Annual report
Ph.D. in Physics and Nanoscience

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Tutor: Andrea Amoretti

Ph.D. cycle: XXXVI, first year

1 Research activity

My research activity focuses on the theory of hydrodynamics, with a particular emphasis towards condensed matter phenomenology.

Hydrodynamics is a many-body effective field theory that allows to describe the dynamics of (almost-)conserved charges near thermal equilibrium in the long wavelength, long time scale regime. It is a very powerful tool to model the phenomenology of (strongly) interacting systems, such as graphene, Weyl semimetals or high-temperature superconductors in the context of condensed matter.

Hydrodynamics is also important from purely theoretical aspects: the fluid/gravity duality in holography relates hydrodynamics to a dual theory of classic gravity (eventually coupled to other fields) in the $\omega \to 0$ limit, so hydrodynamics allows to test some aspects of the holographic conjecture.

In the first few months of the academic year I worked on the topic of my Master thesis, i.e. hydrodynamics in the presence of a $U(1)$ gauge anomaly and its application to describe the thermoelectric properties of a Weyl semimetal. I managed to complete and expand some aspects of my thesis and I showed that there are still some inconsistencies in the literature in the theory of anomalous hydrodynamics.

Next I joined one of my tutor's projects about hydrodynamics in the presence of (pseudo-)spontaneously broken translation invariance, that is the hydrodynamic realization of a Charge Density Wave state in condensed matter (e.g. cuprates high-T_c superconductors near optimal doping are strongly coupled and show a CDW order). In particular we were interested in the thermoelectric properties of such system in the presence of an external magnetic field and in matching the results obtained from hydrodynamics with the ones obtained from holography. We provided a complete analytic description of the model both in the spontaneous and pseudo-spontaneous case from hydrodynamics and then we managed to compare the results against numerical data from holography with great accuracy.

2 Courses and exams

During the first year I followed the following courses:

- GGI winter school in Statistical Field Theory – 8^{th}-19^{th} february 2021, online (34h)
- Theoretical physics (Ridolfi) – Ph.D. course 3 CFU
- Black hole thermodynamics (Giusto) – Ph.D. course 3 CFU
- Introduction to AdS/CFT (Amoretti) – Ph.D. course 3 CFU

and gave the following exams – seminars:

- Theoretical physics – The renormalization group
- Black hole thermodynamics – The information paradox
- Introduction to AdS/CFT – Holographic Charge Density Waves states

3 Publications

Hydrodynamic magneto-transport in holographic charge density wave states – in course of publication (arXiv: 2107.00519)
A. Amoretti, D. Arean, D. K. Brattan, L. Martinoia

4 Conference presentations

I presented a video-poster during the GGI Cortona Young 2021 conference (Jun 09, 2021 - Jun 11, 2021), held online because of the Covid-19 pandemic.
Title: *Thermoelectric conductivities in Charge Density Waves States from hydrodynamics*