凝縮系物理学ゼミナール
Condensed Matter Seminar

Date: 13:00-14:30, Wednesday, 27 December 2023

Title: Exploring Quantum Matter: Exotic transitions, self-similar spectra and learning entanglement from experiments

Speaker: Dr. Gunnar Möller
(Royal Society University Research Fellow,
Physics of Quantum Materials Group,
Physics and Astronomy, Division of Natural Sciences,
University of Kent)

Abstract:

Since the identification of quantum Hall states as topological states of matter, the search for new topological states of matter has been a central endeavour in the field. Interacting particles in flat band models provide a host of opportunities for creating such new states, baptised fractional Chern insulators (FCI), which exploit new physical realisations of synthetic magnetic fields. The interacting Hofstadter model gives blueprint examples of such phases, as predicted by composite fermion theory [1]. We will first review exact diagonalisation results for FCI states stabilised in single Chern bands, and demonstrate that finite-size effects are minimised in the quasi-continuum limit of perfectly flat bands near flux densities $n_\phi \to 1/|C|$ [2,3,4]. Secondly, we demonstrate the presence of interaction-driven quantum Hall plateau transitions in the Hofstadter model, arising from the competition of Chern insulator states at weak interaction with FCI states realised at the same particle density for strong interactions. In one such case, our DMRG data at flux density n_ϕ=3/11 presents a direct transition between a C=4 Chern Insulator and a ν=1/3 Laughlin state [5]. Going beyond ground state properties of quantum Hall systems, we will expose self-similar features of the dynamical response functions arising for a Laughlin state probed at energies lying above the scale of the single-particle gap [6].

Finally, we will discuss the potential for machine learning techniques to extract entanglement properties in many-body systems from a limited set of correlators. We will provide a formal proof that under the assumption of only pairwise spin interactions in magnetic, it is possible to use measurements of the spin structure factor of magnetic systems to deduce the full many-body state (at T=0) or thermal density matrix (at finite T). We the provide numerical data supporting the scope for a practical realisation of this route towards quantum state tomography [7].

References :

[1] Möller, G. & Cooper, N. R. Composite Fermion Theory for Bosonic Quantum Hall States on Lattices. Phys. Rev. Lett. 103, 105303 (2009).
[2] Möller, G. & Cooper, N. R. Fractional Chern Insulators in Harper-Hofstadter Bands

with Higher Chern Number. Phys. Rev. Lett. 115, 126401 (2015).
[3] Andrews, B. & Möller, G. Stability of fractional Chern insulators in the effective continuum limit of Harper-Hofstadter bands with Chern number |C|>1. Phys. Rev. B 97, 035159 (2018).
[4] Andrews, B., Neupert, T. & Möller, G. "Stability, phase transitions, and numerical breakdown of fractional Chern insulators in higher Chern bands of the Hofstadter model" Phys. Rev. B 104, 125107 (2021).
[5] Schoonderwoerd, L., Pollmann, F. and Möller, G. Interaction-driven plateau transition between integer and fractional Chern Insulators, arxiv:1908.00988.
[6] Andrews, B. & Möller, G. Self-similarity of spectral response functions for fractional quantum Hall states. Proc. R. Soc. A 479, 20230021 (2023).
[7] Tymoteusz Tula, J. Quintanilla, and G. Möller, in preparation.