An introduction to many-body localization in condensed matter physics

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The first aim of this seminar is to give a simple and general introduction to the so-called Many-Body Localization (MBL) phenomenon which occurs in a large class of disordered and interacting quantum systems. Then, I will focus on recent results obtained for specific random spin models: the multifractal properties across the MBL transition [1], and a newly discovered chain breaking process [2] which characterises the localized regime, and is at the origin of Kosterlitz-Thouless mechanism for the MBL transition.

[1] N. Macé, F. Alet, N. Laflorencie, Multifractal scalings across the many-body localization transition, Phys. Rev. Lett. 123, 180601 (2019).
[2] N. Laflorencie, G. Lemarié, N. Macé, Chain breaking and Kosterlitz-Thouless scaling at the many-body localization transition in the random-field Heisenberg spin chain, Phys. Rev. Research 2, 042033(R) (2020).

Realizing artificial topological matter in arrays of Rydberg atoms

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In this talk I will show how Rydberg array platforms for quantum simulation allow for an original way of exploring topological phases of matter, by using the resonant dipole-dipole interaction between several Rydberg levels.

I will first describe how, in a Su-Schrieffer-Heeger chain, we not only observed the textbook properties of the SSH model in the single-particle regime, but also could realize a novel phase of matter induced by hard-core interactions between spin excitation and called a symmetry-protected topological phase, by reaching the many-body ground state at half-filling [1].

I will then report on the demonstration of a tool which is required to extend those studies to 2 dimensions, namely spin-orbit coupling. In [2], in a minimal instance of three atoms, we demonstrated the existence of a density-dependent spin-orbit coupling by observing the chiral motion spin excitations. I will conclude by explaining how we now plan to extend this to large two-dimensional arrays.

[1] S. de Léséleuc, V. Lienhard, P. Scholl, D. Barredo, S. Weber, N. Lang, H.P. B üchler, T. Lahaye, and A. Browaeys, Observation of a symmetry protected topological phase of interacting bosons with Rydberg atoms, Science 365, 775 (2019)

[2] V. Lienhard, P. Scholl, S. Weber, D. Barredo, S. de Léséleuc, R. Bai, N. Lang, M. Fleischhauer, H.P. Büchler, T. Lahaye and A. Browaeys, Realization of a density-dependent Peierls phase in a synthetic, spin-orbit coupled Rydberg system, Phys. Rev. X 10, 021031 (2020).