Non-trivial Flat Bands in Three Dimensions

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We report the presence of exactly and nearly flat bands with non-trivial topology in a three-dimensional lattice model. We show that an approximate flat band with finite Chern number can be realized in a two-orbital square lattice by tuning the nearest-neighbor and next-nearest-neighbor hopping between the two orbitals. With this, we construct a minimal three-dimensional flat band model without stacking the two-dimensional layers. Specifically, we demonstrate that a genuine three-dimensional non-trivial insulating phase can be realized by allowing only nearest and next-nearest hopping among different orbitals in the third direction. We find both perfect and nearly perfect flat bands in all three planes at some special parameter values. While the nearly flat band carries a finite Chern number, the perfect flat bands have zero Chern number. Further, we find that such a three-dimensional insulator with flat bands carry an additional three-dimensional topological invariant, namely Hopf invariant. Finally, we show that higher Chern models with Hopf invariant can also be constructed with only nearest and next-nearest hopping, but the appearance of flat bands along high-symmetric points in the Brillouin zone requires long-range hopping. We close with a discussion on possible experimental platforms to realize the model.

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