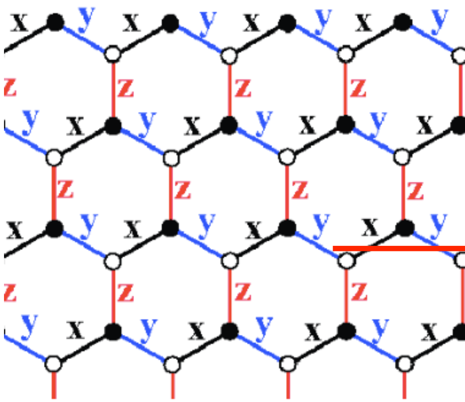
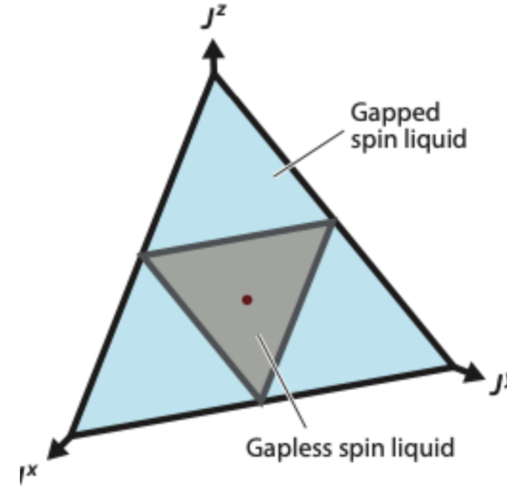
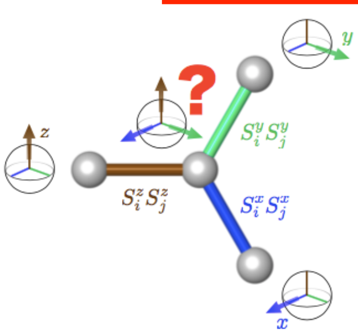
Kitaev Spin Liquids



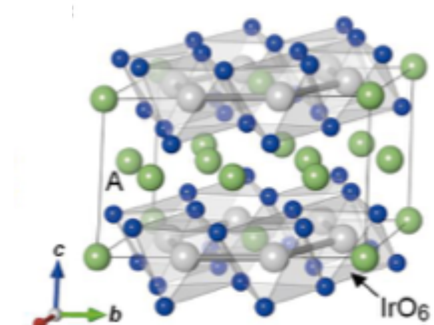
Context
The Model



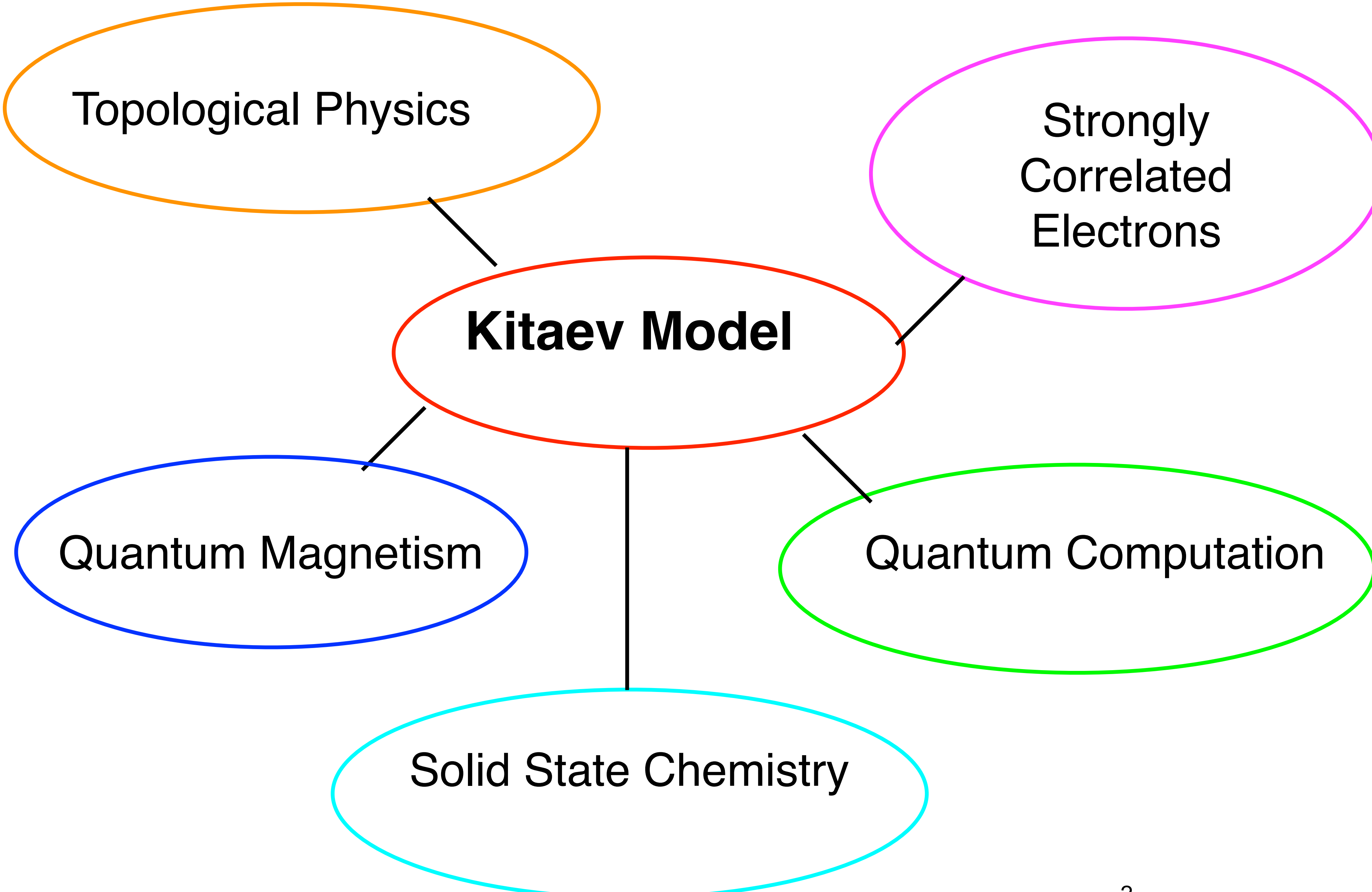
Ying-Ting “Layered Nickelates”
Michael ”Thin-Film Pyrochlore Irridiates”
Skanda “Twisted Bilayer Graphene”



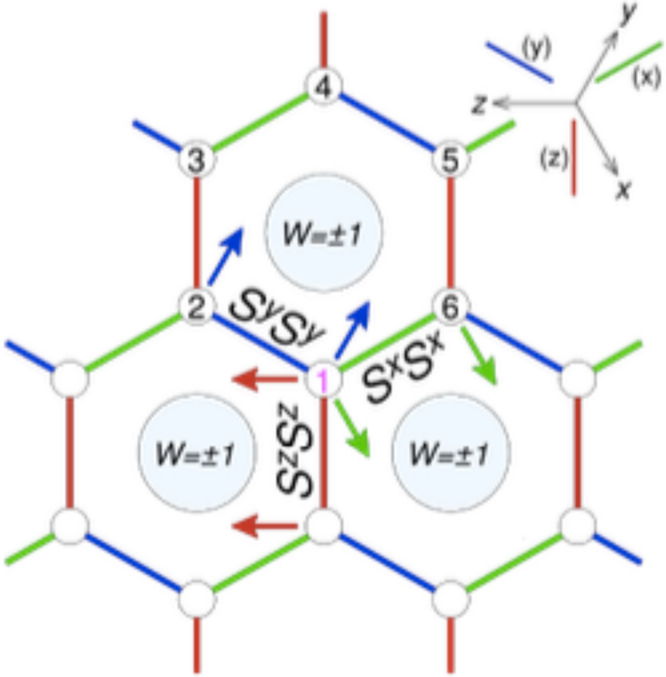
Experimental Realizations



α-A_2IrO_3 (A = Li, Na)


Topological Physics
Strongly Correlated Electrons
Kitaev Model
Quantum Magnetism
Quantum Computation
Solid State Chemistry

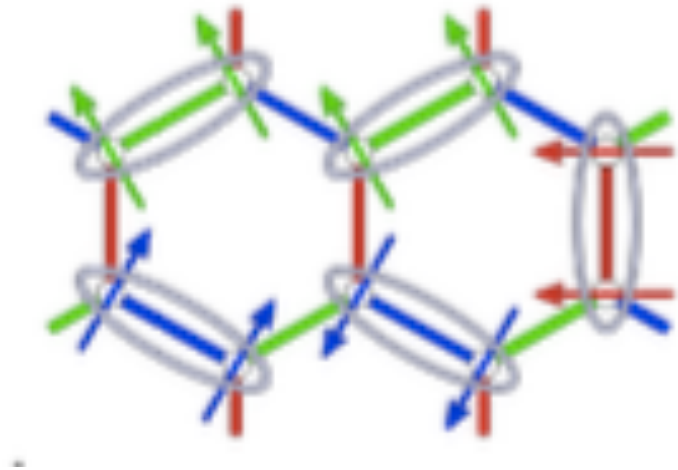
The Kitaev Model on the Honeycomb Lattice



$$H = -\sum_{<ij>_\gamma} K_\gamma S_i^\gamma S_j^\gamma$$

Ising Spins with Bond Anisotropies

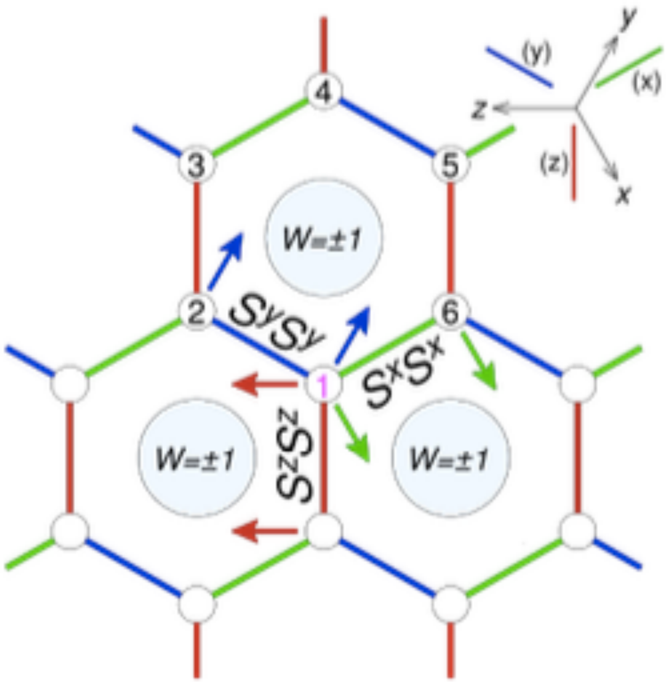
Classical Model



Two "happy" bonds/plaquette

Classical Model has Extensive Ground State Degeneracy

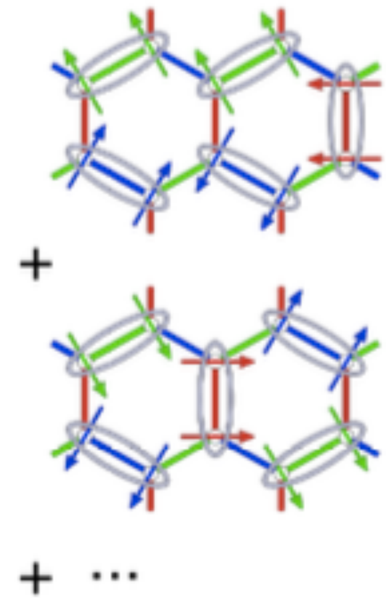
The Kitaev Model on the Honeycomb Lattice



$$H = - \sum_{<ij>_\gamma} K_\gamma S_i^\gamma S_j^\gamma$$

Ising Spins with Bond Anisotropies

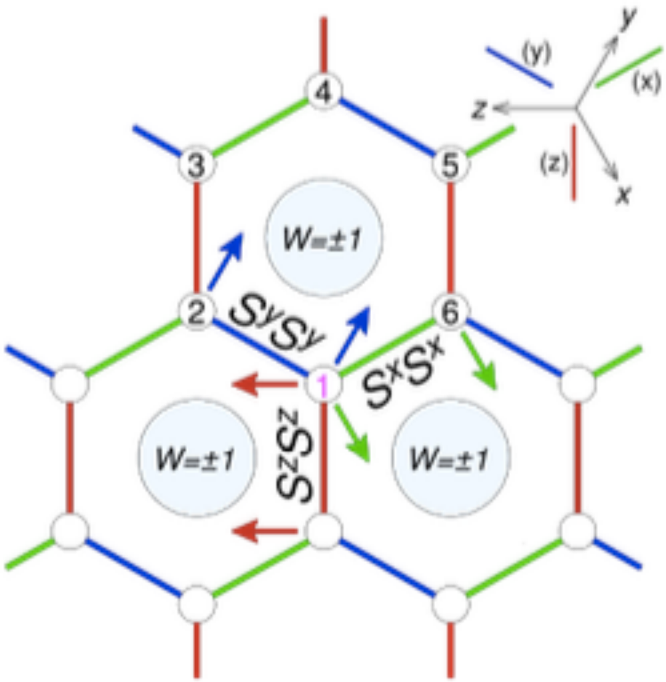
Quantum Model



Superposition of Classical Configurations (similar to RVB)

Highly Entangled Quantum Spin Liquid State

The Kitaev Model on the Honeycomb Lattice



$$H = -\sum_{<ij>_\gamma} K_\gamma S_i^\gamma S_j^\gamma$$

Ising Spins with Bond Anisotropies

$$W_p = 2^6 S_1^z S_2^x S_3^y S_4^z S_5^x S_6^y$$

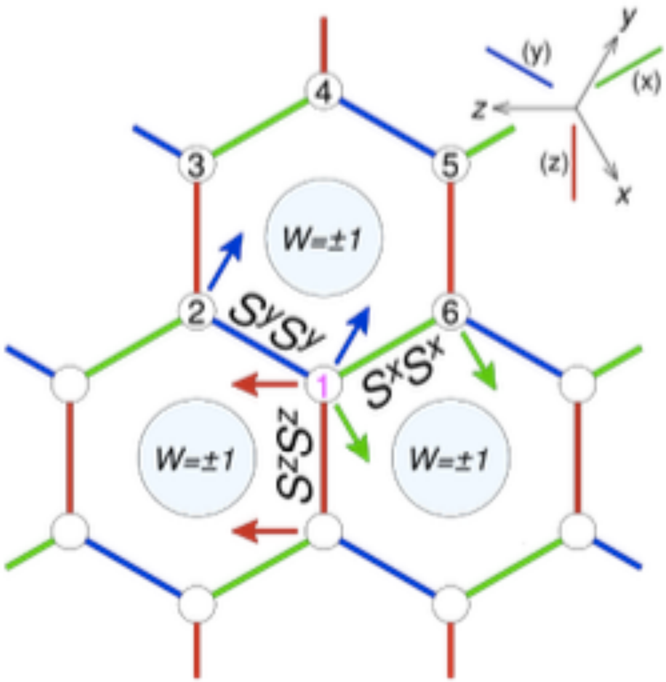
$$S_i^\gamma = \frac{\hbar}{2}\sigma^\gamma$$

$$\sigma^a\sigma^b = \delta_{ab} I + i\epsilon_{abc}\sigma^c$$

$$[\sigma^a, \sigma^b] = 2i\epsilon_{abc}\sigma^c$$

$$[W_p, H] = 0$$

The Kitaev Model on the Honeycomb Lattice



$$H = -\sum_{<ij>_\gamma} K_\gamma S_i^\gamma S_j^\gamma$$

Ising Spins with Bond Anisotropies

$$W_p = 2^6 S_1^z S_2^x S_3^y S_4^z S_5^x S_6^y$$

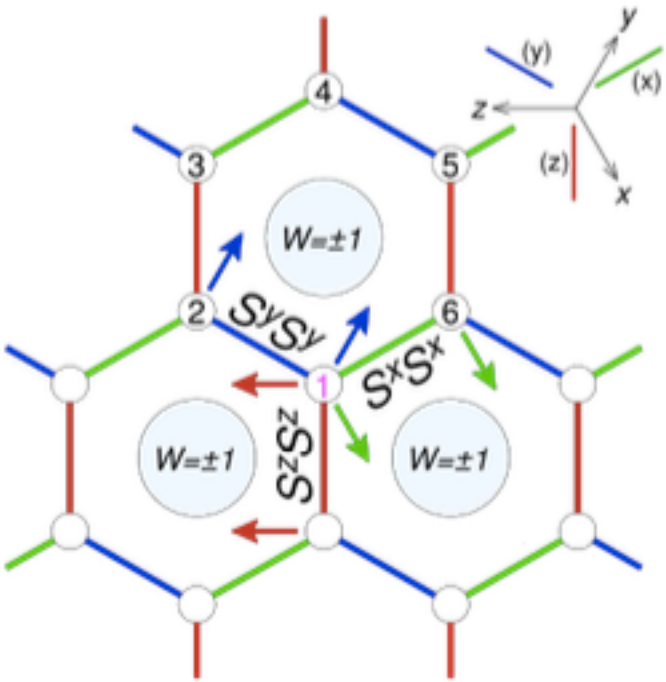
$$[W_p, H] = 0$$

Infinitely Many Conserved Quantities

$$W_p = \pm 1$$

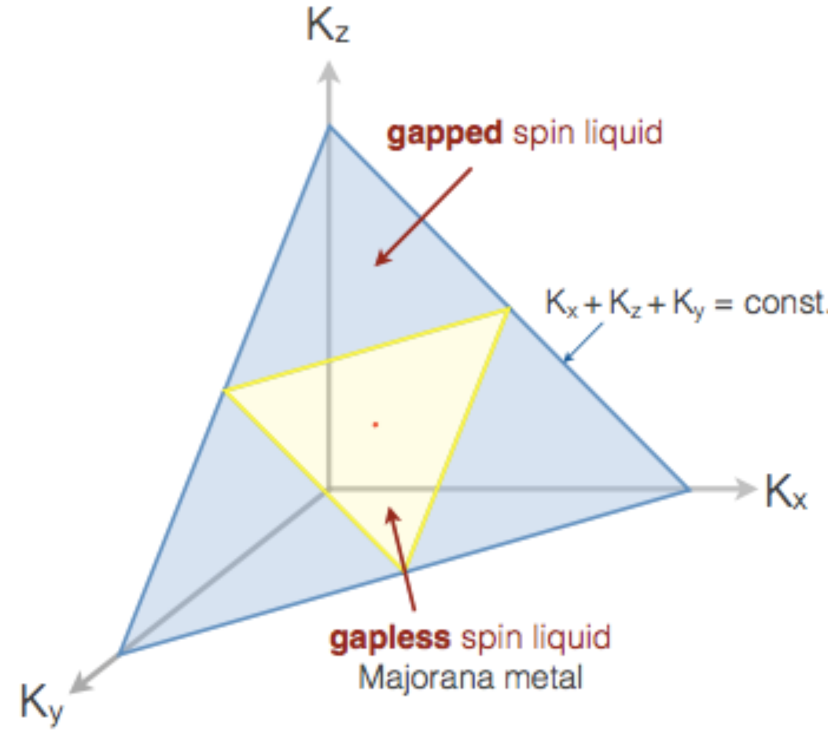
Each many-body eigenstate can be labelled by conserved flux quanta through each hexagon

The Kitaev Model on the Honeycomb Lattice

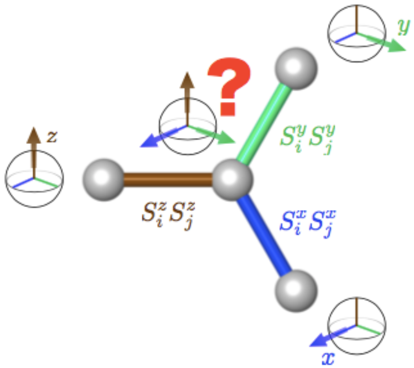


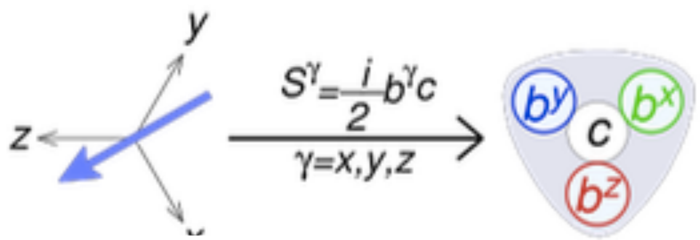
$$H = -\sum_{<ij>_\gamma} K_\gamma S_i^\gamma S_j^\gamma$$

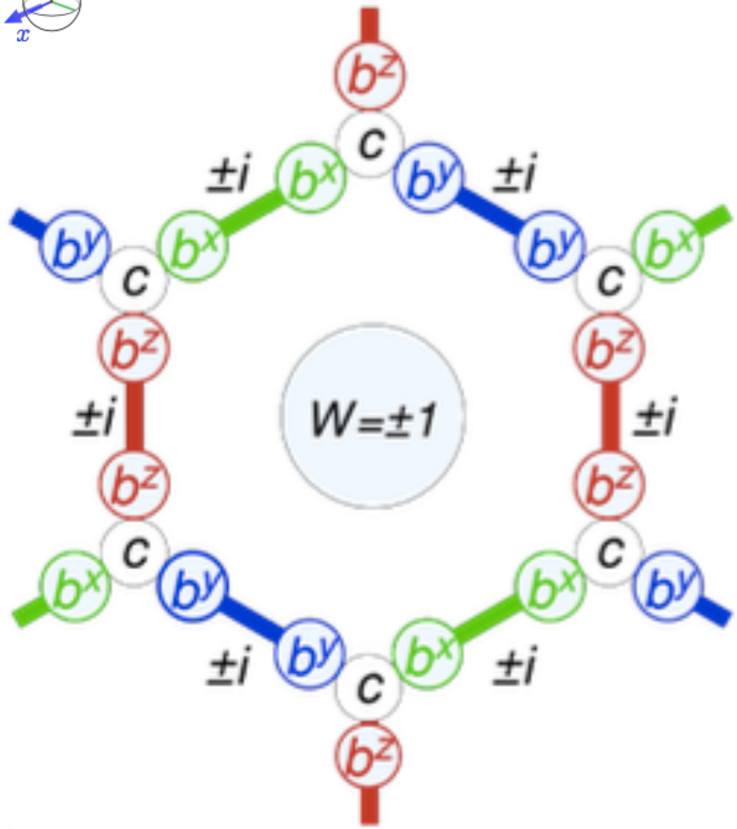
Ising Spins with Bond Anisotropies



The Kitaev Model on the Honeycomb Lattice

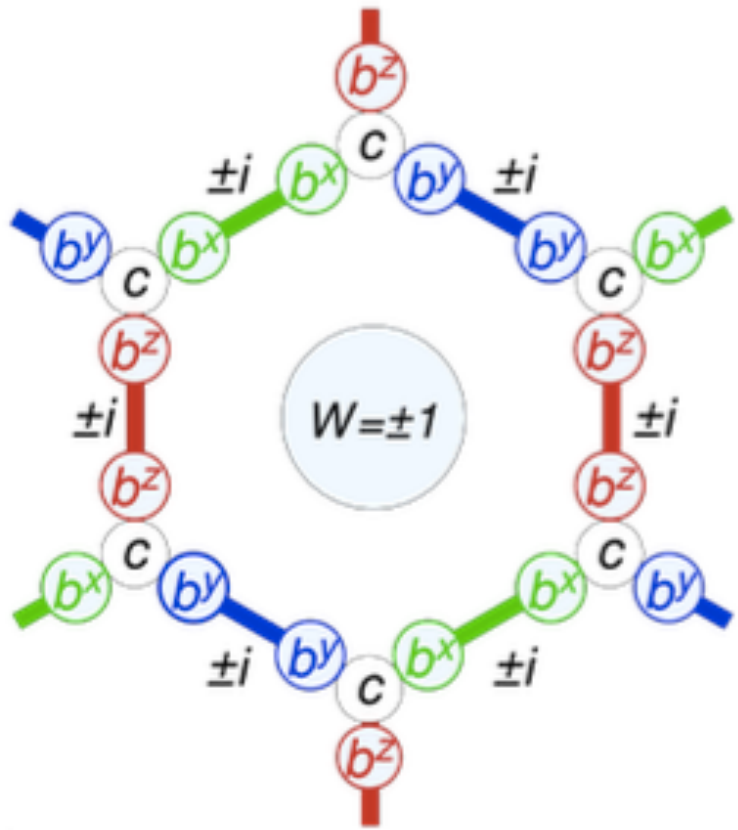






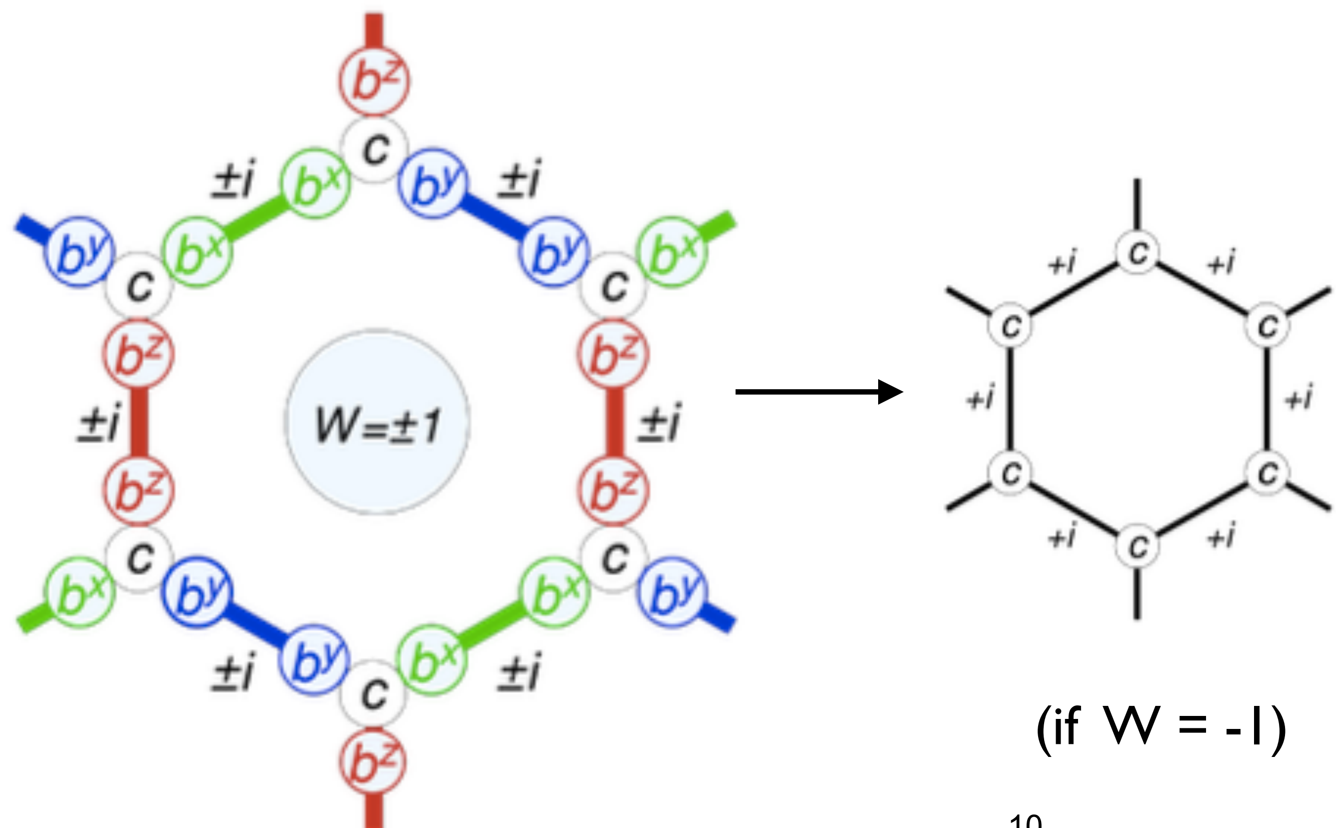
The Kitaev Model on the Honeycomb Lattice

$$H = -\frac{1}{4} \sum_{<ij>_\gamma} K_\gamma u_{ij}^\gamma c_i c_j \qquad (u_{ij}^\gamma = b_i^\gamma b_j^\gamma)$$



The Kitaev Model on the Honeycomb Lattice

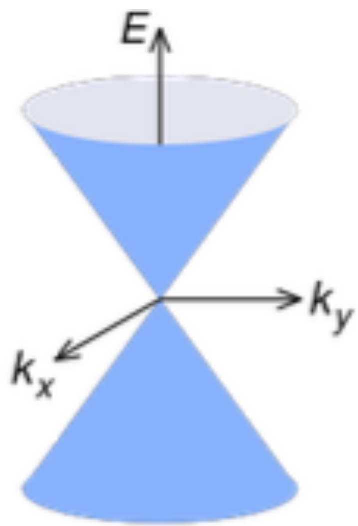
$$H = -\frac{1}{4} \sum_{<ij>_\gamma} K_\gamma u_{ij}^\gamma c_i c_j \qquad (u_{ij}^\gamma = b_i^\gamma b_j^\gamma)$$



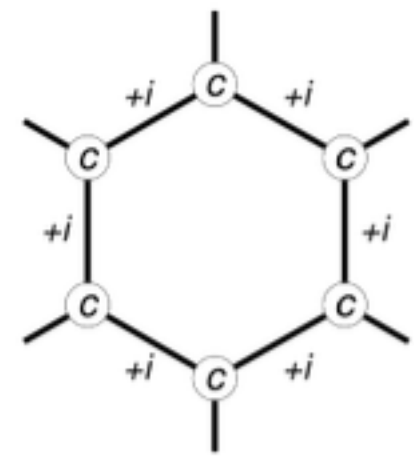
(if W = -1)

The Kitaev Model on the Honeycomb Lattice

$$H = -\frac{1}{4} \sum_{<ij>_\gamma} K_\gamma u_{ij}^\gamma c_i c_j \qquad (u_{ij}^\gamma = b_i^\gamma b_j^\gamma)$$

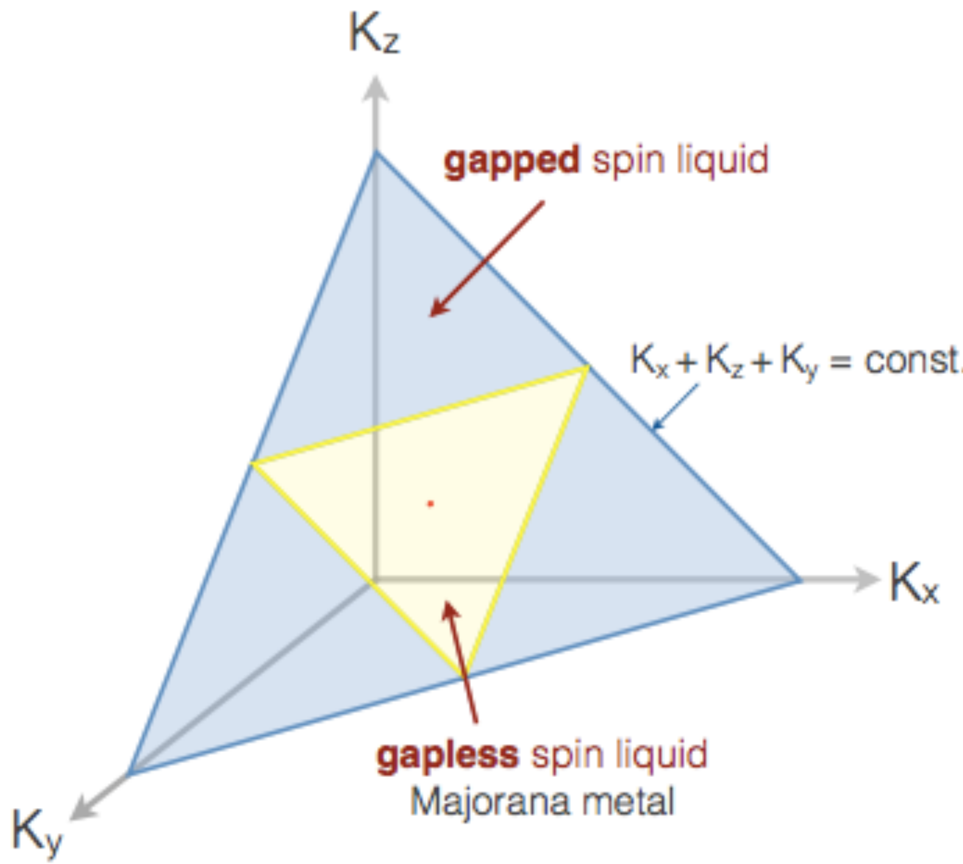


Dirac Dispersion



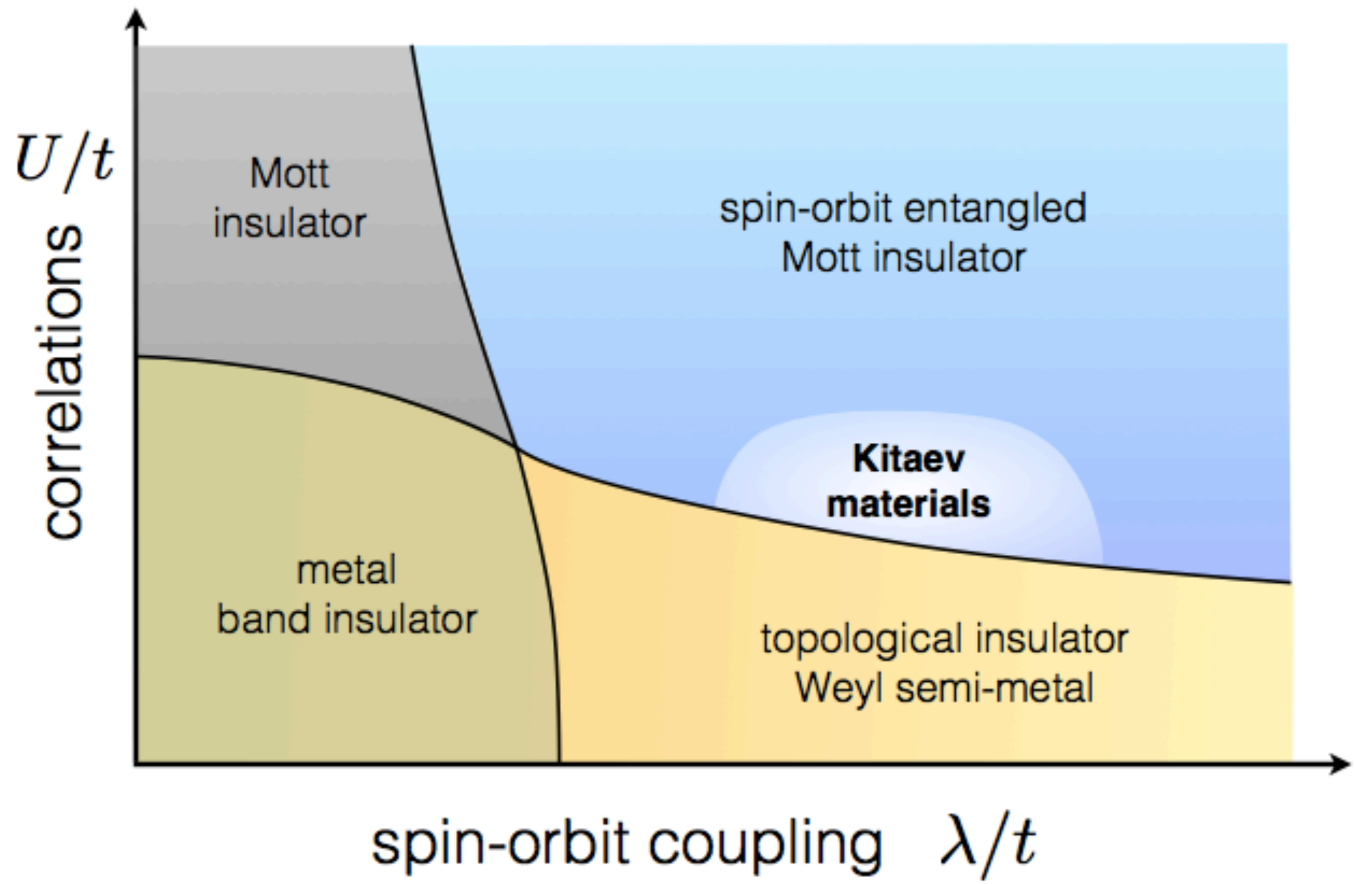
uniform phase

The Kitaev Model on the Honeycomb Lattice



A. Kitaev and C. Laumann, "Topological Phases and Quantum Computation," https://arxiv.org/pdf/0904.2771.pdf

Kitaev Materials



S. Trebst, arXiv 1701.0705

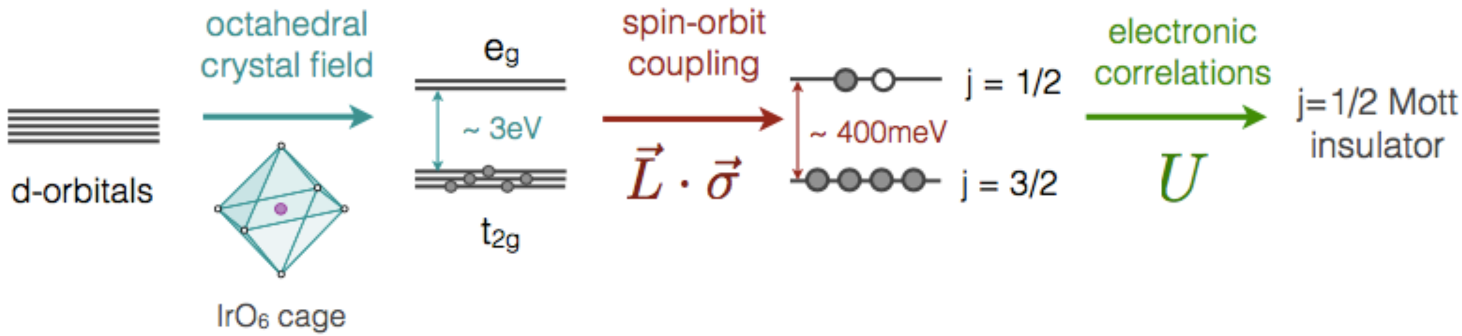


Fig. 2: *Formation of spin-orbit entangled $j = 1/2$ moments for ions in a d^5 electronic configuration such as for the typical iridium valence Ir^{4+} or the ruthenium valence Ru^{3+}.*

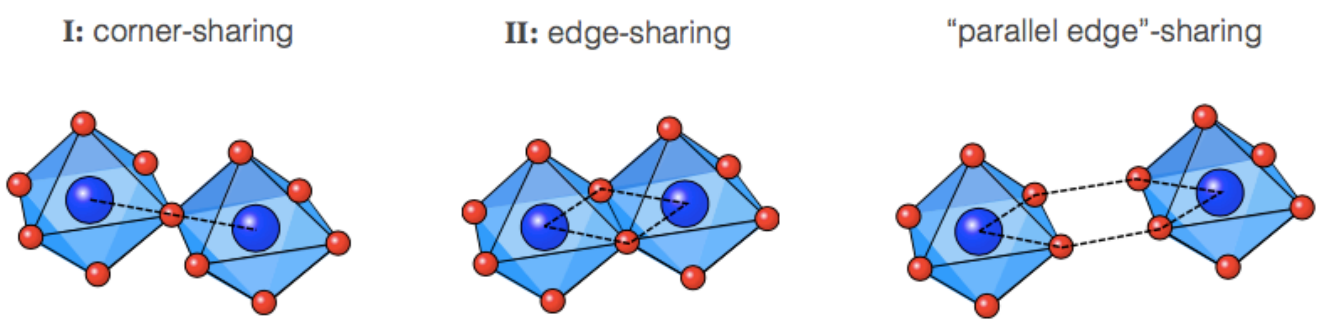


Fig. 3: *Illustration of possible geometric orientations of neighboring IrO_6 octahedra that give rise to different types of (dominant) exchange interactions between the magnetic moments located on the iridium ion at the center of these octahedra. For the corner-sharing geometry (I) one finds a dominant symmetric Heisenberg exchange, while for the edge-sharing geometries (II) one finds a dominant bond-directional, Kitaev-type exchange.*

Ab Initio Calculations

$$H = -\sum_{\gamma-\text{bonds}} J\, \mathbf{S}_i \mathbf{S}_j + K\, S_i^\gamma S_j^\gamma + \Gamma \left(S_i^\alpha S_j^\beta + S_i^\beta S_j^\alpha \right)$$

$$J = \cos\phi, \;\; K = \sin\phi$$

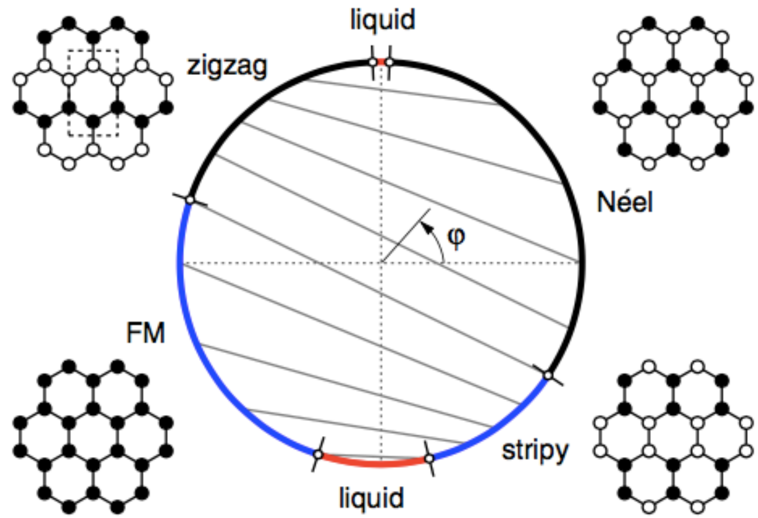


Fig. 6: *Phase diagram of the Heisenberg-Kitaev model, reproduced from Ref. [63].*