INVARIANT CORRELATIONAL ENTROPY AS A SIGNATURE OF QUANTUM PHASE TRANSITIONS IN SPIN-1/2 SYSTEMS

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Outline

- Introduction to QPTs
- Introduction to ICE
- Examine specific spin-½ systems

Introduction to QPTs

- Quantum Phase Transitions
  - Competition between terms
$$H = H_0 + gH_1$$
  - Opening/closing energy gap
  - Orders of Transitions
    - Berezinskii-Kosterlitz-Thouless transition
- Examine the ground state and first excited state

Detecting Transitions

- Have been different ways to detect these transitions, borrowing tools from quantum information
  - Entanglement
    - Concurrence
    - Entanglement entropy
    - Quantum Discord
  - Fidelity

$$F = |\langle \Psi(\lambda) | \Psi(\lambda + \delta) \rangle|$$

  - ICE

Invariant Correlational Entropy

- This quantity is given by

$$S = -\mathrm{Tr}\,\{\bar{\rho}\ln(\bar{\rho})\}$$

- Use average energy density matrix:

$$\bar{\rho} = \frac{\rho_g + \rho_{g+\delta} + \cdots + \rho_{g+(N-1)\delta}}{N}$$

- Check graph for peaks or inflection points

1D Spin-½

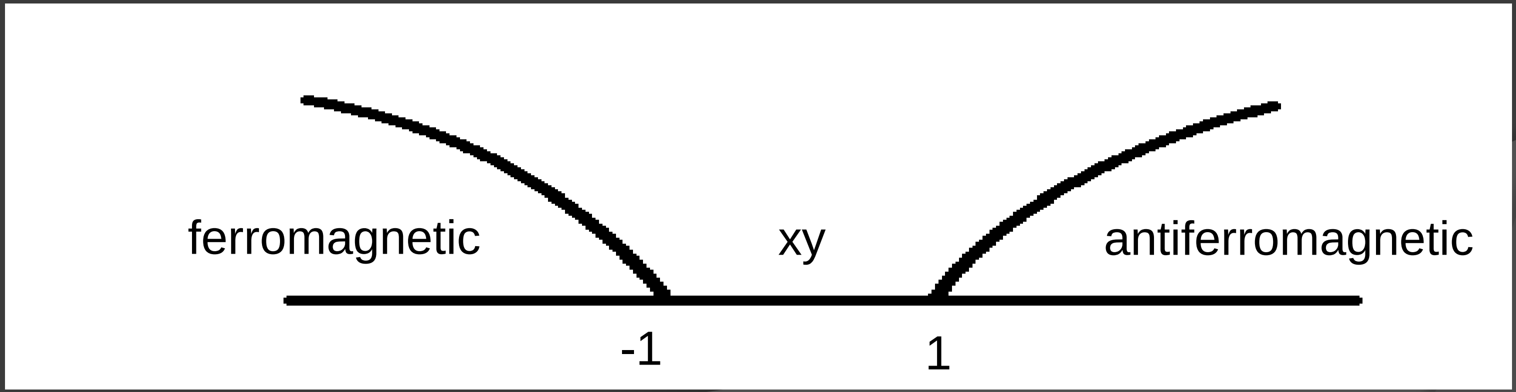
- Typical many body system
- Good model for real materials

XXZ Model-Heisenberg Model

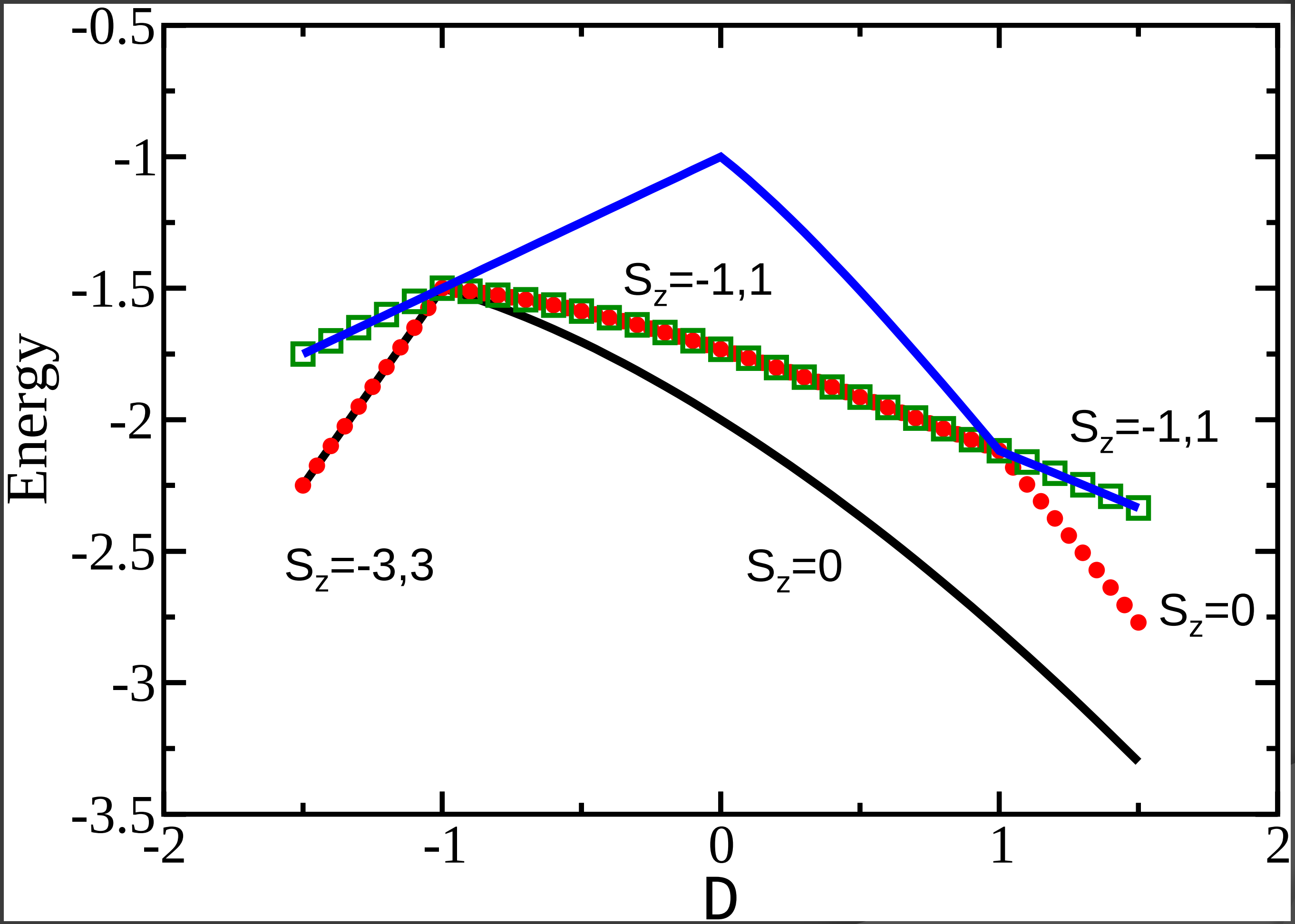
- The Hamiltonian for this model is given by:

$$H = J\sum_{j=1}^{L}\left(S_j^x S_{j+1}^x + S_j^y S_{j+1}^y + \Delta S_j^z S_{j+1}^z\right)$$

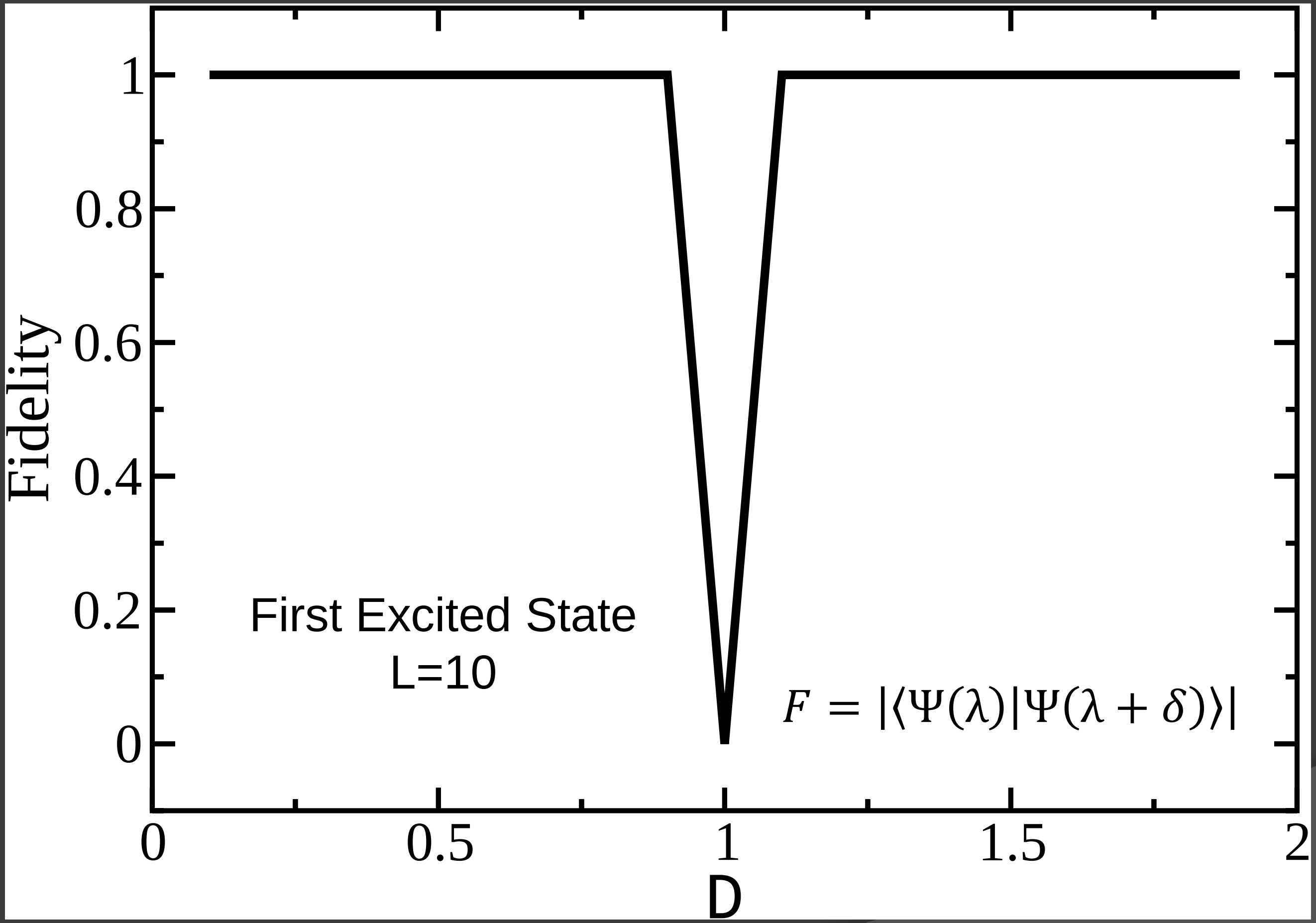
- Parameter to vary: Δ



XXZ Model-Heisenberg Model

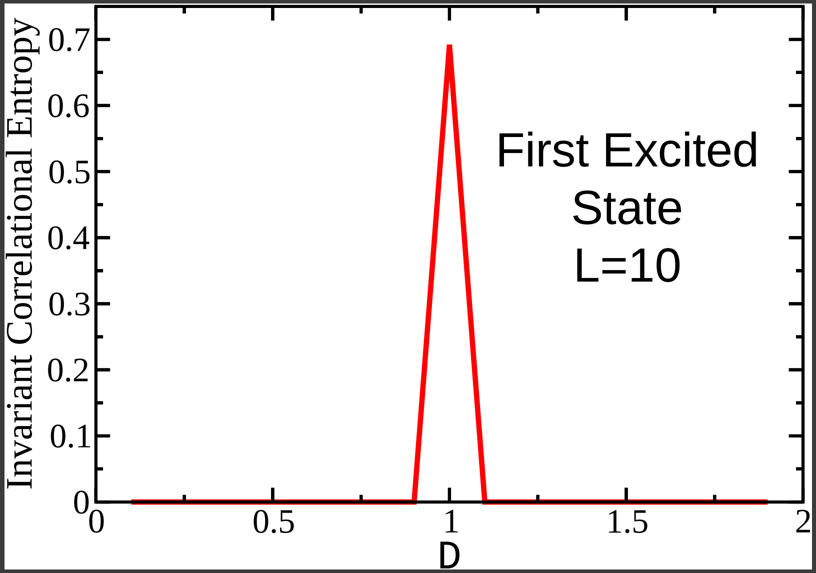


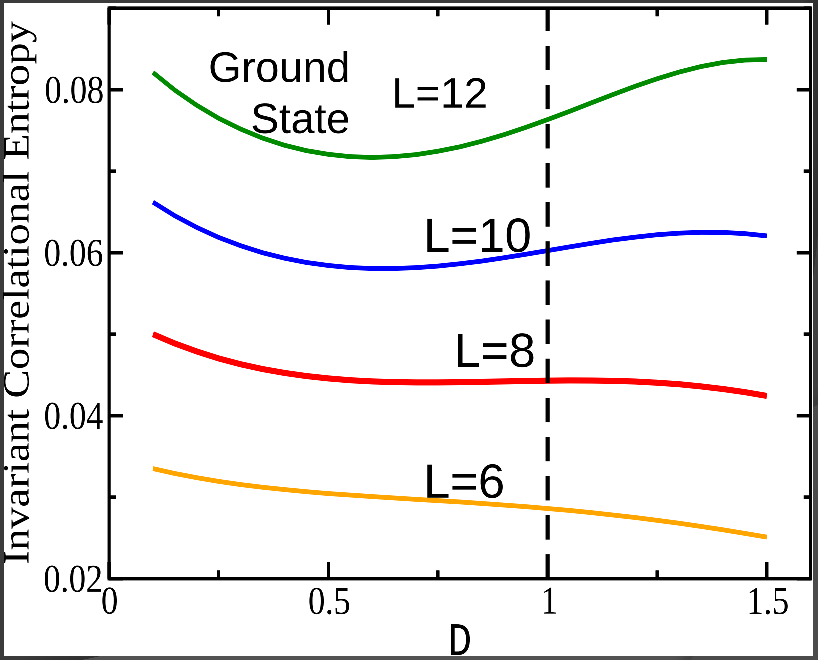
XXZ Model-Heisenberg Model



Using ICE on the XXZ Model

- First excited state: peak at transition
- Ground state: inflection point at transition



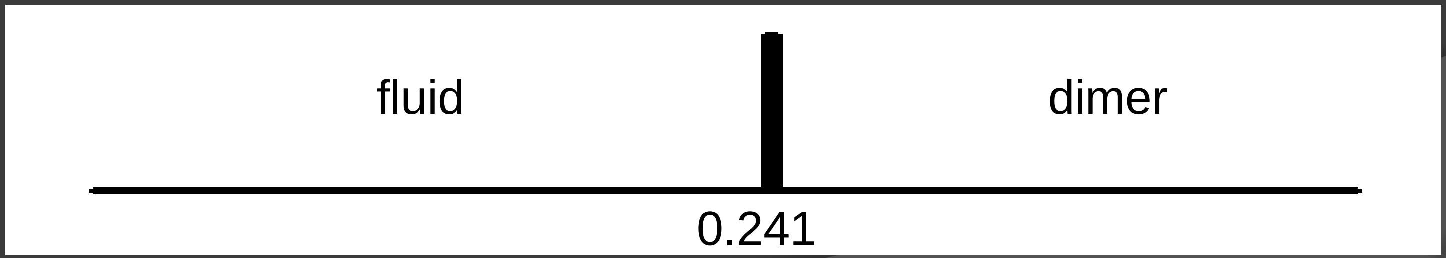


NN+NNN Model

- The Hamiltonian for this model is:

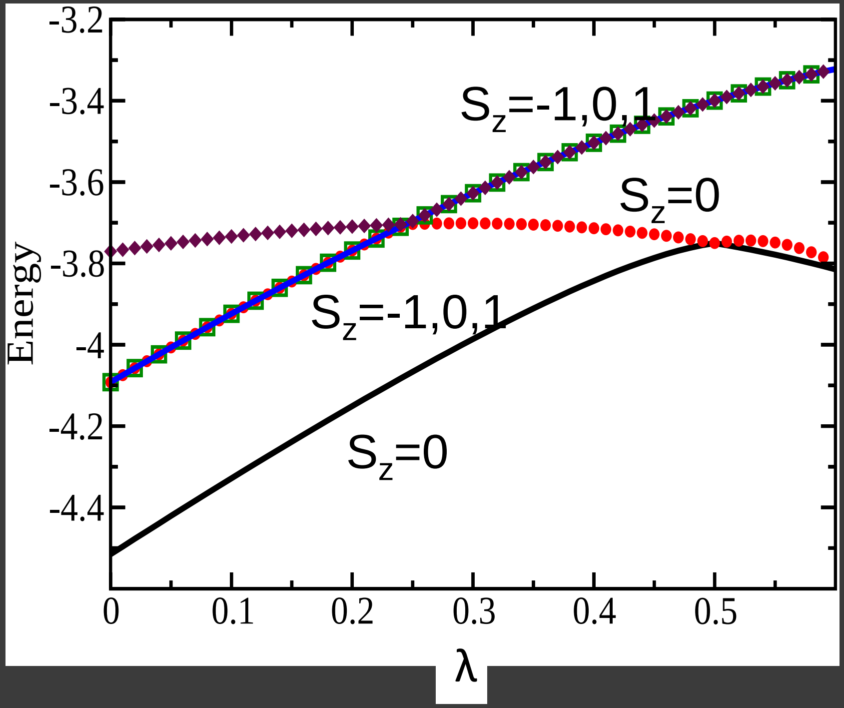
$$H = \sum_{j=1}^{L} S_j S_{j+1} + \lambda S_j S_{j+2}$$

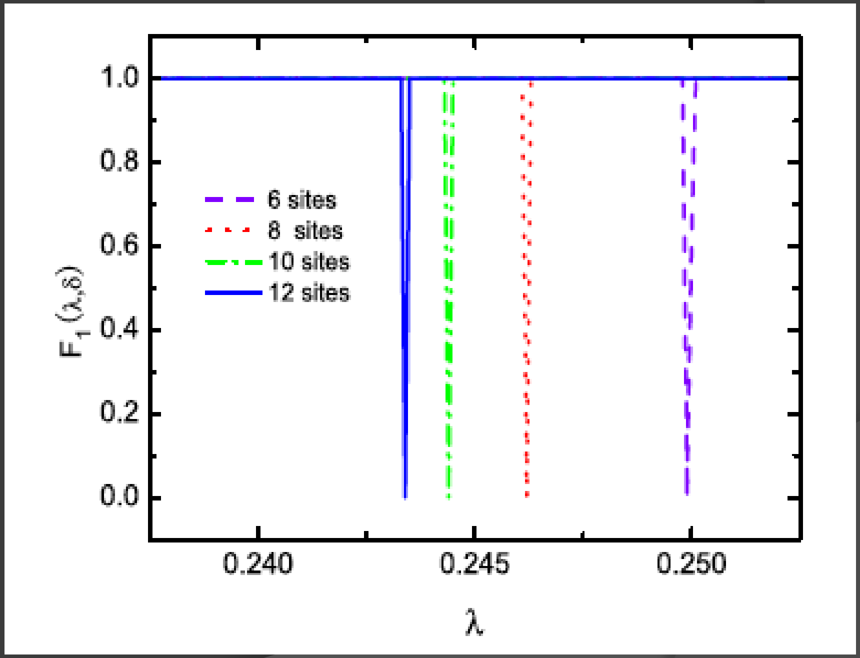
- Parameter to vary: λ
- The transition is found numerically, where an energy gap appears



NN+NNN Model

- First excited state, not ground state
- S_z=0 subspace

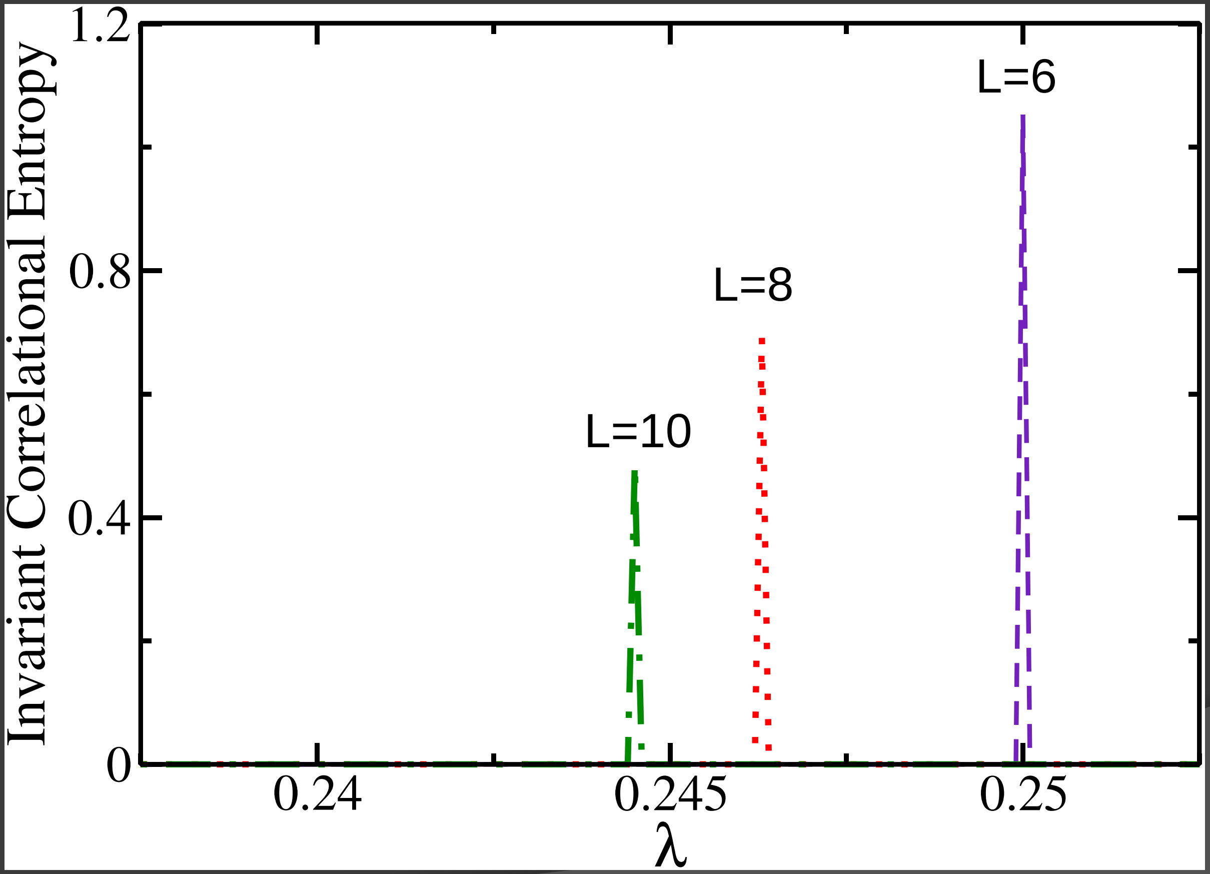




Chen et al
PRE **76**, 061108 (2007)

NN+NNN Model: ICE

- First excited state: peak at transition



Future Directions

- Examine different models
  - Ising Model in the Transverse Field
  - Bose Einstein Condensate
- Study larger systems
  - Scaling analysis

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