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Detecting the topological phase of the Kitaev Model via network analysis

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Abstract

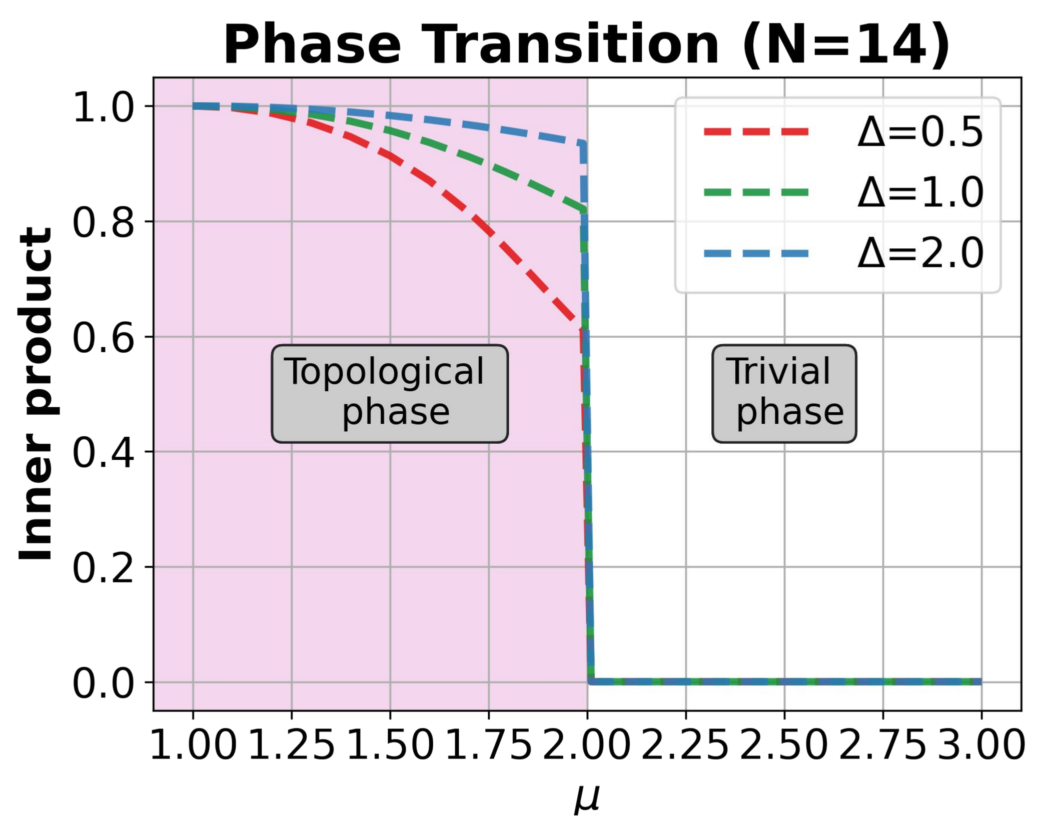
We use a classical network to examine the quantum properties of the finite Kitaev chain.

Using network metrics, we show that classical correlation networks are a useful tool to detect the transition between the topological and trivial regime. It is also shown that other unexpected properties can also be detected by this technique.

Kitaev chain

The Kitaev chain is a one dimensional model based on a lattice of N spinless fermions with c_i, $c^\dagger$ operators.

$$H = -\mu \sum_{i=1}^{N} c_i^\dagger c_i + \sum_{i=1}^{N-1} \left(\Delta c_i^\dagger c_{i+1}^\dagger - \omega c_{i+1}^\dagger c_i + h.c.\right)$$



- μ: chemical potential
- ω: hopping
- Δ: superconducting

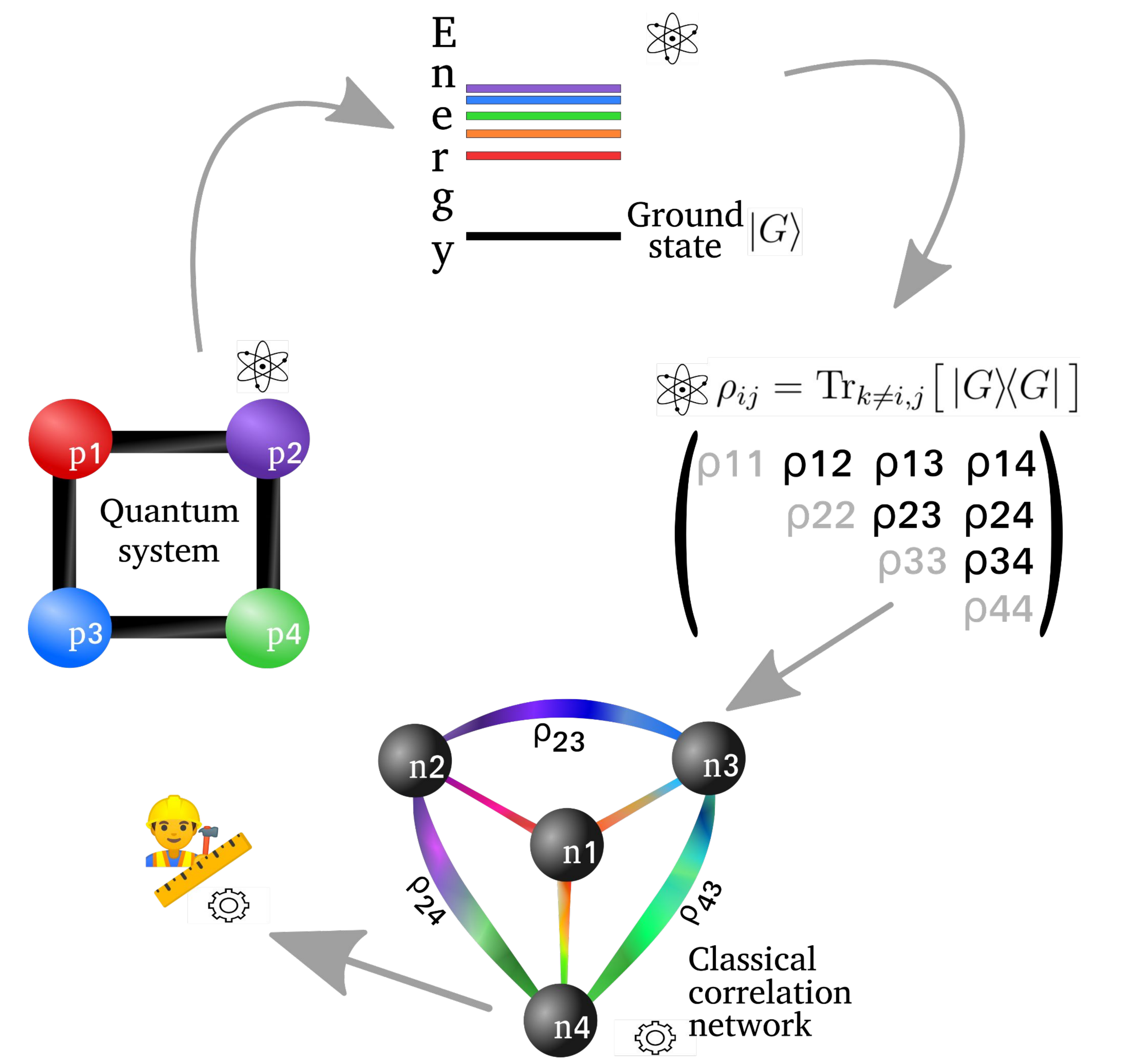
Two phases:
- Topological (μ < 2ω)
- Trivial (μ > 2ω)

Inner product between the ground state at (μ=1) and μ ∈ [1, 3].

(ω=1 in the following)

Network

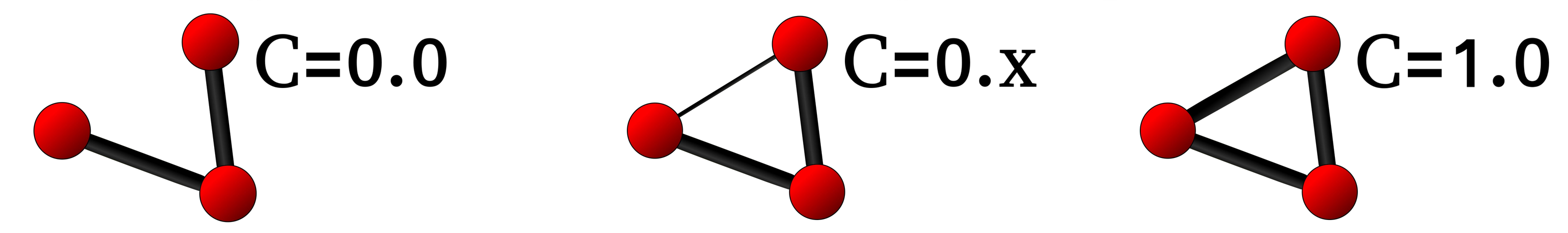
Previous studies have applied network measures to detect the phase transition for the transverse Ising model [1-2].



Results

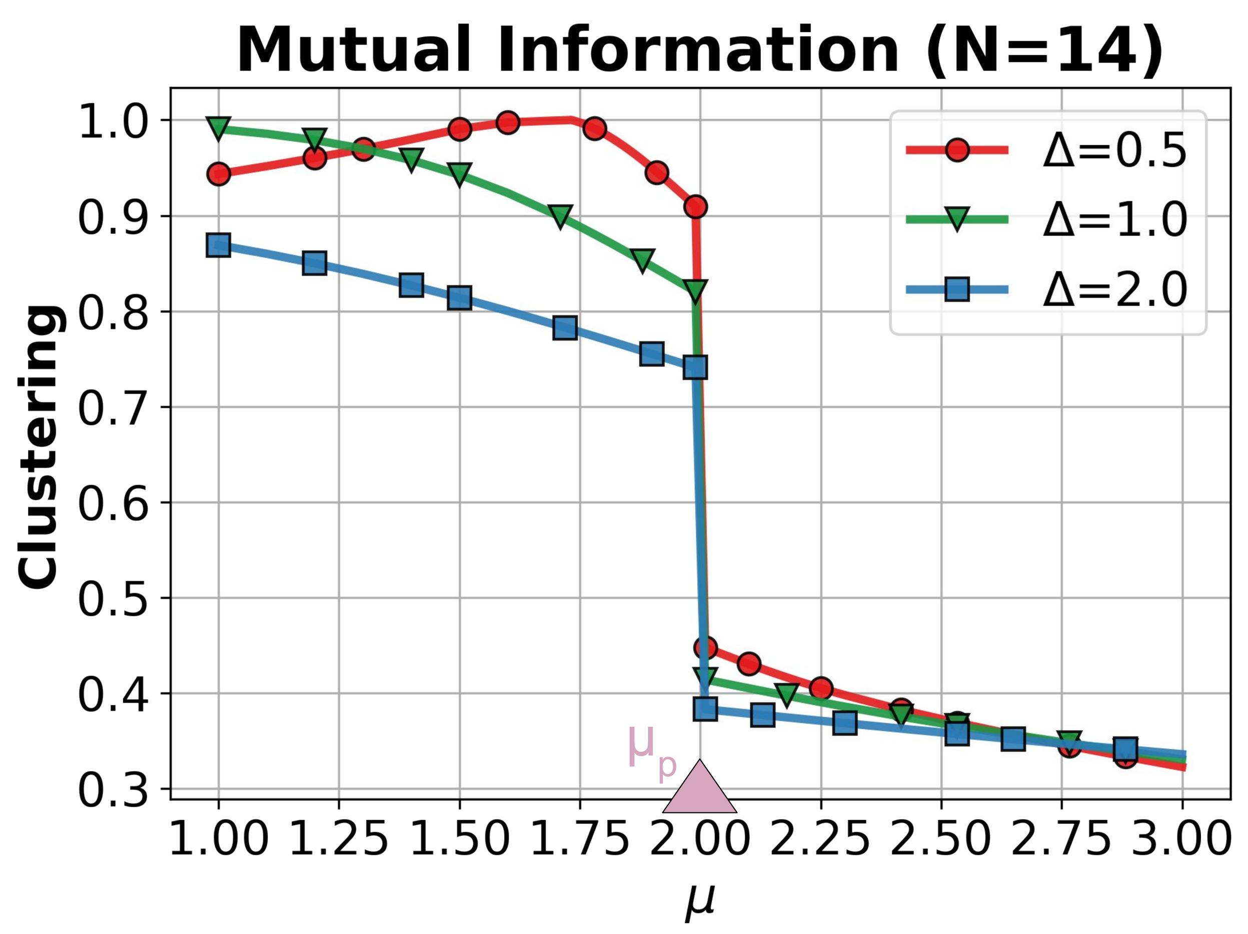
Correlation measures:
- Mutual information: Quantifies how much we can know about particle A if we already know particle B.
- Concurrence: Amount of entanglement between two particles.

Network metric:
- Clustering (C) : Measures the strength of triplets.



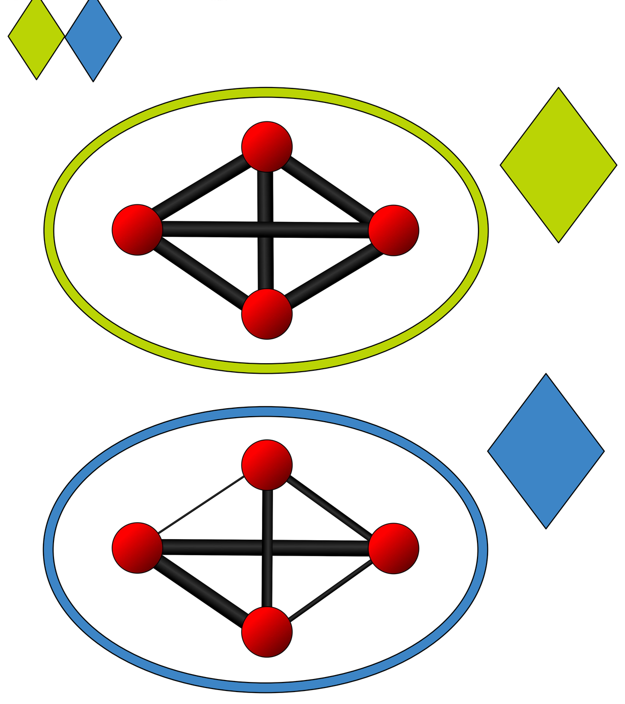
Classical correlation networks detect the critical point (μ_p)

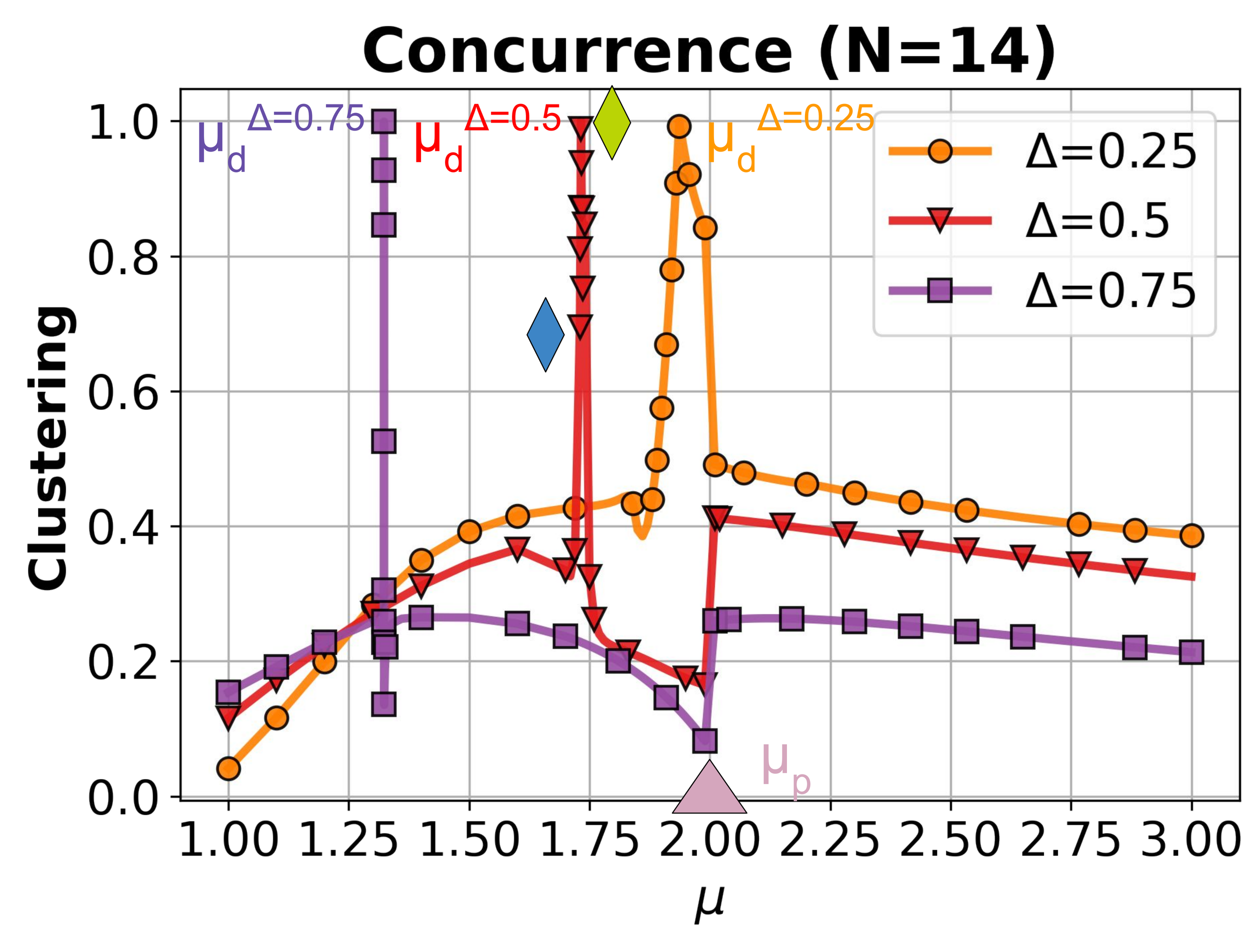
New critical points can be found using network metrics (μ_d) at C=1.



$$\mu_p = 2\omega$$

$$\mu_d = 2\sqrt{\omega^2 - \Delta^2}$$





Conclusions

- Network analysis can be a useful technique to study quantum systems, in particular topological quantum matter.
- Maximum clustering (C=1) implies that entanglement and other correlations don't decay with the distance at μ_d.
  Not found in previous works!!!

References:

[1]:Marc Andrew Valdez, Daniel Jaschke, David L Vargas, and Lincoln D Carr. Quantifying complexity in quantum phase transitions via mutual information complex networks. Physical review letters, 119(22):225301, 2017

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