## Master 2: *International Centre for Fundamental Physics*

## ***INTERNSHIP PROPOSAL***

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR8502
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Internship location: LPS Orsay

Thesis possibility after internship: YES
Funding already obtained for a PhD: NO

### Electron-phonon coupling in exotic density waves

The coupling between electrons and phonons is central in condensed matter, being at the root of the basic structural properties of solids, but also of some of their most exotic phases, including superconductivity. It is however often crudely approximated to be a single constant in theories of quantum states of matter, neglecting its momentum dependence which is known to be large and crucial for even a qualitative understanding of quantum phases in real materials [1]. A new phase of matter, named pair density wave, was discovered recently and is fundamentally based on the momentum dependence of the electron-phonon coupling [2,3]. It is characterised by a superconducting order parameter which is modulated as a function of space, as if the number of superconducting pairs varied depending on the position in the sample. This phase of matter is closely connected to charge density waves, where the electronic charge varies in real space, and whose physics is still not well understood.

This project aims to combine the expertises of two groups: ab-initio calculations in Paris-Saclay University and electron-phonon coupling in the University of Amsterdam, to tackle the challenge of connecting superconductivity with charge order in transition-metal dichalcogenides. The structure of the electron-phonon coupling, which is key in these systems, will be carefully studied.

In this project, the intern will be co-supervised by Corentin Morice in Paris-Saclay and Jasper van Wezel in Amsterdam. They will model the electronic and phononic structures of relevant materials such as Se, NbSe2 and UTe2. It will be possible to choose between more analytical methods, including field theory and tight-binding models, and state-of-the-art computational methods like density functional theory or many-body perturbation theory. The PhD student will model the electron-phonon coupling, and calculate experimentally-relevant observables, such as superconducting gaps, transport and spectroscopic quantities, and make direct comparisons with experimental results.

[1] F. Flicker & J. van Wezel, Phys. Rev. B 92, 201103(R) (2015)
[2] M. H. Hamidian et al., Nature 532, 343 (2016)
[3] X. Liu et al., Science 372, 1447 (2021)

Condensed Matter Physics: YES
Quantum Physics: YES
Soft Matter and Biological Physics: NO
Theoretical Physics: YES