Title: Turbulence.

Time lenght: 30h CM

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Objectives: Turbulent flows are present all around us and are crucial in fields such as aeronautics, industry, meteorology, astrophysics, climate. We know their equation of motions (the Navier-Stokes equations). Yet, several theoretical and practical obstacles preclude the building of a complete theory, and impose to resort to modern and original tools of mathematics and physics, such as weak formalism, non-equilibrium physics, wavelets or multi-fractals. In this class, we will first explain the various difficulties associated with turbulence theory, and describe several tools and approaches that enable to draw a modern picture of turbulence.
For this purpose, we will navigate between theory and practice, using data from real experiments or numerical simulations to put into practice what we have learned.

The final exam will be based upon an homework.

Basic notion of Fluid Mechanics and probability theory are required.

Contents:

- <u>Introduction and examples</u>
- <u>Mathematical and Statistical tools</u>
- <u>Kolmogorov theory and beyond</u> *(Millenium prize, Weak-Karman Howarth)*
- <u>Intermittency description</u> *(wavelets, multifractal, Onsager conjecture)*
- <u>Turbulence in 2D</u> *(cascades and conservation laws)*
- <u>Turbulence modelling</u> *(coarse-graining, stochastic modelling, shell model, EDQNM)*
- <u>Dissipation and irreversibility</u>
- <u>Convection, MHD flows, rotating and stratified flows</u>

Bibliography:

Frisch, Turbulence, Cambridge
Landau & Lifschitz, Fluid Mechanics, Pergamon

Bohr, Jensen, Paladin, Vulpiani, Dynamical Systems Approach to Turbulence, Cambridge
Dubrulle, Beyond Kolmogorov, JFM Perspectives, 2019.