Tuning topological ground states in interacting electronic kagome systems

M. A. Mojarro and S. E. Ulloa

Department of Physics and Astronomy and Nanoscale and Quantum Phenomena Institute, Ohio University, Athens, OH 45701, USA

ulloa@ohio.edu

Kagome lattice symmetries underlie various quantum materials with rich phenomenology, including charge density waves and superconductivity [1]. Some of the unique topological and correlated phases that arise in these lattices are associated with the existence of Dirac fermions, sharp van Hove singularities and flat dispersions in the energy spectrum [2].

We present here our studies on the interplay between attractive electron interactions and topological states in strained kagome lattices. We use an extended Hubbard Hamiltonian to describe the system. It has been shown before that the system is driven into a charge density wave state beyond a critical attractive interaction U_c. Using a mean-field approximation, we study the tunability of U_c under changes in uniaxial strain and doping levels. The competition gives rise to various interesting phases as different physical parameters change.

As uniaxial strain breaks the C_3 symmetry of the lattice, we see the onset of a charge density wave (CDW) ground state for strong attractive interaction. In the presence of spin-orbit interaction, the system changes from a quantum spin Hall state to a charge density wave as strain increases, signaling topological phase transitions that could in principle be controlled in experiments. For intermediate attraction, the system exhibits the coexistence of CDW and topological states with interesting properties.

We will also discuss our studies on the stability of these ground states beyond mean-field using density matrix renormalization group calculations.

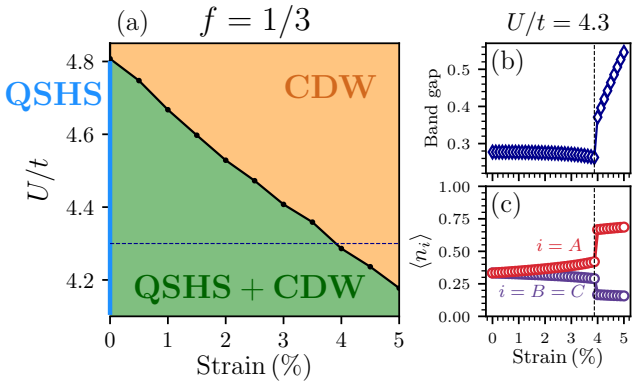

Fig. 1. (a) Phase diagram of 1/3-filled kagome lattice, as function of attractive interaction U and uniaxial strain along one of the lattice vectors. Without strain, the system's ground state is topological, in a quantum spin Hall (QSHS) phase for $U \leq U_c \simeq 4.8t$, before a charge density wave (CDW) state wins for $U > U_c$. As strain is applied, the ground state shows interesting coexistence of QSHS and CDW. For the value of $U = 4.3t$ shown by dashed line in (a): (b) Bandgap and (c) site occupancy vs strain. Similar transitions albeit with their own characteristics are seen for filling factor 2/3, near the highly degenerate kagome band.

References

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[2] M.A. Mojarro and S.E. Ulloa, 2D Materials **11**, 011001 (2024).