Phys525:
Quantum Condensed Matter Physics:
emergent symmetry and phenomena

Topological States, Topological ordered states and SPT


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What do we mean by saying topological matter?

- Two important concepts from 80-90s on topological order (gapped states only)

- Boundary dynamics are important; bulk-edge correspondence emerged during that time (mainly in the context of FQHE).

- “Topological degeneracy”—-that ground states (with TS) can be degenerate. And if not (and if no TS symmetry breaking), non-topological.

- Affleck-Lieb-Mattis theorem on s=1/2 non-topological gapped spin states: breaking

Topological insulators and superconductors (2005~)
(free fermion classification back to 10-fold way)

- topological insulators without symmetry or with Z_1 symmetry—QHE, Haldane lattice model ().

- Topological Insulator with time reversal symmetry —Z_2 topological Insulator

- Topological superfluids without symmetry or with Z_1 symmetry—-p+ip

- topological Superconductors with time reversal symmetry—-(p+ip) X (p-ip)

SPT: symmetry protected topological states (~2010 on)

- A class of states that don't have non-local order or topological order; examples include AKLT, Z2 topological insulators, topological superconductors etc. Not including FQHE, Kitaev spin liquids that are believed to carry non-local order.

Topological Ordered states Vs SpT (Topological states)

FQHE

Kitaev Spin liquids

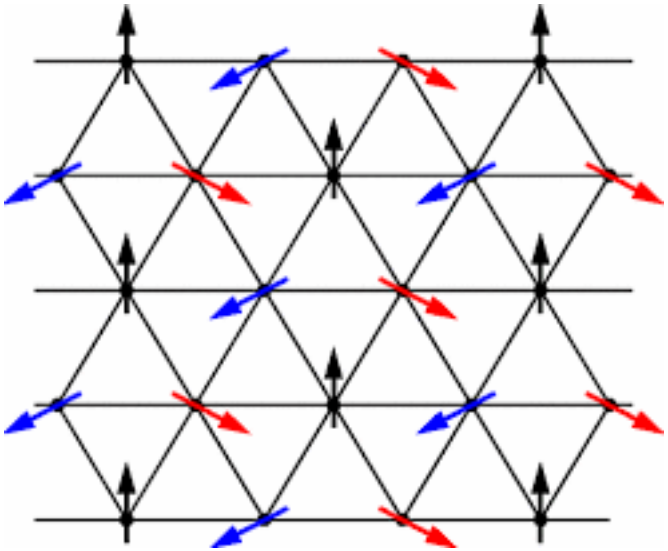
Z_2 - Spin liquids

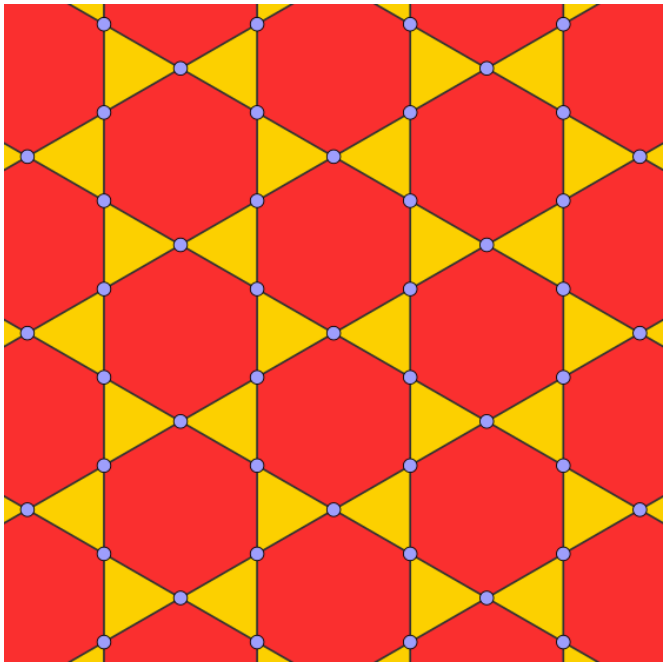
Topological Insulators

Topological Superconductors

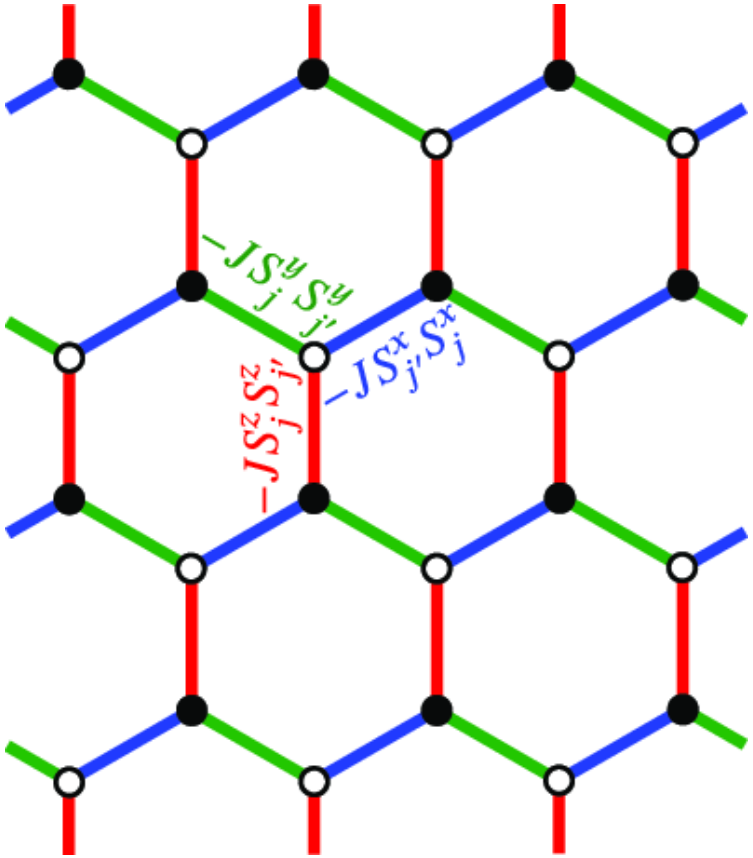
AKLT states (Spin Model)

Triangle and kagaome lattices
(with SU(2) exchange interactions; Z2 spin liquids)



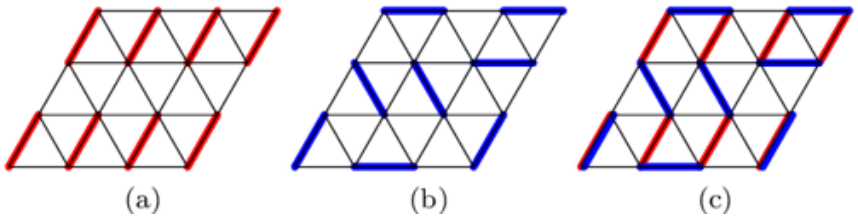


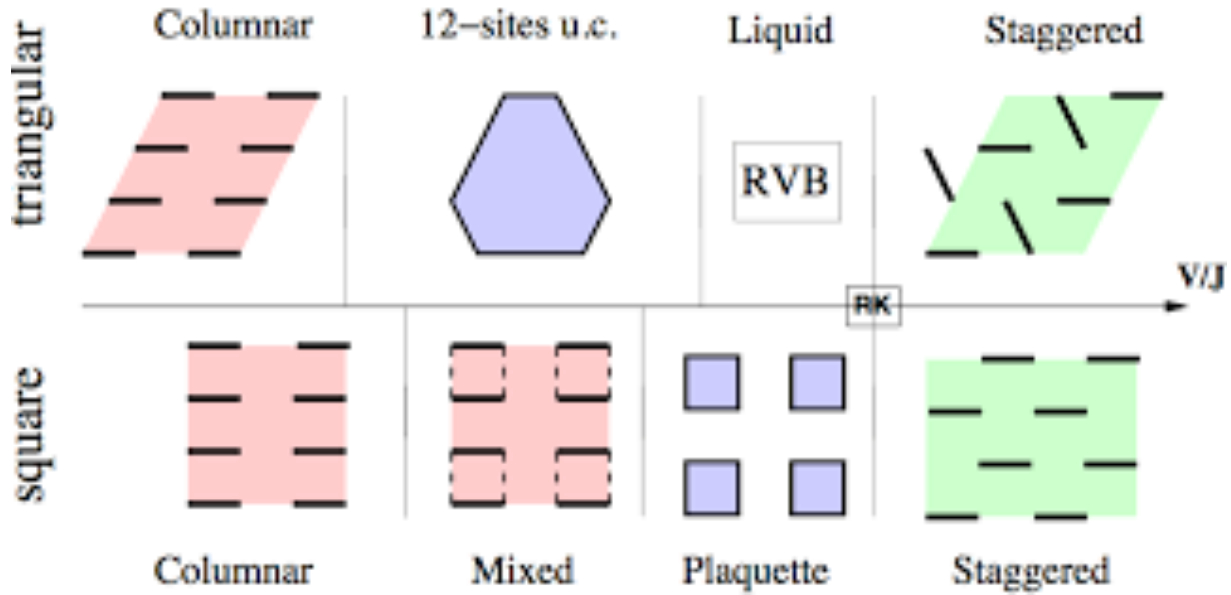
kitaev spin liquid



quantum dimer model

$$H = -t \sum_r \left(|\square\rangle\langle\square| + \text{h.c.} \right)$$
$$+V \sum_r \left(|\square\rangle\langle\square| + |\square\rangle\langle\square| \right)$$
$$-h \sum_l \left(|\text{—}\rangle\langle\bullet\text{—}\bullet| + \text{h.c.} \right)$$
$$-\mu \sum_l \left(|\text{—}\rangle\langle\text{—}| \right),$$





Topological ordered states vs Symmetry protected topological states (~2010)

- Topologically ordered states (TOS) with long range entanglements, or topological entropy; or topological degeneracy on torus etc.

- Symmetry protected topological states (SPT) with short range entanglement entropy; no topological degeneracy on torus etc (discussions on AKLT).