Passive Protection of Quantum Information in Mixed-Range Interacting Quantum Spin Chains

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Quantum error-correction schemes are designed to actively remove errors from large scale quantum processors and are predicted to require a significant number of physical resources. A different 'passive' approach to this problem encodes quantum information in the ground state space of a quantum phase that is protected by symmetry and topology [1].

Our 'passive' approach involves the engineering of a spin chain model Hamiltonian with both short-range nearest-neighbour (NN) interactions and longer-range interactions, beyond next-NN. This model exhibits a high degree of entanglement across the chain and possesses protected degenerate ground states. These robust states energetically suppress errors and can be viable for quantum computation due to their non-local properties [2,3]. We use a density matrix renormalisation group (DMRG) approach to study the entanglement structure with quantum information measures, in order to classify the quantum phases and detect signatures of topologically non-trivial phases. This work can be used to offer further insight into the engineering of qubits for exploiting protection properties of topologically ordered phases of matter.

References

[1] B. Terhal, Rev. Mod. Phys., **87**, 307, (2015)
[2] A. Callison, E. Grosfeld, E. Ginossar, Phys. Rev. B, **96**, 085121 (2017)
[3] P. Brookes *et al.*, Phys. Rev. Applied, **17**, 024057 (2022)

Figures

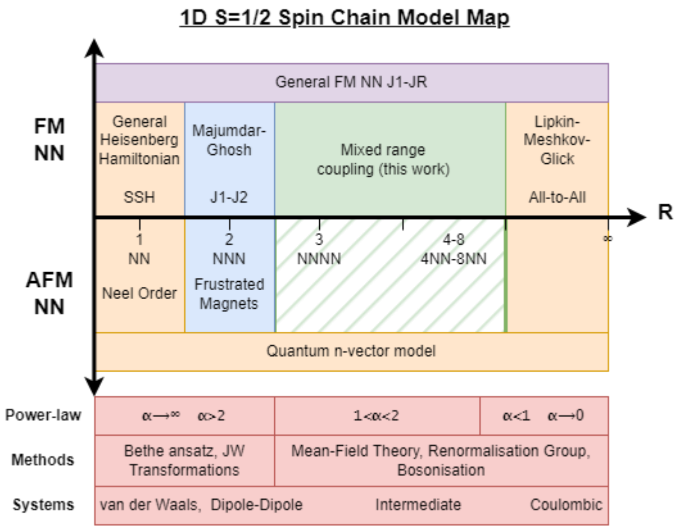

Figure 1: A map of different spin chain models with some example systems placed in terms of their longest interaction, where R is an integer corresponding to the distance between the site numbers in the two-body interactions. Vertical axis represents the sign of the interaction between the NN pairs, ferromagnetic (FM) or antiferromagnetic (AFM). Below represents regimes of power-law models, validity of some analytical methods, and examples of physical systems.