FRUSTRATION OF BEING ODD

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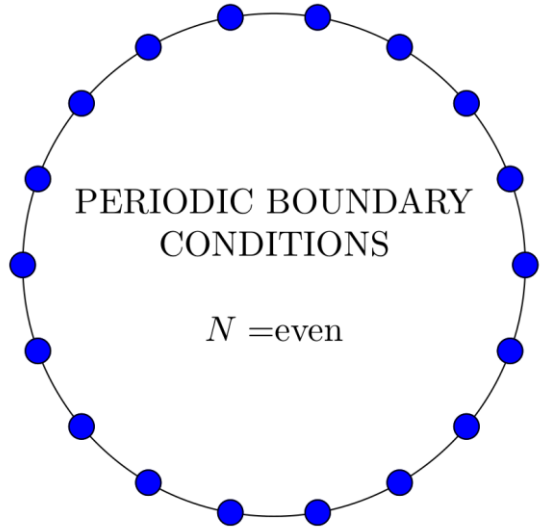
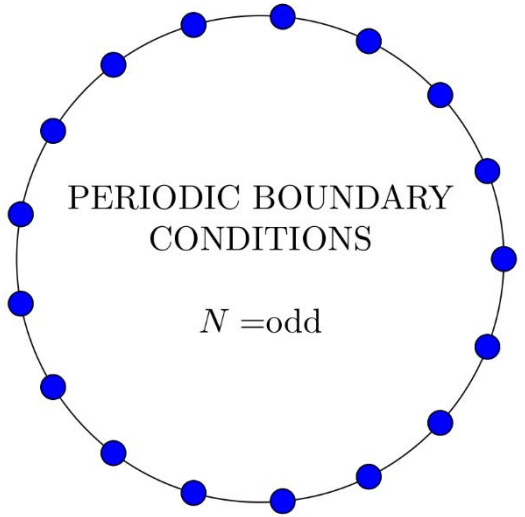
MANY-BODY SYSTEMS WITH LOCAL INTERACTIONS

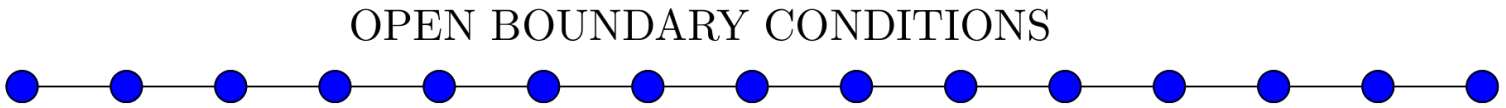
- Typical expectation:

The effects of boundary conditions are negligible.

- We show that this expectation can be wrong.

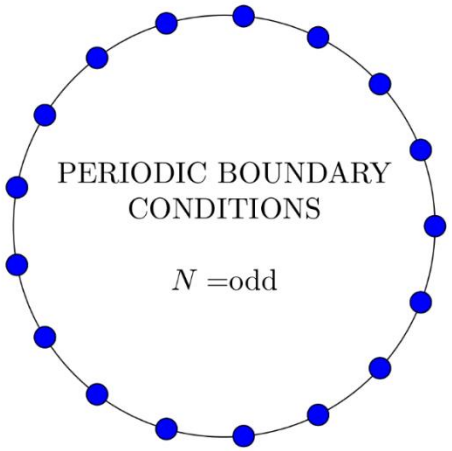






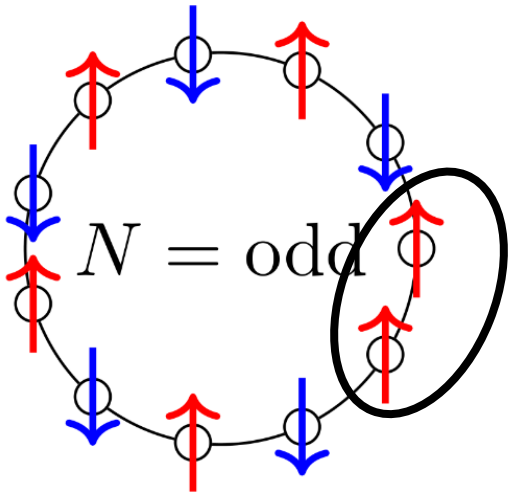
- Studied system: Quantum XY Chain

$$H = \sum_{j=1}^{N} \sigma_j^x \sigma_{j+1}^x + \lambda \sum_{j=1}^{N} \sigma_j^y \sigma_{j+1}^y \ , \ \lambda \in (-1, 1)$$



  - Exactly solvable

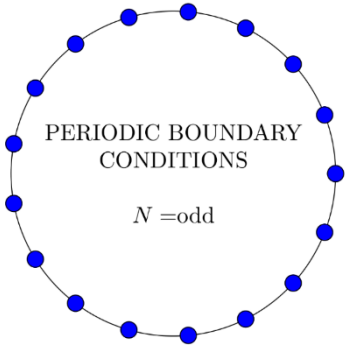
- What is special about this setting?



Geometrical frustration

– Not all spins can be aligned oppositely from their nearest neighbors.

$$H = \sum_{j=1}^{N} \sigma_j^x \sigma_{j+1}^x + \lambda \sum_{j=1}^{N} \sigma_j^y \sigma_{j+1}^y \ , \ \lambda \in (-1, 1)$$



Idea:

- To solve the model and to compute the magnetization $\langle \sigma_j^x \rangle_{\mathrm{GS}}$

References:

- [VM, SM Giampaolo, D Kuić, F Franchini. *The Frustration of being Odd: How Boundary Conditions can destroy Local Order* – New Journal of Physics, 2020.]
- [VM, SM Giampaolo, F Franchini. *The Frustration of being Odd: Can Boundary Conditions induce a Quantum Phase Transition?* – arXiv:2002.07197, 2020.]

Some mathematics had to be developed:

- [VM, F Franchini. *Asymptotic behavior of Toeplitz determinants with delta function singularities*– arXiv:2006.01922, 2020.]

Results

$$H = \sum_{j=1}^{N} \sigma_j^x \sigma_{j+1}^x + \lambda \sum_{j=1}^{N} \sigma_j^y \sigma_{j+1}^y$$

Gapless System, Gap $\sim \frac{1}{N^2}$

$\lambda = -1$ $\lambda = 0$ $\lambda = 1$ λ

2-fold GS degeneracy

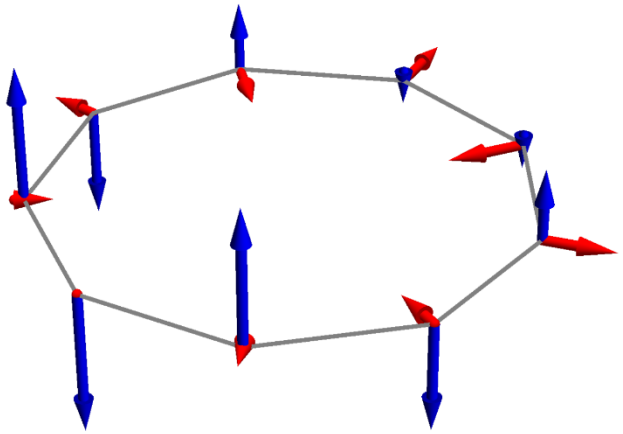
4-fold GS degeneracy

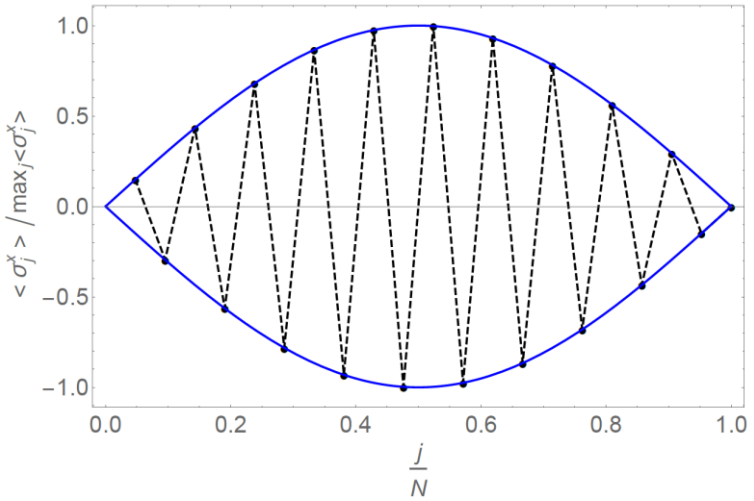
Mesoscopic Ferromagnetic Order

$$\langle \sigma_j^x \rangle_{\mathrm{GS}} \simeq \frac{1}{N}(1-\lambda^2)^{1/4}$$

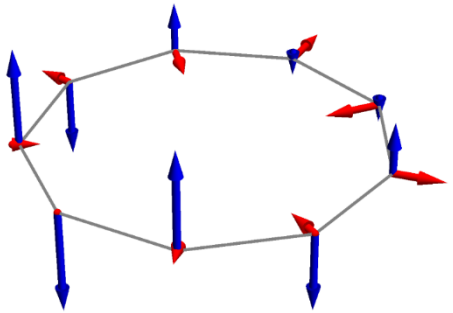
Incommensurate Antiferromagnetic Order

$$\langle \sigma_j^x \rangle_{\mathrm{GS}} \simeq (-1)^j \frac{2}{\pi}(1-\lambda^2)^{1/4} \cos\left(\pi \frac{j}{N} + \theta\right)$$





Conclusions



- Different boundary conditions can result in a different behavior of the order parameter of a quantum system.
- Quantum Phase Transition induced by a special choice of Boundary Conditions.

Other questions:

- How robust is the observed phenomenology to defects?

  [G Torre, VM, F Franchini, SM Giampaolo. *The Frustration of being Odd: effects of defects* – arXiv:2008.08102, 2020.]

- Are there effects in other phases of matter? Topological, nematic...

  [VM, F Franchini, D Kuić, SM Giampaolo. *The Frustration of being Odd: Resilience of the Topological Phases* – arXiv:2006.09397, 2020.]