Internship and thesis proposal – M2 ICFP and M2 PCS

Quantum dynamics and solitons at the edge of a topological quantum many-body system

Laboratory name: Laboratoire de Physique Théorique et Modèles Statistiques (**LPTMS**)
Internship director's name: **MAZZA Leonardo**
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Internship location: LPTMS, Université Paris-Saclay, Bat. 530 "Pascal", Orsay

Condensed Matter Physics: YES
Soft Matter and Biological Physics: NO
Quantum Physics: YES
Theoretical Physics: YES

Ph.D. thesis possibility after internship: YES

Subject of the Stage

In mathematics and physics, **solitons** are localized wave packets that are stable, in that they preserve their shape while propagating at constant velocity in a non-linear medium; first observed in a water channels, they have been subsequently found in many more setups, including optical fibers and Bose-Einstein condensates. Several celebrated equations in mathematical physics describe solitons, the most famous being the Korteweg de-Vries equation.

In this stage we will study solitons appearing at the edges of 2D quantum materials. Our focus will be specifically on the **fractional quantum Hall effect**, a paradigmatic topological system composed of strongly correlated electrons confined in a two-dimensional plane and in the presence of a perpendicular magnetic field. It is well known that these setups support excitations that are strongly localised at the boundary and propagate in only one direction, well-described by a linear and non-dispersive theory.

In recent years, we have contributed to the understanding of the fact that such theory must be complemented by corrections that are non-linear and dispersive. Oddly enough, this theory is the quantum version of the Korteweg De-Vries equation. The question is natural: will this theory support quantum solitons? The master student selected for this internship will try to find the answer using analytical and numerical approaches.

Whom are we looking for?

We look for passionate and motivated students with a strong interest in quantum systems and in the spectacular emergent properties of many-body quantum materials. No specific background is necessary: just curiosity and the desire of learning everything that is necessary to know. If you are looking for a Ph.D. in many-body quantum physics, this is your stage! We are ambitious and we are not going to answer this problem in a few months… We always support our students in the procedures that are necessary for obtaining a Ph.D. salary from a funding agency.

What will you do?

You will work in close contact with L.Mazza and his research group (a few postdocs and Ph.D. students), and specifically with the postdoc (A.Nardin) that is currently working on the quantum Hall effect. You will develop your own numerical code for studying the quantum soliton under our supervision and run it on our cluster. You will develop the analytical tools for describing quantum solitons at the edge of fractional quantum Hall setups.

Are we doing this alone?

No, of course. We are currently working on this subject with our friends in Italy, at the university of Trento, led by Prof. Iacopo Carusotto, and in Japan, at the university of Tokyo, led by Prof. Hosho Katsura. Visiting one or both these research groups during the Ph.D. is definitely possible (and probably necessary).

Some recent literature on the subject: Pustilnik and Matveev, arXiv:1507.05639 (2015) - Nardin and Carusotto, arXiv:2305.00291 (2023) – Nardin et al. arXiv:2403.10598 (2024)

Would you like to know more? Just email: leonardo.mazza@universite-paris-saclay.fr