

Title: Summer Undergrad 2020 - Quantum Information - Lecture 3

Speakers: Alioscia Hama

Collection: Summer Undergrad 2020 - Quantum Information

Date: May 29, 2020 - 10:00 AM

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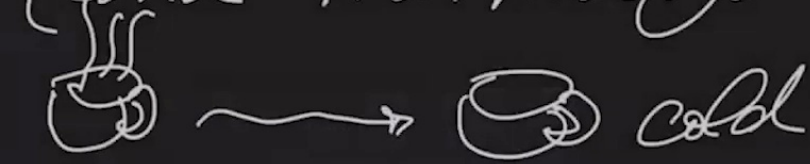
Abstract: Quantum Thermal Operations



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Quantum Equilibration
(and Thermalization)



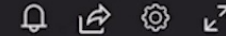


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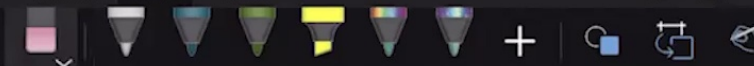
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Microscopic Law
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Microscopic Laws are
Time-reversed !!

Friday, May 29, 2020 10:06 AM

$$H = \sum_n E_n P_n$$

$$P_n = |E_n\rangle\langle E_n|$$

non-degenerate

$$\hat{A} = \begin{pmatrix} p_0 & & \\ & \boxed{\text{diagonal}} & \\ & & p_0 \end{pmatrix}$$

$$|\phi(t)\rangle$$

$$\langle \phi(t) | \hat{A} | \phi(t) \rangle$$

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Microscopic Law
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Microscopic Laws are
Time-reversed !!

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$$H = \sum_n E_n P_n$$

$$P_n = |E_n\rangle\langle E_n|$$

non-degenerate

$$\left(\begin{array}{c} \text{Diagram of a system with states and transitions} \end{array} \right) + eV [H_0, T] = 0$$

$\parallel$
 H_0

$[V, T] = 0$

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10:19 AM

$$H = \sum_n E_n P_n$$

$$\phi_t = U_t \phi = e^{-iHt} \phi e^{iHt}$$

$$\hat{A}_t = U_t A = e^{iHt} \hat{A} e^{-iHt}$$

$$A_t = \text{Tr}[\hat{A} \phi_t] = \text{Tr}[\hat{A}_t \phi]$$

Schrödinger Heisenberg

$$\sum_n p_n \frac{\langle n | \hat{A} | n \rangle}{\text{Tr}[\hat{A}_t \phi_t]}$$



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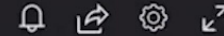


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Equilibration



$$U_t \phi_{eq} = \phi_{eq} \quad \text{fixed point}$$

like $U_t \phi = \phi_{eq}$ if
 $t \rightarrow \infty$ equilibration happens.

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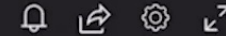


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ϕ_{eq} steady state

$$[U\phi = \phi]$$

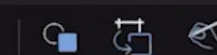
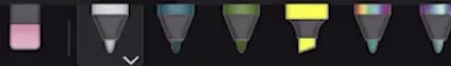
$$|\phi\rangle = |E_n\rangle$$

$$e^{-iHt} |E_n\rangle = e^{-iEt} |E_n\rangle$$



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10:30 AM

Steady States

$$\phi = \frac{e^{-\beta H}}{Z}$$

$$\dot{\phi} = \frac{d}{dt} \phi_t = \frac{d}{dt} U_t \phi$$

$$= \underbrace{\frac{d}{dt} U_t}_{e^{-iHt} \frac{d}{dt} e^{iHt}} \phi$$

$$= -i \underbrace{[\phi, H]}_{=0}$$



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exercise $f(H)$ $e^{-\beta H}$

$$[f(H), H] = 0$$

$$P_1 |E_1\rangle \langle E_1| + P_2 |E_2\rangle \langle E_2|$$

$$P_1 + P_2 = I$$



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$$\frac{e^{-\beta H}}{Z} = \frac{1}{Z} \sum e^{-\beta E_n} |E_n\rangle \langle E_n|$$

$$Z = \text{Tr}[\beta H]$$

$$\sum_n p_n p_n$$

$$\frac{e^{-\beta E_n}}{Z} \equiv p_n$$



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10:37 AM Fri May 29
qi at pi
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Microscopic Law
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Equilibration : is it possible?
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Equilibration : is it possible?

NO! because Time-reversal

$|\psi\rangle \rightsquigarrow \frac{e^{-\beta H}}{Z_r}$

pure

not possible

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Microscopic Law

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Fundamental Law

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$$\phi_{eq} \neq \phi \quad \underbrace{\phi \rightarrow \phi_{eq}}$$

$$\lim_{t \rightarrow \infty} \|\phi_t - \phi_{eq}\| = 0$$

||

$$\lim_{t \rightarrow \infty} \|U_t \phi - U_t \phi_{eq}\| =$$

$$\lim_{t \rightarrow \infty} \|U_t (\phi - \phi_{eq})\| = \|\phi - \phi_{eq}\|$$

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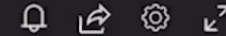


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Fundamental Law

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Friday, May 29, 2020 10:37 AM

$$\phi_{eq} \neq \phi \quad \underbrace{\phi \sim \phi_t \sim \phi_{eq}}$$

$$\lim_{t \rightarrow \infty} \|\phi_t - \phi_{eq}\| = 0$$

$$\parallel$$

$$\lim_{t \rightarrow \infty} \|\mathcal{U}_t \phi - \mathcal{U}_t \phi_{eq}\| =$$

$$\lim_{t \rightarrow \infty} \|\mathcal{U}_t (\phi - \phi_{eq})\| = \|\phi - \phi_{eq}\|$$

$$\phi = \phi_{eq}$$

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Friday, May 29, 2020

10:44 AM

$$\psi_{ck} = \frac{\psi_{\text{cup}} \otimes \psi_k}{(H_{\text{tot}})}$$

$$H = H_c + H_{\text{int}} + H_k \rightarrow \mathcal{U}$$

$$\psi_{ck}^{\dagger} = \mathcal{U}_{\dagger} (\psi_{\text{cup}} \otimes \psi_k)$$

$$\text{tr}_k \psi_c^{\dagger} = \text{tr}_k \mathcal{U}_{\dagger} (\psi_{\text{cup}} \otimes \psi_k)$$



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10:49 AM Fri May 29

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Friday, May 29, 2020
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$$\mathcal{H} = \mathcal{H}_A \otimes \mathcal{H}_B$$

$$\text{tr}(\hat{A} \otimes \mathbb{I}_B \psi) = \text{tr}(\hat{A} \psi_A)$$

$$\psi_A = \text{tr}_B \psi$$

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Esha Gupta

Pirsa: 20050035

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S7ea

 $\phi =$

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exora

 $[f(u)]$

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 $\frac{e^{-\beta H}}{Z}$

Fermi's Golden Rule

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TND!

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 O_{eq}

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 $\frac{H}{T}$

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 $\Psi = 0$

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 t/μ_0

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 e^{-iHt}

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10:49 AM

$$e^{-iHt} = e^{-i(H_c + H_k + \cancel{H_{ck}})t}$$

$$\neq T_c \otimes T_k$$

$$\begin{matrix} \text{C} & & K \\ \text{---} e^{-iH_c t} & & e^{-iH_k t} \text{---} \end{matrix}$$



Diana Méndez Avalo...



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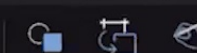
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$$T_{\text{min}} \\ H = \sum$$

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$$\phi_t = u_t$$

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$$\phi_{\text{eq}} \\ [1, 1, 1]$$

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$$\text{Step} \\ \phi =$$

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$$\text{error} \\ [f(H)]$$

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$$\frac{e^{-\beta H}}{Z}$$

Fermi distribution in

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$$TND!$$

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$$\phi_{\text{eq}} =$$

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$$-H$$

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What is the way out?

ϕ_t will not equilibrate

$$\phi = \sum_{h,m} \phi_{hm} |\ln \chi_m|$$



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Friday, May 29, 2020

11:08 AM

$P_1[|A_t - A_{eq}| > \epsilon] \sim$ is
 super small
 Equilibration in probability

A_t has typical
 values $\sim A_{eq}$

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11:09 AM

A_{eq}

$\int A_t$ *fluctuations*

$$A_{eq} = \bar{A} = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T A_t dt$$

$$= \text{Tr} [A \bar{\Phi}]$$

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