Vortex-Wave Interactions in Channel Flows

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Motivation:

For a number of shear flows, such as the flow in a channel geometry driven by the motion of the walls, transition to turbulence is observed in a process seemingly unrelated to the local stability properties of the laminar flow profile. Current thinking views transition for these types of flows as an issue of finding and characterising other fully three-dimensional solutions to the governing Navier-Stokes equations within the same flow configuration. The existence of such solutions, called “exact-coherent structures”, has been demonstrated for a number of different wall-bounded shear flows and appear to capture the main statistical features of turbulent flow[1].

Research:

The asymptotic theory of vortex-wave interaction has been shown to be the high Reynolds number limit of the previously found lower branch equilibrium solutions[2]. Our research focuses on using this asymptotic theory as a means of finding exact-coherent structures in channel flows. Since the asymptotic theory is a formally reduced model, our computational method is arguably faster than current methods of finding exact-coherent structures that depend on solving the fully resolved Navier-Stokes equations. Further, through asymptotic considerations we can propose techniques, such as periodic suction on the walls, in order to reduce the overall drag of such structures.

Application to Industry:

Whilst transition to turbulence in channel flows may seem a world apart from the flow past an aircraft wing there are some similarities[3]. By demonstrating our numerical technqiue and analysing possible drag reduction techniques for channel flows we have laid the groundwork for future studies into exact-coherent structures into more aerodynamically relevant flows.

References

[1] Waleffe F., (2003). Homotopy of exact coherent structures in plane shear flows. *Phys. Fluids* (1994-present), **15** (6), 1517–1534.

[2] Hall, P., & Sherwin, S. (2010). Streamwise vortices in shear flows: harbingers of transition and the skeleton of coherent structures. *J. Fluid Mech.*, **661**, 178-205.

[3] Deguchi, K., & Hall, P. (2014) ”Free-stream coherent structures in parallel boundary-layer flows.” *J. Fluid Mech.* **752**, 602-625.