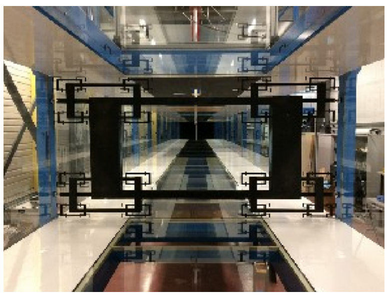
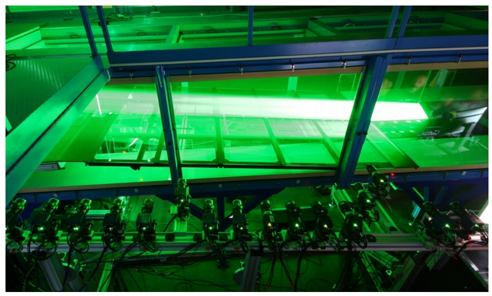
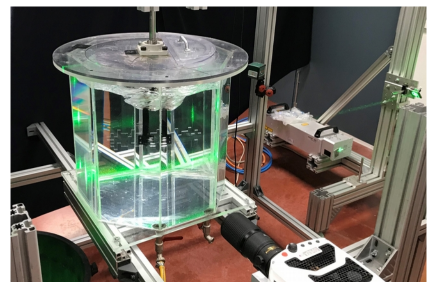
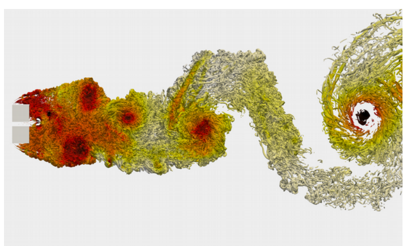
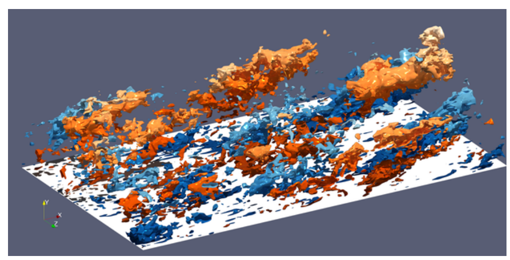
Offer of 2 PhD studentships
on Turbulent Flows

ERC NoStaHo

NON-STATIONARY NON-HOMOGENEOUS TURBULENCE

CONTEXT

Turbulent flows are exceptional for their pervasive importance across a very wide range of industries (aeronautical, chemical, biomedical, pharmaceutical, civil, environmental, mechanical, nuclear and process engineering). They are also key to meteorology and climate studies; geophysics and oceanography; and astrophysics. Through turbulent drag, friction, mixing, heat transfer, combustion and chemical reactors, turbulent flows are estimated to be responsible for over 30% of all energy losses across the board world-wide. They are also sizeable causes of fatigue and noise pollution. For reasons linked to the current energy, environment and climate urgencies, there is an increasingly dramatic need for industries to make quantum leaps in efficiencies and effectiveness with new energy sources by adopting radically new industrial/engineering solutions instead of just improving existing solutions. It is clear from climate change projections that its catastrophic pace will not be averted without radically new technological concepts across the board. This will not happen where turbulent flows are involved (air/sea/land vehicles, static/dynamic mixers, heat exchangers, combustion chambers, gas turbines, wind turbines, chemical reactors, etc) without a paradigm shift in our fundamental understanding of turbulence and turbulent flows.

A paradigm shift leading to fundamental advances in turbulence theory and modelling is therefore not just an academic nicety. It is of critical importance to all technological innovations involving turbulent flows. Current turbulence models and prediction methods cannot predict the behaviour of radically new engineering and industrial designs/concepts which depend on turbulence for their effectiveness and efficiency because these models have been developed mostly on the basis of inadequate 80-year old physics based on the Kolmogorov equilibrium cascade for stationary homogeneous turbulence and various tenuous assumptions concerning eddy viscosities and pressure-velocity interactions. Given the inadequacy of the physics they are based on, turbulence models and prediction methods have been calibrated against a specific set of well-documented turbulent flows and fail when used outside the narrow calibration range. They are therefore unable to predict the turbulent flow behaviour of unprecedented engineering concepts/designs and are in fact even unable to predict significant unsteady and inhomogeneous behaviour in the very flows they have been fitted to. To realise their full technological potential and economic impact, new industrial/engineering concepts reliant on turbulent flow behaviour require major advances and breakthroughs in our fundamental understanding of turbulent flows because they require reliable turbulent flow models enabling to predict what will happen in a variety of continously evolving parameter settings. The alternative consists of having to proceed by trial and error in the laboratory whenever a new flow concept arises. This alternative is too cumbersome, too costly, too slow and often too uncertain, particularly when it is unknown how to scale up. The vision of a future capability to reliably and quickly predict the behaviour of turbulent flows in tests of boldly innovative industrial/engineering solutions on a small laptop is a vision where the trial and error can be done quickly and cheaply on the computer by anyone, and innovation can be unleashed in an unprecedented way across a wide range of industries.

PROJECT

This vision requires a major step change in our understanding of the physics of turbulence and turbulent flows. The past 5 years have seen a number of advances which overturn cornerstone turbulence textbook material and create an unprecedented opportunity for a potentially decisive breakthrough in our fundamental and general understanding of turbulent flows which are typically non-stationary and/or non-homogeneous. These recent advances concern non-stationarity and non-homogeneity in fundamental ways and open new research opportunities with many new questions and hypotheses. This project will seize these new research opportunities with a combination of laboratory, computational and theoretical methods and approaches applied to a variety of turbulent flows. The expected outcome is a transformative, entirely new and extensive, fundamental understanding and theory of non-stationary and/or non-homogeneous turbulence, and a consequent road map for future disruptive turbulent flow prediction methods.

TWO PhD STUDENTSHIPS STARTING SEPTEMBER 2023

The two PhD students will be part of a broader effort under the aegis of ERC AdG project NoStaHo and will therefore be part of a research group consisting of Post Doctoral Researchers and some other PhD students. One of the two PhD studentships will be more experimental and the other will be more computational. There is a raft of topics to chose from and the decision of the actual thesis topic will be made in consultation with the student. Flows to concentrate on include freely decaying or forced homogeneous turbulence, turbulent wakes, turbulent jets, turbulent mixing layers and turbulent boundary layers with/without imposed pressure gradient. Among the many aspects of the flows to concentrate on, are coherent structures and their impacts on turbulence energy exchanges, turbulence cascades and dissipation; impacts of these energy exchanges/transfers through space and across different size eddies on basic statistics and profiles of turbulent flows; fluctuating/intermittent behaviours which can take various forms: fluctuations around equilibrium in the case of statistically stationary homogeneous turbulence; intermittency in the peripheries of turbulent shear flows where the turbulence/non-turbulence interface is the near-singular structure responsible for this external intermittency; internal intermittent fluctuations in the bulk of turbulent shear flows in the absence of equilibrium. The PhD students will have the opportunity to work on a few particular aspects for a particular flow or set of flows and to put their findings in a broader context provided by the overall research in the group thereby allowing them to reach deeper/broader conclusions. They will contribute to the development of the new and extensive fundamental understanding and theory of non-stationary and/or non-homogeneous turbulence that this project aims at, with the identification of universality classes depending on types of non-homogeneity/non-stationarity and a consequent road map for turbulent flow prediction methods.

The two 3-years PhD Studentships will be administred by the CNRS. The experimental PhD student will be supervised by Dr C. Cuvier (Centrale Lille, LMFL) and Dr J.C. Vassilicos (DR CNRS, LMFL) and the computational PhD student will be supervised by Dr J.P. Laval (DR CNRS, LMFL) and Dr J.C. Vassilicos (DR CNRS, LMFL). Experimental methods will include state of the art Particle Image Velocimetry and computational methods will include Direct Numerical Simulation (DNS) using High Performance Computing.

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SELECTED REFERENCES 2018-2022 : (a wider range of references can be found at https://lmfl.cnrs.fr/perso/christos-vassilicos-publications/

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