Spécialité de Master « Optique, Matière, Paris »

Stage de recherche (4 mois minimum, à partir de début mars)

Proposition de stage

Date de la proposition :

Responsable du stage / *internship supervisor*:

Nom / *name*:	SANCHEZ-PALENCIA	Prénom/ *first name* :	Laurent
Tél :	01 64 53 33 47	Fax : 01 64 53 31 00	
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Nom du Laboratoire / *laboratory name*: Laboratoire Charles Fabry

Code d'identification : UMR8501 Organisme : CNRS, Institut d'Optique, Univ Paris-Saclay

Site Internet / *web site*: http://www.uquantmat.fr

Adresse / *address:* 2 avenue Augustin Fresnel, F-91120 Palaiseau

Lieu du stage / *internship place*: Palaiseau

Titre du stage / *internship title*: **Superfluid Quantum Phase Transitions in Low-Dimensional Ultracold Gases**

Résumé / *summary*

One of the most fascinating aspects of many-body quantum systems is the onset of quantum phase transitions, driven by the competition of coupling terms favouring distinct ground states at zero temperature. There are many fascinating examples of quantum phase transitions in condensed matter physics, such as superfluid-insulator or magnetic transitions [1]. They are particularly spectacular in low dimensional systems because quantum fluctuations are strongly enhanced compared to their three-dimensional counterparts, which produces very strong effects. An example of which is the Mott transition in one-dimensional lattices, where an infinitely weak periodic potential can change the system from superfluid to insulator [2].

The study of quantum phase transitions is currently attracting enormous interest in the field of ultracold atoms for they offer unprecedented control possibilities. This is stimulating the development of *quantum simulators*. Besides experimental developments, the advent of quantum simulators now calls for advanced theoretical work to identify new quantum phase transitions in realistic physical systems. The objective is actually threefold: i) characterize phase transitions, ii) interpret experimental observations, and iii) propose new experiments.

The aim of the internship and thesis is to study theoretically superfluid-insulator transitions in low dimensional systems. In a recent work, we reported the characterization of the Mott transition in a one-dimensional optical lattice in collaboration with an experimental group in Italy [3]. Here, we will extend this study two-dimensional systems and study the effect of more complicated potentials, relevant to present-day experiments. These fundamental issues will be addressed from a theoretical point of view, using the most modern many-body approaches, in particular quantum Monte-Carlo methods. Our code is already developed and uses the most powerful approach, known as the "worm algorithm" [4]. A significant part of the project will be developed in direct collaborations with experiments.

[1] S. Sachdev. *Quantum Phase Transitions* (Cambridge Univ. Press, Cambridge, 2011).
[2] T. Giamarchi. *Quantum Physics in One Dimension* (Carendon press, Oxford, 2004).
[3] G. Boéris, L. Gori, M.D. Hoogerland, A. Kumar, E. Lucioni, L. Tanzi, M. Inguscio, T. Giamarchi, C. D'Errico, G. Carleo, G. Modugno & L. Sanchez-Palencia, arXiv:1509.04742
[4] G. Carleo, G. Boéris, M. Holzmann & L. Sanchez-Palencia, Phys. Rev. Lett. **111**, 050406 (2013).

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : OUI / YES**

Si oui, financement de thèse envisagé/ *financial support for the PhD*: **Nous consulter / Consult us**

Lumière, Matière, Interactions	**YES**	Lasers, Optique, Matière	**YES**