Flat Band Structures

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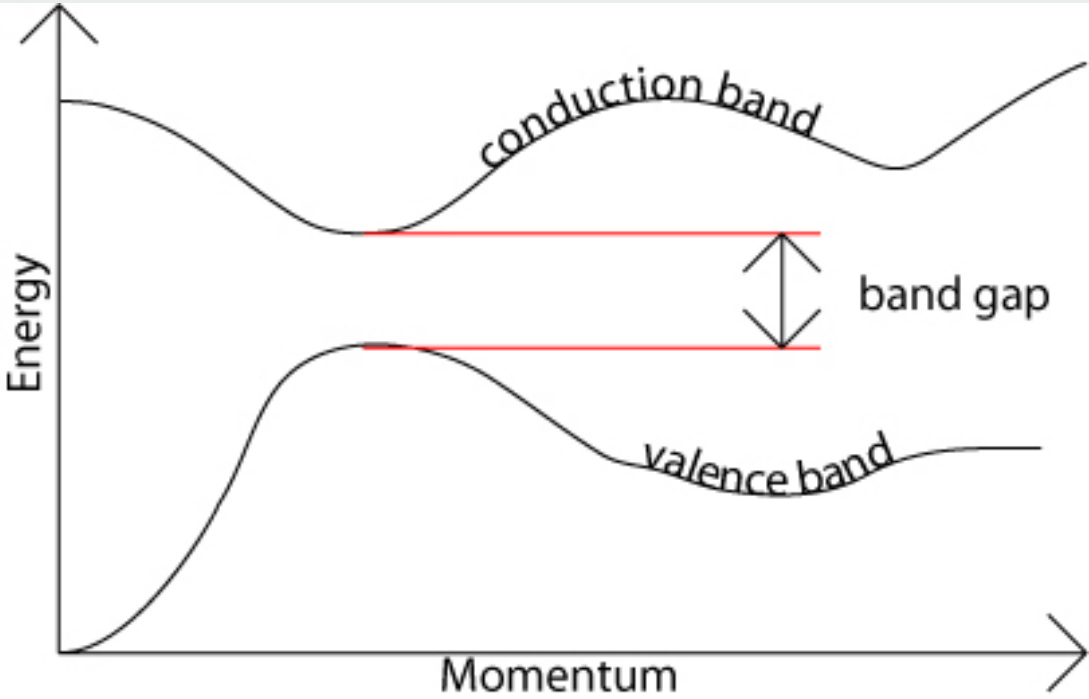
What are Flat Bands

- Flat bands are states in which energy is independent of momentum.
  - Group velocity is zero
- Generally unstable
  - Susceptible to perturbations
- Leads to phenomena such as ferromagnetism, superconductivity, and superfluidity as seen in CuO_2



Lattices

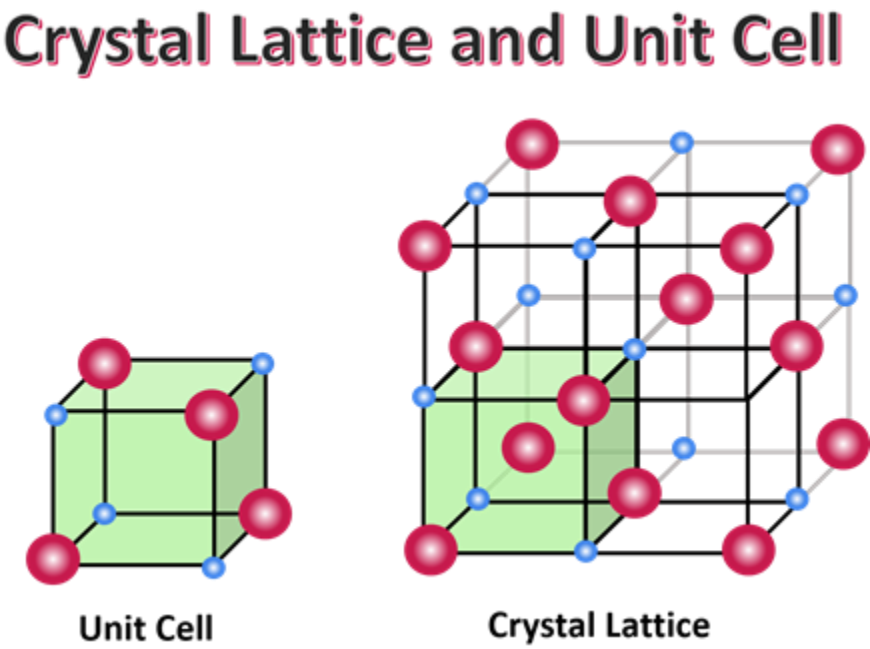
Occured in twisted bilayer graphene

- Attempts to make flat band lattices have

  Used origami rules and fractals

- The edge states are different from the bulk
  - Chiral edge states

$$\psi_{n\vec{k}}(\vec{r}) = e^{i\vec{k}\cdot\vec{r}} u_{n\vec{k}}(\vec{r})$$



Relation to Anomalous Quantum Hall Effect

- The Original Quantum Hall Effect was shown using a magnetic field
  - First example of a topological insulator
  - Conductivity was quantized **σ = C (e^2/h)**
  - **C** here is the chern number, dependent on the topology of the band structure
- The AQHE was demonstrated without the use of an external magnetic field
  - Due to spin-orbit coupling (SOC)

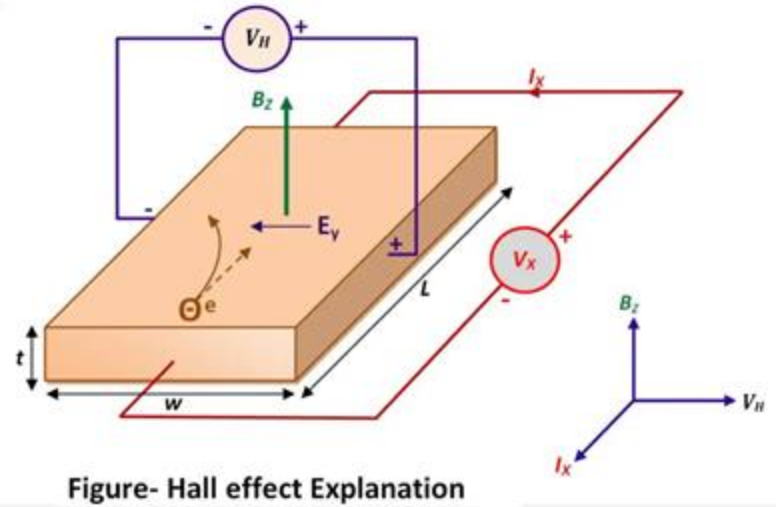


Figure- Hall effect Explanation

What I Will Be Researching

Calculations on

- The Chern number using the Berry curvatures of different materials
- Hall conductivity
- Polarization using the Berry phase
- Orbital Magnetization using Wannier functions

❑ All these relate to topology

Berry Connections and Berry Curvature

- Berry's Connection

$$A_n(R) = i < n(R)|\nabla_R|n(R) >$$

- Berry's Curvature

$$'B' = \nabla_R \times A_n(R)$$

- Berry's Phase

$$\gamma_n(T) = i \oint A_n(R).dR$$

$$\Phi = \int_S B.da$$

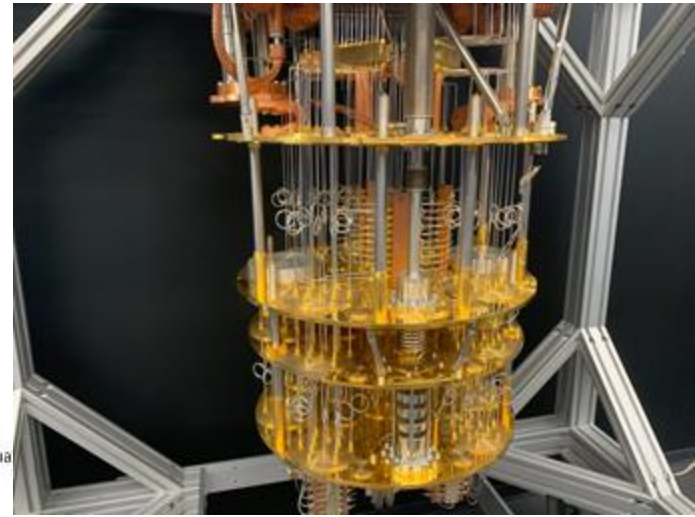
$$B = \nabla \times A$$

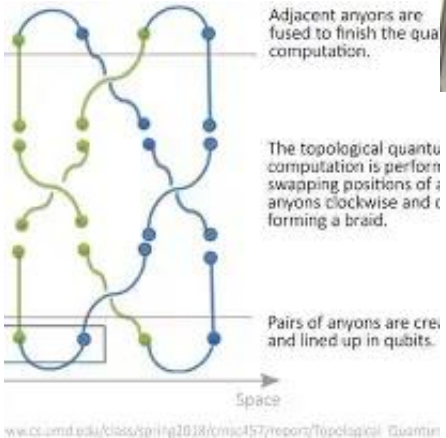
$$\Phi = \int_S (\nabla \times A).da = \oint_C A.dr$$

$$\gamma_n(T) = i \oint < \psi_n|\nabla_R\psi_n > dR$$

Significance of Topological Flat Bands

- Would significantly improve topological quantum computing
  - Information is encoded differently from qubits through anyons
  - Improved coherence times
- Studying correlation electron physics
  - e. g. Mott insulators





Questions?

Works Cited

Crystal Lattice — Structure & Formation - Expii

https://www.slideserve.com/michaelbrooks/chapter-18-electrical-properties-powerpoint-ppt-presentation

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Observation of topological surface state quantum Hall effect in an intrinsic three-dimensional topological insulator