Title: PSI 2019/2020 - Quantum Matter Part 1 - Lecture 11

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Collection: PSI 2019/2020 - Quantum Matter Part 1

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Symmetry Breaking

$[H(\lambda), T] = 0$ T is a global symmetry

e.g. $T = \bigotimes_{j \in \Lambda} \sigma_j^x$

$\lambda > \lambda_c$ GS is unique $\Leftrightarrow$ $[\psi_0, T] = 0$

There is Δ $\Rightarrow \langle 0 | AB | 0 \rangle \sim e^{-d_{AB}/\xi}$

$\lambda < \lambda_c$ degeneracy in the GS e.g. $\mathcal{L} = \text{span}\{|0\rangle^{\otimes N}, |1\rangle^{\otimes N}\} = \text{span}\left\{\frac{|0\rangle^{\otimes N} \pm |1\rangle^{\otimes N}}{\sqrt{2}}\right\}$

$|\phi^+\rangle, |\phi^-\rangle$

$T |0\rangle^{\otimes N} = |1\rangle^{\otimes N}$

$\| [|0\rangle\langle 0|^{\otimes N}, T] \|$ is max over $\mathcal{L}$ unique

$\langle \phi^+ | \sigma_i^z \sigma_j^z | \phi^+ \rangle \sim n_0^2(1)$ Long-Range order

$\langle \sigma_i^z \rangle_{\psi_0 \in \mathcal{L}} \neq 0$ Spontaneous symmetry breaking

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$\langle \phi^+ | \sigma_i^z | \phi^+ \rangle = 0$

$|0\rangle^{\otimes N} \xrightarrow{T} |1\rangle^{\otimes N}$ global (?)

$|\phi^+\rangle \xrightarrow{\sigma_i^z} |\phi^-\rangle$ local

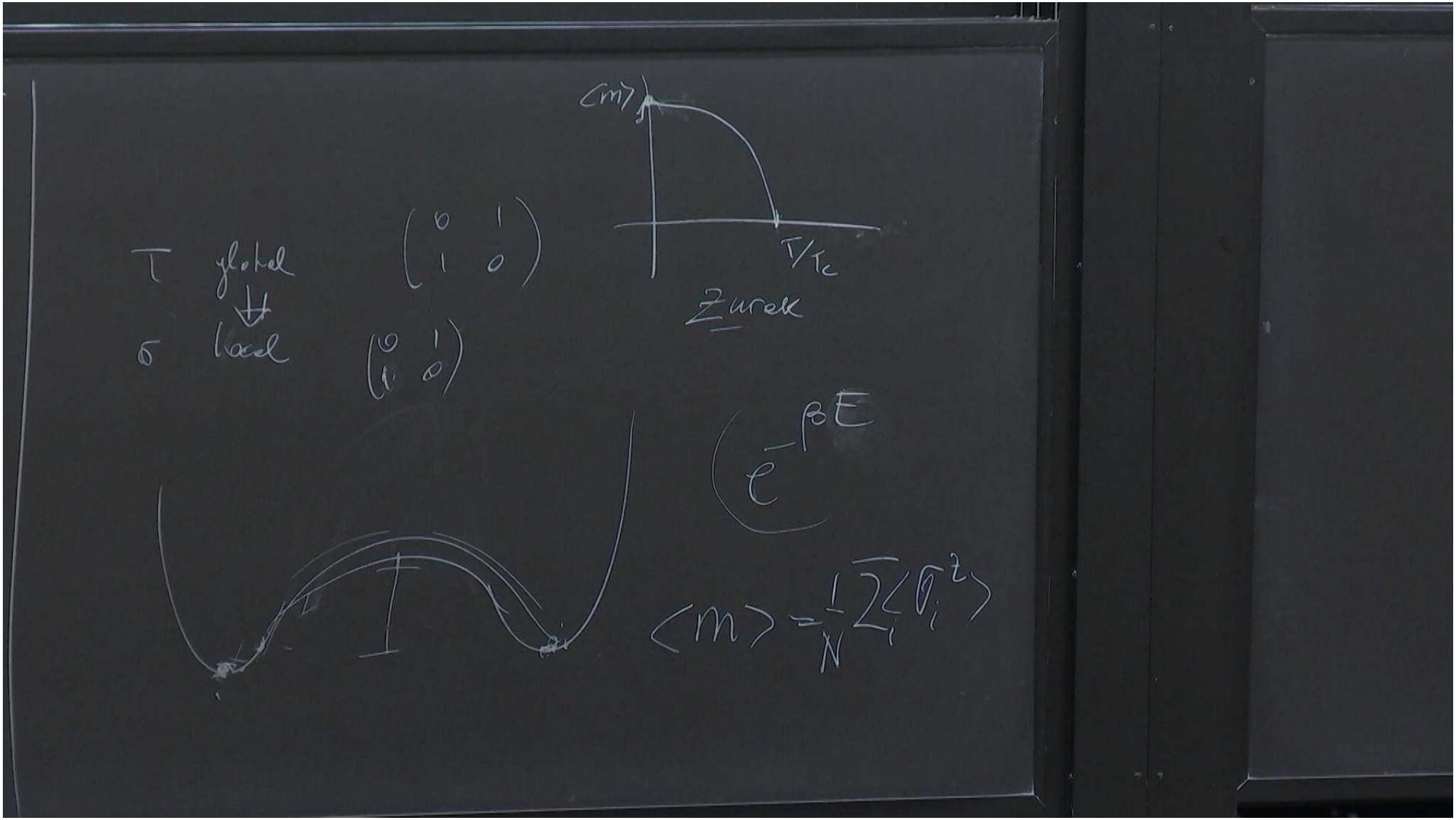
$\longrightarrow$ fragile

- dans $\mathcal{L}$

$\frac{|0\rangle^{\otimes N} \pm |1\rangle^{\otimes N}}{\sqrt{2}}$

$|\phi^+\rangle, |\phi^-\rangle$

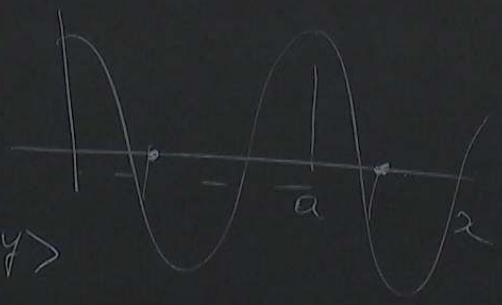
Unique


T global
σ local
Zurek
T/Tc
$e^{-\beta E}$
$\langle m \rangle = \frac{1}{N} \sum_i \langle \sigma_i^z \rangle$

Quantum Gauge Theory (Lattice)

Particle on a straight line $\mathcal{H} = \overset{\text{span}}{\{}|x\rangle : x \in \mathbb{R}\}$

$$H = \frac{p^2}{2m} + V\cos\frac{2\pi x}{a}$$

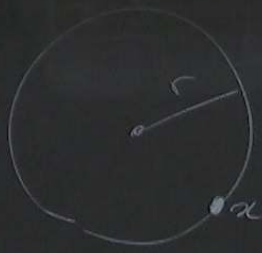


translation operator $T_y|x\rangle = |x+y\rangle$

$[T_a, H] = 0$ symmetry

Particle on a circle

$a = 2\pi r$



$\mathcal{H} = \{ |x + ka\rangle \; ; \; x \in \mathbb{R}, k \in \mathbb{N} \}$

$x \longrightarrow |x\rangle$

$x + a \longrightarrow |x + a\rangle$

$x \bmod a \; ; \; x \in \mathbb{R}$

$|x\rangle \equiv |x + a\rangle$

$\mathcal{H}_{gauge} = \{ |x+ka\rangle \; ; \; x \in \mathbb{R}, k \in \mathbb{N} \}$

Gauge structure

$T_a |x\rangle = |x+a\rangle = |x\rangle$

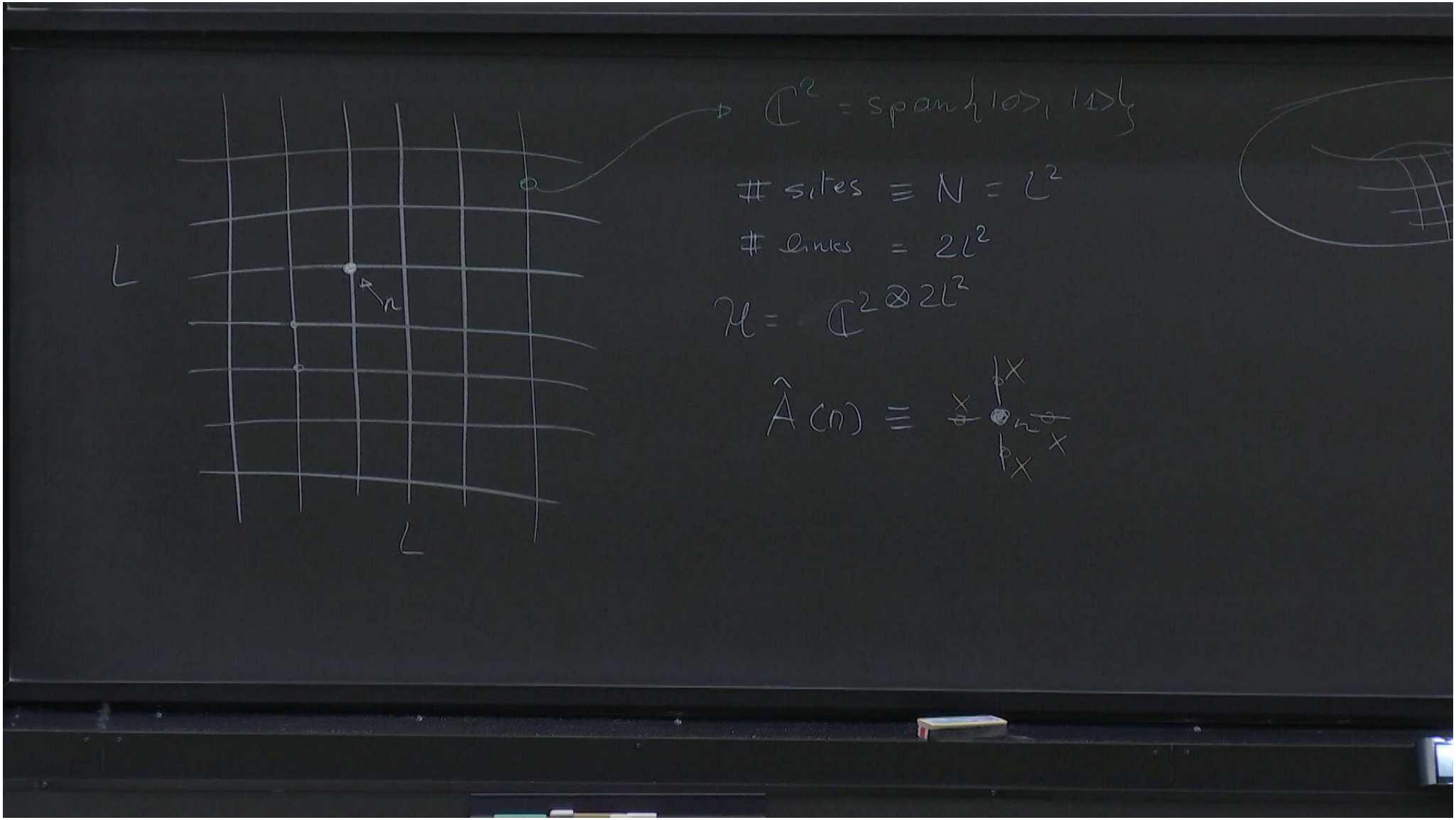
gauge "transf"

do - nothing

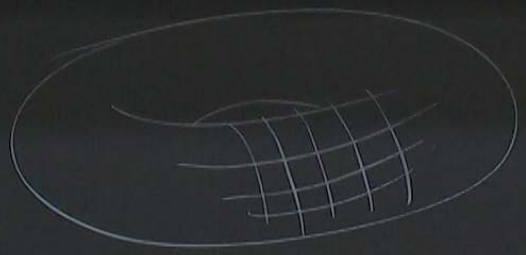
$[H, T_a] \neq 0$?

$|\psi\rangle \in \mathcal{H}_{gauge}$

$H|\psi\rangle \notin \mathcal{H}_{gauge}$


$\mathbb{C}^2 = \mathrm{span}\{|0\rangle, |1\rangle\}$
sites $\equiv N = L^2$
links $= 2L^2$
$\mathcal{H} = \mathbb{C}^2 \otimes 2L^2$
$\hat{A}(n) \equiv$
L
n
L

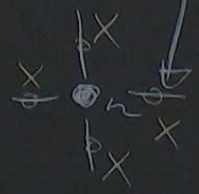
$\mathbb{C}^2 = \text{span}\{|0\rangle, |1\rangle\}$



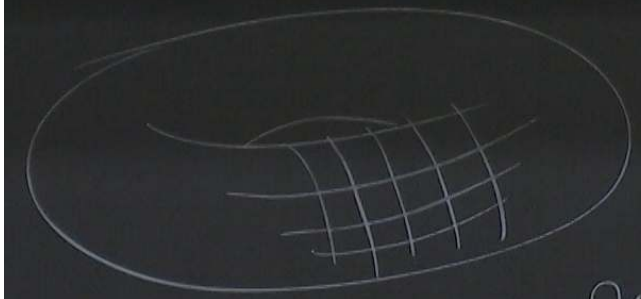
$\#\,\text{sites} \equiv N = L^2$

$\#\,\text{links} = 2L^2$

$\mathcal{H} = \mathbb{C}^2 \otimes 2L^2$

$\hat{A}(n) \equiv$  $= \prod_{\ell \in n} \sigma^x_\ell$

$|\psi\rangle \in \mathcal{H} \xrightarrow{A(n)} A(n)|\psi\rangle$



$$\mathcal{H}_{gauge} = \{ |\psi\rangle \in \mathcal{H} : A(n)|\psi\rangle = |\psi\rangle \}$$

$$\mathcal{H}_{gauge} = \{ |\alpha\rangle \in \mathcal{H} : T_e|\alpha\rangle = |\alpha\rangle \}$$

σ_e^x

$n)|\psi\rangle$