Study of Entanglement in Condensed Matter Systems

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Introduction

During the past year, the research activity of Yang's group has mostly focused on entanglement in various unconventional phases, and states whose entanglement properties have not been studied in detail before. These include symmetry protected topological phases, disordered fermions that go through metal-insulator transitions, and highly excited states in free fermion systems.

Results and Discussion

In Ref. [1], we showed that the degeneracy in the entanglement spectrum of symmetry protected topological phases contains both topologically protected and un-protected contributions. In particular, we showed one can disentangle these two portions by performing a highly non-local unitary transformation.

In Ref. [2], we showed that in addition to entanglement entropy and spectrum, maximally entangled modes (a concept we first introduced in this work) is a very powerful indicator of whether the system is in the metallic or insulating phase, or in particular, at the metal-insulator transition. This work opens the door of using entanglement to study metal-insulator transition based on ground state wave function alone.

In Ref. [3], we studied entanglement entropy of highly excited states of free fermions. Unlike ground state entanglement entropy that follows area law, we showed that such excited states obey a volume law instead. More interestingly, we showed the area and volume laws are two sides of the same coin, in the sense that they are related by a duality transformation between real and momentum spaces. Perhaps the most significant result is under certain conditions, we can prove that the reduced density matrix of a small subsystem takes the form of a thermal density matrix, thus realizing eigenstate thermalization. Our simple and elegant proof clearly demonstrates how statistical mechanics emerges from a single highly excited eigenstate, through entanglement.

Conclusions

Significant progress has been made in the understanding of entanglement properties of many-body systems.

Acknowledgements

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References

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[2] Pouranvari, M. and Yang, K. Phys. Rev. B **89**, 115104 (2014).
[3] Lai, H.-H., Yang, K., arXiv:1409.1224.