Churning the Chern Numbers: An Investigation of the Insulator/Chern-Insulator Transition

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Ferromagnetic insulators that have a non-vanishing Brillouin-zone integral of the Berry curvature (i.e. Chern number) are called *Chern insulators*. At this point, such systems are only a theoretical concept and the search for an experimental realization is a fascinating open problem. While Chern insulators have the interesting feature of showing a quantum Hall effect without Landau levels,[1] their electronic structure has not been investigated in detail. As a result of the non-vanishing Chern number, it is not possible to choose a gauge that is both periodic ($|\Psi_{\mathbf{k}+\mathbf{G}}\rangle = |\Psi_{\mathbf{k}}\rangle$ for Bloch functions separated by a reciprocal lattice vector) and smooth (free of singularities in $\mathbf{k}$). In turn, it is not clear how (or even if) Wannier functions can be constructed for these kinds of systems. With this project we investigate what happens when a normal insulator turns into a Chern insulator. In particular, we are interested in the localization properties of the Chern insulator state. To this end, we study the behavior of the spread functional and the decay of the density matrix near the insulator/Chern-insulator transition in the Haldane model.[1] Our results show that exactly at the phase boundary, the spread functional diverges and the density matrix shows a pure power-law decay similar to metals. Inside the Chern insulator state the spread functional becomes finite again and the density matrix decays exponentially as in normal insulators. We hope that this work will contribute toward attempts to remove a constraint on our recently developed theory of orbital magnetization[2] and extend it to all kinds of insulators, including Chern insulators.

[1] F.D.M. Haldane, Phys. Rev. Lett. **61**, 2015 (1988).

[2] T. Thonhauser, Davide Ceresoli, David Vanderbilt, and R. Resta, Phys. Rev. Lett. **95**, 137205 (2005).