

Title: Quantum Matter Lecture (230428)

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Collection: Quantum Matter (2022/2023)

Date: April 28, 2023 - 10:15 AM

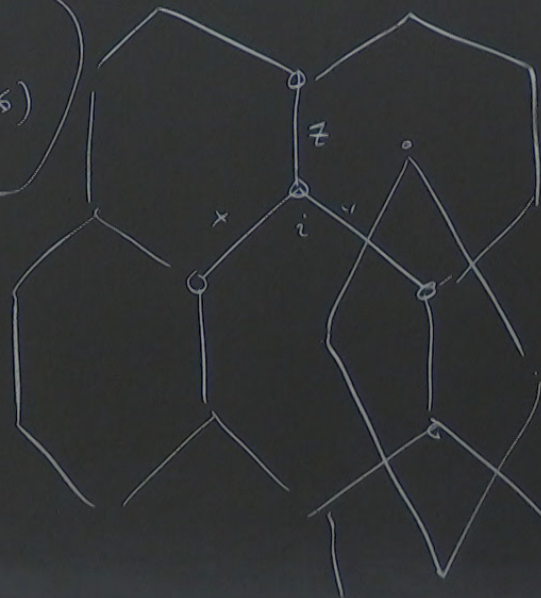
URL: <https://pirsa.org/23040017>

Ann. Phys. 321 2-111 (2006)

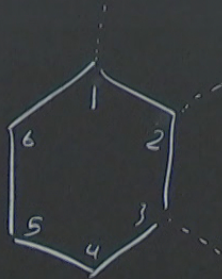
Kitaev & C. Laumann arXiv (2006)

$J > 0$

$$H = J \sum_{\langle i,j \rangle} \vec{S}_i \cdot \vec{S}_j$$



$$|\uparrow \uparrow\rangle$$



$$S_i^z = S_i^x S_i^y$$

$$(S_1^+ S_2^- + S_1^- S_2^+) |\uparrow \downarrow\rangle \rightarrow |\downarrow \uparrow\rangle$$

$$\hat{B}_P = (S_1^z S_2^+ S_3^- S_4^z S_1^- S_2^-)$$

$$|\uparrow \downarrow\rangle - |\downarrow \uparrow\rangle$$

$$= (S_1^y S_2^y S_3^+ S_4^+ S_3^- S_4^- \dots)$$

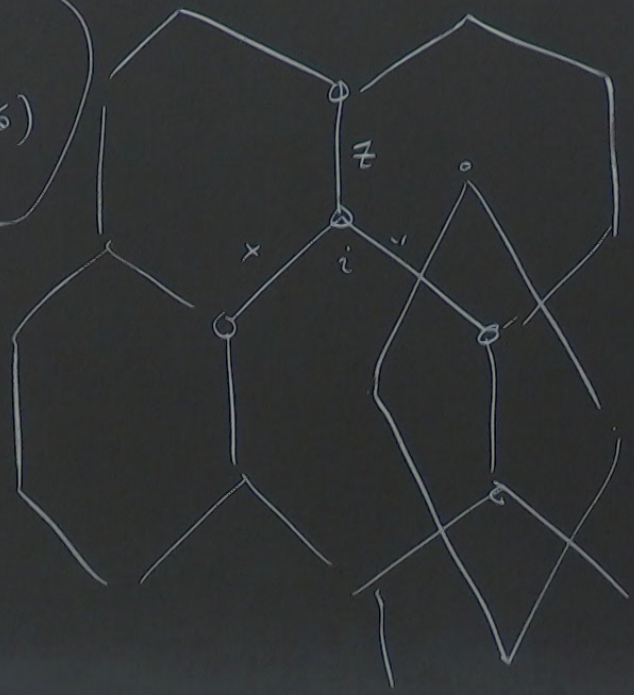
$$J \left(\sum_{\langle ij \rangle_x} S_i^x S_j^x + \sum_{\langle ij \rangle_y} S_i^y S_j^y + \sum_{\langle ij \rangle_z} S_i^z S_j^z \right)$$

$$(\hat{B}_P + I) = 0$$

Sci 2-III (2006)

$$H = J \sum_{\langle i,j \rangle} \vec{s}_i \cdot \vec{s}_j$$

v. C. Laumann arXiv (2006)

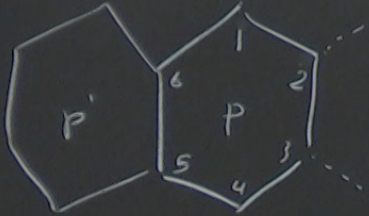


$$\vec{s}_i \cdot \vec{s}_j = (s_i^x s_j^x + s_i^y s_j^y + s_i^z s_j^z)$$

2N

N

$$H = J \sum_{\langle i,j \rangle} s_i^x s_j^x$$



$$s_i^+ = s_i^- s_2^+$$

$$\hat{B}_{p,2} = +1$$

7)

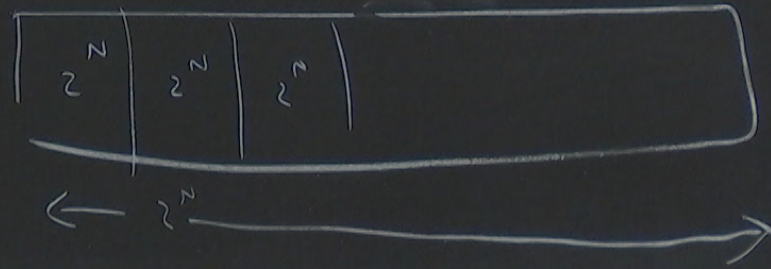
$$\hat{B}_p = (s_1^z s_2^+ s_3^- s_4^z s_5^- s_6^+)$$

$$B_p = \pm 1$$

$$= (s_1^- s_2^- s_3^+ s_4^+ s_5^- s_6^- \dots)$$

z^z
 z^z

$$(\hat{B}_{p,2} + 1) = 0$$



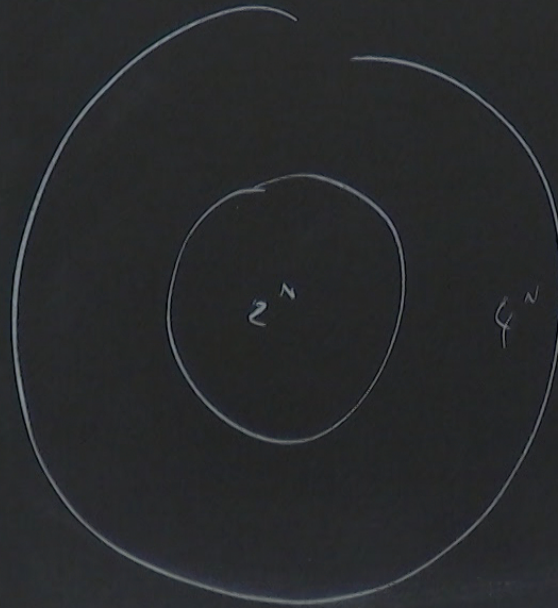
$$\sum s_i^z s_{i+1}^z$$

$$S_i^+ = C_{i\uparrow}^+ C_{i\downarrow}$$

 z^2

$$S_i^- = (n_{i\uparrow} - n_{i\downarrow})$$

$$n_{i\uparrow} + n_{i\downarrow} = 1$$



$$\sqrt{2} \times \sqrt{2}$$
$$C^\dagger = a_i + i b_i$$

$$a_i = 1$$

$$\frac{1}{2} \ln 2$$

\Downarrow

$$\{a_i, a_j\} = 2 \delta_{ij}$$

$$0 \sqrt{2}$$

$$\{a_i, b_j\} = 0$$

Emory of Kivelson

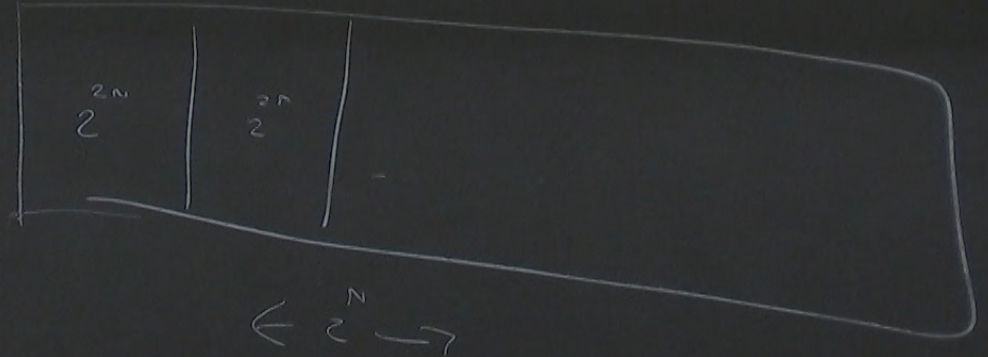
$C_{10}, C_{12}, C_{14}, C_{12}$

$$S_1^x = C_{10} C_{10}$$

$$S_1^y = C_{10} C_{14}$$

$$S_1^z = C_{10} C_{12}$$

$$C_{10} C_{12} C_{14} C_{12} = 1$$



$$\sum_i^x \sum_j^x = C_{i_0} C_{j_0} \boxed{C_{i_x} C_{j_x}} \hat{u}_{i_j x}$$

$$(C_{i_x} C_{j_x})^2 = 1$$

$$\boxed{[H, \hat{u}_{i_j x}] = 0}$$

$$H = \sum_{\langle i, j \rangle_x} C_{i_0} C_{j_0} \hat{u}_{i_j x} + \sum_{\langle i, j \rangle_x} C_{i_x} C_{j_x}$$

$$\sum_i^x \sum_j^x = c_{i0} c_{j0} \boxed{c_{ix} c_{jx}} \quad \boxed{[H, \hat{u}_{ijx}] = 0}$$

$$(c_{ix} c_{jx})^2 = 1$$

$$H = \mathcal{J} \left(\sum_{\langle i, j \rangle_x} c_{i0} c_{j0} \hat{u}_{ijx} + \sum_{\langle i, j \rangle_x} c_{i0} c_{j0} \hat{u}_{ijy} + \sum c_{i0} c_{j0} \hat{u}_{ijz} \right)$$

$$\hat{u}_{ij\alpha}$$

$$c_{j\alpha} \boxed{c_{i\alpha} c_{j\alpha}}$$

$$\boxed{[H, \hat{u}_{ij\alpha}] = 0}$$

$$(c_{i\alpha} c_{j\alpha})^2 = 1$$

$$\left(+ \sum_{\langle i, j \rangle_\alpha} c_{i\alpha} c_{j\alpha} \hat{u}_{ij\alpha} + \sum c_{i\alpha} c_{j\alpha} \hat{u}_{ij\alpha} \right)$$

$$\hat{u}_{ij\alpha} \rightarrow \tau_i \hat{u}_{ij} \tau_j$$

$$c_{i\alpha} \rightarrow \tau_i \hat{u}_{ij\alpha}$$