Effective Edge States of SPT Systems

J.C. Bridgeman, J.C. Wang, L.H. Santos

Perimeter Scholars International

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Overview

- Understanding quantum matter
  - (2+1)-dimensional symmetry protected topological models

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Tensor Network Formalism

$$|\psi\rangle = \sum_{i_1, i_2, \ldots, i_n = 1}^{d} c_{i_1 i_2 \ldots i_n} |i_1\rangle \otimes |i_2\rangle \otimes \cdots \otimes |i_n\rangle$$

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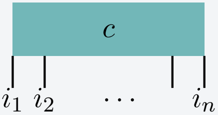

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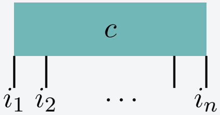
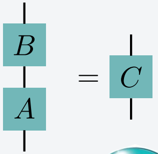
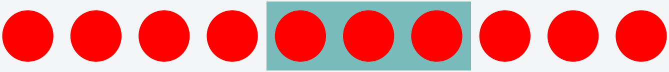
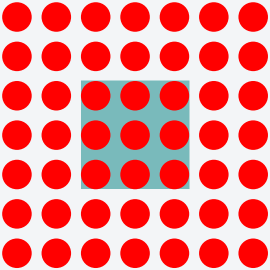


$$A_a^b B_b^c = C_a^c \equiv$$



Entanglement Entropy in Quantum States





$$S_{\text{critical}} \sim \frac{c}{3}\log(L)$$

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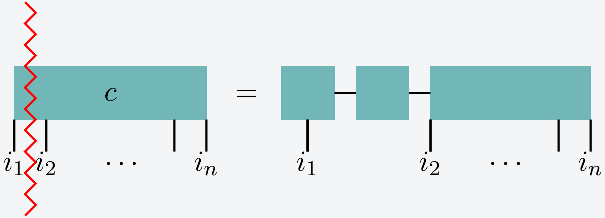
Matrix Product States

$$c_{(i_1)(i_2 i_3 \ldots c_n)} = U_{i_1 j_1} S_{j_1 j_2} V_{(j_2)(i_2 i_3 \ldots c_n)}$$



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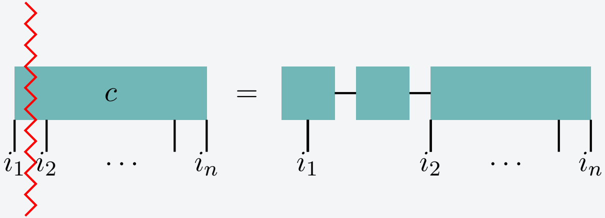
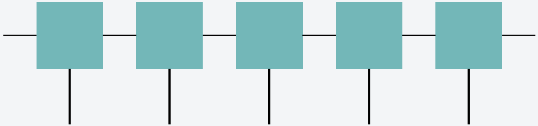
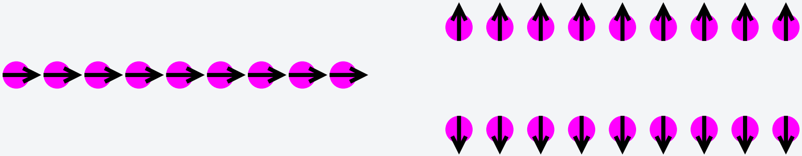




Phase Transitions



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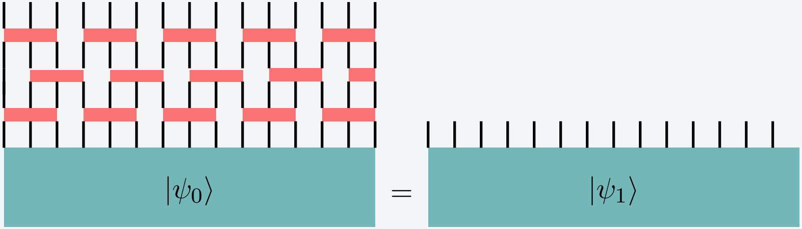

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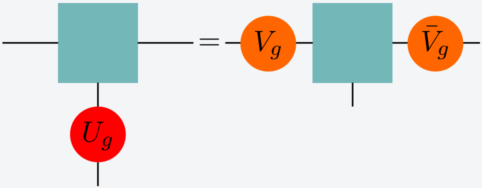
(1+1)-Dimensional SPT Classification



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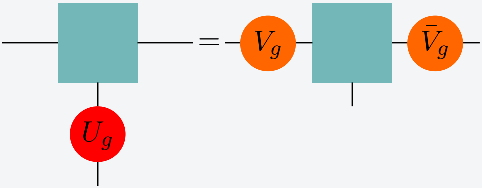

$$V_g V_h = \omega[g,h] V_{gh}$$

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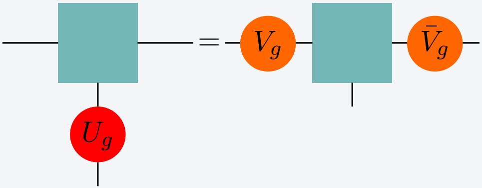

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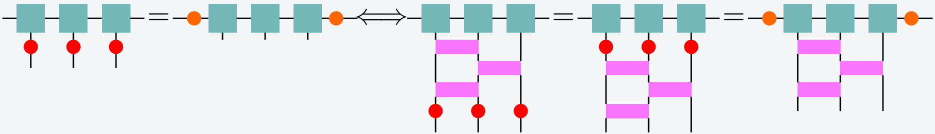
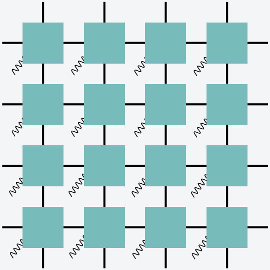


(2+1)-Dimensional SPT Classification?



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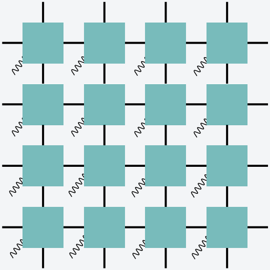

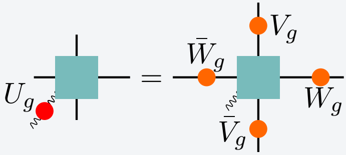

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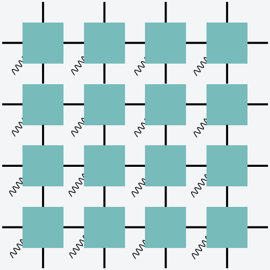

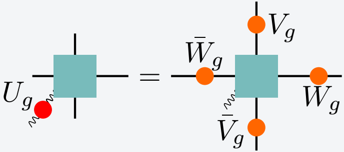

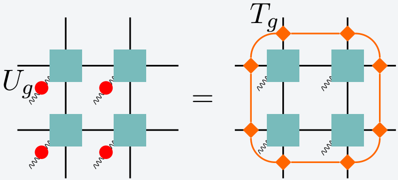

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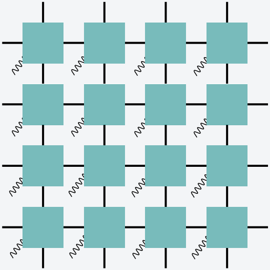
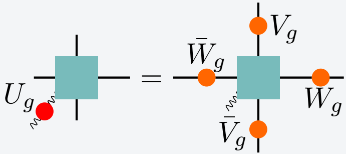
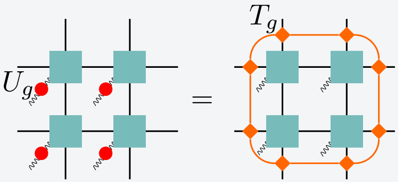
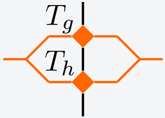
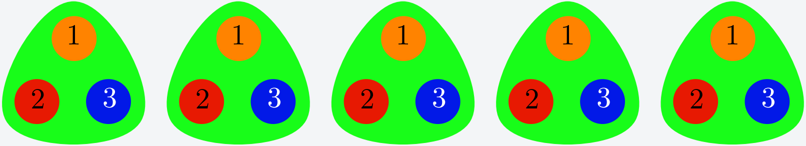








Constructing Models-$\mathbb{Z}_2 \times \mathbb{Z}_2 \times \mathbb{Z}_2$ Symmetry



$$H = -\sum_{a=0}^{1}\sum_{j=1}^{M} S^{-a}\left(X_j^{\{1\}} + X_j^{\{2\}} + X_j^{\{3\}}\right) S^{a}$$

L.H. Santos & J. Wang, Phys. Rev. B 89, 195122 (2014), arXiv:1310.8291.
J.C. Wang, L. Santos & X.G. Wen, arXiv:1403.5256

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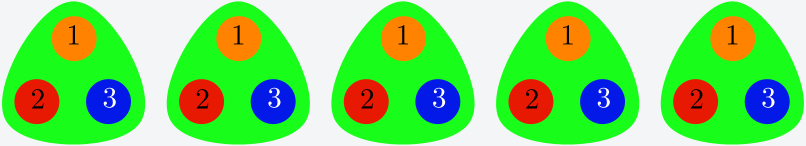

$$H = -\sum_{j=1}^{M} (2X_j^{\{1\}} + X_j^{\{2\}} + X_j^{\{3\}} + Z_{j-1}^{\{3\}} X_j^{\{2\}} Z_j^{\{3\}} + Z_j^{\{2\}} X_j^{\{3\}} Z_{j+1}^{\{2\}})$$

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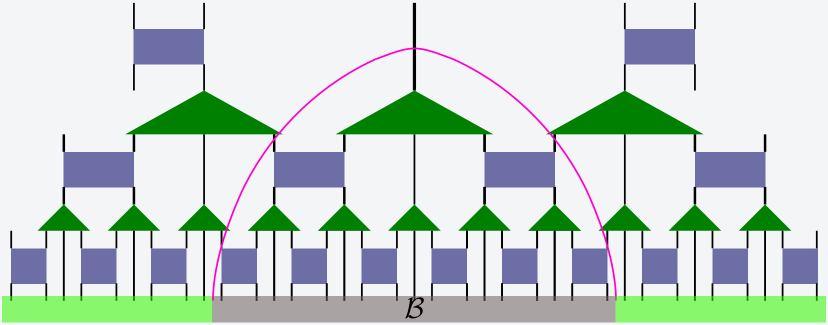
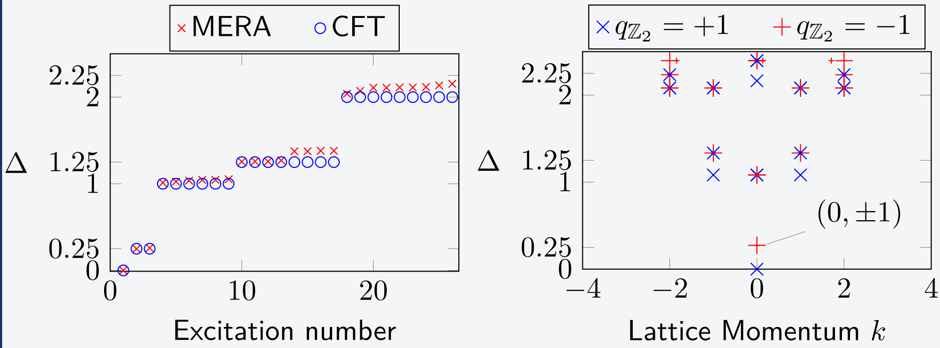
Multiscale Entanglement Renormalisation Ansatz



Spectrum



States labelled by (m, n)

$$c_{\text{MERA}} = 1.0093$$

$$\Delta = \frac{n^2}{4} + m^2$$

$$q_{\mathbb{Z}_2} = \exp\left(i\pi(m+n)\right)$$

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Conclusions

- Motivated group cohomology classification for SPT phases

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- Motivated group cohomology classification for SPT phases
- Non-onsite symmetry in (2+1) dimensions
- Constructed a model for $\mathbb{Z}_2 \times \mathbb{Z}_2 \times \mathbb{Z}_2$ symmetry
- CFT data consistent with $R = 2$ compactified free boson

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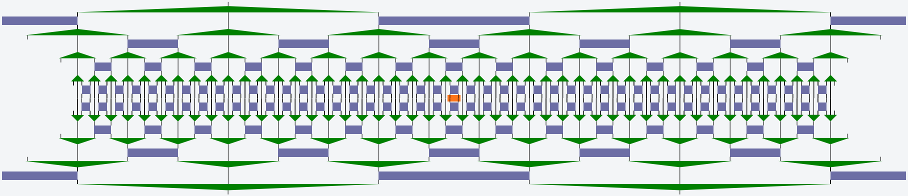
Impurity MERA



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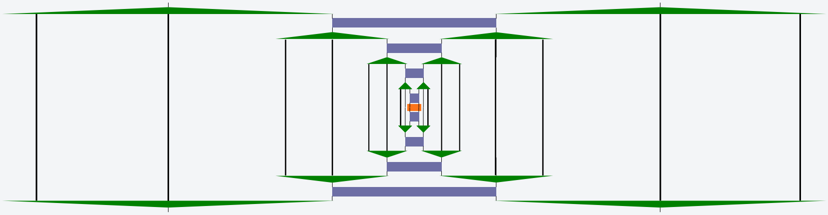

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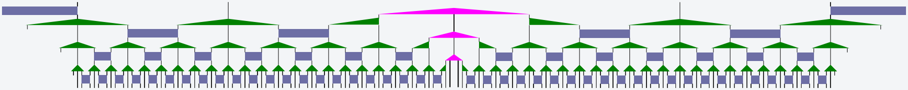
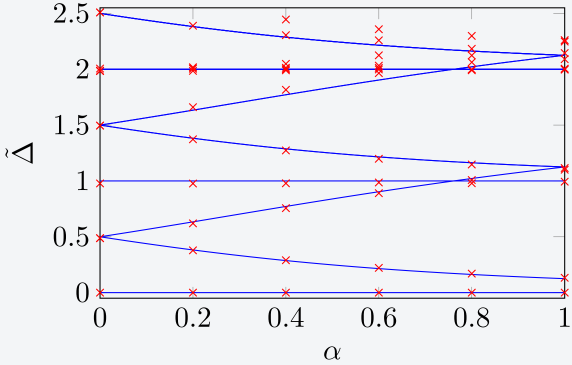


Benchmark Result-Ising with Defect



$$H = -\sum_{j=1}^{M} X_j - \sum_{j=1}^{M-1} Z_j Z_{j+1} - \alpha Z_M Z_1$$

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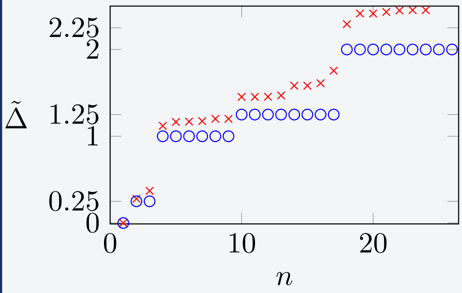
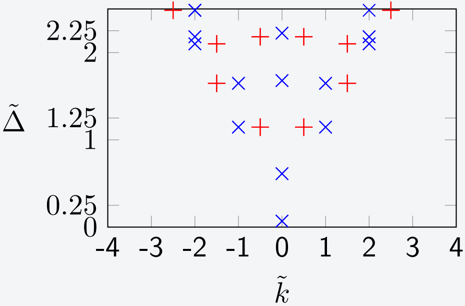
Twisted Model





$$\tilde{\Delta} = \frac{(n+1/2)^2}{4} + m^2$$

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