

INTERNSHIP PROPOSAL

Laboratory name: CPHT

CNRS identification code: UMR 7644

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[Web page at CPHT](#)

CPHT, Ecole Polytechnique, bureau 00.1026 (Aile 0)

Thesis possibility after internship: YES

Funding already obtained for a PhD: NO, will be requested via the doctoral school.

Magnetic GW: A New Many-Body Approach to Realistic Modelling of Quantum Materials

Scientific context: Electrons in quantum materials interact with one another through the Coulomb interaction, giving rise to a rich variety of collective phenomena, including magnetic excitations (magnons), charge-density fluctuations (plasmons), and superconductivity. These collective excitations can strongly influence the electronic structure and determine the magnetic, optical, and transport properties of materials. Understanding their interplay with individual electrons is therefore essential for developing a microscopic description of correlated quantum materials.

A major challenge in theoretical condensed matter physics is to describe these effects quantitatively in realistic materials. One widely used approach is the *GW* approximation, which describes electronic properties in terms of the interaction between electrons and dynamically screened Coulomb fluctuations. However, in materials where magnetic correlations play a dominant role, an accurate treatment of spin fluctuations is particularly important. Developing computationally efficient methods that capture these effects while remaining applicable to realistic materials is an important challenge.

Research project: The goal of this internship is to implement and develop a magnetic *GW* approach that incorporates the effects of magnetic fluctuations into the description of correlated electrons, and to apply this method to realistic quantum materials. The project combines theoretical method development, numerical implementation, and the investigation of physical phenomena.

The project begins with an introduction to the many-body formalism and the role of magnetic fluctuations in correlated electron systems. It then focuses on implementing the magnetic *GW* approach and testing its performance on model systems. Once validated, the method will be applied to selected materials to investigate how magnetic fluctuations influence their electronic properties.

The ultimate goal is to use the newly developed approach to gain physical insight into the interplay between electronic quasiparticles and collective magnetic excitations in realistic materials. Thus, the internship will offer an opportunity not only to develop a computational tool but also to use it to address fundamental questions in the physics of correlated quantum materials.

Methods and skills: The project lies at the intersection of theoretical condensed matter physics, quantum many-body theory, and computational materials science. It involves diagrammatic many-body techniques, numerical implementation of quantum many-body methods, and the analysis of electronic structures in correlated materials.

Profile and skills: The project is intended for a student with a strong interest in condensed matter theory, quantum materials, and computational physics. Good knowledge of general solid-state physics and a solid background in quantum many-body theory are expected. Experience with numerical calculations and programming in Python or C++ would be an advantage.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES

Soft Matter and Biological

Physics: NO

Quantum Physics: YES

Theoretical Physics:

YES