C. R. Physique 13 (2012) 865

Contents lists available at SciVerse ScienceDirect

Comptes Rendus Physique

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Structures and statistics of fluid turbulence / Structures et statistiques de la turbulence des fluides

Foreword

Fluid turbulence is an archetypal out-of-equilibrium system from the field of classical physics. It has been studied for a long time by a vast variety of communities including engineers, physicists, and mathematicians. It maybe is this interdisciplinary interest in turbulent flows that makes it hard to define *the* turbulence problem. From the side of fundamental research, however, the investigation of the simplest idealistic situation that assumes homogeneity and isotropy has a long tradition. And, as also can be seen from a number of articles in this special issue, it is a very active area of research up to today. One reason for this certainly is that this idealized flow is well suited to demonstrate the subtle interplay between nonlinearity of the advective term, nonlocality of pressure effects and dissipative effects on the smallest scales that govern the flow, as given by the Navier–Stokes equations.

Nevertheless, decades of experimental and numerical investigations have underlined the genuine universality of turbulent flows, such as, among others, the Kolmogorov-type power law dependence of the spectral energy in three-dimensional or the inverse energy cascade in two-dimensional flows. Starting probably with Reynolds, a statistical approach has been rapidly adopted in order to describe and predict the complex and multi-scale motions of fluids when diffusive effects can be neglected in front of the internal dynamics of the flows. More recently, several attempts have been made in order to relate intrinsic non-Gaussian features of the fluids with the existence of coherent structures and first principles.

This is the main focus of the present special issue, and we are very pleased that a number of researchers contributed with their recent works to give a partial overview of various theoretical, numerical and experimental investigations of this rapidly evolving field. The article of Ouellette relates an experimental study of coherent structures in two-dimensional turbulence and their possible connection with dynamics. The works of Li as well as Pumir and Naso give a flavor of how the multi-scale statistics of turbulent flows can be related to the basic mechanism of the advection of fluid particles. In Friedrich et al., a link between statistical approaches focusing on probability density functions and the Navier–Stokes equations is proposed. Chevillard et al., in their article, underline the universal nature of the intermittency phenomenon. And Brachet focuses on a rapidly developing approach consisting in relaxing the viscous diffusion while studying turbulence in quantum fluids. We believe that this collection of articles gives an overview of a number of ideas of modern turbulence research and would like to encourage the readers to take a look at the bibliography and/or to directly contact the corresponding authors.

Originally, this special issue was meant to be co-edited by Professor Dr. Rudolf Friedrich. However, we are deeply sorry to inform you about the untimely loss of Rudolf Friedrich, who passed away on August 16th 2012 at the age of 55.

During his scientific career, Rudolf has contributed to a broad range of fields including pattern formation, stochastic processes and data analysis. Fluid mechanics, however, has always been a matter of heart to him, and within the last fifteen years the theory of turbulence more and more moved into the focus of his scientific work. It maybe was his broad scientific background that enabled him to make a number of important and deep contributions to the theory of fully developed turbulence. We are grateful that a review article summarizing works by Rudolf and his group over the last five years had almost been completed before his passing away and now can be part of this special issue.

We would like to dedicate this special issue to the memory of this inspiring scientist, committed colleague and, above all, warm person. He will be greatly missed by those who knew him.

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Available online 31 October 2012

http://dx.doi.org/10.1016/j.crhy.2012.10.005