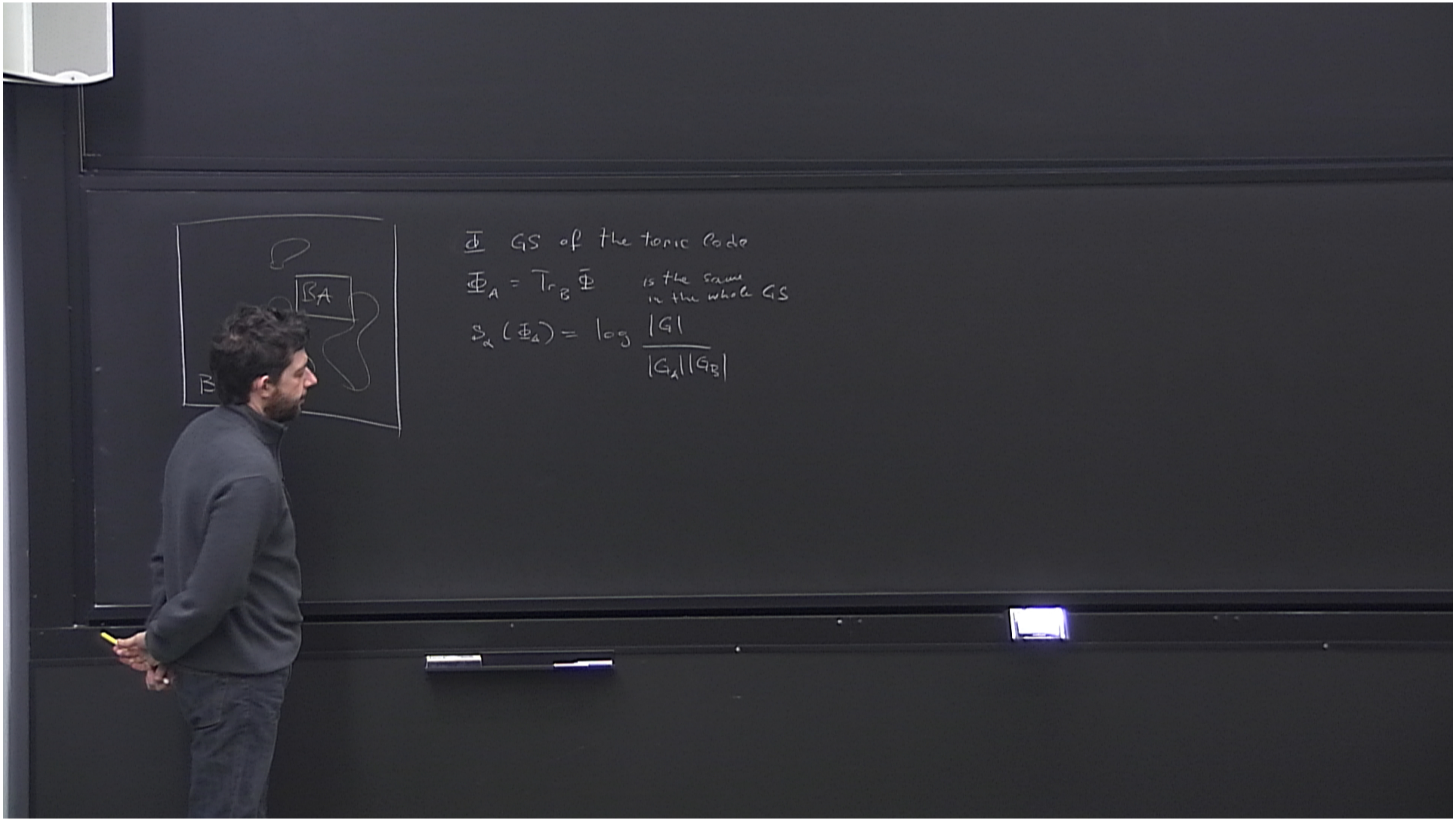
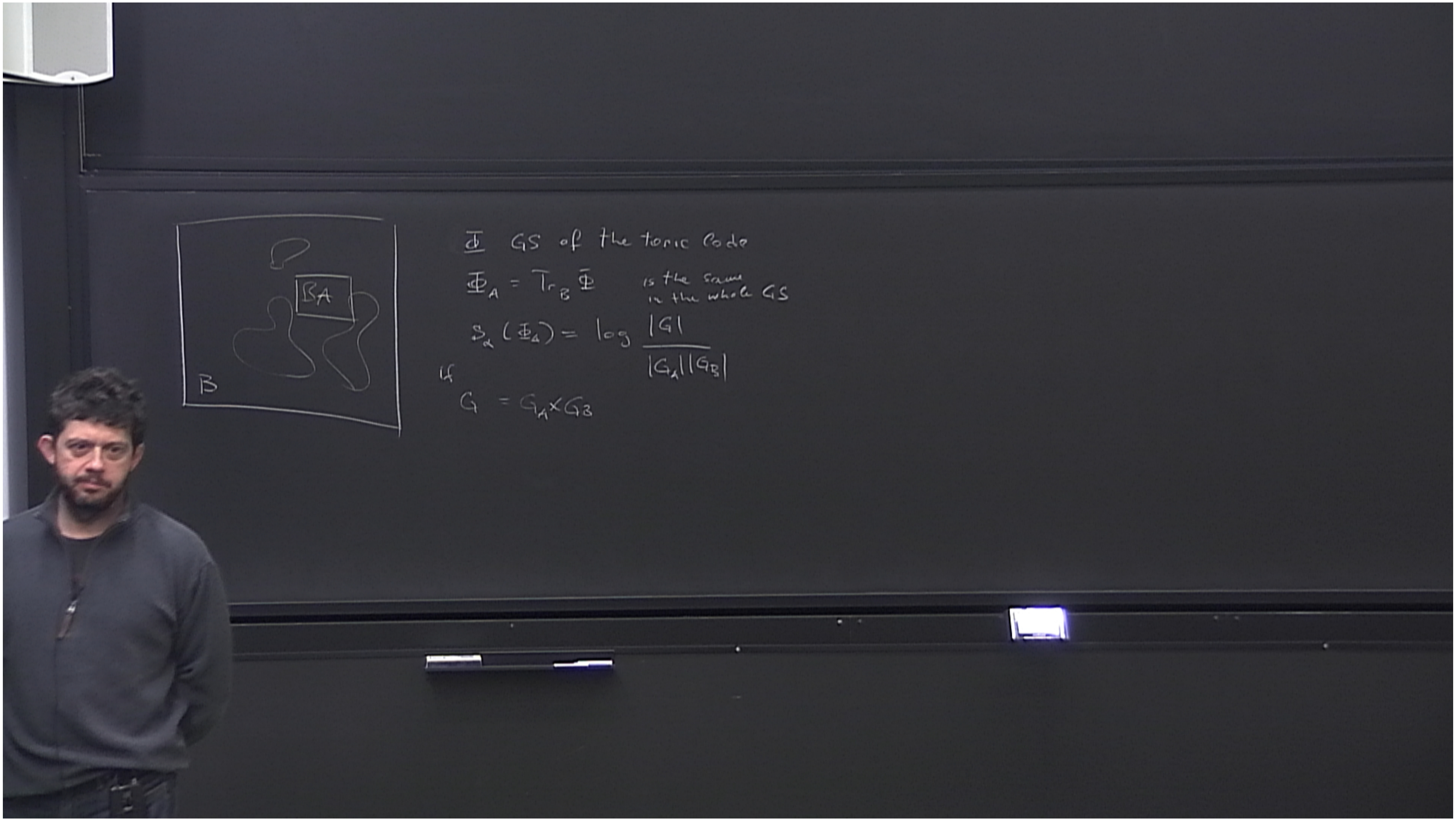
Title: Condensed Matter Review-12

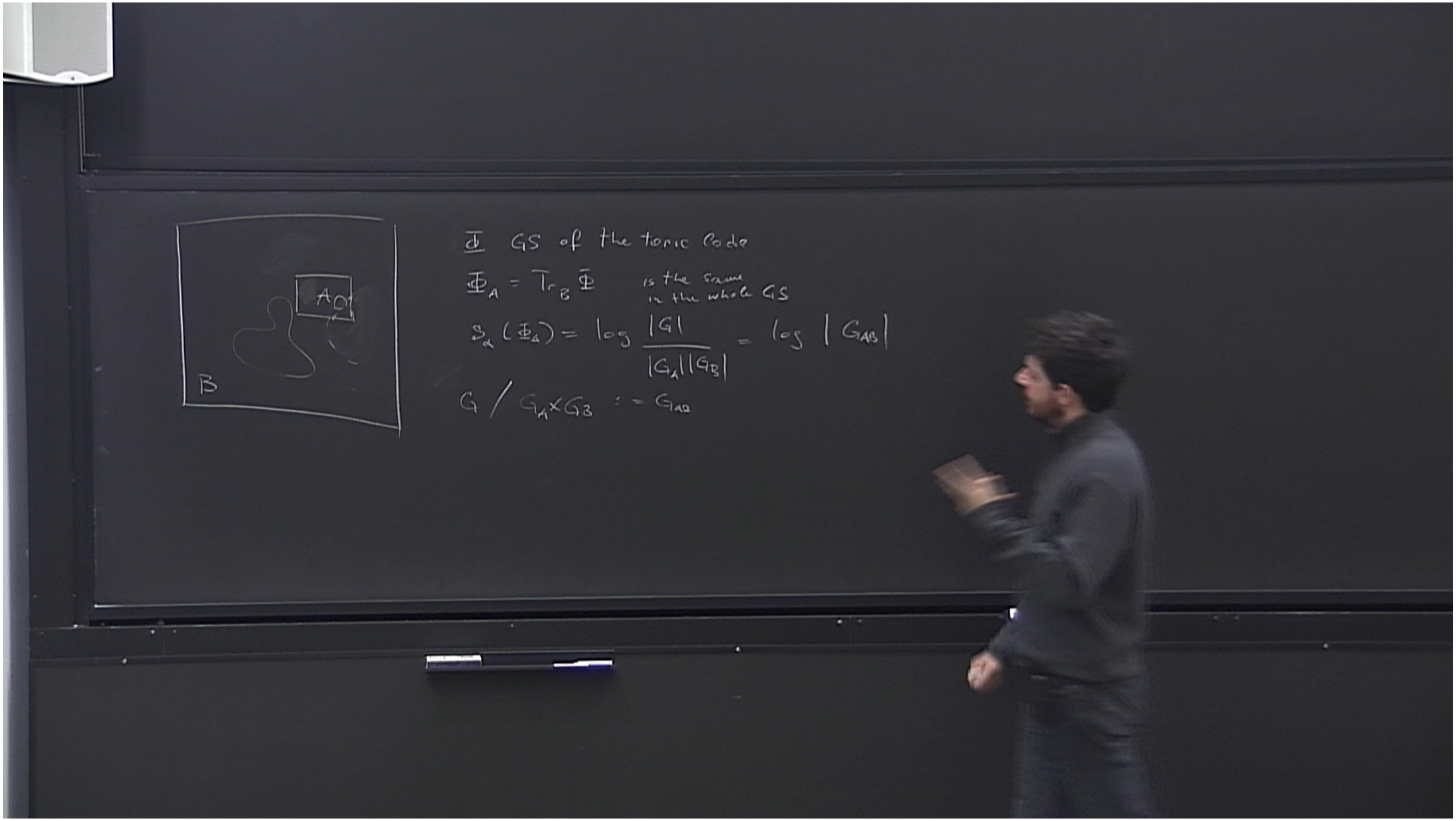
Date: Feb 10, 2015 09:00 AM

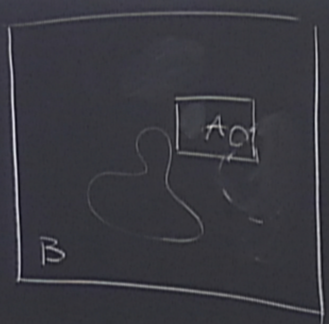
URL: http://pirsa.org/15020009

Abstract:


B A
B
Φ GS of the toric Code
Φ_A = Tr_B Φ
is the same
in the whole GS
S_α (Φ_A) = log |G| / |G_A||G_B|


Φ GS of the toric Code
Φ_A = Tr_B Φ
is the same in the whole GS
S_α (Φ_A) = log |G| / |G_A||G_B|
if G = G_A × G_B
B_A
B


A
B
Φ GS of the toric code
Φ_A = Tr_B Φ
is the same in the whole GS
S_α (Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB



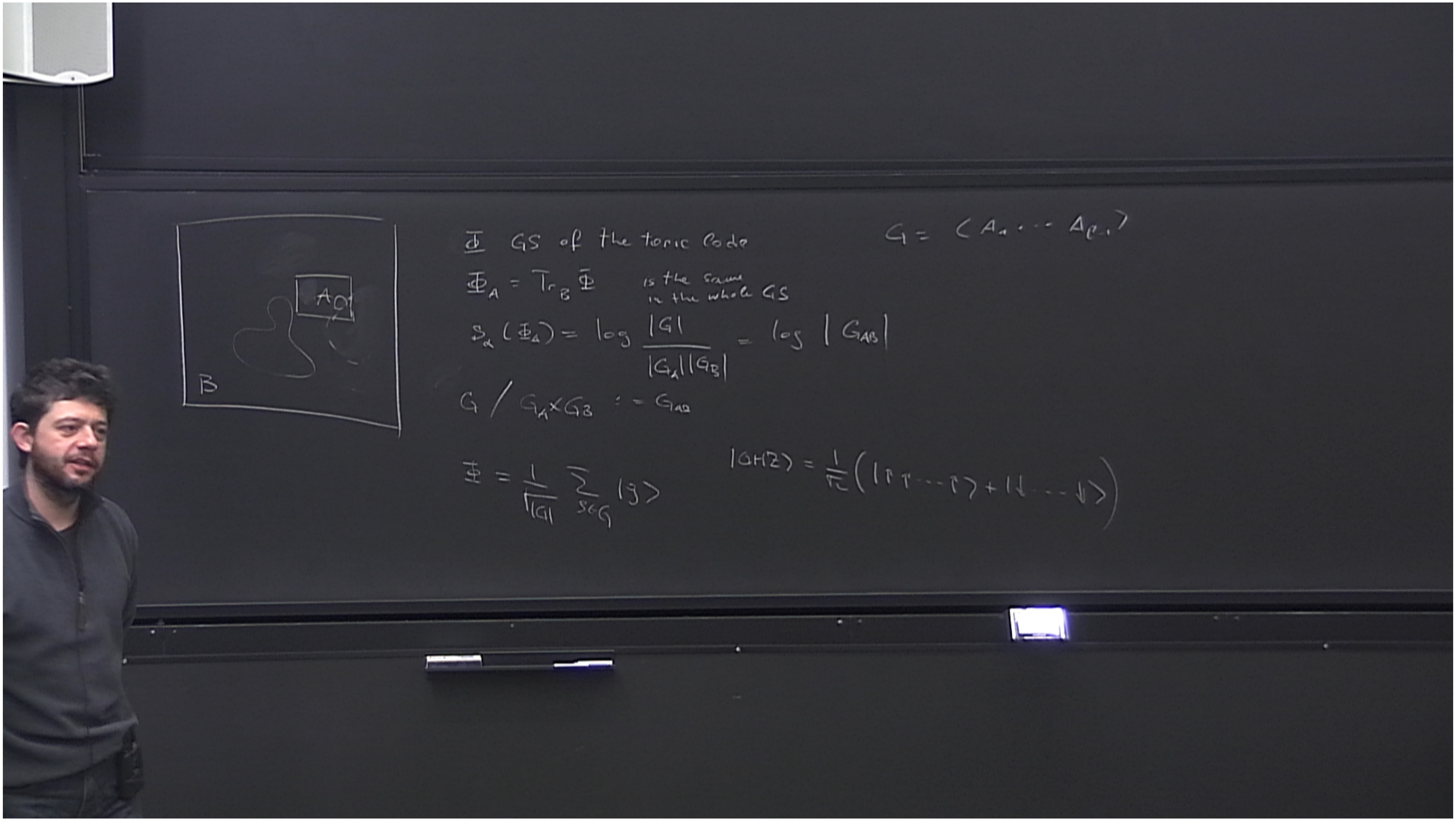
Φ GS of the toric code

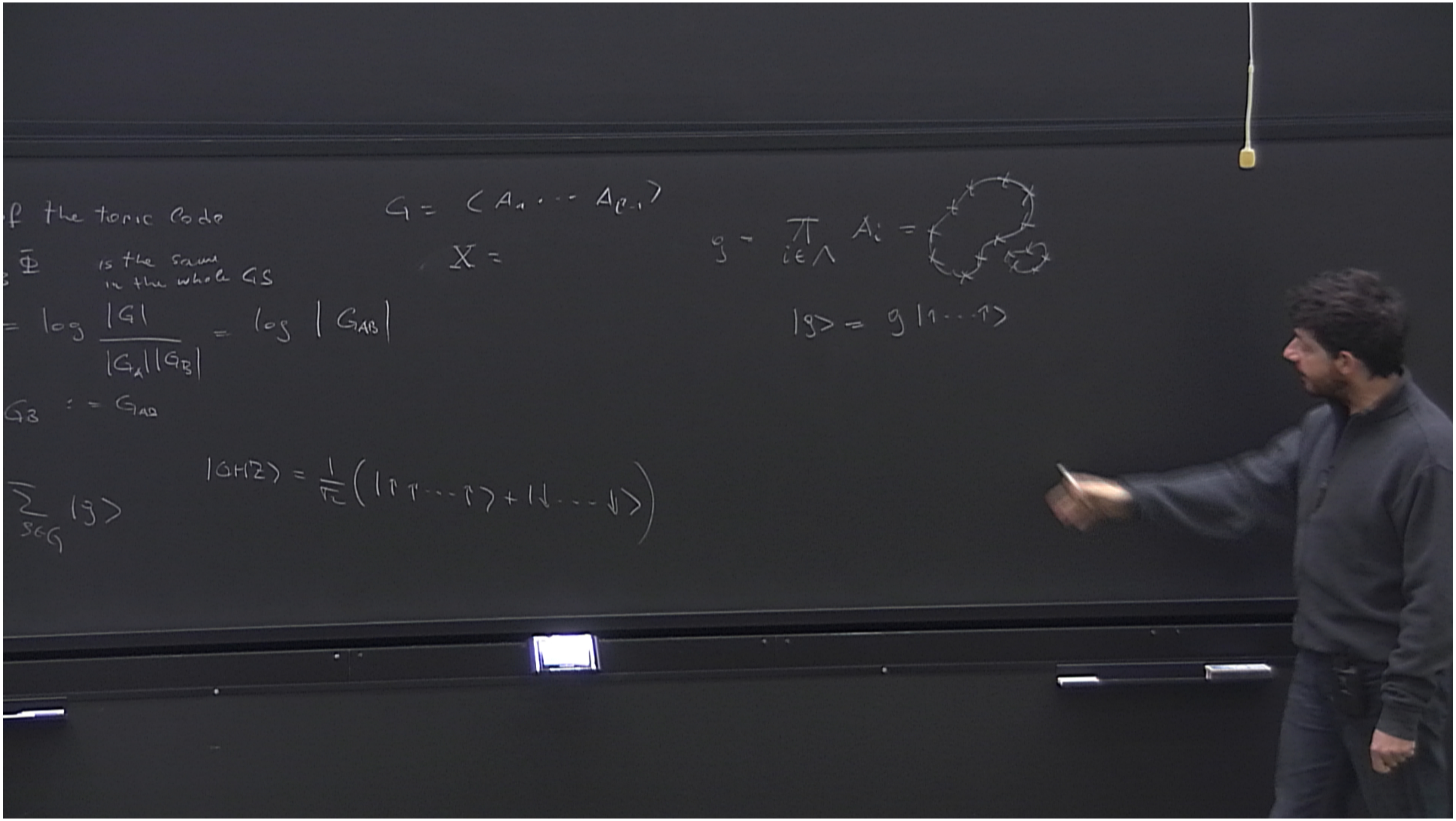
$\Phi_A = \mathrm{Tr}_B \, \Phi$ is the same in the whole GS

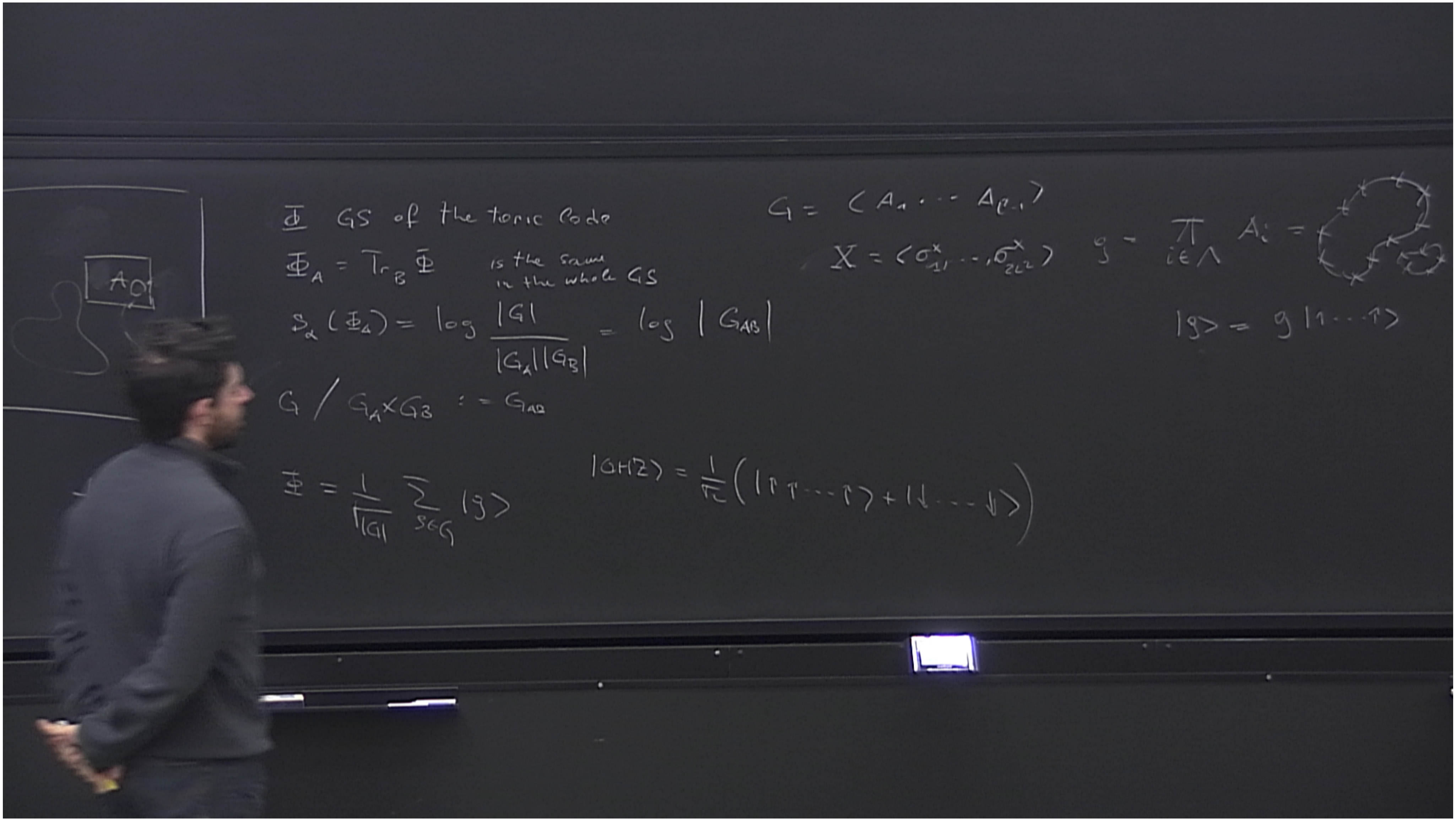
$$S_\alpha(\Phi_A) = \log \frac{|G|}{|G_A||G_B|} = \log |G_{AB}|$$

$$G / G_A \times G_B := G_{AB}$$

$$\Phi = \frac{1}{\sqrt{|G|}} \sum_{g \in G} |g\rangle$$


Φ GS of the toric Code
G = ⟨A₁ ··· A_{P-1}⟩
Φ_A = Tr_B Φ
is the same in the whole GS
A
B
S_α(Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB
Φ = 1/√|G| Σ_{g∈G} |g⟩
|GHZ⟩ = 1/√2 (|↑↑···↑⟩ + |↓···↓⟩)


f the toric code
$\bar{\Phi}$ is the same in the whole GS
$= \log \frac{|G|}{|G_A||G_B|} = \log |G_{AB}|$
$G_B := G_{AB}$
$\sum_{g \in G} |g\rangle$
$|GHZ\rangle = \frac{1}{\sqrt{2}}(|\uparrow\uparrow\cdots\uparrow\rangle + |\downarrow\cdots\downarrow\rangle)$
$G = \langle A_1 \cdots A_{l-1} \rangle$
$X =$
$g = \prod_{i \in \Lambda} A_i =$
$|g\rangle = g|\uparrow\cdots\uparrow\rangle$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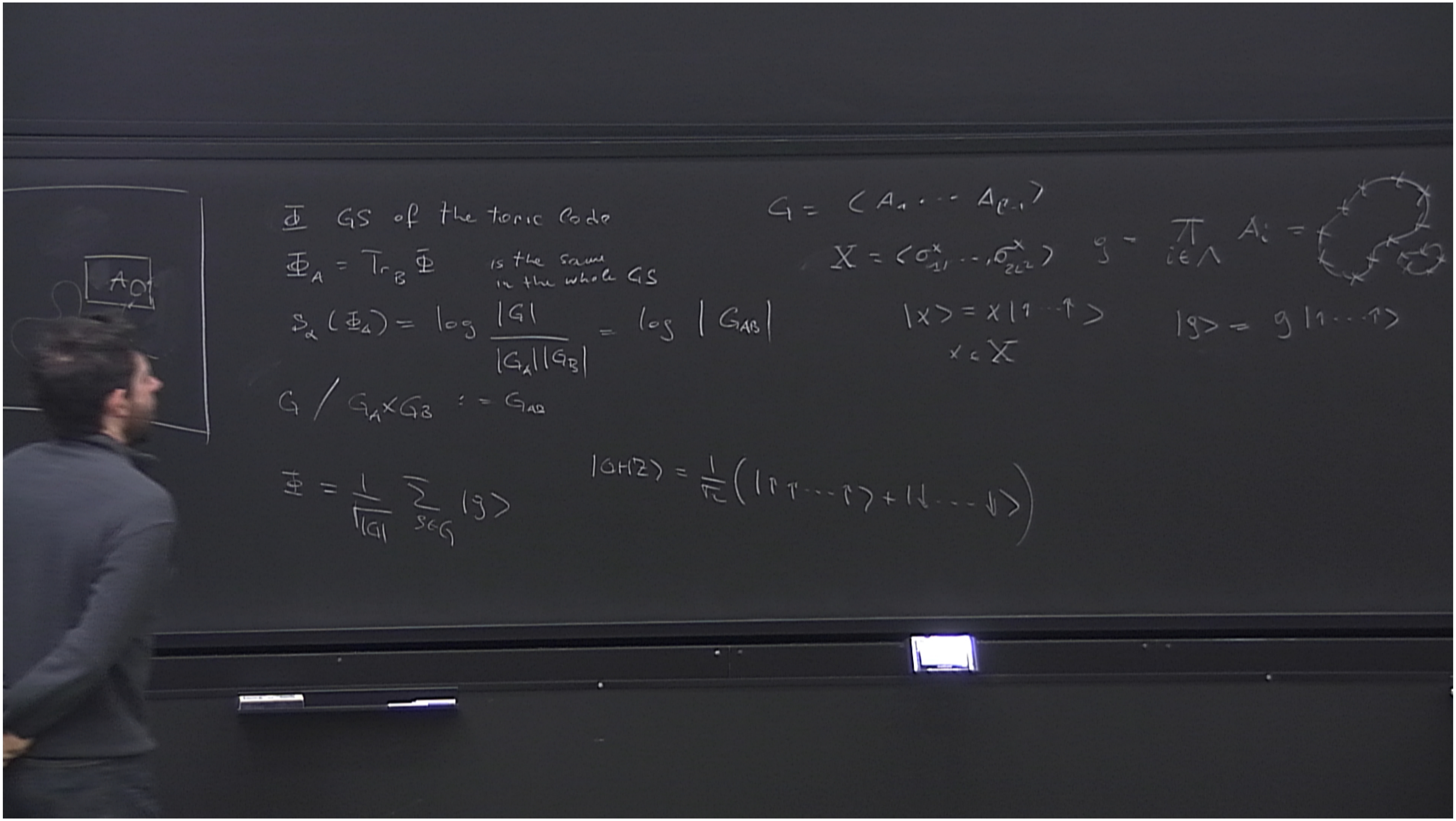
S_α(Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB
Φ = 1/√|G| Σ_{g∈G} |g⟩
|GHZ⟩ = 1/√2 (|↑↑···↑⟩ + |↓···↓⟩)
G = ⟨A_1 ··· A_{ℓ-1}⟩
X = ⟨σ^x_1, ···, σ^x_{2L^2}⟩
g = Π_{i∈Λ} A_i =
|g⟩ = g|↑···↑⟩
A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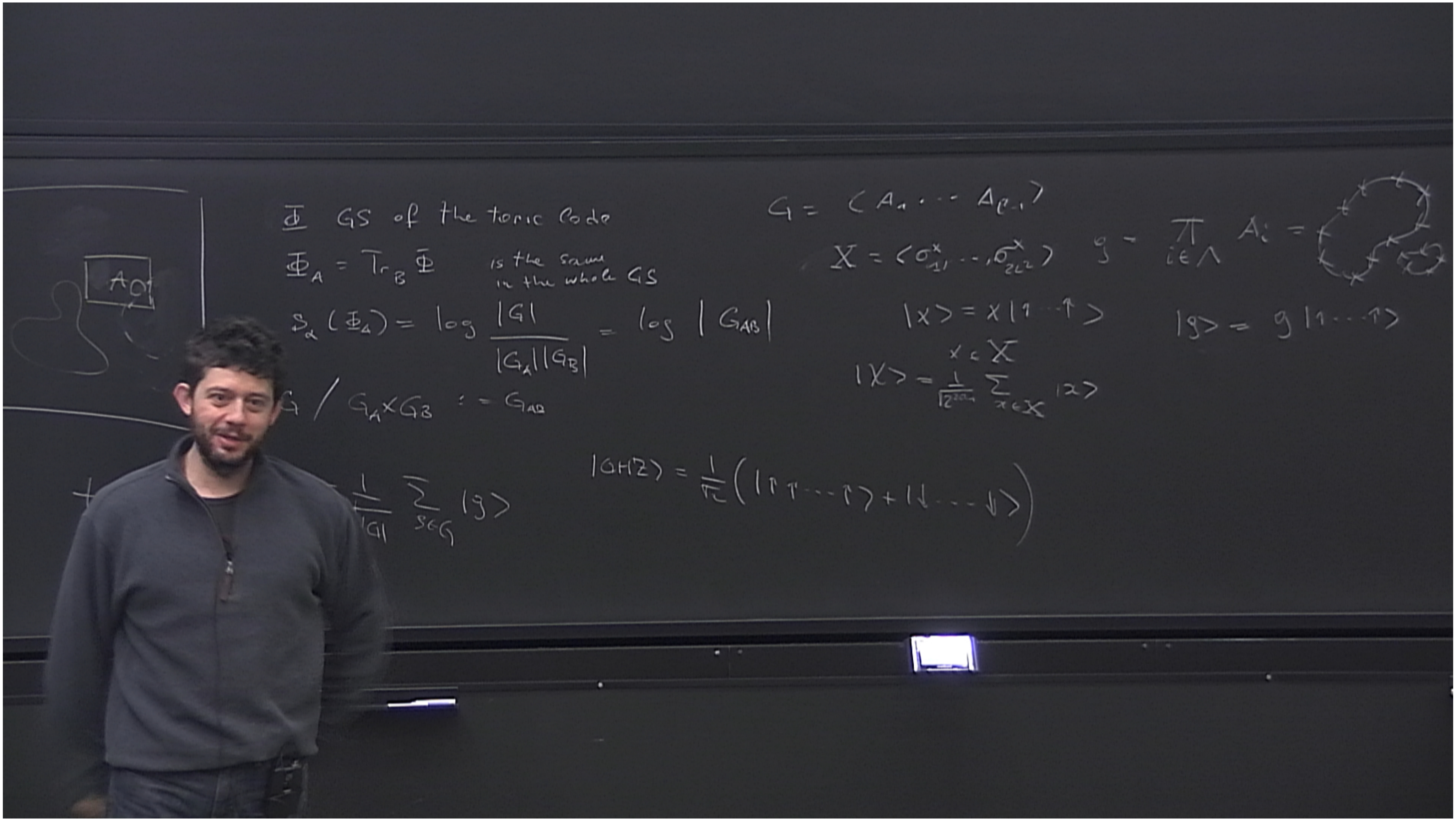
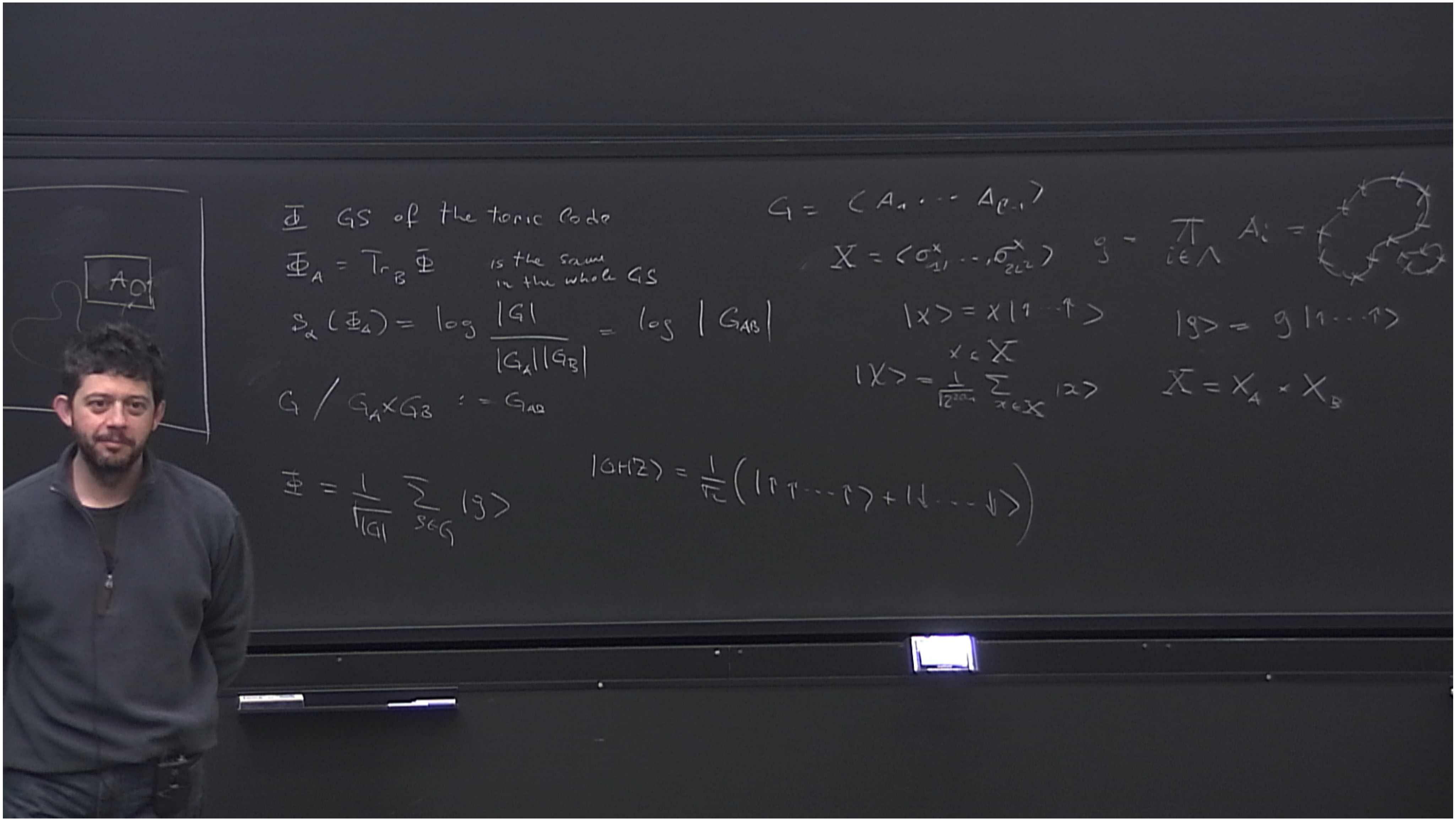
S_α (Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB
Φ = 1/√|G| Σ_{g∈G} |g>
|GHZ> = 1/√2 (|↑↑···↑> + |↓···↓>)
G = < A_1 ··· A_{ℓ-1} >
X = < σ^x_1, ···, σ^x_{2L^2} >
g = Π_{i∈Λ} A_i =
|x> = x |↑···↑>
x ∈ X
|g> = g |↑···↑>
A


Φ GS of the toric code
Φ_A = Tr_B Φ
is the same in the whole GS
S_α (Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A × G_B := G_AB
G = ⟨A_1 ... A_{ℓ-1}⟩
X = ⟨σ^x_1, ..., σ^x_{2L²}⟩
|x⟩ = x |↑...↑⟩
x ∈ X
|X⟩ = 1/√(2^{2L²}) Σ_{x∈X} |x⟩
g = Π_{i∈Λ} A_i =
|g⟩ = g |↑...↑⟩
|GHZ⟩ = 1/√2 (|↑↑...↑⟩ + |↓...↓⟩)
1/√|G| Σ_{g∈G} |g⟩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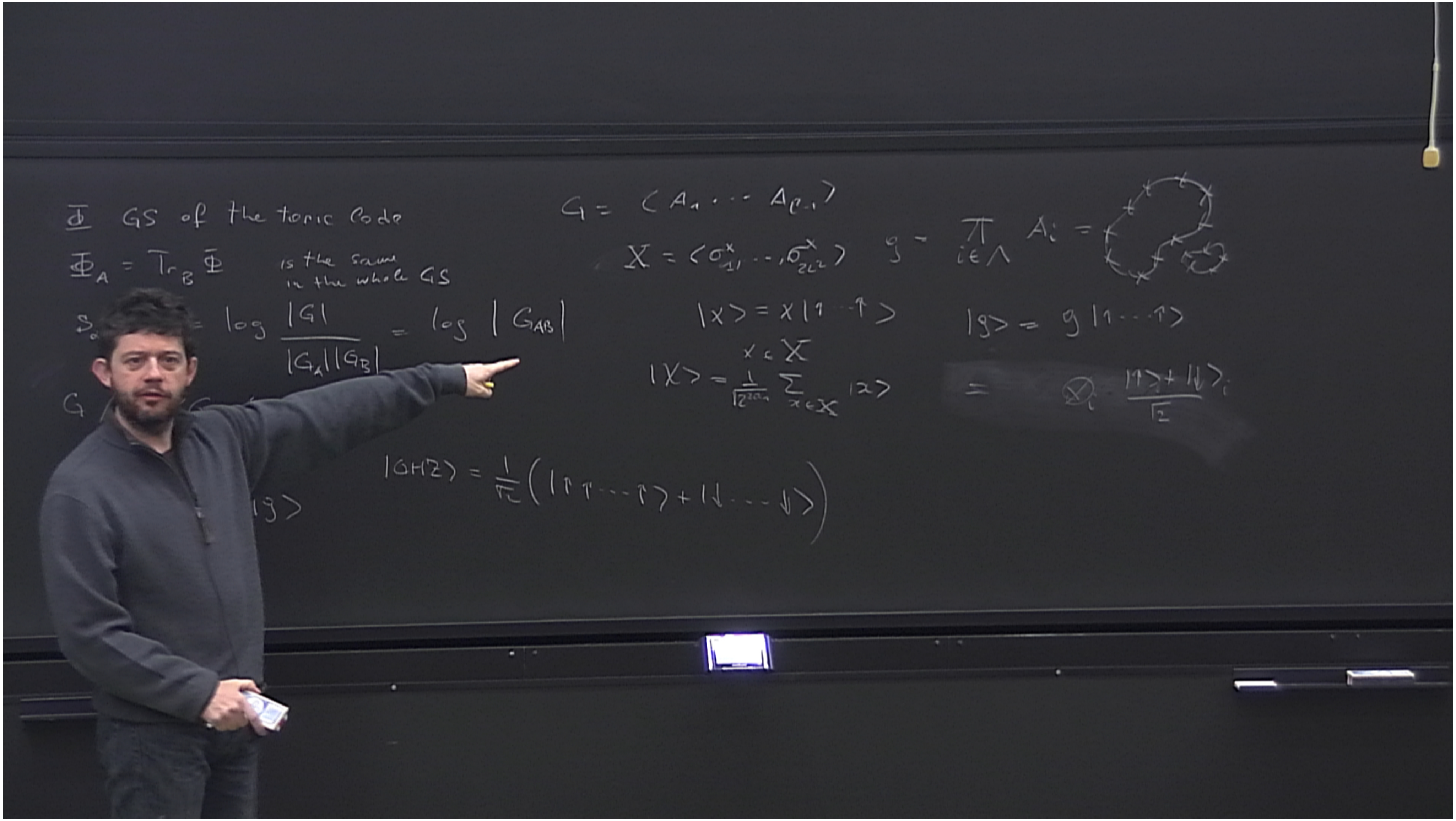
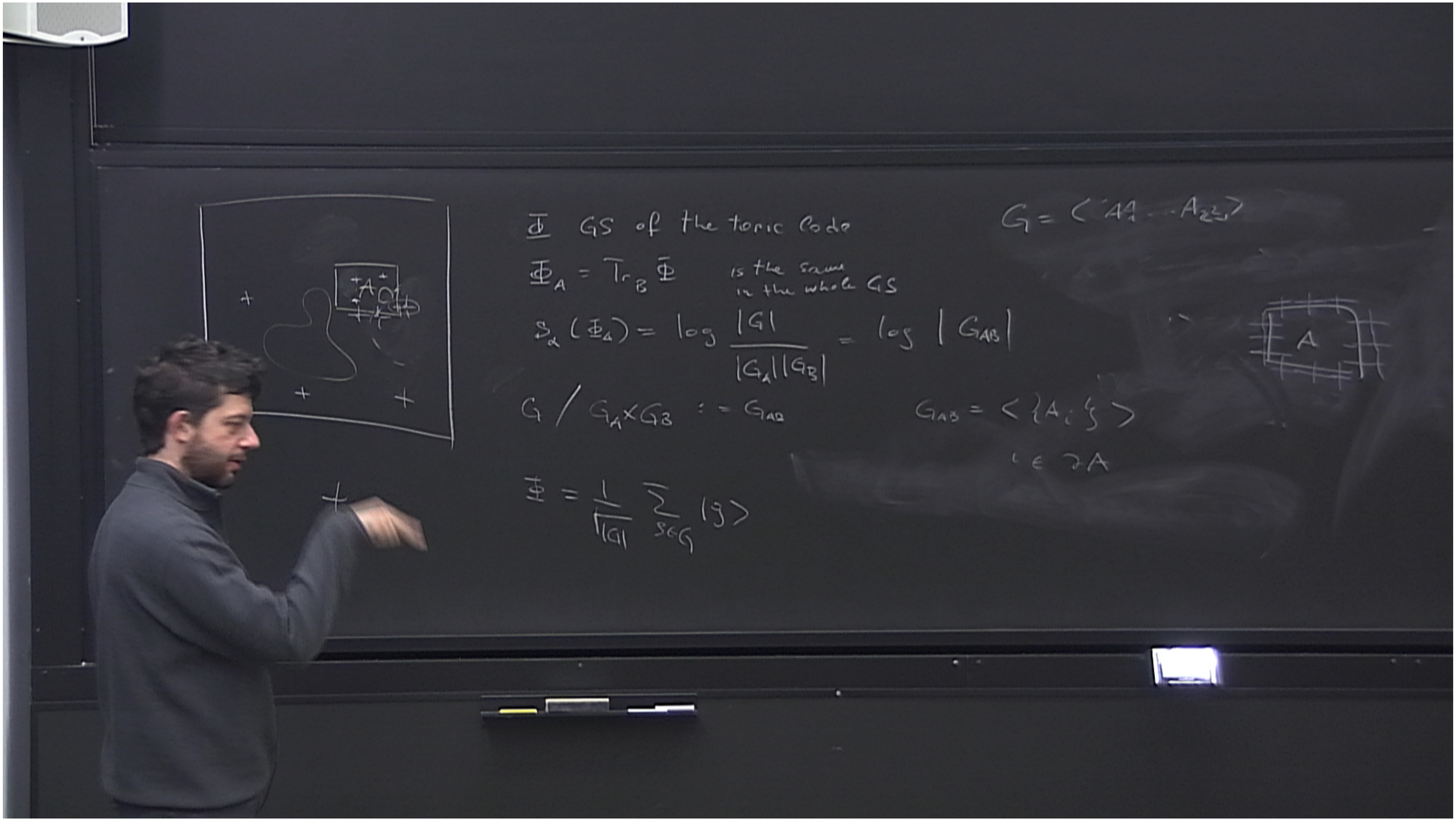
S_α (Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB
Φ = 1/√|G| Σ_{g∈G} |g>
|GHZ> = 1/√2 (|↑↑···↑> + |↓···↓>)
G = <A_1 ··· A_{ℓ-1}>
X = <σ^x_1, ..., σ^x_{2L²}>
g = Π_{i∈Λ} A_i =
|x> = x |↑···↑>
x ∈ X
|X> = 1/√2^{2L²} Σ_{x∈X} |x>
|g> = g |↑···↑>
X = X_A × X_B


Φ GS of the toric code
Φ_A = Tr_B Φ
is the same in the whole GS
= log |G| / |G_A||G_B| = log |G_AB|
G = ⟨A_1 . . . A_{l-1}⟩
X = ⟨σ^x_1, . . , σ^x_{2L²}⟩
g = Π_{i∈Λ} A_i =
|x⟩ = x |↑ . . ↑⟩
x ∈ X
|X⟩ = 1/√(2^{2L²}) Σ_{x∈X} |x⟩
|g⟩ = g |↑ . . . ↑⟩
= ⊗_i (|↑⟩ + |↓⟩)_i / √2
|GHZ⟩ = 1/√2 (|↑↑ . . . ↑⟩ + |↓ . . . ↓⟩)
|g⟩


A
Φ GS of the toric code
Φ_A = Tr_B Φ
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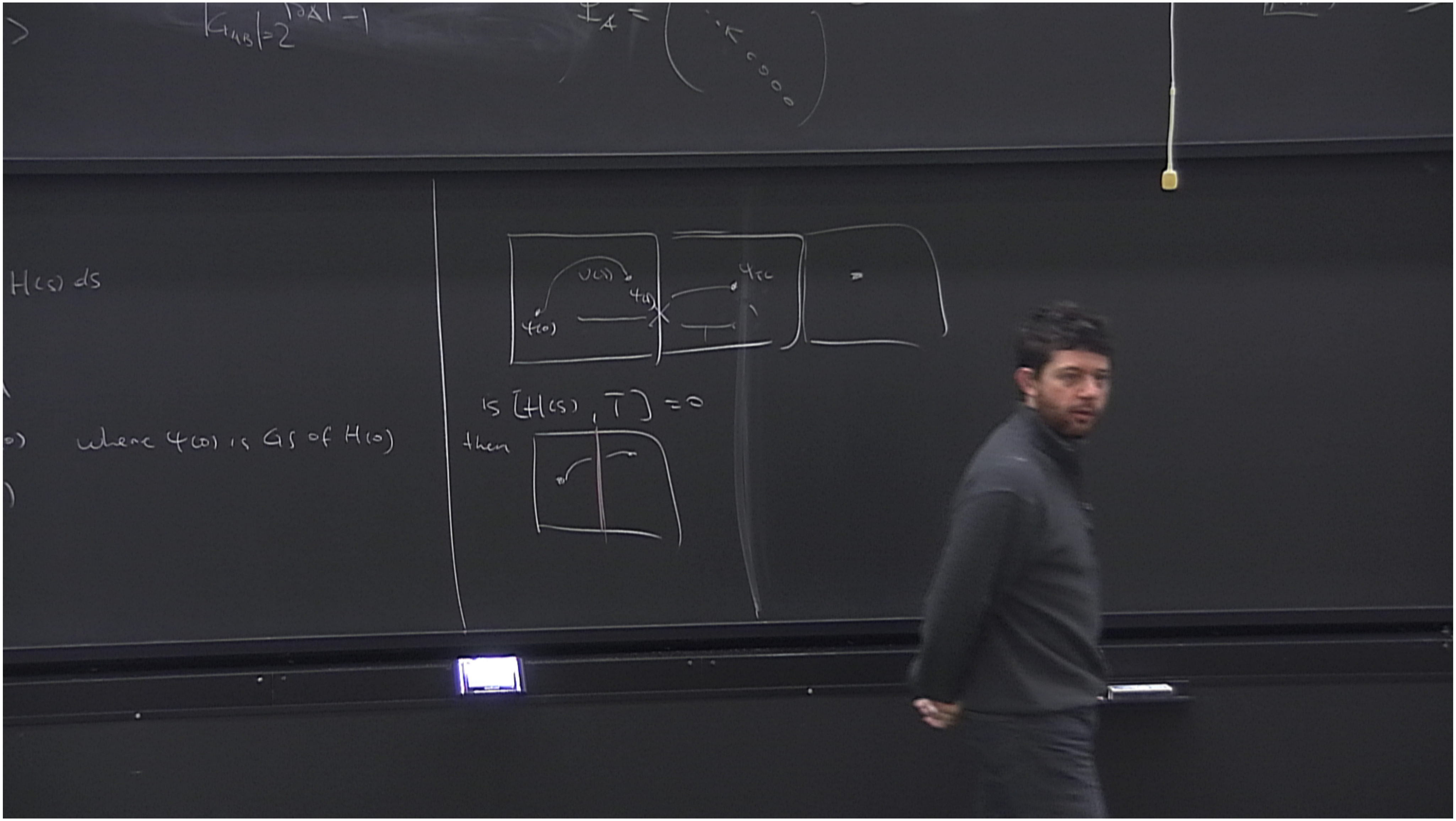
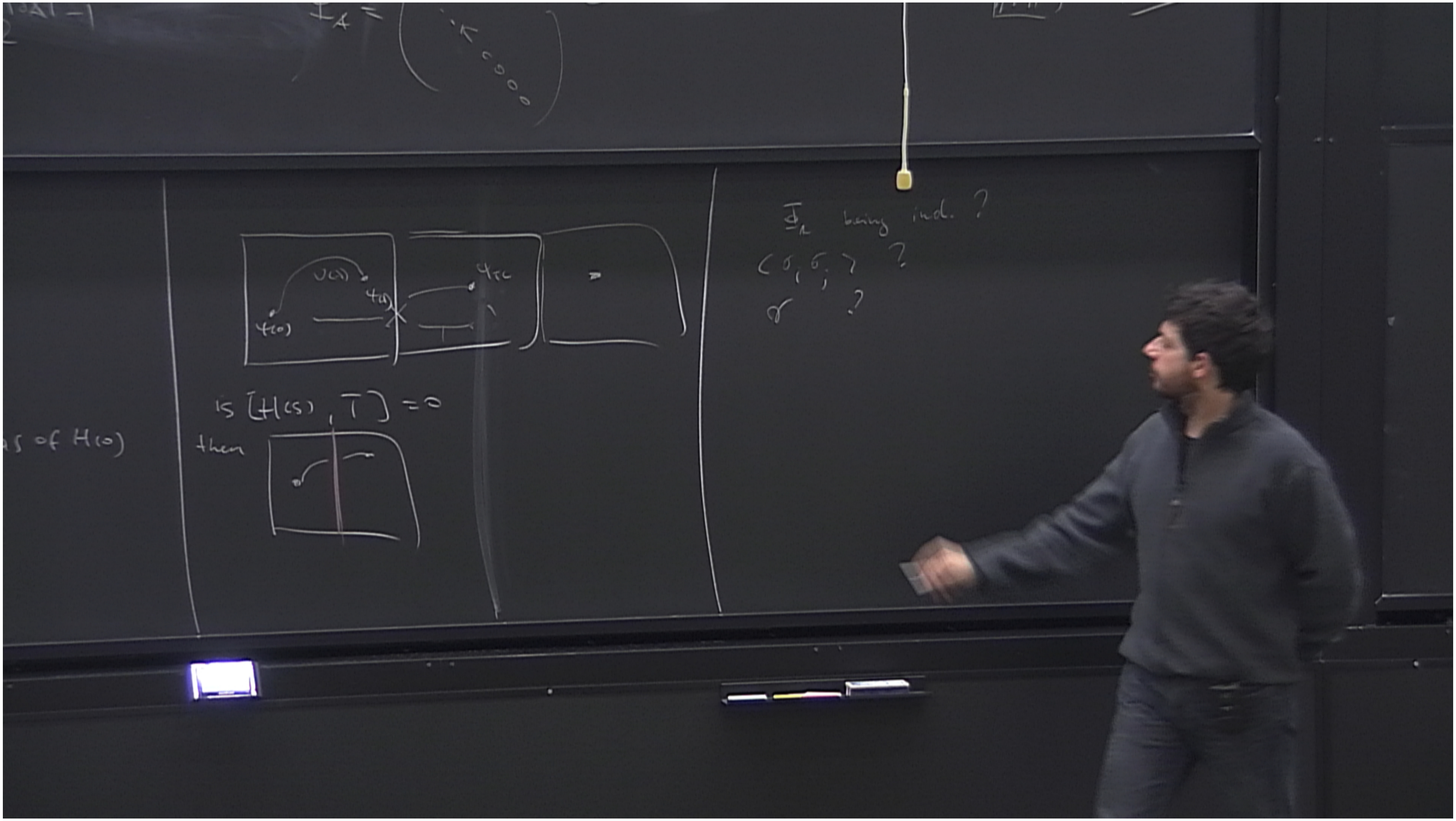
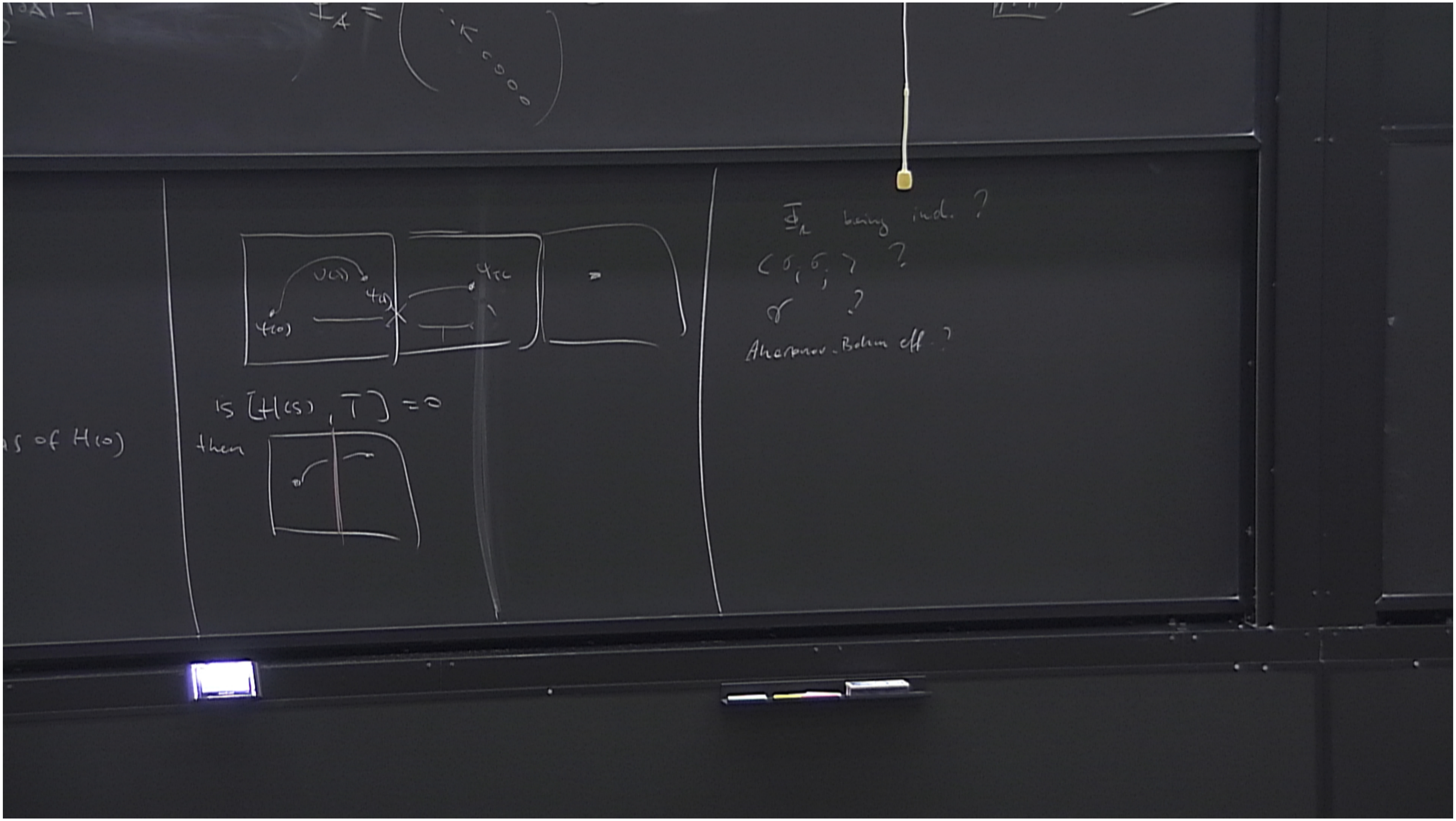
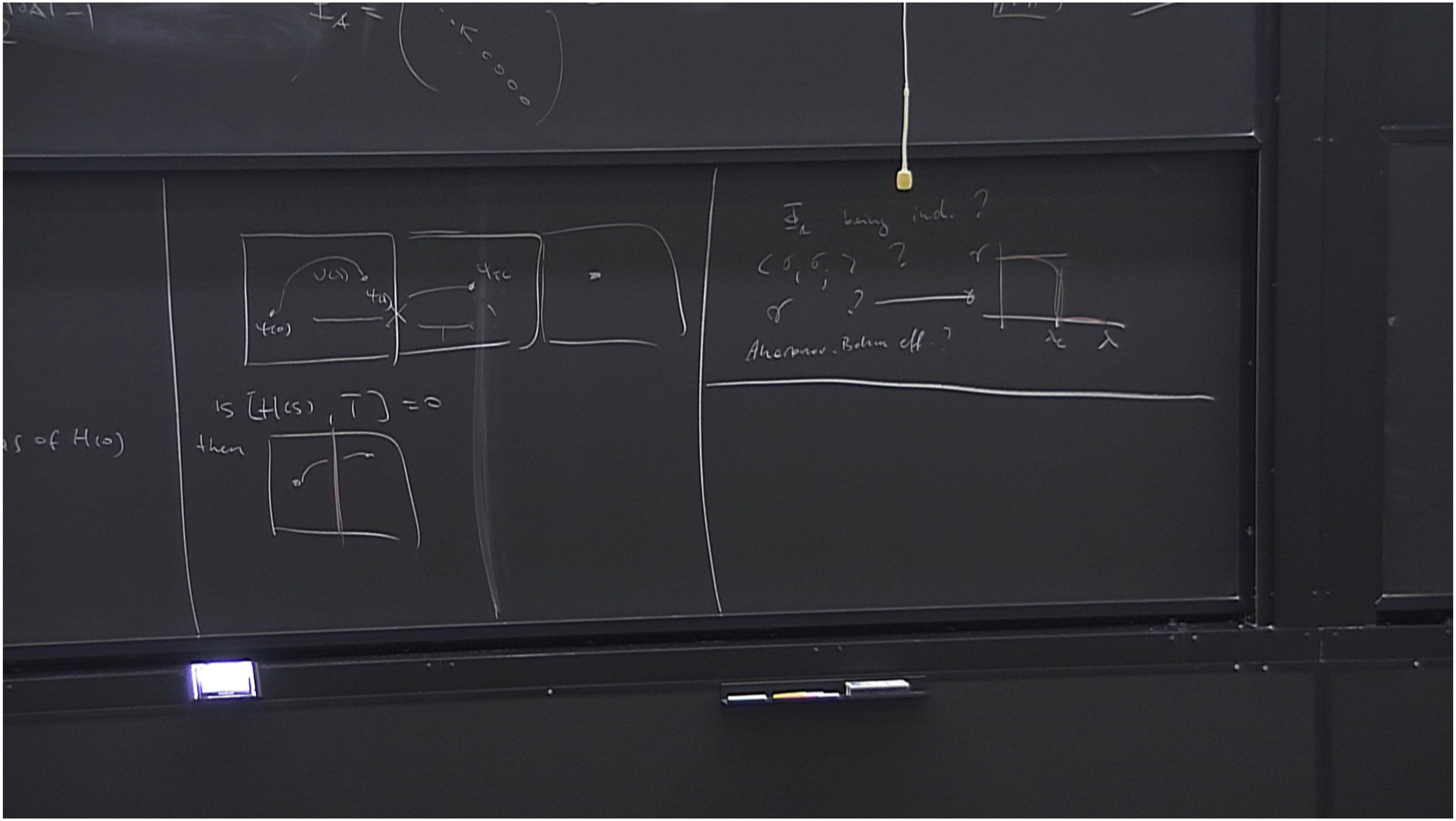
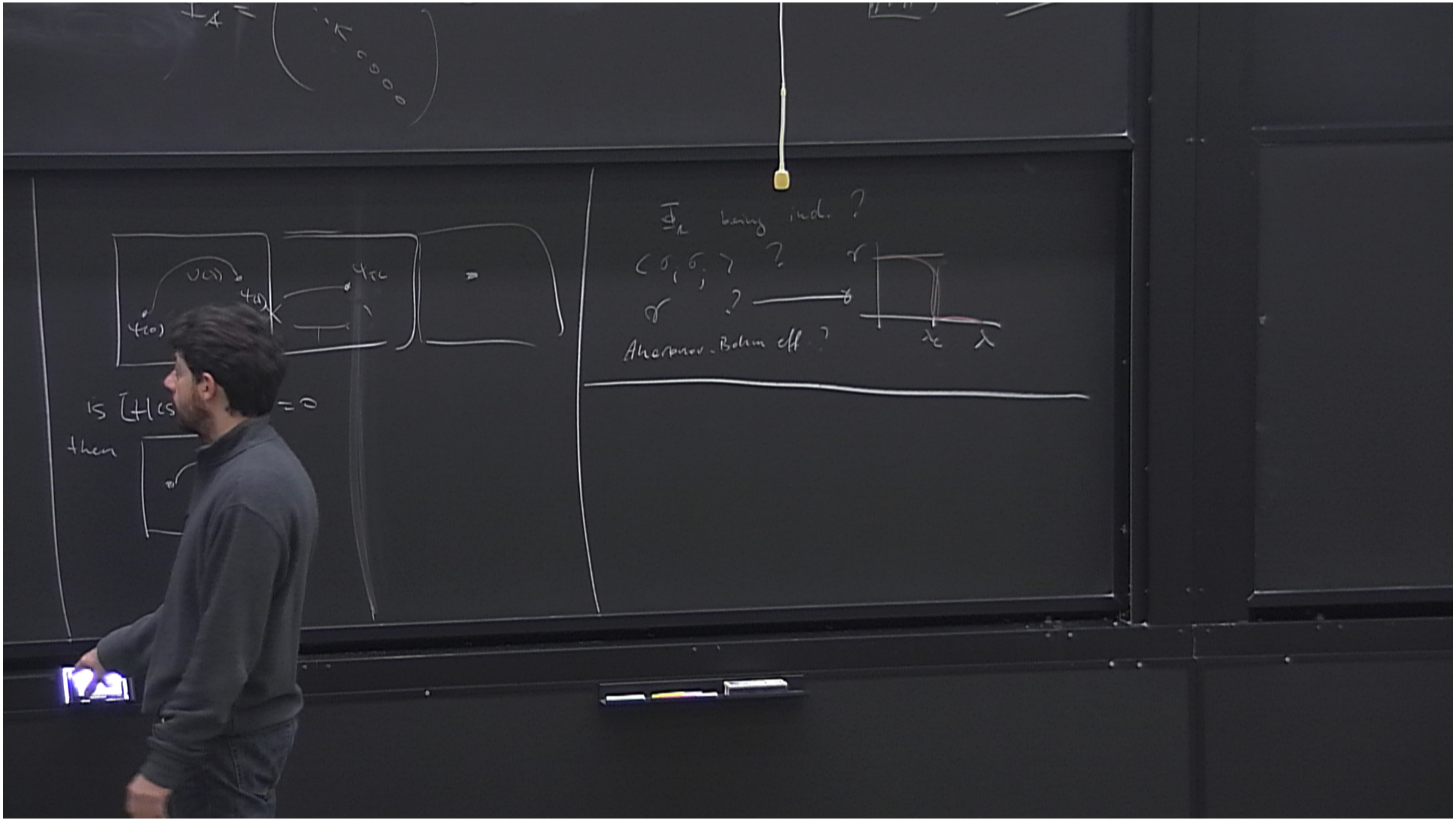
in the whole GS
S_α(Φ_A) = log |G| / |G_A||G_B| = log |G_AB|
G / G_A×G_B := G_AB
Φ = 1/√|G| Σ_{g∈G} |g>
G_AB = <{A_i}>
i ∈ ∂A
A


H(s) ds
where ψ(0) is GS of H(0)
is [H(s), T] = 0
then

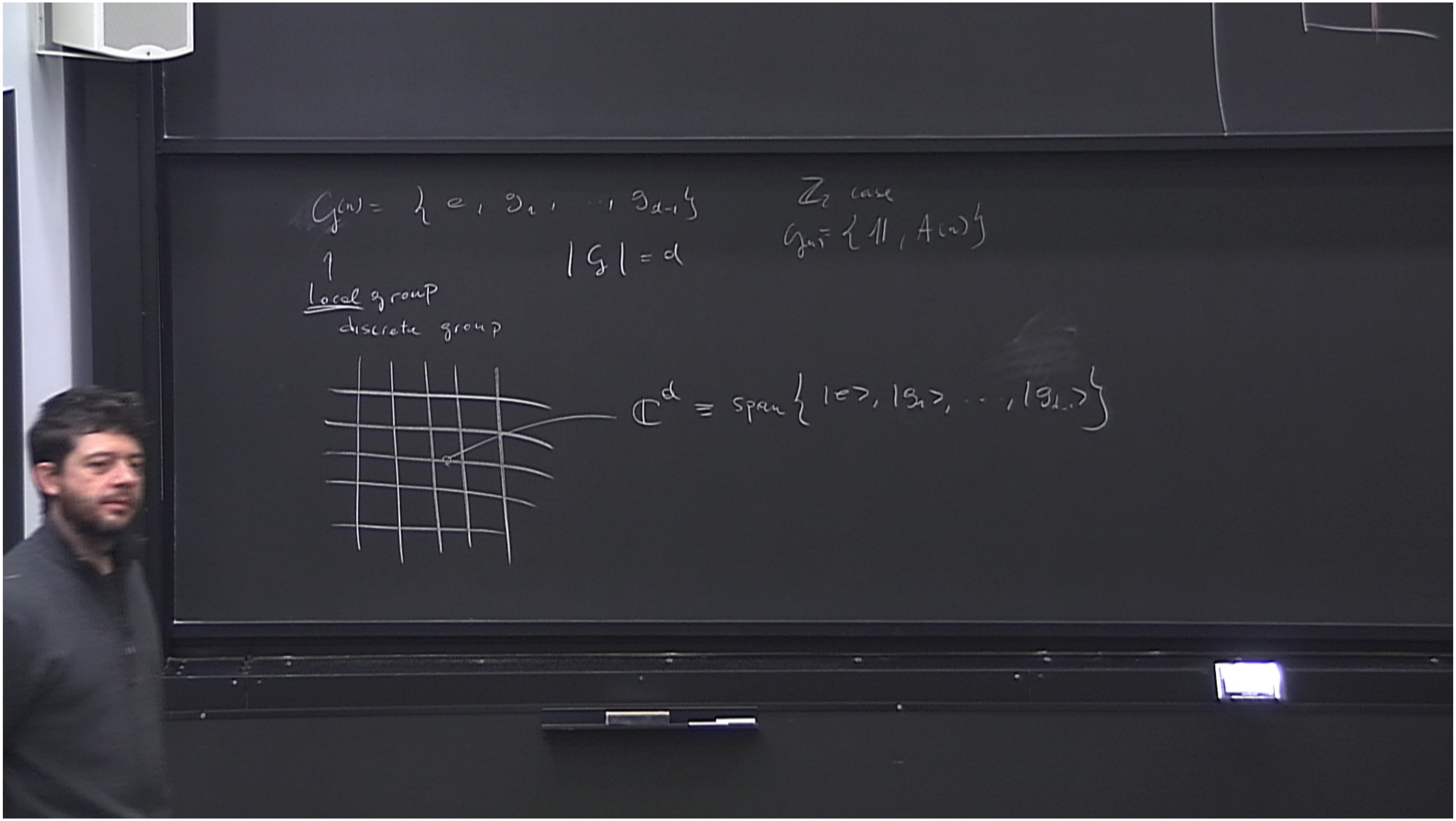

is [H(s) , T] = 0
then
being ind. ?

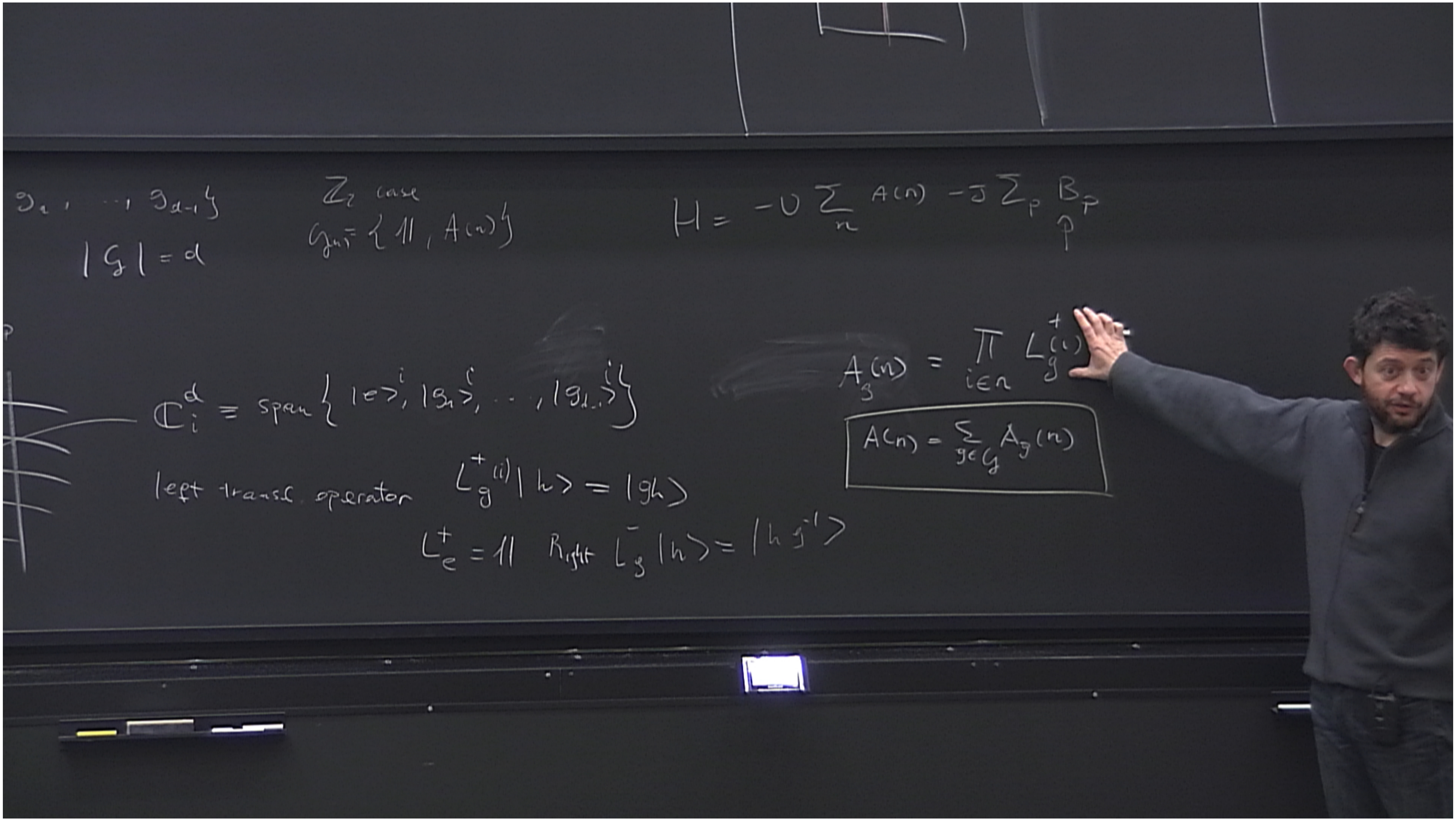

is [H(s), T] = 0
then
of H(0)
being ind. ?
Aharonov-Bohm eff. ?

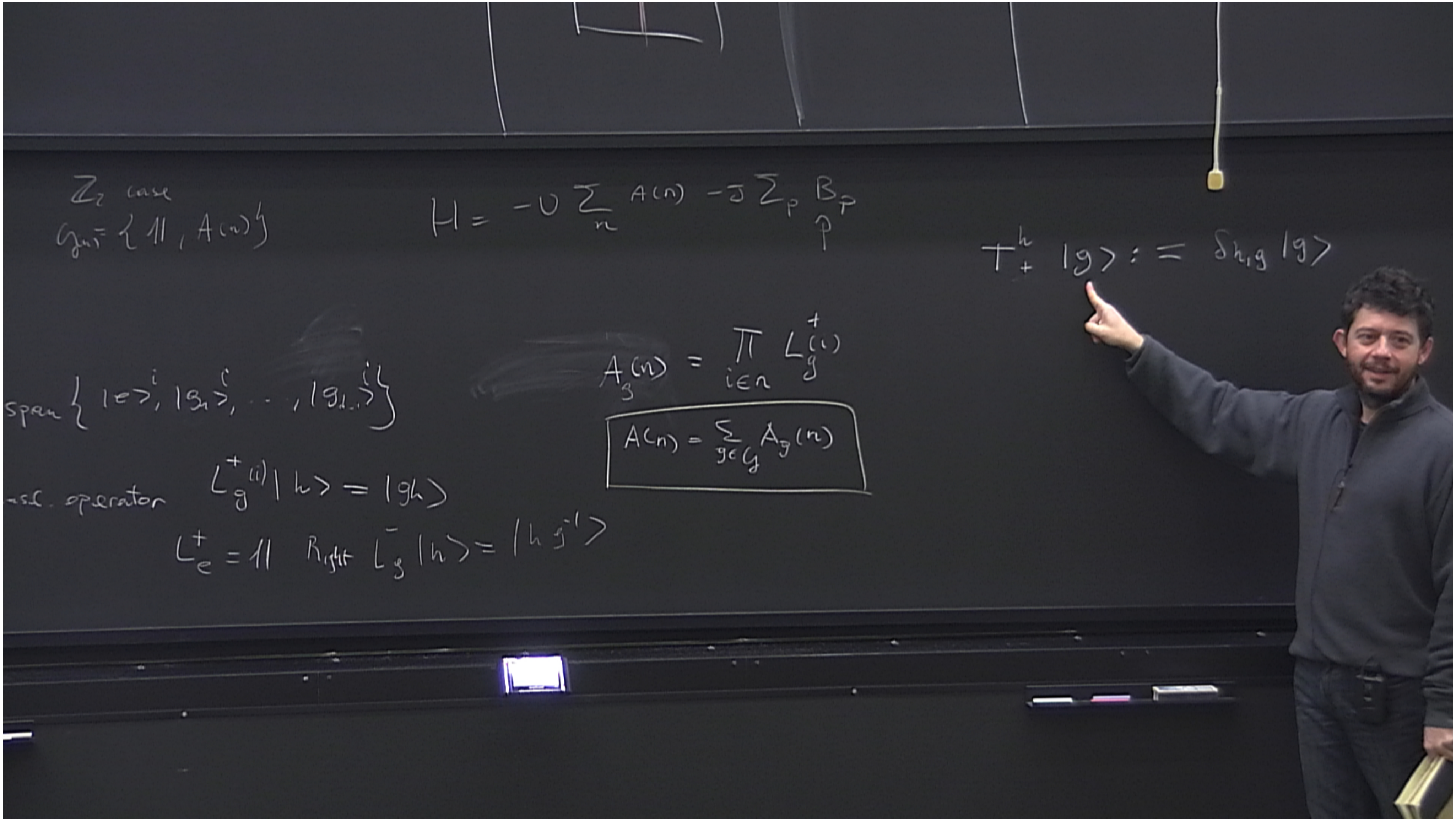

being ind. ?
Aharonov-Bohm eff. ?
is [H(s), T] = 0
then
of H(0)



Φ_A being ind. ?
<σ_i σ_j> ?
γ ?
Aharonov-Bohm eff. ?
λ_c λ


$G(x) = \{ e, g_1, \ldots, g_{d-1} \}$
$|G| = d$
Local group
discrete group
$\mathbb{Z}_2$ case
$G_x = \{ 1\!\!1, A(x) \}$
$\mathbb{C}^d \equiv \mathrm{span}\{ |e\rangle, |g_1\rangle, \ldots, |g_{d-1}\rangle \}$


$g_1, \ldots, g_{d-1}\}$
$|G| = d$
Z_2 case
$G_{n} = \{ 1\!\!1, A(n) \}$
$H = -U \sum_n A(n) - J \sum_p B_p$
$A_g(n) = \prod_{i \in n} L_g^{+(i)}$
$A(n) = \sum_{g \in G} A_g(n)$
$\mathbb{C}_i^d \equiv \mathrm{span}\{ |e\rangle^i, |g_1\rangle^i, \ldots, |g_{d-1}\rangle^i \}$
left transl. operator $L_g^{+(i)} |h\rangle = |gh\rangle$
$L_e^+ = 1\!\!1$ Right $L_g^- |h\rangle = |hg^{-1}\rangle$


Z2 case
Gn = { 11 , A(n) }
H = -U Σn A(n) - J Σp Bp
T+h |g> := δh,g |g>
Ag(n) = Π i∈n Lg+(i)
span { |e>i, |g1>i, . . . , |gd-1>i }
A(n) = Σ g∈G Ag(n)
operator Lg+(i) |h> = |gh>
Le+ = 11 Right Lg- |h> = |h g-1>

Z_2 case

$G_n = \{ 1\!\!1 , A(n) \}$

$$H = -U \sum_n A(n) - J \sum_p B_p$$

$$T^h_\pm |g\rangle := \delta_{h^{\pm 1}, g} |g\rangle$$

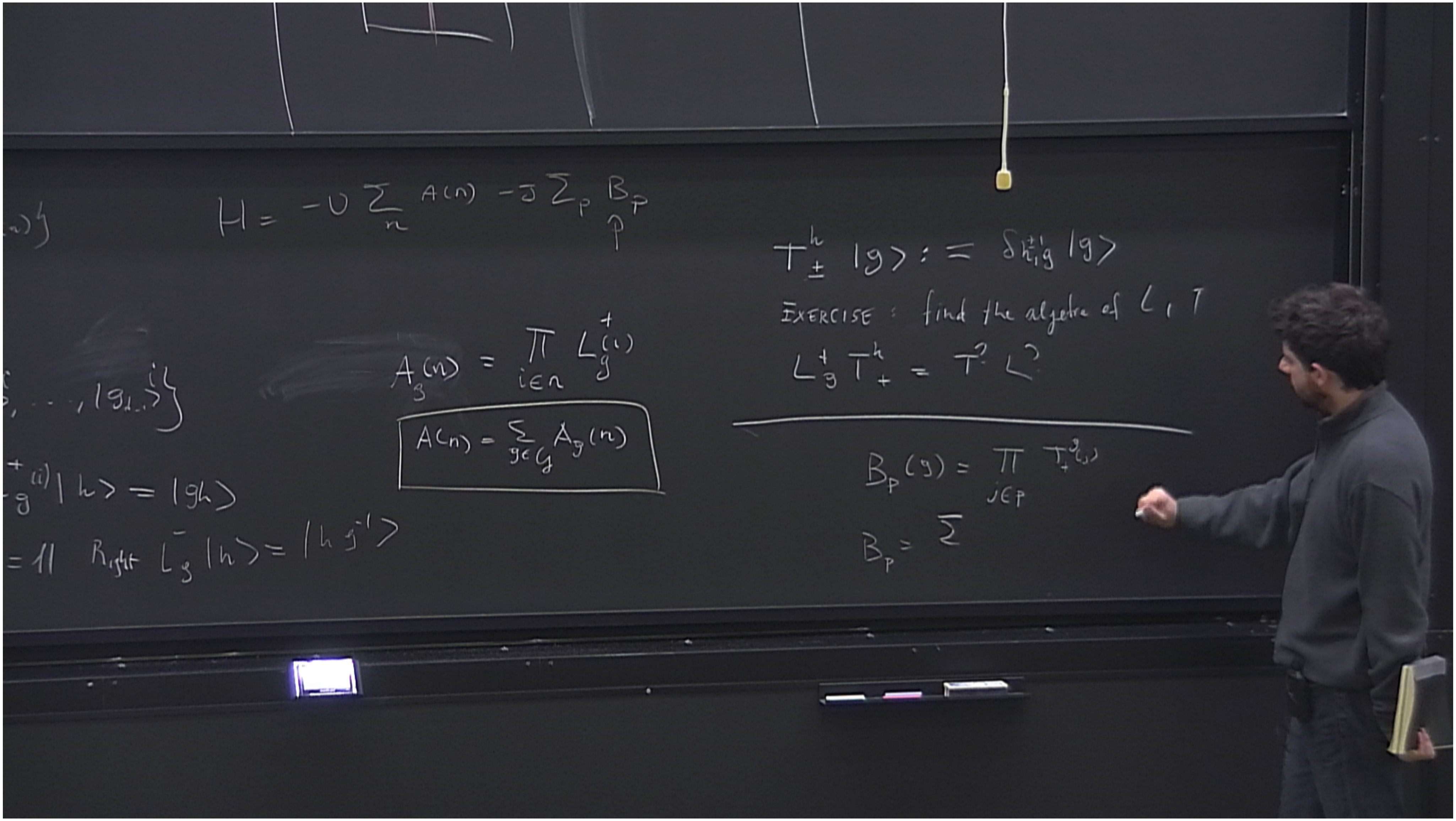
$$A_g(n) = \prod_{i \in n} L_g^{+(i)}$$

$$\boxed{A(n) = \sum_{g \in G} A_g(n)}$$

span$\{ |e\rangle^i, |g_1\rangle^i, \dots, |g_{|G|}\rangle^i \}$

...ss. operator $L_g^{+(i)} |h\rangle = |gh\rangle$

$L_e^+ = 1\!\!1$ Right $L_g^- |h\rangle = |h g^{-1}\rangle$


H = −U Σ_n A(n) − J Σ_p B_p
T^h_± |g> := δ_{h^{±1}, g} |g>
EXERCISE : find the algebra of L, T
L^+_g T^h_+ = T^? L^?
A_g(n) = Π_{i∈n} L^+_g(i)
A(n) = Σ_{g∈G} A_g(n)
L^+_g(i) |h> = |gh>
Right L^-_g |h> = |hg^{-1}>
B_p(g) = Π_{j∈p} T^g_+(j)
B_p = Σ

$$H = -U\sum_n A(n) - J\sum_p B_p$$

$$T^h_\pm |g\rangle := \delta_{h^{\pm 1},g}|g\rangle$$

EXERCISE: find the algebra of L, T

$$L^+_g T^h_+ = T^? L^?$$

$$, \ldots, |g_{d..}\rangle\}$$

$$A_g(n) = \prod_{i\in n} L_g^{+(i)}$$

$$\boxed{A(n) = \sum_{g\in G} A_g(n)}$$

$$L_g^{+(i)}|h\rangle = |gh\rangle$$

$= 1\!\!1$ Right $L^-_g|h\rangle = |hg^{-1}\rangle$

$$B_p(g_1g_2g_3g_4) = \prod_{j\in p} T_+^{g_j}(p)$$

$$B_p = \sum_{g_1g_2g_3g_4=e} B_p$$