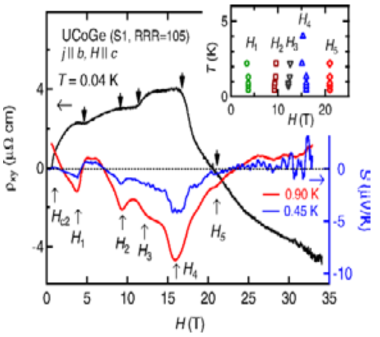

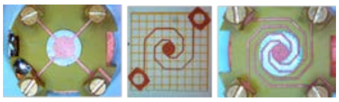

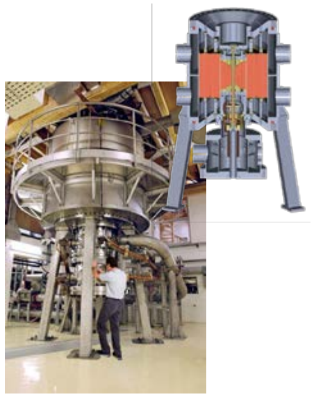

Open PhD position

in the framework of the research project

Interplay between Electronic Topological Transitions and Thermodynamics – IET³

Scientific background

Fermi surface instabilities have regained strong interest very recently with the discovery of topological materials where new exotic topological orders are expected to emerge close to a Fermi surface reconstruction. When the connectivity number or topology of the Fermi surface changes under the influence of an external parameter such as chemical doping, pressure, or a magnetic field (H), the transition is called a Lifshitz transition. Lifshitz transitions, known since the 1960s, are continuous quantum phase transition at zero temperature and are referred to in the literature as **2 1/2** order phase transitions using the Ehrenfest terminology, or electronic topological transitions. Among the different ways to induce Lifshitz transitions, the magnetic field induced Lifshitz transitions have only been observed recently and are poorly discussed theoretically. Particularly, the consequence of field induced Lifshitz transitions on the thermodynamic properties (magnetization) through the density of states is not well understood because, in transport properties (resistivity, thermoelectric power), it has been suggested that it is indeed the scattering term which changes drastically at the Lifshitz transition. So the main expected result of this study is to reveal what is the major consequence of a Lifshitz transition: kink in density of states or extra scattering process due to the newly appearing or disappearing Fermi surface pockets. In order to look for thermodynamic signatures of the observed changes of the Fermi surface (magnetic or not), we propose to use a very innovative and newly developed set-up for magnetization measurement in the high magnetic field facility (LNCMI-Grenoble). This set-up is based on the principle of a Faraday balance much more sensitive compared to the conventional compensated-coil technique.

The main objective of this *collaborative* project between LNCMI Grenoble and PHELIQS laboratories is to use the newly developed magnetization technique as a complement to the different well-established quantum oscillations probes (resistivity, Hall effect, thermoelectric power, and torque) to study the interplay of field induced *Fermi surface instabilities* and *thermodynamics*. Through a co-supervised PhD thesis this project will strengthen an already quite fruitful collaboration between the two partner laboratories (see refs. and publication lists for past common papers) and benefit from our local and widely acknowledged expertise in fine-probing Fermi surfaces and their changes (at high magnetic fields) with different techniques on “in house” grown very high quality single crystals. We will focus our study first on systems well known in the laboratory namely the highly correlated electrons systems like the ferromagnetic UCoGe (also superconducting) and YbNiSn, and the antiferromagnetic UPd_2Al_3 compounds. These highly correlated electron systems are characterized by flat bands at the Fermi level which are very sensitive to external magnetic fields. Nevertheless, these systems present the disadvantage to have a complex band structure leading generally to a rich and complicated Fermi surface topology. This is why in the second part of the project we will make similar studies on systems where the Fermi surface is much simpler. We have chosen to concentrate on semi-metals where only few carriers are present at the Fermi level. More specifically, we will work on topological Weyl and Dirac semi-metals (WSMs and DSMs) like Cd_3As_2 and Na_3Bi because, compared to other semi-metallic materials, they present a very high mobility, and since very recently topological transitions are expected to occur in these emerging systems.

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Pheliqs Quantum Physics & Engineering
LNCMI

PhD student activity

The candidate will be involved in the characterization measurements (resistivity, thermoelectric power, specific heat, magnetization ...) at very low temperature (**Pheliqs**) and high magnetic field (**LNCMI Grenoble**), data analysis, and improving the experimental devices. In addition to the 2 supervisors, the PhD student will also collaborate with other researchers in both laboratories doing complementary measurements on these compounds. If necessary, some measurements may be extended up to higher fields (60 or 90T) at LNCMI Toulouse (pulsed field facility).
It is also considered giving the student (if she/he is interested) the unique opportunity to synthesize her/his own single crystals because **Pheliqs** laboratory has a very performing crystal growth team.
The candidate will possess a strong background in physics of condensed matter and/or quantum mechanics and strong motivation for experimental work requiring complex and delicate instrumentation. She/he will become independent on cryogenic techniques, crystal growth and particularly various characterization probes, relying initially on the expertise of the researchers in the laboratories. Active participation in discussions with the teams involved in the research topic are also part of the PhD work, as well as communicating obtained results at national or international workshops and conferences.
The initial part of the project (studying Fermi surface changes under (high) magnetic field with thermodynamic probes and by quantum oscillations in strongly correlated electron systems) is embedded in the long history of heavy fermion research in Grenoble laboratories and will therefore benefit from the local outstanding experience in this field. The second part, concerning the study of 3D topological semimetals, is naturally more explorative since it is at the very forefront of an actually emerging research topic. However, for the PhD candidate a strong continuity will be achieved by the use of the same experimental probes throughout the entire PhD period.

PhD position details

The PhD project will be located in Grenoble (presqu'île scientifique), jointly hosted by PHELIQS laboratory (CEA) and the National High Magnetic Field laboratory (LNCMI-CNRS).
This research project has been awarded a special budget by Grenoble University, including a PhD scholarship of about 1400€ net per month during 3 years.
Start date: *not later than October 2017*

Requirements

Master degree in condensed matter physics
Good understanding of solid state physics
Good experimental skills
Good team player
Prior hands-on experience in cryogenics would be an asset

Contact / supervisors

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Recent related publications

-A. Gourgout, A. Pourret, G. Knebel, D. Aoki, G. Seyfarth, and J. Flouquet,"Collapse of Ferromagnetism and Fermi Surface Instability near Reentrant Superconductivity of URhGe", Phys. Rev. Lett. **117**, 046401 (2016)
-G. Bastien, A. Gourgout, D. Aoki, A. Pourret, I. Sheikin, G. Seyfarth, J. Flouquet, G. Knebel, *Lifshitz Transitions in the Ferromagnetic Superconductor UCoGe*, Phys. Rev. Lett. **117**, 206401 (2016)
-D. Aoki, G. Seyfarth, A. Pourret, et al., "*Field-Induced Lifshitz Transition without Metamagnetism in* $CeIrIn_5$", Phys. Rev. Lett. **116**, 037202 (2016)
-A. Palacio-Morales, A. Pourret, G. Seyfarth, M.T. Suzuki, D. Braithwaite, G. Knebel, D. Aoki, and J. Flouquet, *"Fermi surface instabilities in* $CeRh_2Si_2$ *at high magnetic field and pressure"*, Phys. Rev. B (editor's suggestion) **91**, 245129 (2015)

Key words

Fermi surface – strong electronic correlations – heavy fermion systems – Dirac and Weyl semi-metals – high magnetic fields – low temperatures – quantum oscillations – thermoelectric power – magnetization