NOON States via a Quantum Walk of Bound Particles

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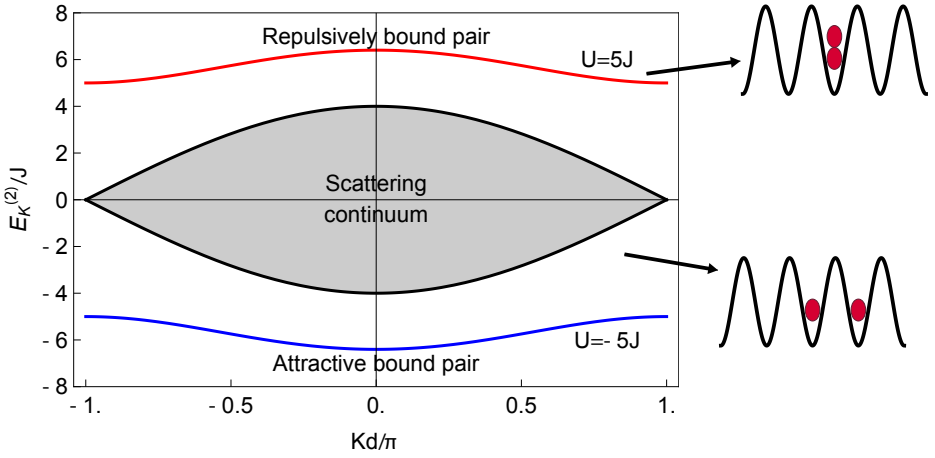
Bound States in the Bose-Hubbard

Bound states of strongly interacting particles in a 1D tight-binding lattice model

$$H = -J\sum_{j=1}^{L-1}\left(a_j a_{j+1}^{\dagger} + a_j^{\dagger} a_{j+1}\right) + \sum_{j=1}^{L} U n_j(n_j-1) - \sum_{j=1}^{L}\mu_j n_j$$



- The interaction enables the creation of bound composite objects
- An energy gap guarantees a dynamical stability

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LETTERS

Repulsively bound atom pairs in an optical lattice

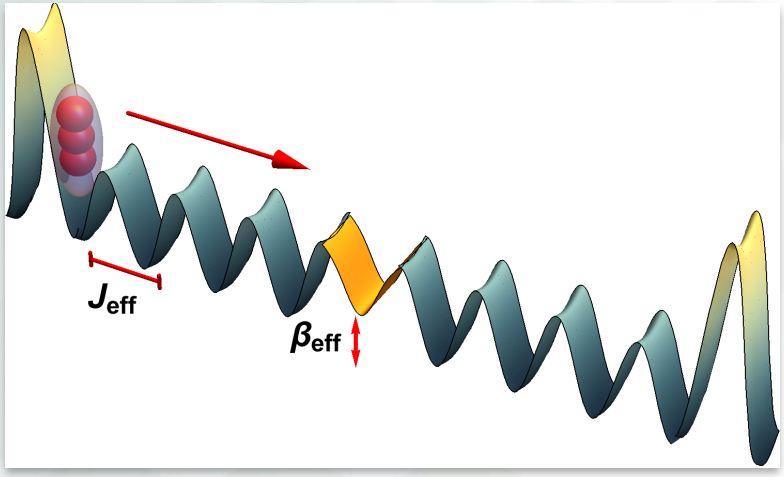
K. Winkler[1], G. Thalhammer[1], F. Lang[1], R. Grimm[1,3], J. Hecker Denschlag[1], A. J. Daley[2,3], A. Kantian[2,3], H. P. Büchler[2,3] & P. Zoller[2,3]

How to harness the natural mobility of bound states in a finite chain for applications is still an open question

Valiente, *et. al.*, J. Phys. B: At. Mol. Opt. Phys. **41**, 161002 (2008)
Valiente, *et. al.*, Phys. Rev. A **81**, 011601 (2010)

NOON States with Bound States

We study how to generate a coherent split via minimal engineering tuning of the chain couplings



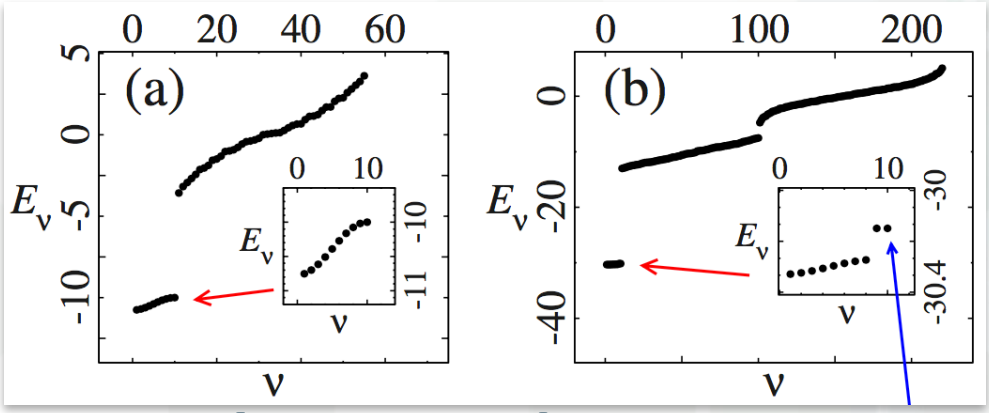
Atom interaction can be exploited to go beyond the traditional linear optics regime

$$|N_1 0_L\rangle \rightarrow \frac{1}{\sqrt{2}}\left(|N_1 0_L\rangle + i|0_1 N_L\rangle\right)$$

- Non-classical states enhance the sensitivity in interferometry applications

Edge localisation in open chains

- A spectral gap inhibits the dynamics of N ≥ 3 particles initially in one edge sites



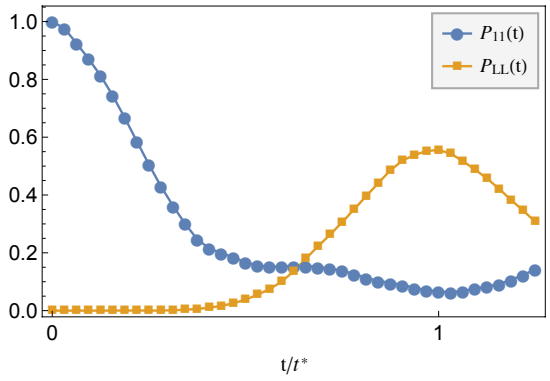
A. Pinto, *et. al.*, Phys. Rev. A **79**, 052118 (2009)

Results

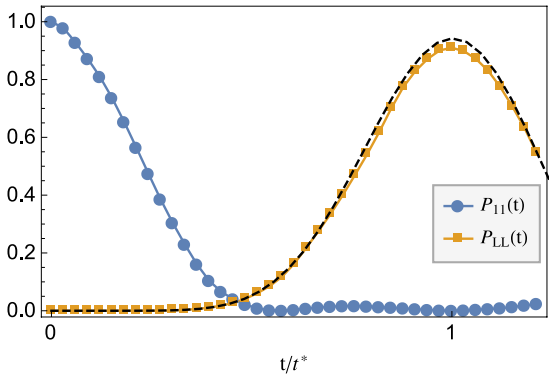
Effective Hamiltonian for two particles

$$J_{\text{eff}} = \frac{J^2}{2U} \qquad B_j^{\text{eff}} = \begin{cases} \frac{J^2}{2U} + U \ , & \text{for} \quad j = 1, L \ , \\ \frac{J^2}{U} + U & \text{for} \quad j \neq 1, L \ . \end{cases}$$

Quasi-Edge localisation



Quasi-Edge Unlocking



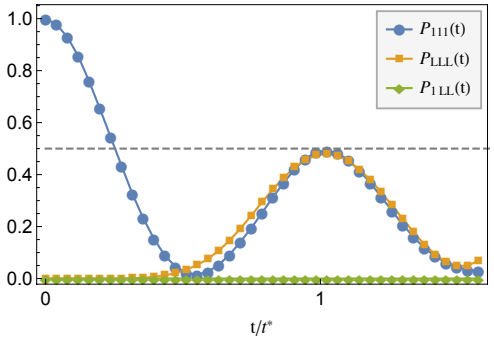
$$B_1' = B_L' = J^2/2U$$

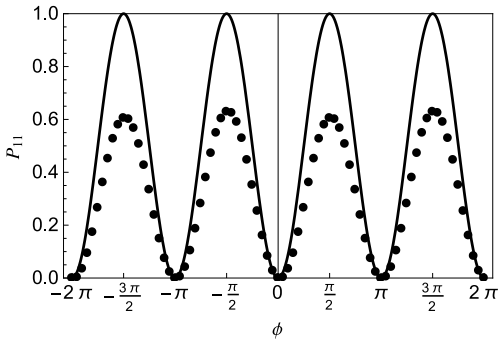
$$J_{\text{eff}} \propto J^N/U^{N-1}$$

$$B_{\text{eff}} \propto \mu/J_{\text{eff}}$$

$$B_1' = B_L' \propto J^2/U$$

NOON States with N particles





E. Compagno, L. Banchi, C. Gross & S. Bose, PRA **95**, 012307 (2017)