Topological Phases on the Kagome Lattice

Irakli Titvinidze [titvinidze@itp.uni-frankfurt.de]

- Ultracold atomic gases confined in optical lattices provide a new laboratory for investigating quantum many-body problems with high precision and tunability. [1]
- Local Hubbard interaction between two fermions can be tuned using Feshbach resonance.
- With the help of the laser fields it is possible to engineer spin-orbit coupling between two fermions. [2]
- The behaviour of the system can be investigated in the presence of flux, but since atoms are charge neutral, artificial gauge fields are needed. [3]
- Ultracold atomic gases enable the generation of Quantum-Hall and Quantum-Spin-Hall states.
- The Kagome lattice for ultracold atoms can be realized by superimposing two commensurate triangular optical lattices. [4]

In order to characterize the behaviour of Chern insulators with broken time-reversal symmetry, the Chern number

$$C = -\frac{1}{\pi} \sum_{n=1}^{N} \int_{BZ} d\mathbf{k} \left( \frac{\partial}{\partial k_x} u_n, k \right) \left( \frac{\partial}{\partial k_y} u_n, k \right)$$

is used, while the time reversal invariant Topological Insulators (TIs) are characterized by a $\mathbb{Z}_2$ invariant.
- The bulk of a 2D TI is insulator, while its surfaces are conducting.
- TIs are often studied for non-interacting systems, but the effect of the two particle interaction is particularly interesting.

For some parameter sets, the Kagome lattice has a flat band.
- DOS for the flat band diverges. Thus interesting physics can be realized in the system.

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Hofstadter-Hubbard model on the Kagome lattice

\[ H = H_0 + H_U \]

\[ H_0 = -t_1 \sum_{r \in R} \left[ c_{r,0}^\dagger c_{r+1,0} + c_{r+1,0}^\dagger c_{r,0} + H.c \right] - t_2 \sum_{r \in R} \left[ c_{r,0}^\dagger e^{-i2\pi \sigma_x} c_{r+1,0} + c_{r+1,0}^\dagger e^{-i2\pi \sigma_y} c_{r,0} + H.c \right] - t_3 \sum_{r \in R} \left[ c_{r,0}^\dagger e^{i\phi_{r,0}} c_{r+1,0} + c_{r+1,0}^\dagger e^{i\phi_{r,0}} c_{r,0} + H.c \right] + \sum_{r \in R} \left[ \lambda_{R} n_{r,0} + \lambda_{B} n_{r+1,0} + \lambda_{G} n_{r+1,0} \right] \]

\[ H_U = U \sum_{r} \left[ n_{r,0} n_{r+1,0} + n_{r+1,0} n_{r,0} + n_{r,0} n_{r+1,0} + n_{r+1,0} n_{r,0} \right] \]

Spin-orbit interaction

Staggered potential

Magnetic flux

Already studied for the Kagome:
- Spinless fermions (only one component) in the presence of magnetic flux. [5]
- Two-component fermionic gas with spin-orbit coupling, but without magnetic flux and Hubbard interaction. [6,7]

Our goal is to take into account the effect of:
- both magnetic flux and spin orbit coupling (without Hubbard interaction)
- staggered potential
- Hubbard interaction

Depending on the parameter set, we expect competition between band insulator, quantum spin Hall effect, semi-metal and Mott insulator phases.

Similar to the triangular lattice, the Kagome lattice is also frustrated with respect to antiferromagnetic order.

Due to the flat band interesting physics can take place in the system.

Literature
(13)M. Z. Hasan and C.L. Kane, Rev. Mod. Phys. 82, 3045 (2010)