

**Title : Modern approaches to hydrodynamics: effective actions and gauge/gravity duality**

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**Research Area :** Mathematical Physics or High Energy Physics (primary), Condensed Matter (secondary)

**Methods:** Thermal Quantum Field Theory, Gauge/Gravity duality

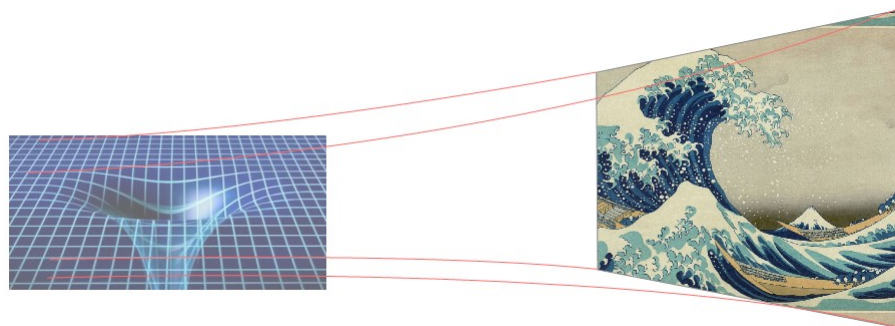
**PhD track subject :**

Any interacting system can be described by hydrodynamics at sufficiently late times and long wavelengths. In this effective approach, the dynamics of individual particles is eschewed and replaced by the collective dynamics of conserved densities, which follow from the symmetries of the system. Famously, diffusion is the collective process which describes the return to equilibrium of particles in a reservoir, but also the flow of transverse momentum in the Quark-Gluon-Plasma, or heat transport for electrons in ultra pure Graphene.

This PhD topic will start from the old textbook approaches to hydrodynamics via the equations of motion, with the aim to reach recent developments and go beyond them:

- the construction of effective actions for hydrodynamics via the Schwinger-Keldysh formalism
- the role of fluctuations in the hydrodynamic effective action and how they generally destroy hydrodynamics at very long times and distances
- gauge/gravity duality and how hydrodynamics arises from the dynamics of black holes in asymptotically anti de Sitter spacetimes
- the spontaneous breaking of symmetries and the coupling of the associated Goldstone modes to the conserved densities in the hydrodynamic theories
- the interplay of spontaneous symmetry breaking with soft explicit breaking

Which of these developments are studied in practice will depend on the background of the applicant, their taste and progress during the project. Depending on all of this, the project may have a stronger flavor of Quantum Field Theory, Condensed Matter, Statistical Physics, General Relativity, String Theory, be purely analytical or include a numerical component.



**References:** <http://arxiv.org/abs/1205.5040>, <http://arxiv.org/abs/1805.09331>,  
<http://arxiv.org/abs/1612.07324>, <http://arxiv.org/abs/2110.00961>