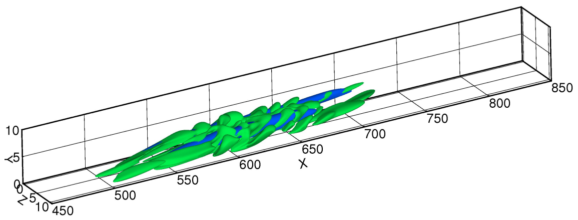
ABSTRACT

The recent progress in understanding transition to turbulence in parallel flows, i.e. plane Couette and pipe flows, has been based on the discovery of *exact* non-linear solutions of the Navier-Stokes equations and *edge states*, which are now being interpreted as forming the skeleton of turbulence (see Eckhardt et al., 2007). In this work we follow these paradigms to identify, for the first time in a boundary-layer flow, the structures living on the edge of chaos. We use a shooting procedure to compute the trajectory in the phase-space which does not lead to turbulence nor to the laminar state (see Schneider et al. 2007). To initialize the computation, two different rapidly growing perturbations have been used, a linear and a non-linear optimal one (see Cherubini et al., 2010). For both initial states, mildly varying flow structures have been observed on the edge of chaos, which indicate the existence of relative chaotic attractors embedded in it. Remarkable differences have been found between these edge structures, indicating that the edge state for the boundary-layer flow is not unique. The edge reached by the linear optimal perturbation is characterized by streamwise streaks and vortices with sinous modulations (see Fig. 1(a)), and has a low spreading rate in space/time. The edge reached by the non-linear optimal perturbation is more efficient in spreading out. It is characterized by a main hairpin vortex at the leading edge, and $\Lambda-$vortices and streaks in its body (see Fig.1(b)). The shape of the wave packet and its advection velocities are very close to the ones characterizing a turbulent spot, indicating that it can be considered the precursor of a turbulent spot. The presence of the slowly varying flow structures here described suggests the existence of localized exact coherent solutions embedded in the edge of chaos for the case of boundary-layer flows.



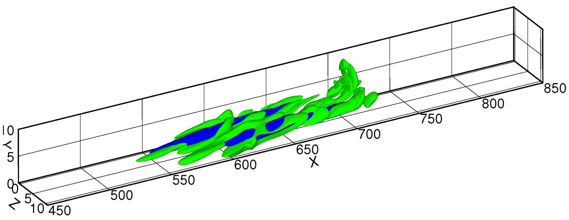


Figure 1: Snapshots of the streamwise component of the perturbation (blue) and of the Q-criterion (green) on the edge of chaos for a linear (a) and non-linear (b) initial perturbation.

REFERENCES

[1] Eckhardt, B. and Schneider, T. M. and Hof, B. and Westerweel, J. *Turbulence transition of pipe flow* , Annu. Rev. Fluid Mech. **39**, 447-468, 2007

[2] Schneider, T. M. and Eckhardt, B. and Yorke, J.A. *Turbulence Transition and the Edge of Chaos in Pipe Flow*, Phys. Rev. Lett. **99**, 034502, 2007.

[3] S. Cherubini, P. De Palma, J. C. Robinet, and A. Bottaro *Rapid path to transition via non-linear localized optimal perturbations*, Phys. Rev. E **82**, 066302, 2010.