

Title: 13/14 PSI - Condensed Matter Review - Lecture 8

Date: Feb 06, 2014 09:00 AM

URL: <http://pirsa.org/14020042>

Abstract:

ψ that has corr. length χ

$$|\langle \hat{O}_P \hat{O}_Q \rangle_c| \leq e^{-\frac{d_{PQ}}{\chi}}$$

$$\psi \rightarrow U_H(t) \psi$$

ψ that has corr. length χ

$$|\langle \hat{O}_P \hat{O}_Q \rangle_c| \leq C_1 e^{-\frac{d_{PQ}}{\chi}}$$

$$\psi \rightarrow U_H(t) \psi = \psi(t)$$

$$|\langle \hat{O}_A \hat{O}_B \rangle_c^{\psi(t)}| = |\langle \hat{O}_A(t) \hat{O}_B(t) \rangle_c|$$

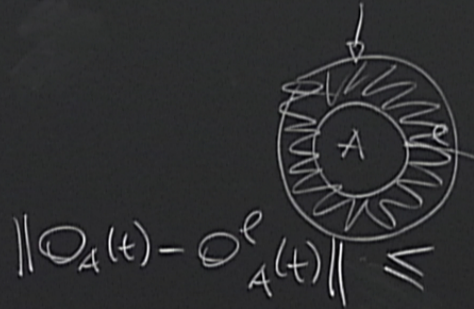
Lemma $\mathcal{O}_A(t) \sim \mathcal{O}_A^l(t) \equiv \text{Tr}_S \mathcal{O}_A(t) \otimes \frac{\Pi_S}{d_S}$



$S = \{ \text{spins at distance } > l \text{ from } A \}$

Lemma $\mathcal{O}_A(t) \sim \mathcal{O}_A^l(t) \doteq \text{Tr}_S \mathcal{O}_A(t) \otimes \frac{\Pi_S}{d_S} =$

$S = \{ \text{spins at distance} > l \text{ from } A \}$

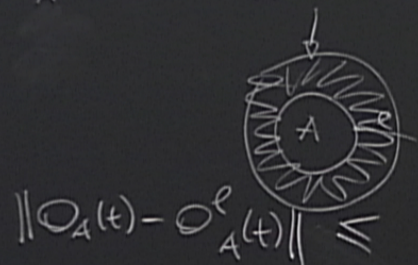


$$\|\mathcal{O}_A(t) - \mathcal{O}_A^l(t)\| \leq$$

Lemma $O_A(t) \sim O_A^l(t) := \text{Tr}_S O_A(t) \otimes \frac{\prod_s}{ds} =$

$S = \{ \text{spins at distance } > l \text{ from } A \}$

$dn(U)$ Haar measure



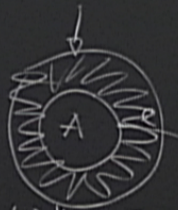
$$\|O_A(t) - O_A^l(t)\| \leq$$

Lemma $O_A(t) \sim O_A^l(t) := \text{Tr}_S O_A(t) \otimes \frac{\Pi_S}{d_S} = \int d\mu(U_S) U_S O_A(t) U_S^\dagger$

$S = \{ \text{spins at distance } > l \text{ from } A \}$

$d\mu(U)$ Haar measure

$\|O_A(t) - O_A^l(t)\| \leq$



ψ that has corr. length χ

$$|\langle \hat{O}_P \hat{O}_Q \rangle_c| \leq C_1 e^{-\frac{d_{PQ}}{\chi}}$$

$$\psi \rightarrow U(t) \psi = \psi(t)$$

$$|\langle \hat{O}_A \hat{O}_B \rangle_c^{CH}| = |\langle \hat{O}_A(t) \hat{O}_B(t) \rangle_c| \leq |\langle \hat{O}_A^l(t) \hat{O}_B^l(t) \rangle_c| + 2C_2 e^{-\frac{e^{-\chi t}}{\chi}}$$

Lemma $O_A(t) \sim O_A^l(t) :=$



$$\|O_A(t) - O_A^l(t)\| \leq \int dM$$

ψ that has corr. length χ

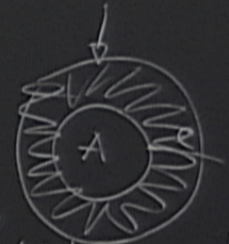
$$|\langle \hat{O}_P \hat{O}_Q \rangle_c| \leq C_1 e^{-\frac{d_{PQ}}{\chi}}$$

$$\psi \rightarrow U(t) \psi = \psi(t)$$

$$|\langle \hat{O}_A \hat{O}_B \rangle_c^{CH}| = |\langle \hat{O}_A(t) \hat{O}_B(t) \rangle_c| \leq |\langle \hat{O}_A^l(t) \hat{O}_B^l(t) \rangle_c| + 2C_2 e^{-\frac{e^{-\chi t}}{\chi}} \leq C_1$$

$d_{AB} \geq 2\ell$

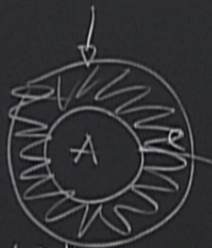
Lemma $O_A(t) \sim O_A^l(t) :=$



$$\|O_A(t) - O_A^l(t)\| \leq \int dM$$

$$\rho_A(t) \sim \mathcal{O}_A^l(t) := \text{Tr}_S \mathcal{O}_A(t) \otimes \frac{\Pi_S}{d_S} = \int d\mu(U_S) U_S \mathcal{O}_A(t) U_S^\dagger$$

$S = \{ \text{spins at distance} > l \text{ from } A \}$



$$\|\rho_A(t) - \mathcal{O}_A^l(t)\| \leq \int d\mu \| [U_S, \mathcal{O}_A(t)] \| \leq C_2 e^{-\frac{l-vt}{\xi}} \quad \begin{array}{l} d\mu(U) \text{ Haar measure} \\ \text{LR Bound} \end{array}$$

$$|1 + 2C_2 e^{-\frac{l-vt}{\xi}}| \leq C_1 e^{-\frac{d_{AB}-2l}{\chi}} + 2C_2 e^{-\frac{l-vt}{\xi}} \leq \dots$$

Quasi-adiabatic
connectivity

$$H(g)$$

$$g = (g^1, \dots, g^n)$$

$$U(s) = \mathcal{T} e^{-i \int_0^s H(g(s)) ds}$$

$\psi \rightarrow \psi(s) = U(s)\psi$ This is a Quantum
as the G.S. $\tilde{H}$ (local Hamiltonian) Phase

Theorem $\psi(s)$ is the G.S. of $\tilde{H}(s) = U(s)H U^\dagger(s)$

$$H(g)$$

$g < 1$ Ferromagnetic phase

$g > 1$ Param. phase

$$H(g, \phi)$$

$$R(\phi) = \Pi_i e^{\frac{i\sigma_i^z \phi}{2}}$$

Sym1	Sym2	Sym3
Sym4	Sym5	

to phase
phase

Sym1	Sym2	Sym3
Sym4	Sym5	

- ① Do we have quantum phases Beyond symmetry?
- ② Is it possible to have degeneracy AND finite corr. length?

Lattice Gauge Theory Wegner '71

(Ising)

d-dim cubic lattice $n + \hat{v}$ $(n + \hat{\mu} + \hat{v}, -\hat{\mu}) \equiv (n + \hat{v}, \hat{\mu})$

nodes by n

links by $(n, \hat{\mu})$

$(n, \hat{v})$

n

$n + \hat{\mu}$

$n + \hat{\mu} + \hat{v}$

$(n + \hat{\mu}, \hat{v})$

$n + \hat{\mu}$

Place Ising variables $\sigma^z(n, \hat{\mu}) = \pm 1$

Lattice Gauge Theory Wegner '71 (Ising)

d-dim cubic lattice

nodes by n

links by $(n, \hat{\mu})$

$(n+\hat{\mu}, -\hat{\mu}) \equiv (n+\hat{\nu}, \hat{\mu})$

$n+\hat{\nu}$

$n+\hat{\mu}+\hat{\nu}$

$(n, \hat{\nu})$

$(n+\hat{\mu}, \hat{\nu})$

n

$n+\hat{\mu}$

Place Ising variables $\sigma^z(n, \hat{\mu}) = \pm 1$

local (gauge) transf.

$$\begin{array}{c} \uparrow \\ \downarrow \\ \downarrow \\ \uparrow \end{array} \begin{array}{c} \uparrow \\ \downarrow \\ \downarrow \\ \uparrow \end{array} \xrightarrow{G(n)} \begin{array}{c} \downarrow \\ \uparrow \\ \uparrow \\ \downarrow \end{array} \begin{array}{c} \downarrow \\ \uparrow \\ \uparrow \\ \downarrow \end{array}$$

$$\sigma^z(n, \hat{\mu}) \sigma^z(n+\hat{\mu}, \hat{\nu}) \sigma^z(n+\hat{\nu}, \hat{\mu}) \sigma^z(n, \hat{\nu})$$

local (gauge) transf.

$$(n+\hat{v}, \hat{\mu}) \quad \begin{array}{c} \uparrow \\ \text{---} \text{---} \text{---} \\ \downarrow \end{array} \xrightarrow{G(n)} \begin{array}{c} \downarrow \\ \text{---} \text{---} \text{---} \\ \uparrow \end{array}$$

$$\sigma^z(n, \hat{\mu}) \sigma^z(n+\hat{\mu}, \hat{v}) \sigma^z(n+\hat{v}, \hat{\mu}) \sigma^z(n, \hat{v})$$

local (gauge) transf.

$$(n+\hat{v}, \hat{\mu}) \xrightarrow{G(n)} \begin{array}{c} \uparrow \quad \downarrow \\ \downarrow \quad \uparrow \\ \uparrow \quad \downarrow \\ \downarrow \quad \uparrow \end{array}$$

$$\sigma^z(n, \hat{\mu}) \sigma^z(n+\hat{\mu}, \hat{v}) \sigma^z(n+\hat{v}, \hat{\mu}) \sigma^z(n, \hat{v})$$

$$H = -J \sum_p \sigma^x \sigma^z \sigma^x \sigma^z$$

local (gauge) transf.

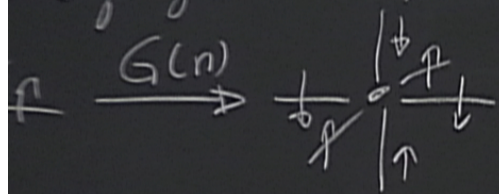
$$\equiv (n, \hat{v}, \hat{\mu}) \quad \begin{array}{c} \uparrow \quad \downarrow \\ \downarrow \quad \uparrow \\ \uparrow \quad \downarrow \\ \downarrow \quad \uparrow \end{array} \xrightarrow{G(n)} \begin{array}{c} \downarrow \quad \uparrow \\ \uparrow \quad \downarrow \\ \downarrow \quad \uparrow \\ \uparrow \quad \downarrow \end{array} \rightarrow \prod_{l \in n} \hat{\sigma}_l^x$$

$$1) \quad \sigma^z(n, \hat{\mu}) \sigma^z(n + \hat{\mu}, \hat{v}) \sigma^z(n + \hat{v}, \hat{\mu}) \sigma^z(n, \hat{v}) \rightarrow \prod_{l \in P} \hat{\sigma}_l^z$$

$$H = -J \sum_P \sigma^z \sigma^z \sigma^z \sigma^z$$

$$\{\sigma_e^z\} \rightarrow |\{\sigma_e^z\}\rangle \quad : \quad \frac{1}{\sigma_l^z} |\psi\rangle = \sigma_l^z |\psi\rangle$$

(gauge) transf.



$$\rightarrow \prod_{l \in n} \hat{\sigma}_l^x$$

$$(\hat{\mu}, \hat{\nu}) \sigma^z(n+\hat{\nu}, \hat{\mu}) \sigma^z(n, \hat{\nu}) \rightarrow \prod_{l \in p} \hat{\sigma}_l^z$$

$$-\tau \sigma^z \sigma^z \sigma^z$$

$$\frac{1}{\sigma_l} |15\rangle = \sigma_l^z |15\rangle$$

$$\langle \sigma_l^z \rangle_h = \frac{\text{Tr } e^{-\beta H_{\sigma_l^z}}}{\sum_i}$$

$$\tilde{h} = \beta h$$

$$-h \sum_l \sigma_l^z$$

$$\beta \sum_p \sigma^z \sigma^z \sigma^z + \tilde{h} \sum_l \sigma_l^z$$

$$= \frac{1}{Z} \sum_{\{\sigma_l^z\}} e^{\dots}$$