

Contrats doctoraux 2026

Titre du projet de thèse : A non-perturbative approach to the Anderson transition using functional renormalization group

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Résumé du projet de thèse (en 20 lignes maximum) :

The transport of information lies at the heart of communication technologies. Quantum effects play an increasingly important role in devices used for communications and information processing. For example, secure cryptography based on quantum entanglement between photons has now become a commercial technology. Thanks to recent technological advances, classical systems are gradually being replaced by mesoscopic systems, which implies that quantum interference effects are becoming increasingly important.

The great majority of quantum systems are affected by disorder, due for instance to fabrication imperfections. This can create challenges for quantum technologies, because it can be difficult to control and manipulate quantum information when it is impacted by disorder. For example, if the quantum particles used to store and process information are exposed to external perturbations, this can affect their behavior and compromise the quality of the information they handle. It is therefore crucial to understand the effects of imperfections and disorder in cold-atom experiments, in order to better control these new kinds of simulators.

The Quantum Systems group at PhLAM, which includes Adam Rançon, is internationally recognized for its experimental and theoretical work on the effects of disorder on the propagation of quantum waves, in particular in the context of Anderson localization. This phenomenon—transport suppression caused by disorder-induced interference—is universal, and also appears in disordered metals, the propagation of acoustic and seismic waves, etc.

While the phenomenology of the metal–insulator transition (critical exponents, multifractality, characteristic length scales, etc.) is well established numerically and experimentally, a controlled theoretical description is still lacking. This is due to the complexity of the underlying theoretical model: a highly intricate supersymmetric field theory. Standard field-theoretical approaches, such as perturbative expansions, are ineffective for this problem and do not yield precise quantitative predictions at the transition.

The proposed PhD project aims to address this issue using a modern non-perturbative method, the functional renormalization group (FRG). This powerful technique has already proven useful for several problems in the physics of disordered systems. Adam Rançon is an expert in this method, and has developed new implementations for strongly correlated quantum systems, which can be used to tackle the Anderson transition.

To this end, we will first study simpler supersymmetric models that also exhibit localization transitions. This will make it possible to adapt functional renormalization techniques to these models, before generalizing them. We will study properties at criticality, such as universal critical exponents and multifractality.

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Remarques/commentaires supplémentaires :