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Quantum simulations with ultracold atoms: Beyond standard optical lattices[1]

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Many prominent problems of quantum many-body physics (such as high-Tc superconductivity or quark confinement) remain unsolved, because the exponential growth of Hilbert space prevents numerical treatment of more than a few particles. To solve such models, Feynman proposed thirty years ago to design quantum devices that are governed by the same equations as the original, abstract model. Ultracold atoms in optical lattices are – thanks to their unprecedented cleanness and control – ideal candidates for such "quantum simulators," and experiments that exceed the capabilities of classical computers are already being performed. In this talk, I present various new avenues that become open by going beyond standard setups, e.g., via exotic geometries, higher orbitals, or spin-dependent lattices. In particular, I discuss the exciting possibilities given by a periodical lattice driving, which allows us to explore frustrated quantum magnetism and synthetic gauge fields. First experiments using this technique have already been performed, opening prospects for the realizion of topological phases, anomalous quantum-Hall states, or spin liquids, thus promising insight into some of the most important problems of condensed-matter and high energy physics.

[1]This work was performed at the Universitat Politecnica de Catalunya - Barcelona Tech and the Institute of Photonic Sciences, Castelldefels (Barcelona), under the supervision of Prof. Maciej Lewenstein