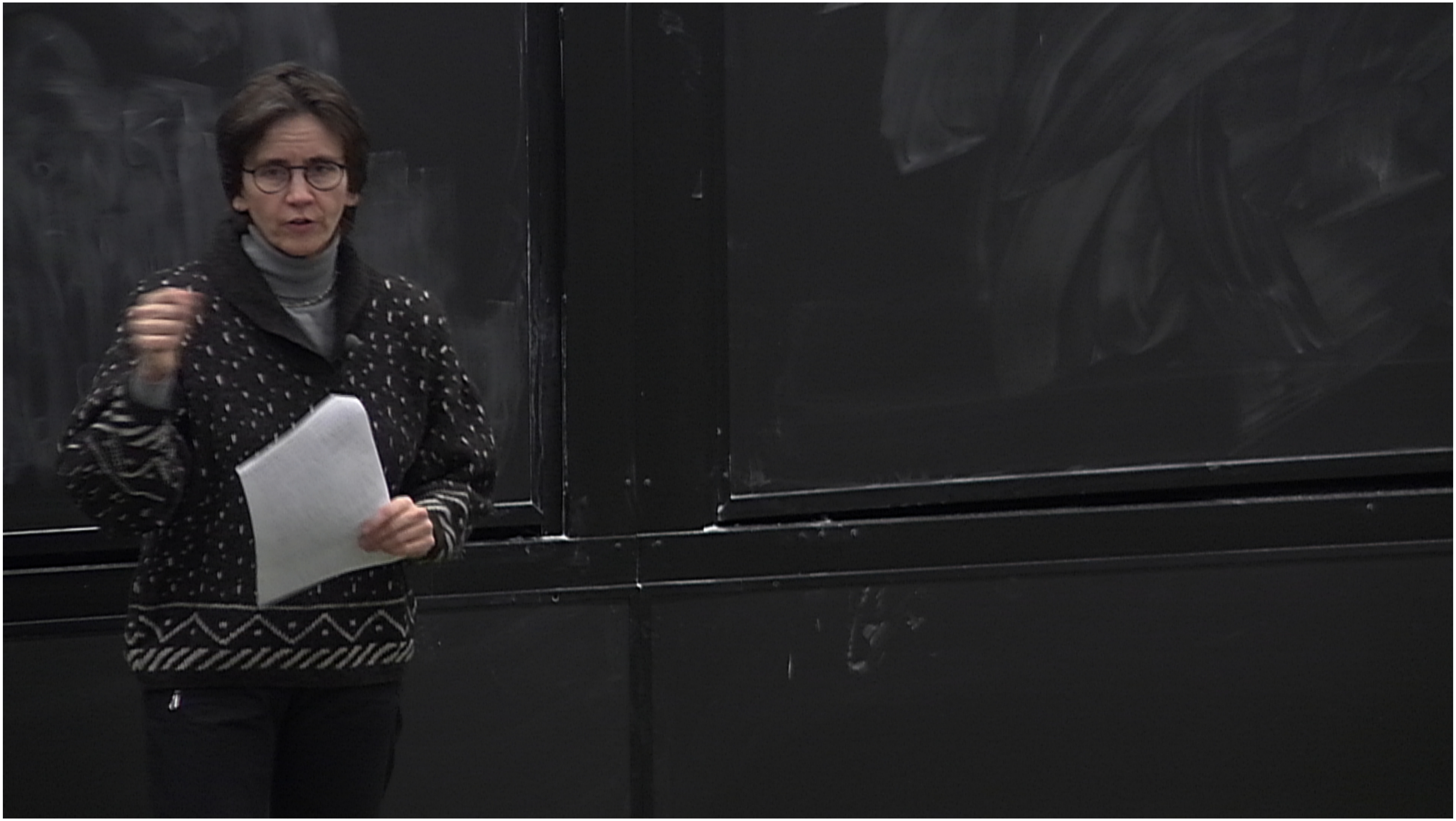
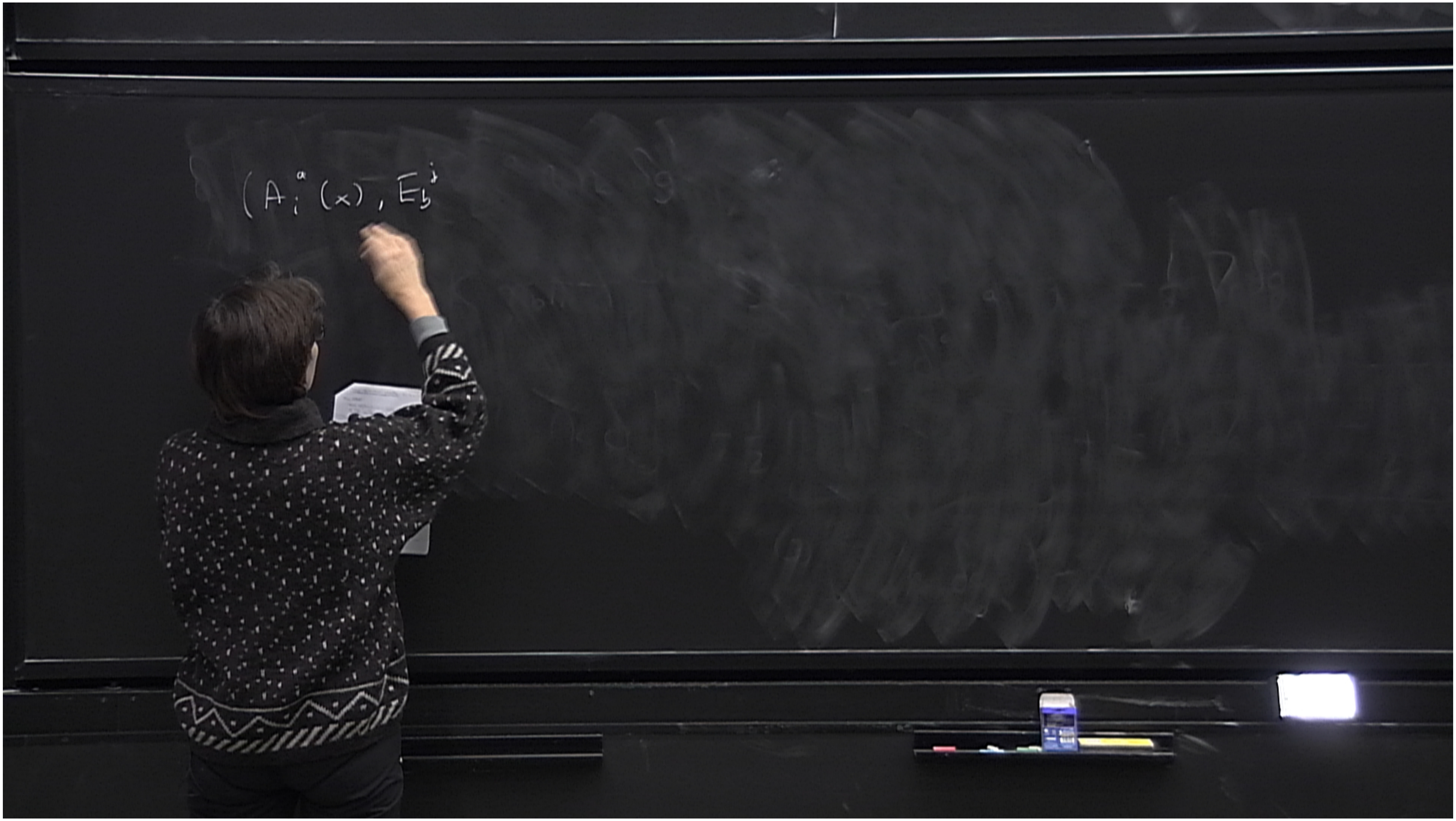
Title: Quantum Gravity (Review) - Lecture 11

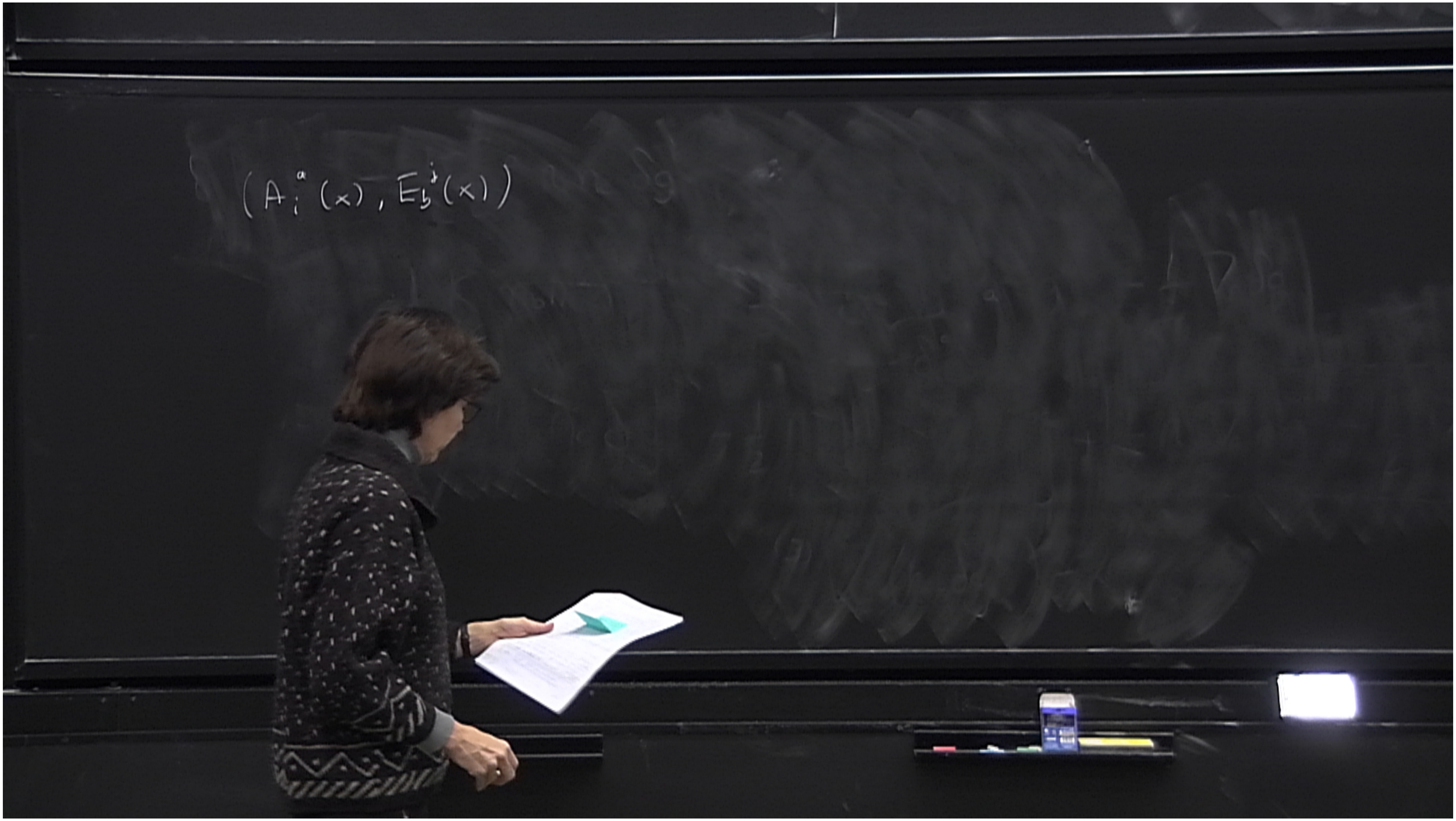
Date: Feb 06, 2012 10:15 AM

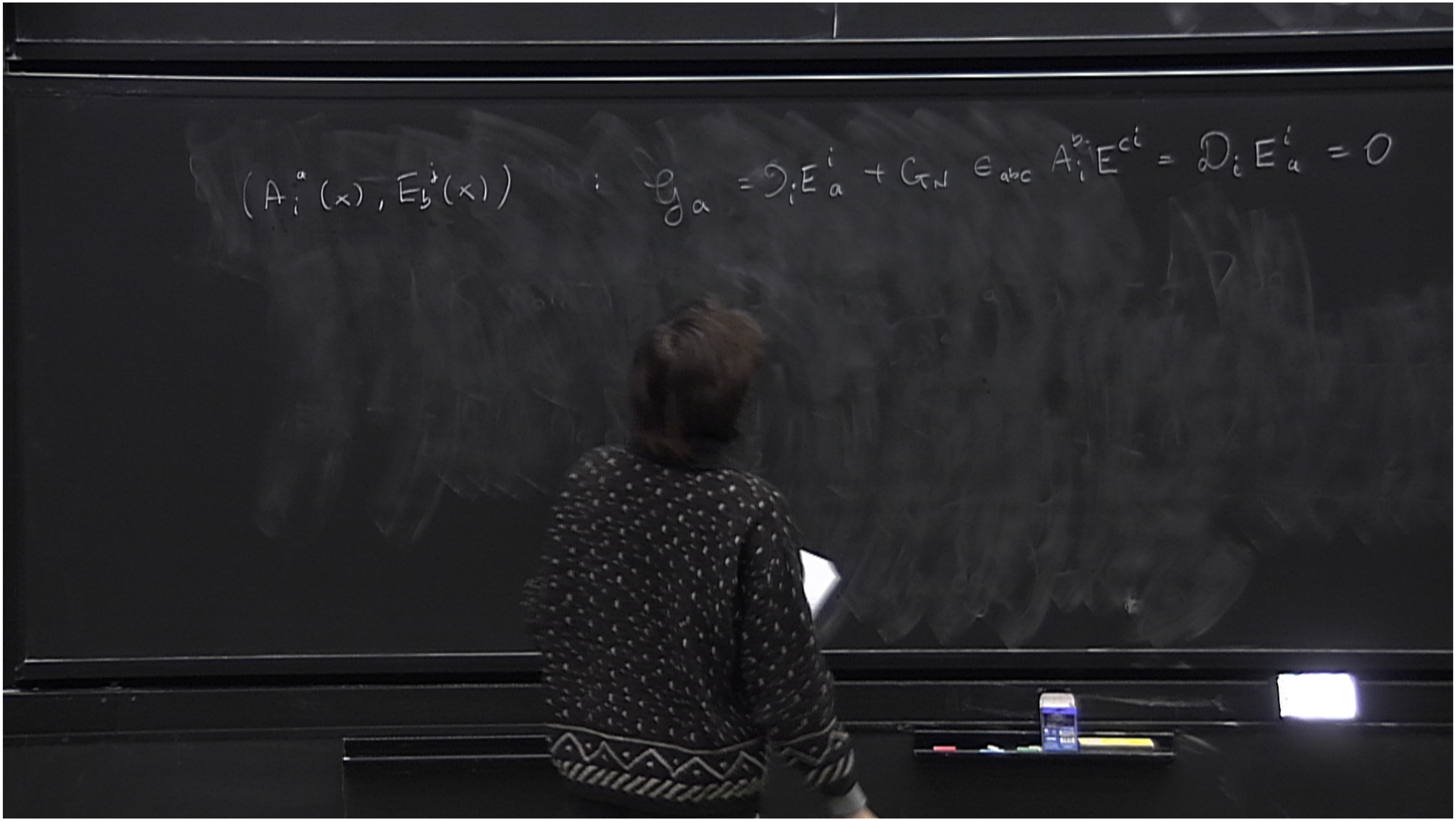
URL: http://pirsa.org/12020005

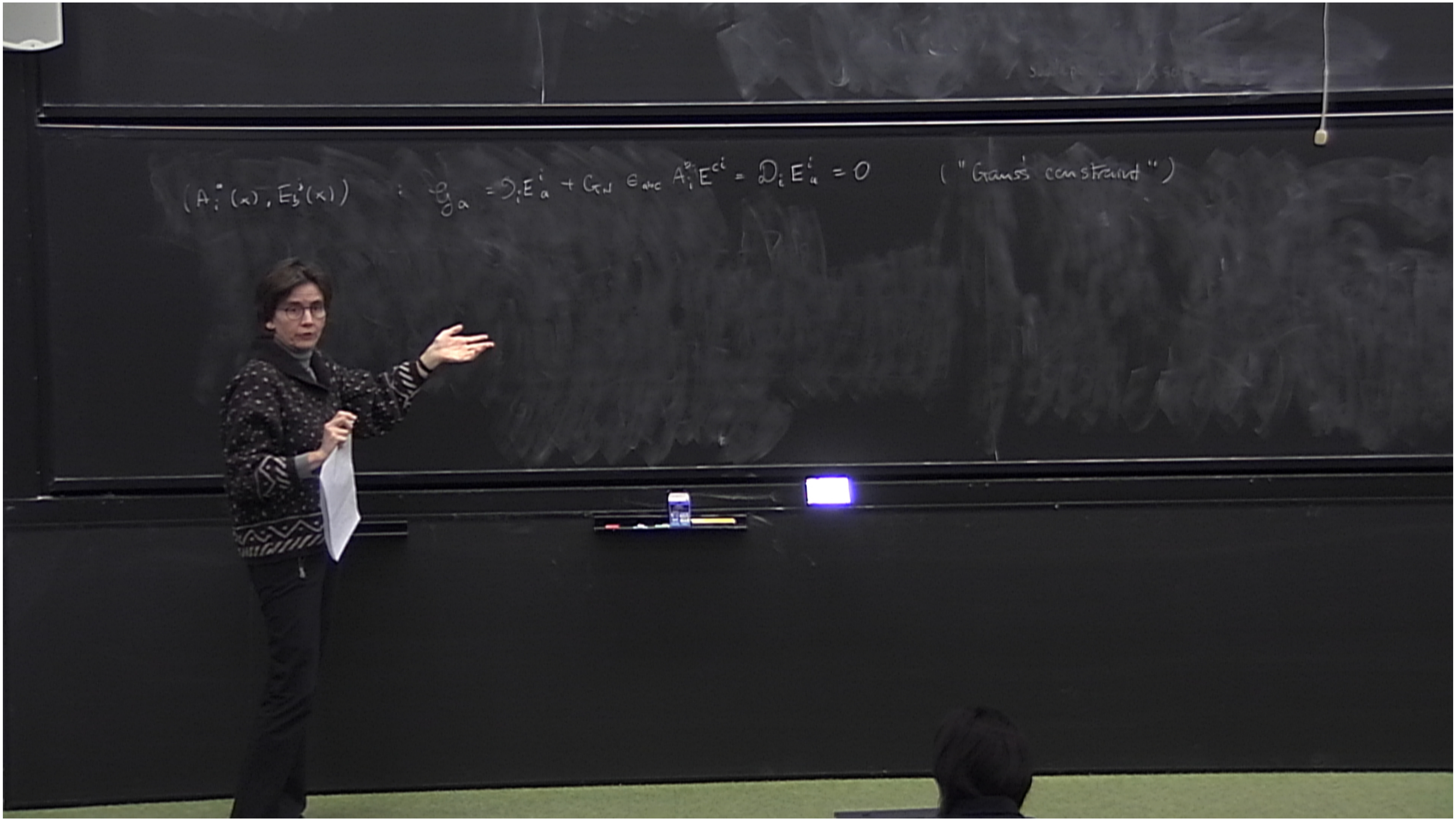
Abstract:




$(A_i^a(x), E_b^j$


$(A_i^a(x), E_b^j(x))$


$(A_i^a(x), E_b^j(x))$: $\mathcal{G}_a = \partial_i E^i_a + G_N \epsilon_{abc} A_i^b E^{ci} = \mathcal{D}_i E^i_a = 0$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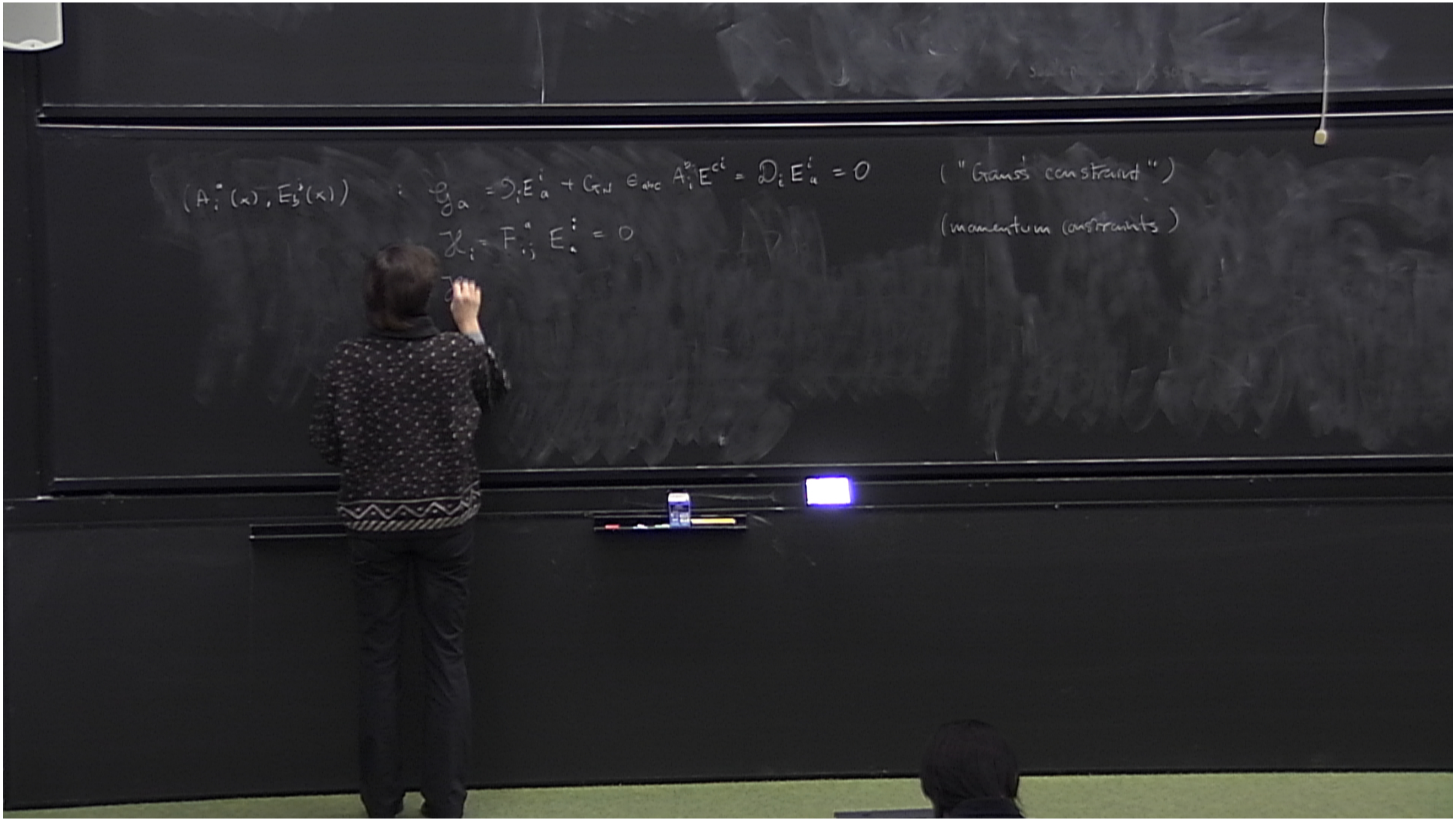
("Gauss' constraint")



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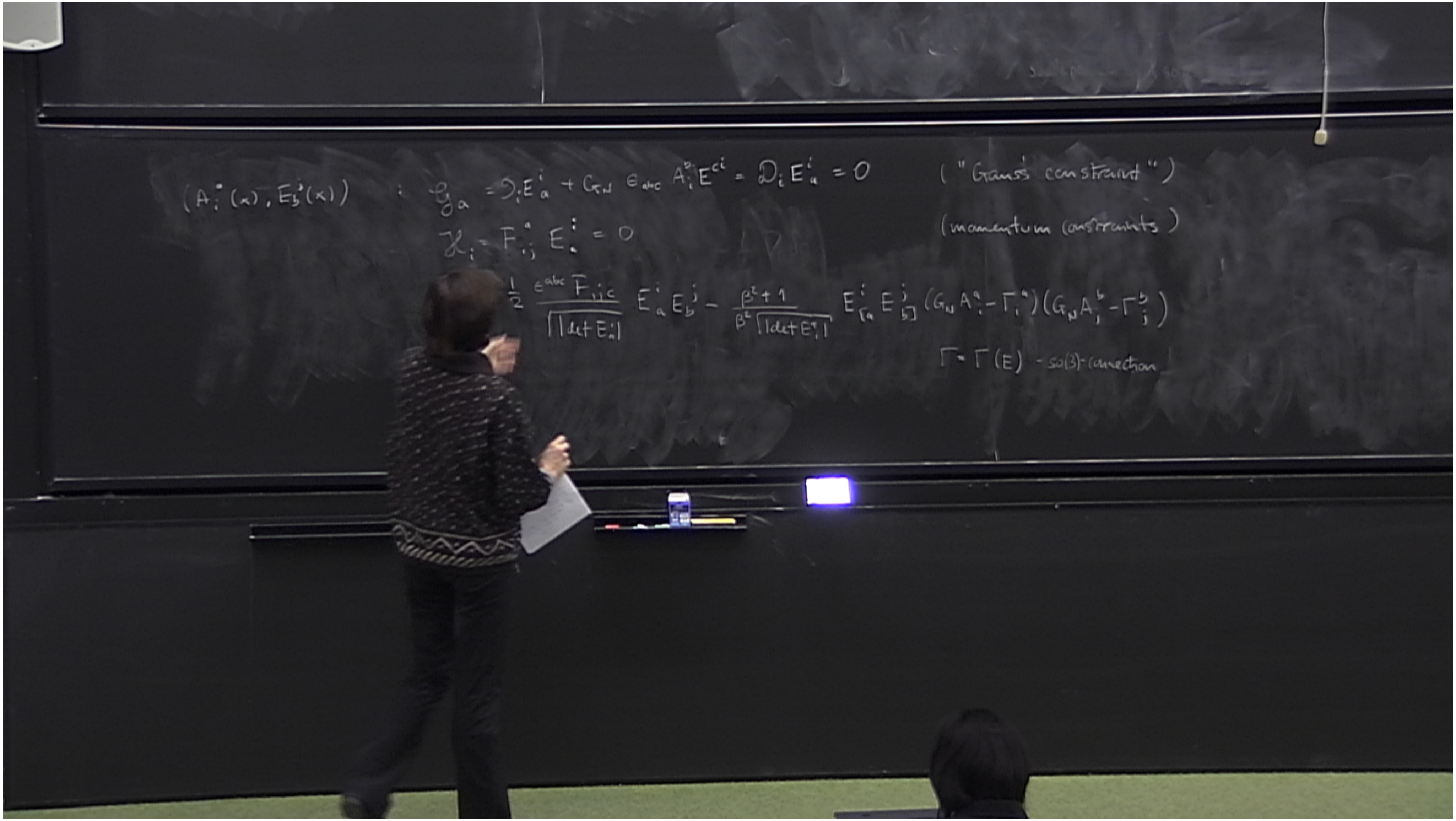
$\mathcal{H}_i = F^a_{ij} E^j_a = 0$
(momentum constraints)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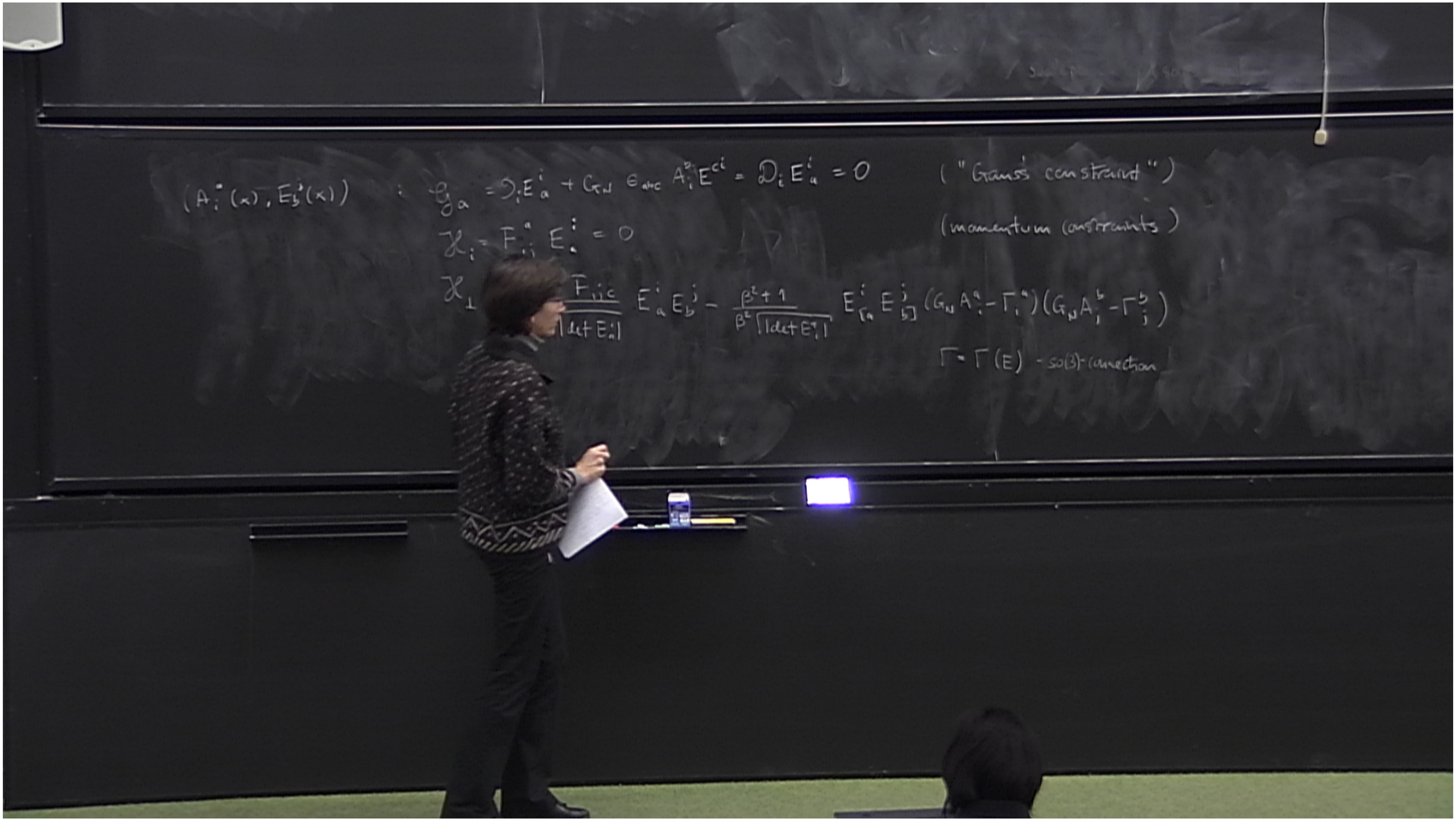
$\frac{1}{2} \frac{\epsilon^{abc} F_{ijc}}{\sqrt{|\det E^i_a|}} E^i_a E^j_b - \frac{\beta^2+1}{\beta^2 \sqrt{|\det E^a_i|}} E^i_{[a} E^j_{b]} (G_N A^a_i - \Gamma^a_i)(G_N A^b_j - \Gamma^b_j)$
$\Gamma = \Gamma(E)$ - so(3)-connection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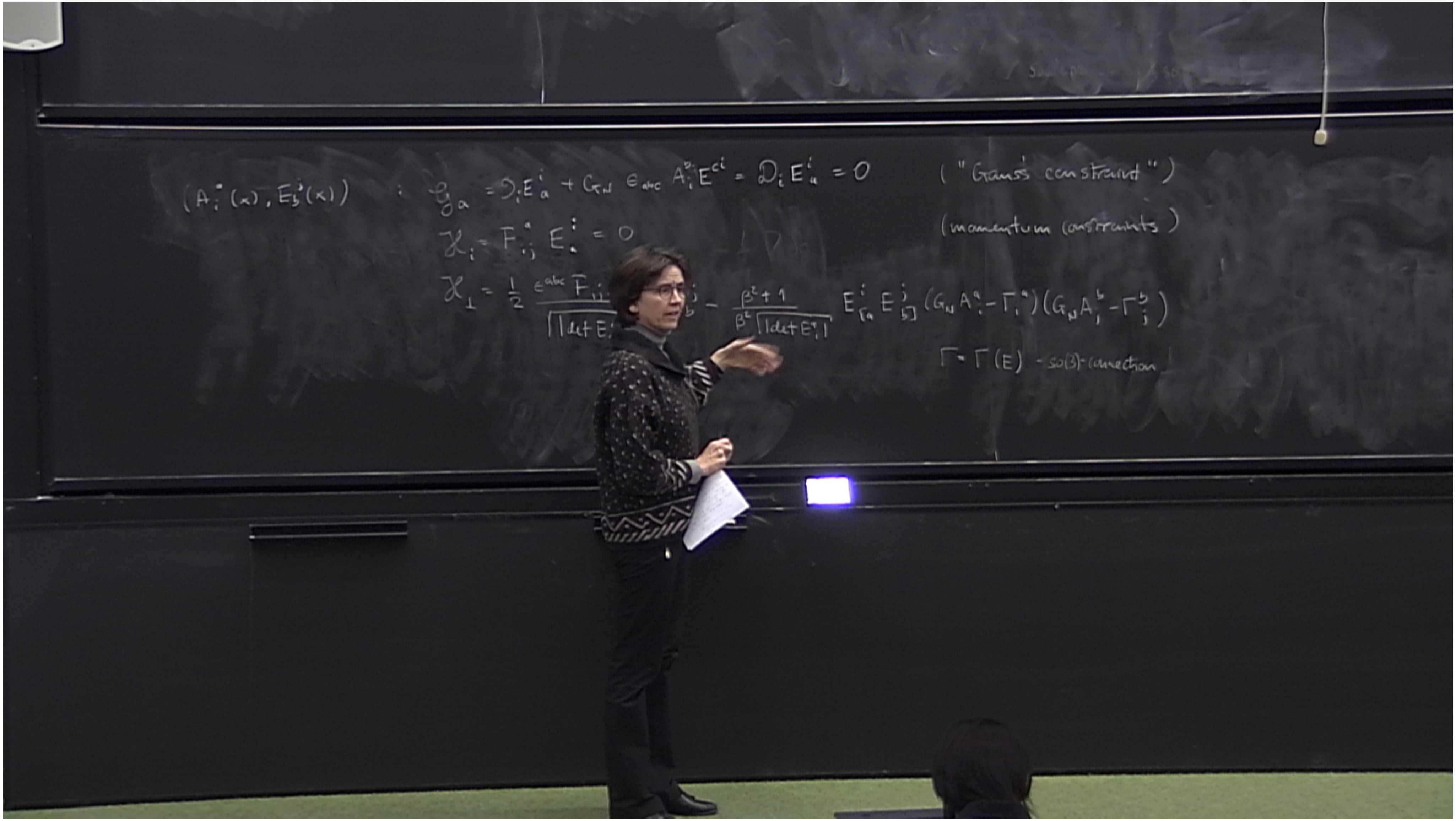
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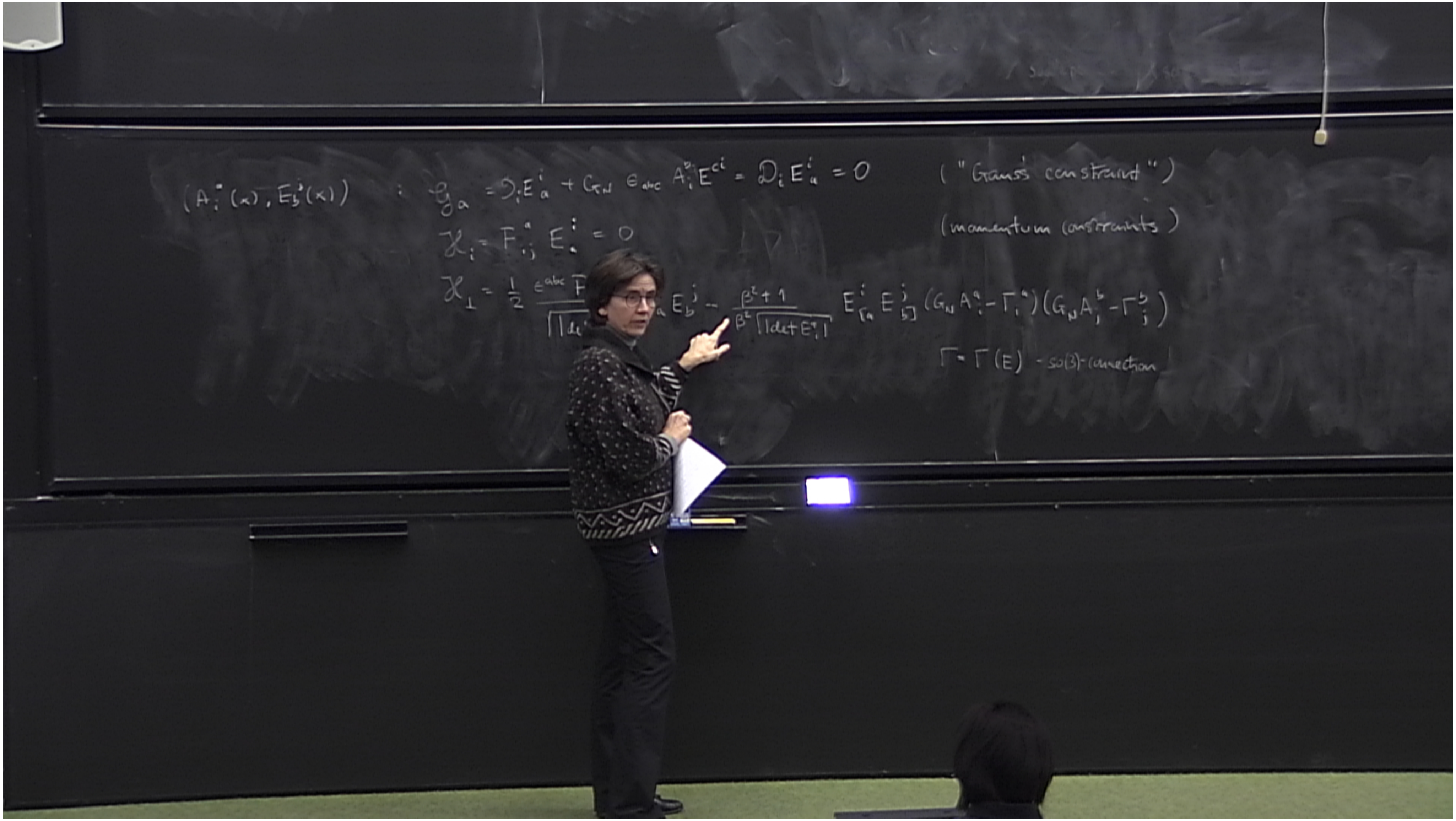
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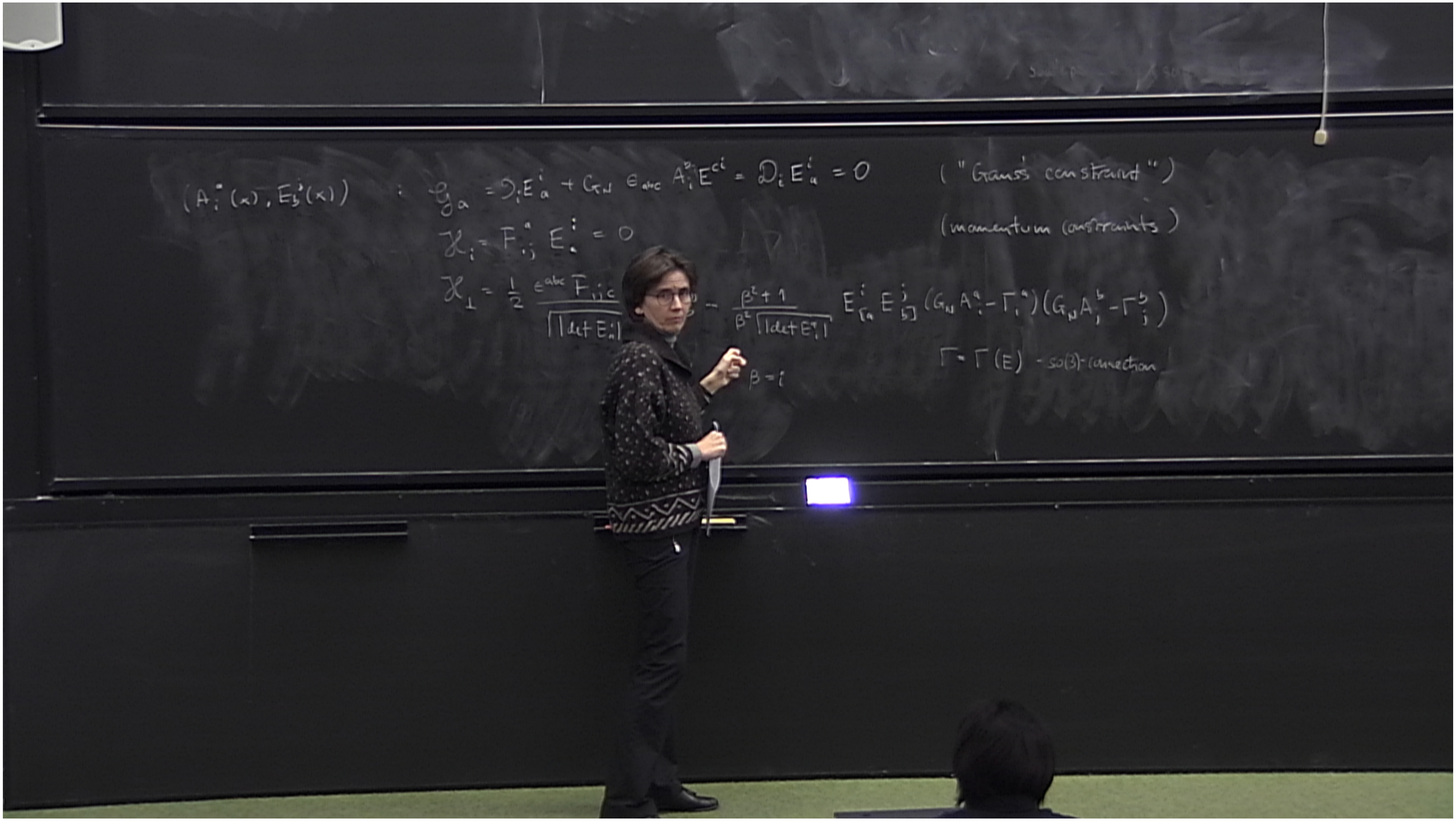
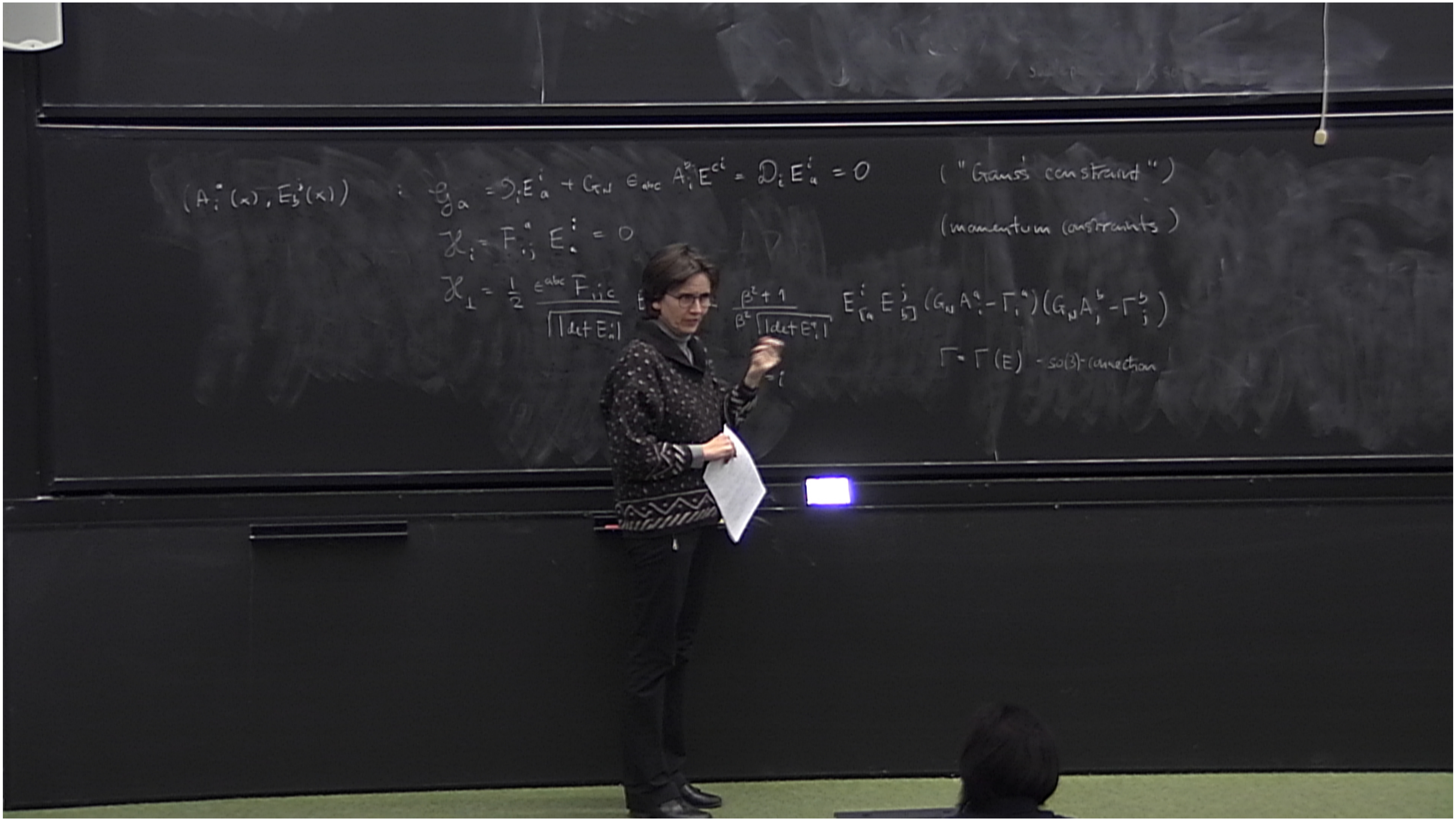
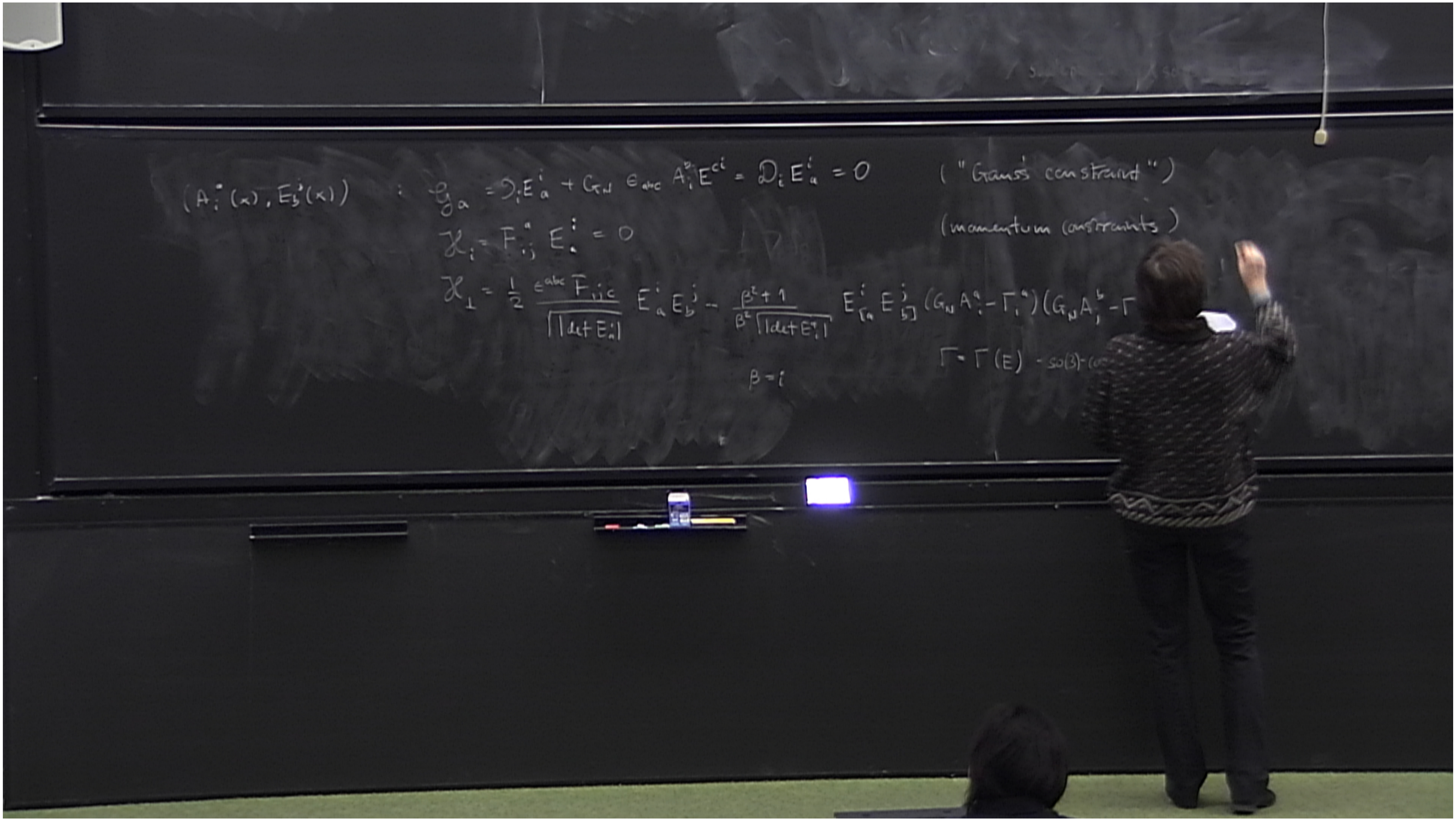

("Gauss's constraint")
(momentum constraints)
Γ = Γ(E) - so(3)-connection
β = i


("Gauss' constraint")
(momentum constraints)
so(3)-connection



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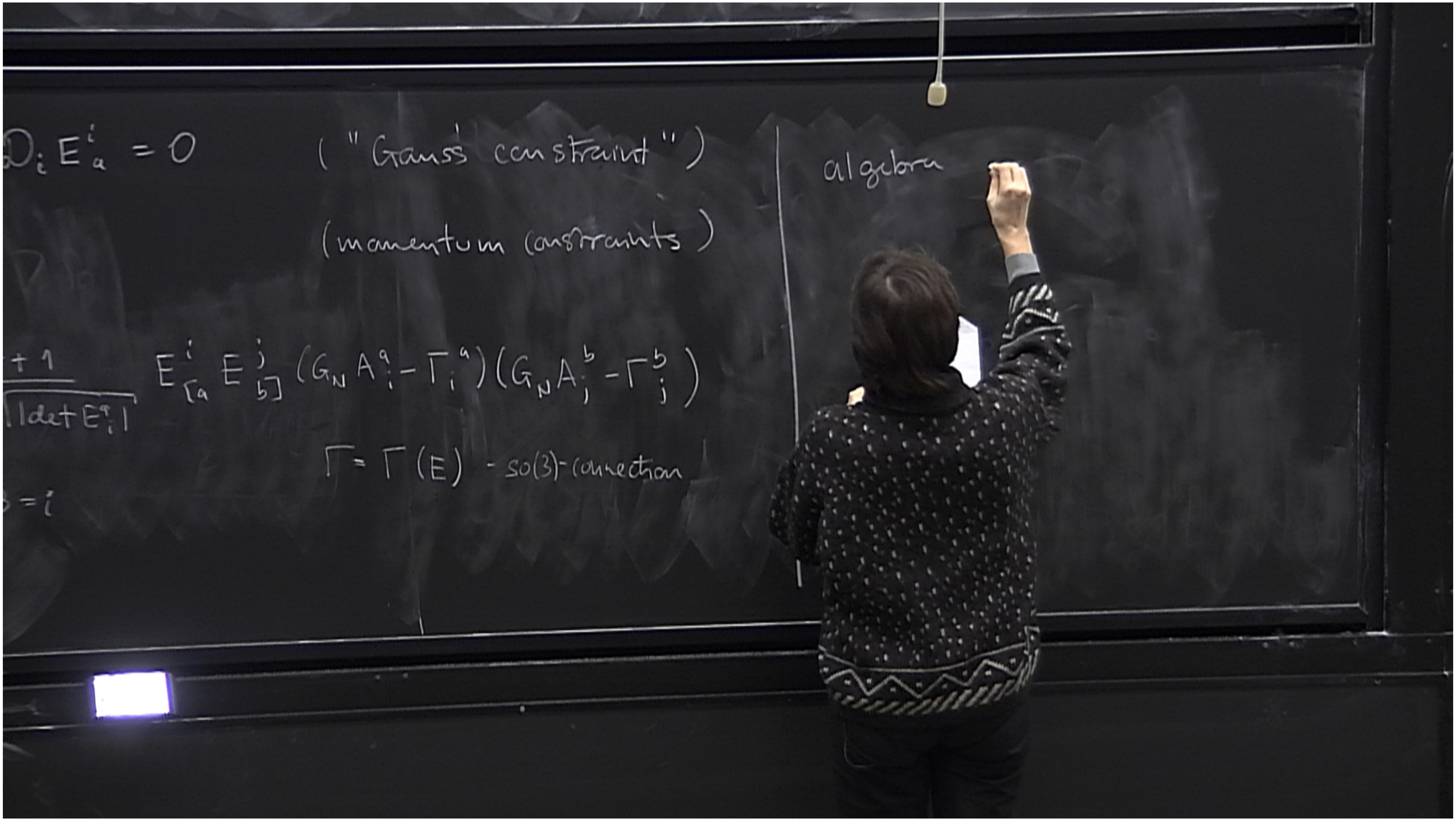
$\Gamma = \Gamma(E)$ - so(3)-
$\beta = i$


("Gauss' constraint")
(momentum constraints)
algebra
so(3)-connection

$\mathcal{D}_i E^i_a = 0$ ("Gauss' constraint")

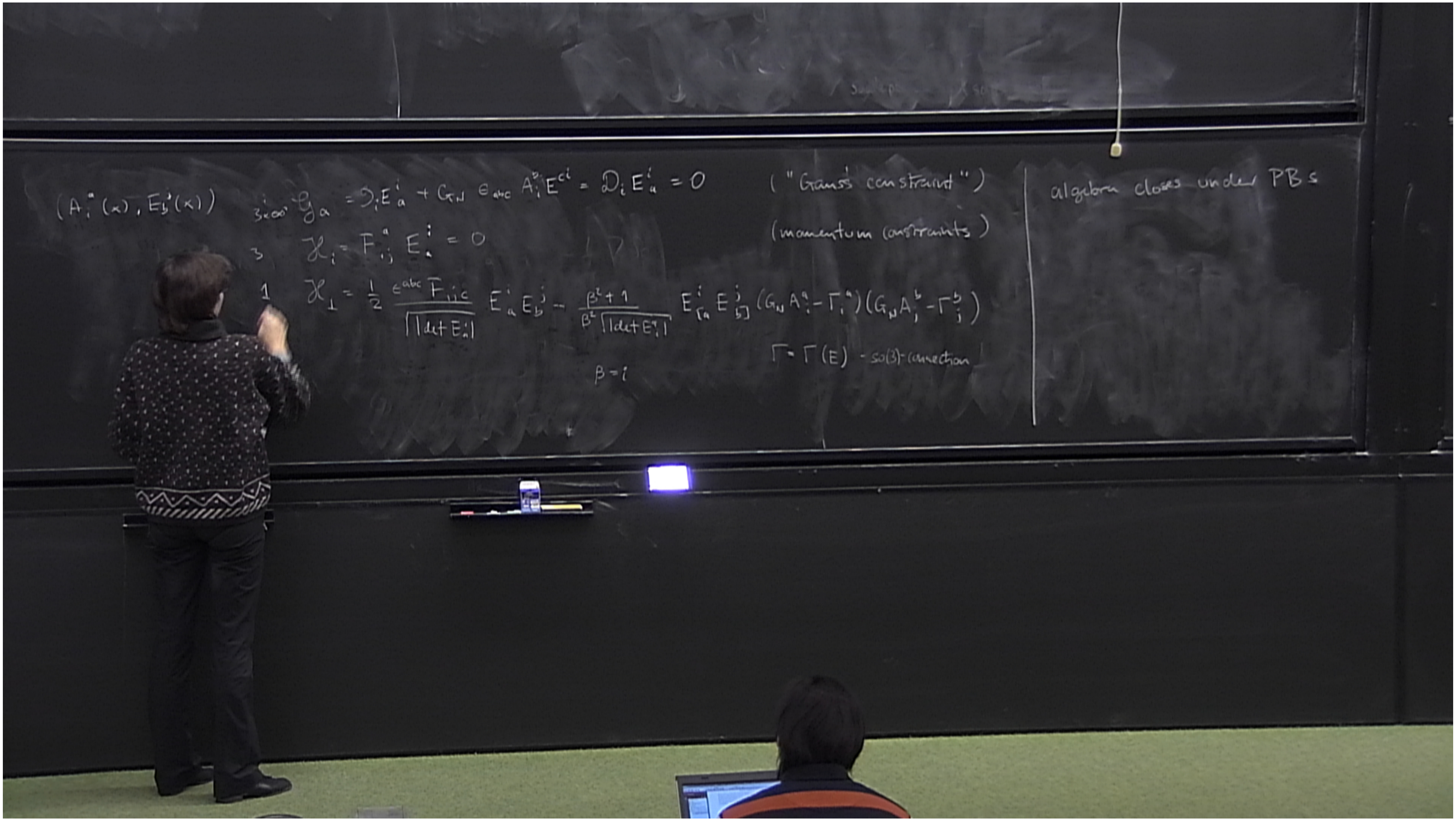
(momentum constraints)

$\frac{[illegible] + 1}{\sqrt{|\det E^a_i|}} E^i_{[a} E^j_{b]} (G_N A^a_i - \Gamma_i^a)(G_N A^b_j - \Gamma^b_j)$

$\Gamma = \Gamma(E)$ - so(3)-connection

$[illegible] = i$

algebra closes under PBs


$(A_i^a(x), E_b^j(x))$
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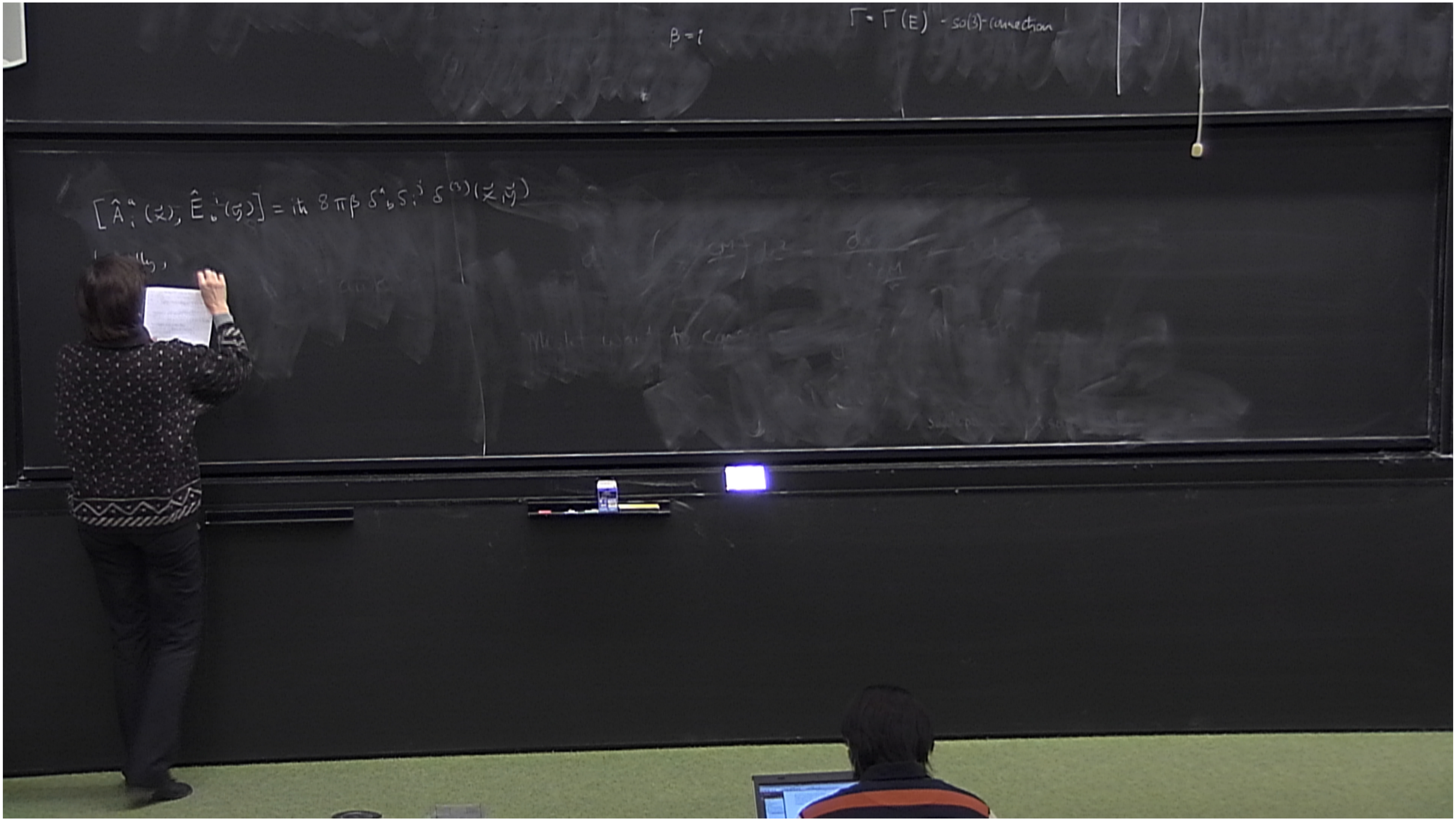
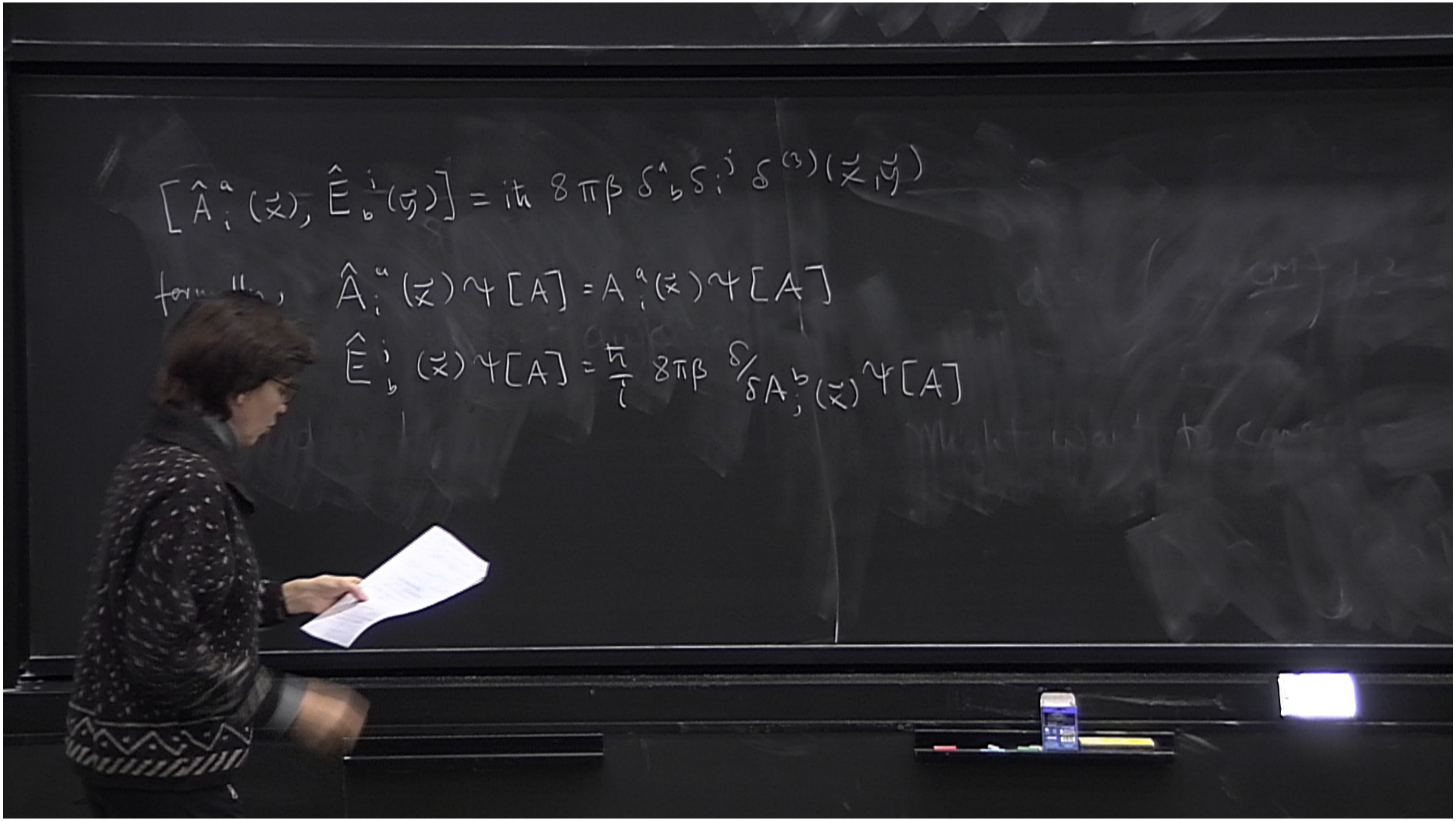
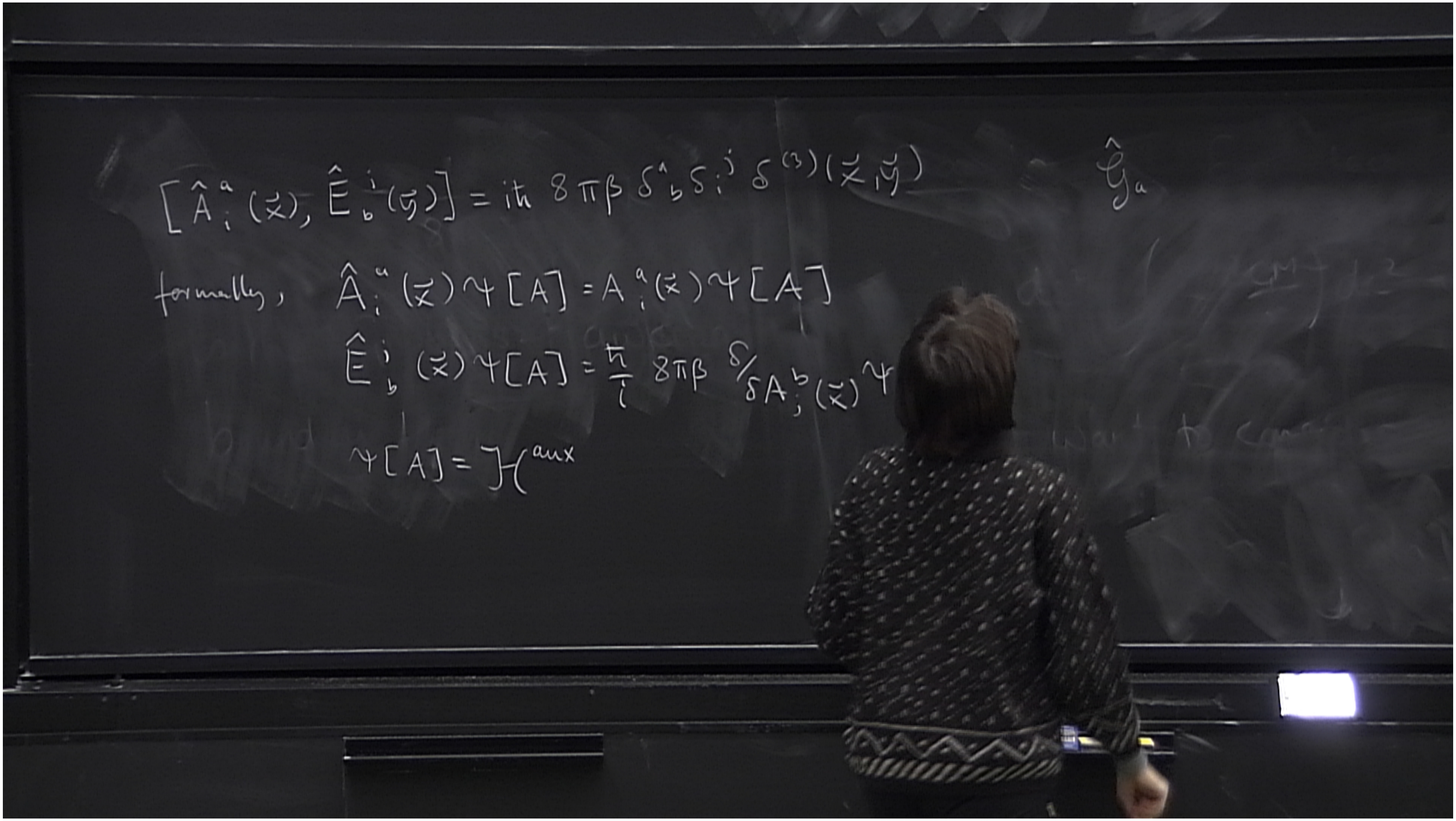
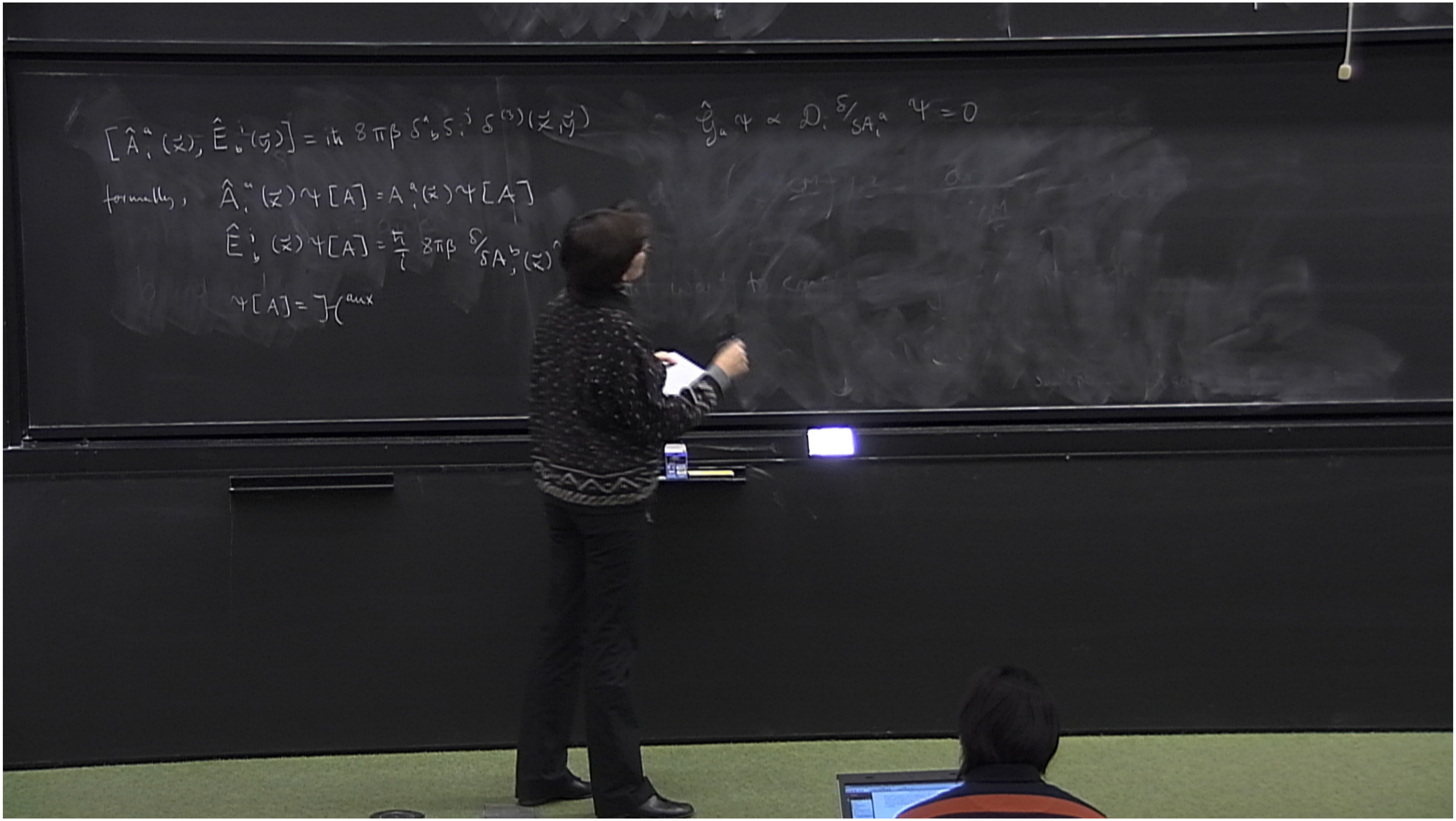
$\Gamma = \Gamma(E)$ - so(3)-connection
$\beta = i$
algebra closes under PBs


β = i
Γ = Γ(E) - so(3)-connection
[Â^a_i(x), Ê_b^j(y)] = iħ 8πβ δ^a_b δ_i^j δ^(3)(x,y)


$[\hat{A}^a_i(\vec{x}), \hat{E}^j_b(\vec{y})] = i\hbar\, 8\pi\beta\, \delta^a_b \delta_i^j \delta^{(3)}(\vec{x},\vec{y})$
$\hat{A}^a_i(\vec{x})\Psi[A] = A^a_i(\vec{x})\Psi[A]$
$\hat{E}^i_b(\vec{x})\Psi[A] = \frac{\hbar}{i} 8\pi\beta \frac{\delta}{\delta A^b_i(\vec{x})}\Psi[A]$


$[\hat{A}_i^a(\vec{x}), \hat{E}_b^j(\vec{y})] = i\hbar\, 8\pi\beta\, \delta^a_b \delta_i^j \delta^{(3)}(\vec{x},\vec{y})$
$\hat{\mathcal{G}}_a$
formally, $\hat{A}_i^a(\vec{x})\Psi[A] = A_i^a(\vec{x})\Psi[A]$
$\hat{E}_b^i(\vec{x})\Psi[A] = \frac{\hbar}{i}\, 8\pi\beta\, \delta/\delta A_i^b(\vec{x})\, \Psi$
$\Psi[A] = \mathcal{H}^{aux}$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$\hat{\mathcal{G}}_a \Psi \propto \mathcal{D}_i \frac{\delta}{\delta A_i^a} \Psi = 0$
formally, $\hat{A}_i^a(\vec{x})\Psi[A] = A_i^a(\vec{x})\Psi[A]$
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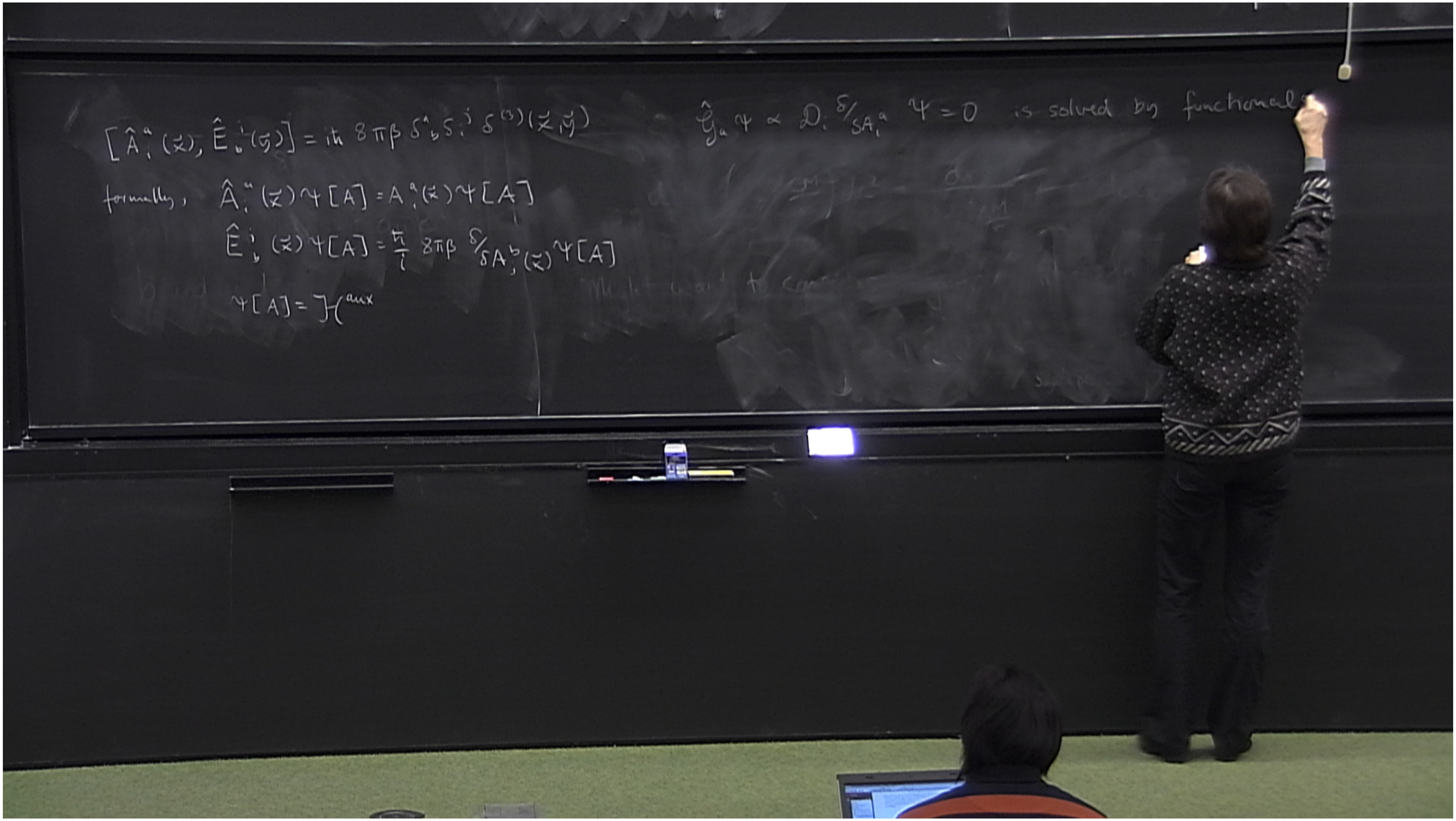
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$\hat{\mathcal{G}}_a \Psi \propto \mathcal{D}_i \delta/\delta A_i^a \Psi = 0$ is solved by functional
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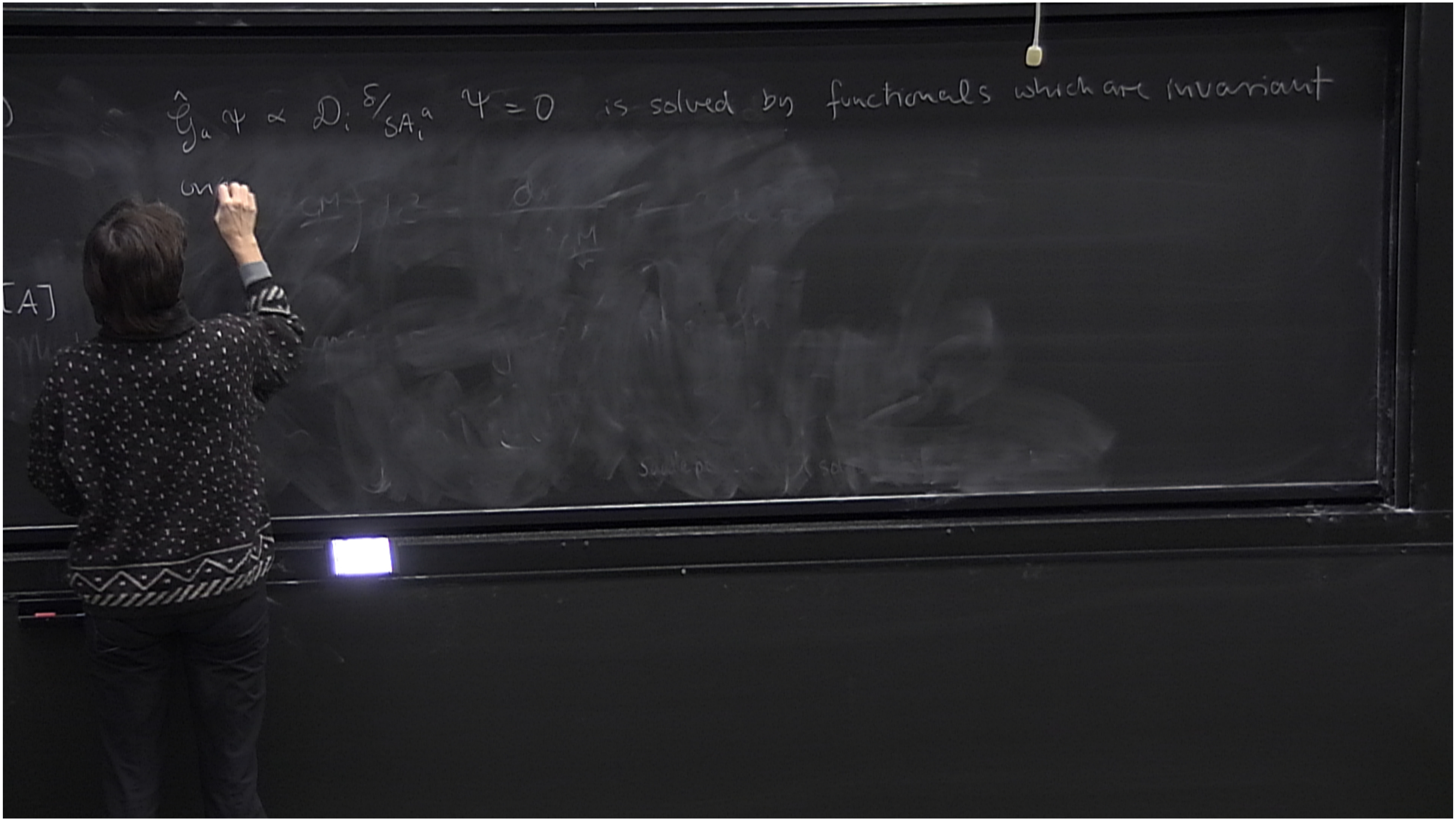
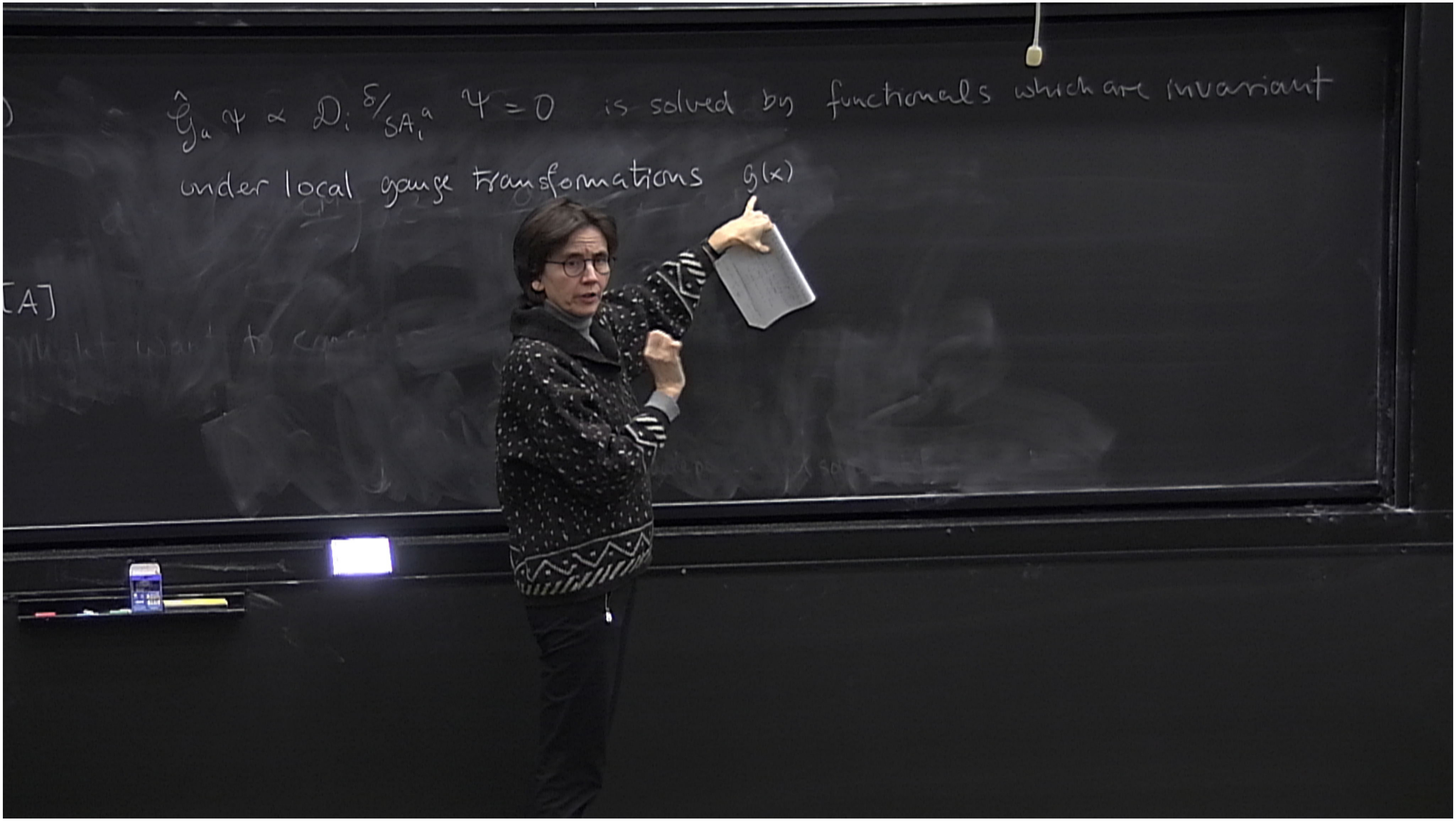
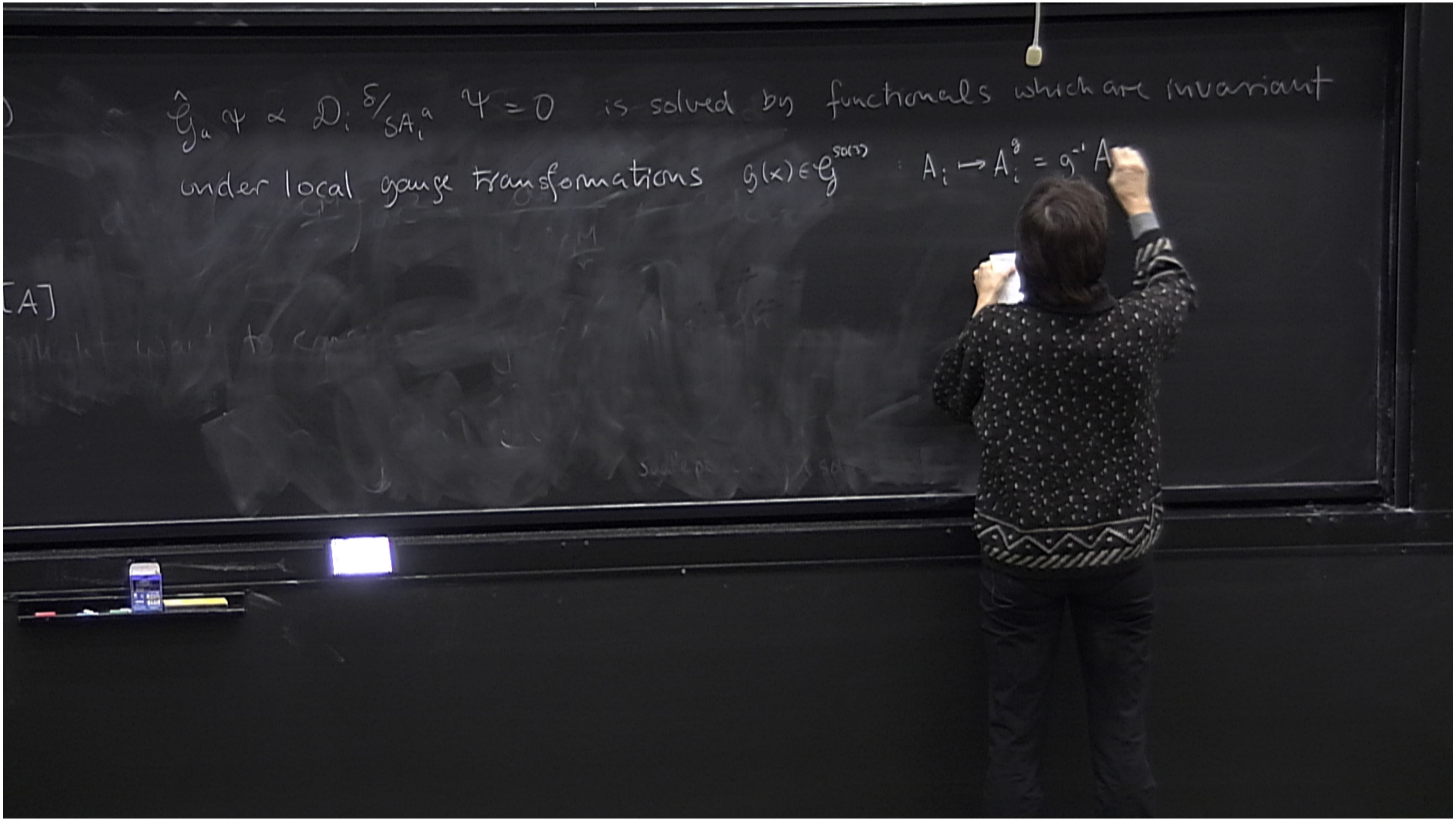

$\hat{\mathcal{G}}_a \Psi \propto \mathcal{D}_i \,{}^{\delta}/_{\delta A_i^a}\, \Psi = 0$ is solved by functionals which are invariant
[A]


$\hat{G}_a \Psi \propto D_i \frac{\delta}{\delta A_i^a} \Psi = 0$ is solved by functionals which are invariant
under local gauge transformations $g(x)$
[A]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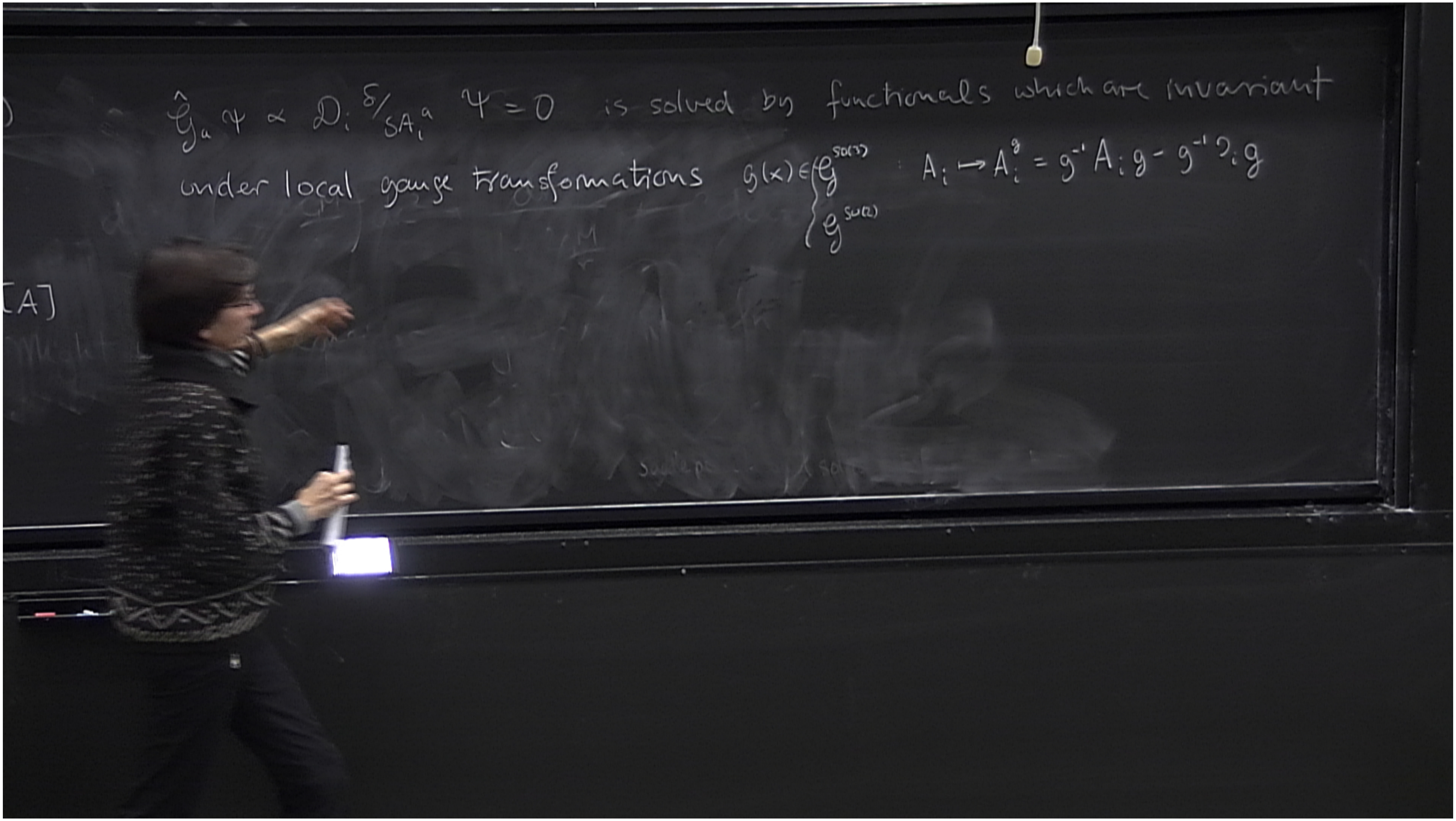
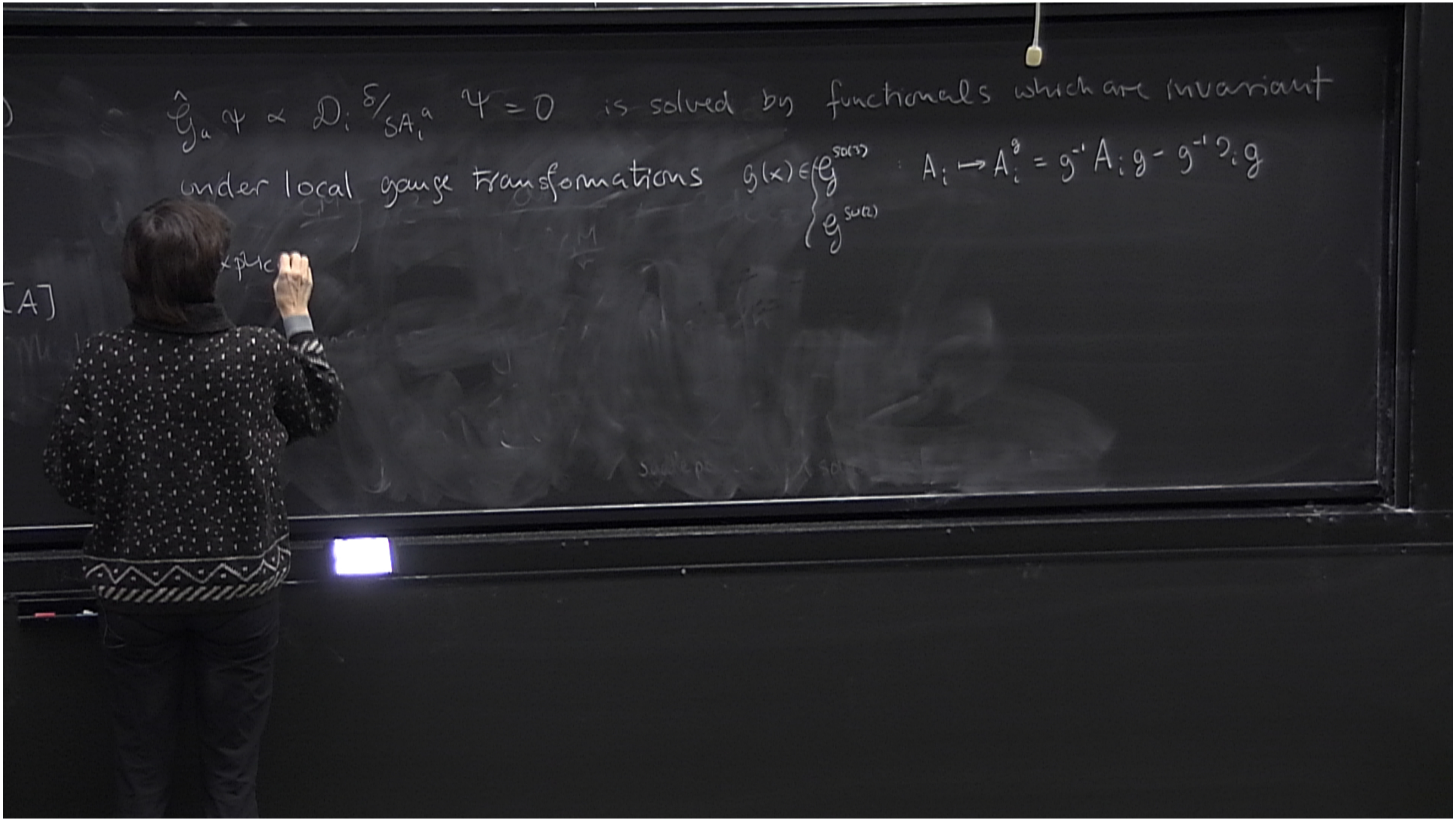
under local gauge transformations $g(x) \in \mathcal{G}^{SO(3)}$: $A_i \to A_i^g = g^{-1} A$
[A]


$\hat{\mathcal{G}}_a \Psi \propto \mathcal{D}_i \, \delta / \delta A_i^a \, \Psi = 0$ is solved by functionals which are invariant
under local gauge transformations $g(x) \in \begin{cases} \mathcal{G}^{SO(3)} \\ \mathcal{G}^{SU(2)} \end{cases}$: $A_i \mapsto A_i^g = g^{-1} A_i g - g^{-1} \partial_i g$
[A]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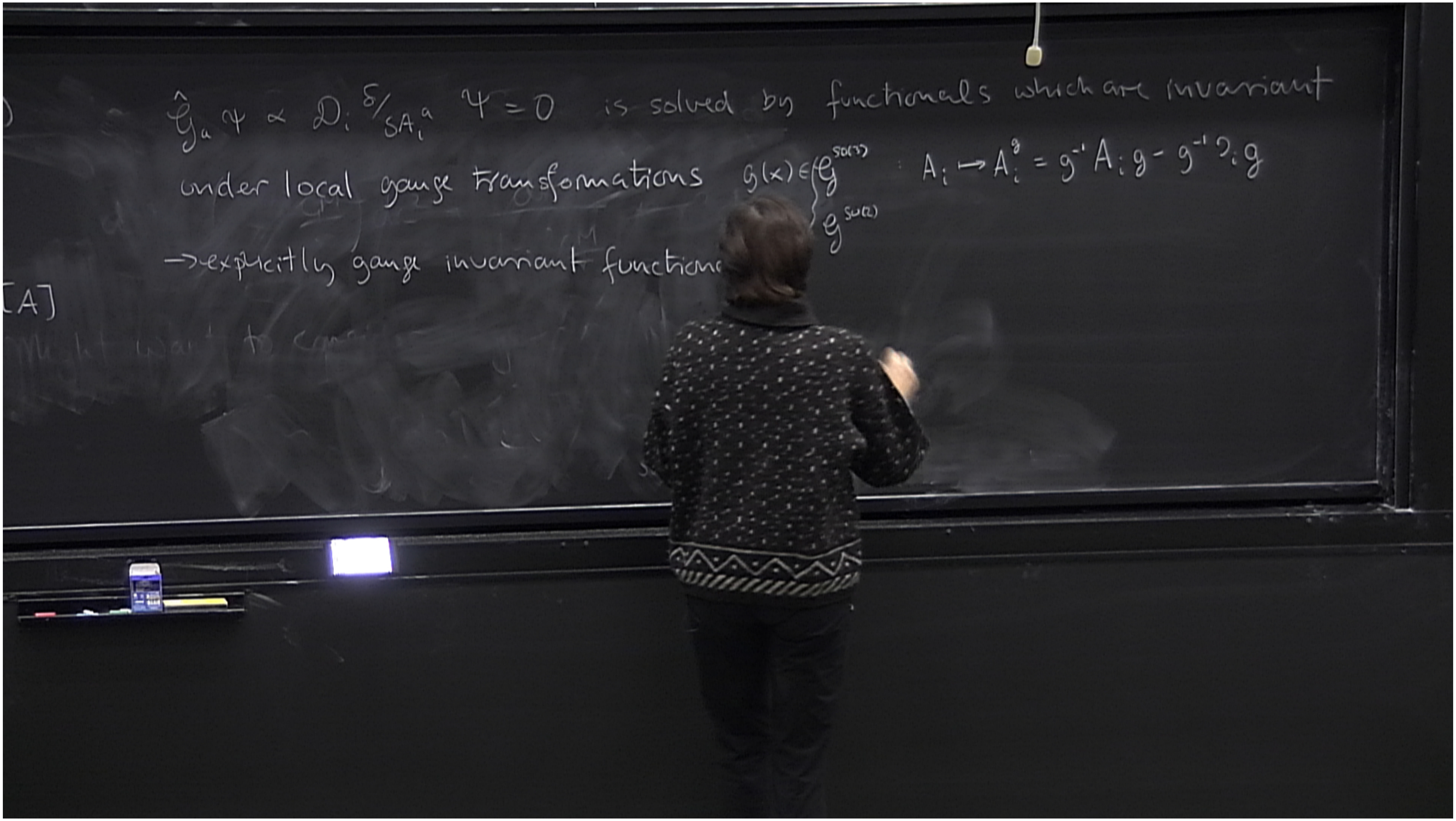

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→ explicitly gauge invariant functiona
[A]

$\hat{\mathcal{G}}_a \Psi \propto \mathcal{D}_i \, \delta/_{\delta A_i^a} \, \Psi = 0$ is solved by functionals which are invariant

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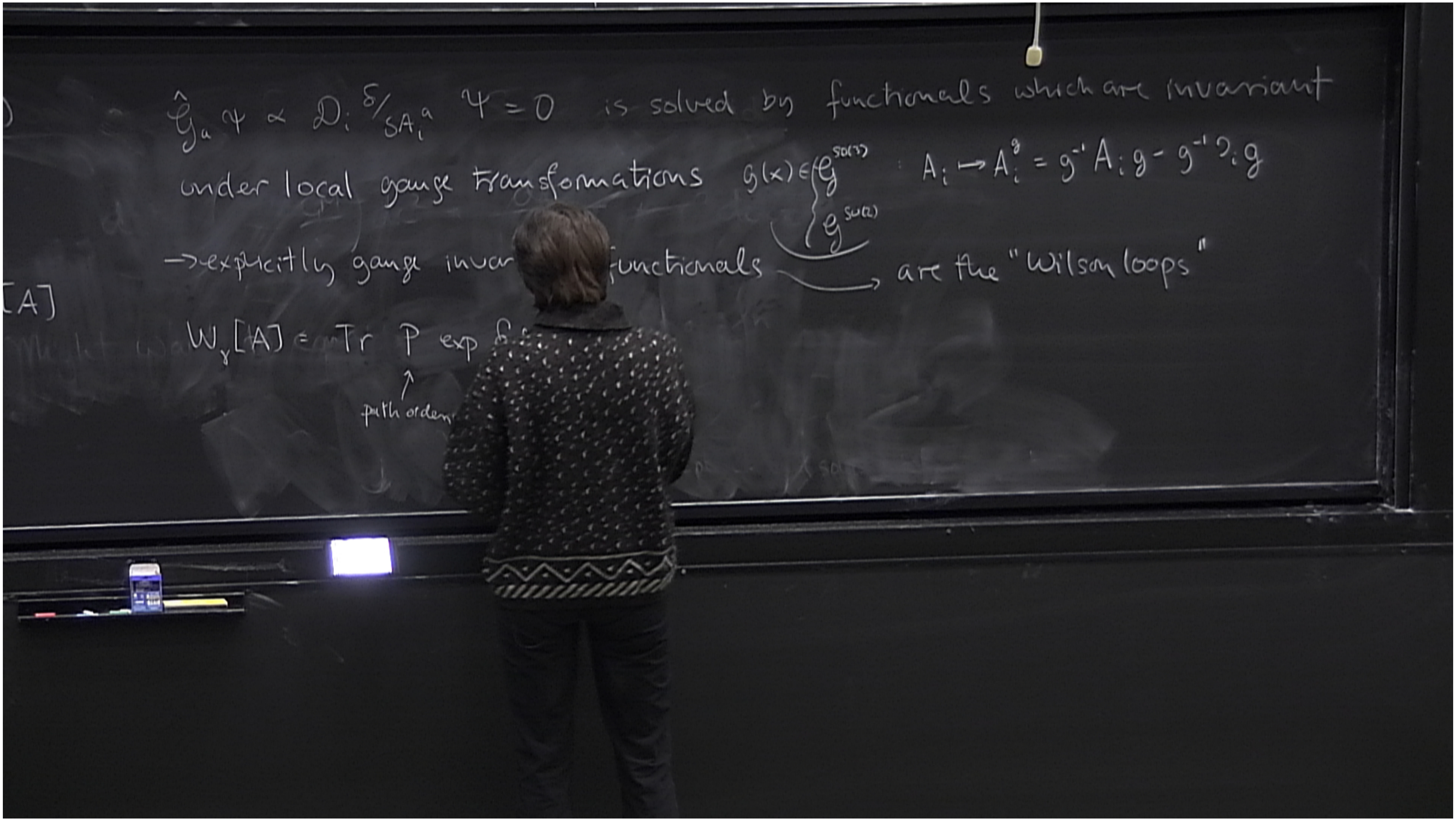
→ explicitly gauge invariant functionals ⟶ are the "Wilson loops"

$W[A]$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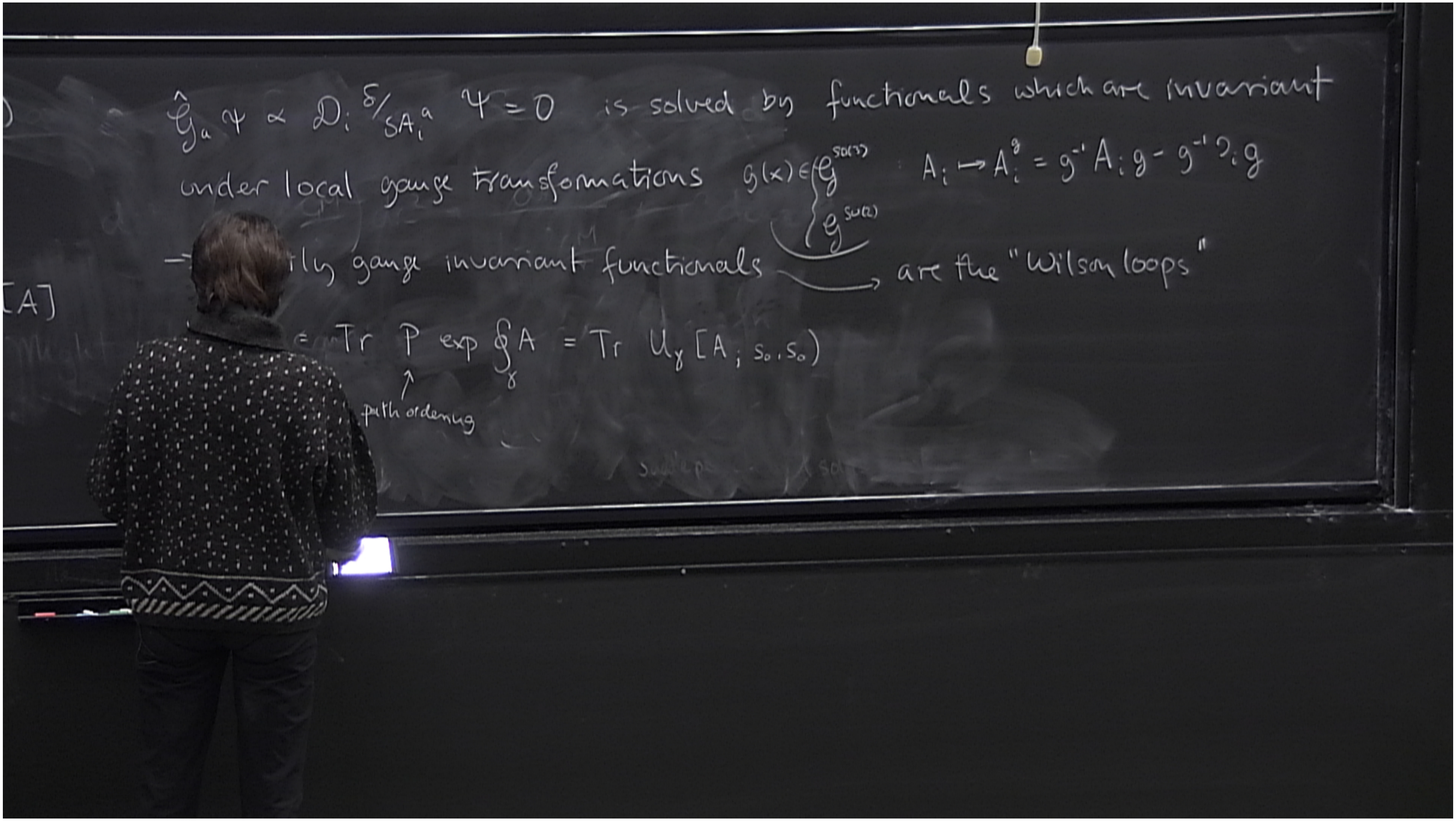
→ explicitly gauge invar functionals → are the "Wilson loops"
$W_\gamma[A] = \mathrm{Tr}\ P \exp$
path orden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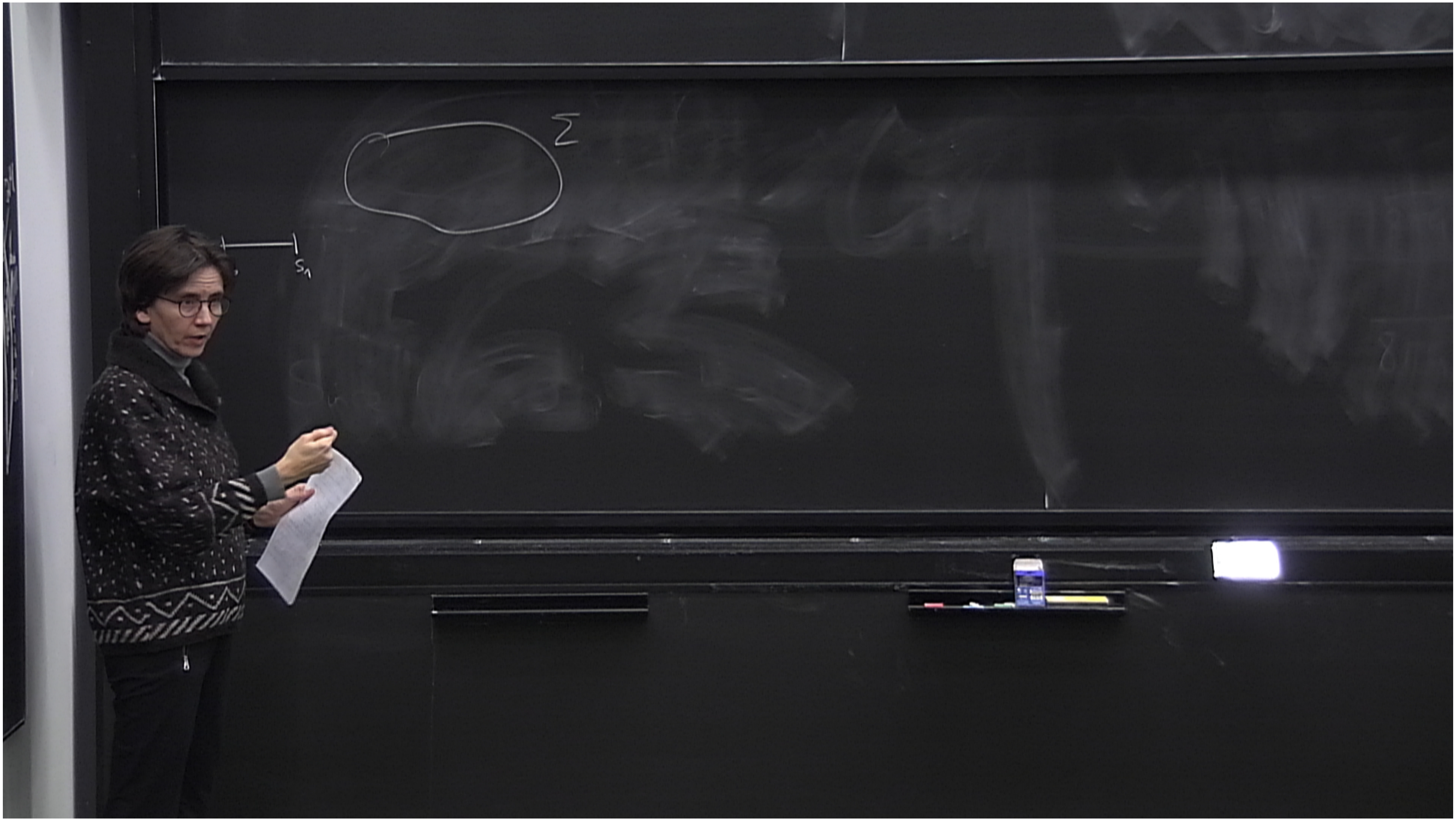
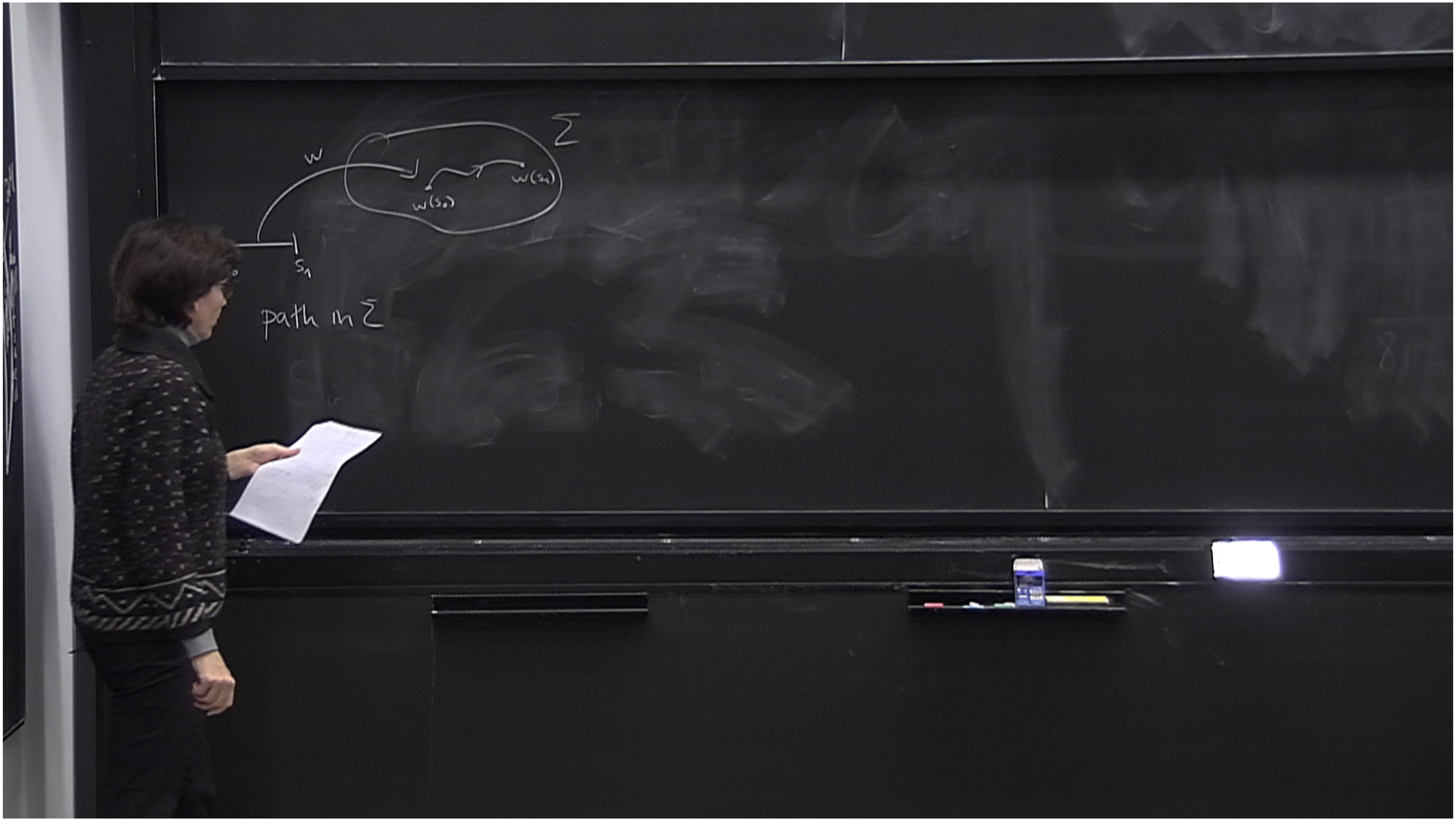
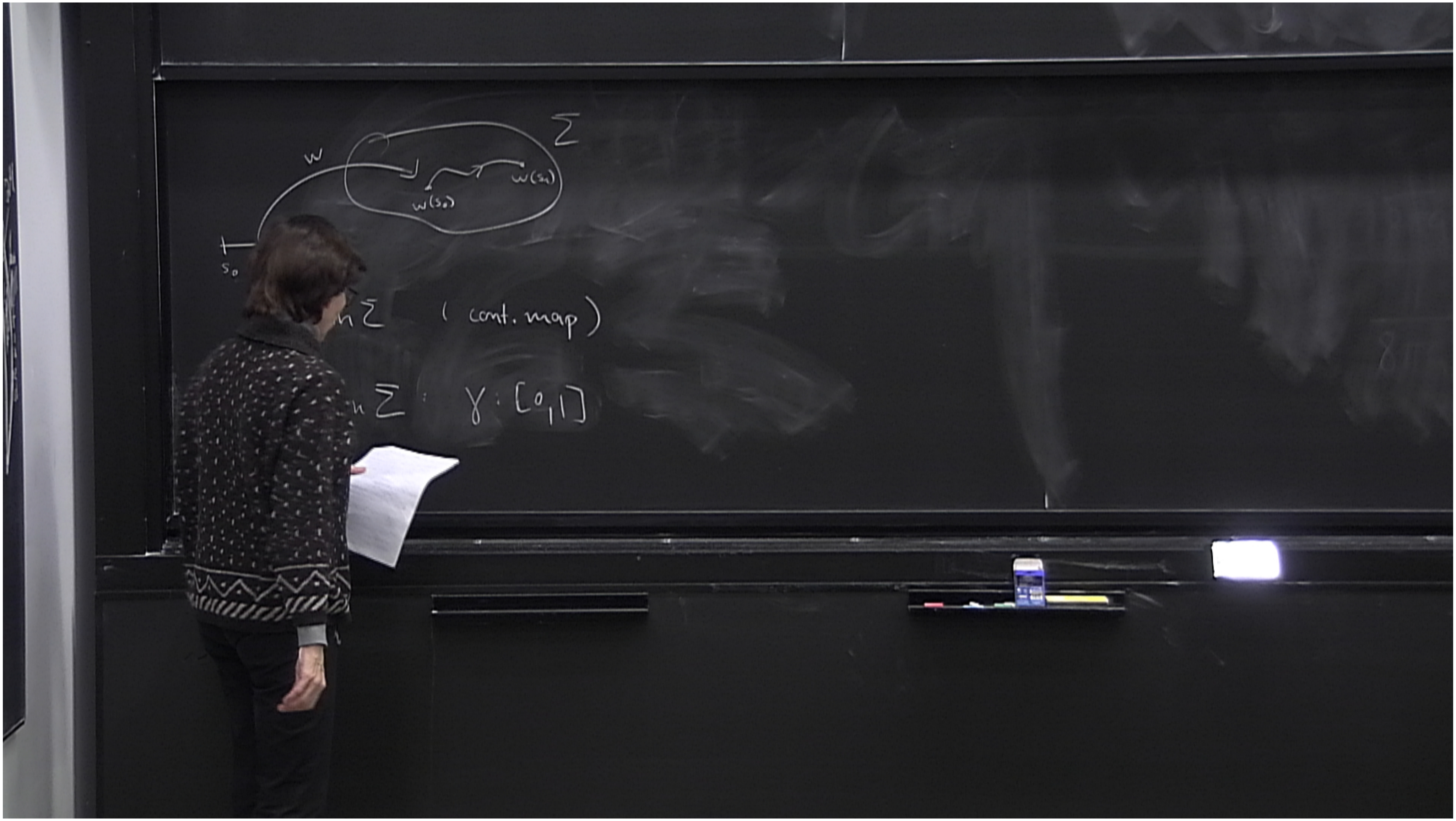
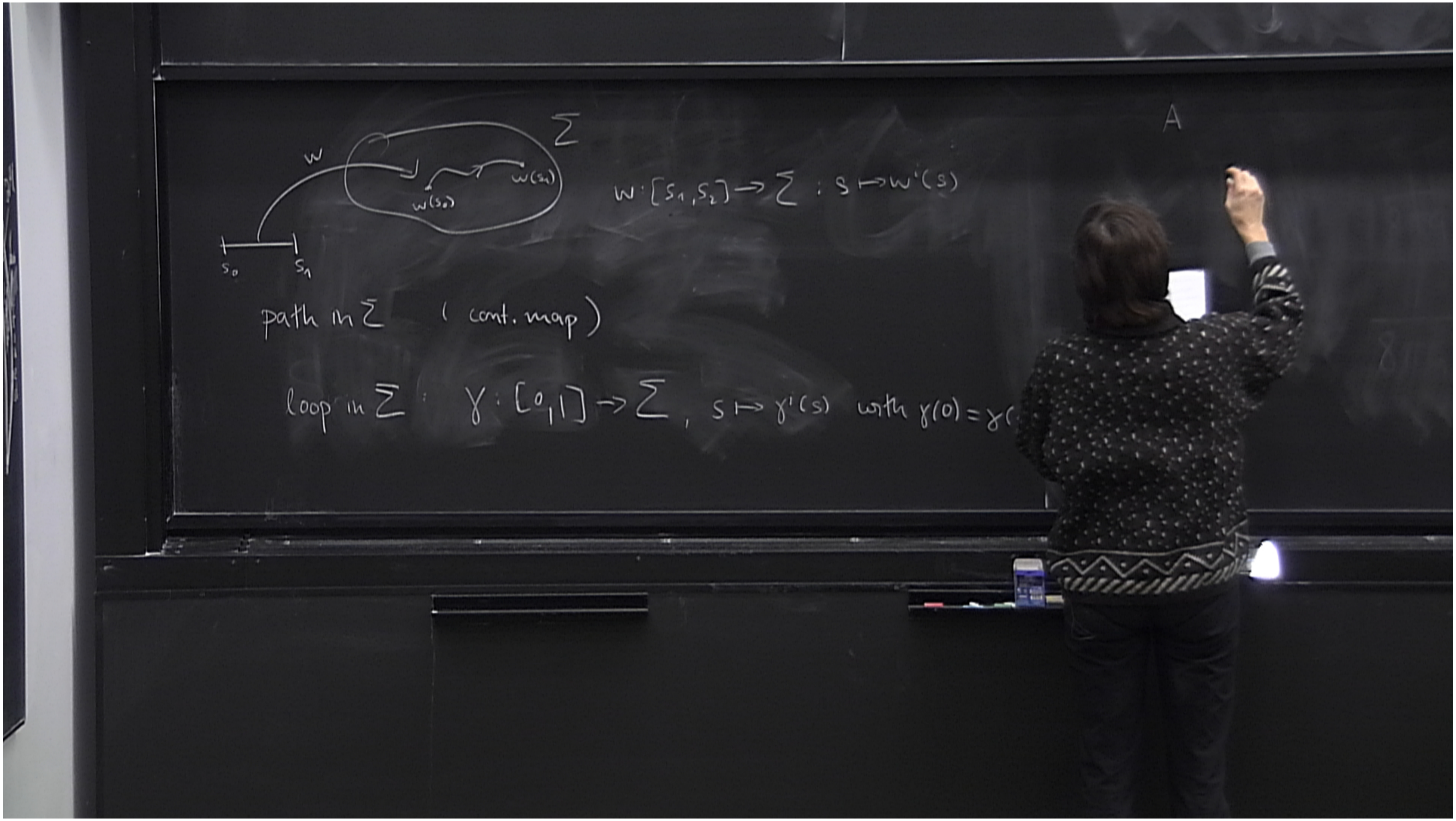
ly gauge invariant functionals
are the "Wilson loops"
$= \mathrm{Tr}\, P \exp \oint_\gamma A = \mathrm{Tr}\, U_\gamma [A; s_0, s_0)$
path ordering
[A]

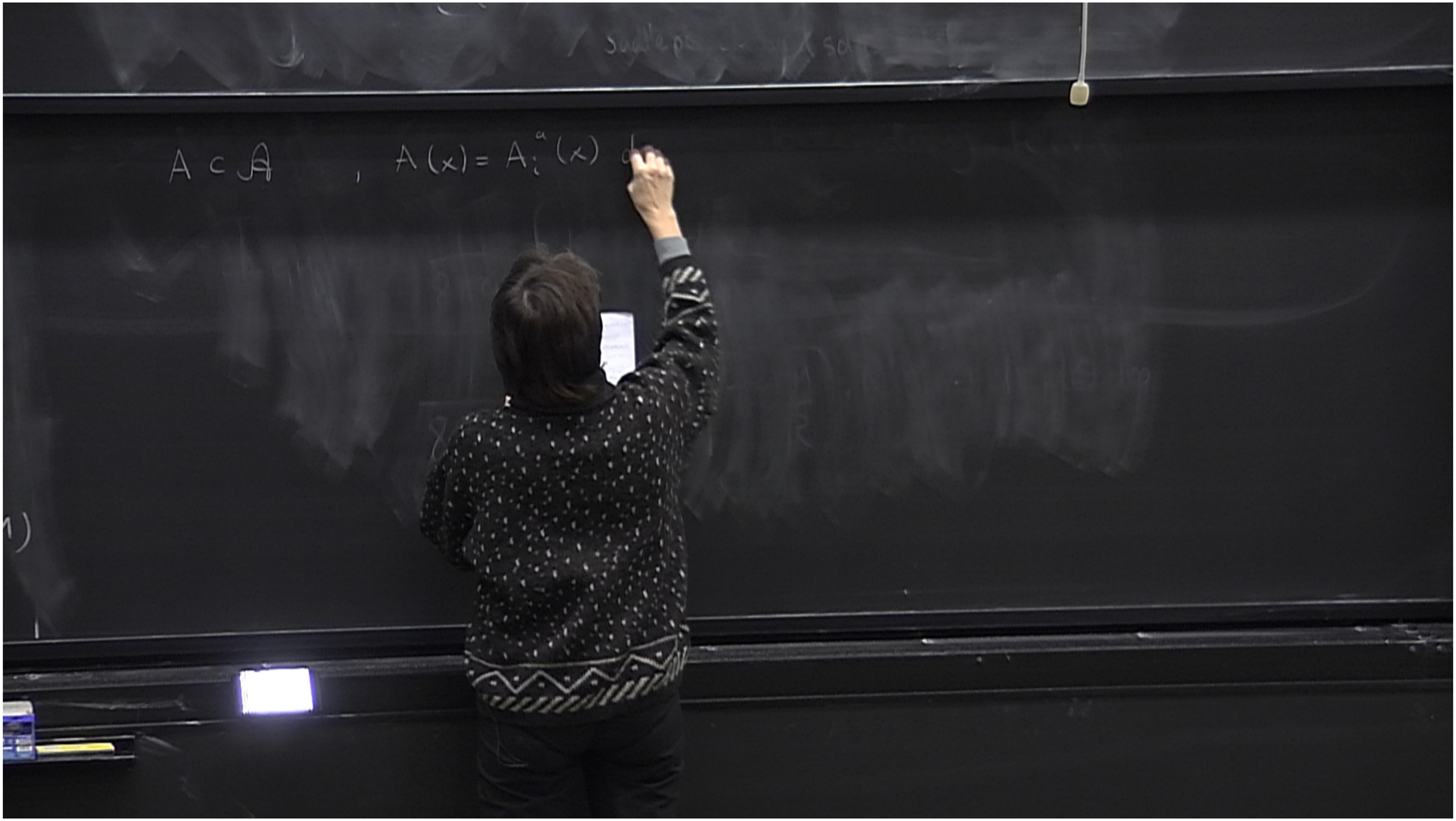


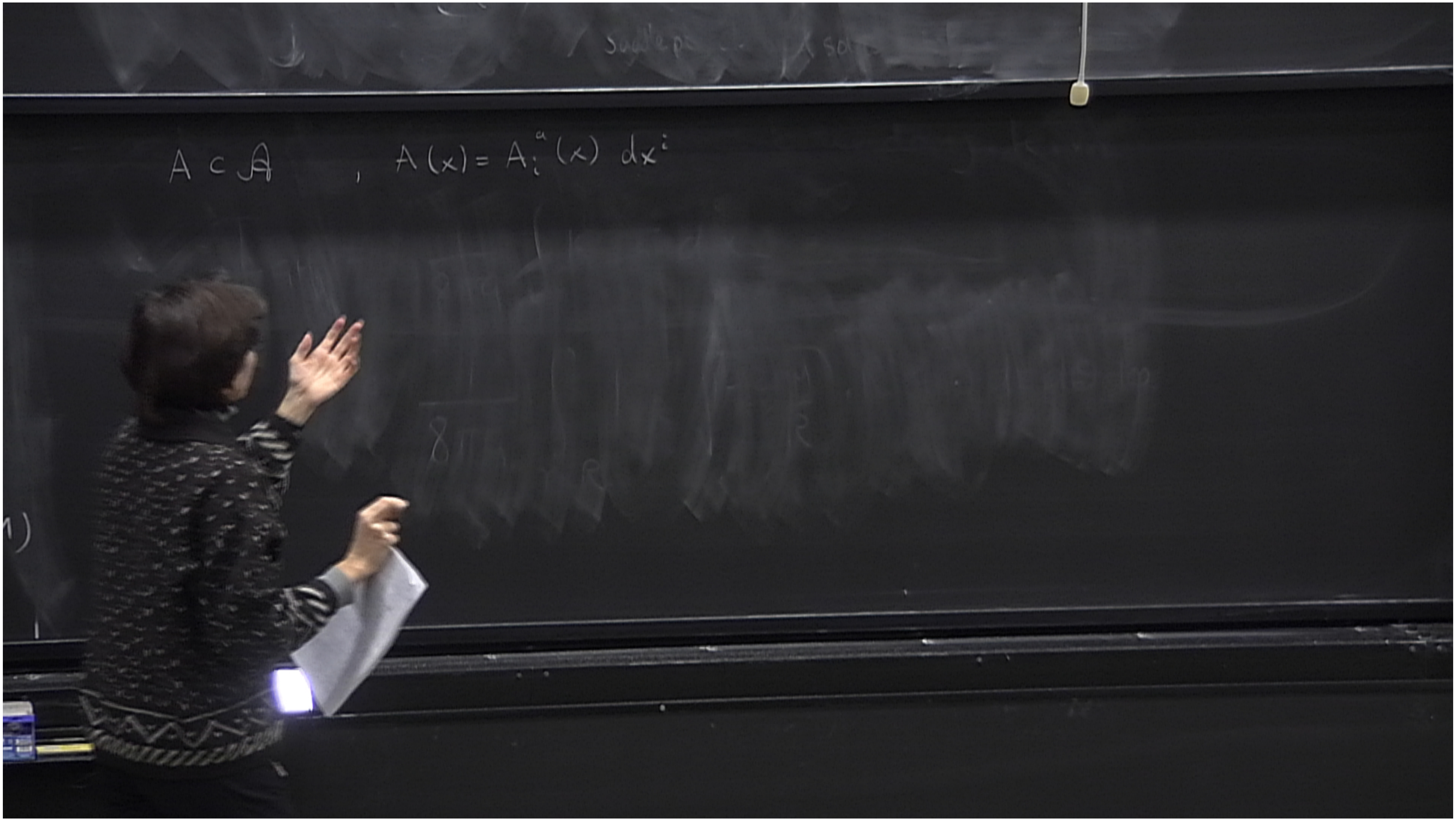
Σ
s_1

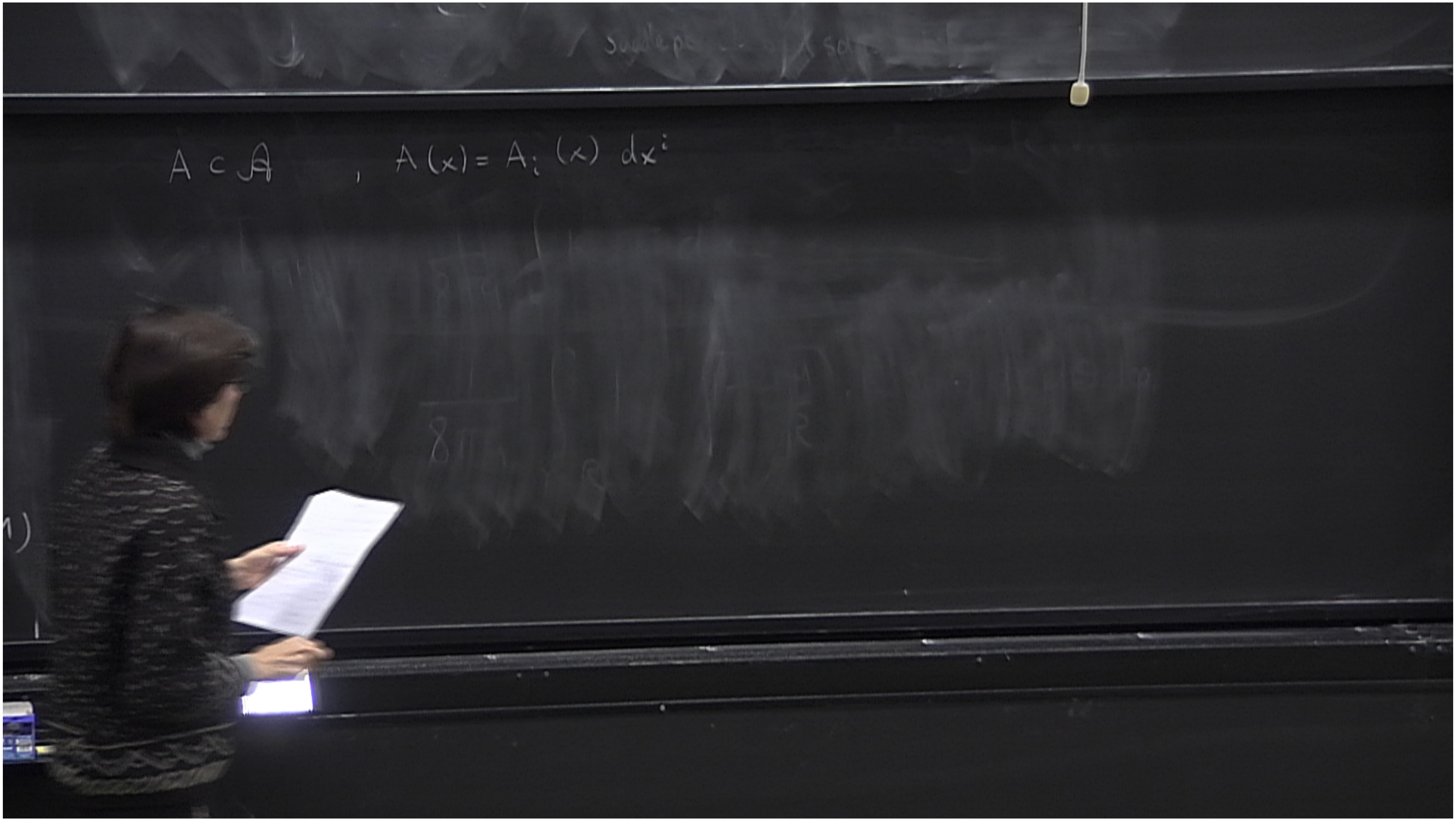

w
Σ
w(s₀)
w(s₁)
s₁
path in Σ


Σ
w
$w(s_0)$
$w(s_1)$
s_0
n Σ (cont. map)
n Σ : $\gamma : [0,1]$


Σ
w
w(s₀)
w(s₁)
s₀
s₁
A
w: [s₁, s₂] → Σ : s ↦ w'(s)
path in Σ (cont. map)
loop in Σ : γ: [0,1] → Σ , s ↦ γ'(s) with γ(0) = γ(


$A \subset \mathcal{A}$, $A(x) = A_i^a(x)$


$A \subset \mathcal{A}$, $A(x) = A_i^a(x)\, dx^i$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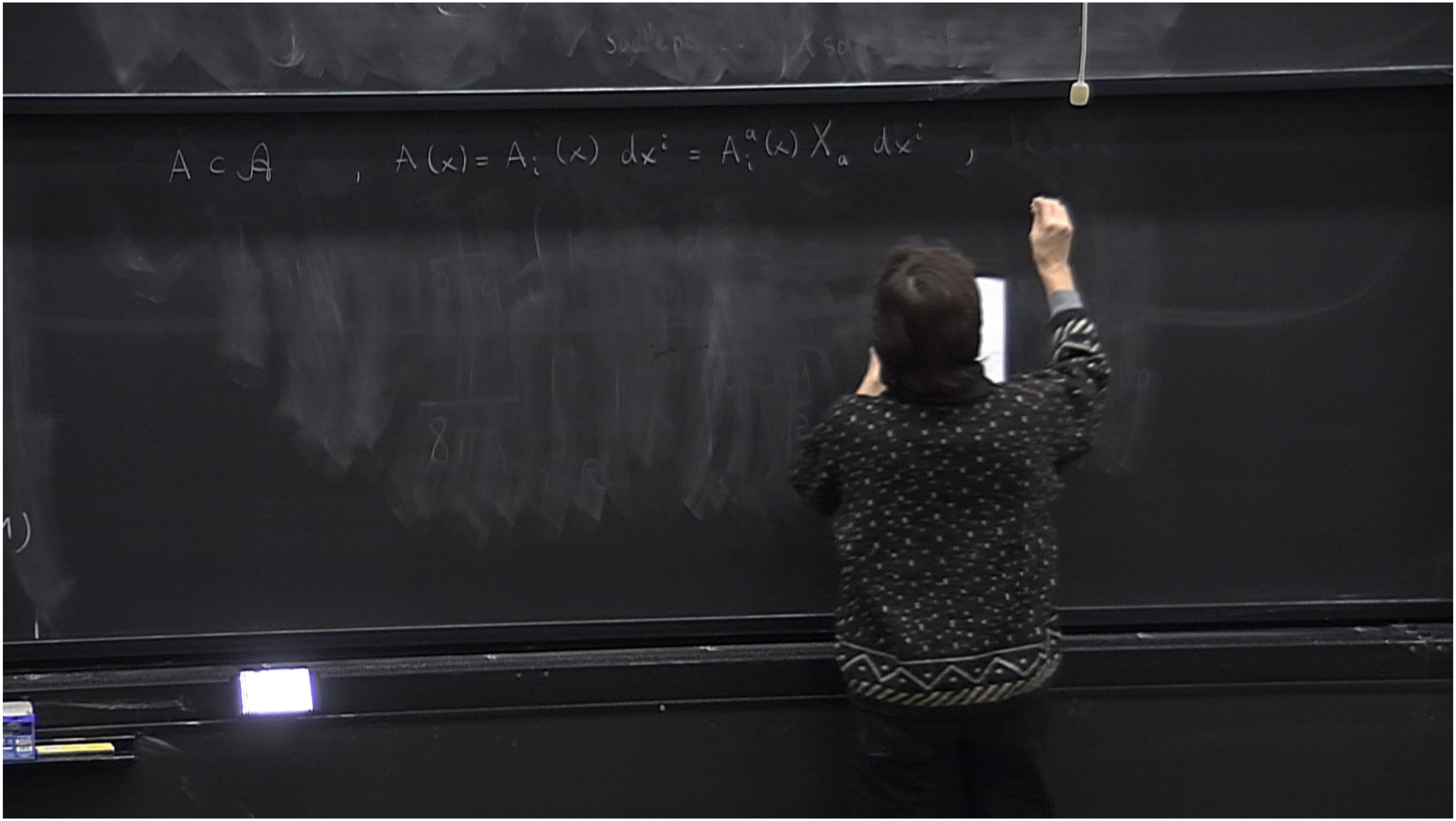
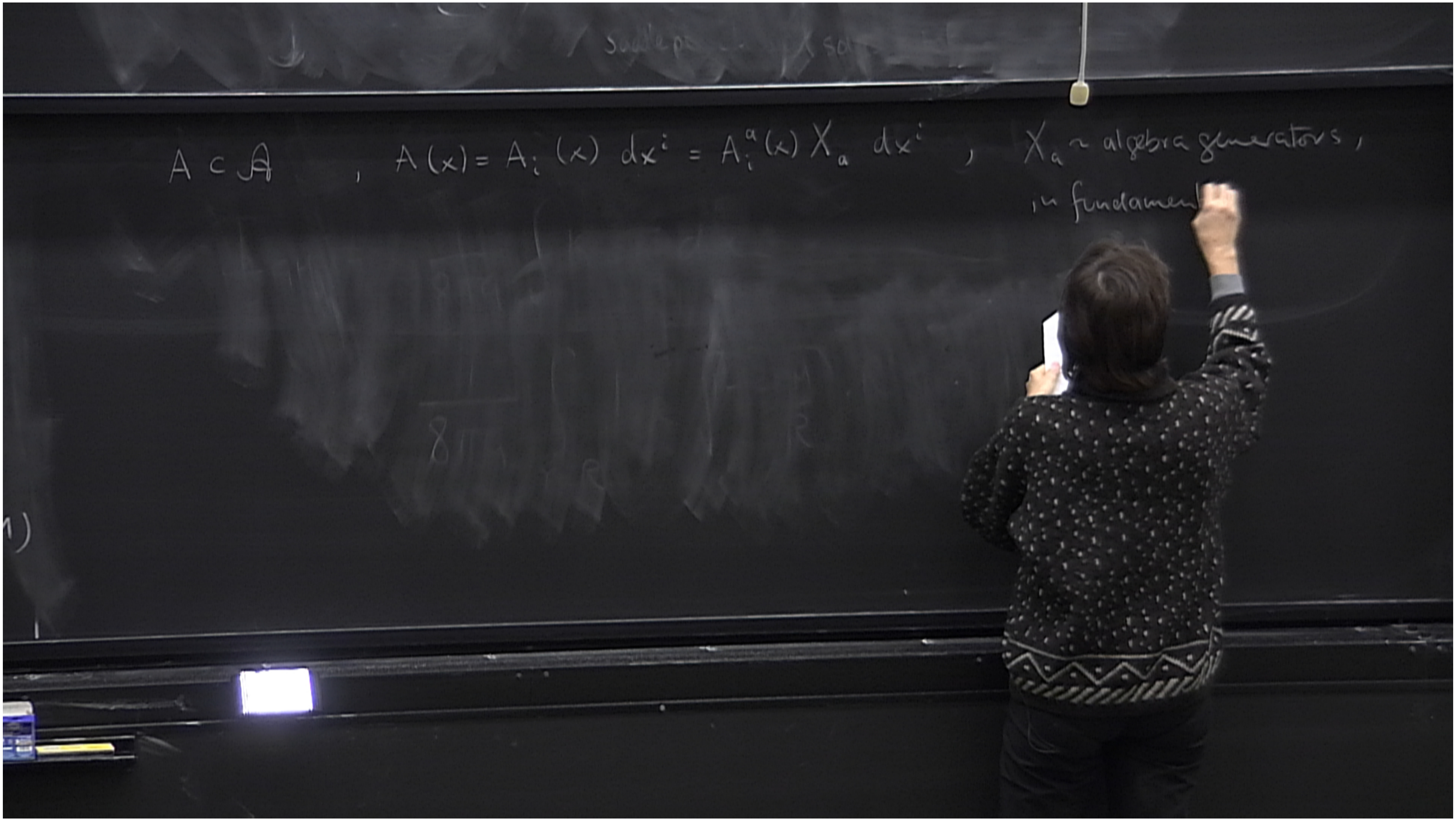
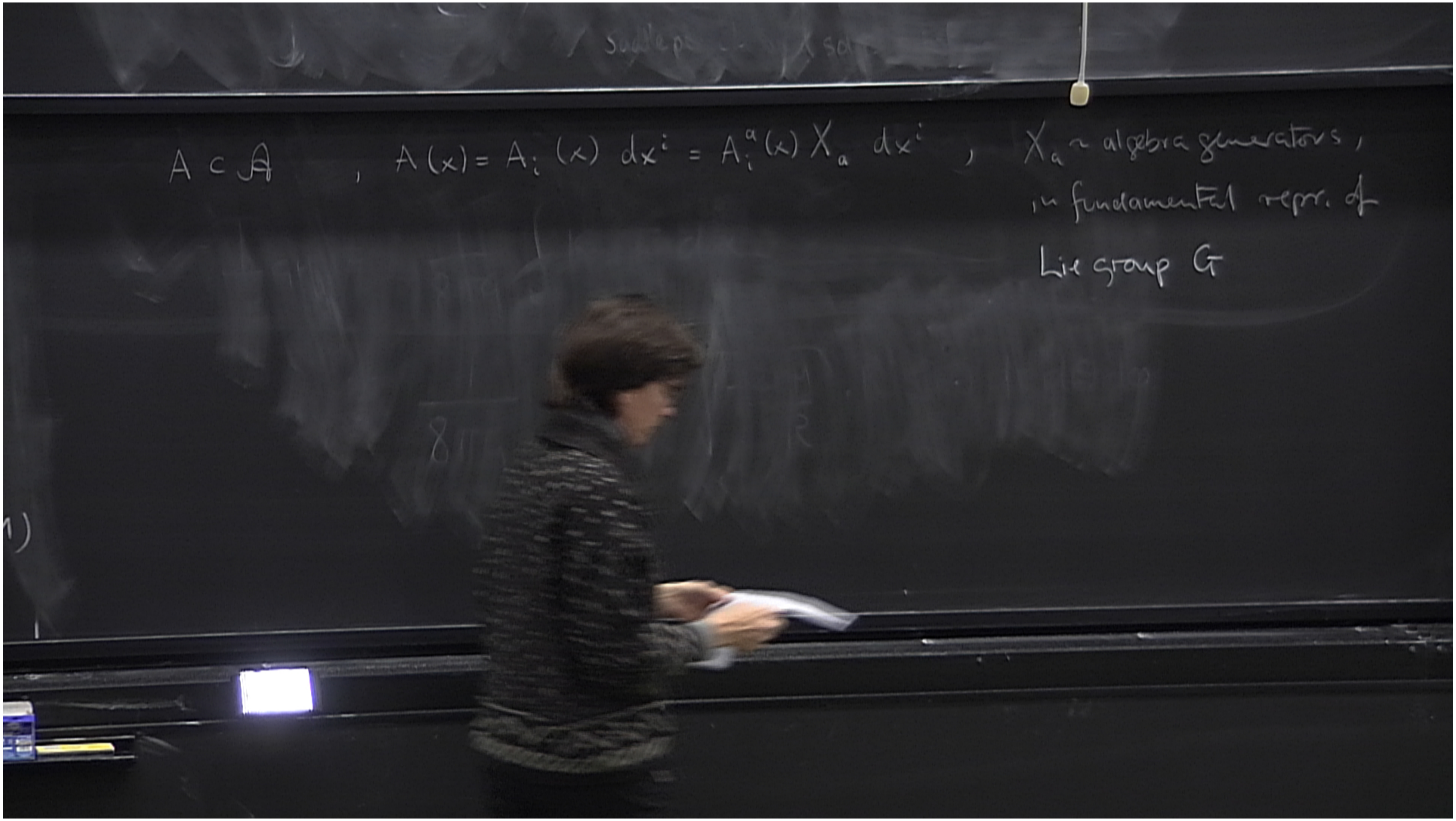
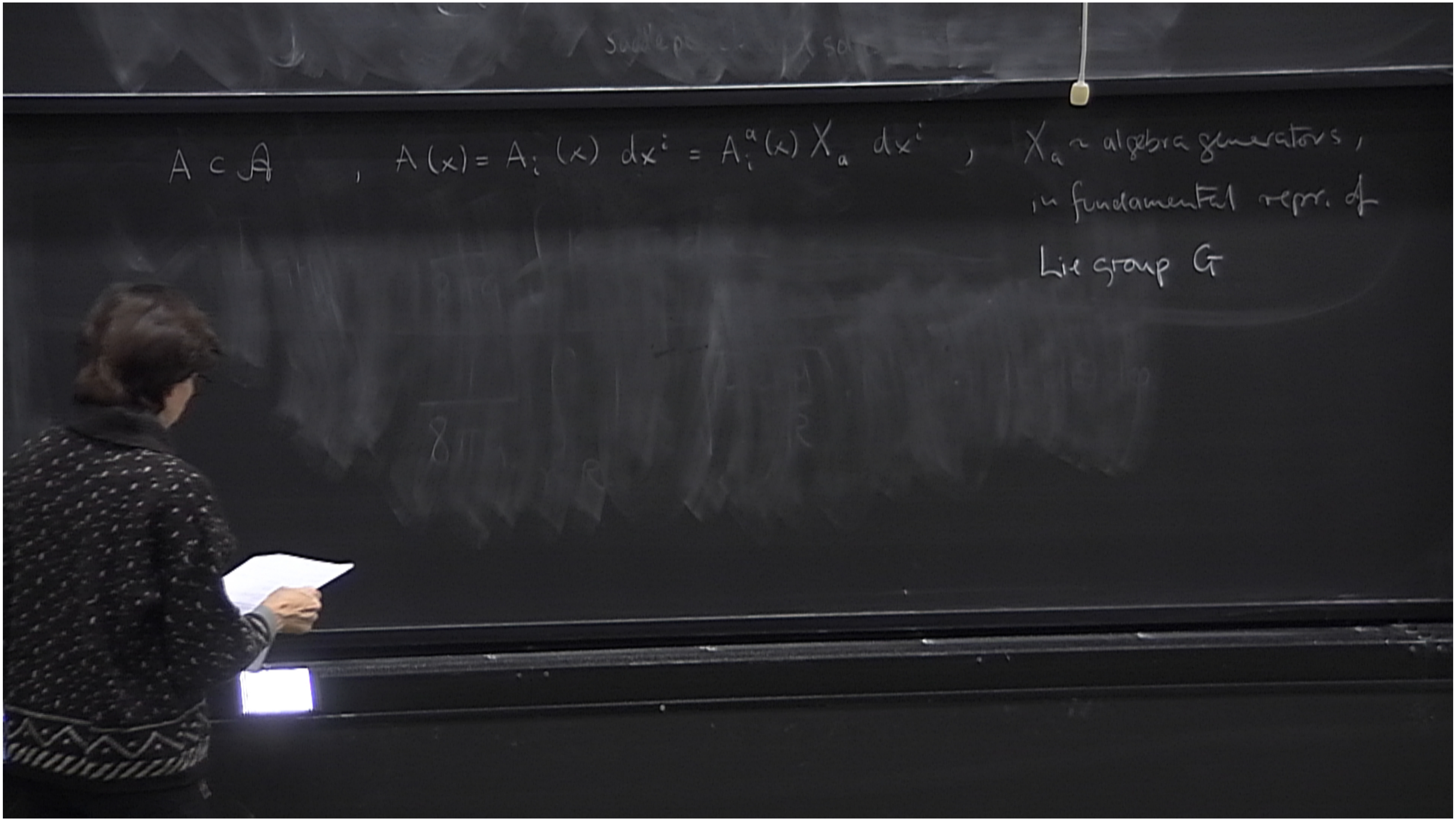

$A \subset \mathcal{A}$, $A(x) = A_i(x)\, dx^i = A_i^a(x)\, X_a\, dx^i$,


$A \subset \mathcal{A}$, $A(x) = A_i(x)\, dx^i = A_i^a(x) X_a\, dx^i$, $X_a \sim$ algebra generators,
in fundamen


$A \subset \mathcal{A}$, $A(x) = A_i(x)\, dx^i = A_i^a(x)\, X_a\, dx^i$,
$X_a \sim$ algebra generators,
in fundamental repr. of
Lie group G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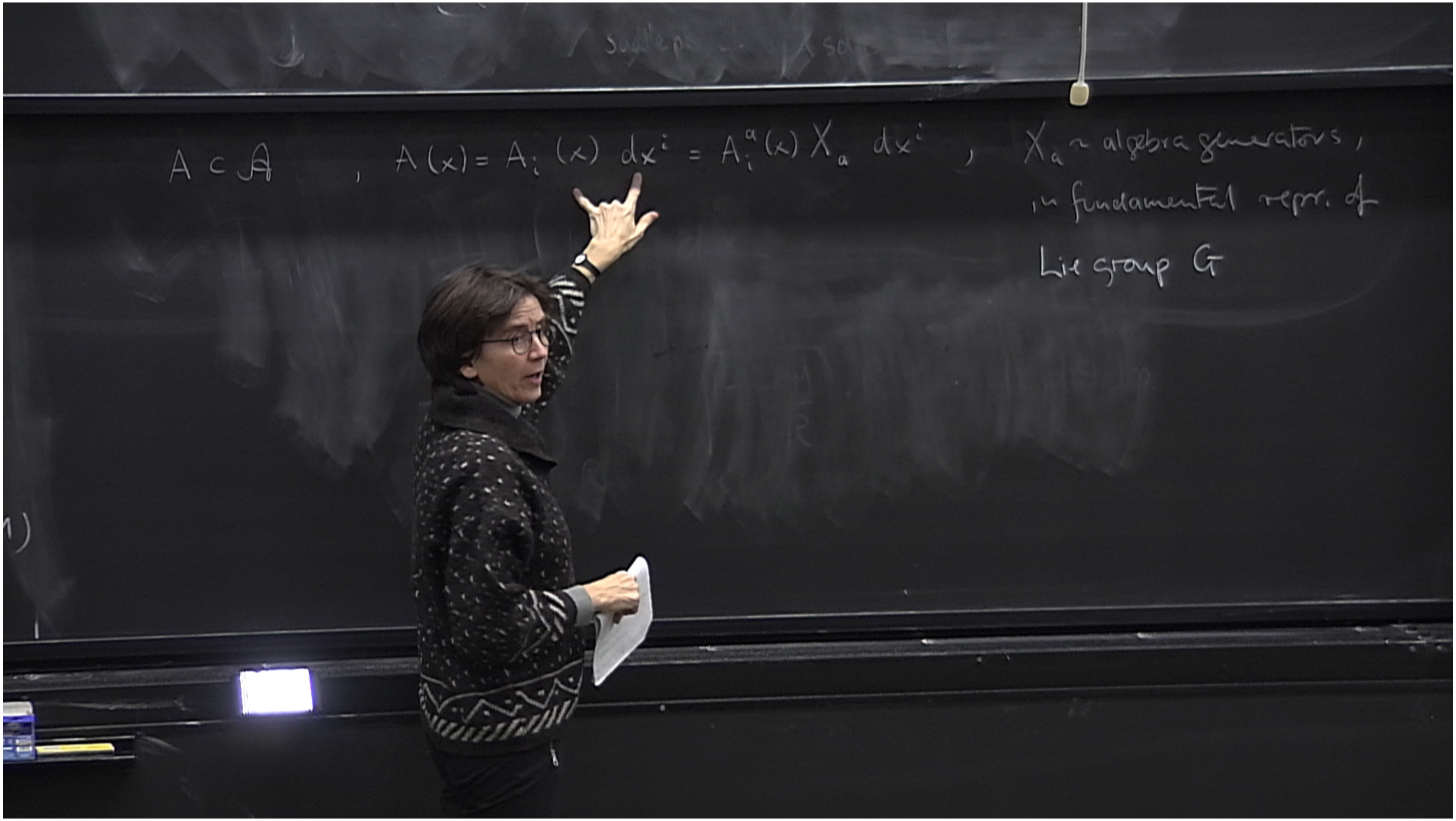
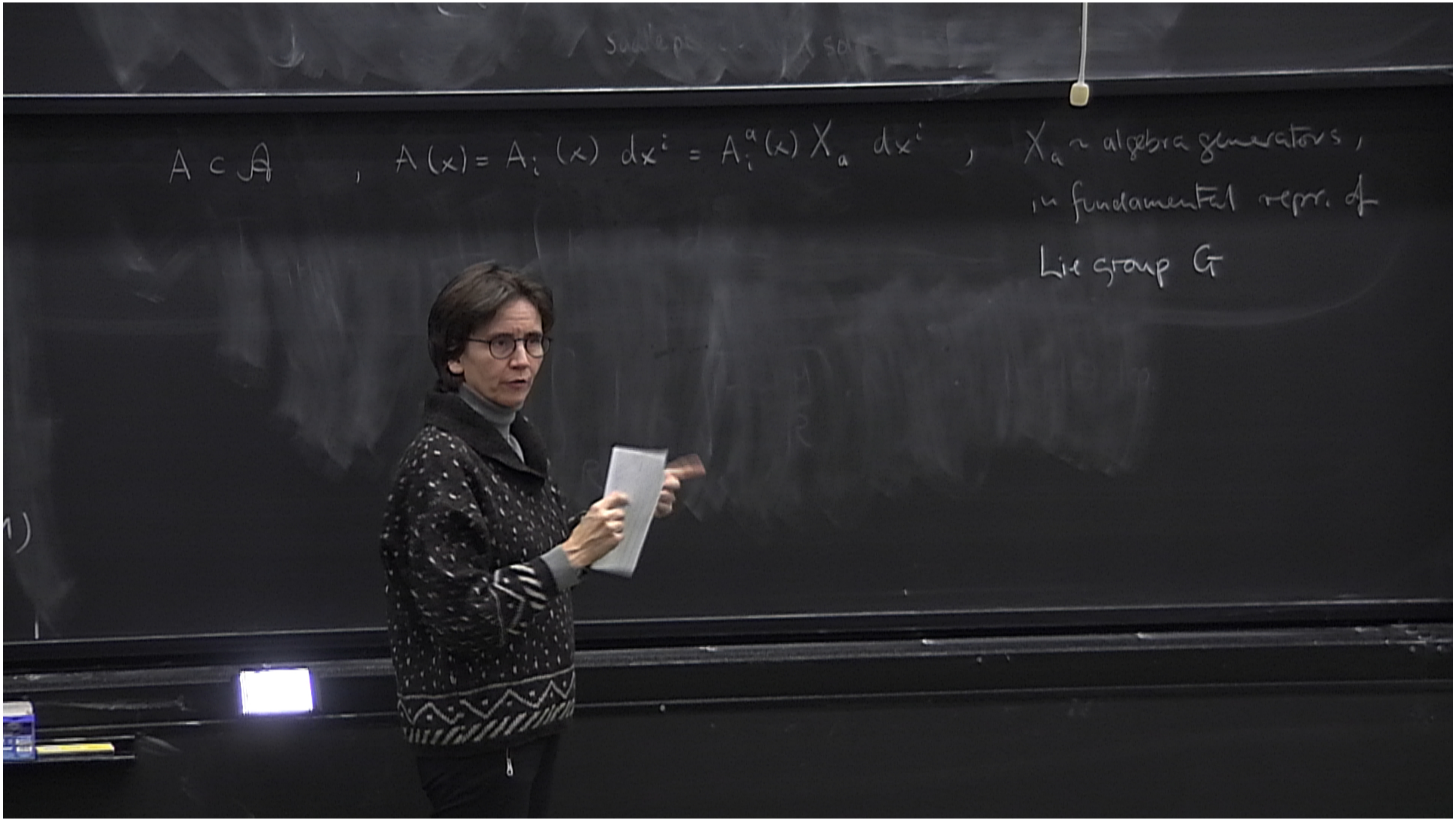
$A \subset \mathcal{A}$, $A(x) = A_i(x)\, dx^i = A_i^a(x)\, X_a\, dx^i$, X_a ~ algebra generators, in fundamental repr. of Lie group G


A ⊂ 𝒜 , A(x) = A_i (x) dx^i = A_i^a(x) X_a dx^i ,
X_a ~ algebra generators,
in fundamental repr. of
Lie group G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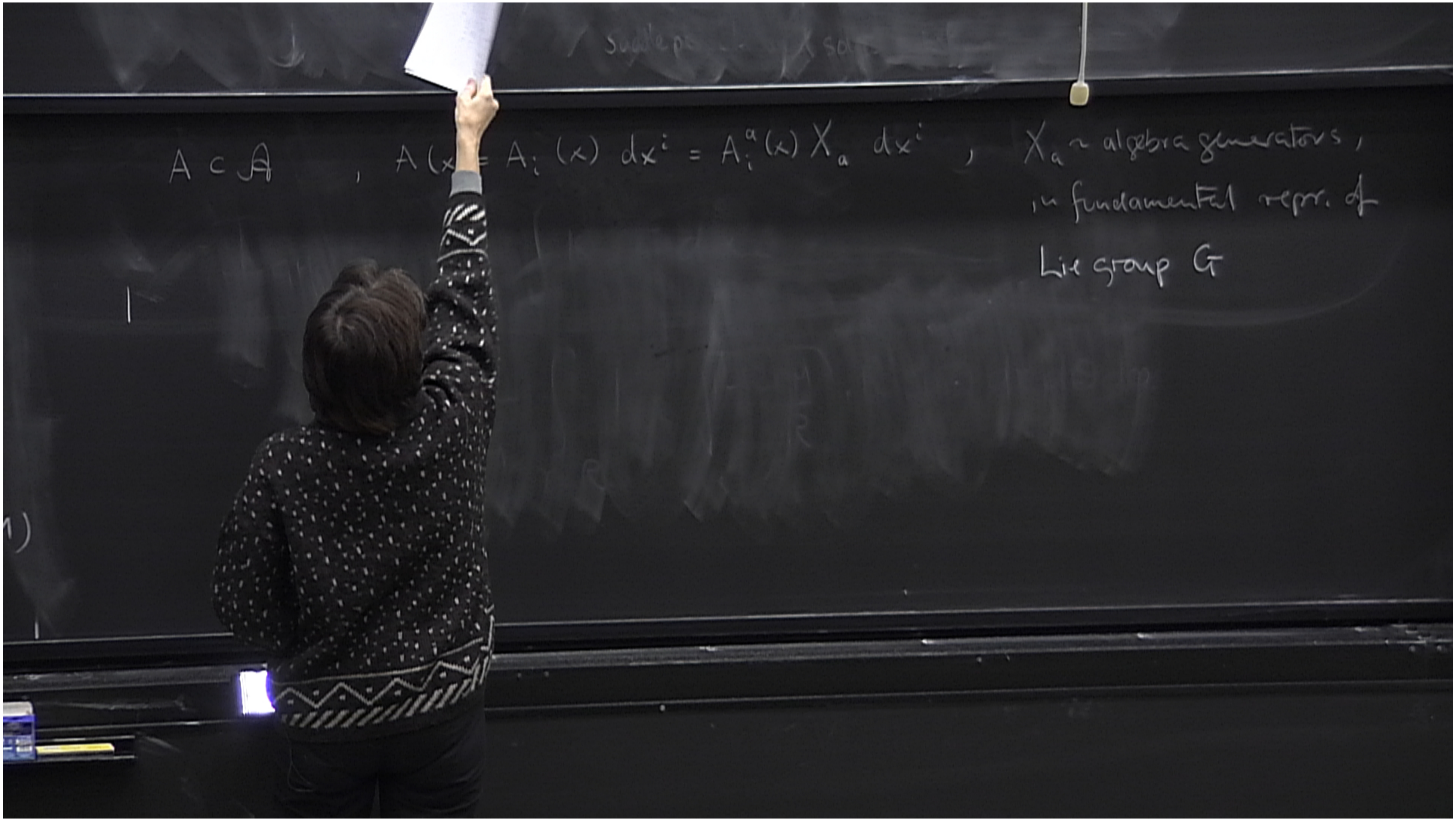
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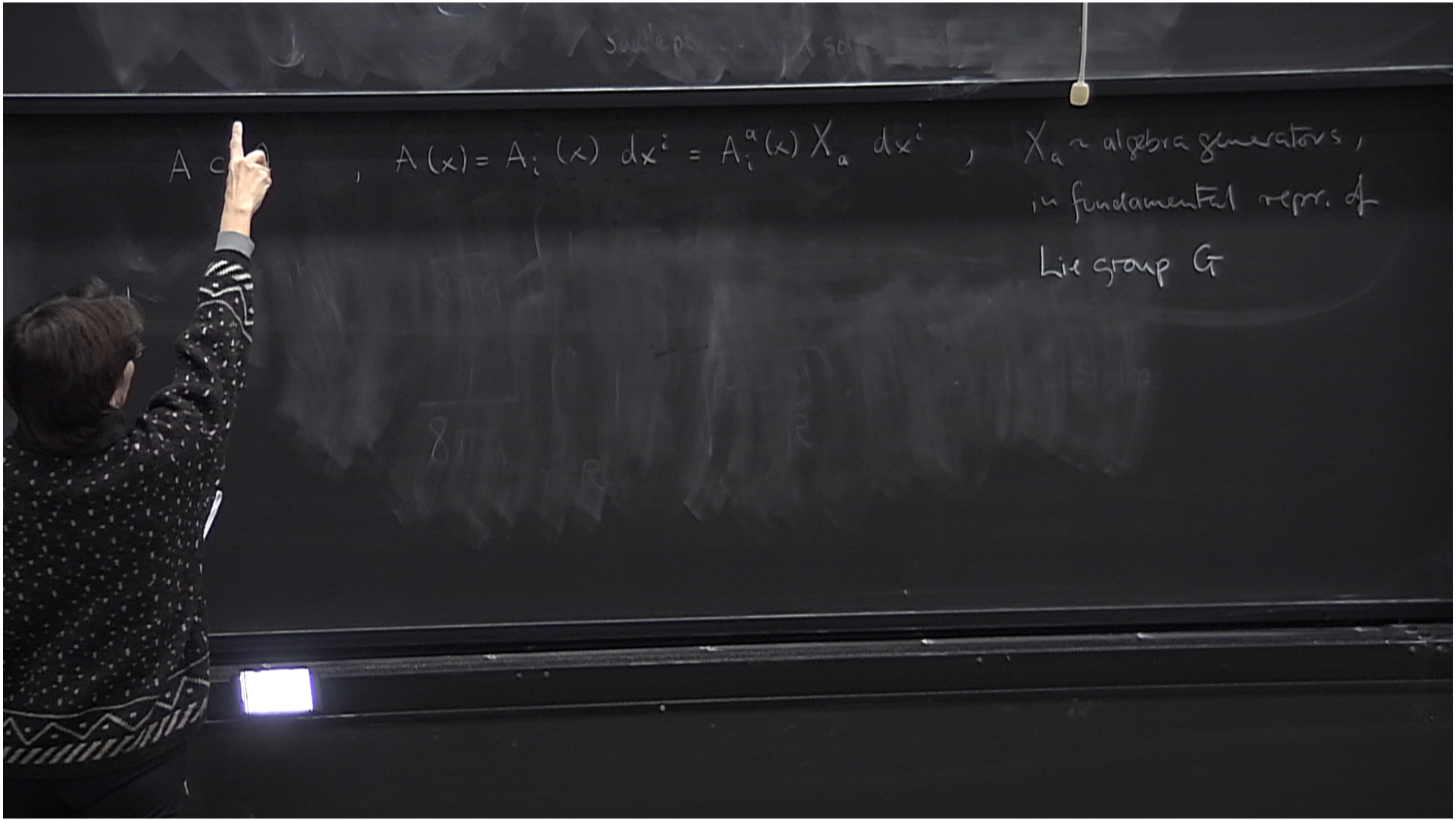
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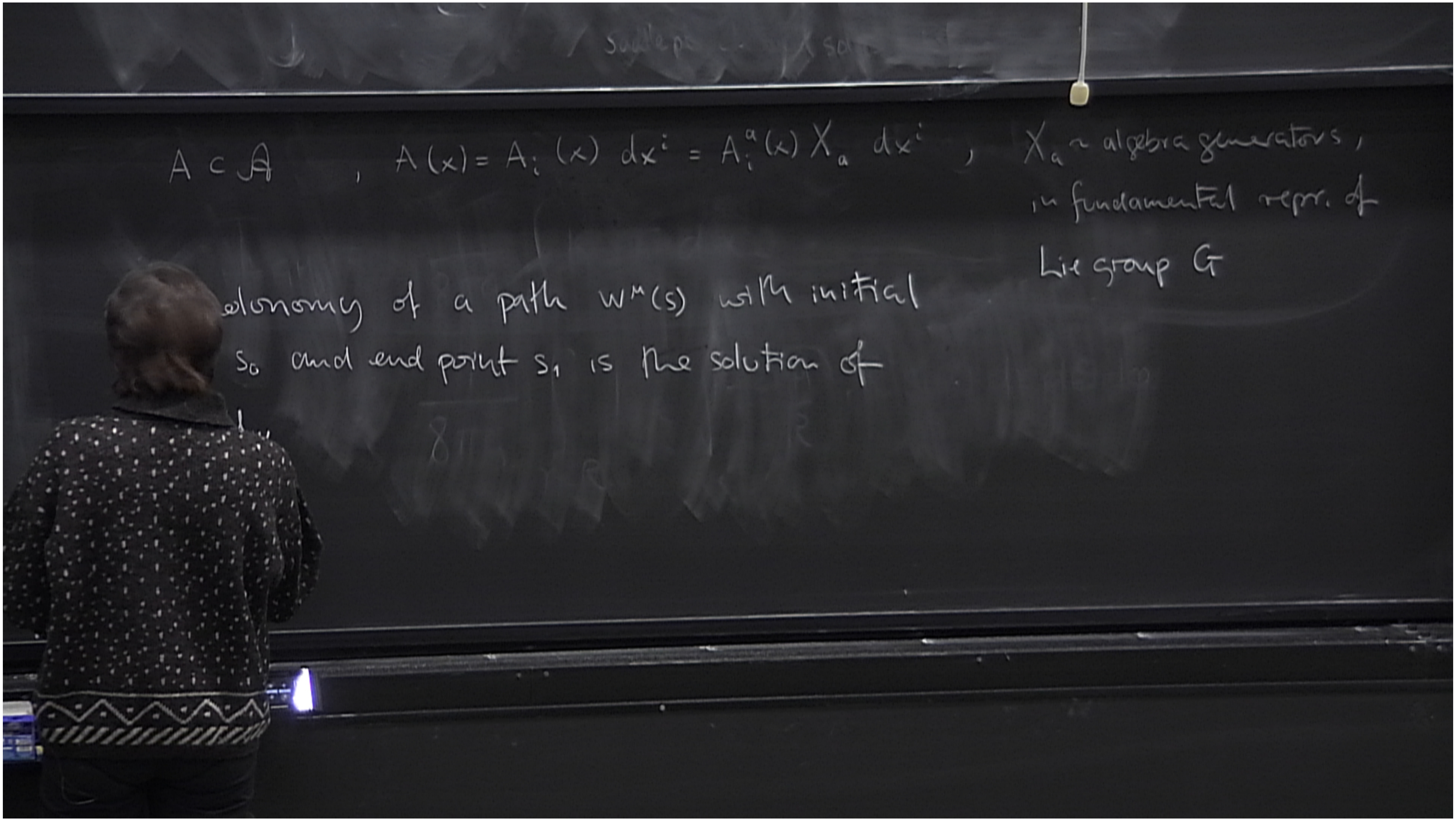
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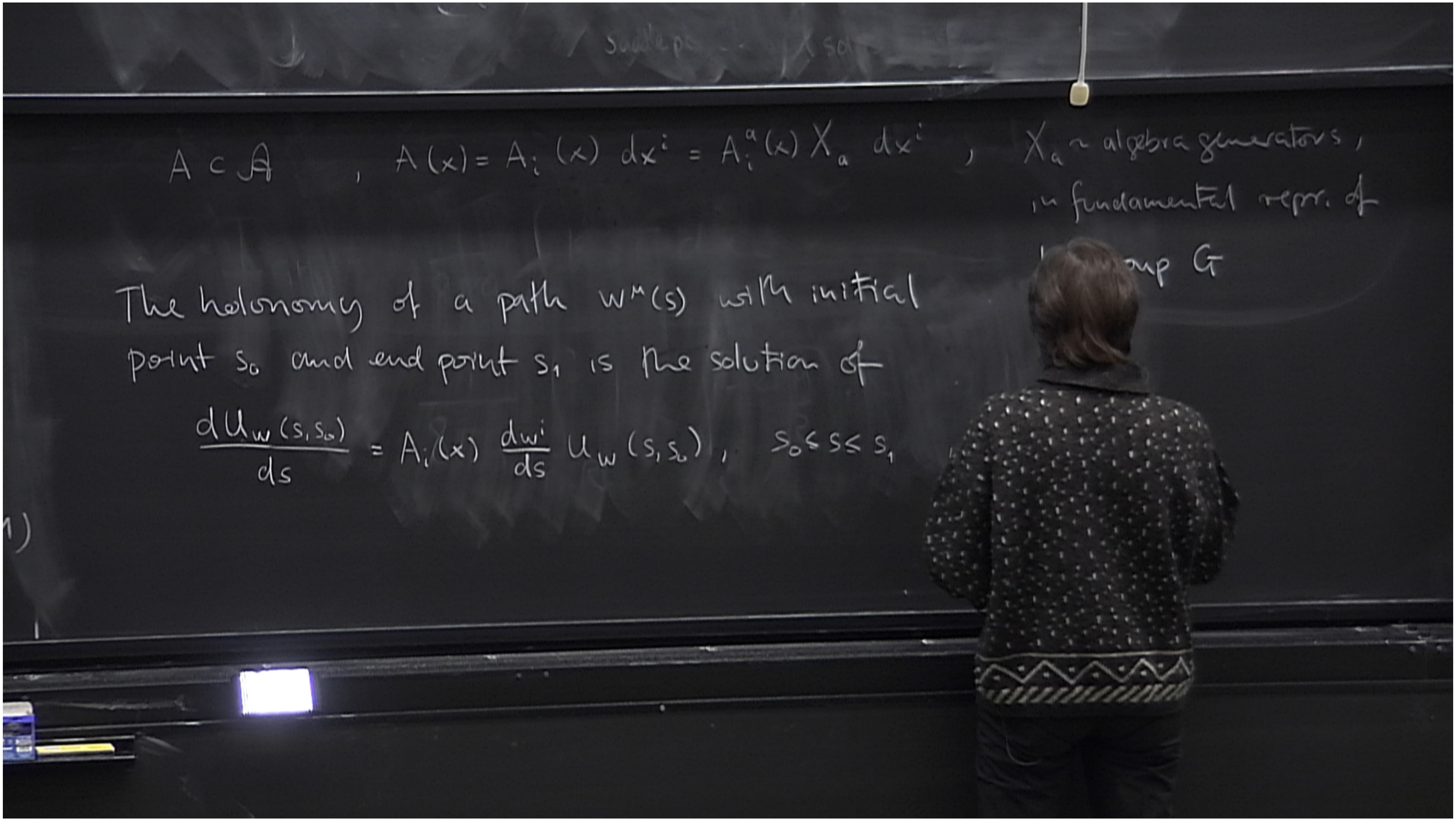

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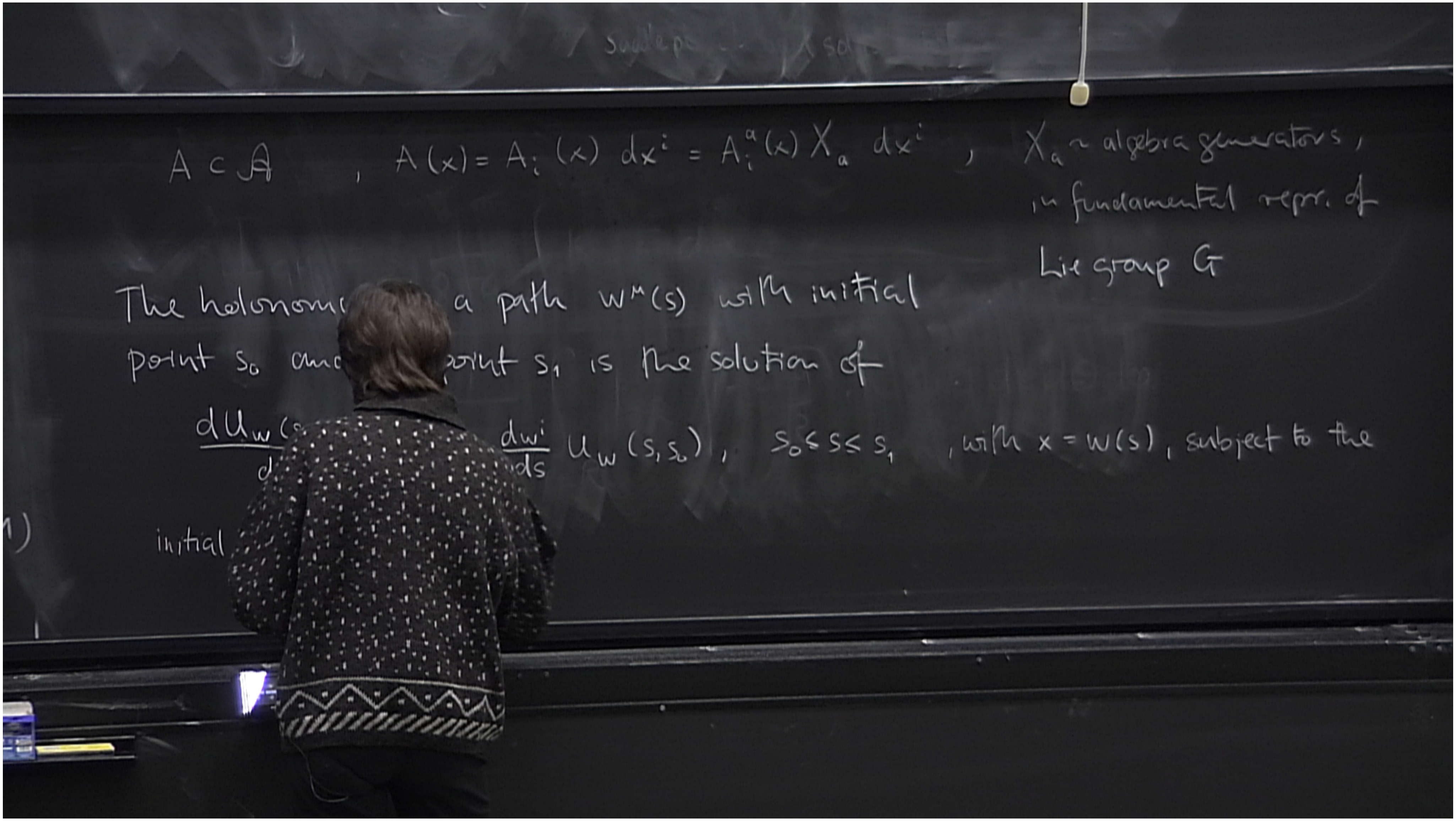

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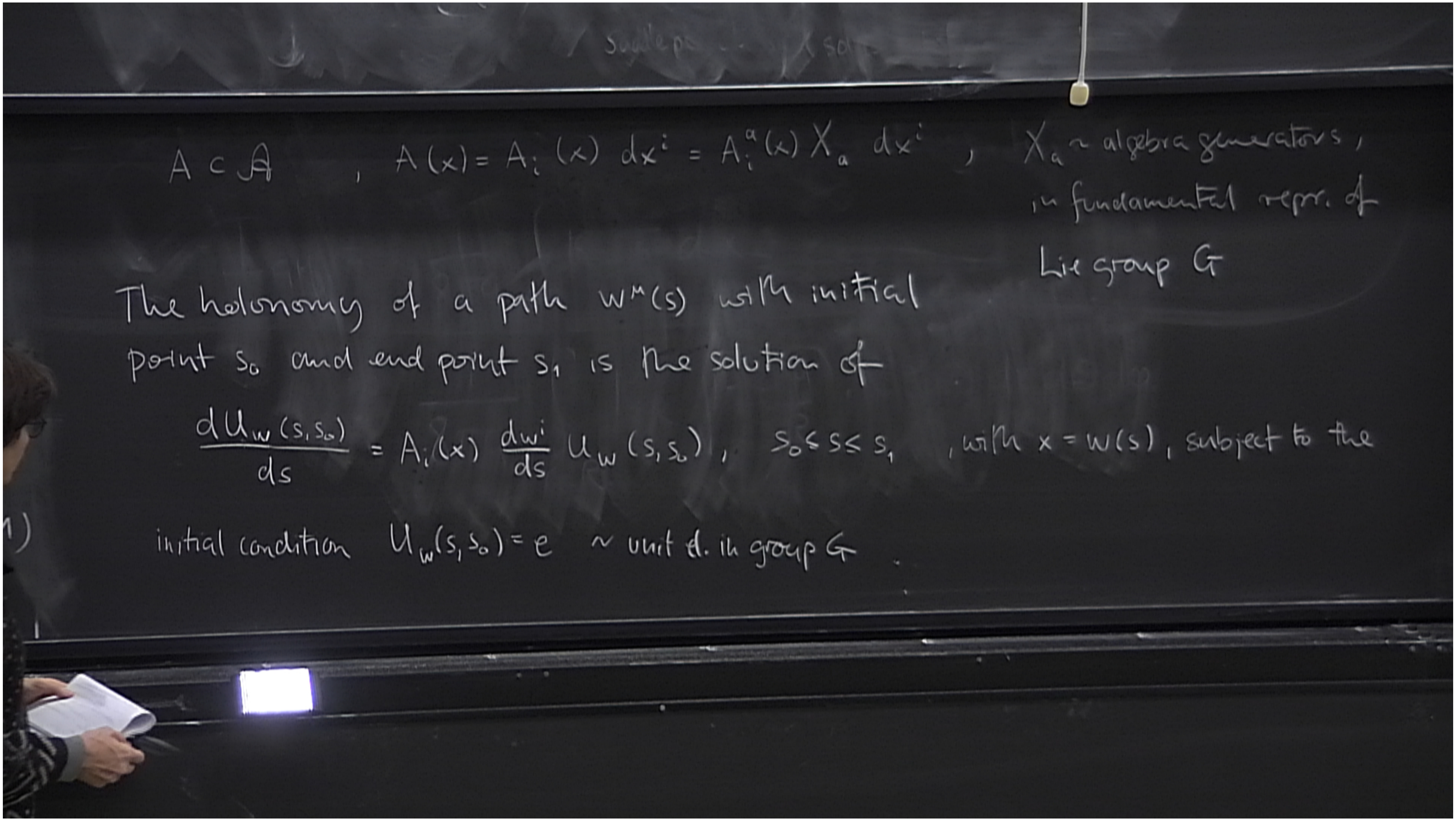
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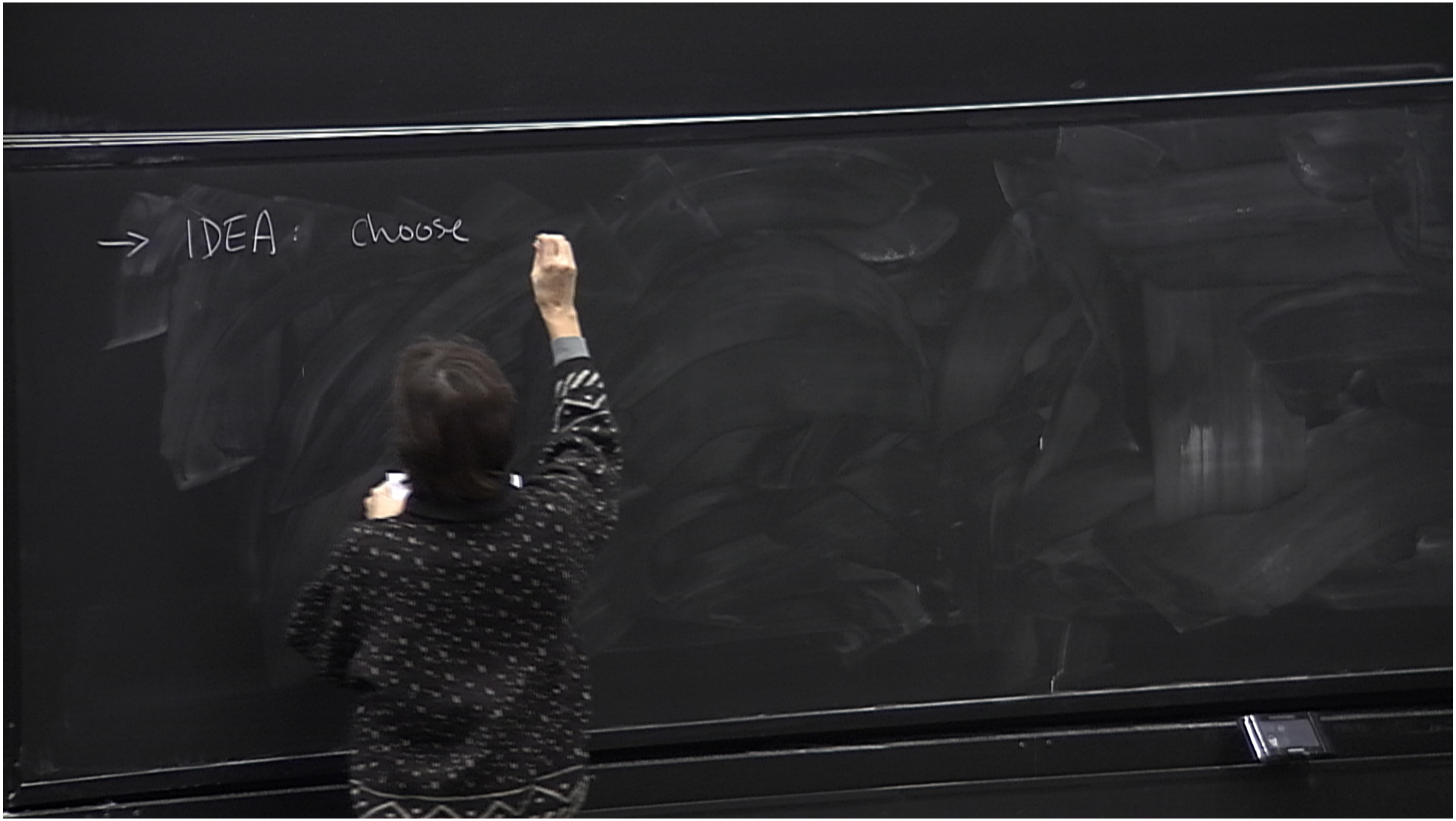
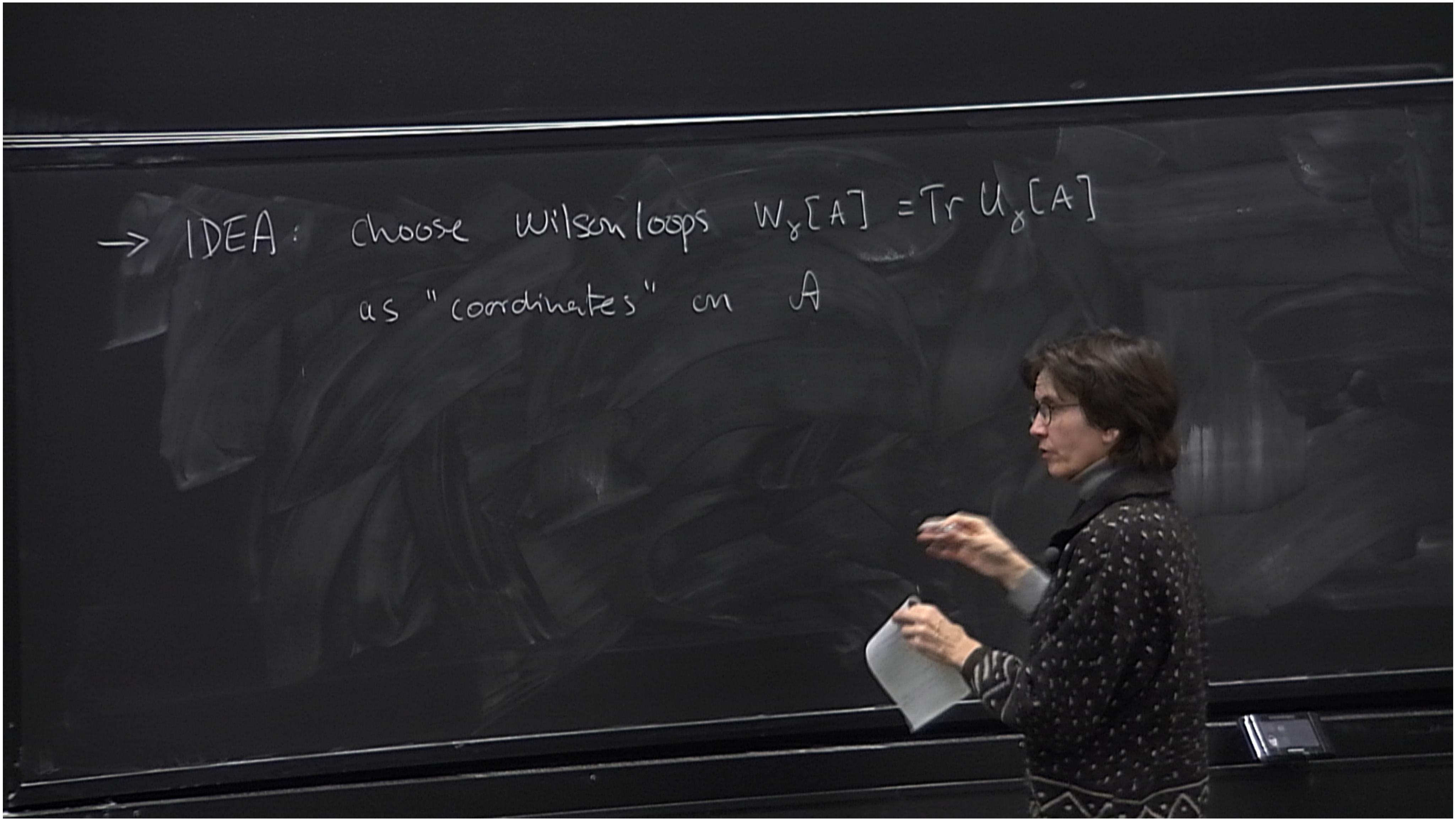
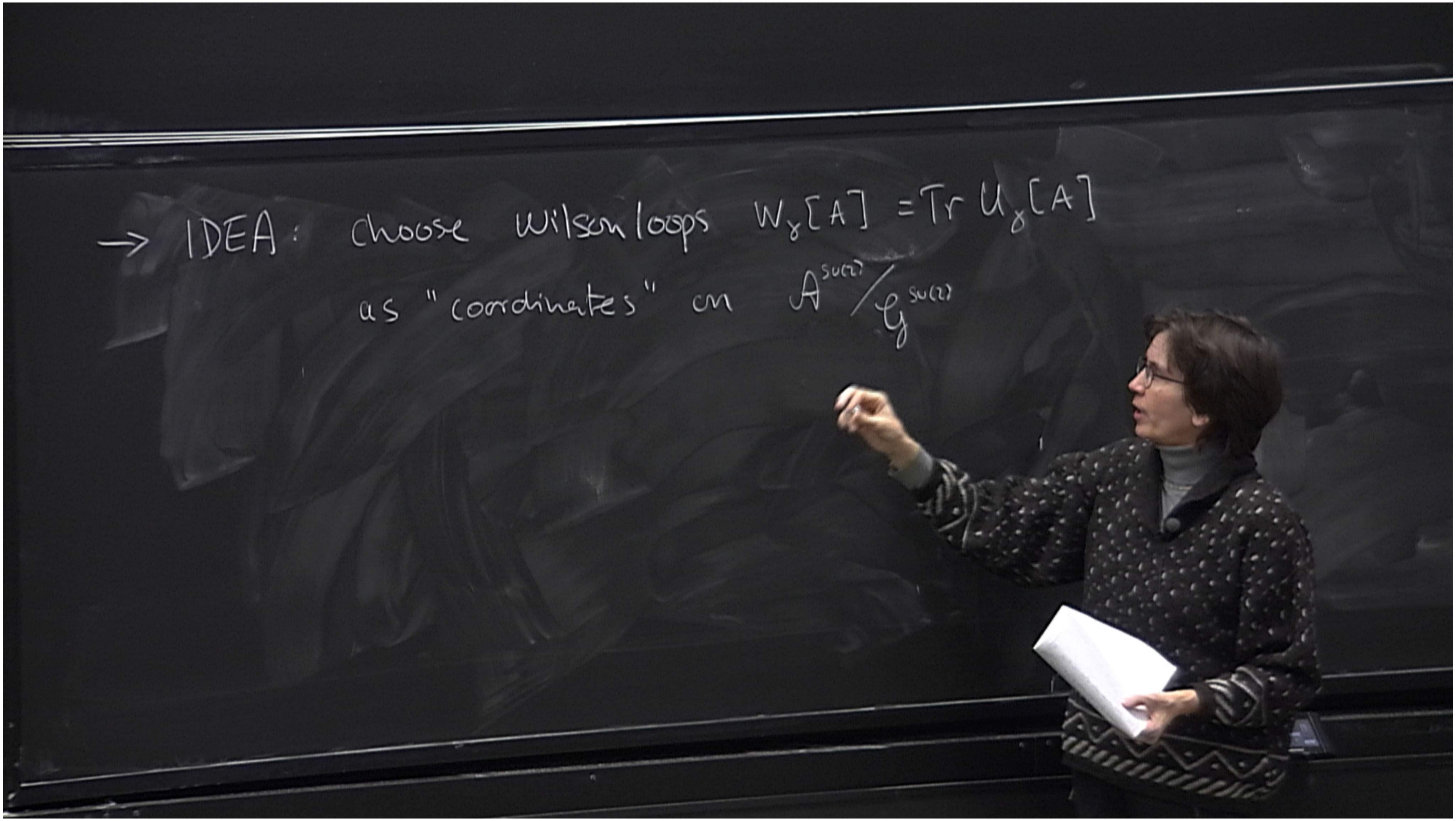

→ IDEA: choose


→ IDEA: choose Wilson loops $W_\gamma[A] = \mathrm{Tr}\, U_\gamma[A]$
as "coordinates" on $\mathcal{A}$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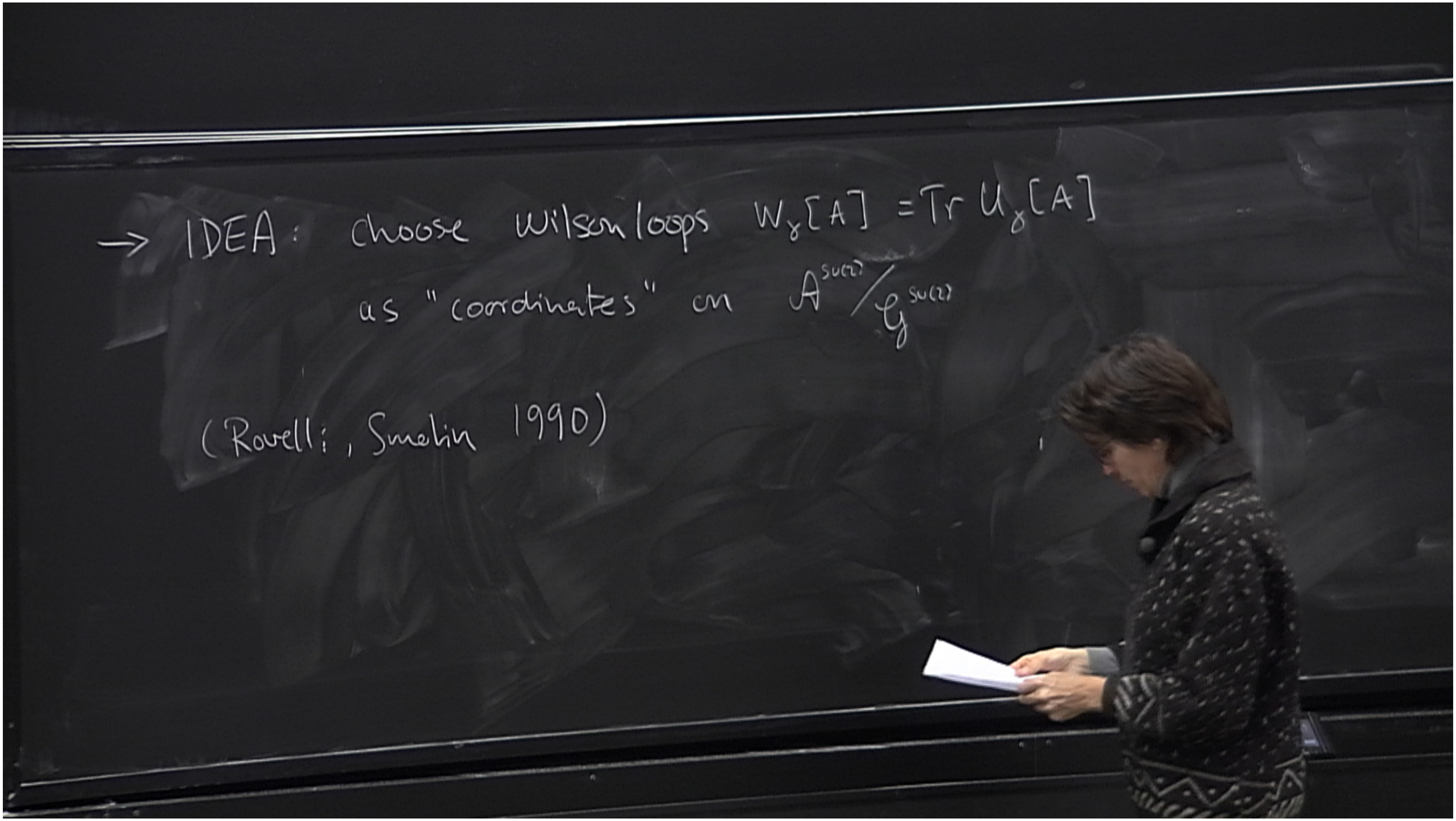
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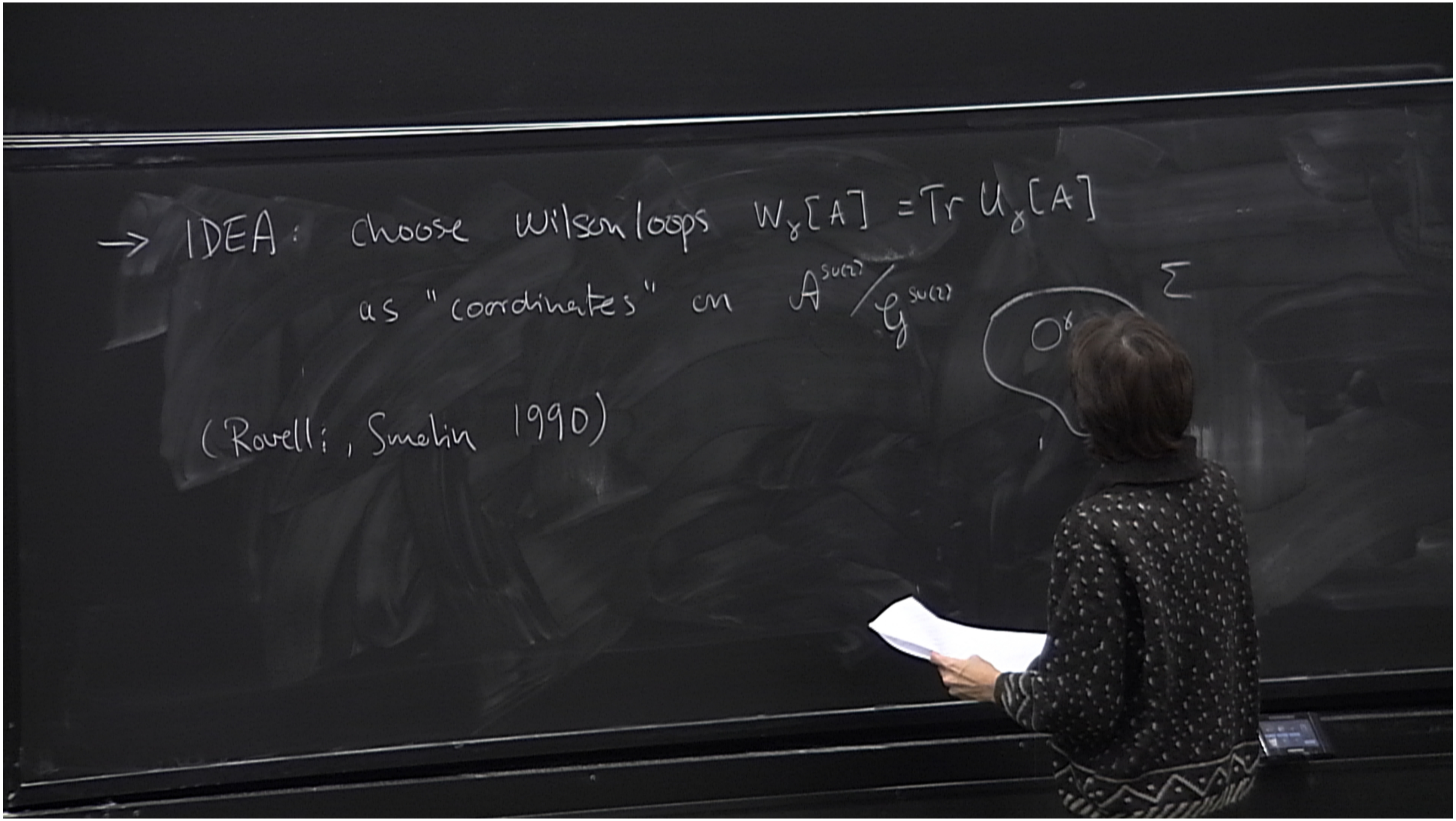
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Σ
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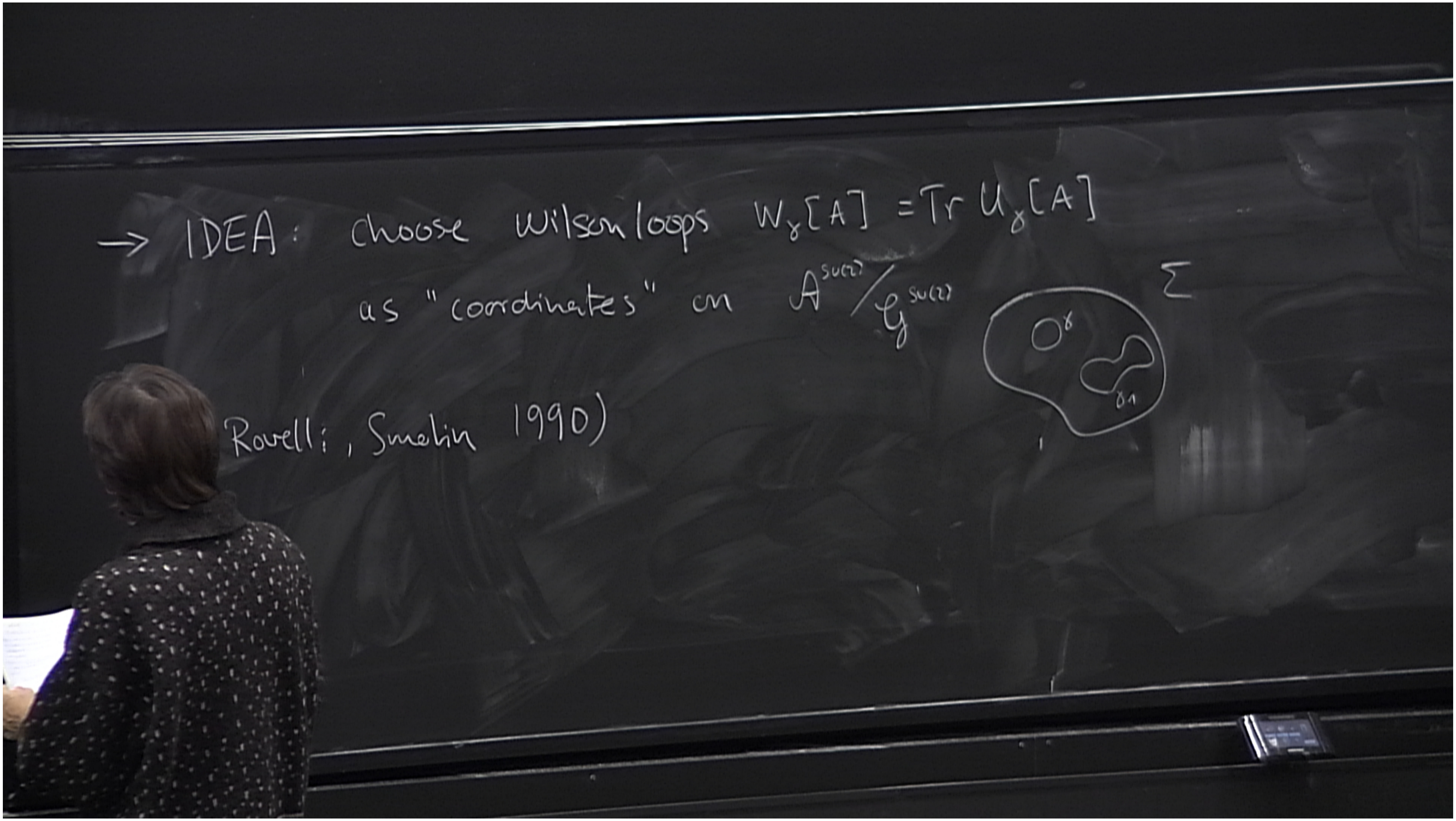
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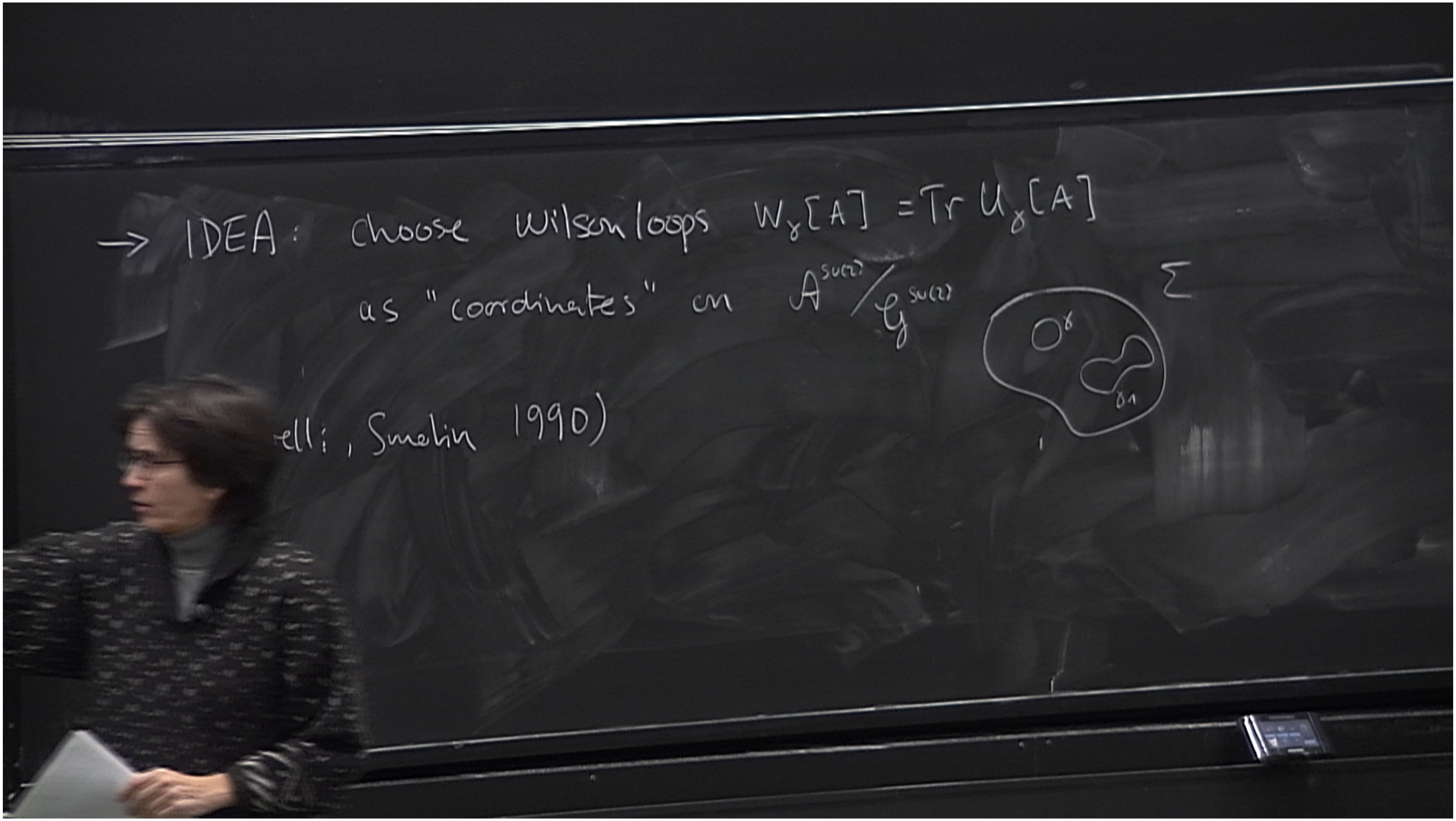
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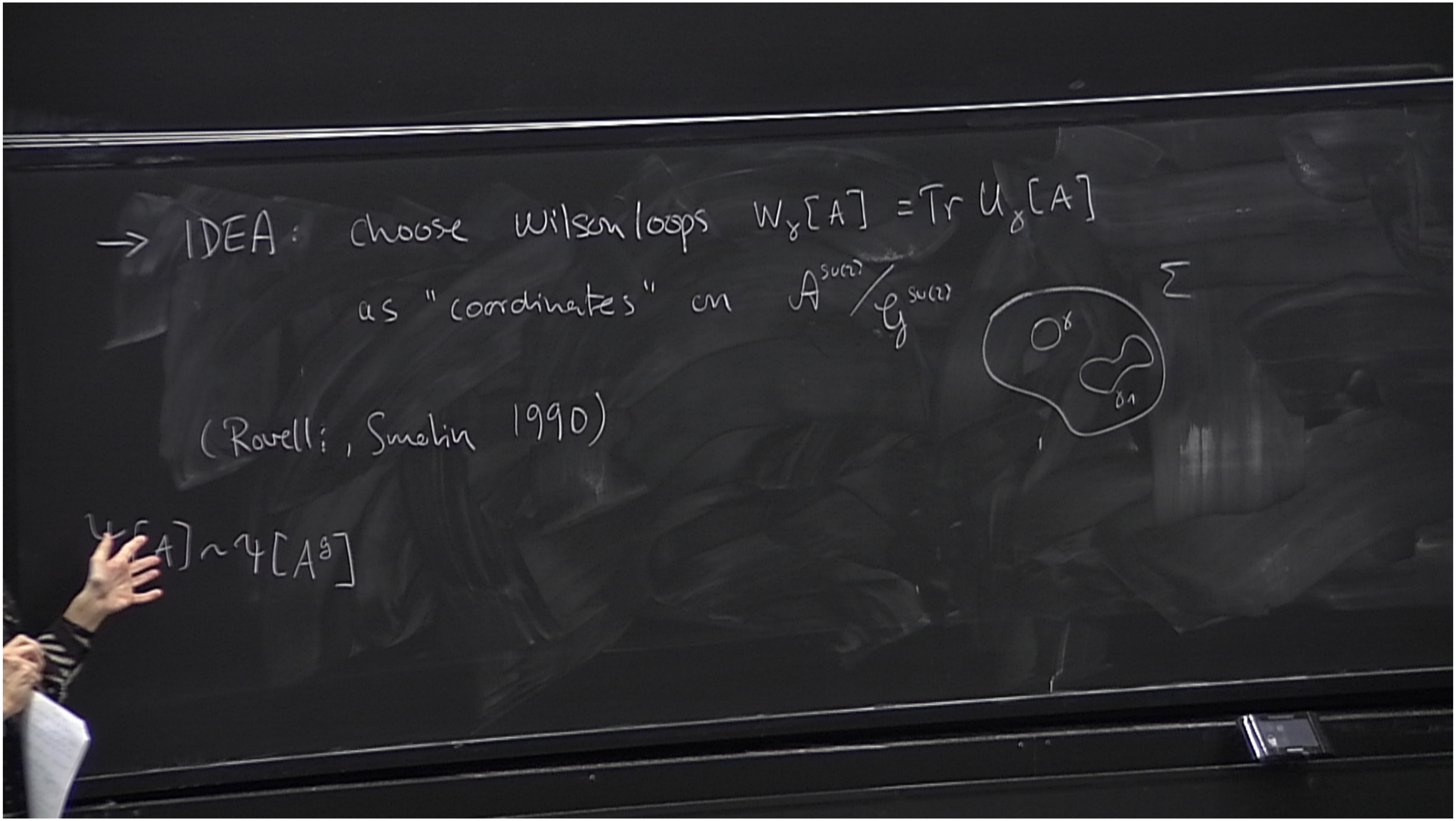
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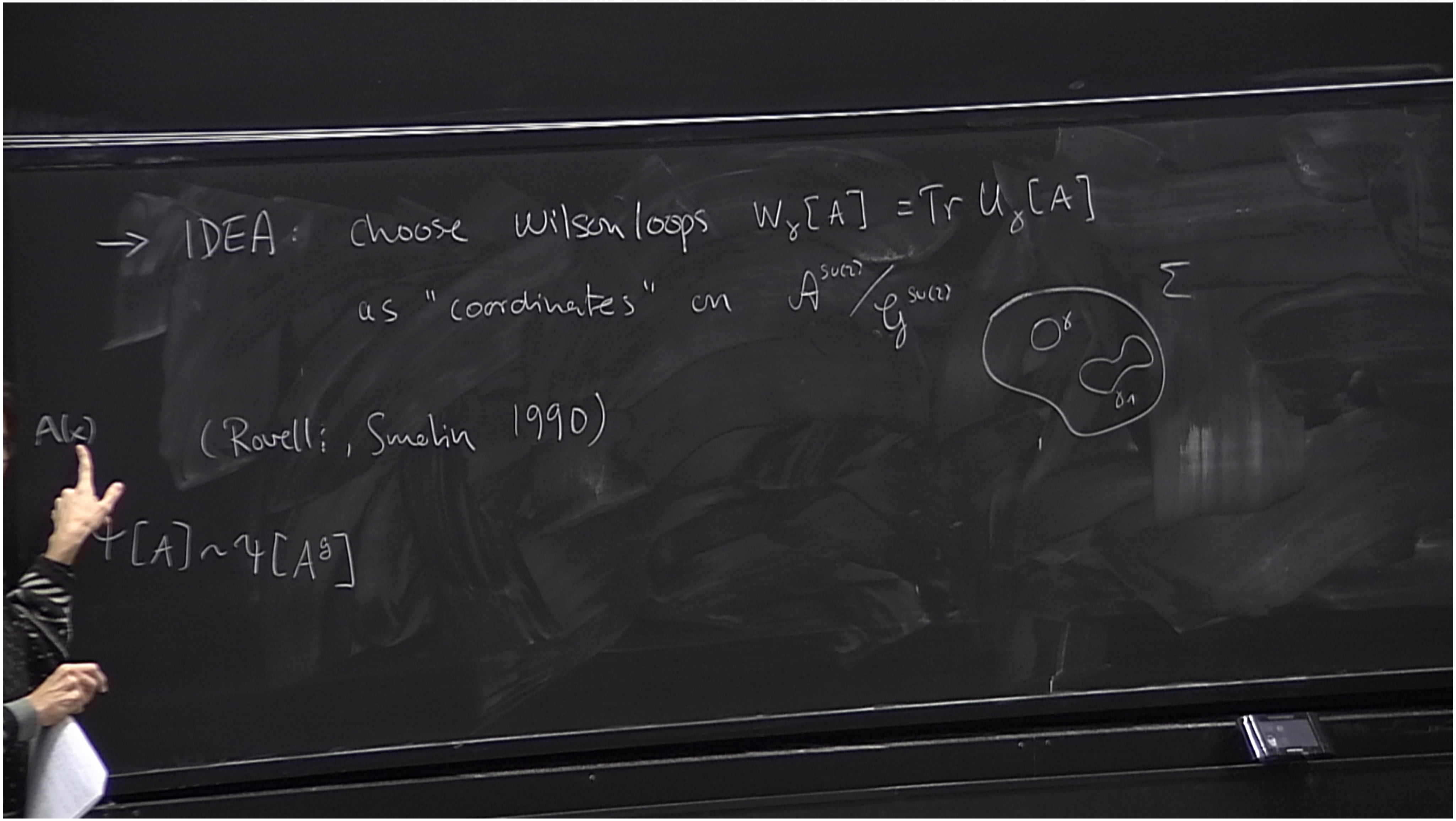
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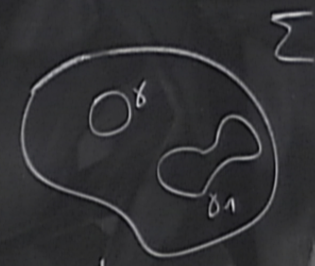

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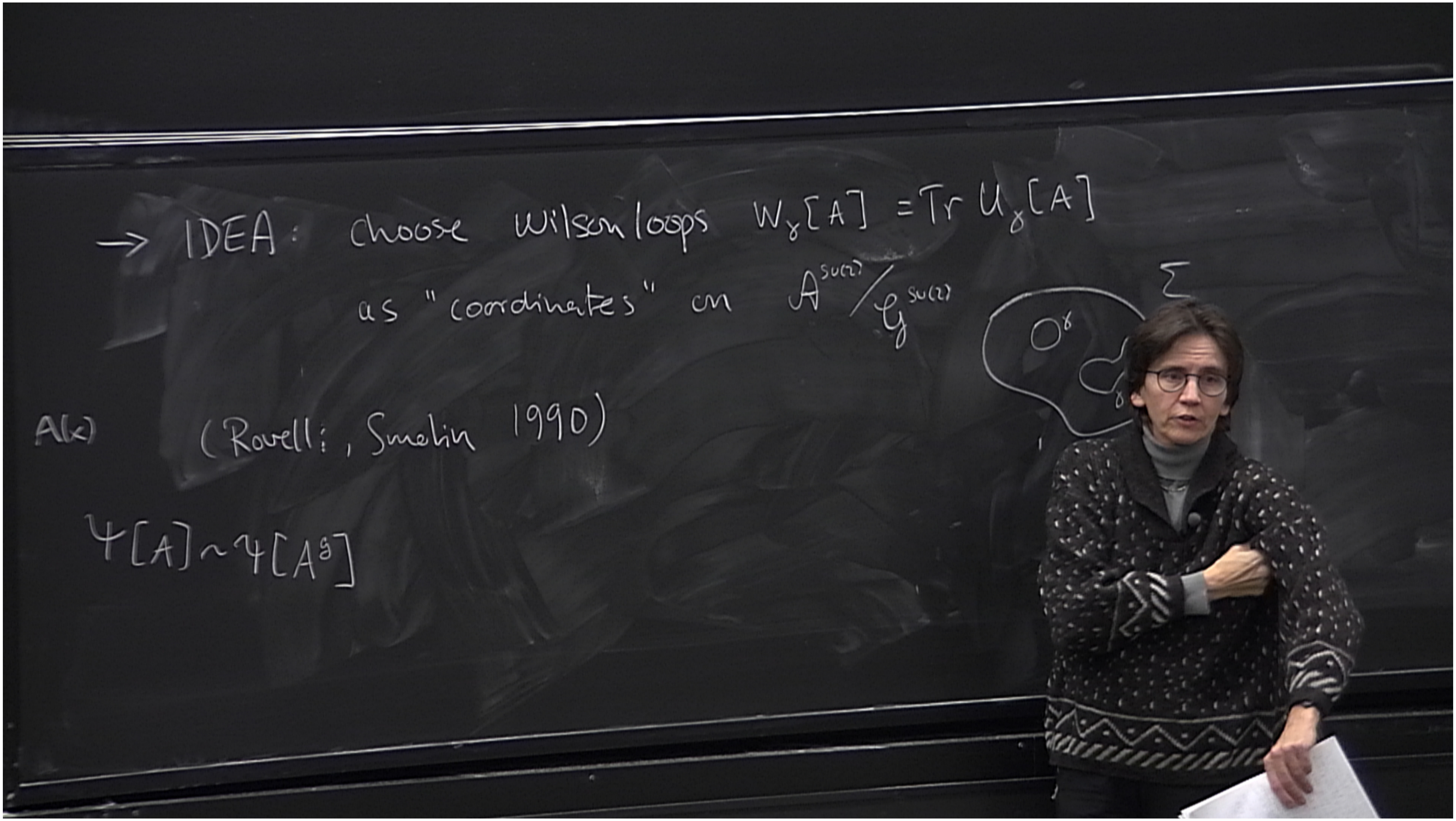
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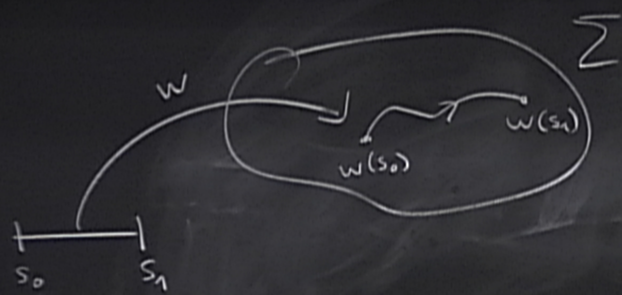


$w : [s_1, s_2] \to \Sigma \ : \ s \mapsto w(s)$

path in Σ (cont. map)

loop in Σ : $\gamma : [0,1] \to \Sigma$, $s \mapsto \gamma(s)$ with $\gamma(0) = \gamma(1)$

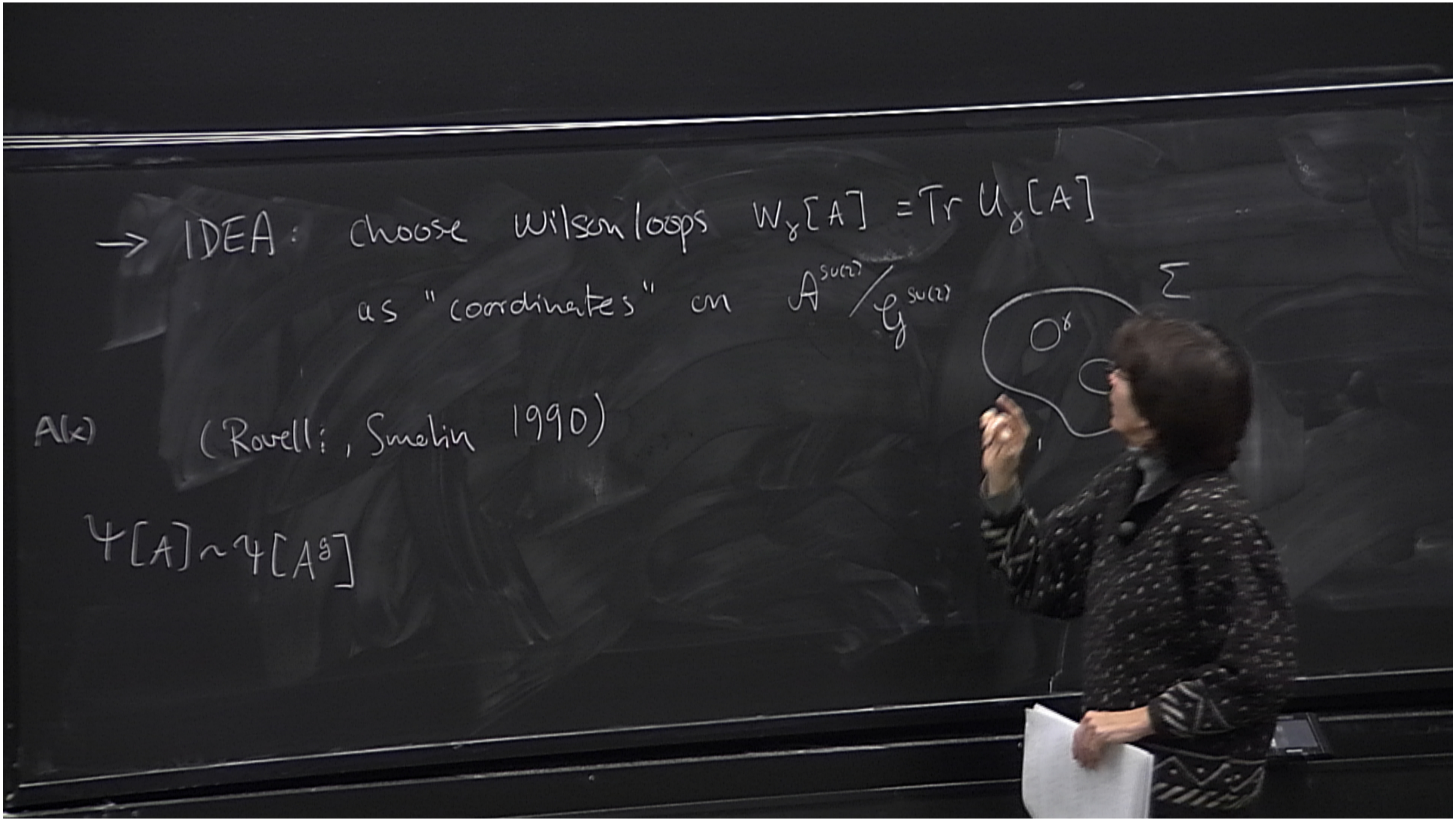
$A \in \mathcal{A}$,

The holonomy

point s_0 and en

$$\frac{dU_w(s, s_0)}{ds} =$$

initial condition U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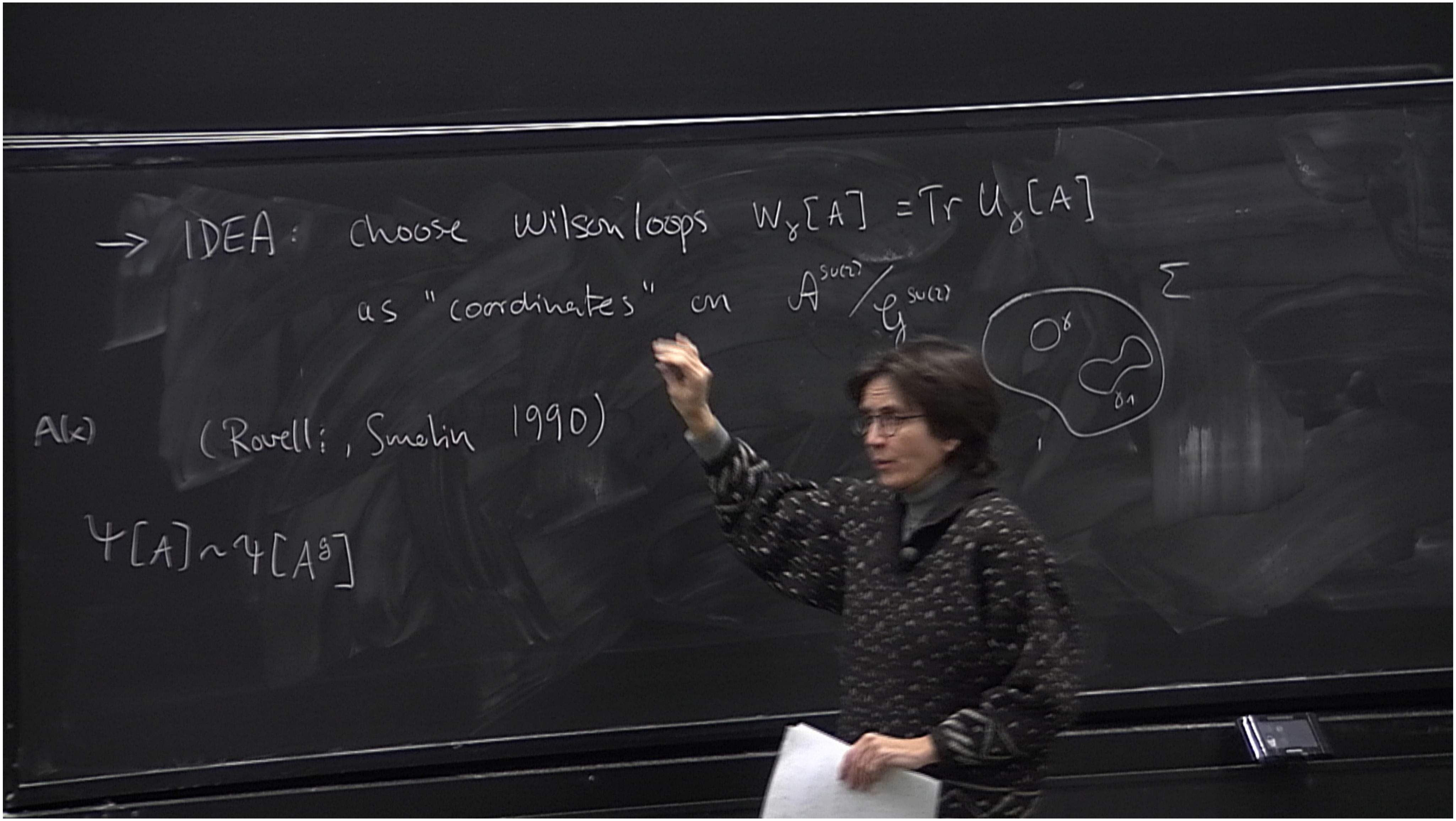
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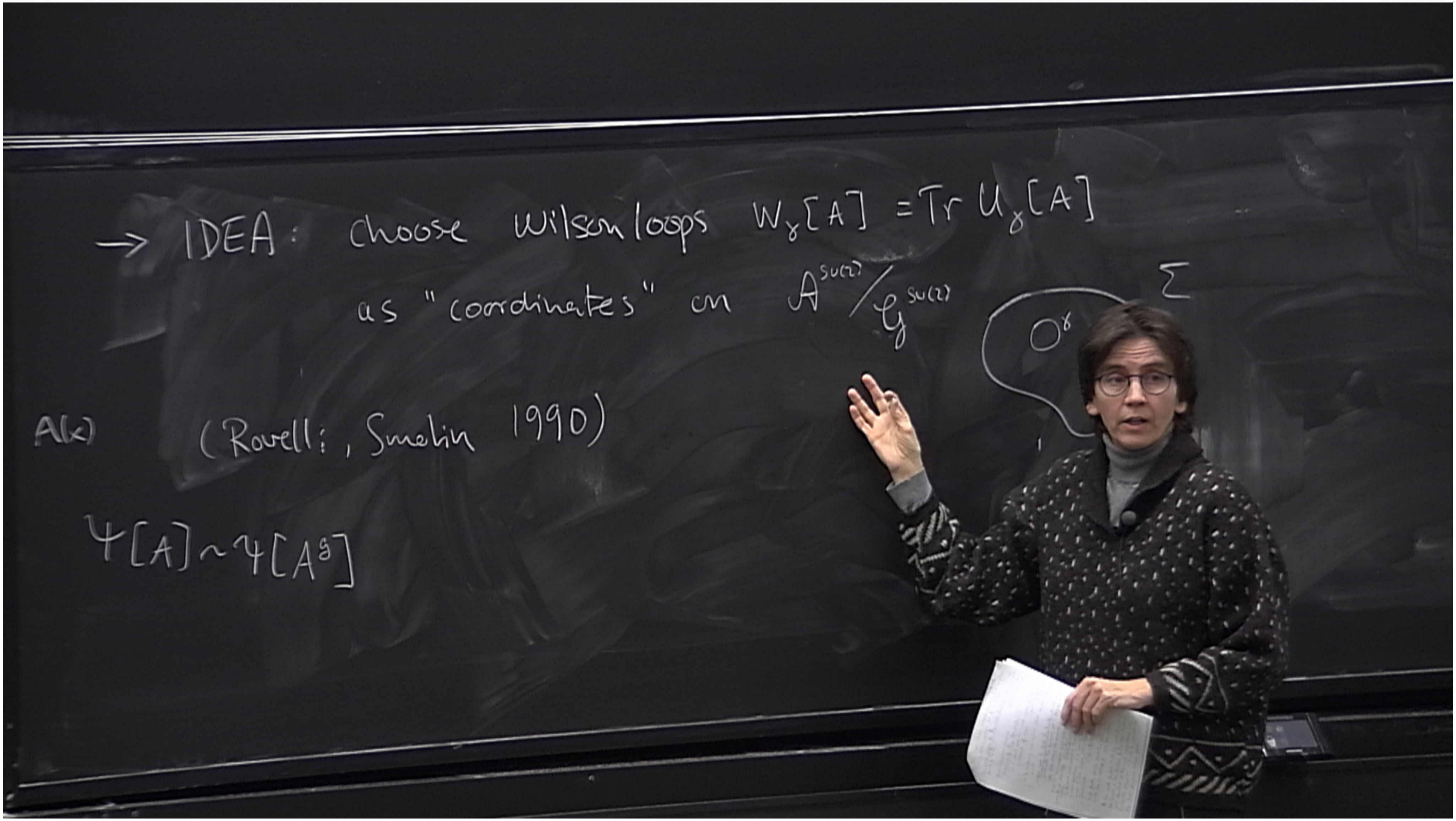
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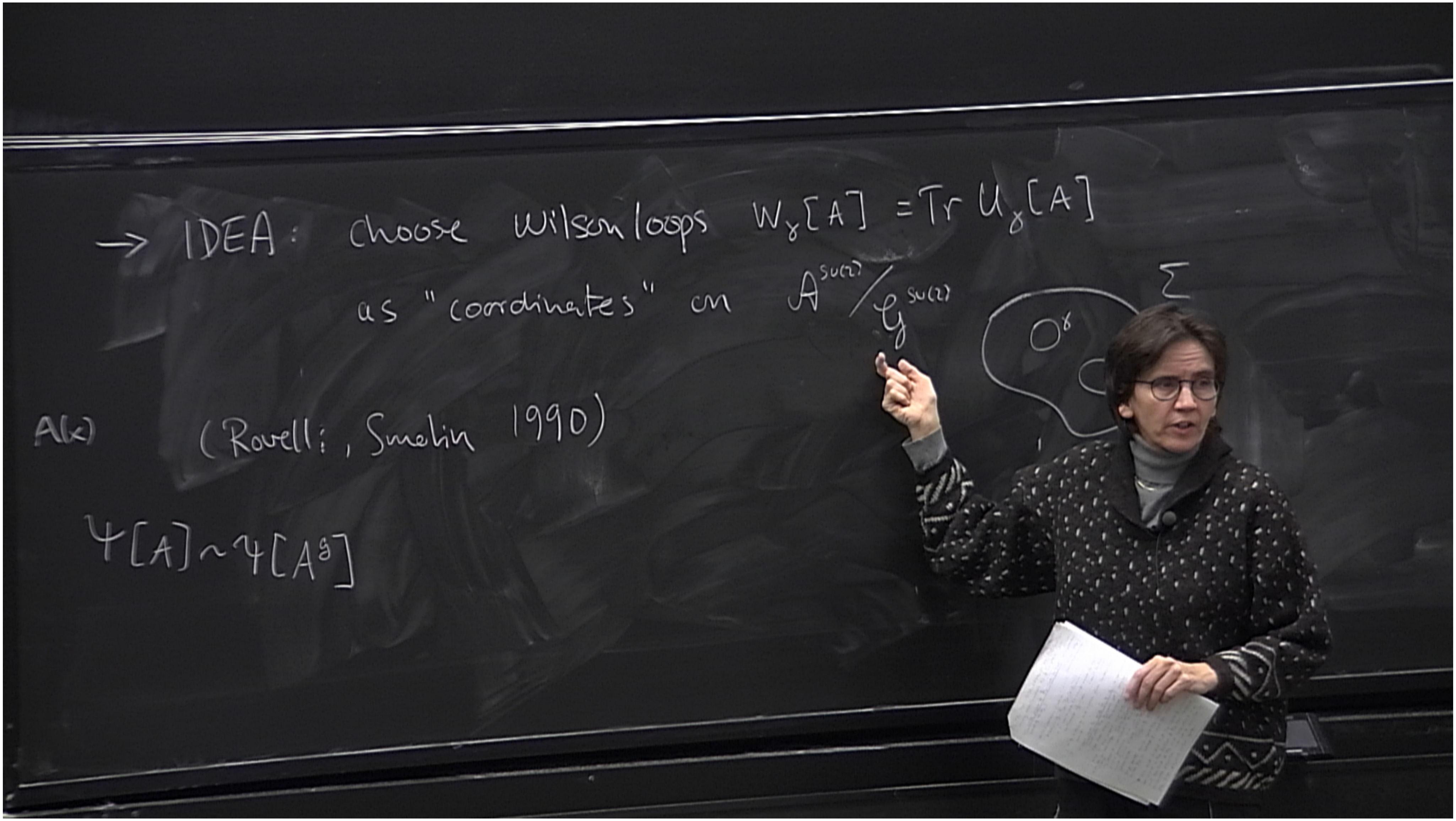
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Σ
A(x)
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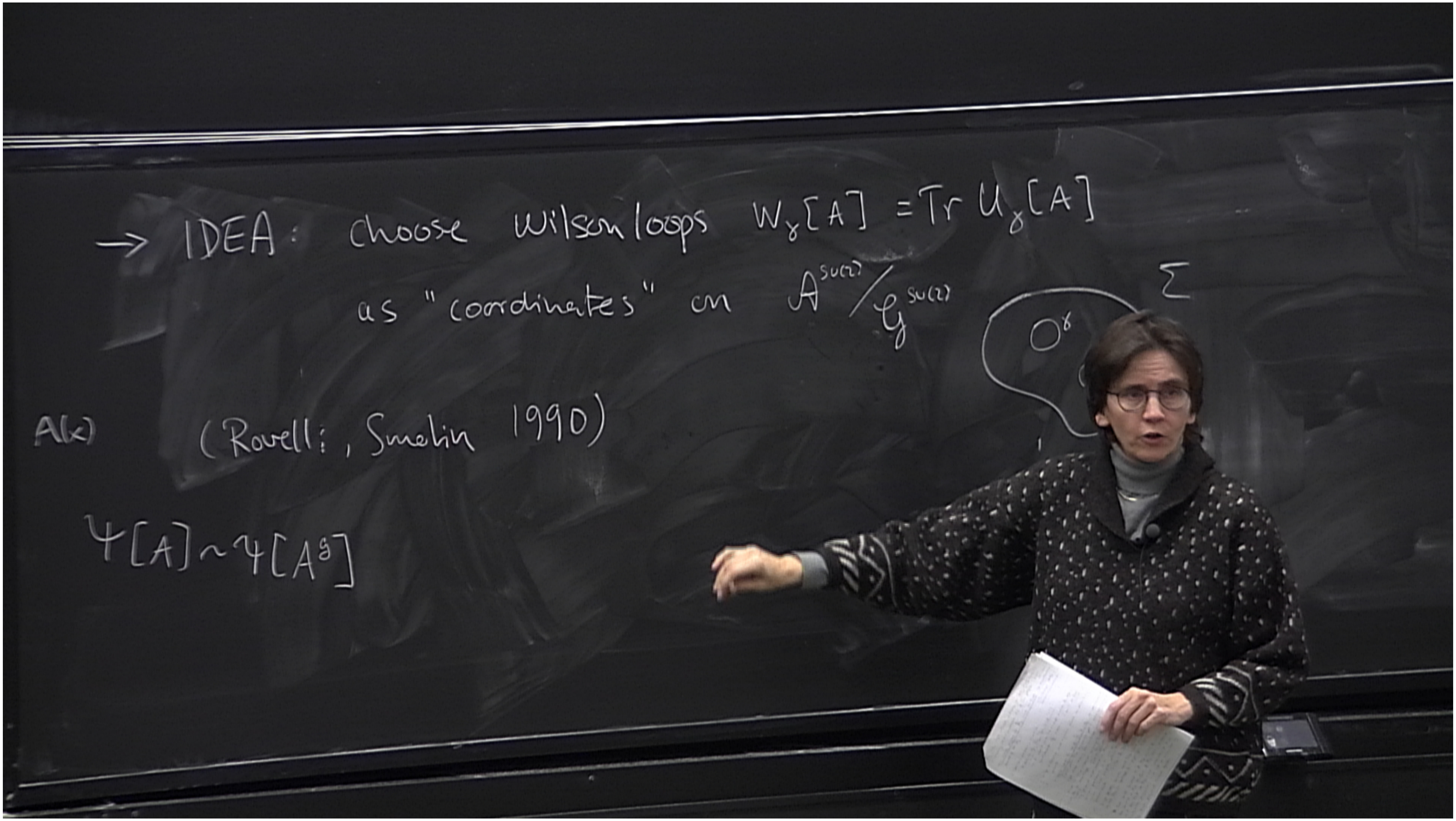
Ψ[A] ~ Ψ[A^g]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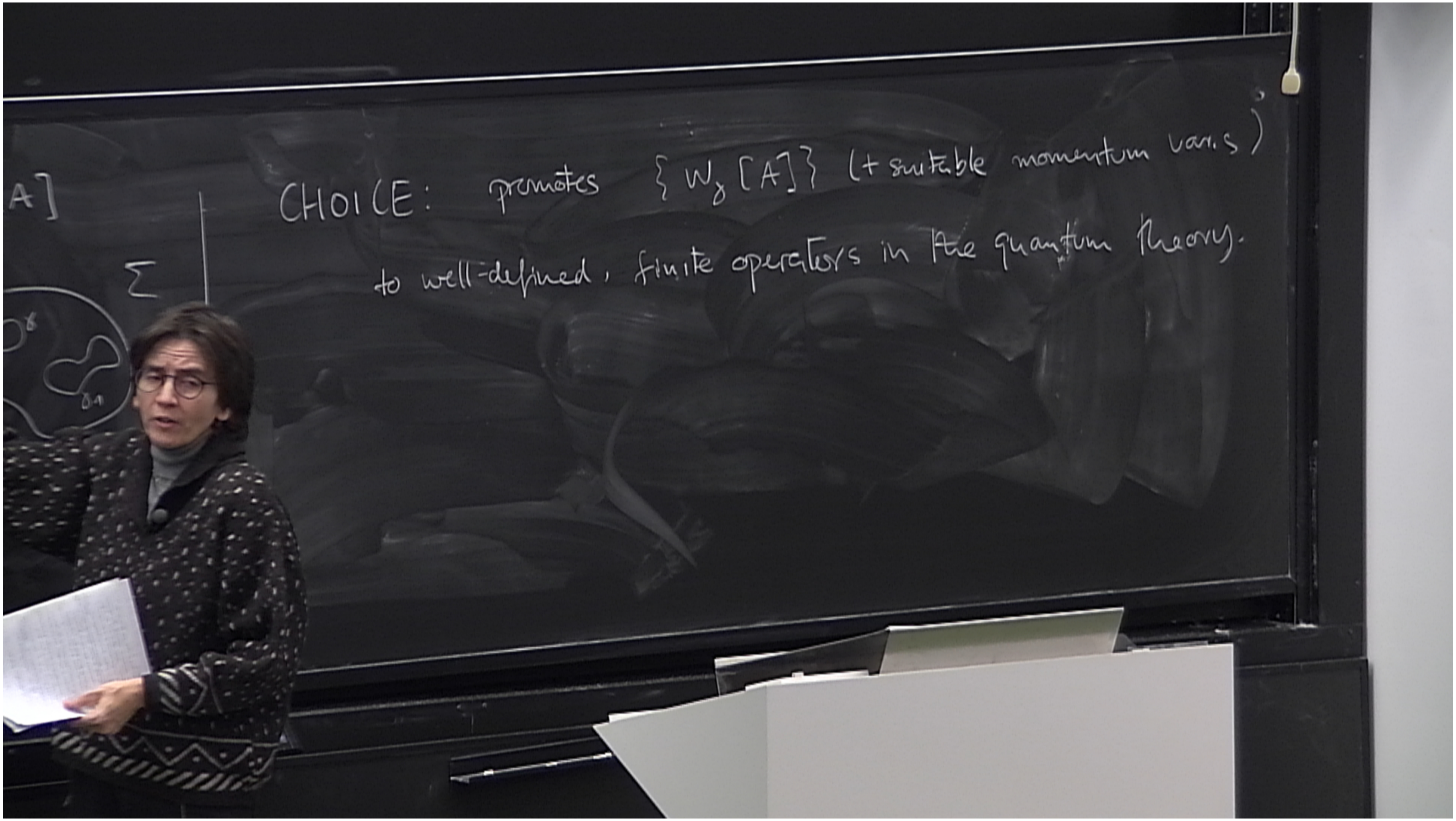
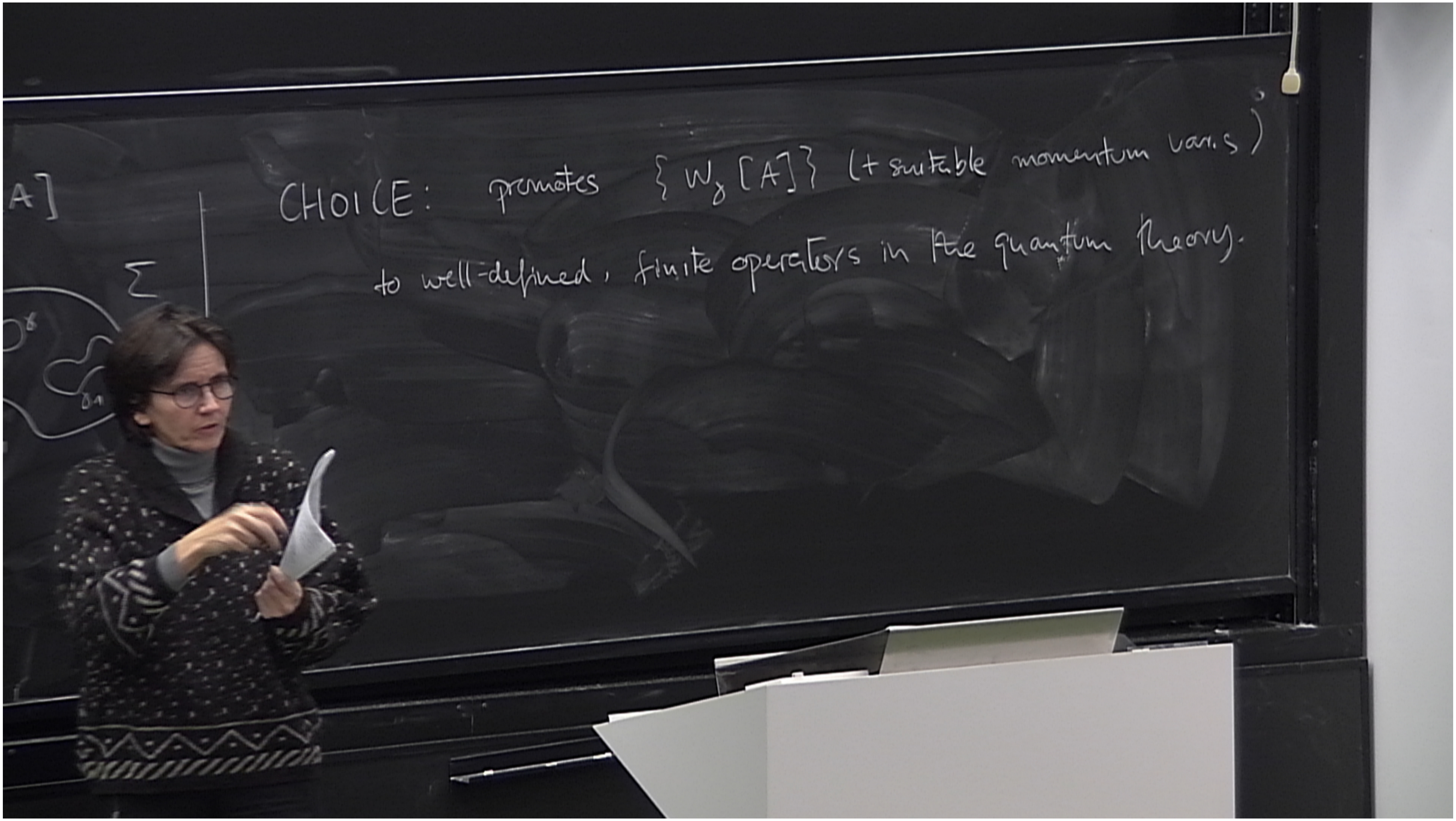

CHOICE: promotes { W_γ [A] } (+ suitable momentum var.s)
to well-defined, finite operators in the quantum theory.
Σ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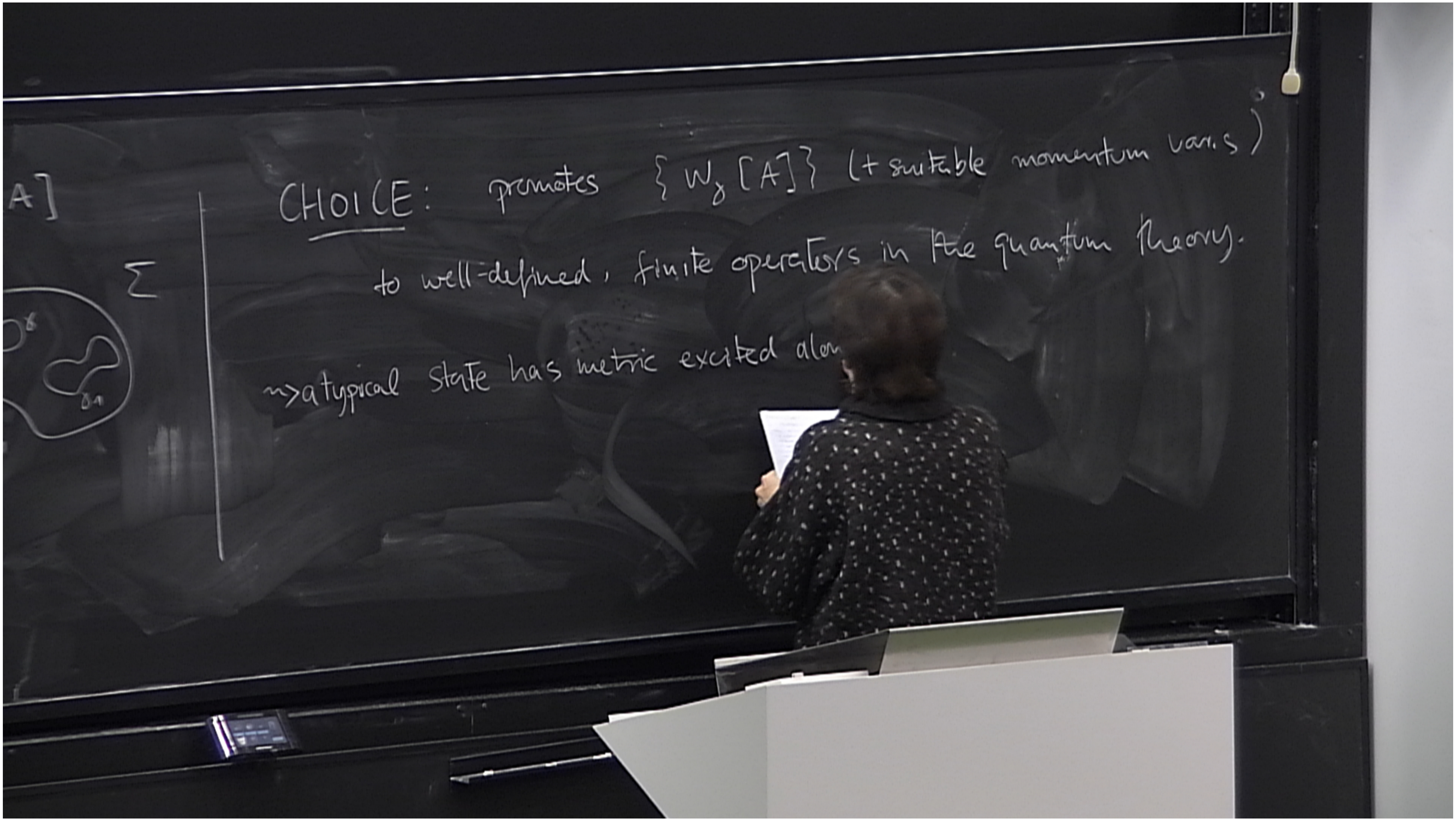
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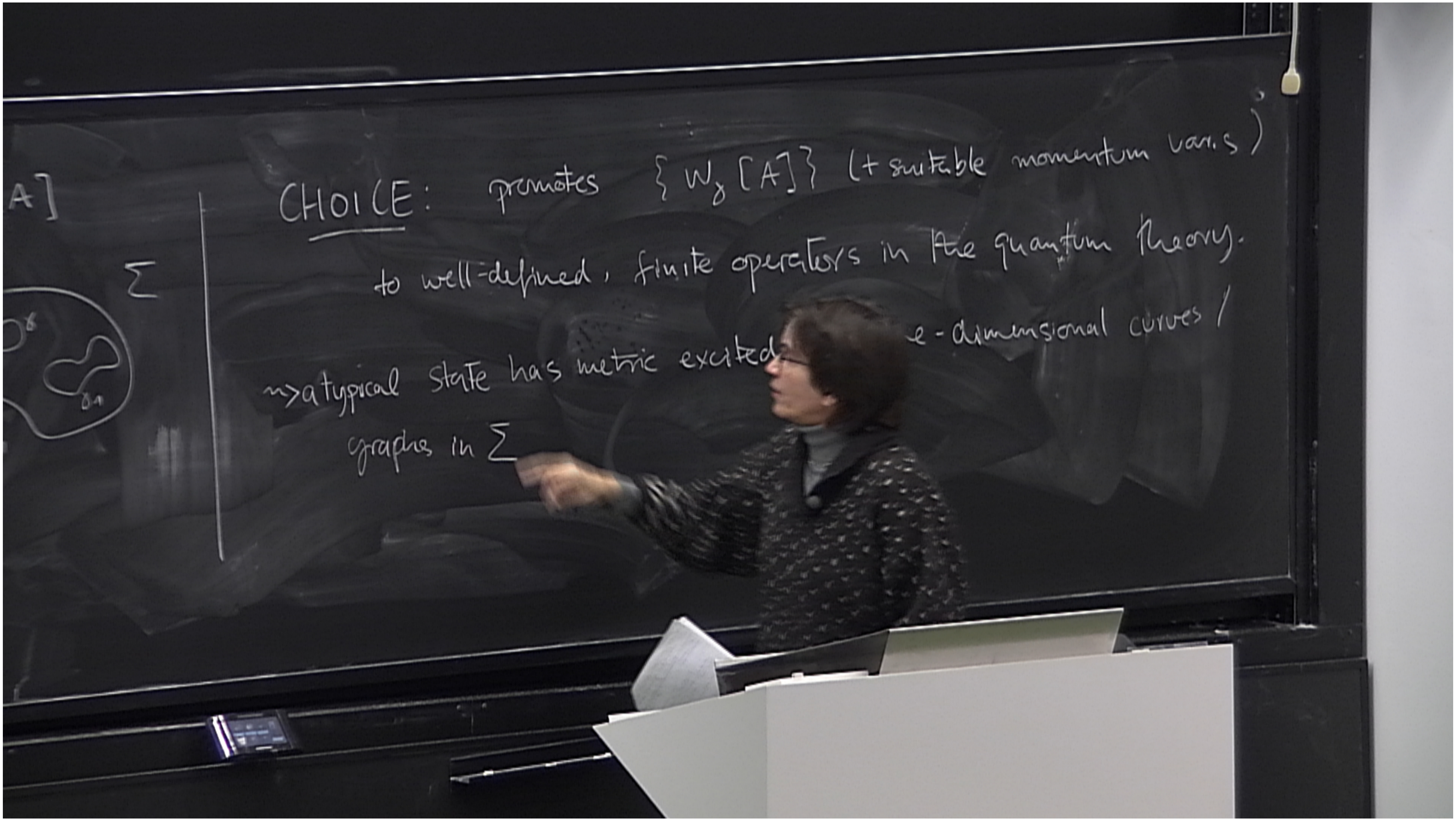
Σ
~> a typical state has metric excited alon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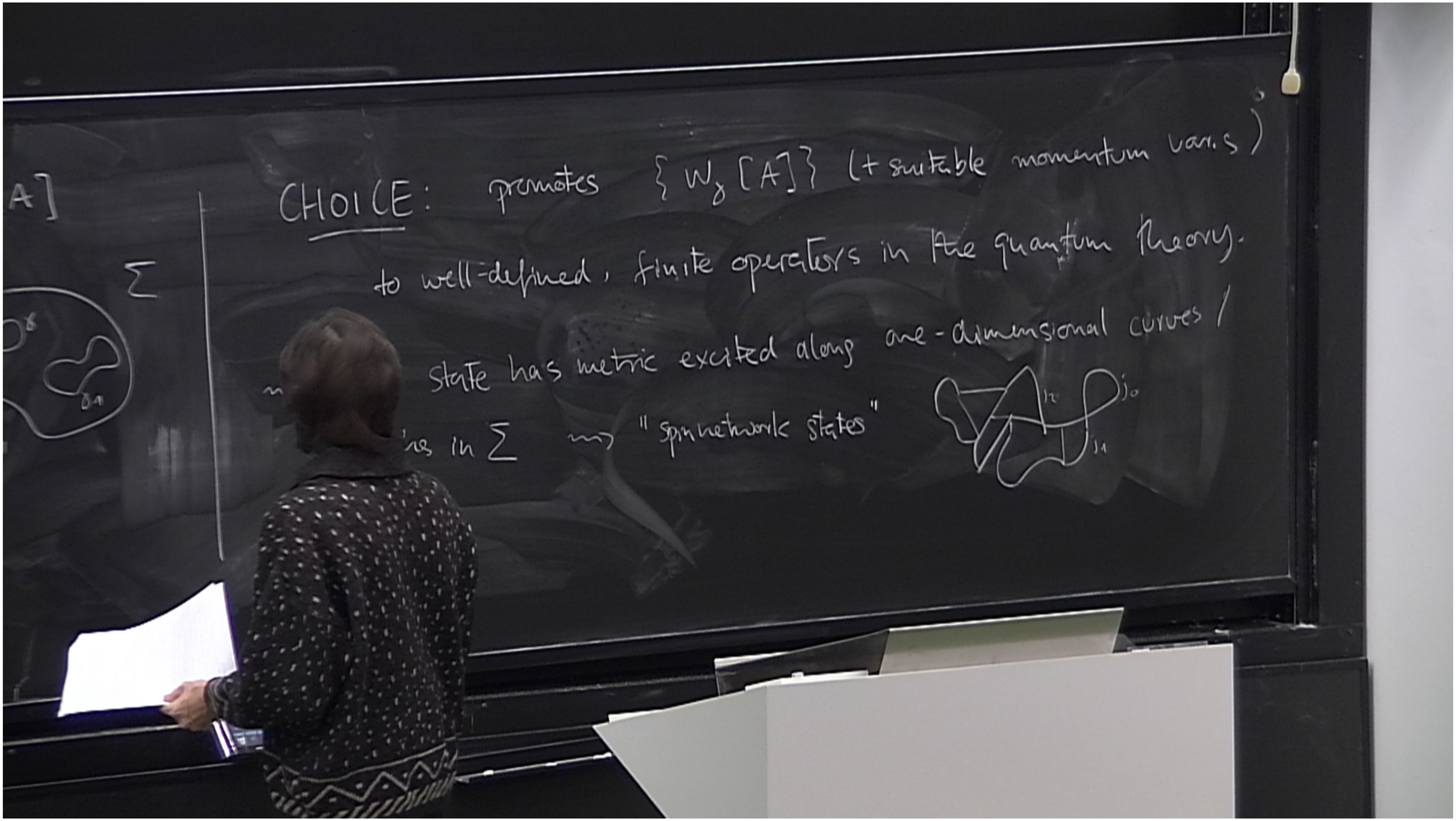
Σ
⇝ a typical state has metric excited
e-dimensional curves /
graphs in Σ


A]
Σ
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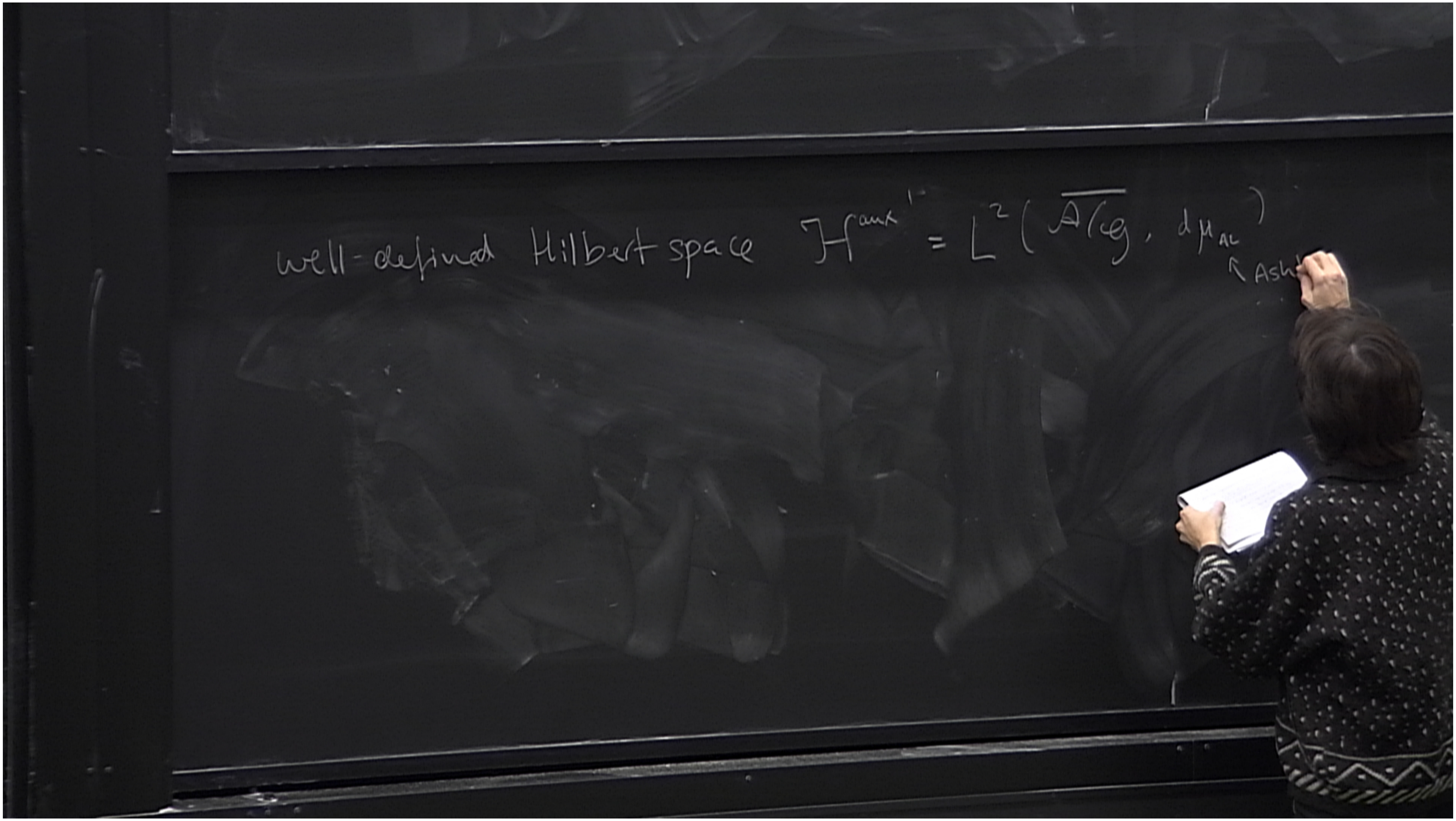
state has metric excited along one-dimensional curves /
es in Σ
"spin network states"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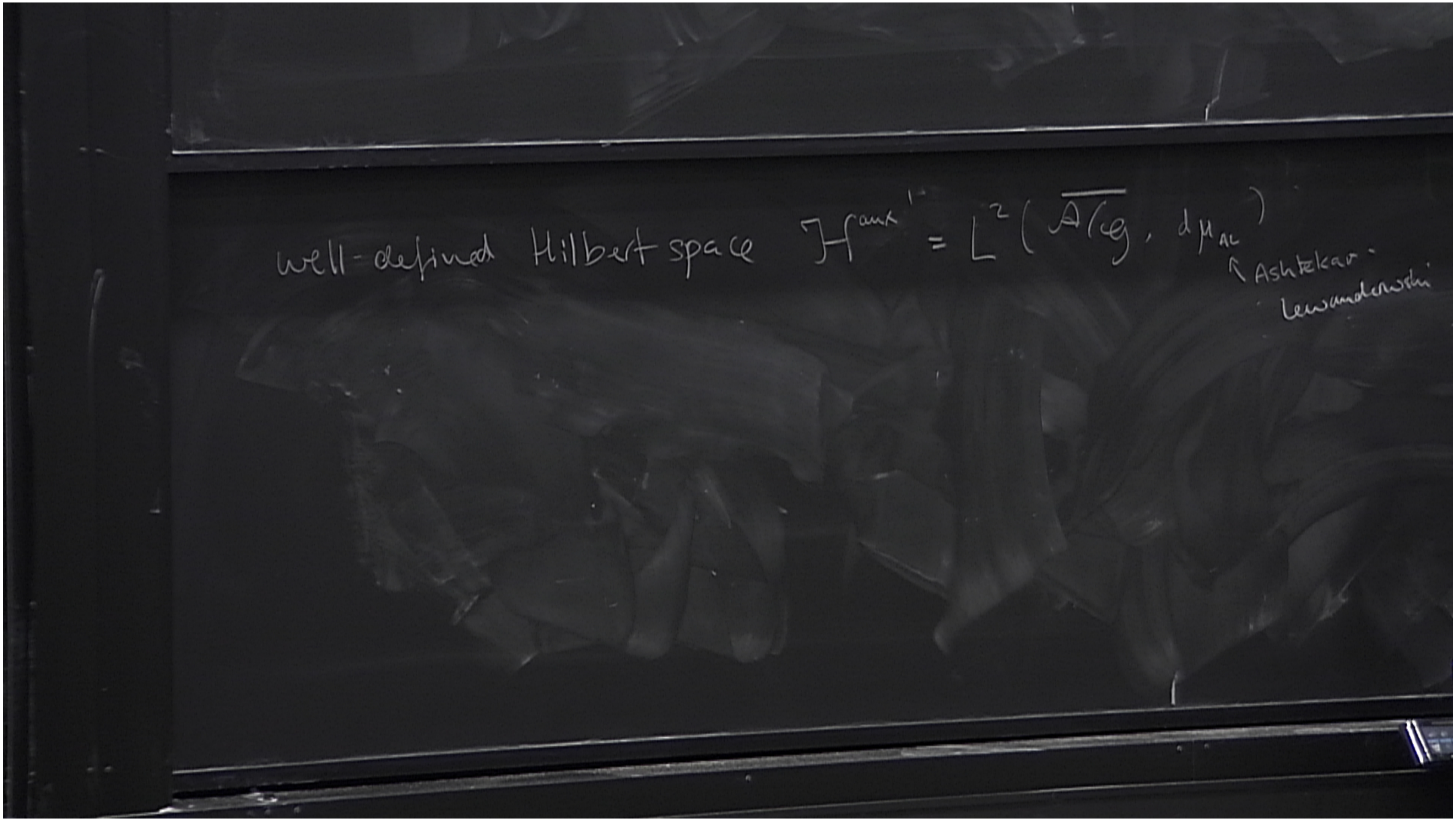
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Ashtekar-
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