

Title: An Infalling Observer in AdS/CFT and the Information Paradox

Date: May 03, 2013 11:00 AM

URL: <http://pirsa.org/13050016>

Abstract: We reconstruct the experience of an infalling observer using the AdS/CFT correspondence.

We write operators both outside and inside the black hole in terms of CFT operators.

Our construction provides a natural realization of black hole complementarity, and a way of preserving information without the need for firewalls.

1211.6767

w k Papadodimas

- 1) local experiments
in AdS using CFT

1211.6767

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- 1) local experiments
in AdS using CFT
- 2) look beyond a b.h. horizon.
- 3) info par.

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$$\phi(x_{\text{bulk}}) =$$

$$\phi(x_{\text{bulk}}) = \int O(x_{\text{drg}}) K(x_{\text{drg}}, x_{\text{bulk}}) dx_{\text{drg}}.$$

$$\langle O(x_1) O(x_2) \dots O(x_p) \rangle = \langle O(x_1) O(x_2) \rangle \dots \langle O(x_{p-1}) O(x_p) \rangle + \frac{1}{N}.$$

g CFT
horizon

$$a_{w,k} = \frac{O_{w,k}}{(\omega^2 - k^2)^{D/2 - d/4}}$$

$$a_{w,k}^+ = \frac{O_{-w,-k}}{(\omega^2 - k^2)^{D/2 - d/4}}$$

$$a_{\omega, k} = \frac{O_{\omega, k}}{(\omega^2 - k^2)^{\frac{D-d}{2}}}$$

$$a_{\omega, k}^{\dagger} = \frac{O_{-\omega, -k}}{(\omega^2 - k^2)^{\frac{D-d}{2}}}$$

$$\phi(x_{\omega/k}) = \int a_{\omega, k} \xi_{\omega, k}(x_{\omega/k}) + h.c.$$

$$a_{\omega, k} = \frac{O_{\omega, k}}{(\omega^2 - k^2)^{\frac{D-d}{2}}}$$

$$a_{\omega, k}^+ = \frac{O_{-\omega, -k}}{(\omega^2 - k^2)^{\frac{D-d}{2}}}$$

$$\phi(x_{\omega/k}) = \int a_{\omega, k} \xi_{\omega, k}(x_{\omega/k}) + h.c.$$

$$a_{\omega, k} = \frac{O_{\omega, k}}{(\omega^2 - k^2)^{\frac{D-d}{2}}}$$

$$a_{\omega, k}^+ = \frac{O_{-\omega, -k}}{(\omega^2 - k^2)^{D/2}}$$

$$\phi(x_{\omega, k}) = \int a_{\omega, k} \xi_{\omega, k}(x)$$

$$a_{w,k} = \frac{O_{w,k}}{\left[G_{\beta}(w,k) - G_{\beta}(-w,-k) \right]^{1/2}}$$

$$a_{w,k} = \frac{O_{w,k}}{\left[G_{\beta}(w,k) - G_{\beta}(-w,-k) \right]^{1/2}}$$

$$\langle O_{w,k} \ O_{-w,-k} \rangle$$

$$a_{w,k} = \frac{O_{w,k}}{\left[G_B(w,k) - G_B(-w,-k) \right]^{1/2}}$$

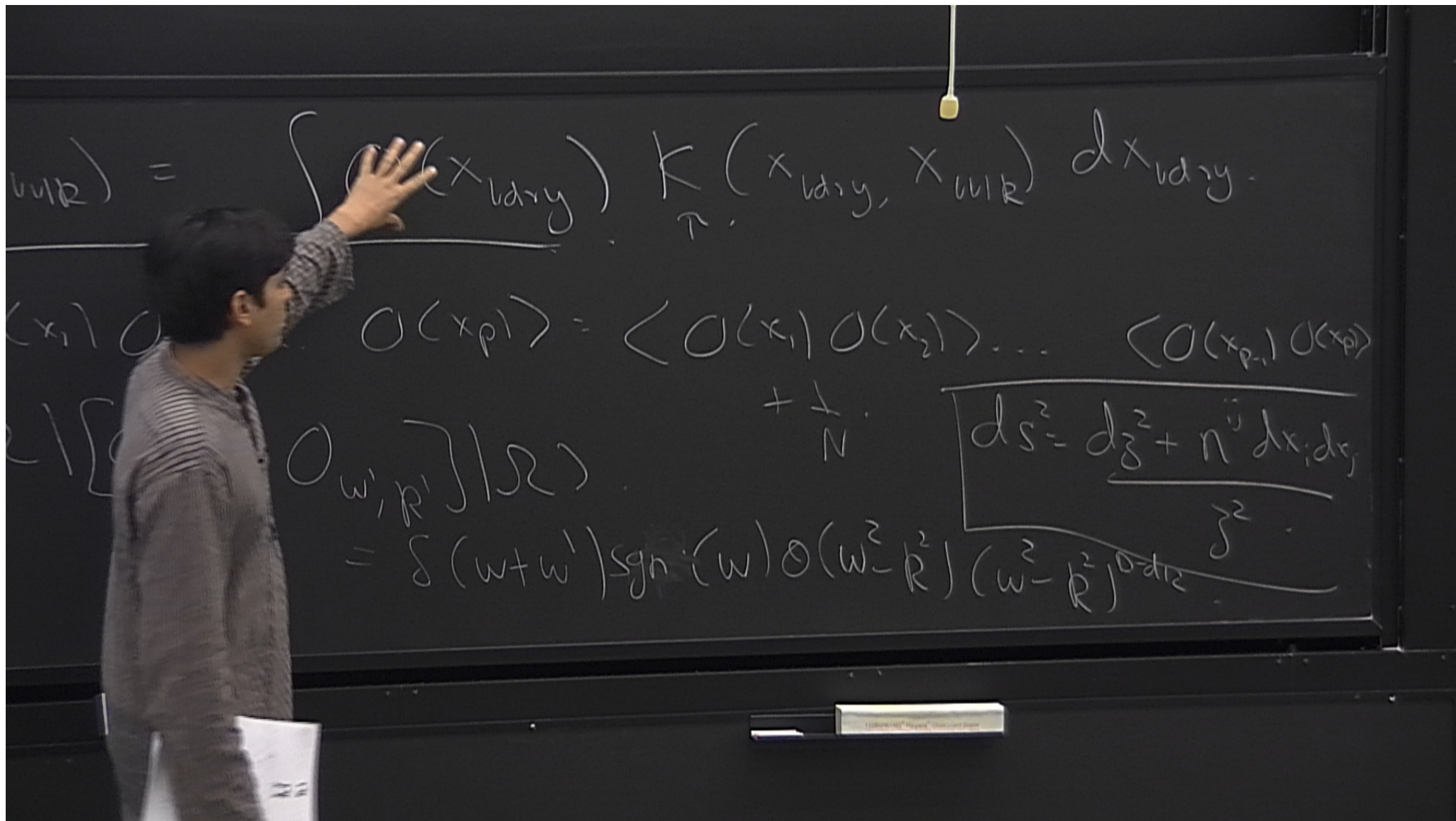
$$\langle O_{w,k} O_{-w,-k} \rangle_B = G_B$$

$$a_{w,k} = \frac{O_{w,k}}{\left[G_{\beta}(w,k) - G_{\beta}(-w,-k) \right]^{1/2}}$$

$$|a_{w,k} = e^{\beta|k|/2} O_{w,k}|$$

$$\langle O_{w,k} O_{-w,-k} \rangle_{\beta} = G_{\beta} - \beta|k|/2$$

$$G_{\beta}(w,k) \xrightarrow[k \rightarrow \infty]{w \text{ fixed}} e^{-\beta|k|/2}$$



$$w|k) = \int O(x_{\text{vary}}) K_{\tau}(x_{\text{vary}}, x_{w|k}) dx_{\text{vary}}.$$

$$\langle x_1 | O(x_2) \dots O(x_p) \rangle = \langle O(x_1) O(x_2) \rangle \dots \langle O(x_{p-1}) O(x_p) \rangle$$

$$+ \frac{1}{N} \cdot \boxed{ds^2 = d\vec{z}^2 + \underbrace{n^{\bar{i}} dx_i dx_j}_{\vec{z}^2}}$$

$$2/[O_{w,k}, O_{w',p'}]/\Omega)$$

$$= \delta(w+w') \text{sgn}(w) \theta(w^2 - k^2) (w^2 - k^2)^{D-1/2}$$

$$a_{w,k} = \frac{O_{w,k}}{\left[G_B(w,k) - G_B(-w,-k) \right]^{1/2}}$$

$$|a_{w,k} = e^{\beta|k|/2} O_{w,k}|$$

$$\langle O_{w,k} O_{-w,-k} \rangle_B = G_B$$

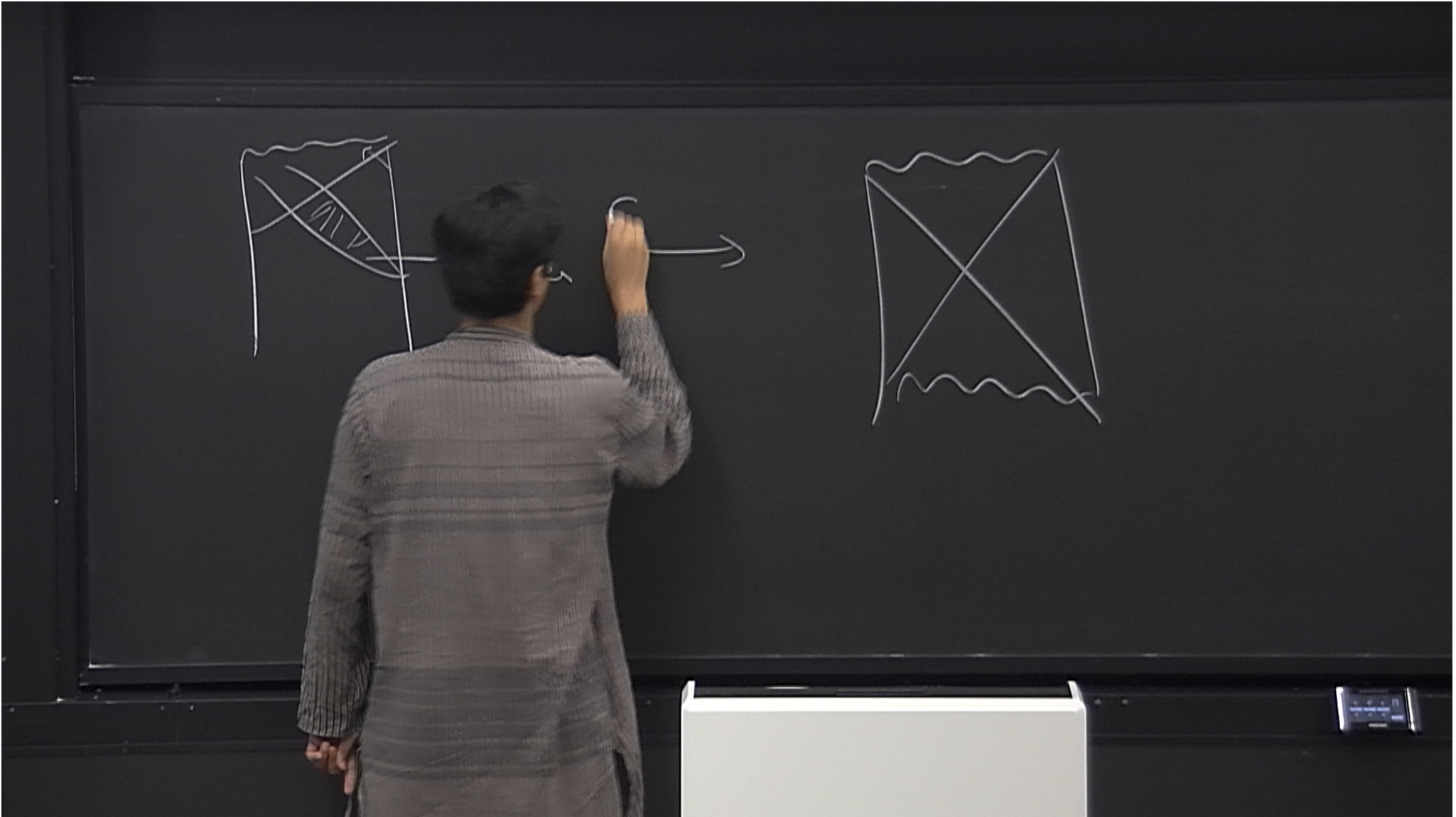
$$G_B(w,k) \xrightarrow[k \rightarrow \infty]{w \text{ fixed}} e^{-\beta|k|/2}$$

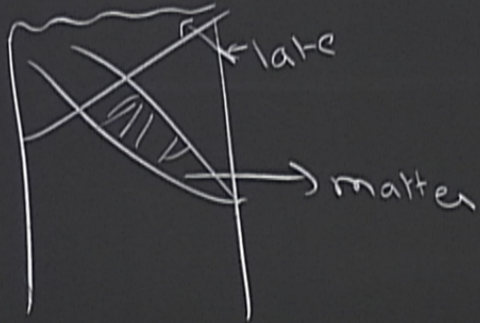
$$a_{w,k} = \frac{O_{w,k}}{\left[G_{\beta}(w,k) - G_{\beta}(-w,-k) \right]^{1/2}}$$

$$|a_{w,k} = e^{\beta|k|/2} O_{w,k}|$$

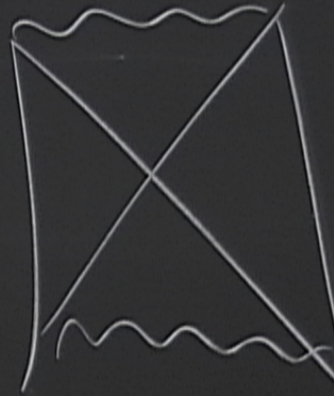
$$\langle O_{w,k} O_{-w,-k} \rangle_{\beta} = G_{\beta}(w,k) e^{-\beta|k|/2}$$

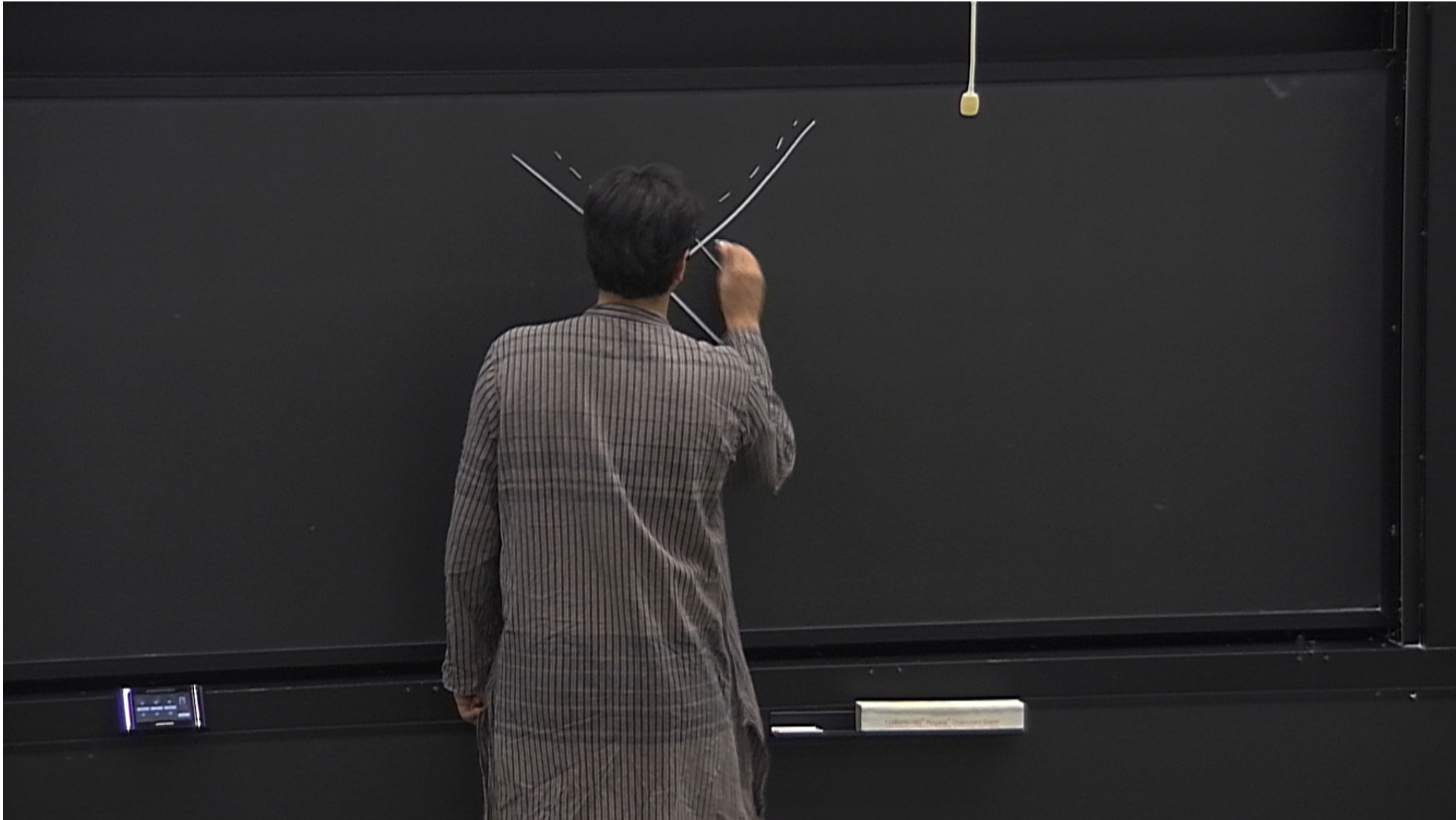
$\xrightarrow[k \rightarrow \infty]{w \text{ fixed}}$

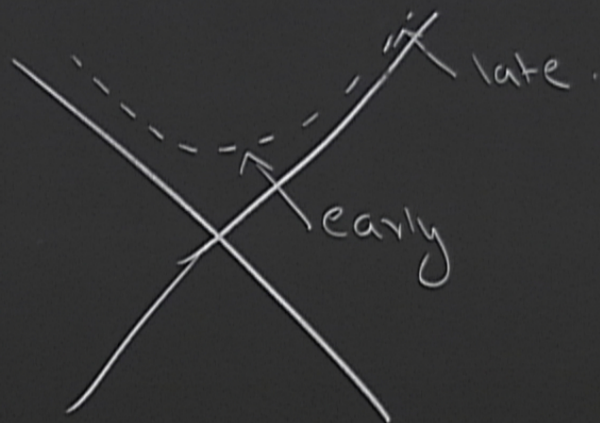


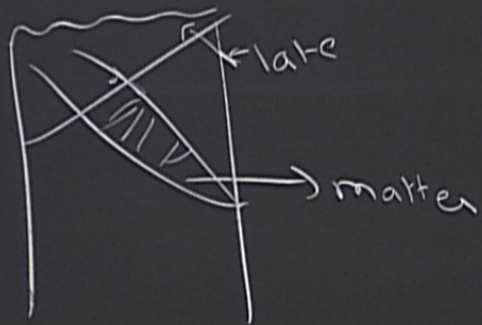


for
→
a late
observer.

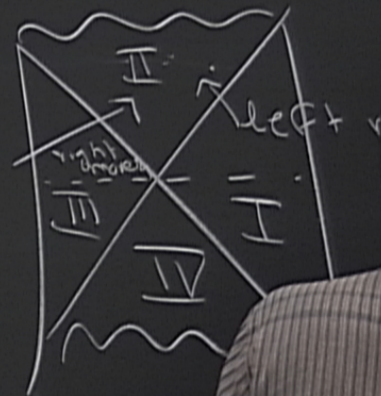




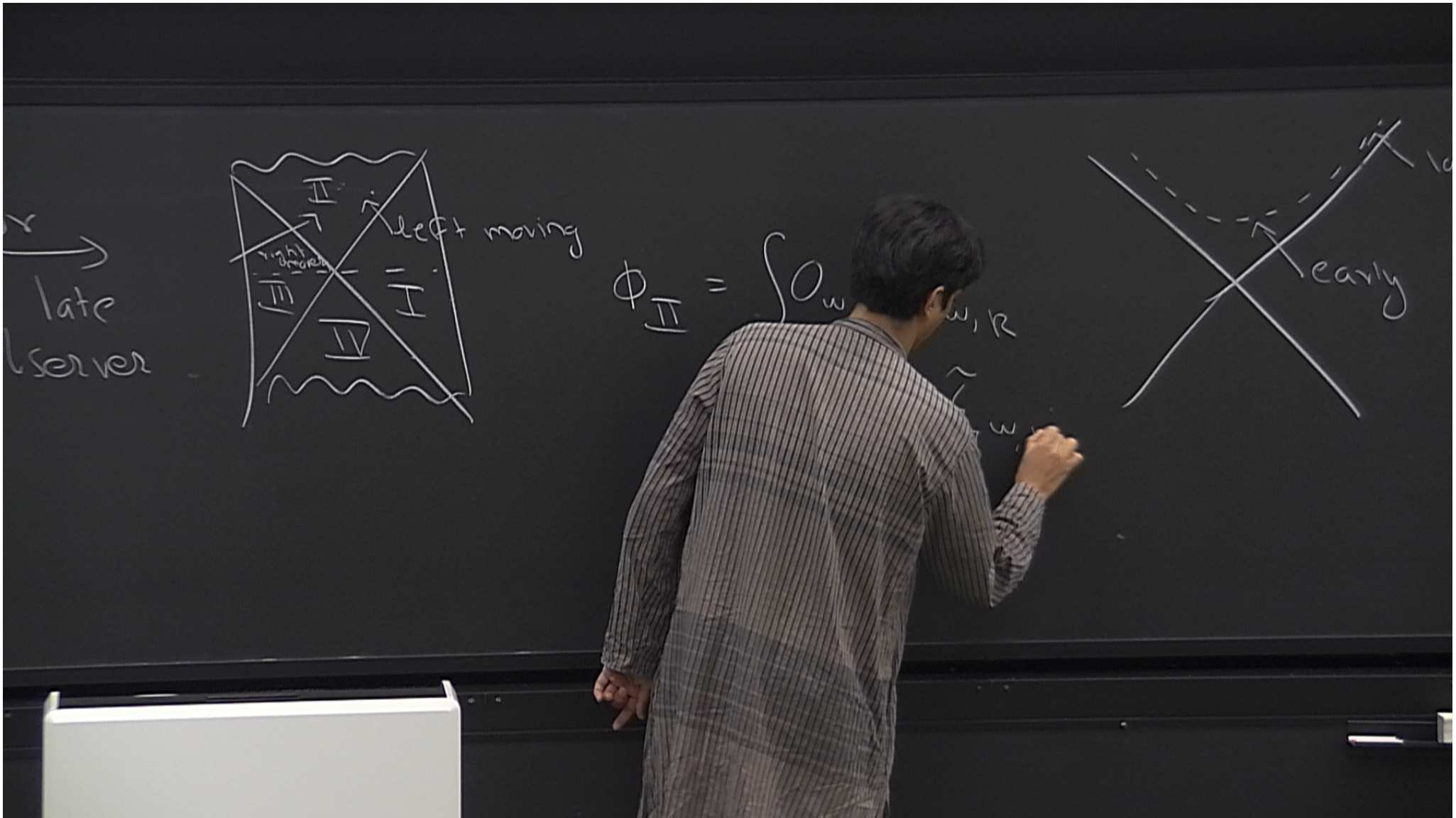




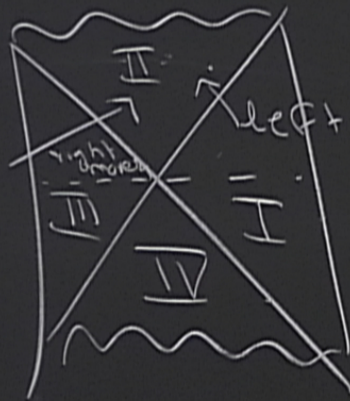
for
a late
observer



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 Π

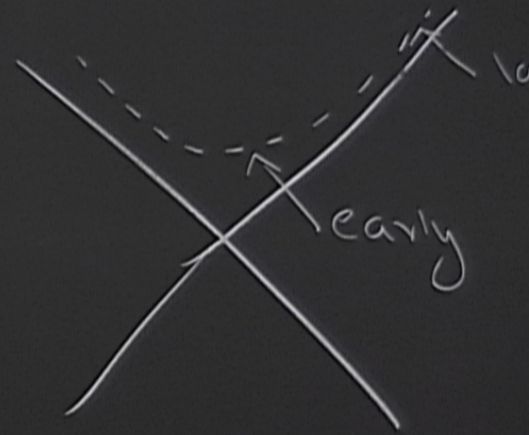


→
late
server

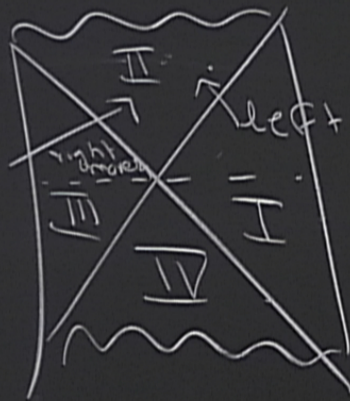


left moving

$$\Phi_{II} = \int \mathcal{O}_{w,r} \zeta_{w,r} + \tilde{\mathcal{O}}_{w,r} \tilde{\zeta}_{w,r}$$

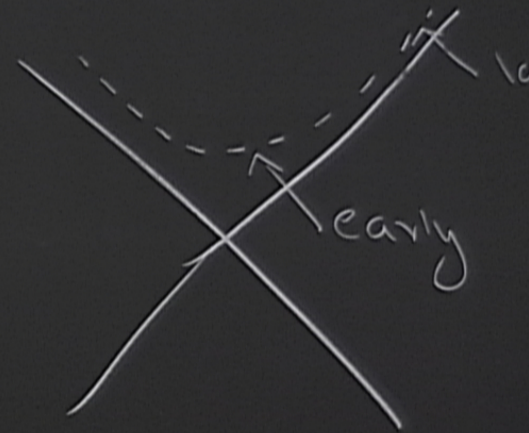


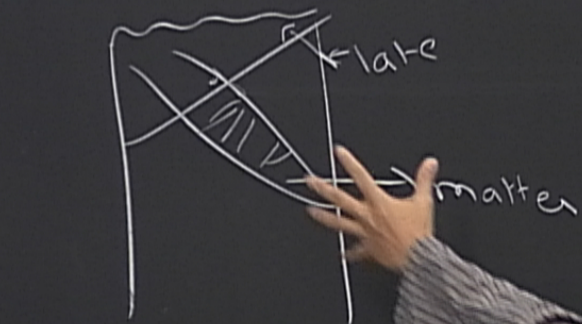
late
server



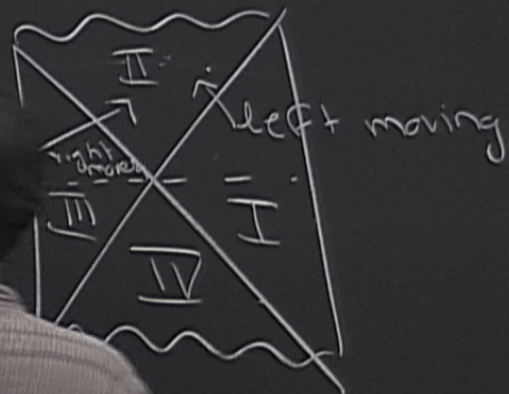
left + moving

$$\Phi_{II} = \int \mathcal{O}_{w,r} \zeta_{w,r} + \tilde{\mathcal{O}}_{w,r} \tilde{\zeta}_{w,r}$$





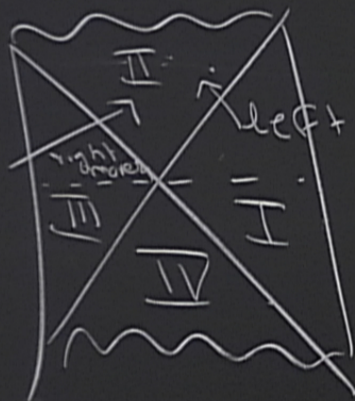
for
a late
decrease



$$\Phi_{II} = \int$$

$$\langle \psi | a_{w_1, k_1} a_{w_2, k_2} | \psi \rangle$$

$$H_{Full}$$



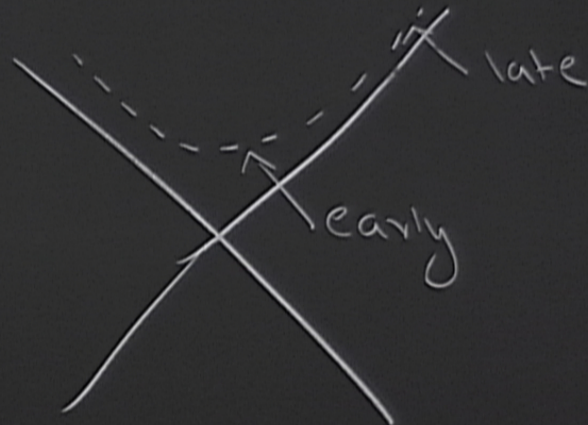
left + moving

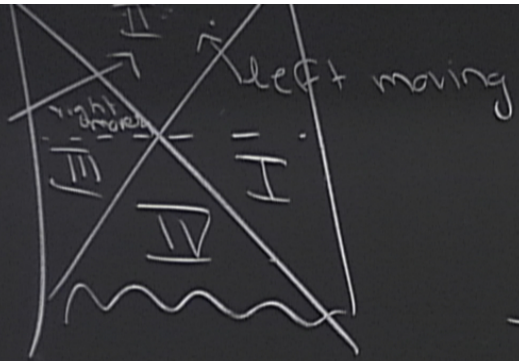
$$\phi_{II} = \int \psi_{w,r}$$

$$\tilde{\psi}_{w,r}$$

$\otimes H_{\text{fine}}$

F



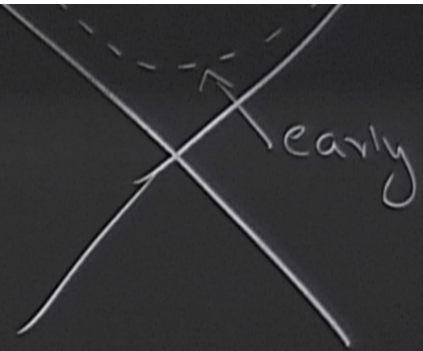


$$\Phi_{II} = \int \mathcal{O}_{w,k} \mathcal{L}_{w,k}$$

$$+ \tilde{\mathcal{O}}_{w,k} \tilde{\mathcal{L}}_{w,k}$$

$$H_{Full} = H_{coarse} \otimes H_{fine}$$

$\downarrow$
 GFF



$$|\psi\rangle = \sum \alpha_{ij} |i\rangle_{\text{coarse}} |j\rangle_{\text{fine}}.$$

BH
 + Hawking
 gas

$|\psi\rangle =$
 BH
 + Hawking
 gas

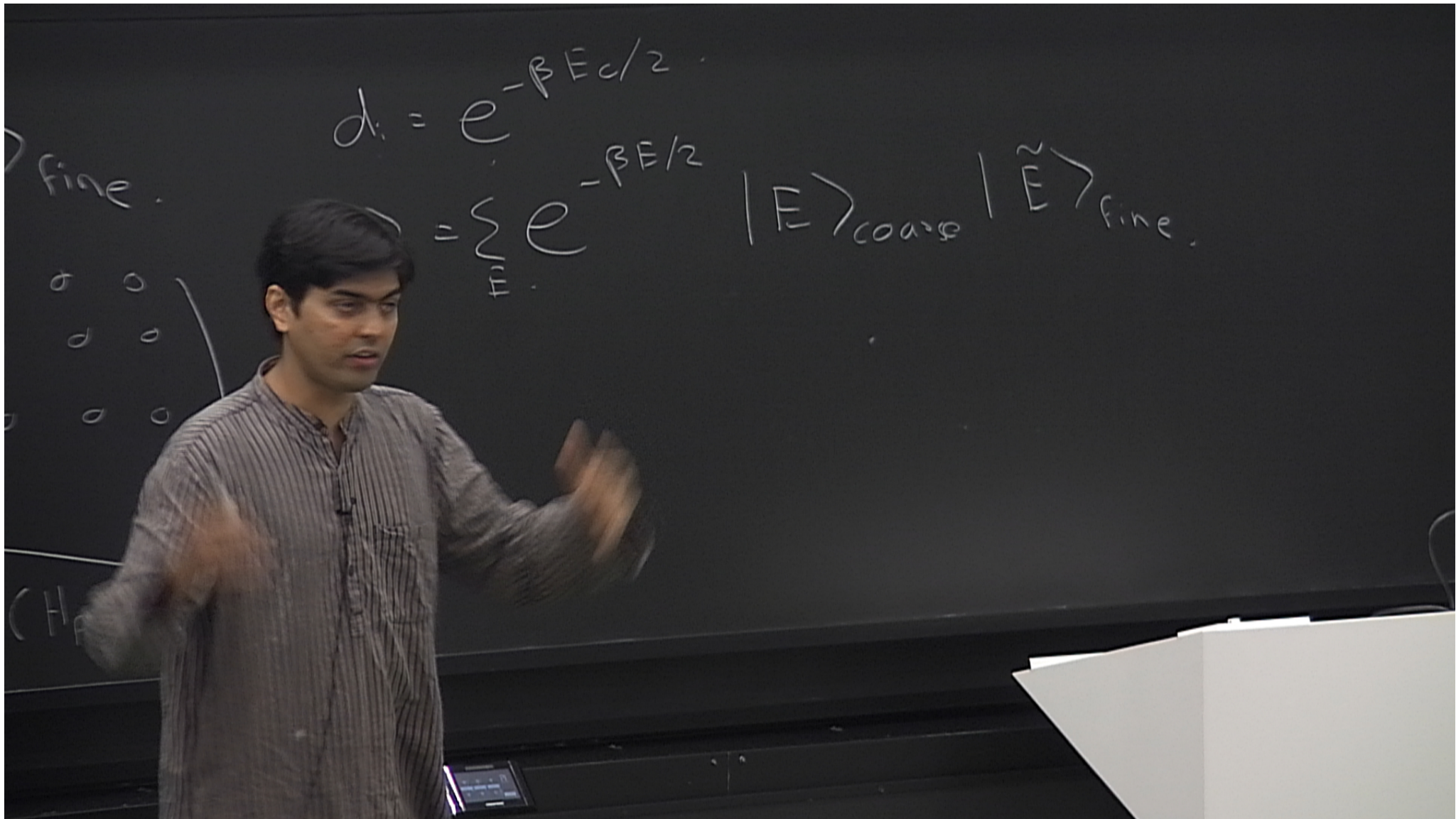
$$\sum \alpha_{ij} |i\rangle_{\text{coarse}} |j\rangle_{\text{fine}}$$

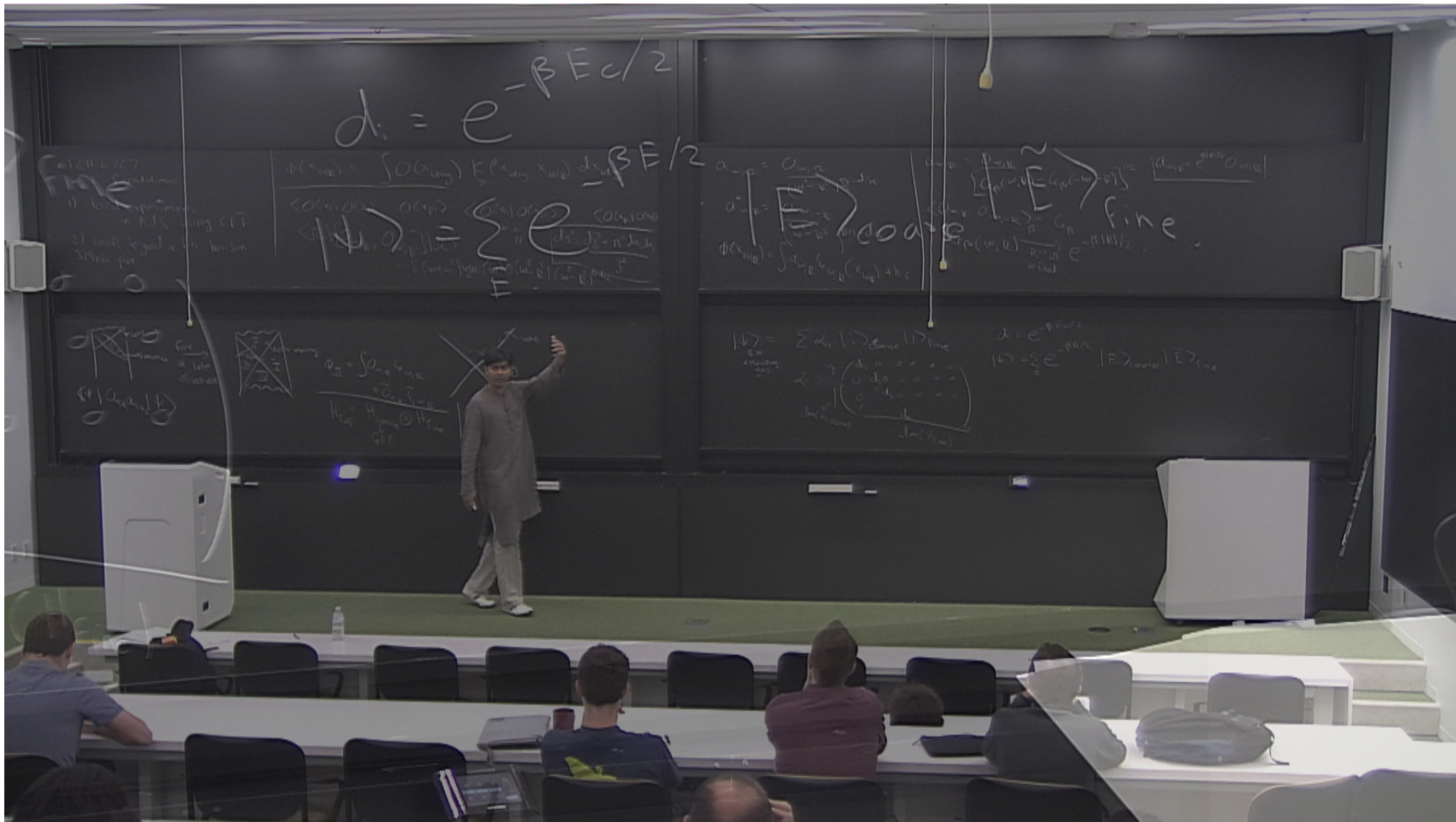
$$d_i = e^{-}$$

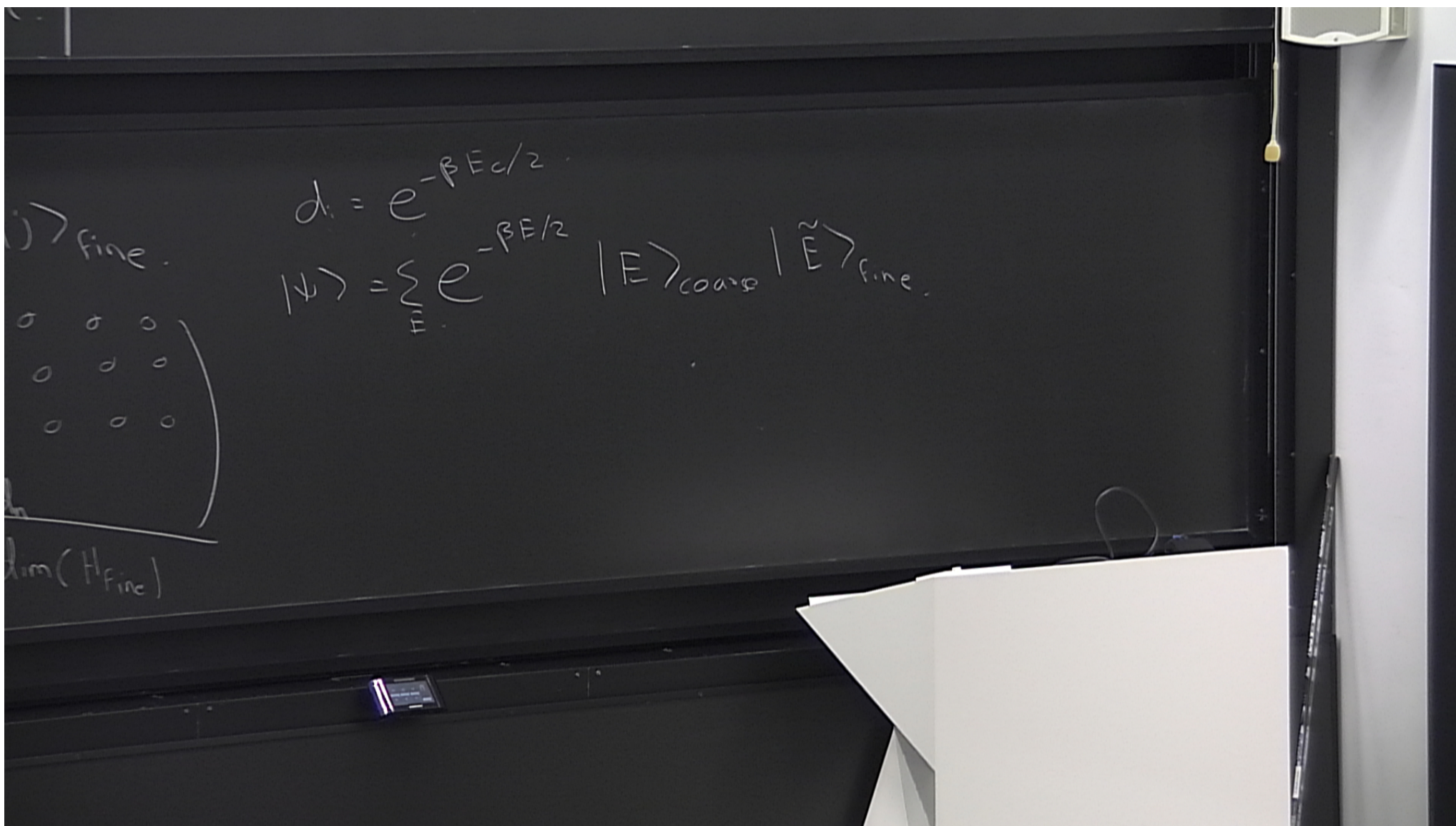
$$L = \begin{pmatrix} d_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & d_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & d_3 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \end{pmatrix}$$

$\uparrow$
 $\downarrow$
 $\dim(H_{\text{coarse}})$

$\xrightarrow{\quad d_n \quad}$
 $\dim(H_{\text{fine}})$







$$d_i = e^{-\beta E_i/2}$$

$$|\psi\rangle = \sum_E e^{-\beta E/2} |E\rangle_{\text{coarse}} |\tilde{E}\rangle_{\text{fine}}$$

$$O = \sum_{E_1, E_2} Q_{E_1, E_2} |E_1\rangle_{\text{coarse}} \langle E_2|_{\text{coarse}}$$

$$\tilde{O} = \sum_{\tilde{E}_1, \tilde{E}_2} Q_{\tilde{E}_1, \tilde{E}_2}^* |\tilde{E}_1\rangle_{\text{fine}} \langle \tilde{E}_2|_{\text{fine}}$$

$$\dim(H_{\text{fine}})$$

$$|\psi\rangle = \sum \alpha_{ij} |i\rangle_{\text{coarse}} |j\rangle_{\text{fine}}$$

BH
+ Hawking
gas

$$\mathcal{L} = \begin{pmatrix} d_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & d_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & d_3 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & d_n & 0 \end{pmatrix}$$

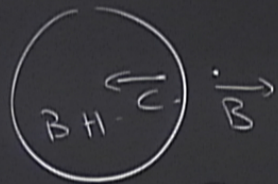
$\dim(H_{\text{coarse}})$ $\dim(H_{\text{fine}})$

$$\dim(H_{\text{coarse}}) \leq \dim(H_{\text{fine}})$$

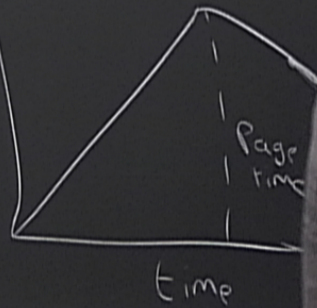
$$d_i = e^{-E_i}$$

$$|\psi\rangle = \sum_i e^{-E_i} |i\rangle$$

O_{coarse}
 $\sim$
 O_{fine}

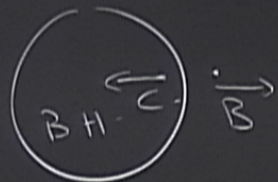


S_A

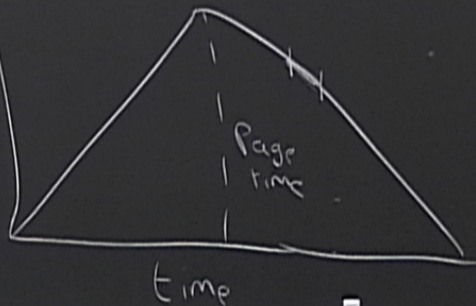


$$S_A = -E_V (P_A \ln P_A)$$

$$S_{AB} < S_A$$



S_A



A

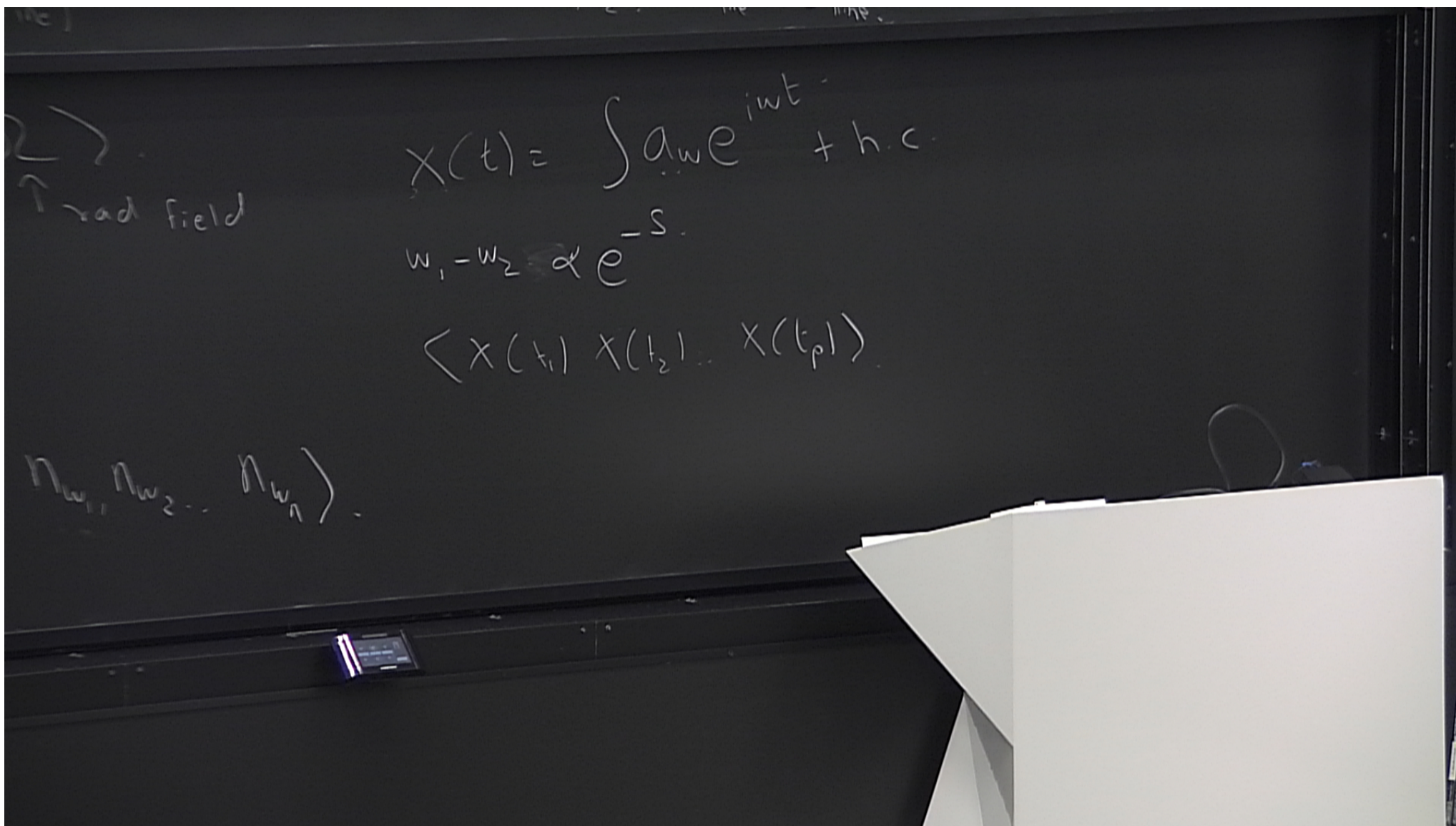
$$S_A = -E_V (P_A \ln P_A)$$

$$S_{AB} < S_A \rightarrow \text{unitary}$$

$$S_{BC} = 0 \rightarrow \text{ev}$$

$$S_B = S_C > 0 \rightarrow$$

S_A



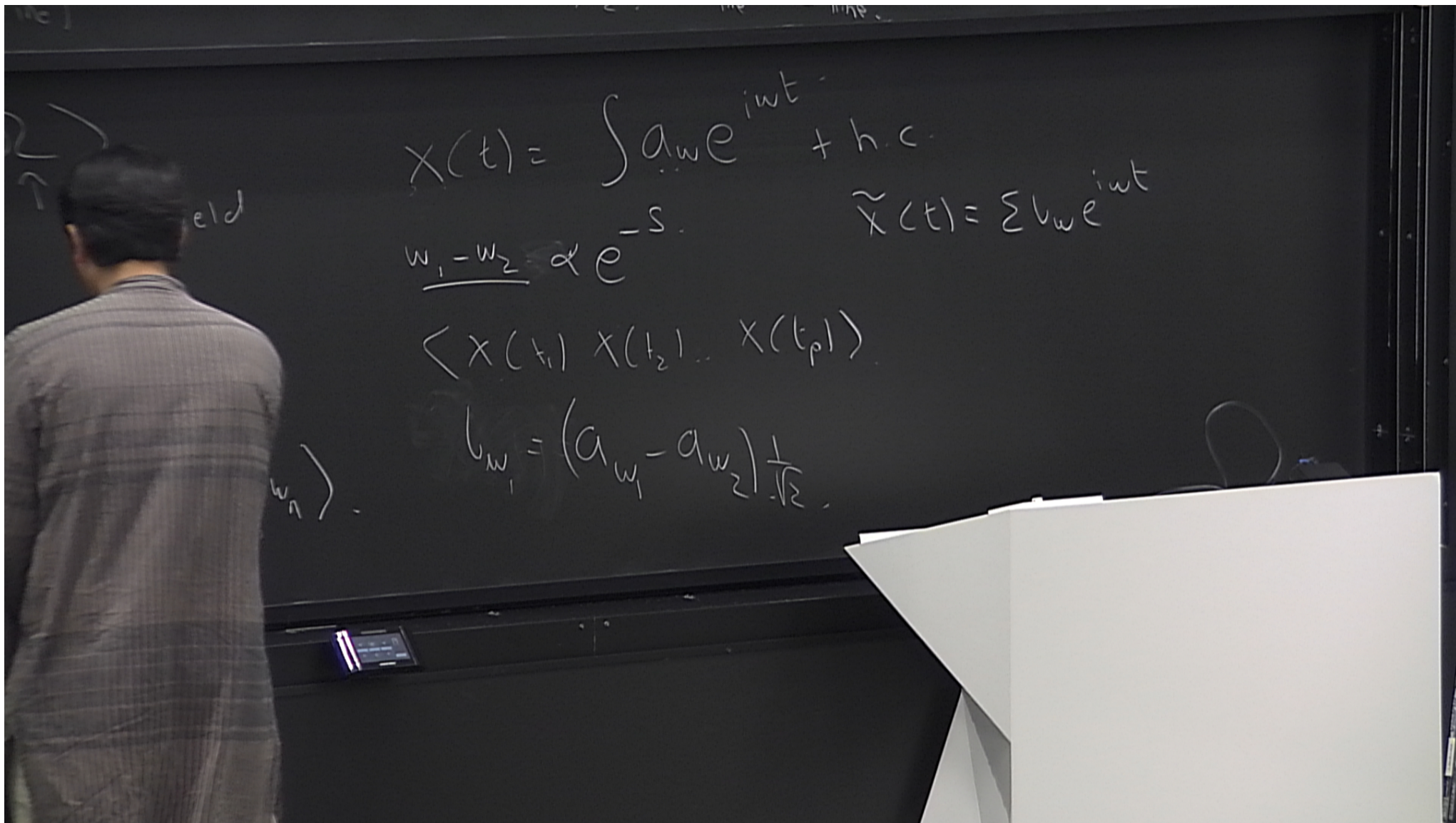
field

$$X(t) = \int a_{\omega} e^{i\omega t} + h.c.$$

$$\omega_1 - \omega_2 \propto e^{-s}$$

$$\langle X(t_1) X(t_2) \dots X(t_p) \rangle$$

$$b_{\omega_1} = (a_{\omega_1} - a_{\omega_2}) \frac{1}{\sqrt{2}}$$



$$X(t) = \int a_w e^{iwt} + h.c.$$

$$\underline{w_1 - w_2} \propto e^{-s}$$

$$\tilde{X}(t) = \sum b_w e^{iwt}$$

$$\langle X(t_1) X(t_2) \dots X(t_p) \rangle$$

$$b_{w_1} = (a_{w_1} - a_{w_2}) \frac{1}{\sqrt{2}}$$