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Edge states and their stability of 2D antiferromagnets

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Introduction

Topological insulator (TI)

Quantum orderings unexplained by local order parameters

- Order parameters are defined global operators…

  ex. Quantum hole state,
  Quantum-spin hole state (Topological Insulator) etc…

Non-trivial state

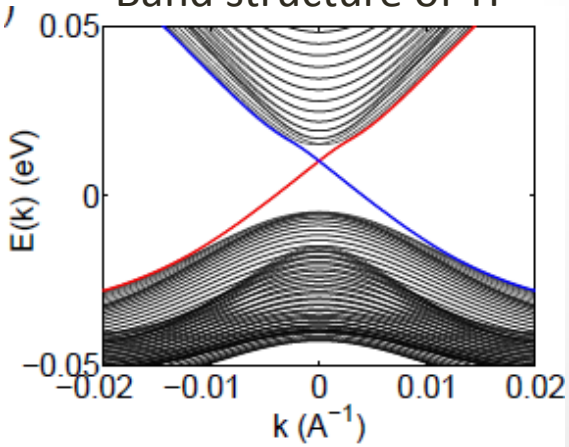
Characteristics of TIs

- **Balk** ▶ Insulatoring
- **Edge** ▶ Metallic

Existence of robust gapless modes against perturbations

▶ ***Bulk-Edge Correspondence***

Band structure of TI



X.-L. Qi and S-.C. Zhang, arviv:1008.2026.

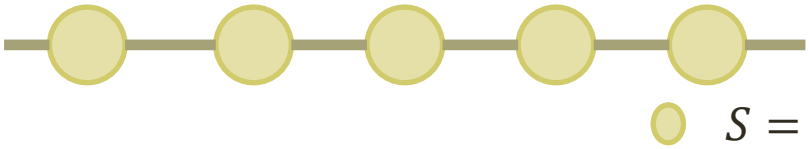
Haldane chain

F. D. M. Haldane, Phys. Lett. A, 93, 464 (1983).

What corresponds to topological insulators in quantum magnets?...

Haldane gap state

Ground state of 1d antiferromagnetic Heisenberg spin chain (AFHC)

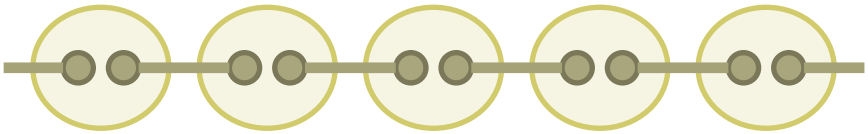


$S = 1\ spin$

$$H_0 = J \sum_i S_i S_{i+1}\ , \qquad J > 0$$

If the spin S is integer value(S=1,2,3,....), an energy gap exists between the ground state and the lowest excited state.

Valence-bond-solid picture for Haldane gap state



Singlet covering

$S = 1/2\ spin$

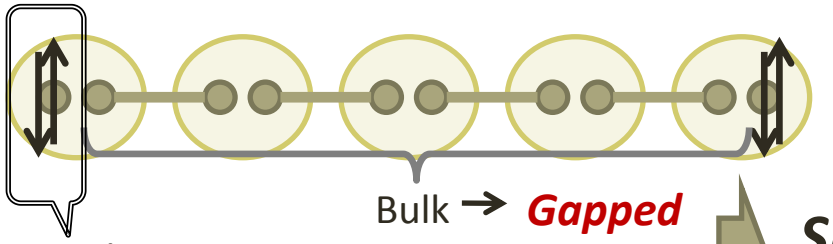
$Singlet$: $\frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle\right)$

Haldane gap state is identified by non-local order parameter.

Ground state of Haldane spin chain

‘Edge state’ of Haldane gap state

S. Qin, et al., Phys. Rev. B 52, 12844 (1995).



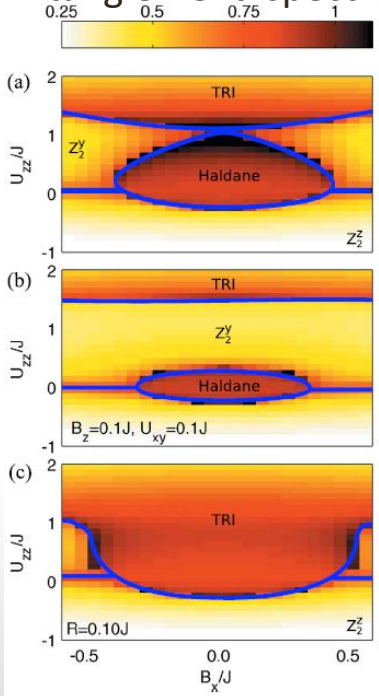
Bulk → ***Gapped***

Edge → ***Gapless***

When we consider the O.B.C.,
free spins appear at the edge…

Similarity to the original TI

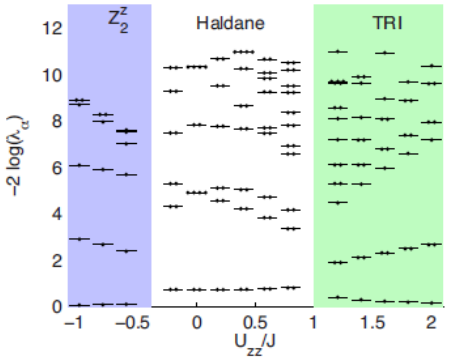
Entanglement spectrum



Another aspect of Haldane gap state

F. Pollmann and E. Berg, and M. Oshikawa, Phys. Rev. B 81, 064439 (2010).

Entanglement spectrum for 1D AFHC with single-ion anisotropy



In Haldane gap phase, all eigen states for entanglement spectrum are doubly degenerated.

The degeneracy is protected by these symmetries…

- Z_2xZ_2
- Time reversal

$$S_j^{x,y,z} \rightarrow -S_j^{x,y,z}$$

- Inversion

$$S_j^{x,y,z} \rightarrow S_{-j+1}^{x,y,z}$$

In this talk...

- What state corresponds to the topological insulator in 2D quantum magnets?
- If exists, how about its stability for perturbations?

ex：2D Haldane gap state

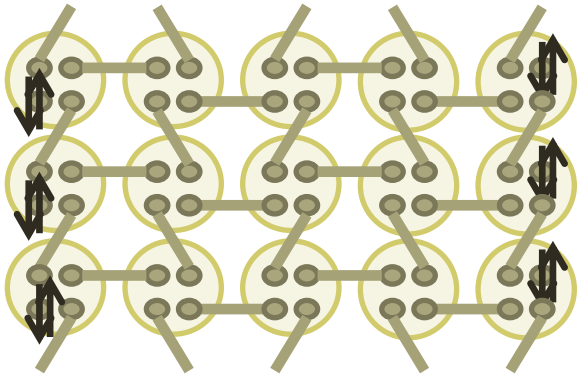
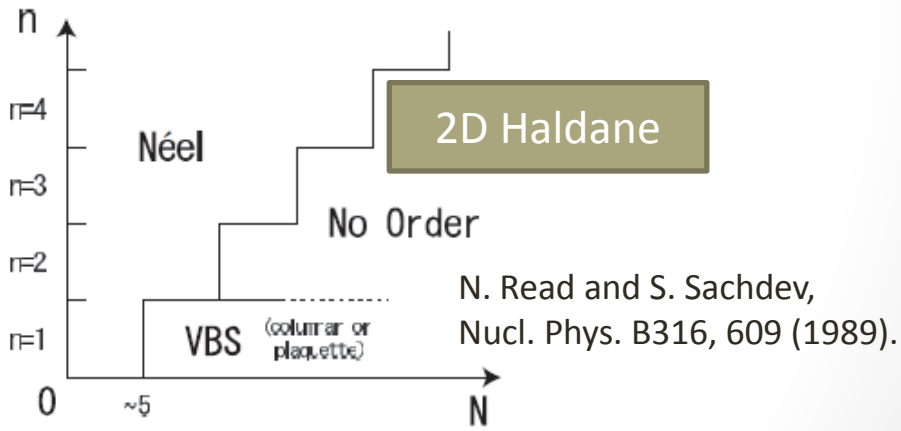


図３：Schimatic spin configuration for **SU(N) spin n=0 (mod 4) model**



N. Read and S. Sachdev, Nucl. Phys. B316, 609 (1989).

Realistic model for experiments?

Stability for Perturbations (DM, Modulation, etc...)?