EFFECTS OF DISORDER ON TRANSPORT GAP IN FRACTIONAL QUANTUM HALL STATES AND FRACTIONAL QUANTUM HALL - INSULATOR TRANSITION

K. Yang (NHMFL/FSU, Physics)

Introduction

The fractional quantum Hall (FQH) effect is a macroscopic quantum phenomena in which a two-dimensional electron gas (2DEG) exhibits quantized Hall resistance while has zero longitudinal (or dissipative) resistance. It results from formation of incompressible electron liquid states when the 2DEG is subject to a strong perpendicular magnetic field, and the electrons partially fill the lowest Landau level. The incompressibility is due to strong correlation between the electrons, and is characterized by a mobility gap above which mobile charge carriers can be excited. These mobile charge carriers contribute to longitudinal resistance, as well as deviation of the Hall conductance from the quantized value. Experimentally the mobility gap can be extracted from the temperature dependence of the longitudinal resistance, and has been found to be strongly dependent on the disorder strength of the system. Theoretically, the quantitative dependence of the mobility gap on disorder has been poorly understood. In this work the PI and collaborators have performed systematic numerical studies to address this issue.

Method, Results and Discussion

We have performed finite-size numerical studies on fractional quantum Hall liquids in the presence of random potential, in systems with torus geometry. We diagonalize the many-body Hamiltonian exactly, and calculate the Chern numbers of eigen states of the system [1,2]. The Chern number is a topological quantum number that equals the boundary condition averaged Hall conductance of the state. The quantization of the Chern number allows us to distinguish current-carrying states from insulating states unambiguously in finite-size systems. While this topological approach has been used in the past to study transport properties of single electron states, our work represents the first attempt to apply it to many-body states in interacting systems. From these results we are able to extract the dependence of the mobility gap on disorder strength, which is in quantitative agreement with experimental data [3] that remain unexplained for nearly 20 years. In addition we observe a fractional quantum Hall - insulator transition at critical disorder strength, which is characterized by a change of ground state Chern number to zero; our method thus allows for numerical studies of this transition in the future. It is worth emphasizing that this topological approach we developed is the only known method to distinguish between current-carrying and insulating states in finite-size systems, and study localization transition for interacting many-particle systems; other numerical methods used to study single particle states cannot be used here due to the presence of interactions.

Acknowledgements

Work supported by National Science Foundation Grant DMR-0225698.

References