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Quantum simulation of extended Bose-Hubbard models

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The realization of the Bose-Hubbard model with cold atoms, twenty years ago, can be considered the birth of quantum simulation. Today, advanced quantum simulators provide us with the opportunity to explore more exotic models, including models with flat energy bands, multi-band models, or models with long-range interactions. In these contexts, I discuss the intriguing scenario of Bose-Einstein condensation in a flat band system, and show that, by adding Hubbard interactions, a topological superfluid can be produced [1]. I also present results for a two-band Bose-Hubbard model with nearest-neighbor interactions in 1D and 2D. Recently, excitons in a quantum double well subject to a synthetic lattice potential have allowed for a realization of this model, and signatures of the checkerboard phase have been observed - a Mott insulating phase that spontaneously breaks a symmetry of the lattice [2]. The possibility of other exotic scenarios, such as "proximity-induced" supersolidity from the combination of superfluid and symmetry-broken bands is analyzed.

[1] Z. Jalali-Mola, T. Grass, V. Kasper, M. Lewenstein, U. Bhattacharya: Topological Bogoliubov quasiparticles from Bose-Einstein condensate in a flat band system, arXiv:2302.09910

[2] C. Lagoin, U. Bhattacharya, T. Grass, R. Chhajlany, T. Salamon, K. Baldwin, L. Pfeiffer, M. Lewenstein, M. Holzmann, F. Dubin: Extended Bose-Hubbard model with dipolar excitons Nature 609, 485 (2022)

Primary authors: LAGOIN, Camille (CNRS); DUBIN, François (CNRS); BALDWIN, Kirk (Princeton); PFEIFFER, Loren (Princeton); LEWENSTEIN, Maciej (ICFO); HOLZMANN, Markus (Univ. Grenoble Alpes); CHHAJLANY, Ravindra (U Poznan); GRASS, Tobias (DIPC - Donostia International Physics Center); SALAMON, Tymoteusz (ICFO); BHATTACHARYA, Utso (ICFO); KASPER, Valentin (ICFO); WATANABE, Yuma (ICFO); JALALI-MOLA, Zahra (ICFO)

Presenter: GRASS, Tobias (DIPC - Donostia International Physics Center)

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