Quantum Hall effect in a Weyl-Hubbard model: interplay between topology and correlation

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In condensed matter systems, interplay between topology and electronic correlation effects offers a rich avenue for discovering emergent quantum phenomena. Starting from the Weyl-Hubbard model, we investigate the quantum Hall effect to explore the effect of onsite Hubbard repulsion on nontrivial Weyl band topology in the presence of an external magnetic field (B). Within the framework of Gutzwiller approximation, we find the system encounters multiple topological phase transitions, including two Weyl phases with different pairs of Weyl nodes and a trivial narrow band insulator by tuning on-site Coulomb interaction in the presence of B. Interestingly, along with narrowing bandwidth, these two Weyl phases can be distinguished by the sign of their chiral Landau levels. We explore the possible experimental signature of these topological phases and correlation effects by calculating magnetic-field dependent two-dimensional Sheet Hall conductivity (SHC) and three-dimensional quantum Hall conductivity (QHC) within the Kubo response theory. Specifically, the SHC in both Weyl phases depicts staircase profile as a function of chemical potential (electron filling factor). Interestingly, the qualitative difference of quantization appears in SHC due to the degeneracy of Landau levels, which can therefore, track the phase transition between two different Weyl phases. In contrast to the SHC, the QHC does not show any quantized profile. Instead, a linear-chemical potential behavior appears within the bulk gap of WSM phases due to chiral Landau levels, where its slope can be tuned by changing the magnetic field direction. Recent discovery of correlated magnetic Weyl semimetals such as $Co_3Sn_2S_2$, $Pr_2Ir_2O_7$ [1,2] offers the platform to verify our proposed results experimentally.

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