Matter-wave solitons in optical lattices

Abstract: “We investigate atomic Bose-Einstein condensates, with attraction between atoms, under the action of strong transverse confinement and periodic (optical-lattice) axial potential. Using a combination of the variational approximation, one-dimensional nonpolynomial Schrödinger equation, and direct numerical solutions of the underlying 3D
Gross-Pitaevskii equation, we show that the ground state of the condensate is a soliton belonging to the semi-infinite bandgap of the periodic potential [1]. The soliton may be confined to a single cell of the lattice, or extend to several cells, depending on the effective
self-attraction strength (which is proportional to the number of atoms bound in the soliton) and depth of the potential. It is found that, due to the 3D character of the underlying setting, the ground-state soliton collapses at a critical value of the interaction strength, which gradually decreases with the increase of the depth of the periodic potential [1]. Very recently, the experimental observation of these discrete bright matter-wave solitons made of cesium atoms in an optical lattices was achieved [2] by using an "accordion lattice" with adjustable spacing.”

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[1] L. Salasnich, A. Cetoli, B. A. Malomed, F. Toigo, Nearly-one-dimensional self-attractive Bose-Einstein condensates in optical lattices, Phys. Rev. A 75, 033622 (2007).

[2] R. Cruickshank, F. Lorenzi, A. La Rooij, E. Kerr, T. Hilker, S. Kuhr, L. Salasnich, and
E. Haller, Experimental Observation of Single- and Multi-Site Matter-Wave Solitons in 1D Optical Lattices, e-preprint arXiv:2504.11046.