Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: Centre de Physique Theorique, CPHT Ecole Polytechnique
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Thesis possibility after internship: Yes/No
Funding: If YES, which type of funding:

Title Topological Quantum States, Interactions and Light Spheres

Summary (half a page maximum)

Recently, progress has been done in solid-state physics, cavity and circuit quantum electrodynamics and cold atoms to achieve and probe new states of matter. Our goals are to address new models and entangled behaviours with applications in quantum materials and devices, at the same time developing tools (mathematical and numerical).

This research starts from topology which is characterised through a mathematical number, the topological invariant or Chern number, classifying properties of (Bloch) energy bands, related to topological edge modes. This gives rise to the periodic Table of topological insulators and superconductors. Another way to achieve simply topology is to apply a radial magnetic field on an atomic or mesoscopic Bloch sphere characterising a spin-1/2 particle such that it produces an effective topological unit charge at the core of the sphere. The sphere can then be identified as a coffee cup. This sphere is realised in circuit quantum electrodynamics and atoms. Recently, we have proposed a two-spins' 1/2 model with radial magnetic field from the curved space showing that a new topology with rational "one-half" number is possible due to entanglement between spheres [1]. The effect is stable towards various forms of interactions. These spheres also find new applications in bilayer graphene models [2] with a Z2 symmetry [1]. The objective of this project is to study a wire of such quantum spheres corresponding to new spin-1/2 chain models with radial magnetic fields and interactions between the spheres. This model may find new applications in light-matter coupling [3,4] and protocols in time [1], new interaction effects linked to quantum technology and new topological states of matter in coupled planes or coupled wires.

[1] Joel Hutchinson and Karyn Le Hur, arXiv:2002.11823,
https://arxiv.org/pdf/2002.11823.pdf
[2] Peng Cheng, Philipp Klein, Kirill Plekhanov, Klaus Stengstock, Monika Aidelsburger, Christoph Weitenberg, Karyn Le Hur, Phys. Rev. B 100, 081107 (2019)
https://arxiv.org/pdf/1901.09748.pdf
[3] Philipp Klein, Adolfo Grushin, Karyn Le Hur, arXiv:2002.01742
https://arxiv.org/pdf/2002.01742.pdf
[4] Loic Henriet, Antonio Sclocchi, Peter P. Orth and Karyn Le Hur, Phys. Rev. B 95, 054307 (2017), https://arxiv.org/abs/1611.05085

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

Condensed Matter Physics: YES Macroscopic Physics and complexity: YES
Quantum Physics: YES Theoretical Physics: YES