Onset of turbulence in linearly stable shear flows

Kerstin Avila*, **Dave Moxey**†, **Alberto de Lozar***, **Marc Avila***, **Dwight Barkley**† **& Björn Hof***

* Max Planck Institute for Dynamics and Self-Organization
Bunsenstr. 10, 37073 Göttingen, Germany
e-mail: kavila@ds.mpg.de

†University of Warwick, Coventry, United Kingdom

ABSTRACT

Pipe flow is a classical example of a shear flow that is linerly stable and its onset of turbulence was already investigated by Reynolds more than 125 years ago [1]. Due to the lack of an linear instability, the precise Reynolds number at which the flow becomes turbulent depends on the care taken to minimize disturbances in the experimental setup. In order to avoid this setup effects, we induce an external localized perturbation in the laminar flow and analyze the development of the ensuing localized turbulent patch (puff) while traveling downstream. Although it was recently found that the puffs are transient for all Reynolds number Re, puffs may grow and split, leading to a spread of turbulence. Here we analyze the splitting of puffs quantitatively and show that it is the competition between decaying and splitting that determines the onset of sustained turbulence. In an in depth experimental investigation, of more than 800.000 measurements in pipes of up to 3.400 diameters in length combined with two sets of direct numerical simulations, we determine the critical Reynolds number for the onset of sustained turbulence in pipe flow.

But how are these results related to other linearly stable shear flows? This is the question we address in the second part of the talk with a newly build Taylor–Couette experiment. While turbulent puffs in pipe flow are only able to grow in the streamwise direction, in the Taylor–Couette system turbulent spots are able to grow also in the spanwise direction. A previous study has shown that these turbulent spots are transient at low Re [2] and similar to pipe flow it is not clear how or if turbulence becomes sustained in the lineraly stable parameter regime. Here we analyze the differences and analogies between the turbulence sustaining mechanism in pipe and Taylor-Couette flow.

REFERENCES

[1] Osborne Reynolds *An experimental investigation of the circumstances which determine whether the motion of water shall be direct or sinuous, and of the law of resistance in parallel channels*, Proc. R. Soc. London **35**, 84-99, 1883.

[2] Daniel Borrero-Echeverry, Michael F. Schatz and Randall Tagg *Spatio-temporal intermittency in coupled map lattices*, Phys. Rev. E **81**, 025301/1-4, 2010.