Relevance of electronic interactions at quasiperiodicity-driven localization transitions

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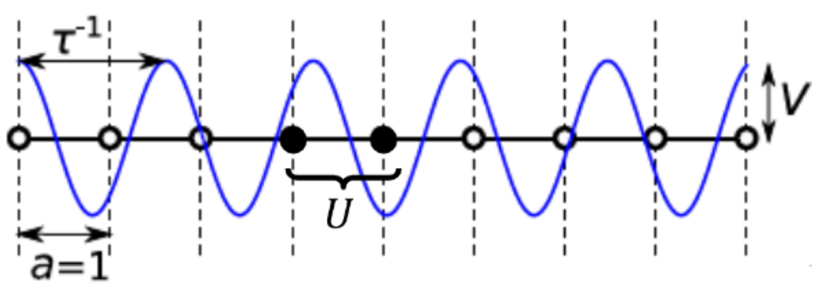
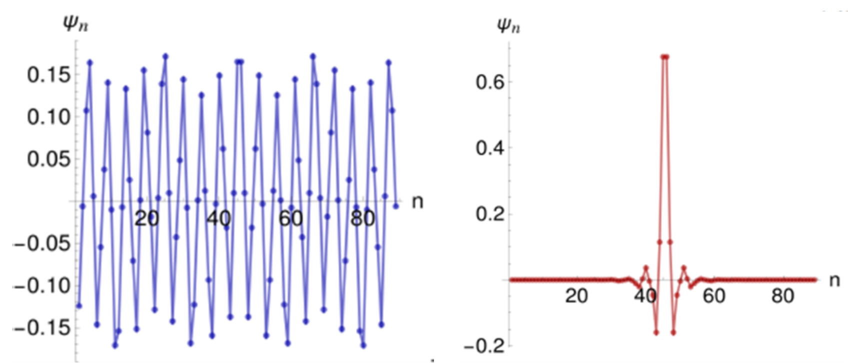
Motivation

1D system of tight-binding fermions in a quasiperiodic potential



- Non-interactive fermions
- Interacting spinless fermions

Both exhibit a localization-delocalization transition!
Interactions in this case are irrelevant around the transition



Do spin interactions change the nature of the quasiperiodicity-driven localization phase transition?

DMRG Algorithm

DMRG - Density Matrix Renormalization Group

- Why? Allows us to efficiently study ground-state properties for fairly larger 1D system sizes

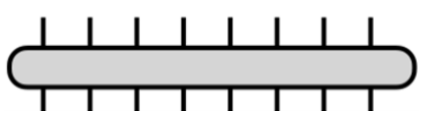
Matrix Product States (MPS)

Parameterize a given quantum state in terms of matrix products

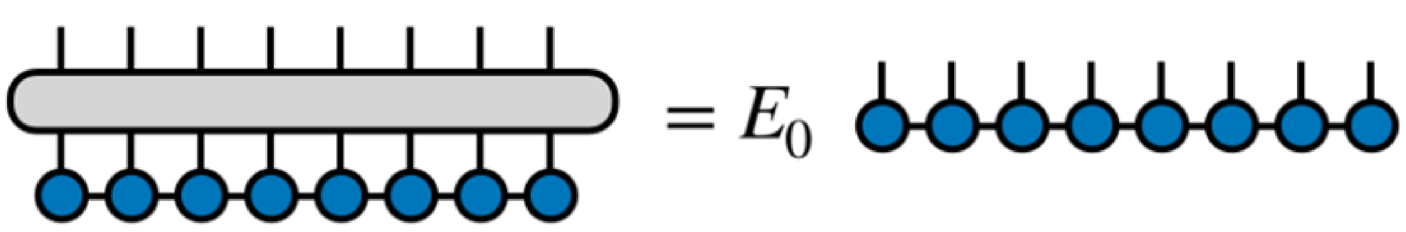
Truncate MPS

Valid when entanglement entropy is bounded!

Matrix Product Operators (MPO)



Find ground-state iteratively, guaranteeing convergence



Benchmarking with known results

- **Tested quantities:**

Inverse Participation Ratio (IPR)

$$\mathrm{IPR}^{\alpha}(q=2) = \frac{\sum_{n=0}^{N-1}|\Psi_n^{\alpha}|^4}{\left(\sum_{n=0}^{N-1}|\Psi_n^{\alpha}|^2\right)^2}$$

Correlation Matrix

$$\chi_{rr'}^{N_p,N} = \langle c_r c_{r'}^{\dagger}\rangle_{N_p}$$

$$\Delta\chi_{rr'} = \chi_{rr'}^{N_p,N} - \chi_{rr'}^{N_p-1,N}$$

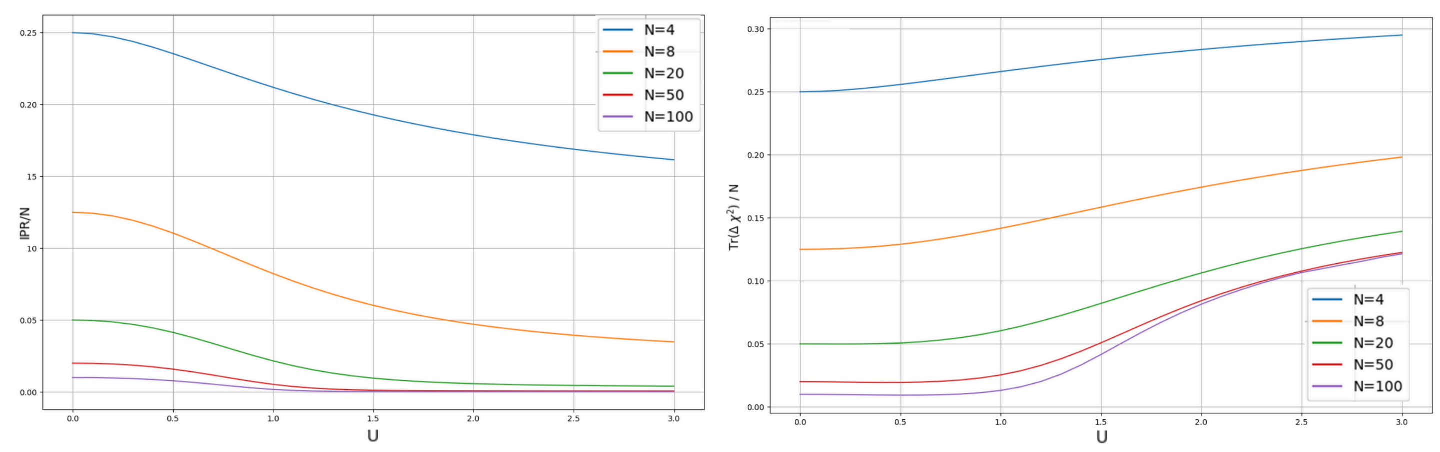
$$\mathrm{Tr}(\Delta\chi_{rr'}^2)$$

- **Tested System - Spinless Model:**

⚠ **without** quasiperiodic potential!

$$H = -t\sum_{\langle ij\rangle}(c_i^{\dagger}c_j + c_j^{\dagger}c_i) + \frac{U}{2}\sum_{\langle ij\rangle} n_i n_j$$

- **Results - variation with interaction term:**



Detecting localization transition for large enough N!

Next Steps

- Analyse Hubbard Model with quasiperiodic potential

$$H = -t\sum_{j=0,\sigma}^{L-1}(c_{j,\sigma}^{\dagger}c_{j+1,\sigma} + c_{j+1,\sigma}^{\dagger}c_{j,\sigma}) + U\sum_{j=0}^{L-1} n_{j,\uparrow}n_{j,\downarrow} + V\sum_{j=0}^{L-1}\cos(2\pi\tau j+\phi)c_j^{\dagger}c_j$$

$$\tau = a/\lambda \notin \mathbb{Z}$$

- Determine phases and phase transitions
- Evaluate universality properties of the transition

Find out more

sites.google.com/tecnico.ulisboa.pt/qmat

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