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 $R_g$ 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 $R_t$ 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 $R_g$ 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 $R_t$ 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 $R_t$ 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.