Fun Phys Master2 internship project 2021

Name of the laboratory: Centre de Physique Théorique CNRS UMR 7332
http://www.cpt.univ-mrs.fr/
Nanophysics team E6

Internship advisor: Thierry MARTIN
Co-advisors: B. Grémaud, T. Jonckheere, A. Popoff, L. Raymond and J. Rech
Emails: martin@cpt.univ-mrs.fr, thibaut.jonckheere@cpt.univ-mrs.fr, kf.popoff@gmail.com, laurent.raymond@univ-amu.fr, jerome.rech@cpt.univ-mrs.fr
Centre de Physique Théorique, Bat TPR2, 163 Av. de Luminy, Case 907, 13288 Marseille Cedex 09
Tel: 04 91 26 95 41

Web page of the team: http://www.cpt.univ-mrs.fr/~jonckheere/equipe.htm

Title: **Non equilibrium noise in the presence of a temperature gradient in hybrid junctions between a normal metal and a conventional/topological superconductor.**

Subject description:

The nanophysics team of CPT is looking for a motivated M2 student to study the non-equilibrium noise generated by a thermal gradient in hybrid superconducting systems. This constitutes the so-called “Delta T noise problem”, which was recently studied in atomic normal metal break junctions at the Weizmann institute as in ongoing research of the team. In the absence of voltage and in the presence of electron-hole symmetry, no net charge current flows through the device, but charge carriers are nevertheless exchanged stochastically between the two leads, giving rise to current fluctuations.

For such systems, we have in mind either a normal metal – quantum dot – BCS superconductor junction, or a single junction between a normal metal and a topological superconductor, which bears Majorana fermions at its extremities. Indeed, transport is characterized by the charge or spin current, but also by more involved quantities giving additional information, like the current-current correlations in time, called noise, and in full generality the higher current moments. The study of hybrid structures containing BCS superconductors or new materials like topological superconductors offers new perspectives in this domain.

In hybrid structures containing superconductors, when voltage biases are applied to the leads, one has to resort to specific methods, in particular the Keldysh Green’s function formalism issued from Quantum field theory. The CPT nanophysics team has a strong tradition in using these tools to study the current and noise correlations in superconducting hybrid structures, where a special transport channel called Andreev Reflection operates (the reflection of an electron incident on the superconductor into a hole).

In topological superconductors, a lot of attention was drawn recently to the possibility for detecting the presence of Majorana fermions: excitations which are their own antiparticle. Such excitations have been studied a century ago in the context of particle physics, but they are now believed to occur in the collective phenomena of condensed matter systems. It is therefore natural for the nanophysics team to study Delta T noise in a device consisting of a topological superconductor nanowire and a normal metal lead. The manifestation of Majorana fermions could possess a particular signature.

During the internship, the first part of the work will be to get familiar with the bibliography on BCS and topological superconductors as well as to familiarize oneself with the non-equilibrium methods of quantum field theory. The average current and zero frequency noise can then be computed using the Keldysh Dyson equation. The boundary Green's function of the topological superconductor can be determined from the microscopic model of the Kitaev chain.

It will be relevant to compare the two systems because for a normal metal - quantum dot – BCS superconductor junction, when the dot level corresponds to the chemical potential of the superconductor, a zero energy Andreev bound states arises, which gives rise to a similar zero bias anomaly than that of a junction between a normal metal and a topological superconductor. We therefore hope that Delta T noise will allow to differentiate the behavior of the two systems, allowing yet another manifestation of the presence of Majorana fermions

This internship involves analytical as well as numerical calculations.

References:

1 Noise in mesoscopic physics, Thierry Martin, les Houches Session LXXXI, H. Bouchiat et. al. eds. (Elsevier 2005). arXiv:cond-mat/0501208

2 Quantum Transport, Y. Nazarov and Y. Blanter, Cambridge University Press.

3 Low energy transport in Majorana wire junctions, A. Zazunov, R. Egger, and A. Levy Yeyati, Phys Rev B 94, 014502 (2016).

4 O. Lumbroso, L. Simine, A. Nitzan, D. Segal, and O. Tal, Nature 562, 240 (2018).

5 Negative Delta-T Noise in the Fractional Quantum Hall Effect, J. Rech, T. Jonckheere, B. Grémaud, and T. Martin, Phys. Rev. Lett. 125, 086801 (2020).

6 Scattering Theory of Non-Equilibrium Noise and Delta T current fluctuations through a quantum dot, A. Popoff, S. Malherbe, J. Rech, T. Jonckheere, B. Grémaud, and T. Martin, in preparation (2021)

7 Current and noise correlations in a double-dot Cooper-pair beam splitter, D. Chevallier, J. Rech, T. Jonckheere, and T. Martin, Phys. Rev. B 83, 125421 – Published 23 March 2011

Duration: the normal duration of a CPT internship

Any self-financial support? NO this internship would be financed by the CPT.

Specify whether the internship project may naturally lead to a PhD thesis.

Yes. The complete program of the internship is ambitious and is likely to continue if a thesis contract is available. However, it depends on the level of other CPT students who apply to the PhD program via the doctoral school ED 352.