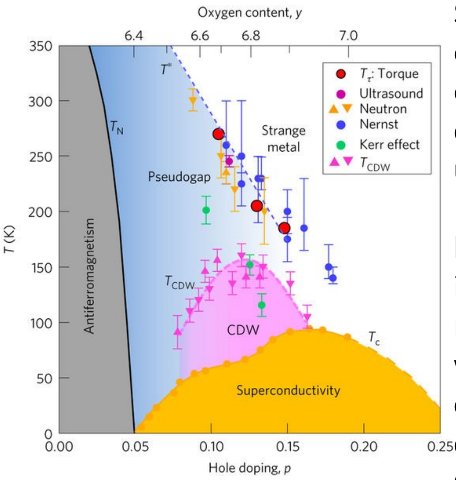
Unconventional superconducting mechanisms

Name of laboratory : Laboratoire de Physique des Solides (LPS)
Address : Paris Saclay University, Bâtiment 510, 91405 Orsay CEDEX
Name of thesis advisor : Marcello Civelli
E-mail : marcello.civelli@universite-paris-saclay.fr **Phone number** : +33 (0)169156937
Web Page : https://sites.google.com/view/ataualpa/home
Thesis possibility after internship: YES
Funding: No, application to a grant via doctoral school EDPIF (co-tutelle abroad possible)



Superconductivity, the dissipation-less flow of charge, is one of the most fascinating macroscopic manifestations of an exotic quantum state of matter. Over the last decades more and more materials presenting unconventional superconductivity have been discovered (we mention e.g. the multilayered graphene, the Iron-based the Nickel-based, Iridium-based superconductors, in TaS and TaSe….). These new superconducting materials elude our current understanding framed within the stand theory of superconductivity. The role of correlation and the competition with other exotic quantum phases (like e.g. the charge density wave CDW, see the phase diagram figure) have made the validation of a theory impossible up to now, as well-controlled calculations are complicate to perform.
This project aims to introduce the student into the problematics of unconventional superconductivity by employing a state of the art methods based on Dynamical Mean Field Theory[1,2], which is able to well treat the electronic correlation and study the competition between different quantum phases. During the internship, the student will study within a simple implementation of the DMFT the correlated CDW phase, extending an analytical work on this subject that we already published [3]. This work can develop into a thesis, where more advanced DMFT implementation[4] available within our group will be employed to study the unconventional superconductivity rising from the competition with other quantum phases, like the aforementioned CDW, but also e.g. exotic magnetism or nematic instability (spontaneous breaking of the x-y lattice symmetry). Collaborations are open with theory groups and experimentalists in Paris area and Grenoble, but also at the international with USA, Brazil, Quebec and Italy.

Skills required : background in condensed matter physics, many-body, quantum field-theory, and positive attitude to learn and employ numerical methods

References :
[1] https://indico.flatironinstitute.org/event/3575/attachments/773/1158/DMFT-Lecture.pdf
[2]https://www.researchgate.net/publication/237811021_Strongly_Correlated_Materials_Insights_From_Dynamical_Mean-Field_Theory
[3] Raman response of the charge density wave in cuprate superconductors
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Phys. Rev. B 108, 165111 – Published 10 October 2023
[4] Pyqcm: An open-source Python library for quantum cluster methods, Théo N. Dionne, Alexandre Foley, Moïse Rousseau, David Sénéchal, SciPost Phys. Codebases 23 (2023)