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About the transition to turbulence in wall-bounded flows.

The transition to turbulence is progressive when the flows under consideration are subject to linear instabilities. Landau-type modal approaches (instability cascade), including the possibility of chaos à la Ruelle-Takens, offer an appropriate conceptual framework for the globally supercritical case, as for natural convection.
Open flows, particularly those controlled by wall effects, are more complex due to a specific interaction between advection, inertia and viscosity which thwarts the appearance of linear instabilities while allowing the development of finite amplitude disturbances. The flow in a tube, shear flows between parallel planes, between cylinders, or under the effect of an imposed pressure gradient are emblematic examples. In all these cases, the transition is globally subcritical. The trivial, uniformly laminar regime coexists in physical space with a non-trivial, locally vigorously turbulent flow over a finite Reynolds number interval.
Analysing the physical mechanisms that maintain the turbulent flow introduces an internal scale, which makes it possible to reduce the number of degrees and account for non-trivial local dynamics at this scale, to be studied within the dynamical systems theory. The concepts it introduces then lead to a first zero-dimensional (0D) level of interpretation, making it possible to understand the coexistence of the different regimes in phase space from an abstract, essentially temporal, point of view. However, This approach is insufficient to integrate the spatiotemporal features of the transition, where laminar flow and turbulence coexist in physical space. Considering the system as composed of interacting distributed bistable subsystems, each of which can be either in the trivial laminar (absorbing) state or the non-trivial turbulent (active) state, makes the transition akin to directed percolation, with a globally active regime resulting from an indefinite contagion of the laminar flow. Examples can be found in systems where the dynamics appear unidimensional (1D), e.g. in tubes. Laterally less confined systems, planar or cylindrical, have a more complex transitional regime with the formation of two-dimensional (2D) oblique laminar-turbulent textures, further exhibiting a statistically stable turbulent fraction. Reducing these systems' dimensions to quasi-one-dimensional by assuming an externally imposed orientation helps one understand part of their dynamics. However, orientation fluctuations and large-scale flows modulating the internal scales' chaotic dynamics are essential to reach a faithful account of the patterns' emergence, whereas directed percolation remains relevant to their decay. Following the thread of effective dimensionality and pointing to still open questions, we will review the different facets of the transition to/from turbulence in wall-bounded flows and support our viewpoint with recently obtained results on Couette and Poiseuille plane flows.

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