# Monday

**08:30 – 09:00**

Welcome

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**09:00 – 09:45  Keynote Lecture**

*Speaker:* **Bagnato, Vanderlei**; University of São Paulo, Brasil.

*Title:* Experimental observations in a turbulent BEC: Demonstration of non-thermal states and universal scaling properties

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**09:45 – 10:05**

*Speaker:* **Proment, Davide**; University of East Anglia, UK.

*Title:* Irreversible dynamics of superfluid vortex reconnections

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**10:05 – 10:25**

*Speaker:* **Danaila, Luminita**; Université de Rouen, France.

*Title:* Quantum turbulence exploration using the Gross-Pitaevskii equation

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**10:25 – 10:45**

*Speaker:* **Lvov, Victor**; Weizmann Institute of Science, Israel.

*Title:* Superfluid turbulence: energy suppression by mutual friction in He-3, intermittency enhancement in coflowing He-4 and strong anisotropy of counterflowing He-4

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**10:45 – 11:15**

Tea/Coffee break

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**11:15 – 11:35**

*Speaker:* **Bulgac, Aurel**; University of Washington, USA.

*Title:* Towards Quantum Turbulence in Cold Atomic Fermionic Superfluids

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**11:35 – 11:55**

*Speaker:* **Bourgoin, Mickael**; ENS de Lyon and CNRS, France.

*Title:* Lagrangian particle tracking in normal and superfluid turbulent flow

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**11:55 – 12:15**

*Speaker:* Nore, Caroline; Univ. Paris-Sud, Université Paris-Saclay, Frace.

*Title:* Von Kármán flows: when simulations meet experiments

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**12: 15 – 12:35**

*Speaker:* **Bec, Jérémie**; Mines-ParisTech, Sophia-Antipolis, France.

*Title:* Are PDEs providing relevant tools to describe turbulent flows?

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**12:35 – 14:00**

Lunch @ Conference venue

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**14:00 – 14:30**

*Speaker:* **Frisch, Uriel**; Univesité Côte d'Azur - Observatoire de la Côte d'Azur, France.

*Title:* Non-selfsimilar time decay of the total energy in fully developed turbulence

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**14:30 – 14:50**

*Speaker:* **Dauxois, Thierry**; CNRS and ENS de Lyon, France.

*Title:* Energy cascade in internal wave attractors

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**14:50 – 15:10**

*Speaker:* **Thalabard, Simon**; IMPA, Brazil.

*Title:* Spontaneous randomness and Kelvin-Helmholtz interfaces

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**15:10 – 15:40**

Poster Micro-talks

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**15:40 – 16:00**

*Speaker:* **Matsumoto, Takeshi**; Department of physics, Kyoto university, Japan.

*Title:* Numerical simulation of dissipative solutions to the Euler equations

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**16:00 – 16:30**

Tea/Coffee break

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**16:30 – 16:50**

*Speaker:* **Venaille, Antoine**; ENS de Lyon CNRS, France.

*Title:* Topological Waves in Fluids

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**16:50 – 17:35 Keynote Lecture**

*Speaker:* **Cadot, Olivier**; University of Liverpool, UK.

*Title:* Multistability in turbulent wake : symmetry breaking state and high Reynolds number bifurcation

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# Posters

Presenter: Allende, Sofia; Univesité Côte d'Azur, France.
Title: Dynamics and fragmentation of small flexible fibers in turbulence

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Presenter: Azam, Pierre; INPHYNI, UCA, France.
Title: TBA

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Presenter: Campolina, Ciro; Instituto de Matemática Pura e Aplicada - IMPA, Brasil.
Title: Singularities in the 3D Incompressible Euler Equations on Logarithmic Lattices

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Presenter: Faller, Hugues; CEA Saclay, France.
Title: High order numerical methods for Computational Fluid Dynamics

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Presenter: Giuriato, Umberto; Univesité Côte d'Azur - Observatoire de la Côte d'Azur, France.
Title: Clustering and phase transitions in a 2D quantum fluid with impurities

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Presenter: Griffin, Adam; University of warwick, UK.
Title: Vortex scattering by impurities in a Bose–Einstein condensate

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Presenter: Lydon, Karl; Aston University, UK.
Title: Towards a Kinetic Theory of Dipoles

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Presenter: Miloshevich, George
Title: Imbalanced collisionless Alfven wave turbulence and the inverse cascade of the generalized cross-helicity

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Presenter: Tavares, Hugo; Instituto de Matemática Pura e Aplicada-IMPA, Brasil.
Title: Lattice-Boltzmann simulations for immiscible 2D Rayleigh-Taylor turbulence

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Presenter: Verma, Akhilesh K.; Indian Institute of Science, Bangalore, India.
Title: PERSISTENCE-TIME PROBLEM IN THE THREE-DIMENSIONAL HVBK MODEL FOR SUPERFLUID TURBULENCE

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# ABSTRACTS

*Title:*
Experimental observations in a turbulent BEC: Demonstration of non-thermal states and universal scaling properties

*Speaker:*
**Bagnato, Vanderlei**; IFSC – University of São Paulo – São Carlos –SP - Brazil

*Abstract:*
One of the out-of-equilibrium states of great interest in superfluids is the state of turbulence. In this state, the proliferation of vortices or waves, creates one of several known states of turbulence. From equilibrium, with energy injection, there is evolution establishing a cascade of energy that causes migration of energy to high moments, resulting in a dependence of power law type in the energy spectrum. The reason the system evolves this way has to do with its quest for equilibrium, reaching possibly a stationary state. If the energy injection is ceased, the system evolves in time. Observing the high moment component in the distribution allows us to verify its dependence by determining whether it is a non-thermal state. We detected in our experiment regions of excitation, where exponential (rather than Gaussian) dependence reveals the presence of non-thermalizing states. Such out-of-equilibrium states exhibit universal behavior when scaled. This universal behavior is of great interest, specially if associated with turbulent states. ( Financial support from FAPESP, CNPq and CAPES. This work had the participation of A. Garcia, A. Cedrim, G. Roati, G. Telles )

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*Title:*
Irreversible dynamics of superfluid vortex reconnections

*Speaker:*
**Proment, Davide**; University of East Anglia, Norwich, UK

*Abstract:*
I will present a numerical investigation of vortex reconnections in superfluids in the limit of zero temperature and modelled using the Gross-Pitaevskii equation. Specifically, I will consider the decay of a quantum vortex Hopf link into ring(s), discus how the geometry of the reconnecting filaments is related to the emission of phonons, and, eventually, characterise the irreversible dynamics observed statistically in the system. (Joint work with Alberto Villois and Giorgio Krstulovic)

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*Title:*
"Quantum turbulence exploration using the Gross-Pitaevskii equation"

*Speaker:*
**Danaila, Luminita**; Université de Rouen, France.

*Abstract:*
We solve numerically the Gross-Pitaevskii (GP) equation to simulate the dynamics of Quantum Turbulence (QT) in a periodic box. This intends to model the behaviour of superfluid helium in the low-temperature regime, therefore a viscous-free flow. Simulations are performed with a spectral code solving the GP equation using MPI-OpenMP parallel programming. We assess the effect of different initial conditions on the statistical behaviour of the flow, through both spectra and structure functions. Closures for non-linear energy transfer terms are proposed and validated, mainly based on vortex reconnection mechanism. Analogies and differences between QT and CT are drawn.

This is joint work with M. Kobayashi, F. Luddens, C. Lothodé, Ph. Parnaudeau, I. Danaila and M. Brachet

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*Title:* Superfluid turbulence: energy suppression by mutual friction in He-3, intermittency enhancement in coflowing He-4 and strong anisotropy of counter-flowing He-4

*Speaker:* **L'Vov, Victor**; Weizmann Institute of Science, Israel.

*Abstract:*
Liquid 4He and 3He at very low temperature become quantum fluids, consisting of interacting viscous normal and inviscid superfluid component.
Superfluid component consists of Bose-Einstein condensate (BEC) of atoms of 4He or Bardeen-Cooper-Schrieffer pairs of 3He Fermi atoms, while normal fluid component is exited over the BEC Bose atoms of 4He or BCS-pairs of 3He Fermi atoms.
I will remind basic ideas in turbulence of classical fluids, the peculiarities of superfluid dynamics and turbulence and discuss the recent ideas, experiments and physical models of superfluid turbulence.

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*Title:*
Towards Quantum Turbulence in Cold Atomic Fermionic Superfluids

*Speaker:*
**Bulgac, Aurel**; University of Washington, USA.

*Abstract:*
Fermionic superfluids provide a new realization of quantum turbulence, accessible to both experiment and theory, yet relevant to phenomena from both cold atoms to nuclear

astrophysics. In particular, the strongly interacting Fermi gas realized in cold-atom experiments is closely related to dilute neutron matter in neutron star crusts. Unlike the liquid superfluids 4He (bosons) and 3He (fermions) where quantum turbulence has been studied in the laboratory, superfluid Fermi gases stand apart for a number of reasons. They admit a reliable theoretical description based on a DFT called the TDSLDA that describes both static and dynamic phenomena. Cold atom experiments demonstrate exquisite control over particle number, spin polarization, density, temperature, and interaction strength. Topological defects such as domain walls and quantized vortices, which lie at the heart of quantum turbulence, can be created and manipulated with time-dependent external potentials, and agree with the time-dependent theoretical techniques. While similar experimental and theoretical control exists for weakly interacting Bose gases, the unitary Fermi gas is strongly interacting. The resulting vortex line density is extremely high, and quantum turbulence may thus be realized in small systems where classical turbulence is suppressed. Fermi gases also permit the study of exotic superfluid phenomena such as a 3D LOFF supersolid, and a finite temperature pseudo-gap in the regime of classical turbulence. The dynamics associated with these phenomena has only started to be explored. Finally, superfluid mixtures have recently been realized, providing experimental access to phenomena like Andreev-Bashkin entrainment. Superfluid Fermi gases thus provide a rich forum for addressing phenomena related to quantum turbulence with applications ranging from terrestrial superfluidity to astrophysical dynamics in neutron stars.

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*Title :*
Lagrangian particle tracking in normal and superfluid turbulent flow

*Speaker :*
**Mickaël Bourgoin** [1, @] , Fatimata Sy, Pantxo Diribarne, Mathieu Gibert, Bernard Rousset [@]
**1 :** Laboratoire de Physique, ENS de Lyon & CNRS (LPENSL)
*École Normale Supérieure - Lyon, CNRS : UMR5672, Université Claude Bernard - Lyon I*

*Abstract :*
We present a new comparison between normal and quantum turbulence based on the estimation, in statistically stationary conditions, of the turbulent energy dissipation rate at different relevant scales : from the large scales at which energy is injected down to small scales, through the inertial range of scales. For that purpose, an oscillating grid experiment was designed to explore the characteristics of turbulence in normal liquid helium and superfluid helium, allowing for the comparison of the behavior of those two fluids. High-speed 2D Lagrangian Particle Tracking diagnosis has been implemented and used to perform the estimation of the turbulent energy dissipation rate accross scales.

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*Title :*
Von Kármán flows: when simulations meet experiments

*Speaker :*
**Caroline Nore**[1,@] , Loic Cappanera[2] , Daniel Castanon Quiroz[3] , Bérengère Dubrulle[4] , Hugues Faller[5] , Jean-Luc Guermond[6]
**1 :** Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur [Orsay] (LIMSI) - ***Website***
*Université Pierre et Marie Curie (UPMC) - Paris VI, Université Paris XI - Paris Sud, CNRS : UPR3251, Université Pierre et Marie Curie [UPMC] - Paris VI*
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*Institut Montpelliérain Alexander Grothendieck*
**4 :** CEA, *SPEC*
**5 :** LIMSI-CNRS and SPEC-CEA, *LIMSI*
**6 :** Department of Mathematics [Texas] (TAMU) - ***Website***
*Mailstop 3368 - Texas A&M University - College Station, TX 77843-3368 - United States*

*Abstract :*
Hydrodynamic and magnetohydrodynamic (MHD) simulations of flows in the Von-Kármán setup are presented. The counter-rotating impellers that were used in the successful 2007 dynamo experiment (Monchaux et al., 2007) are modelled by means of a pseudo-penalty method. High kinetic Reynolds number hydrodynamic simulations are performed using a Large Eddy Simulation (LES) technique.

We first present MHD computations: at fixed kinetic Reynolds number, increasing the magnetic permeability of the impellers reduces the critical magnetic Reynolds number above which a magnetic field is generated and maintained, i.e. for dynamo action; at fixed magnetic permeability, increasing the kinetic Reynolds number also decreases the dynamo threshold. Our results support the conjecture that the critical magnetic Reynolds number tends to a constant as the kinetic Reynolds number tends to infinity. The resulting magnetic field generated by dynamo action is a mostly axisymmetric axial dipole with an azimuthal component concentrated near the impellers like in the dynamo experiment (see Nore et al., EPL, 2016 and JFM, 2018).

We also compare in the Von-Kármán flow the torque and the flow topology obtained by experiments, direct numerical simulations, and LES at various Reynolds numbers ranging from Re=100 to O(10^5). The level of agreement that is observed between the experimental and the numerical data shows that the degree of accuracy of each of these techniques is reaching a threshold beyond which it is possible to use each of them with high confidence to explore and better understand turbulence in complex flows at Re=10^5 and beyond.

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*Title:*
Are PDEs providing relevant tools to describe turbulent flows?

*Speaker:*
**Bec, Jérémie**; Mines-ParisTech, Sophia-Antipolis, France.

*Abstract:*
Accurate and efficient models of turbulence are key in a multitude of applications in industrial and natural sciences. Flows develop in an unsteady and chaotic turbulent state when the amount of injected kinetic energy overwhelms viscous damping. This excess results in a cascading process where a wide range of excited scales are strongly tied up. Energy dissipation is then sustained by violent fine-scale structures, leading to the persistence of a finite viscous dissipation in the limit of infinite Reynolds numbers. This phenomenon, dubbed "dissipative anomaly", rests on the singular nature and deep irreversibility of turbulent flows, and is the primary source of difficulties when developing turbulence models.

An idea underlying most models is to describe the large scales of the flow by Euler inviscid equations. The concept of solution must then be weakened to obtain turbulent velocity fields. As conjectured by Onsager [1], and recently demonstrated [2], finite dissipation requires that the velocity has a Hölder exponent of less than 1/3. The construction of such weak solutions, however, shows certain limitations. On the one hand, they are not unique [3], suggesting that the constraint of decreasing energy is not necessarily sufficient to ensure their physical relevance. On the other hand, the regularization of these singular solutions can in certain cases lead to probabilistic solutions [4], a phenomenon which is known as spontaneous stochasticity. All this suggests that the construction of turbulent solutions of the Euler equations requires an even weaker notion of solutions, such as the measure-solutions of DiPerna and Majda [5] where velocity is not defined in a unique way, but rather prescribed by a local probability distribution, namely a Young's measure.

An important consequence of a probabilistic velocity is that the trajectories of fluid elements themselves become probabilistic and that the concept of Lagrangian flow collapses. The formulation of solutions of the Euler equations must then build for instance on the generalized Lagrangian least-action principle formulated by Brenier [6].

[1] Onsager, L. "Statistical hydrodynamics." Nuovo Cimento 6, 279–287 (1949).
[2] Isett, P. "A proof of Onsager's conjecture." Ann. Math. 188, 871–963 (2018).
[3] Daneri, S., & Szekelyhidi, L. "Non-uniqueness and h-principle for Hölder-continuous weak solutions of the Euler equations." Arch. Ration. Mech. Anal. 224, 471–514 (2017).
[4] Biferale, L. Boffetta, G., Mailybaev A. & Scagliarini, A. "Rayleigh-Taylor turbulence with singular non- uniform initial conditions." Phys. Rev. Fluids 3, 092601 (2018).
[5] DiPerna, R. & Majda, A. J. "Oscillations and concentrations in weak solutions of the incompressible fluid equations." Commun. Math. Phys. 108, 667–689 (1987).
[6] Brenier, Y. "The least action principle and the related concept of generalized flows for incompressible perfect fluids." J. Am. Math. Soc. 2, 225–255 (1989).

*Title:*
Energy cascade in internal wave attractors

*Speaker:*
**Dauxois, Thierry**; CNRS and ENS de Lyon, France.

*Abstract:*
Internal gravity waves play a primary role in geophysical fluids: they contribute significantly to mixing in the ocean and they redistribute energy and momentum in the middle atmosphere. In addition to their very interesting and very unusual theoretical properties, these waves are linked to one of the important questions in the dynamics of the oceans: the cascade of mechanical energy in the abyss and its contribution to mixing.

Combining the physics of waves, dynamical systems theory and oceanography, I will discuss a unique self-consistent experimental and numerical setup that models a cascade of triadic interactions transferring energy from large-scale monochromatic input to multi-scale internal wave motion. I will also provide explicit evidence of a wave turbulence framework for internal waves. Finally, I will show how beyond this regime, we have a clear transition to a cascade of small-scale overturning events which induce mixing.

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*Title:*
Spontaneous randomness and Kelvin-Helmholtz interfaces

*Speaker:*
**Thalabard, Simon**; IMPA, Brazil.

*Abstract:*
Lagrangian particles moving in spatially rough environments are known to display exotic behaviors, among them spontaneous randomness: Particles that initially coincide almost surely separate in finite time, provided that the underlying velocity field is sufficiently rough. The corresponding Lagrangian trajectories then need to be described in probabilistic terms. Our intention in this talk is to examine an Eulerian counterpart to the spontaneous randomness phenomenon, that applies at the level of the velocity dynamics itself. Sources of singularity for the velocity could include finite-time blow up, but also and more simply initial conditions.
The latter case is of particular relevance in the context of turbulence generation, as randomly perturbed unstable shear layers provide natural example of such non-smooth initial configurations. For instance, incompressible Kelvin-Helmoltz interfaces are characterized by a discontinuous velocity fields and have therefore infinite vorticity: Are they also``spontaneously unstable'' ?

Joint work with J. Bec and A. Mailybaev

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*Title :*
Topological Waves in Fluids

Speaker :
**Antoine Venaille**[1, @]
**1 :** Laboratoire de Physique de l'ENS Lyon
*CNRS : UMR5672, École Normale Supérieure - Lyon*

*Abstract :*
The concept of topologically-protected transport along the edge of physical systems was born three decades ago in the context of quantum Hall electronics, and has now spread over all fields of physics. Waves are topologically-protected from disorder and backscattering when emerging at the boundary separating bulk materials characterized by different topological invariants called Chern numbers. These invariants describe the winding of bulk eigenmodes around band degeneracy points in parameter space. We apply these tools to two celebrated models of geophysical and astrophysical flows. We relate the emergence of unidirectional equatorial waves that play a central role in El Nino phenomenon to a Chern number and to the breaking of time-reversal symmetry by Coriolis forces [1]. We then explain the emergence of bottom trapped Lamb waves in compressible stratified flows, in relation with broken mirror symmetry due to gravity [2]. This second case leads to the prediction of a new class of waves that could be present in the radiative zone of massive stars.
[1] Delplace, Marston, Venaille, *Topological Origin of Equatorial Waves,* Science 2017
[2] Perrot, Delplace, Venaille, *Topological Transition in Stratified Fluids,* Nature Physics 2019

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*Title :*
Multistability in turbulent wake : symmetry breaking state and high Reynolds number bifurcation

*Speaker :*
**Olivier Cadot** ; University of Liverpool (School of Engineering), *LIverpool - United Kingdom*

*Abstract :*
The communication will present recent experimental progress in the comprehension of the large-scale dynamics of turbulent wakes produced by three-dimensional bluff bodies. A focus will be done on the identification of the static symmetry breaking mode leading to bifurcations and multi-stable dynamics with turbulent background.