Topological Quantum Phase Transitions

Yang, K. and Liou, S. (NHMFL); Hu, Z. (Chongqing Univ.)

Introduction

Topological phases of quantum matter, and in particular transitions between them, are of strong current interest. In the past year we have made significant progress in our studies of both static and dynamical properties of a number of such topological quantum phase transitions.

Methods of Theoretical Studies and Results

In Ref. [1] we used exact diagonalization to study possible quantum phase transition from an integer quantum Hall state of spin-1/2 fermionic atoms at Landau level (LL) filling factor 2, to a fractional quantum Hall state of bosonic molecules made of a pair of atoms at LL filling factor 1/2. In agreement with earlier field theoretical predictions, we found a 2^{nd} order quantum phase transition between them.

In Ref. [2] we studied quench dynamics across 2nd order topological phase transitions, in particular how excitations are generated by such quenches, and their dependence on the quench rate. Specifically we studied two free fermion models: (i) The Haldane model on honeycomb lattice that undergoes a transition in which the ground state Chern number changes from 0 (trivial, no edge states) to 1 (non-trivial, with edge states); and (ii) a checkerboard lattice model in which the ground state Chern number changes from -1 to 1, resulting in a reversal of edge state chirality. While our results on bulk excitations turned out to be quite easy to understand in terms of the Kibble-Zurek theory and its proper extension to topological phase transitions, what we found for edge excitations is very surprising: there is an anti-Kibble-Zurek regime, in which the density of edges excitations generated by quench increases with decreasing quench rate, and the range of this regime increases with system size. The physical mechanism behind this counter-intuitive behavior turns out to be topological (or Thouless) pumping of electrons from one edge to the other during the quench process.

Conclusions

We have performed comprehensive theoretical studies on topological quantum phase transitions. Our results shed considerable light on their static and dynamical properties.

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References

[1] Liou, S., Hu, Z., Yang, K., Phys. Rev. B 97, 245140 (2018).
[2] Liou, S., Yang, K., Phys. Rev. B 97, 235144 (2018).