Mechanism for streamwise localisation in 2D plane-Poiseuille flow

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ABSTRACT

Turbulent flows are ubiquitous both in nature and in engineering applications, with far-reaching implications. Turbulence in wall bounded shear flows such as that in pipes, channels and boundary layers feature turbulent transition at Reynolds numbers for which the laminar flow is linearly stable [1], and often do so in the form of discrete patches of turbulence surrounded by quiescent fluid [2]. The bistability of shear flows has been shown to rely on the existence of disconnected exact solutions of the Navier-Stokes [3] equations that undergo a bifurcation cascade that increases space-time complexity eventually leading to turbulence [4]. Fully developed turbulence in minimal flow units emanates from the destabilisation of exact solutions that are periodic in space. Meanwhile, initial localised turbulence in extended domains seems to follow the destabilisation of localised exact solutions [5].

Periodic and localised solutions have been recently shown to be related by a localisation process. Spanwise localization of channel flow has been shown to result from subharmonic instability of spanwise periodic waves that become localized in a wave packet [6] via a snaking mechanism. Streamwise localisation has been found to also emerge from subharmonic instability of streamwise periodic solutions [7], but snaking does not seem to operative.

Here we address the issue of streamwise localisation in the simplest extended shear flow: 2D plane-Poiseuille flow. We compute the periodic soultions and analyse their subharmonic stability to track spatially modulated wave packets that eventually localise. Thus, wavelength and Reynolds number are systematically varied to completely unfold the mechanism behind streamwise localisation in shear flows.

REFERENCES

[1] O. Reynolds, Phil. Trans. Roy. Soc. Lond. 174, 935 (1883).
[2] I. Wygnanski and F. Champagne, J. Fluid Mech. 59, 281 (1973).
[3] B. Hof, C. van Doorne, J. Westerweel, F. Nieuwstadt, H. Faisst, B. Eckhardt, H. Wedin, R. Kerswell, and F. Waleffe, Science 305, 1594 (2004).
[4] J. Jimenez, J. Fluid Mech. 218, 265 (1990).
[5] M. Avila, F. Mellibovsky, N. Roland, and B. Hof, Phys. Rev. Lett. 110, 224502 (2013).
[7] T. Schneider, J. Gibson, and J. Burke, Phys. Rev. Lett. 104, 104501 (2010).
[6] M. Chantry, A. P. Willis, and R. R. Kerswell, Phys. Rev. Lett. 112 (2014).