

INSTITUT NEEL Grenoble

Quantum internship – Academic year 2025-2026

Resonances versus localization in quasiperiodic XXZ chain

Level : M1

General Scope : Isolated many-body quantum interacting systems in the presence of disorder are notoriously difficult to study, yet they raise fundamental questions in quantum statistical physics. In 1958, Anderson formulated a simple problem. For a fermion jumping in a random potential, he showed that, for strong enough disorder, all eigenstates - even at high energy - are localized. This provides an example of a "real system with an infinite number of degrees of freedom (...) in which the approach to equilibrium is simply impossible" [1]. How do interactions modify this picture ? Can localization persist at finite energy density, giving rise to a genuinely non-ergodic many-body phase ? Despite nearly two decades of intense study [2], the existence and stability of such a many-body localized (MBL) phase remains debated [3], even one dimension where localization is expected to be most robust. The random-field XXZ spin chain has attracted a majority of the debate. Yet, studying its quasiperiodic counterpart is particularly relevant due to its ease of realization in cold atomic experiments. An important aspect of the debate is the presence, deep in the presumably many-body localized regime, of resonances at long distances. Recently, these were found in both the random field and the quasiperiodic many-body localized regimes [4]

[1] Anderson, Phys. Rev. 1958

[2] Basko, Aleiner, Altshuler, Annals of Physics, 2006

[3] Sierant, Lewenstein, Scardicchio, Vidmar, Zakrewski, Rep. Prog. Phys, 2025

[4] Colbois et al. PRB (2024), Laflorencie et al., PRB (2025), Padhan et al, arXiv:2510.24704.

Research topic and facilities available :

In these analysis, the results were obtained on chains with periodic boundary conditions. This was done to avoid edge effects, but in the quasiperiodic case, the periodic boundary conditions are incompatible with the quasiperiodic fields and can induce an artificially small field difference. The objective of this project is to verify that the same physics is observed in the case of open boundary conditions. As a warm up, we will focus on the non-interacting, random-fields and Aubry-André chains and study short-range resonances.

Possible collaboration and networking :

The student will join the NEEL theory team with well-established expertise in the effect of disorder on quantum spin chains. They will be welcome and encouraged to interact with and learn from other researchers and PhD students.

Required skills :

Solid background in quantum mechanics, statistical mechanics and ideally solid state physics / condensed matter theory. Curiosity towards theory and experiments, open-mindedness, enthusiasm to perform analytical and numerical computations.

Starting date and duration : Up to 14 weeks from middle of May 2026 (date to be agreed upon)

Contact: Jeanne Colbois, Institut Néel, Condensed matter theory team (TMC)

Phone : [04 76 88 79 97](tel:0476887997)

e-mail : jeanne.colbois@neel.cnrs.fr