

INTERNSHIP PROPOSAL

Laboratory name: LPTMC, SU
CNRS identification code: UMR 7600
Internship director's surname: Nicolas Dupuis
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Internship location: Sorbonne Université (campus Jussieu)

Thesis possibility after internship: YES

Funding: NO

If YES, which type of funding:

Weakly Coupled One-Dimensional Bose Gases

One-dimensional quantum systems occupy a special place in many-body physics because they can be studied using a wide range of powerful theoretical methods. In particular, bosonization provides a remarkably simple framework to describe a broad class of systems known as Luttinger liquids, which include interacting fermions, bosons, and quantum spin chains [1]. At low energies, these systems are governed by a quadratic Hamiltonian characterized by only two parameters: the velocity of the low-energy mode (i.e., the sound mode velocity in a Bose gas) and the Luttinger parameter, which encodes the interaction strength. The asymptotic behavior of the correlation functions is entirely determined by the Luttinger parameter, which thus sets the nature of the dominant fluctuations.

The goal of this internship is to apply bosonization, together with the non-perturbative functional renormalization group (a modern implementation of the Wilsonian renormalization group [2]), to study weakly coupled one-dimensional Bose gases. These highly anisotropic systems are expected to display a rich phase diagram, featuring superfluid, density-wave, and possibly supersolid phases. The internship will involve both analytical calculations and numerical solutions of renormalization-group flow equations.

The project could be extended into a PhD thesis, focusing on Bose gases that deviate from the Luttinger-liquid paradigm. In particular, we will explore the effects of a periodic potential (leading to a superfluid–Mott-insulator transition, described by the sine-Gordon model) and of a random potential (which may give rise to a localized phase known as “Bose-glass”) [1]. In both cases, the non-perturbative functional renormalization group offers a powerful framework to determine the phase diagram and low-energy properties in the one-dimensional limit [3, 4]. Studying weakly coupled one-dimensional Bose gases, starting from the one-dimensional limit, is not only interesting in its own right but also provides a promising route to understanding the physics of two- and three-dimensional Bose gases, where direct approaches based on isotropic models are often difficult. Similar studies may be considered for Fermi gases.

[1] T. Giamarchi, *Quantum Physics in One Dimension*, (Oxford University Press, 2004).

[2] N. Dupuis et al., [Phys. Rep. 910, 1 \(2021\)](#).

[3] R. Daviet and N. Dupuis, [Phys. Rev. Lett. 122, 155301 \(2019\)](#); P. Jentsch et al., [Phys. Rev. D 105, 016028 \(2022\)](#).

[4] N. Dupuis and R. Daviet, [Phys. Rev. E 101, 042139 \(2020\)](#); R. Daviet and N. Dupuis, *Phys. Rev. Lett.* [125, 235301 \(2020\)](#), *Phys. Rev. E* [103, 052136 \(2021\)](#); V. Grison and N. Dupuis, arXiv:2511.xxxxx

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