Corner modes of the breathing kagome lattice: Origin and robustness

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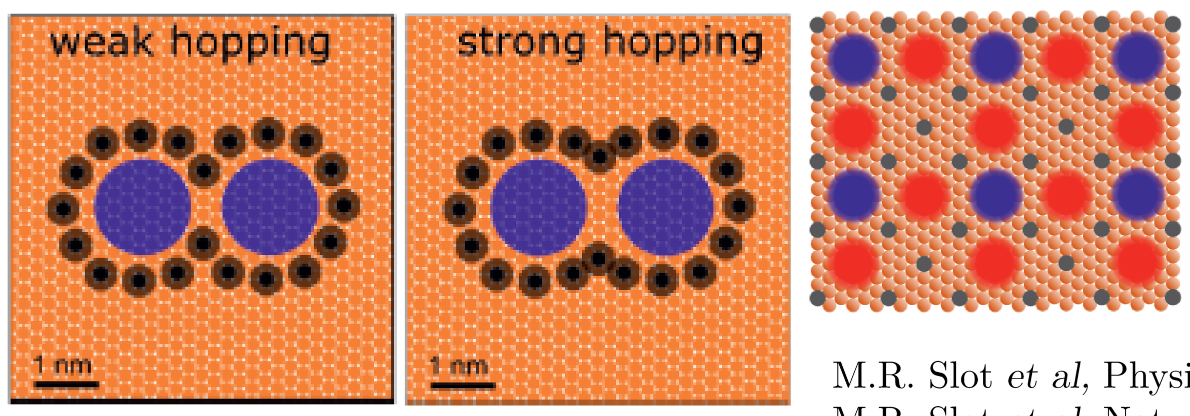
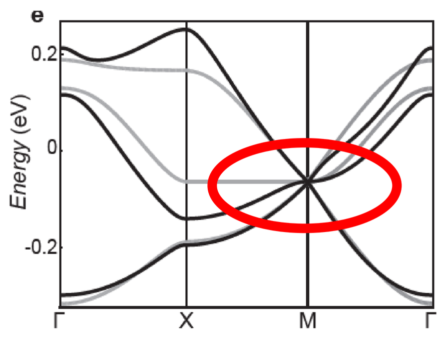
Muffin tin method: designing antilattices

Place CO molecules on top of Cu(111),
Solve Schrödinger by plane wave expansion

$$\left(\frac{1}{2}(\mathbf{k}-\mathbf{G})^2-\mathcal{E}_n\right)c^n_{\mathbf{k}-\mathbf{G}}+\sum_{\mathbf{G}'}V_{\mathbf{G}'-\mathbf{G}}c^n_{\mathbf{k}-\mathbf{G}'}=0$$



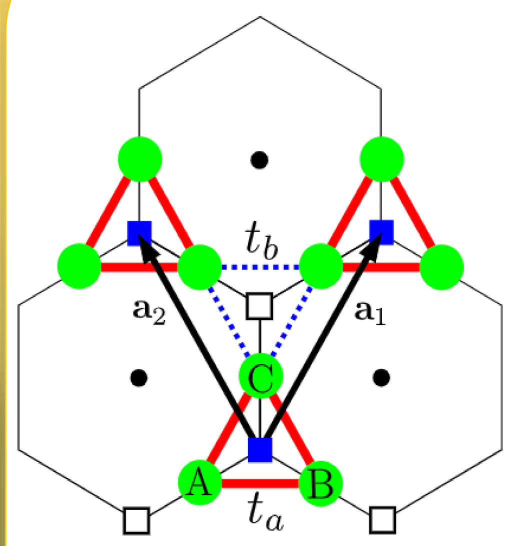


M.R. Slot *et al*, Physical Review X **9**, 011009 (2019)
M.R. Slot *et al*, Nature Physics **13**, 672 (2017)

Pros:
- Electronic quantum simulator.
- Simple mathematical solution.

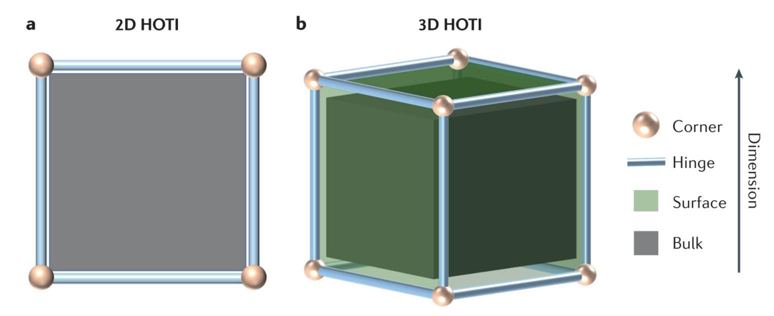
Cons:
- Not very large clusters of molecules.
- Symmetry of the substrate may affect the symmetry of the lattice.

Breathing kagome lattice



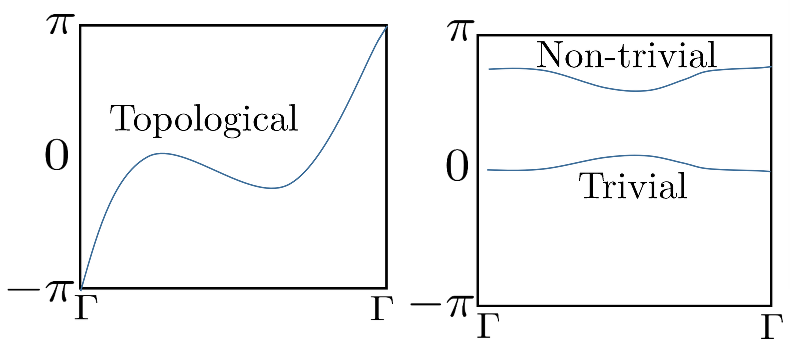
Kagome lattice with different intra- and inter-cell hopping amplitudes.
The breathing process reduces the symmetry from p6mm to p3m1.
Displays two phases, one with corner modes (non-trivial) and another without them (trivial).

Such corner modes have suggested that non-trivial breathing kagome is HOTI, when it is not.



Wilson loops and Wannier center

$$W^n_\ell=\mathcal{P}\exp\left\{-i\int_\ell d\ell\cdot\mathbf{A}_n\right\}$$



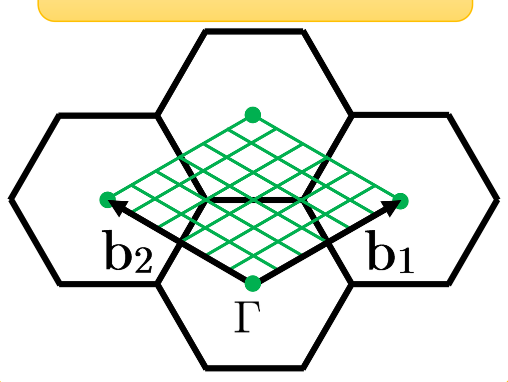
Discretization

$$W^n_{\mathbf{k}+\mathbf{b}_1\leftarrow\mathbf{k}}=W^n_{\mathbf{b}_1}(k_2)=$$

$$=\langle u_n(\mathbf{k}+\mathbf{b}_1)|\prod_{j=1}^{N-1}\mathcal{P}(\mathbf{k}^j)|u_n(\mathbf{k})\rangle$$

Non-topological phases $\quad \mathbf{r}_{WC}=\frac{\vartheta^1}{2\pi}\mathbf{a_1}+\frac{\vartheta^2}{2\pi}\mathbf{a_2}$

Discretization



Topological quantum chemistry

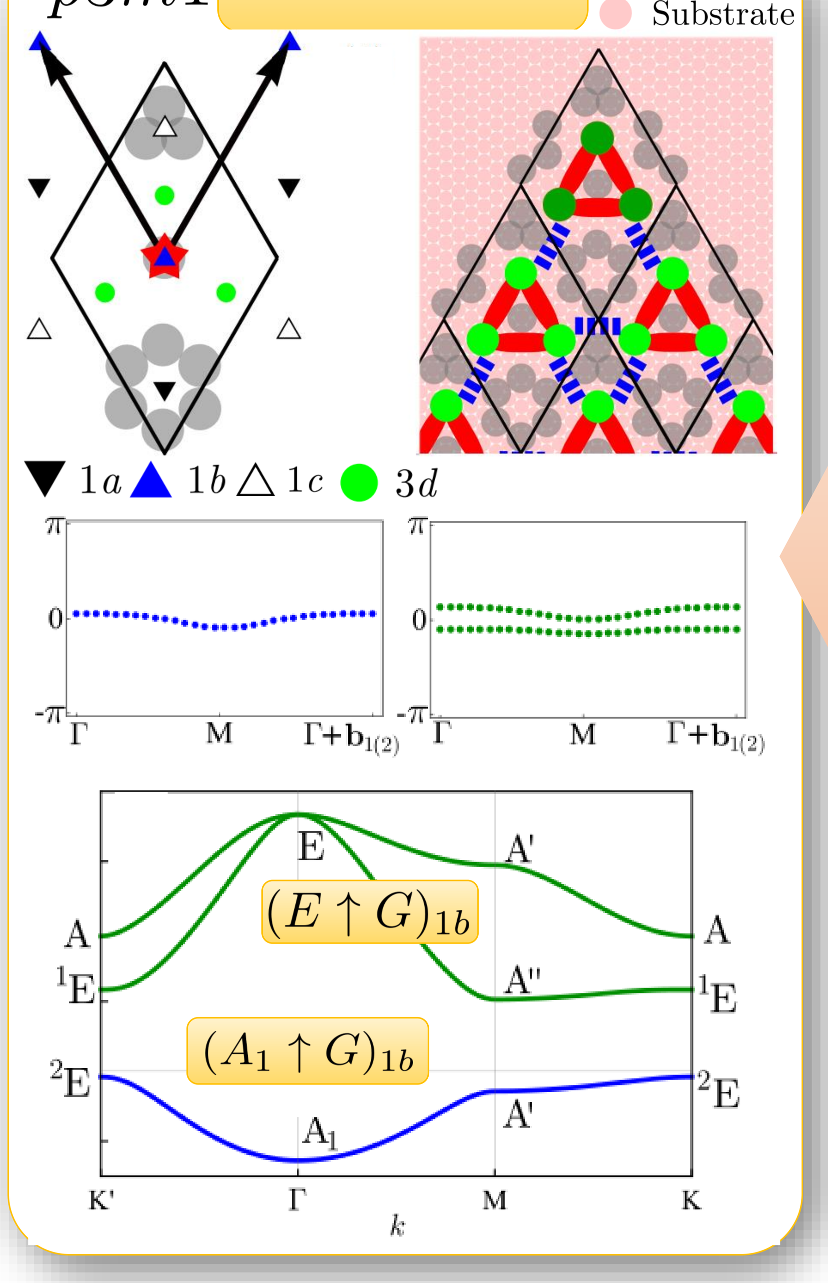
Space group + Irrep assignment + Wannier center

Non-topological band representation + Occupied Wyckoff positions

Trivial/non-trivial classification: trivial and obstructed atomic limits

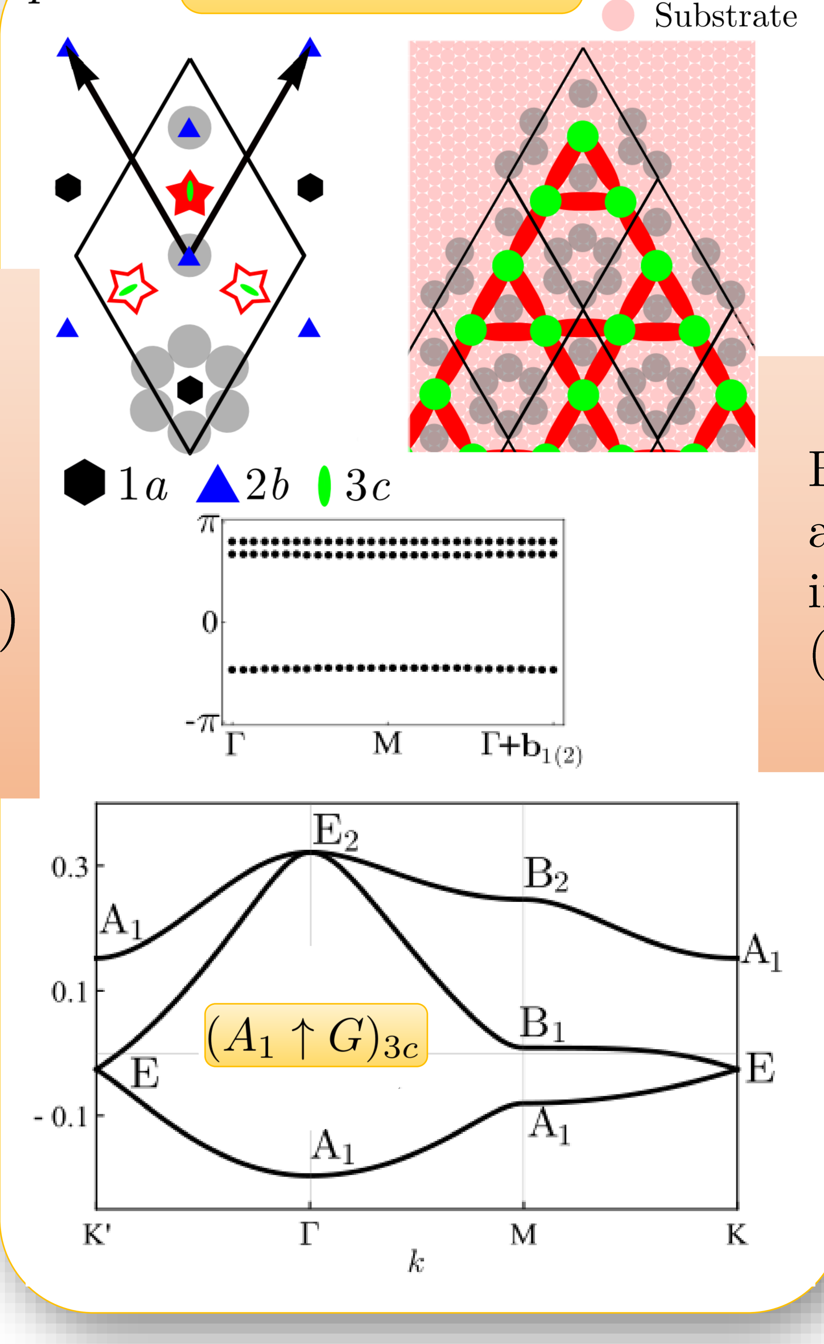
Breathing kagome lattice + Muffin tin

Trivial



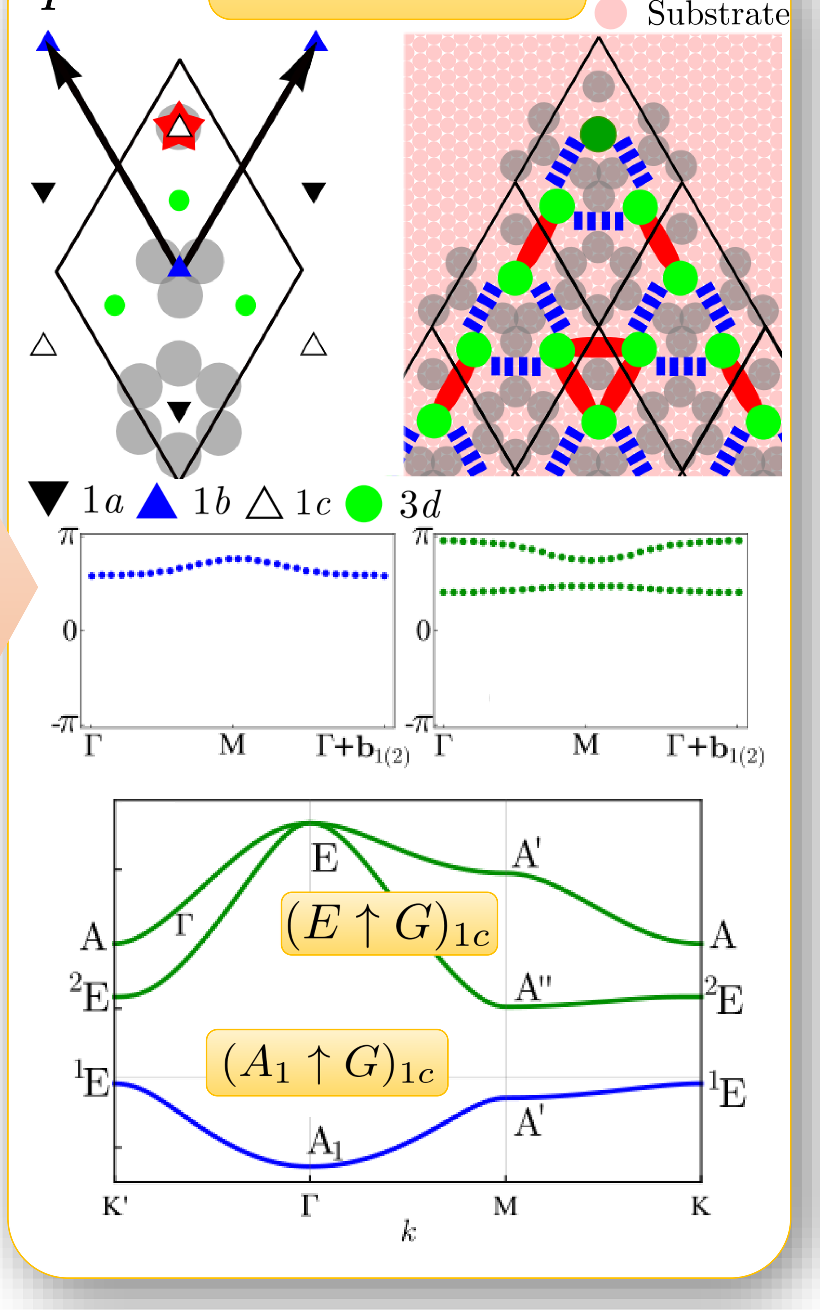
Break C_6 by allowing intra>inter (contracted UC)

Canonical

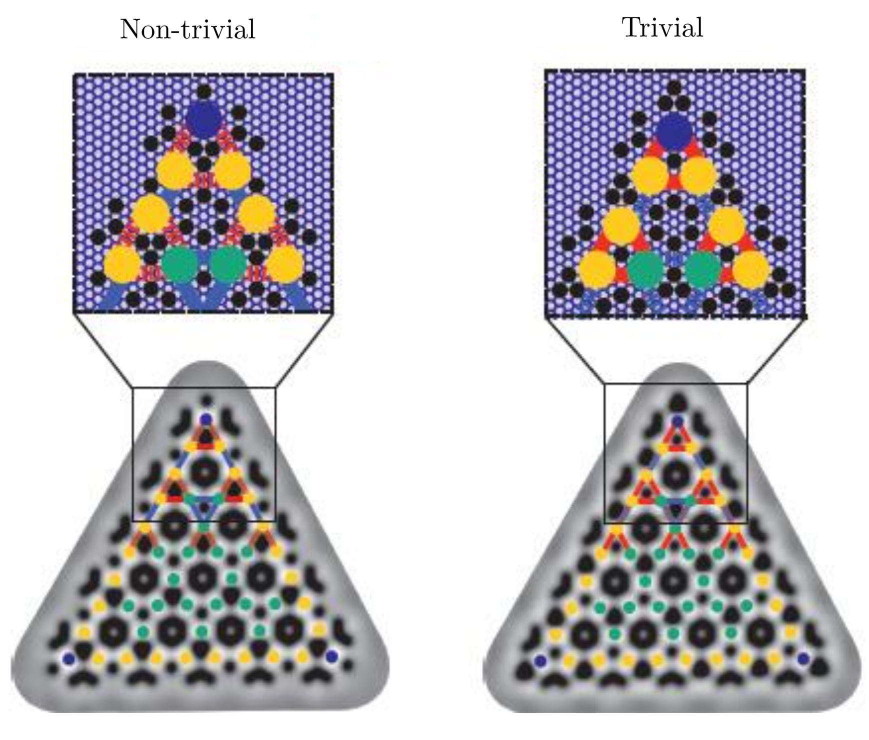


Break C_6 by allowing intra<inter (expanded UC)

Non-trivial



Experimental realization

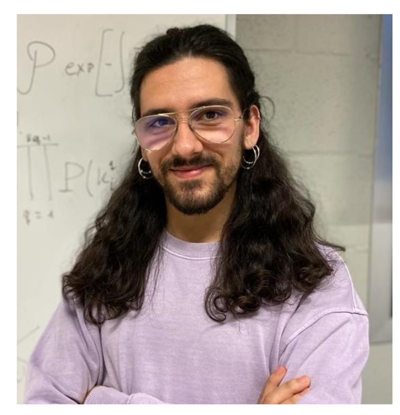


S.N. Kempkes, *et al.* Nature Materials **18**, 1292 (2019).

Conclusions

- The breathing kagome lattice exhibits **two topologically distinct phases**.
- However, these two phases are indeed **non-topological**. They both correspond to (different) **obstructed atomic limits**.
- One of the phases (the non-trivial one) hosts **corner modes**, as well as **edge modes**. Thus, the breathing kagome lattice is not a HOTI by definition.
- The corner modes can be perturbed but never removed, so they are robust.
- This robustness depends on three factors: the symmetry of the lattice, the generalized chiral symmetry and in the connectivity of the lattice site.

Check out this work!



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