Subject Panel: Mathematical Methods and Applications
Suggested title of dissertation: Transition to turbulence scenario in pipe flows
Dissertation supervisor: Dr. Vassilios Dallas
[redacted]

Description of proposal:

The transition to turbulence in the flow along a pipe (see Fig. 1) is an outstanding enigma in hydrodynamic stability since the seminal work of Osborne Reynolds in 1883 [1]. The flow is controlled by a single dynamical parameter $Re = \frac{Ud}{\nu}$ where U is the velocity of the flow along the pipe of diameter d and ν is the kinematic viscosity of the fluid. This parameter is called the Reynolds number and all theoretical and numerical work indicates that the flow is stable for all values of Re. The enigma is that all pipe flows ought to be laminar in theory and yet most are turbulent even at modest flow rates. The challenge of understanding this apparent dichotomy between theory and experiments remains a deep mystery and severely limits our ability to control the flow with important implications in numerous Engineering applications.

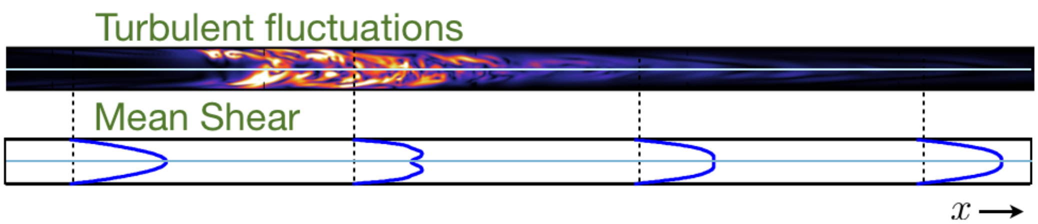

Figure 1: Transition to turbulence in a pipe flow

Experimental results obtained with different methods of driving the flow produce qualitatively different outcomes. Constant mass flux conditions produce a definite lower value of Re which is required to maintain turbulent flow [2] whereas flows driven by pressure gradients give long term transient behaviour [3]. However, preliminary numerical investigations [4] at values of $Re = 2000$ find the dynamics to be independent of the methods of driving the flow.

This project will involve numerical simulations which will be performed using a code that has been extensively tested on a variety of pipe flows [5]. This code is ideally suited to our study solving the Navier-Stokes equations in cylindrical coordinates. The main focus of the project is to study the effect of different mechanism driving the flow in pipes (i.e. constant mass flux conditions versus constant pressure gradient) on the transition to turbulence. Our study will provide new insights into the onset and sustenance of the dynamics by controlling the primary dynamical parameter Re.

Possible avenues of investigation:

The main objective of this project is to clarify whether there are any qualitative differences in the basic dynamics of the transition which arise from the method of driving the flow. The results will provide new insights into fundamental aspects of this outstanding challenging problem. This project will provide a unique experience in theoretical fluid dynamics, dynamical systems, numerical methods and scientific computing. Important results will be prepared for publication in a peer-reviewed journal. The project will be carried out in collaboration with Prof. Tom Mullin, who is a top expert in the problem of transition to turbulence in pipe flow and holds a Visiting Professor position at the Mathematical Institute.

Pre-requisite knowledge (listed as essential, recommended, useful)

Recommended: Since this project will involve studying nonlinear PDEs, experience in numerical simulations of PDEs and ODEs will be helpful.

Useful reading

1. Mullin T. 2011 Experimental Studies of Transition to Turbulence in a Pipe. *Ann. Rev. Fluid Mech.* **43**, 1–24.

2. Peixinho, J. & Mullin, T. 2006 Decay of turbulence in pipe flow. *Phys. Rev. Lett.* **96**, 094501.

3. Barkley D. 2016 Theoretical perspective on the route to turbulence in a pipe. *J Fluid Mech.* **803**, 1–80.

4. Willis A.P. & Kerswell R.R. 2009 Turbulent dynamics of pipe flow captured in a reduced model: puff relaminarization and localized 'edge' states. *J Fluid Mech.* **619**, 213–33.

5. Willis A.P. 2017 The Openpipeflow Navier-Stokes Solver. *SoftwareX* **6**, 124–127.