Topological States of Quantum Matter

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What we do

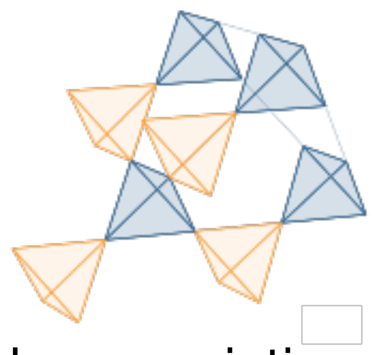
We study **crystalline materials** that exhibit robust and universal phenomena that can be understood with the mathematical tools of **topology**. These **novel states of quantum matter** may be useful for future low-power electronics or for quantum information processing.

Strongly interacting

How strong are correlations?

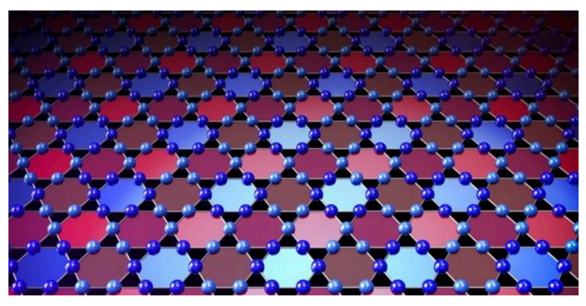
Non-interacting

Quantum magnets and spin liquids



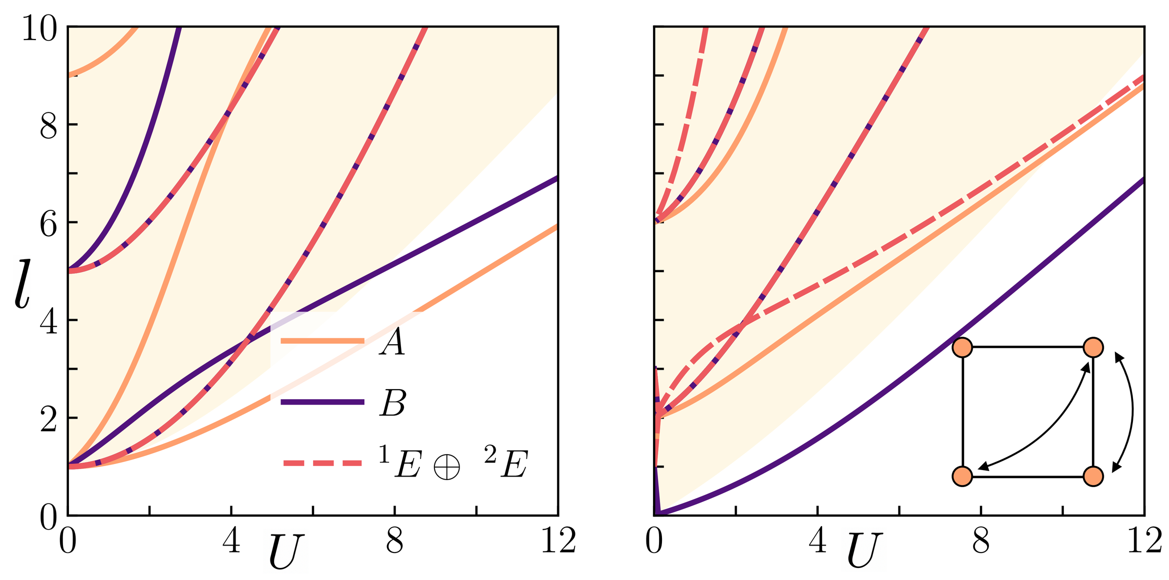
Neural Networks as variational Ansatz for wave functions of complex 3D magnets, called the **Neural Quantum States** method, can yield novel physical results in hard problems.

Kagome magnets and superconductors



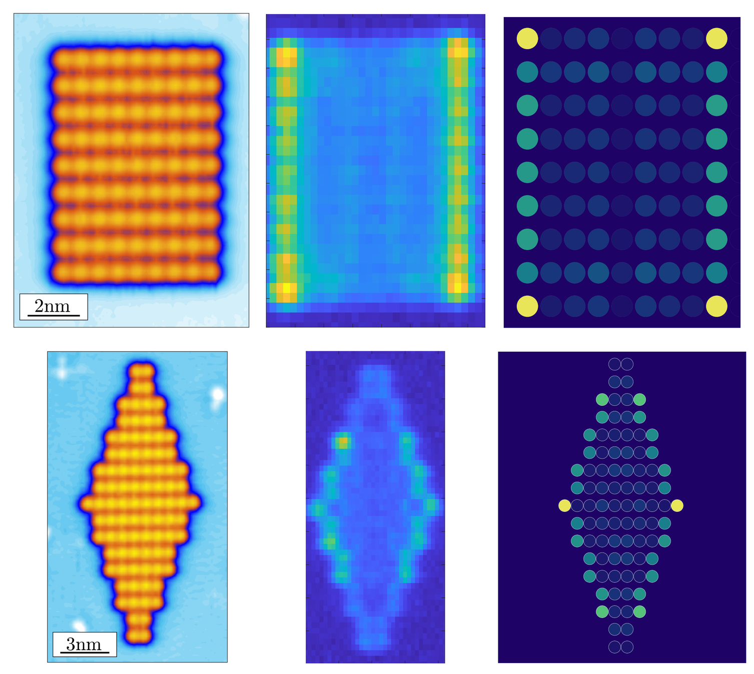
The kagome lattice is a well-known theoretical playground for exotic electronic phases. Recently, a novel material class was found which hosts sought after **unconventional charge order** and **superconductivity**.

Interacting topological quantum chemistry

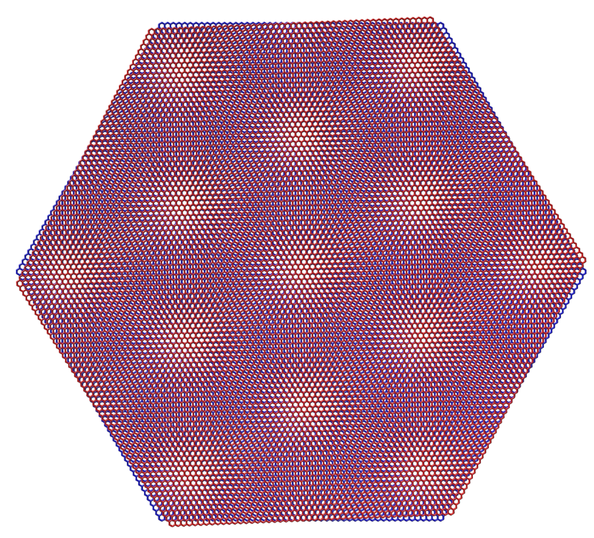


Crystalline materials where electrons are weakly interacting have been classified by **'topological quantum chemistry' (TQC)**, a theory that has led to the identification of many topological materials. We have extended the ideas of TQC to **interacting systems,** where we use Green's function to classify interacting states.

Topological states in artificial lattices

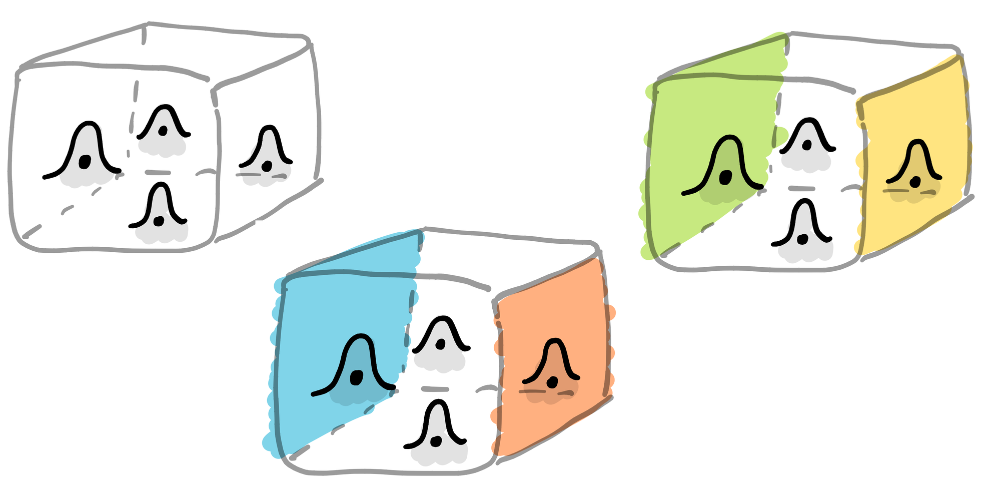


Magnetic atoms deposited on a superconducting surface can form **Shiba bound states**. When placed in an ordered lattice, they may realise topological phases with protected edge modes.



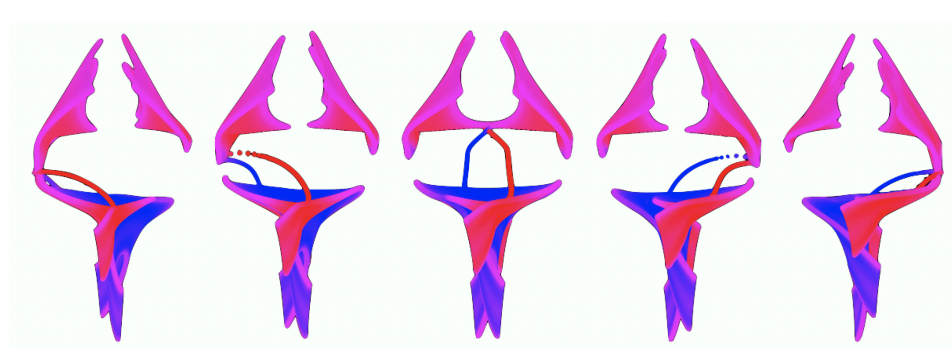
When **two graphene layers are twisted** by the 'magic angle' (MATBG), they become superconducting. Understanding this may shed light on high temperature superconductors.

Disordered systems



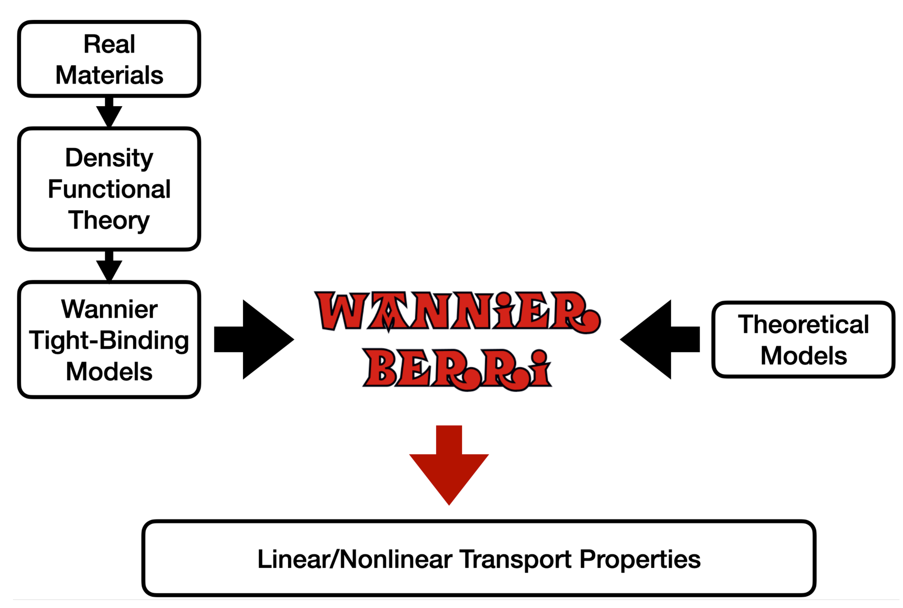
While topological insulators are expected to host delocalised states in their bulk in the presence of **disorder**, we introduced a novel phase of matter, dubbed **Topologically Localized Insulators**, that have a **fully localized bulk**, while still having non-trivial delocalized boundary states.

Exceptional topological insulators



The dynamics or response of **open quantum systems** is often described by local **non-Hermitian operators**. The **exceptional topological insulator** is an example of a non-Hermitian topological state of matter that features exotic surface states which can only exist within the 3D bulk embedding.

Berry curvature induced transport



WannierBerri is a code to calculate linear/nonlinear transport properties in real materials.

Study of abstract models

How realistic are the materials studied?

Real materials