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New Paradigms for Topological Matter

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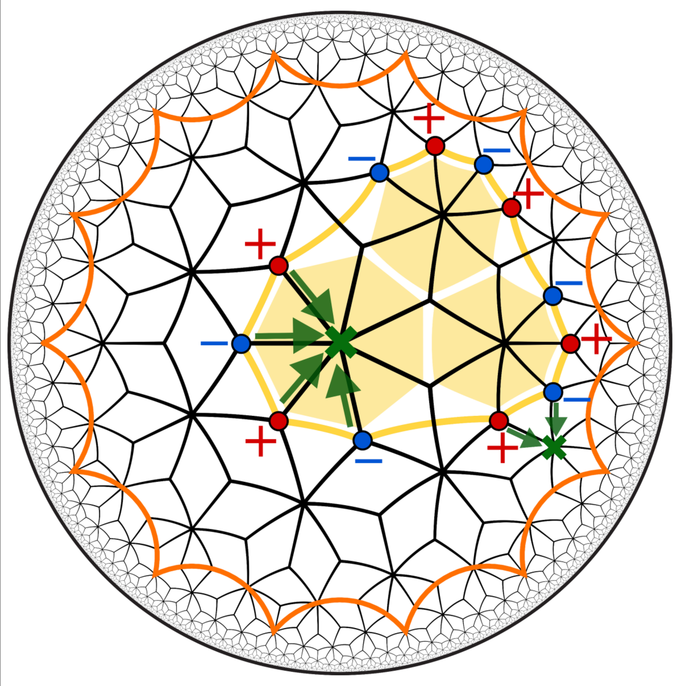
learn more:
(group website)

What we do

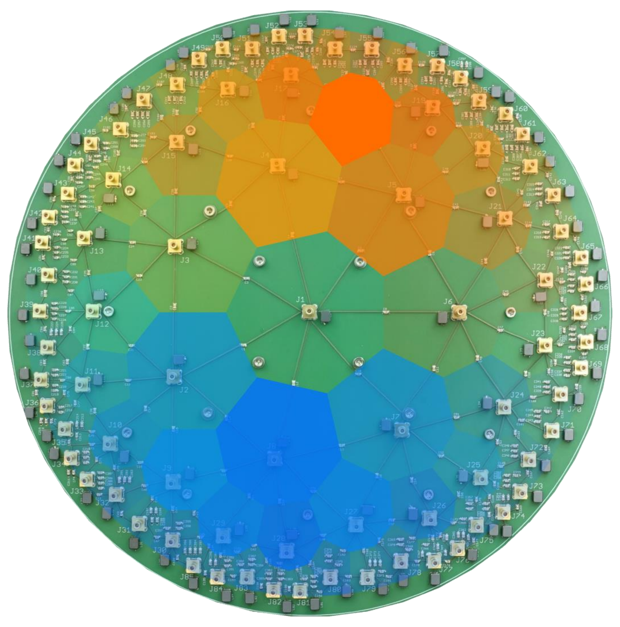
We study the mathematical characterization and physical manifestations of **topological phases of matter**. This includes topological aspects of electron energy bands in crystalline solids, notably in topological insulators, (semi)metals, and superconductors. In addition, we consider artificial (e.g. hyperbolic) lattices and also non-equlibrium (driven and dissipative) systems. The research group has just launched in September 2023!

Flat bands and correlations

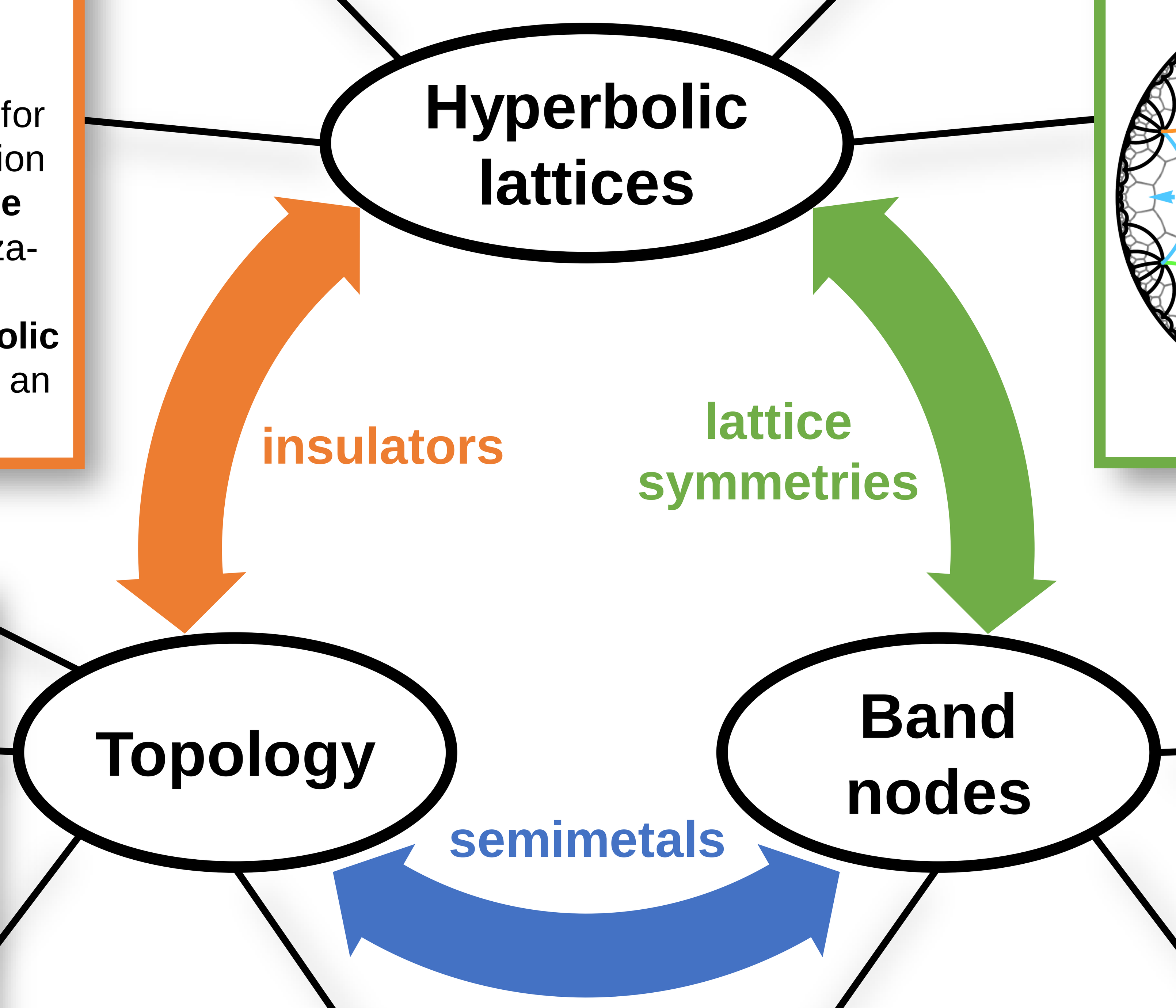


In models with **dispersionless (flat) bands**, the kinetic energy is small, and the physics is **dominated by particle interactions**. We aim to study correlated phases in hyperbolic lattices (with and without flat bands).

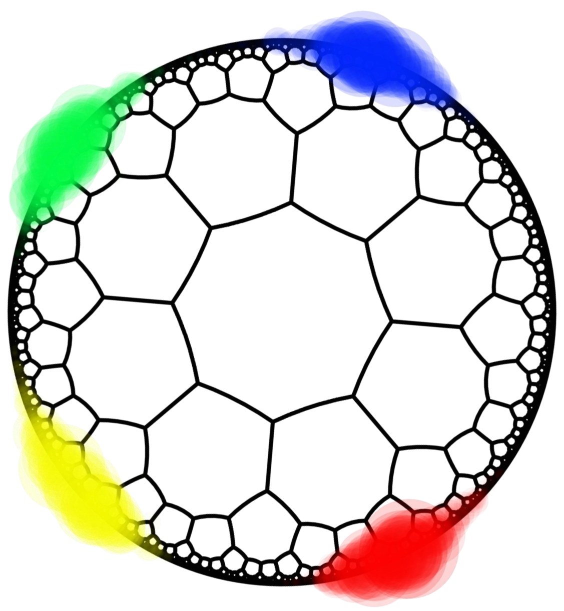
Artificial lattices (metamaterials)



Metamaterials (such as electric-circuit networks, or coupled photon resonators) allow for **controlled experimental realizations** of designed systems on **arbitrary lattices**. Even lattices in negatively curved space, which can't be realized with crystalline solids, can be emulated.

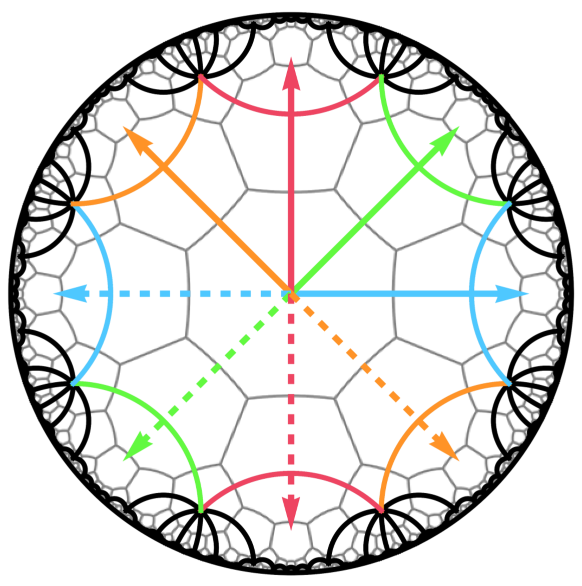


Hyperbolic topological insulators



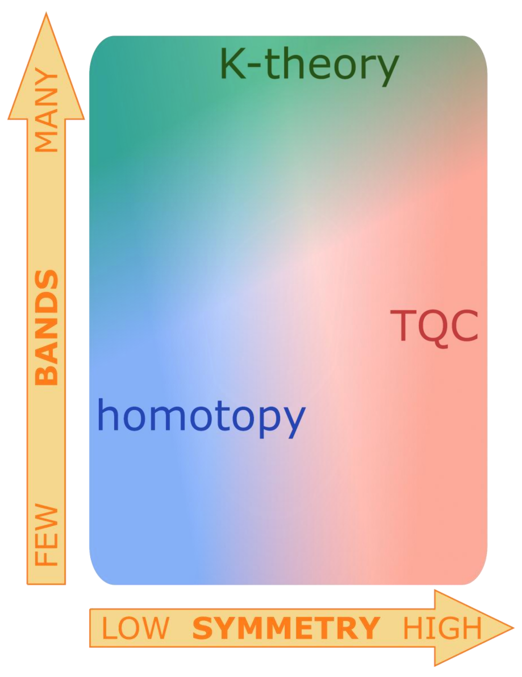
Hyperbolic lattices have an **extensive boundary**, which might be favorable for an efficient realization of **topological edge states**. Characterization of topological states with **hyperbolic band theory** is still an open problem.

Translation symmetry



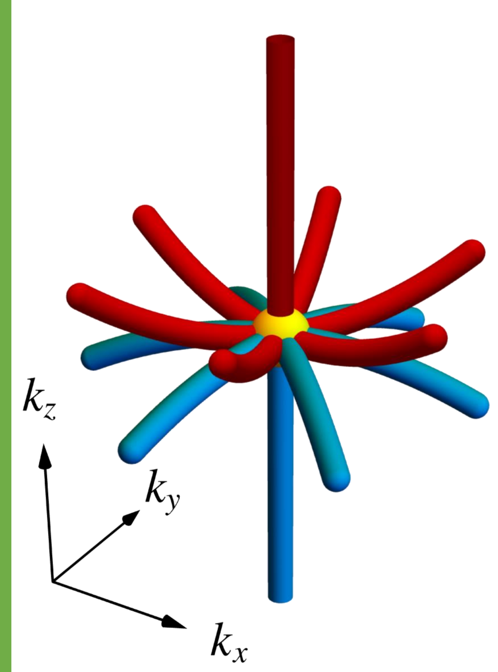
Translations in hyperbolic lattices **do not commute**. This has important consequences for the hyperbolic extension of the (Bloch) band theory; for example, the **Brillouin zone** becomes **higher-dimensional**.

Classification of topological invariants



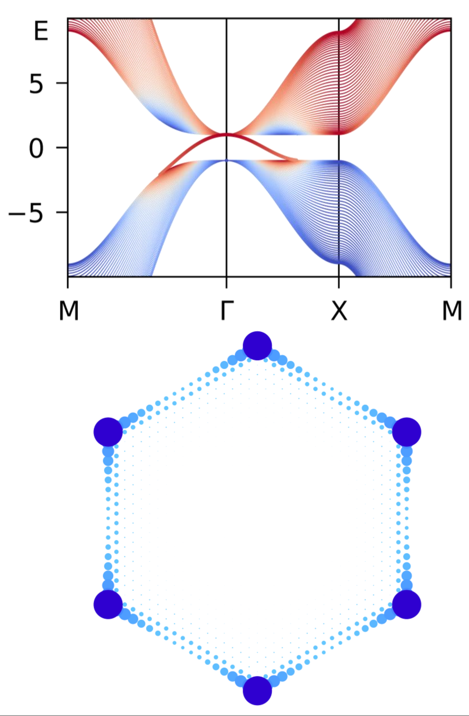
Depending on the **symmetry** and the available **degrees of freedom**, diverse mathematical techniques are useful for capturing **topological features**, coming in varying **levels of robustness**.

Characterization of band nodes



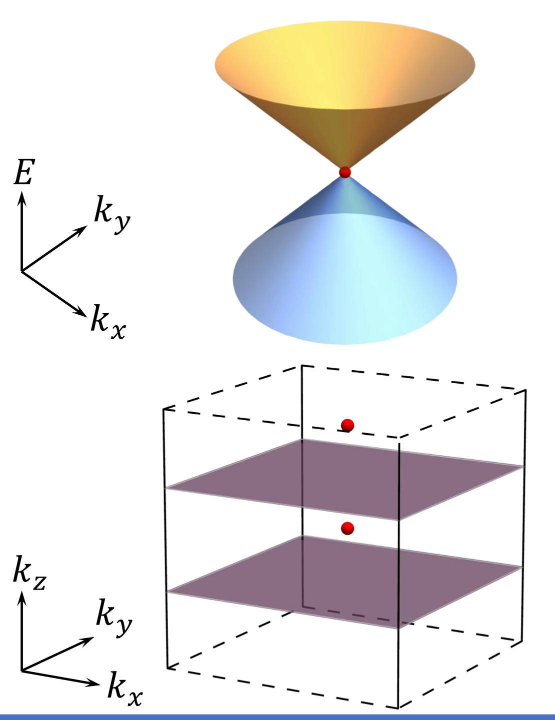
Symmetries do not only **protect** certain **band nodes**, but they also constrain the Hamiltonian in their vicinity. This allows us to **predict and classify** certain **nodal features** using symmetry.

Bulk boundary correspondence



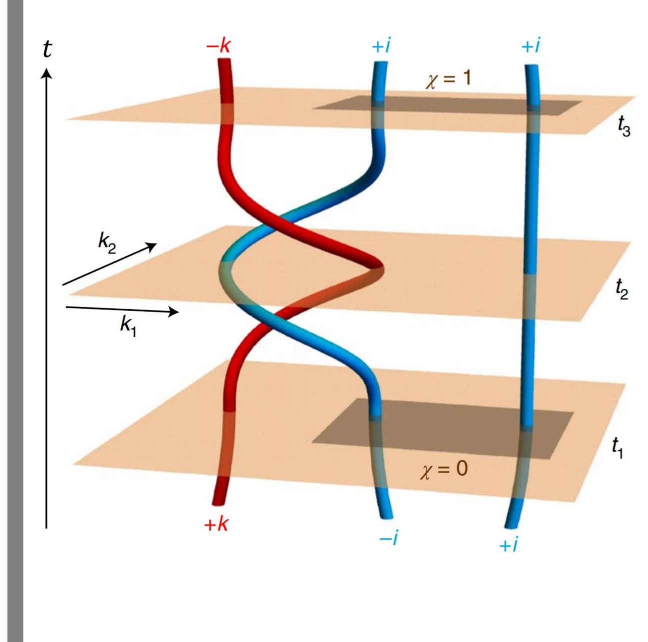
Non-trivial bulk topology in insulators and semimetals is reflected in their **boundary signatures**. Often, these are **conducting states** on the surface, but they can also be more intricate, such as a **fractional electric charge** accumulated **at corners**.

Topological semimetals



Band topology also plays a role in semimetals, where it relates to degeneracies of energy bands, known as **band nodes**. These take the role of metallic (i.e. gap-closing) transitions separating **slices of insulators** in one fewer dimensions.

Non-Abelian braiding



Usually, band nodes are characterized by additive topological "charges" (such as $\mathbb{Z}$ or $\mathbb{Z}_2$). However, sometimes, these **charges** are **non-commutative**, thus enabling their non-trivial **braiding in momentum space**.