HENRI BENARD PILOT CENTRE
REPORT 2017-2019

Mikhael Gorokhovski (Coordinator) in collaboration with
Claude Cambon (SIG 35), Christophe Bailly (SIG 39), Raffaele Marino (SIG 50)
and Fabien Godeferd (Coordinator, 2015-2019)
Laboratoire de Mécanique des Fluides et d'Acoustique,
UMR 5509 CNRS – Ecole Centrale de Lyon – INSA – Université Claude Bernard Lyon 1,
69134 Ecully Cedex, France.

Henri Bénard (1874-1939)

MAIN FOCUS

Our main interest is related to the multi-scale physics behind turbulent interactions in simple academic and complex engineering systems, in the nature of our planet and in astrophysics. The activity of the Henri Bénard Pilot Centre (PC) is to promote new ideas and understandings in this scientific area. To this end, our approach is to develop new relationships between scientific laboratories. We encourage and make visible these partnership on both national and European levels. Thereby we try also to promote the collaboration with different partners from industry, ecology and health care.

HENRI BÉNARD PC MEMBERS:

- Université Grenoble-Alpes – UGA
  Laboratoire des Ecoulements Géophysiques et Industriels - LEGI - UMR CNRS 5519
  http://www.legi.grenoble-inp.fr/web/
  Contact: Joel Sommeria
  LEGI Domaine Universitaire CS 40700 38058 Grenoble Cedex 9 France

- Ecole Centrale de Lyon - ECL
  Laboratoire de Mécanique des Fluides et d'Acoustique - LMFA - UMR CNRS 5509
  http://lmfa.ec-lyon.fr/
  Contact : Philippe Blanc-Benon
  Laboratoire de Mécanique des Fluides et d'Acoustique, École Centrale de Lyon
  36, avenue Guy de Collongue, 69134 Écully cedex

- Sorbonne University

Institut Jean le Rond d'Alembert UMR CNRS 7190
http://www.dalembert.upmc.fr/
Contact : Sergio Chibbaro
Institut ∂'Alembert, boîte 162, 4, Place Jussieu 75252 Paris Cedex 05, France

- Ecole Normale Superieure de Lyon – ENSL
Laboratoire de Physique - LP - UMR CNRS 5672
http://www.ens-lyon.fr/PHYSIQUE
Contact : Mickael Bourgoin
Laboratoire de Physique (UMR CNRS 5672)
ENS de Lyon
46, allée d'Italie, 69364 Lyon cedex 07, France

- The French Alternative Energies and Atomic Energy Commission - CEA
Fundamental Research Direction - SBT
The Interdisciplinary Research Institute of Grenoble (IRIG)
http://www.cea.fr/drf/irig/
Contact: Bernard Rousset
CEA-Grenoble
17 rue des Martyrs, 38054 Grenoble cedex 09 France

OUTLINES 2017-2019

During the last three years, we focused our attention on understanding of the multi-scales nature in inhomogeneous turbulence. The emphasis is put on effects of intermittency and anisotropy in sheared, rotating, unstably stratified and wall-bounded turbulence. The thorough discussions and thematic sections were also addressed to the interplay of waves and turbulence with effects of rotation, stratification, aero-acoustics, MHD and plasmas. Besides, a continued attention was devoted to the turbulent energy transport and spectra in compressible turbulence, to different aspects of two-points statistics in scalar mixing driven by buoyancy. In two-phase turbulence, we advanced different themes concerning the intermittent dynamics of heavy particles, droplets and bubbles, including droplet vaporization in the high Reynolds number turbulence and turbulence modification by dispersed particles. In the majority of all these problems, both Eulerian and Lagrangian frameworks were considered and theoretical contributions were largely completed by numerical simulation. The latter was also focused on development of new technics in high performance computations.

The new key words, issued as remarkable results, are:

- Generalization of EDQNM closures in turbulence under "non-Orszag" anisotropic conditions: instable stratification, rotation, Coriolis forces, Lorenz forces, shear [1-2]. LMFA, CEA, Oracle-Paris
- Intermittency effect in terms of the Lagrangian acceleration in the inhomogeneous turbulence. Stochastic models of the acceleration [3-7].

LP ENSL, LMFA, LEGI, Institut Jean le Rond d'Alembert, ONERA-Palaiseau (The French Aerospace Lab.)

- Non-stationary cascades at final Reynolds number: self-similar regimes, the iterative cascade of instabilities, duality, nonlinear transverse interactions [8-11].
  LMFA, LP ENSL, CEA
- Nearness and specific abilities of interactions in wave and strong turbulences. Local/non-local interactions in the surface wave turbulence. Interactions in gravity and gravity-capillary waves turbulence [12-15].
  LEGI, LMFA, LP ENSL
- Effects of intermittency on the dynamics of heavy particles below and above the Kolmogorov scale. Collective effects of inertial particles. Non-spherical particles settling. Effects of turbulence on droplets vaporization. New measurements, new numerical methids and Lagrangian stochastic modelling of particles in bubbly and particle-laden turbulent flows [16-24].
  LMFA, LEGI, LP ENSL, Institut Jean le Rond d'Alembert, Volvo Trucks, Continental Automotive France SAS

New themes are emerging as domain of our interests with perspectives of new collaborations:

- Renormalization group approach to turbulence description
  LMFA, Centre National de la Recherche Scientifique, LPMMC, LP ENSL, LEGI,
- Turbulence in the presence of free interface
  LMFA, Institut Jean le Rond d'Alembert, FAST lab. Paris-Saclay University
- Active particle turbulence
  LP ENSL, LMFA
- Superfluid turbulence
  LMFA, LP ENSL, University of Rouen Normandie-LMRS
- Fragmentation
  LMFA, Institut Jean le Rond d'Alembert
- Turbulence and instability in astrophysical plasmas – the newly organized SIG 50

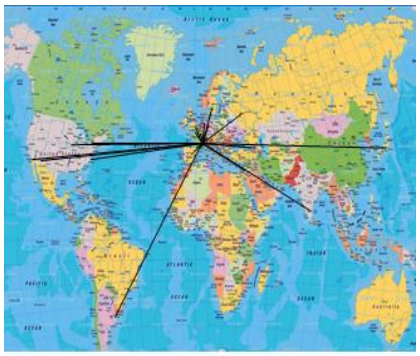
SYNOPSIS OF ORGANIZED EVENTS IN 2017-2019

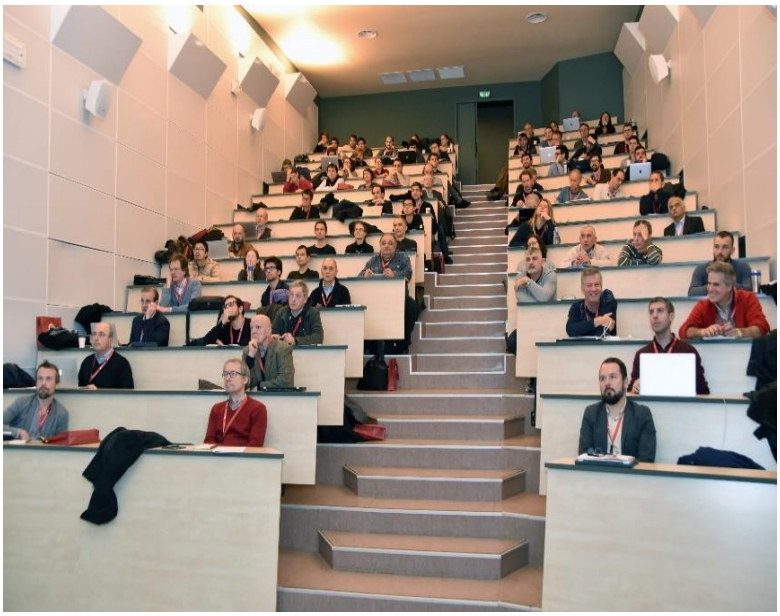
2017a. ERCOFTAC - Euromech 589, Henri Bénard PC SIG 35, SIG 39 : Turbulent Cascade II. Ecole Centrale de Lyon, LMFA, France [24] https://turb-cascades-2.sciencesconf.org/

Organizers: M. Gorokhovski, F. Godeferd, J. Peinke, B. Geurts and C. Cambon

Two kind of questions motivated this Workshop. The first one raised earlier during "hot" discussions started in Lille 2015 (Euromech ERCOFTAC Workshop "Turbulent Cascade") in the following context. Most part of DNS and experiments provide the evidence of non-local interactions in the high Reynolds number turbulence, which is different from the KO-41 cascade picture. The highly energetic vortical structures, revealed on smallest turbulent scales, may persist and interact directly with other energetic structures. This leads to violent gradients of the velocity giving rise to long-range correlations. On the other hand, the -5/3 law of KO-41 is

always confirmed in DNS and experiment, and not only in a wide range of hydrodynamic flows, but also in astrophysics and biological systems. The question is why?





The second question concerned the physics of turbulent cascade in complex conditions, like turbulence modulation by dispersed inertial particles or bubbles, as wavy structures of the gas/liquid interface and interface surface tension, as the presence of compressibility, shear, body-forces, etc. After this colloquium in Lyon, the number of open question to turbulence in the complex conditions has not decreased but increased. So much the better!

2017b: ERCOFTAC Henri Bénard PC SIG 35 Workshop "Systems approach to turbulence and interactions: towards high Reynolds number" Ecole Centrale de Marseille, M2P2, Marseille, France.
Organizers: Claude Cambon and Pierre Sagaut

This workshop followed partly two previous workshops organized by CHB and SIG 35 at the Institut Jean le Rond d'Alembert, in May 2015 and May 2016. The new question which motivated the organization of the Workshop in 2017 was the following : How the anisotropy of the velocity field, induced by such effects as mean shear and mean stratification, may impact the scalar mixing, and so in turn how the scalar mixing may modulate the turbulence through the buoyancy effects? Different closures of such interactions were assessed by comparisons with high resolution DNS.

2018a: ERCOFTAC Centre Pilot Henri Bénard PC SIG 35 meeting "The scientific legacy of Henri Bénard". Ecole Centrale in Lyon, LMFA, France.

Organizers: Claude Cambon and Fabien Godeferd

This meeting was intended for a large audience – students, graduate and postgraduate students, researchers and teachers. The objective was to introduce the classical discovery of Henri Bénard of cellular structures in natural convection. The meeting started by one-hour lecture of José

Eduardo Wesfreid (CNRS – ESPCI, PMMH laboratory, Paris, France) "Henri BENARD: convection thermique et tourbillons derrière un obstacle" and then it was continued by several talks concerning spatio-temporal dynamics of cellular structures (talks from the Mediterranean Institute of Oceanography – Toulon/France, from PPRIME lab – Poitiers/France, from Oracle-Paris)

2018b: ERCOFTAC CHB SIG 35 Workshop "A Systems Approach to Turbulence and Interactions, from Single Phase flow to Two-Phase Flow" Ecole Centrale de Lyon, LMFA, France.

Organizers: Claude Cambon, Christos Vassilicos and Fabian Godeferd

Behind the title of this Workshop "a system approach to turbulence …" in the view of SIG35, three coupling steps are comprehended: linear mean-to-fluctuating interactions, as in "Rapid Distortion Theory", following by feed-back from the fluctuating-to-mean via the Reynolds stress generation, and then the nonlinear fluctuating-to-fluctuating interaction. The latter requires further development of nonlinear closure models. This issue was largely presented during the Workshop (talks from LMFA, CEA, Imperial College, London, UK ENS-Cachan), as well as during the previous workshops, organized by CHB and SIG 35. It should be noted however, that a significant function of this Workshop was also to gather specialists from two-phase turbulence (talks on turbulence in active matter, simulation of under-resolved dynamics of heavy particle, turbulent fluidization of dense suspensions, mixing of phoretic particles, settling and collisions of ice-crystals in turbulence -LMFA, LP ENSL) and from Aeroacoustics (SIG 39, talks from LMFA) to combined our efforts with SIG 39 and GDR "Turbulence" in highlighting new themes in which a system approach in study is also naturally imposed.

2018c: ERCOFTAC course in Computational Aeroacoustics 4-5 June 2018, ONERA Chatillon (near Paris), France

SIG 39, LMFA CA (Christophe Bailly, Coordinator) participated highly in the organization of this event.

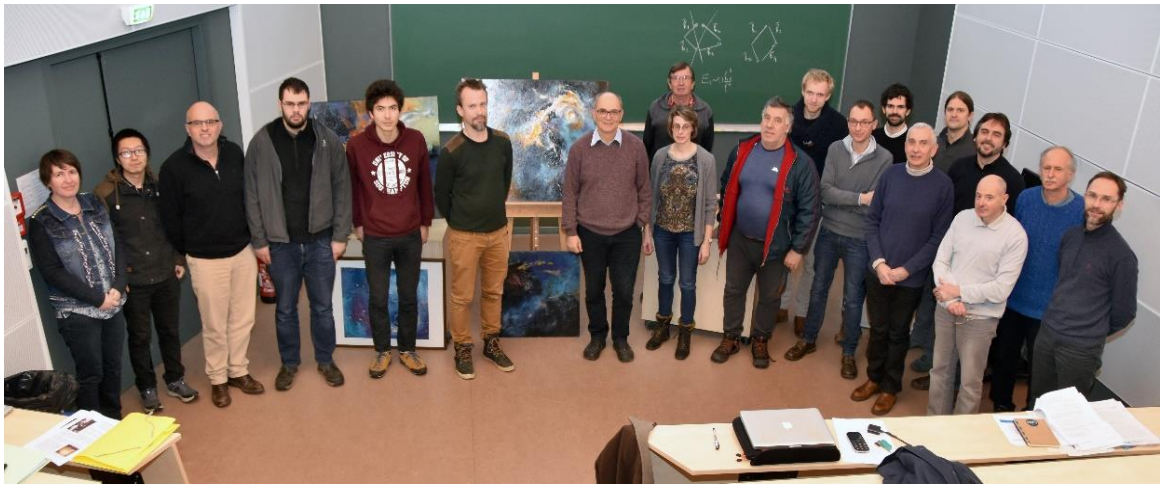
This course was intended for researchers in industry and in academia including Ph.D. Students with a good knowledge in fluid mechanics, who would like to build up or widen their knowledge in the field of aeroacoustics (modeling, computational tools and industrial applications). It provided a comprehensive overview of recent insights of aeroacoustics theories (Lighthill's analogy and vortex sound theory, extensive hybrid approaches and wave extrapolation methods, duct acoustics) and a number of practical problems including CFD/CAA (Computational AeroAcoustics software) coupling strategies (e.g. a mesh design for aeroacoustics applications using LES, inclusion of mean flow effects via hybrid formulations such as the acoustic perturbation equations, presence of surfaces, aeroacoustic couplings, …) and realistic applications performed by the instructors (aeronautics, car industry, propulsion, energy,…). Specific topics reflecting participant interests were discussed in a final round table session.

2019 a: The SIG 39, after its main role in the organization of AIAA/CEAS Aeroacoustics Conference in 2016 in Lyon, France http://aeroacoustics2016.com/

participated strongly also in the organization of the 25th AIAA/CEAS Aeroacoustics Conference, 20-23 May, Delft, The Netherlands, https://www.nlr.org/aeroacoustics-2019/

2019b: ERCOFTAC Henri Bénard PC, SIG 35 Workshop "ASTROFLU IV"

Organizers Claude Cambon and Fabien Godeferd

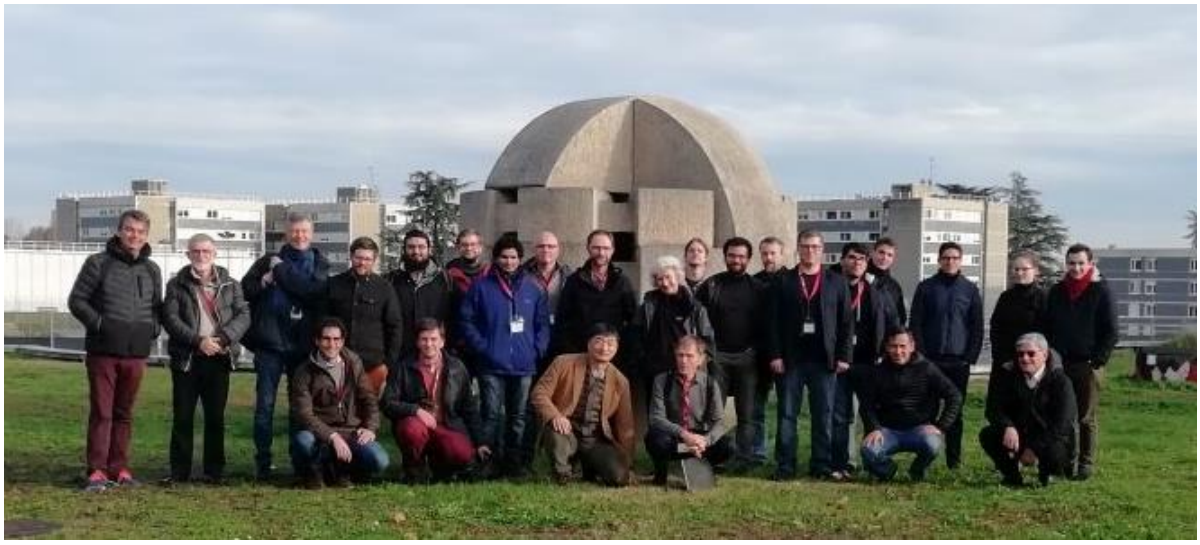


The first two local events 'ASTROFLU' (Lyon 2008 and Lyon 2011) principally supported by the Henri Bénard PC. The ASTROFLU III 2013 was intended for larger audience, including European scientists, and was supported by ERCOFTAC. The aim of this workshop ASTROFLU IV was to gather again fluid mechanics specialists from different scientific areas in order to exchange ideas and discussions on common interests. Two main themes concerned the pulsating stars (highly compressible flows, with particular emphasis on shock / turbulence interactions) and rotating shear flows with stratification and MHD (accretion discs in the astrophysical applications, oceanic and atmospheric flows).

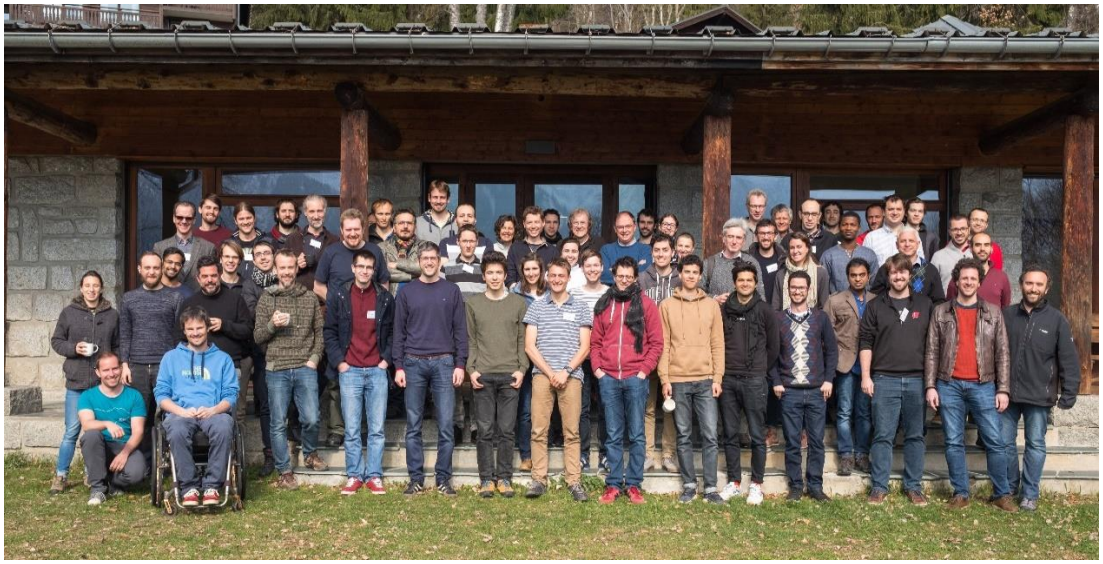
2019c: ERCOFTAC Henri Bénard PC, SIG 50 Workshop on Turbulence and Instabilities in Plasma Flows [25].

Organizers: Raffaele Marino, Emmanuel Lévêque and Fabien Godeferd

This workshop addressed fundamental issues and major science and engineering applications of the research on plasmas, with a special focus on non-linear turbulent dynamics and flow instabilities. The event gathered scientists working on novel theoretical and numerical methods for plasma modeling, space plasmas and next generation of experimental fusion and cold plasma facilities. The workshop hosted as well the kick-off meeting of the recently approved ERCOFTAC "Special Interest Group" (SIG 50) on geophysical fluids and astrophysical plasmas. A one-day session has therefore been dedicated to presentations on recent research initiatives on the topics of the SIG 50



CO-ORGANISATION OF THE THEMATIC SCHOOL "NEW CHALLENGES IN TURBULENCE RESEARCH V" 2019



This thematic school was organized at the École de Physique des Houches in the French Alps and offered its participants a detailed view on some of the major topics of the current research on hydrodynamic turbulence. The school focused on the following topics https://www.houches-school-physics.com/program/program-2020/:

- ✓ Fundamental aspects of turbulence

- ✓ Geophysical turbulence
- ✓ Quantum turbulence
- ✓ Instrumentation and analysis for the study of turbulence

ADMINISTRATION AND MANAGEMENT OF HENRI BÉNARD PC

The budget components consist of partner contributions and ERCOFTAC grants arrowed on workshops for young researchers.
The expenses consist of operating costs (ERCOFTAC meetings in particular) and grants in support of the organization of scientific events as well as the participation of young researchers, in connection with other ERCOFTAC events and subsidies arrowed on independent SIG.

PLANS FOR FUTURE

HENRI BÉNARD PC will continue the activity described above with larger orientation to partners from industry, ecology and health care. Concerning the latter for example, we are going to focus our efforts on understanding of turbulence in all aspects of respiratory sprays (air assisted accelerated/decelerated saliva atomization, infected droplets dispersion and evaporation, droplets/droplets and droplets/turbulence interactions). We hope that this will help to learn more about the dispersion and removal of infected droplets in the atmosphere.

We are going to maintain further our common interests with GDRs « Turbulence » (Mickael Bourgoin coordinator) and «Transferts et Interface» (Michel Gradeck and Nicolas Rimbert, coordinators), both are newly approved by CNRS.

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