

Abstract Submitted  
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**Multipartite Entanglement in the Disordered Quantum Ising Model**<sup>1</sup> JAY ZOU, ISTVN KOVCS, Northwestern University — Entanglement is a distinguishing property of quantum mechanics, offering fundamentally stronger correlations than classical physics. Entanglement entropy of a single subsystem in the disordered quantum Ising model is well understood, demonstrating a non-universal area law and a universal logarithmic term unique at quantum phase transitions. However, entanglement of multiple subsystems in interacting quantum systems remains a challenging open problem. Entanglement negativity and mutual information are promising ways to quantify entanglement across multiple subsystems. In this project, we explore entanglement negativity and mutual information between two subsystems of length  $l$  separated by distance  $d$ . Both are calculated by a numerical implementation of the asymptotically exact strong disorder renormalization group method. As an application, we identify the requirements of constant, universal, distance-independent entanglement between two subsystems. Our numerical results are further supported by analytic results, providing strict universal upper-bounds for multipartite entanglement based on gap-size statistics. Our findings reveal universal principles of how entanglement connects distant subsystems with potential implications for quantum communication.

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