Laminar-turbulent patterning in transitional flows, a review of recent results

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Wall-bounded flows typically experience a subcritical transition to turbulence due to linear stability of the laminar base flow at values of the Reynolds number R for which nontrivial solutions to the Navier-Stokes equations can exist. It is characterized by the coexistence of laminar and turbulent domains in a transitional regime extending above a lower threshold Rg below which any form of turbulence decays, possibly at the end of overlong chaotic transients. At sufficiently high R, uniform (featureless) turbulence is recovered, and depending on the geometry, either one-dimensional, pipe-like, or two-dimensional, along or between plates, this coexistence can take different forms [1]. I will focus on the second case marked by the presence of a more or less regular pattern of alternatively laminar and turbulent bands obliquely inclined with respect to the stream-wise direction [2]. On general grounds, this organization disappears above a second threshold Rt bounding the transitional regime from above. I will review several systems recently under focus, with shear flow between coaxial cylinders or parallel plates (Couette geometry) viewed as a prototype. Decay of the bands at Rg has been the subject of many studies recently, pointing out the relevance of directed percolation and criticality in the sense of statistical-physics phase transitions [3]. As of today, the nature of the transition at Rt where bands develop remains more mysterious. Usual pattern forming instabilities such as convection develop at increasing control parameter on a laminar background. In contrast, the bands emerge at Rt out of a uniform turbulent background at decreasing control parameter but quantitative results are still scarce [2]. While local collapse of turbulence can be understood as an immediate consequence of large deviations associated with sub-criticality, the mechanisms for a progressive large scale organization of laminar troughs with abrupt and fluctuating laminar-turbulence interfaces are still poorly understood. In this respect, the relevance of the Reaction-Diffusion scheme found valuable to discuss the one-dimensional case of transitional pipe flow [4] will be examined in view of interpreting band formation in terms of a Turing instability of featureless turbulence [5], while probing the role of large scale flow inside the laminar patches.

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