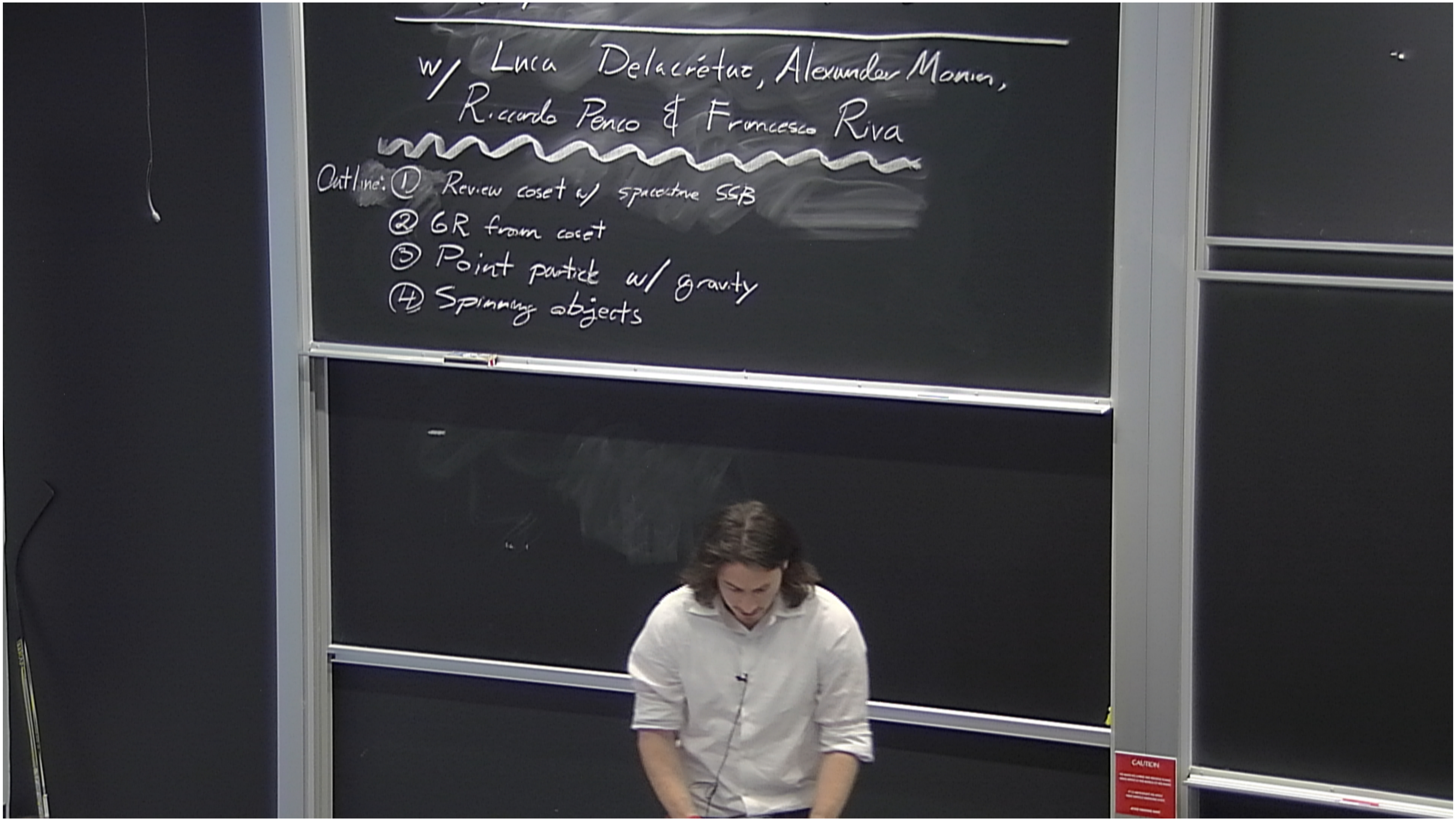
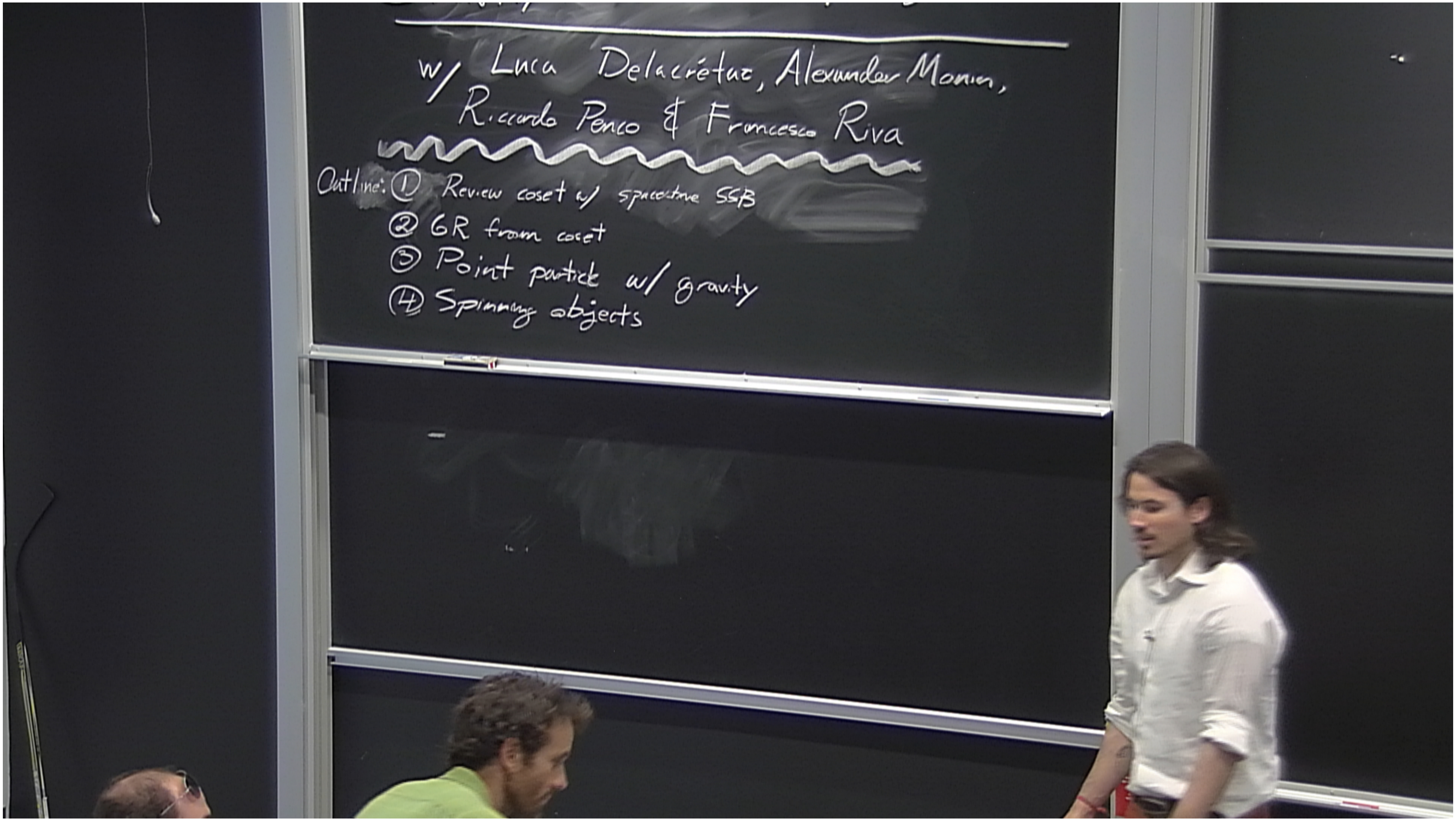
Title: Spontaneous symmetry breaking, gravity, and spinning objects

Date: May 29, 2014 02:30 PM

URL: http://pirsa.org/14050111

Abstract: Space-time symmetries are a crucial ingredient of any theoretical model in physics. Unlike internal symmetries, which may or may not be gauged and/or spontaneously broken, space-time symmetries do not admit any ambiguity: they are gauged by gravity, and any conceivable physical system (other than the vacuum) is bound to break at least some of them. Motivated by this observation, I will sketch how to couple gravity with the Goldstone fields that non-linearly realize spontaneously broken space-time symmetries by weakly gauging the Poincare symmetry group in the context of the coset construction. To illustrate the power of this perspective I will build a low energy effective action that describes spinning objects coupled to gravity and describe its interpretation.


w/ Luca Delacrétaz, Alexander Monin,
Riccardo Penco & Francesco Riva
Outline: ① Review coset w/ spacetime SSB
② GR from coset
③ Point particle w/ gravity
④ Spinning objects
CAUTION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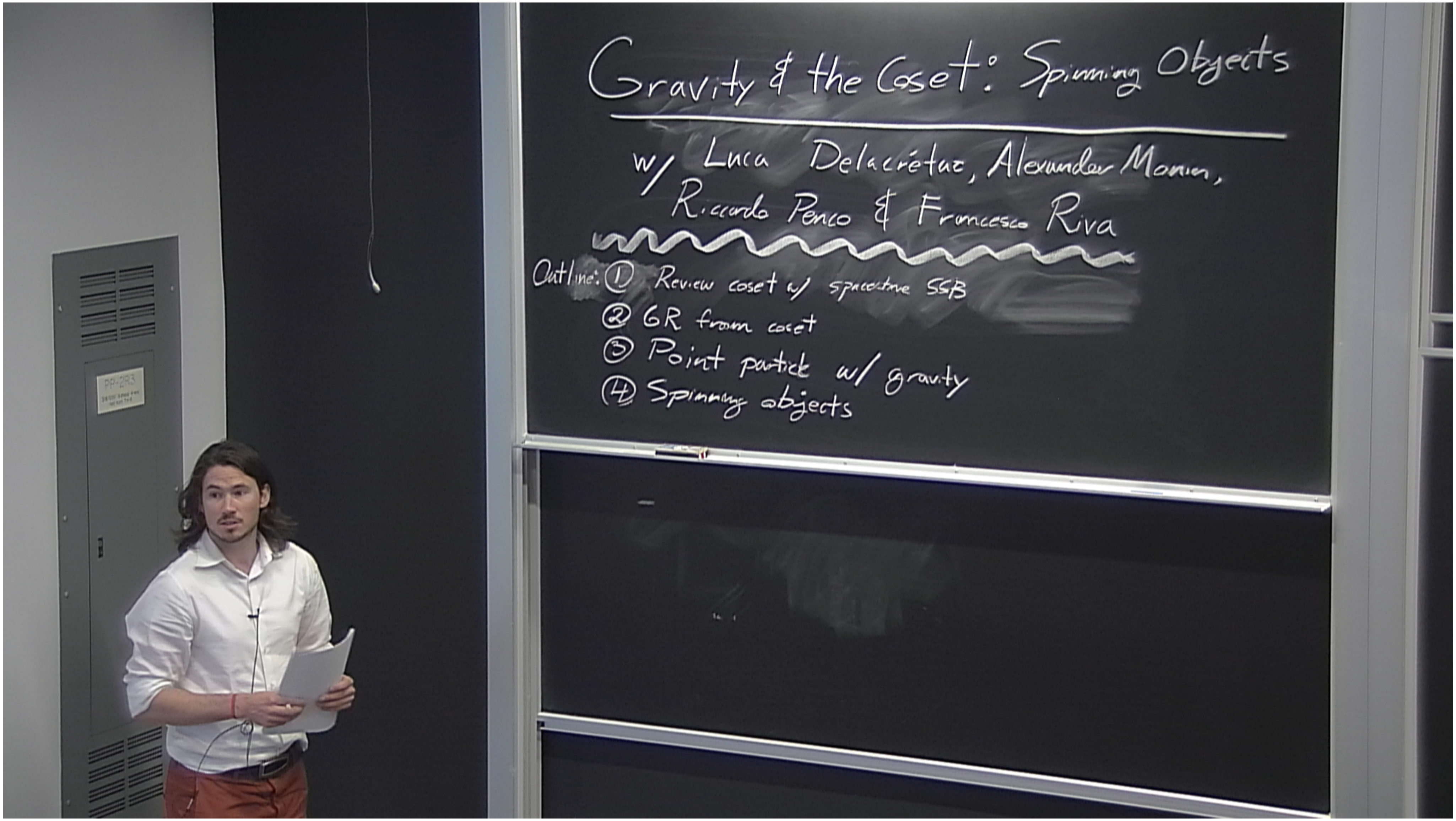
Gravity & the Coset: Spinning Objects
w/ Luca Delacrétaz, Alexander Monin,
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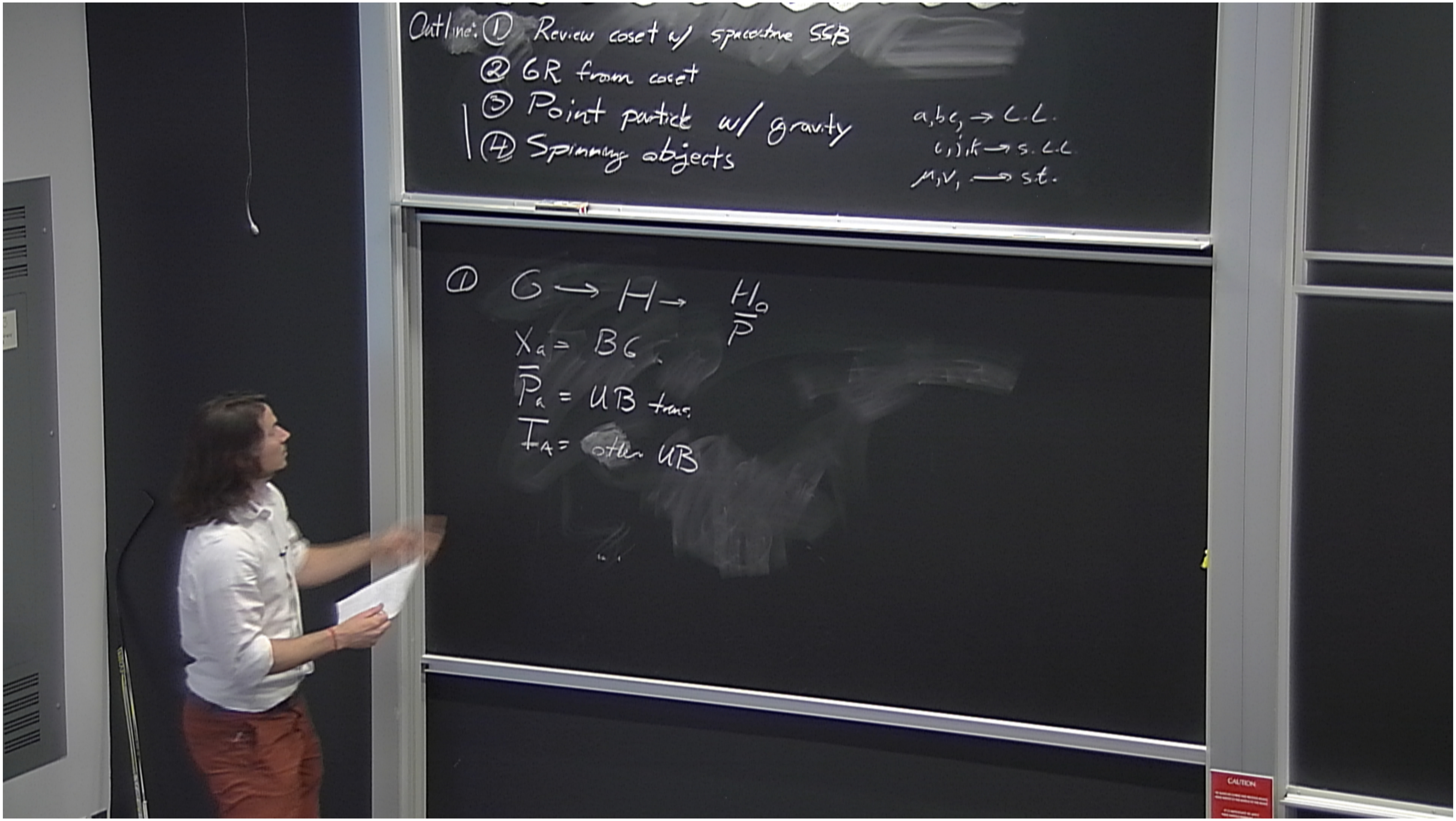
PP-2R3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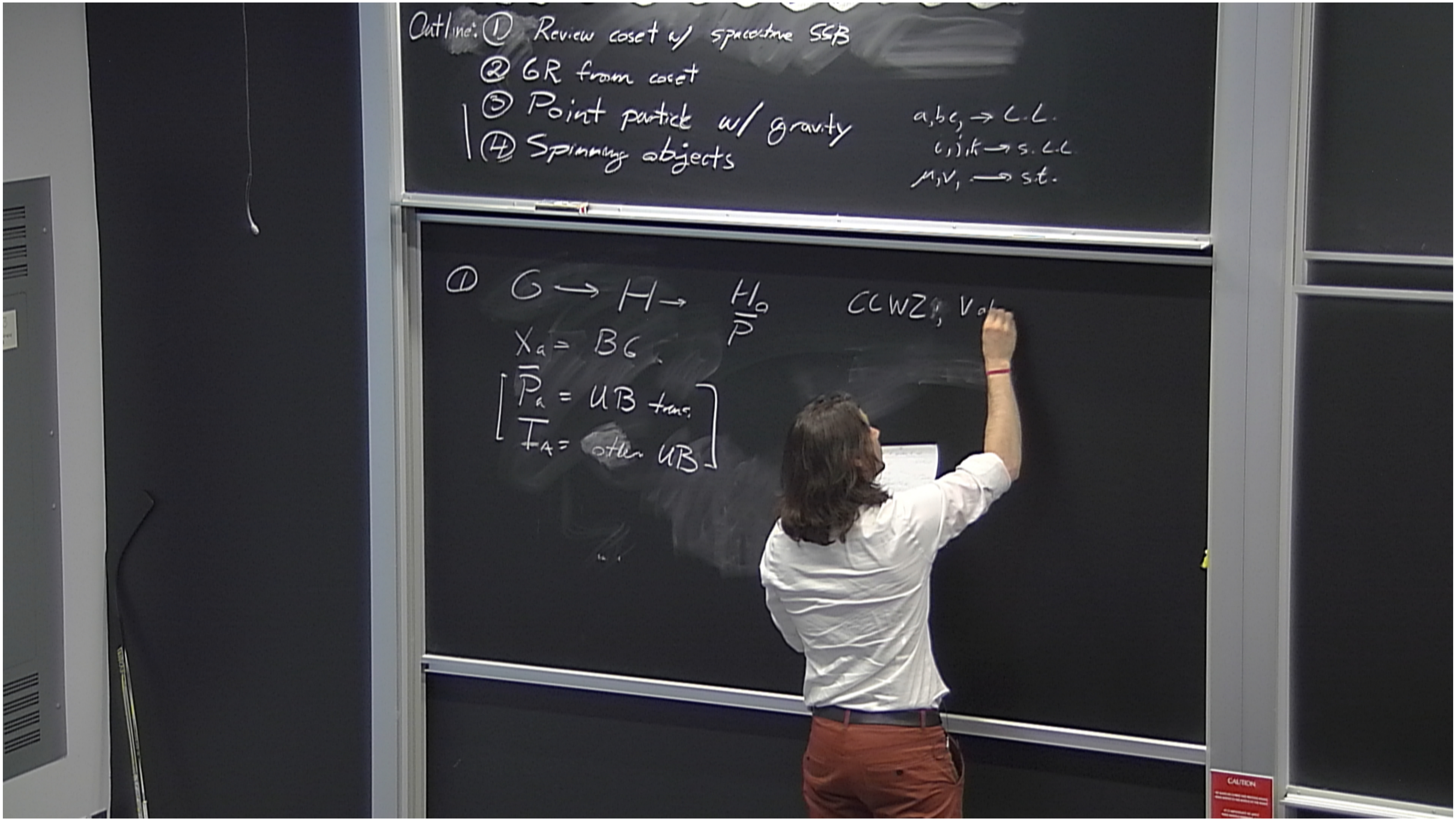
② GR from coset
③ Point particle w/ gravity
④ Spinning objects
a,b,c, → L.L.
i,j,k → s. L.L
μ,ν, → s.t.
① G → H →
X_a = BG
P̄_a = UB trans
I_A = other UB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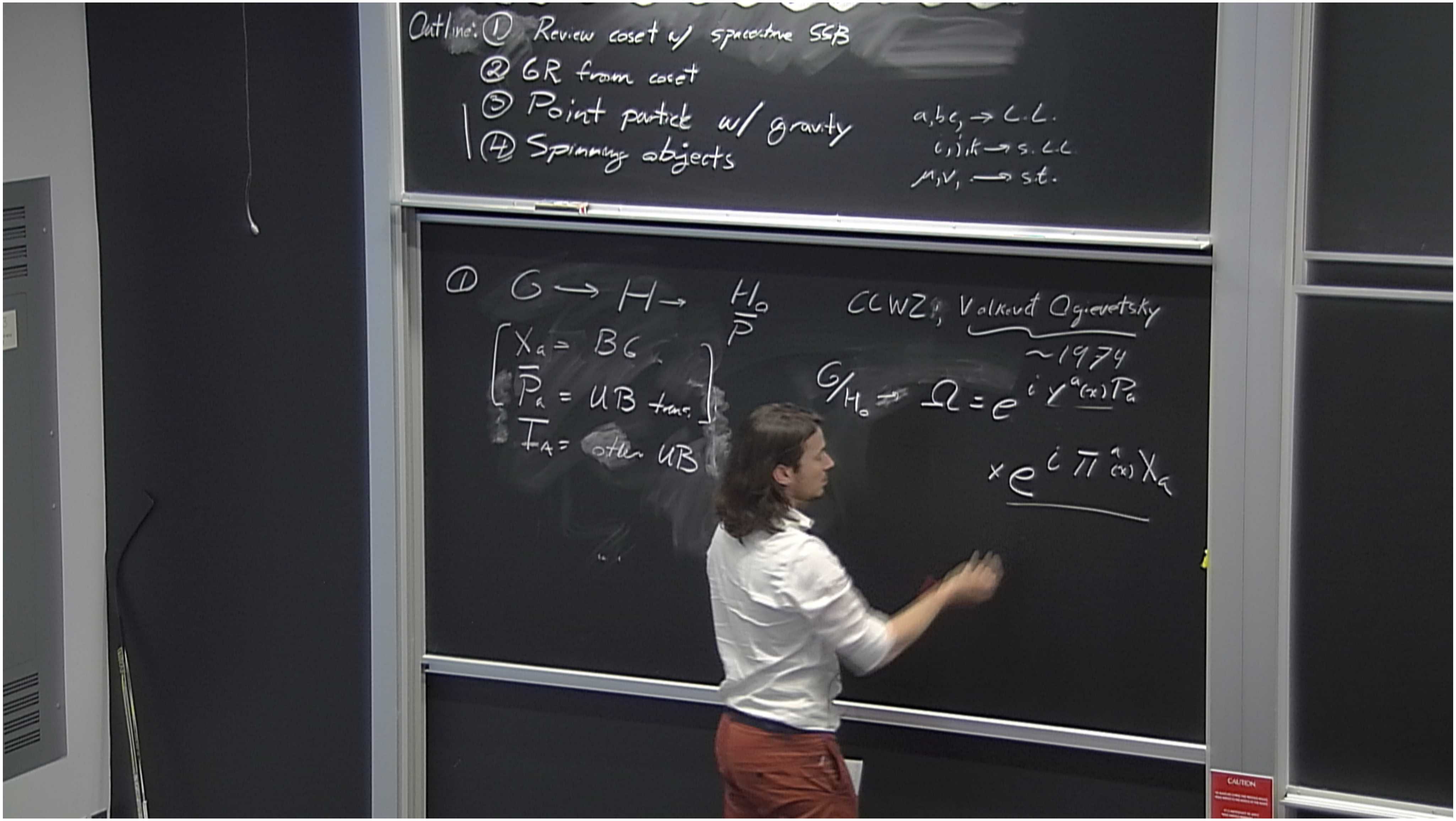
a,b,c, → L.L.
i,j,k → s. L.L
μ,ν, → s.t.
① G → H → H_0
P̄
CCWZ, V
X_a = BG
P̄_a = UB trans
T_A = other UB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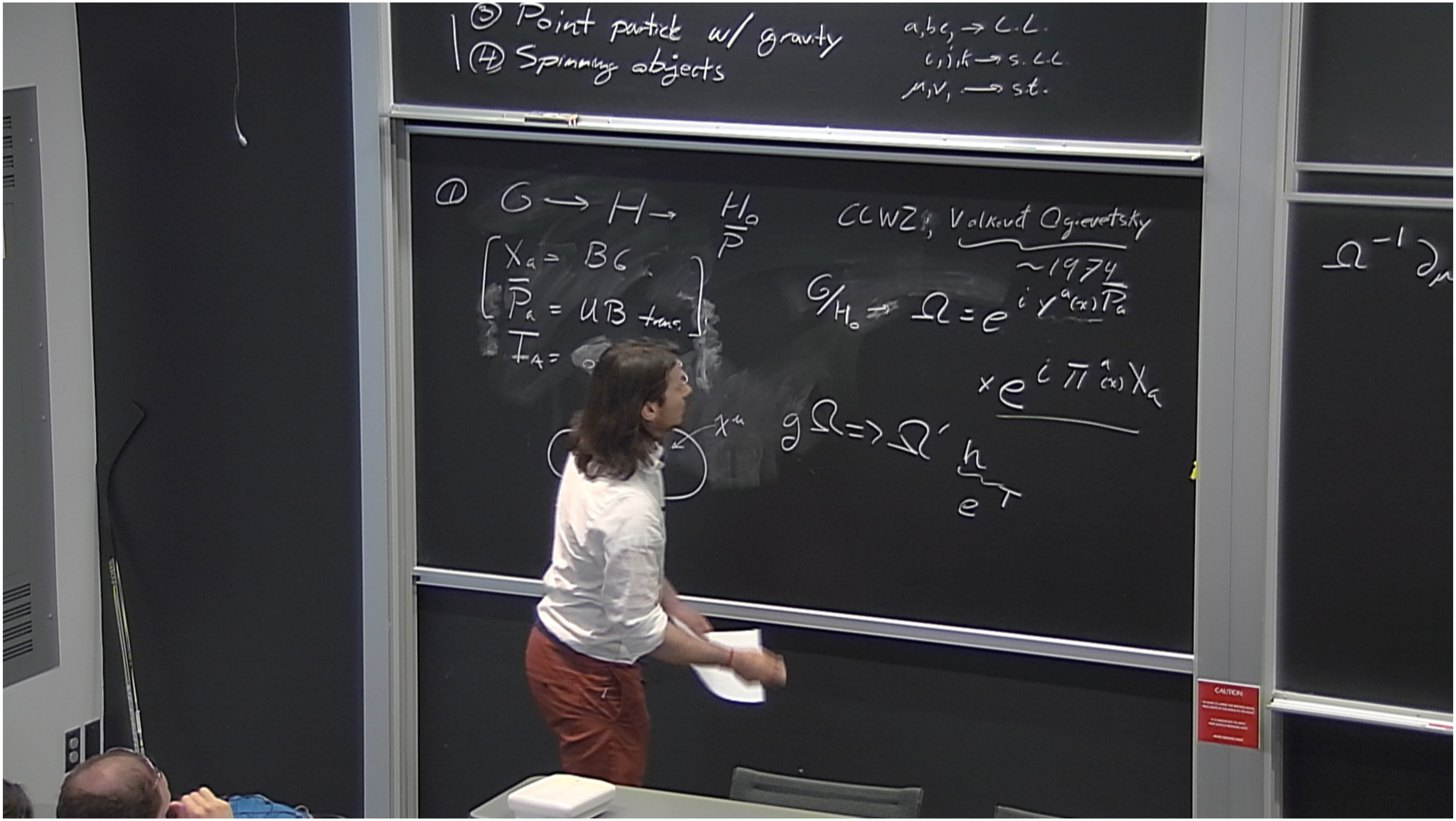
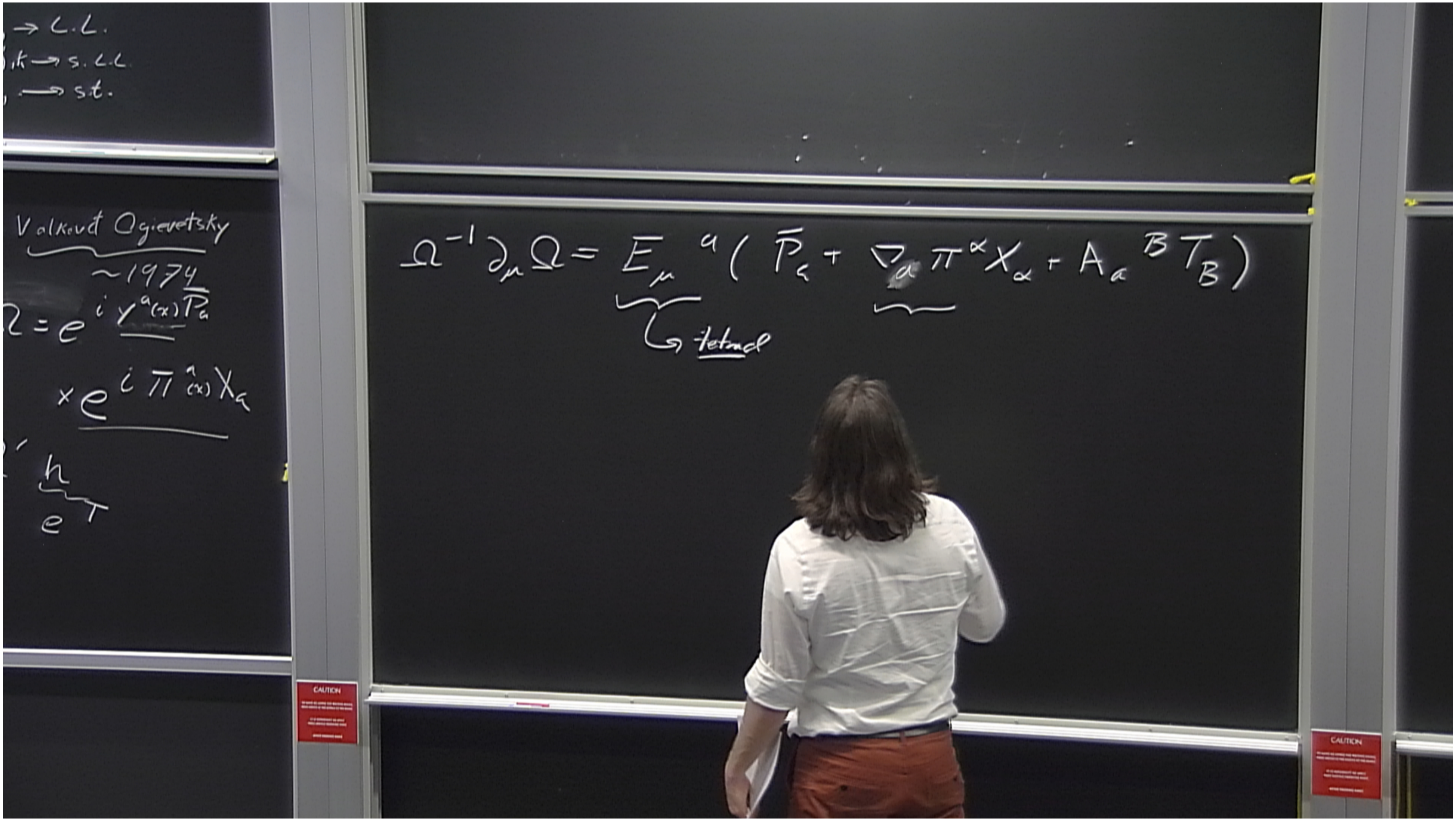
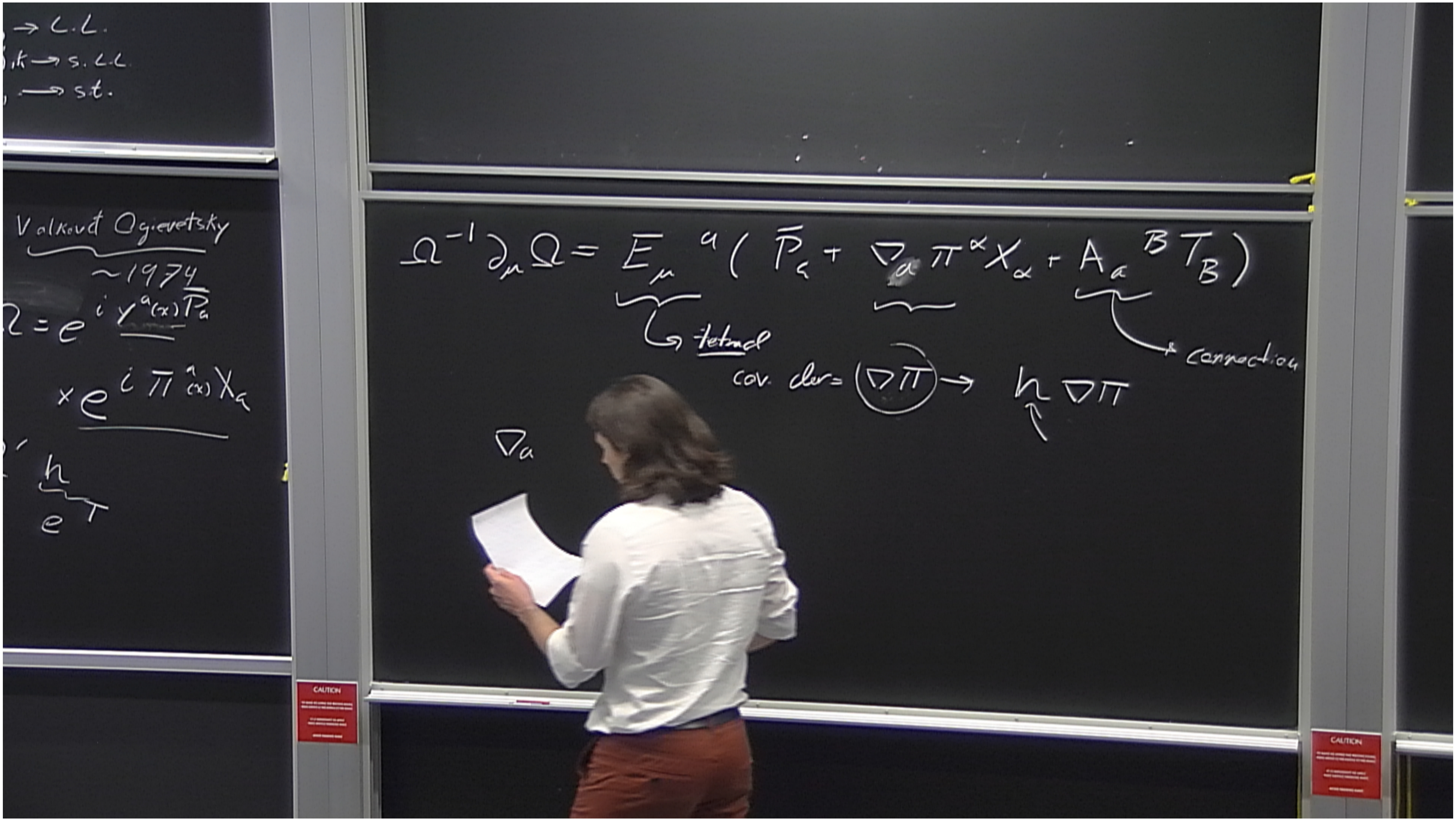
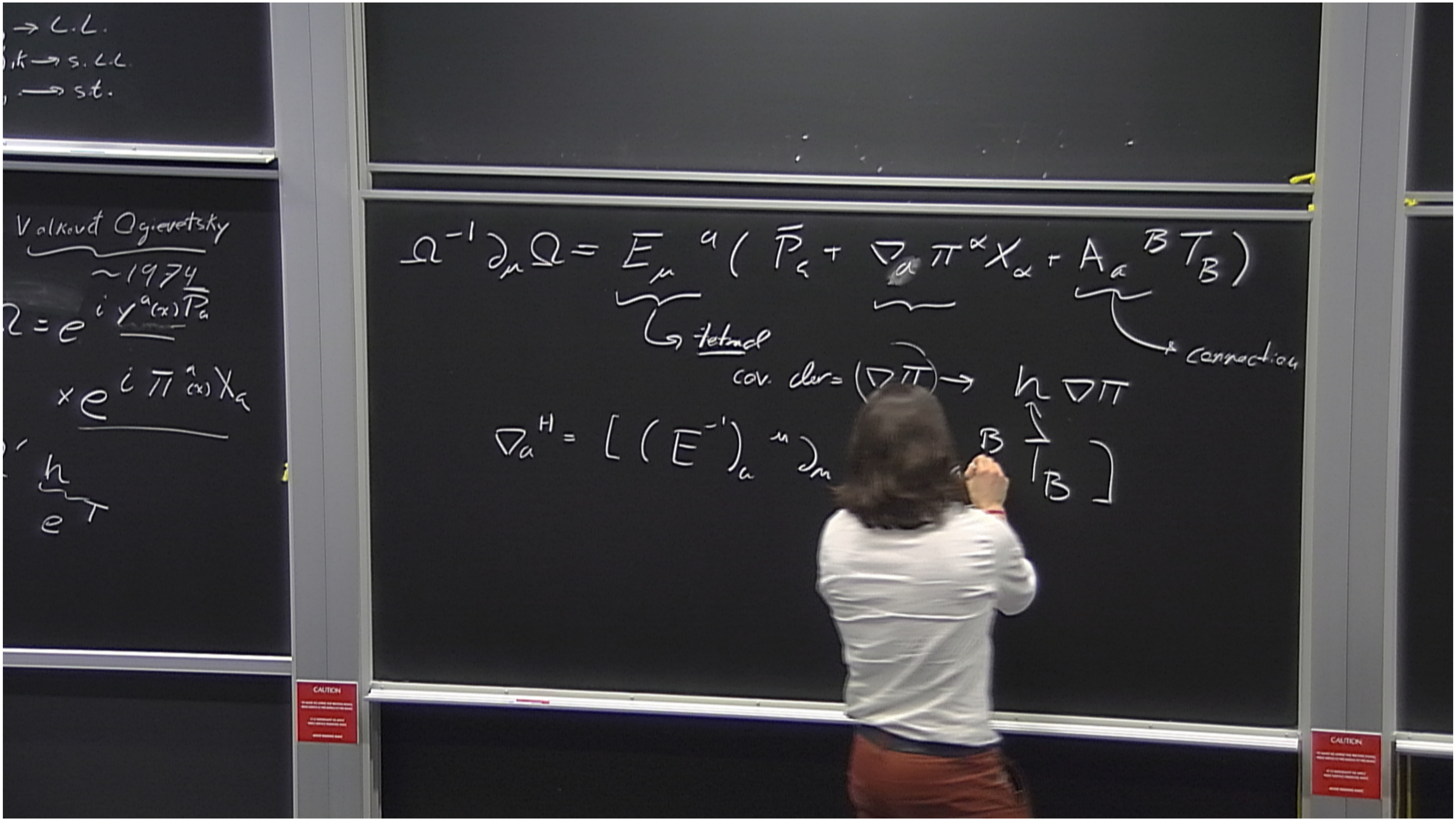
a,b,c, → L.L.
i,j,k → s. L.L.
μ,ν, → s.t.
① G → H → H₀
X_a = BG
P̄_a = UB trans.
I_A = other UB
CCWZ, Volkov Ogievetsky
~1974
G/H₀ ⇒ Ω = e^{i y^a(x) P_a}
× e^{i π^a(x) X_a}

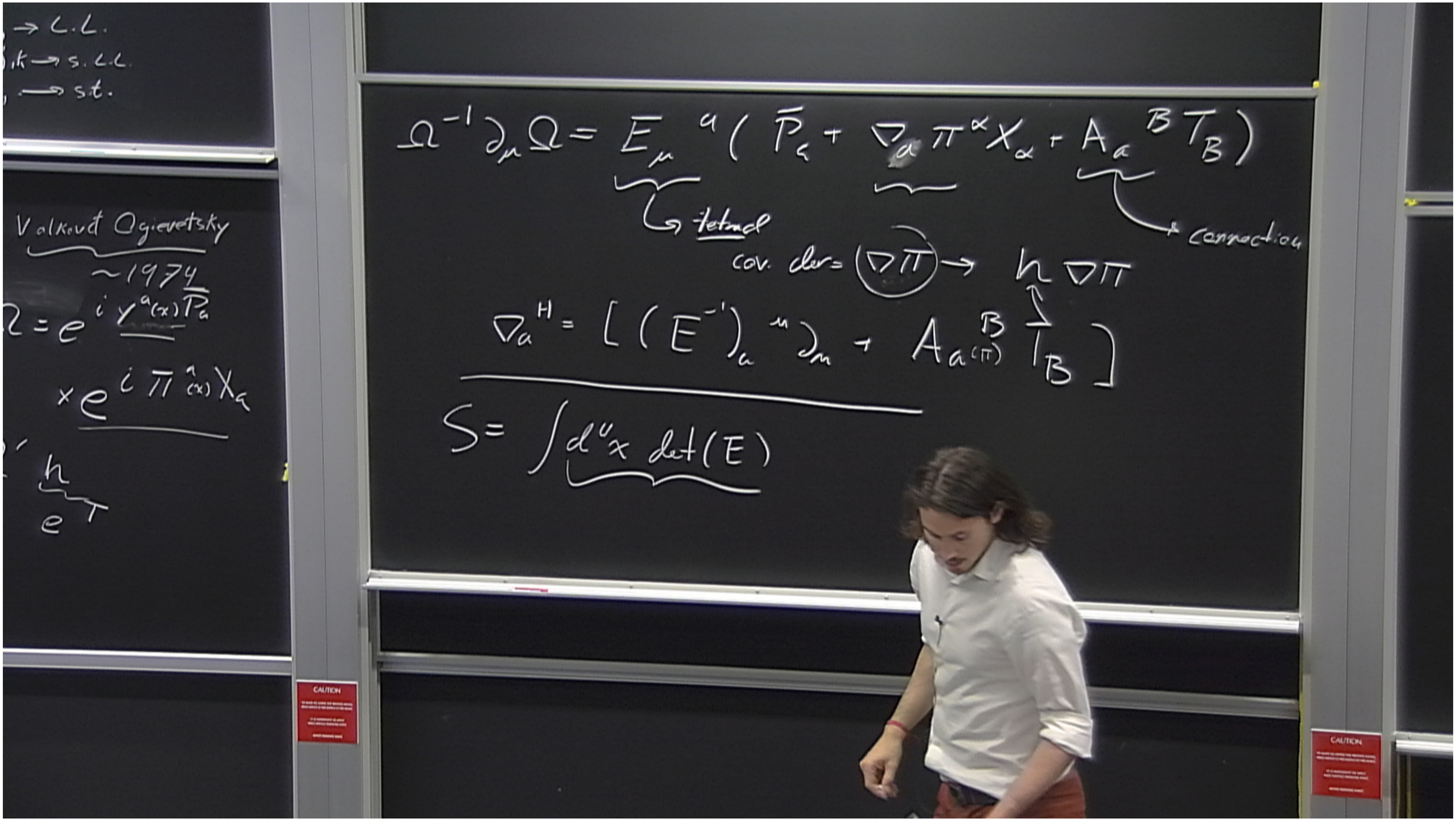

③ Point particle w/ gravity
④ Spinning objects
a,b,c, → L.L.
i,j,k → s.L.L.
μ,ν, → s.t.
① G → H → H₀
CCWZ, Volkov Ogievetsky
~1974
Ω⁻¹ ∂

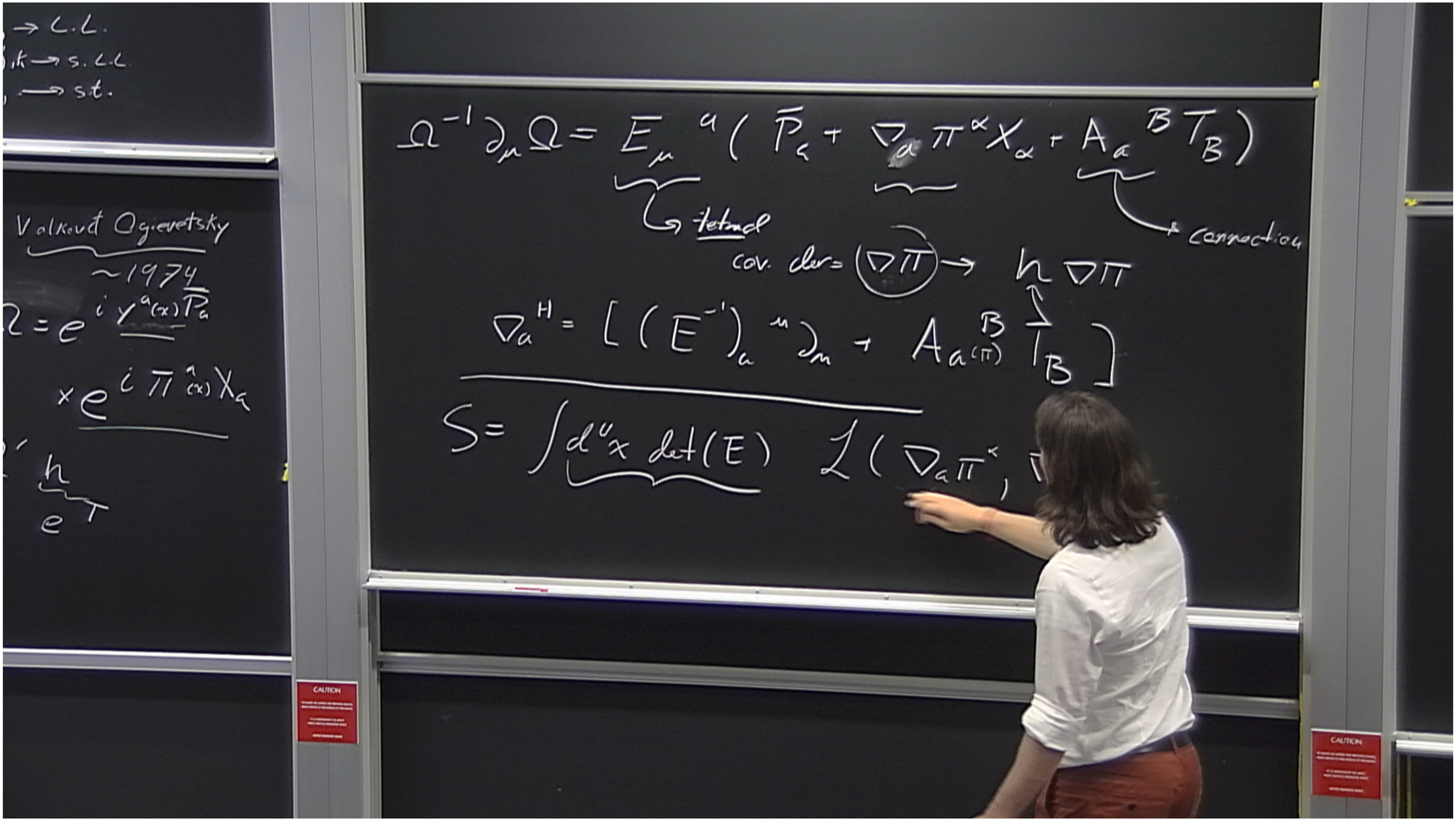

→ L.L.
→ s.L.L.
→ s.t.
Volkov Ogievetsky
~1974
tetrad

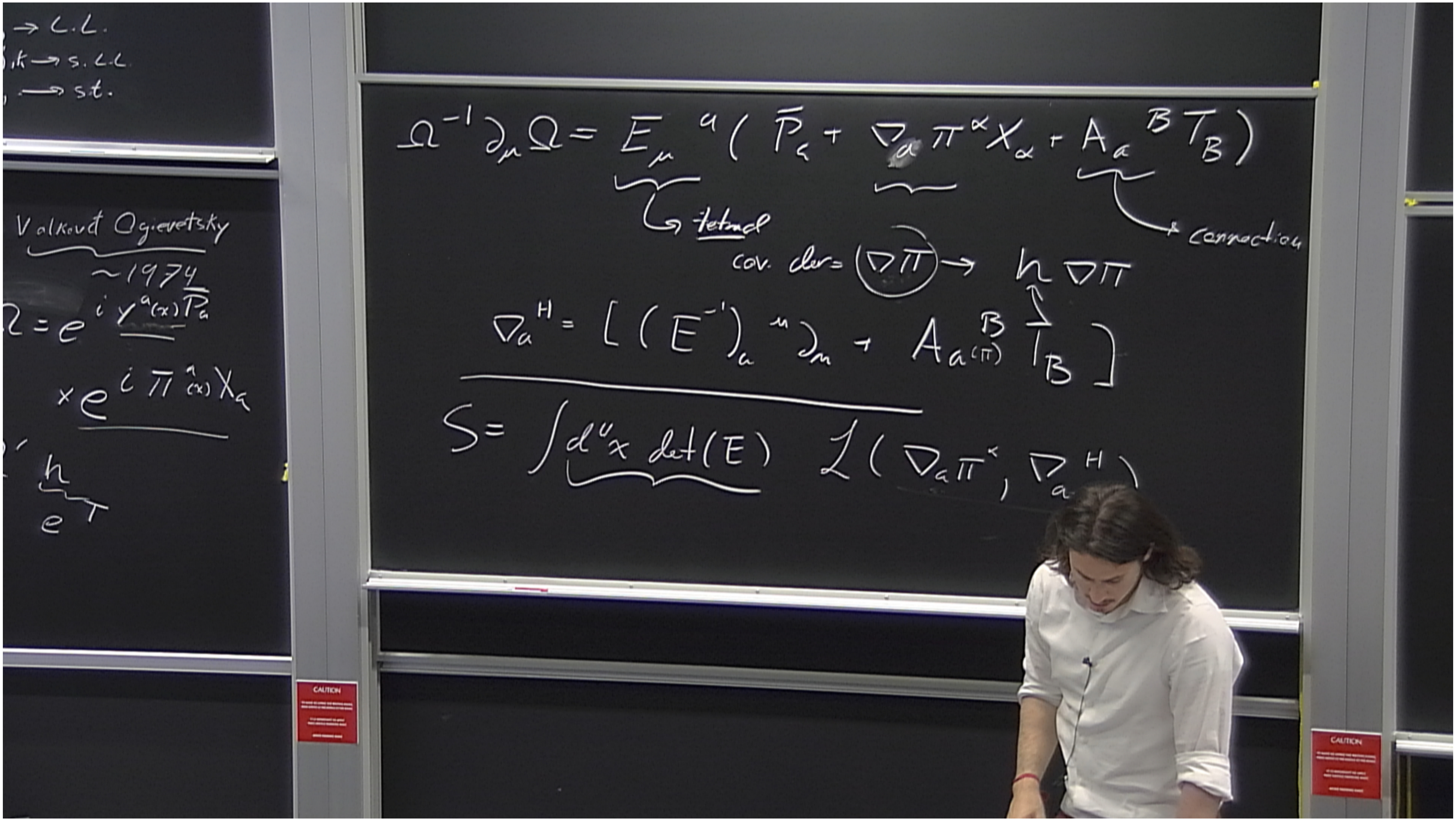

→ L.L.
k → s.L.L
→ s.t.
Volkov & Ogievetsky
~1974
Ω = e^{i y^a(x) P_a}
× e^{i π^a(x) X_a}
h
e^T
Ω^{-1} ∂_μ Ω = E_μ^a (P_a + ∇_a π^α X_α + A_a^B T_B)
tetrad
connection
cov. der = (∇π) → h ∇π
∇_a

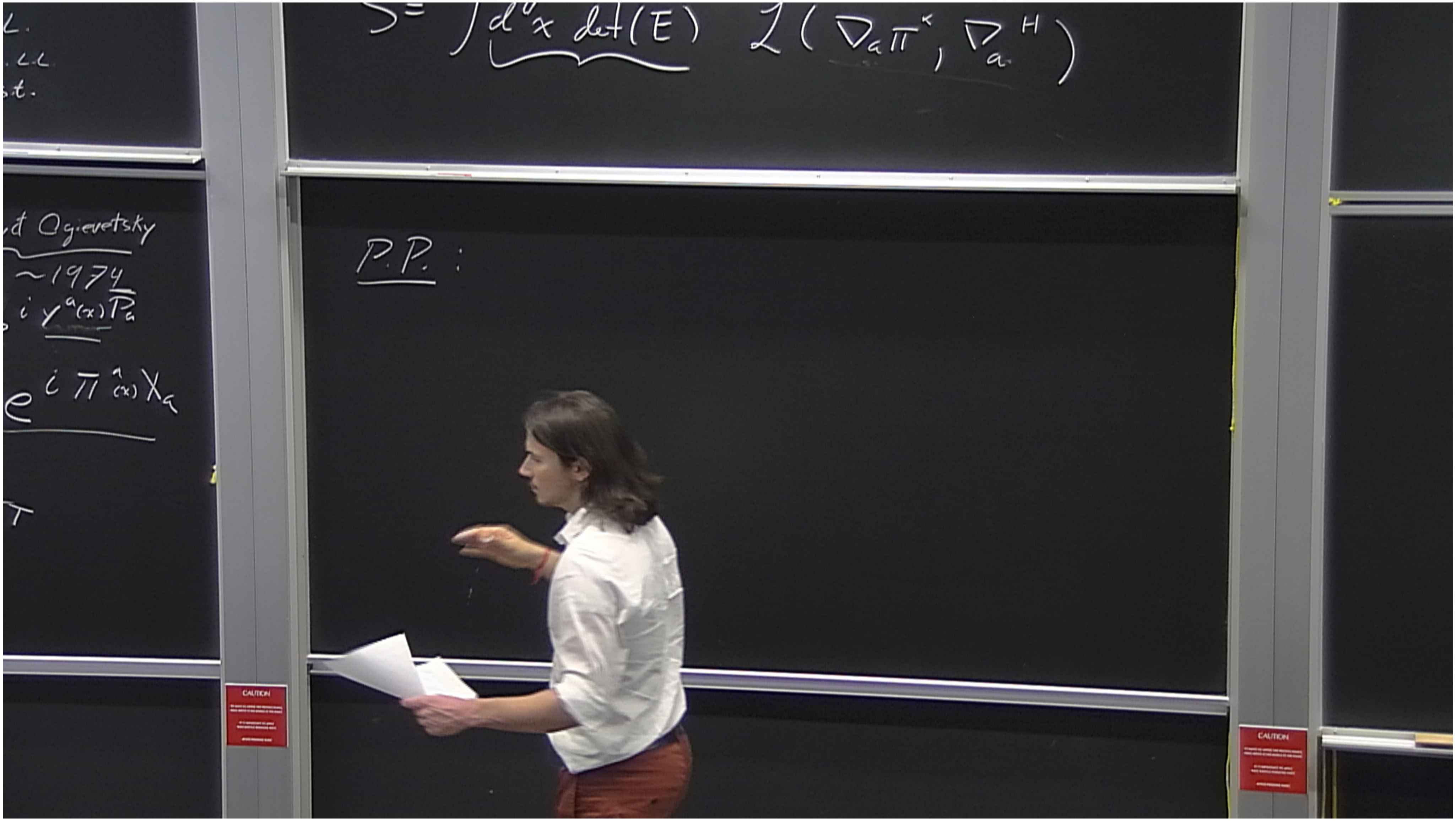


→ L.L.
→ s.L.L
→ st.
Ogievetsky
~1974
$\Omega^{-1}\partial_\mu\Omega = E_\mu{}^a(\bar{P}_a + \nabla_a\pi^\alpha X_\alpha + A_a{}^B T_B)$
tetrad
connection
cov. der = $(\nabla\pi) \to h\,\nabla\pi$
$\times e^{i\pi^a(x)X_a}$

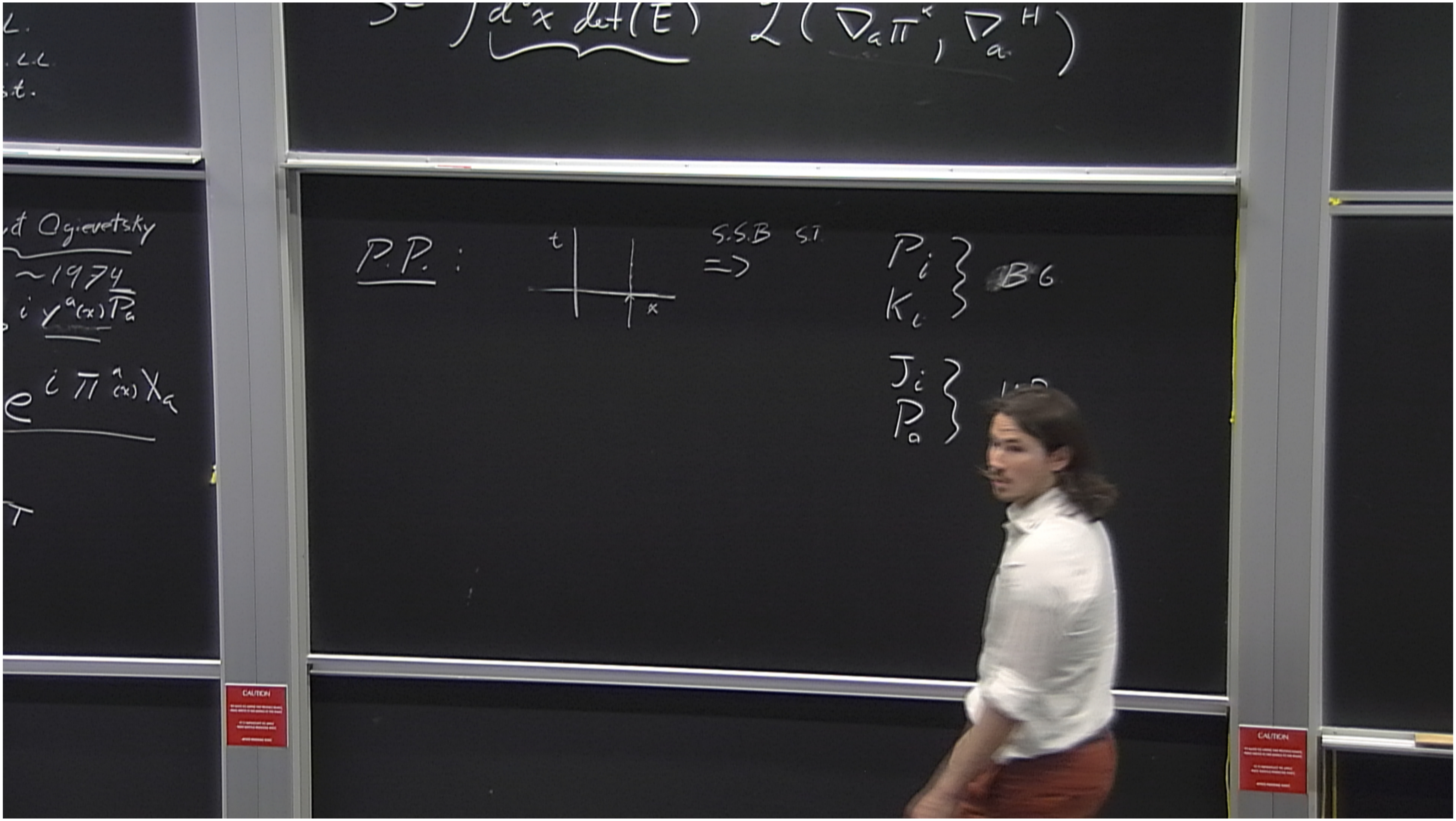

→ L.L.
→ s.L.L.
→ s.t.
Volkov & Ogievetsky
~1974
cov. der.
tetrad
connection
S = ∫ d⁴x det(E)
CAUTION

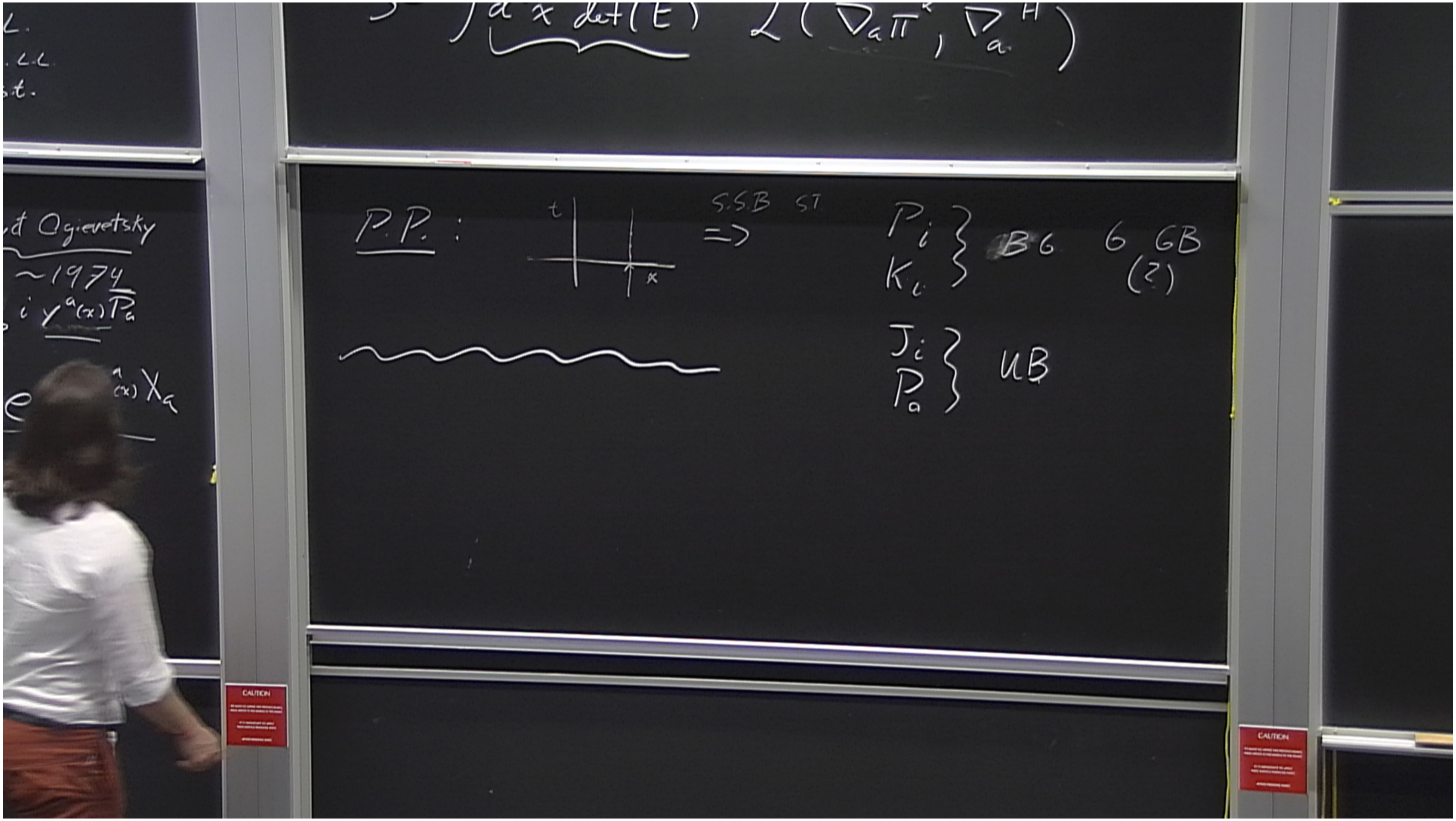

→ L.L.
→ s.L.L
→ s.t.
Volkov & Ogievetsky
~1974
×e
h
e T
Ω^-1 ∂_μ Ω = E_μ^a (P_a + ∇_a π^α X_α + A_a^B T_B)
tetrad
connection
cov. der. = (∇π) → h ∇π
∇_a^H = [(E^-1)_a^μ ∂_μ + A_a^B(π) T_B]
S = ∫ d^4x det(E) L(∇_a π^α ,
CAUTION

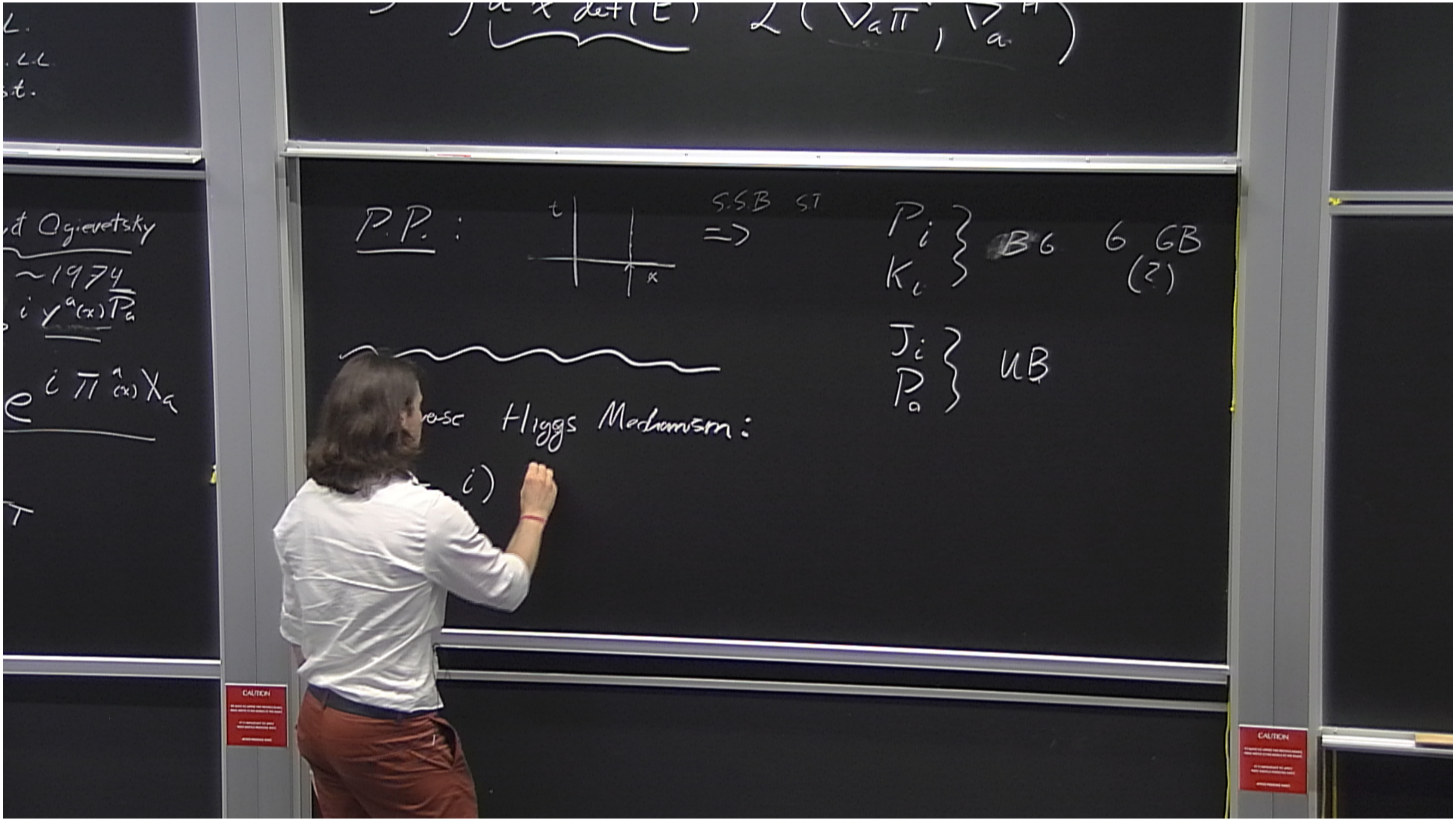

→ L.L.
→ s.L.L.
→ st.
Volkov Ogievetsky
~1974
Ω = e^{i y^a(x) P_a}
× e^{i π^a(x) X_a}
Ω^{-1} ∂_μ Ω = E_μ^a (P_a + ∇_a π^α X_α + A_a^B T_B)
tetrad
connection
cov. der = (∇π) → h ∇π
∇_a^H = [(E^{-1})_a^μ ∂_μ + A_a(π)^B T_B]
S = ∫ d^4x det(E) L(∇_a π^α , ∇_a^H)

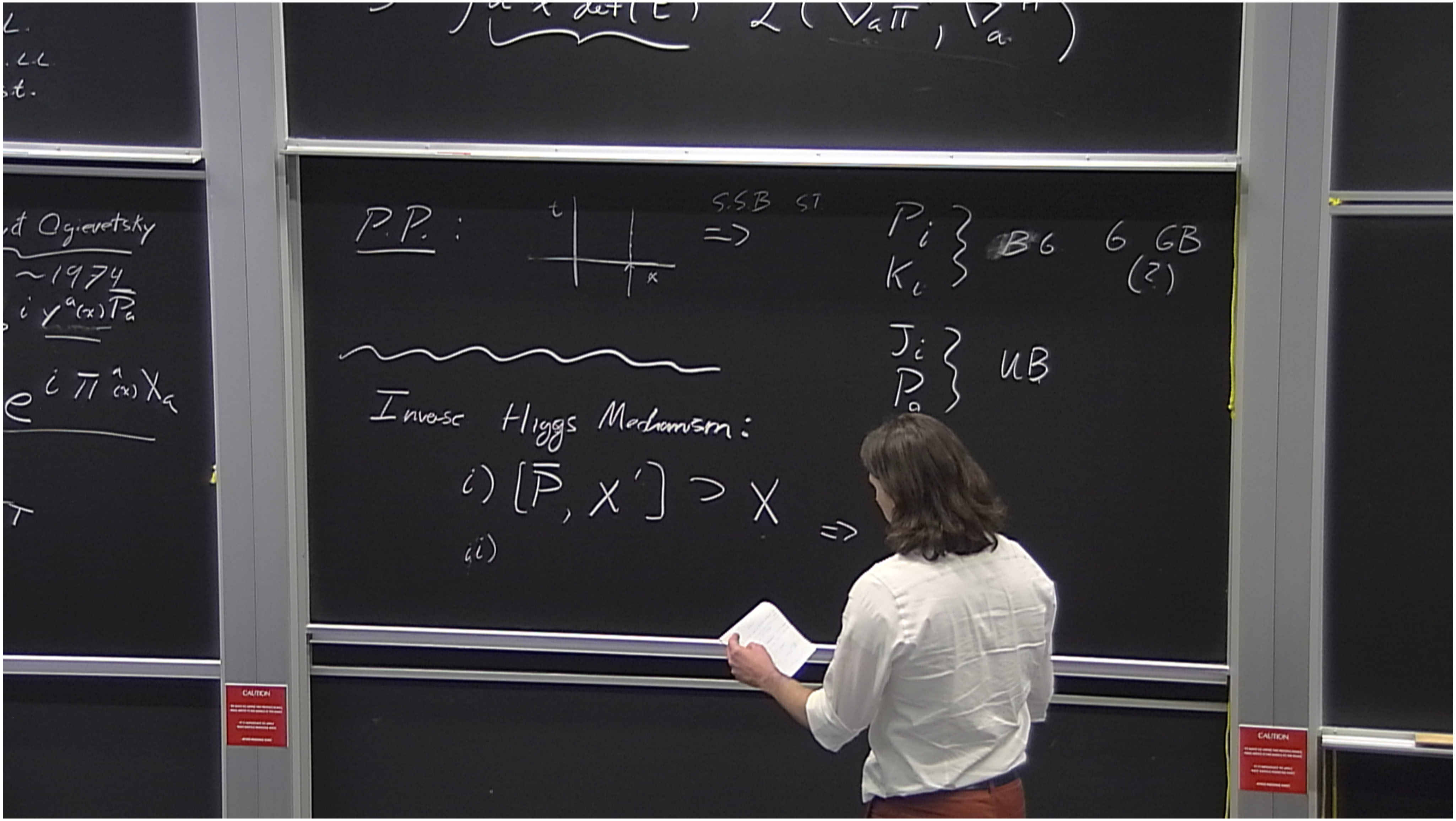


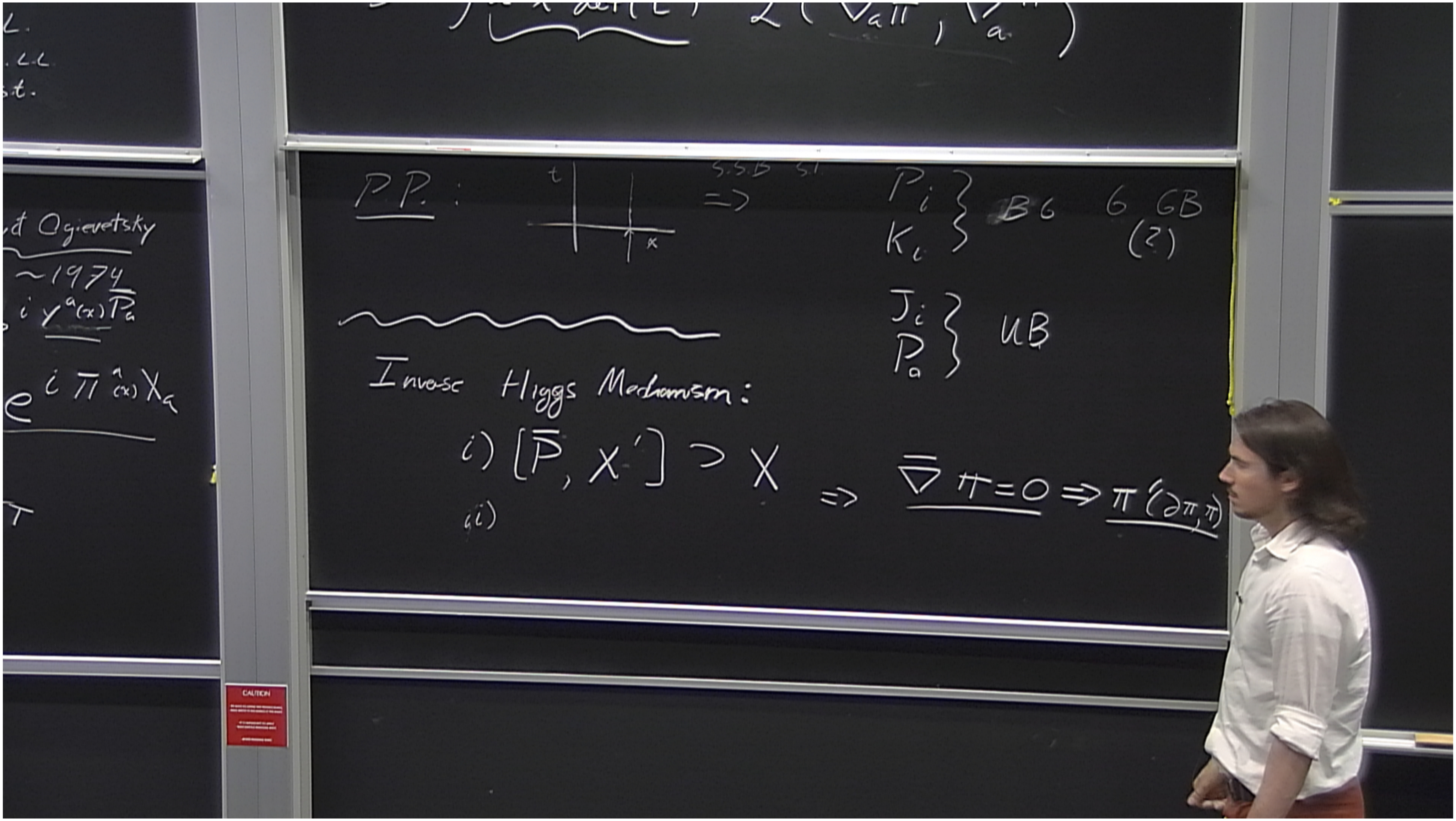
P.P. :
Ogievetsky
~1974
CAUTION

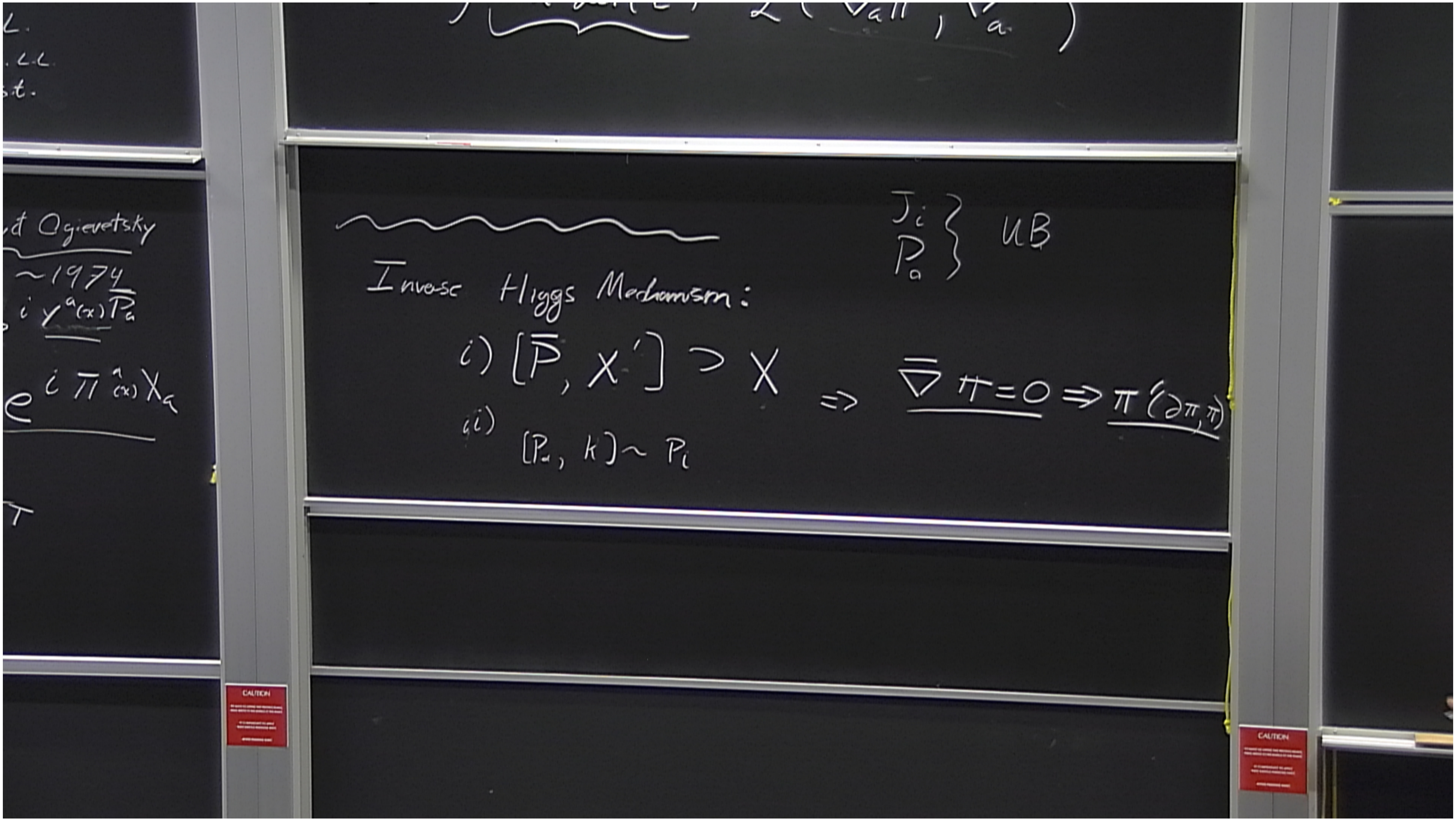


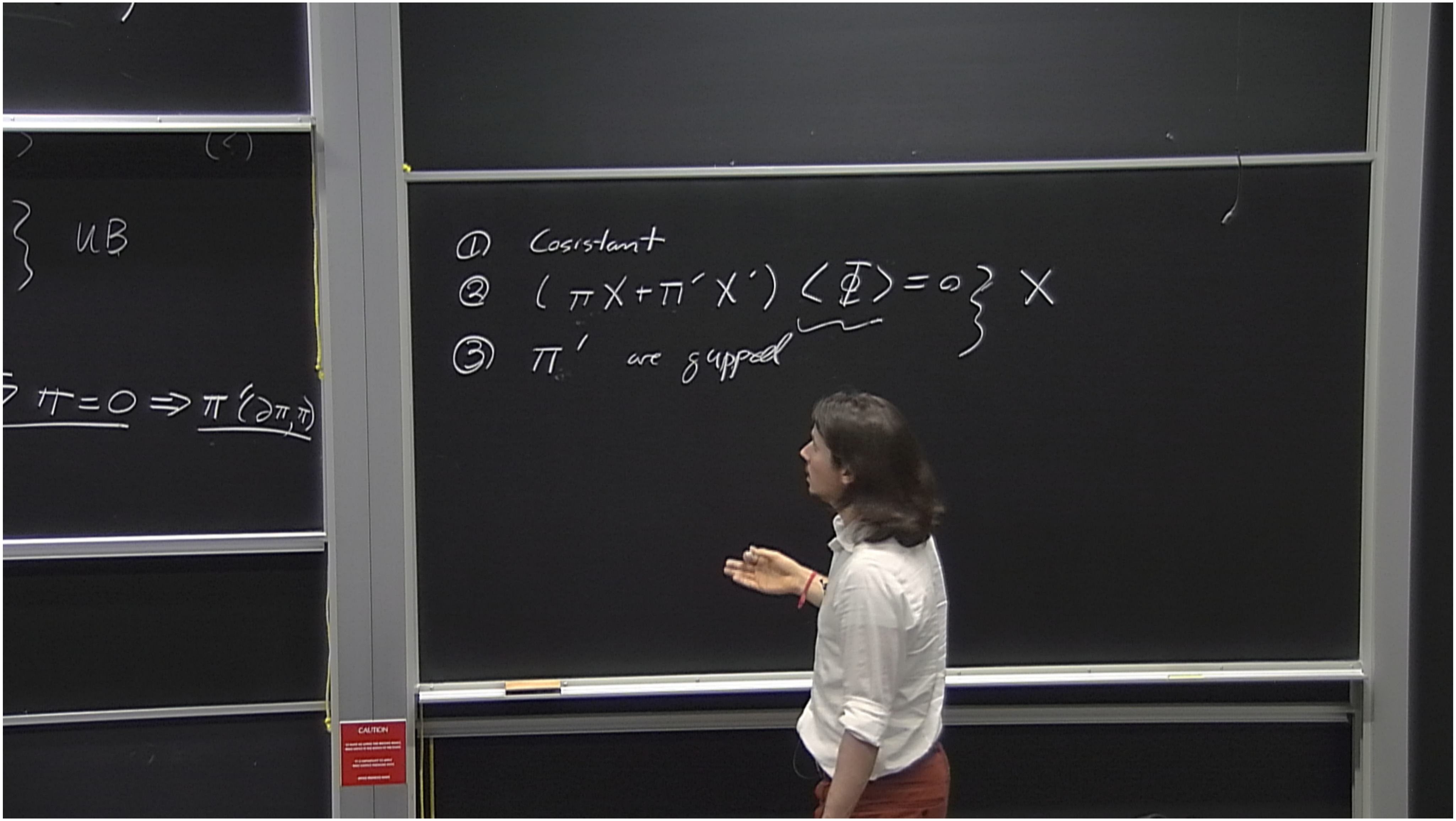


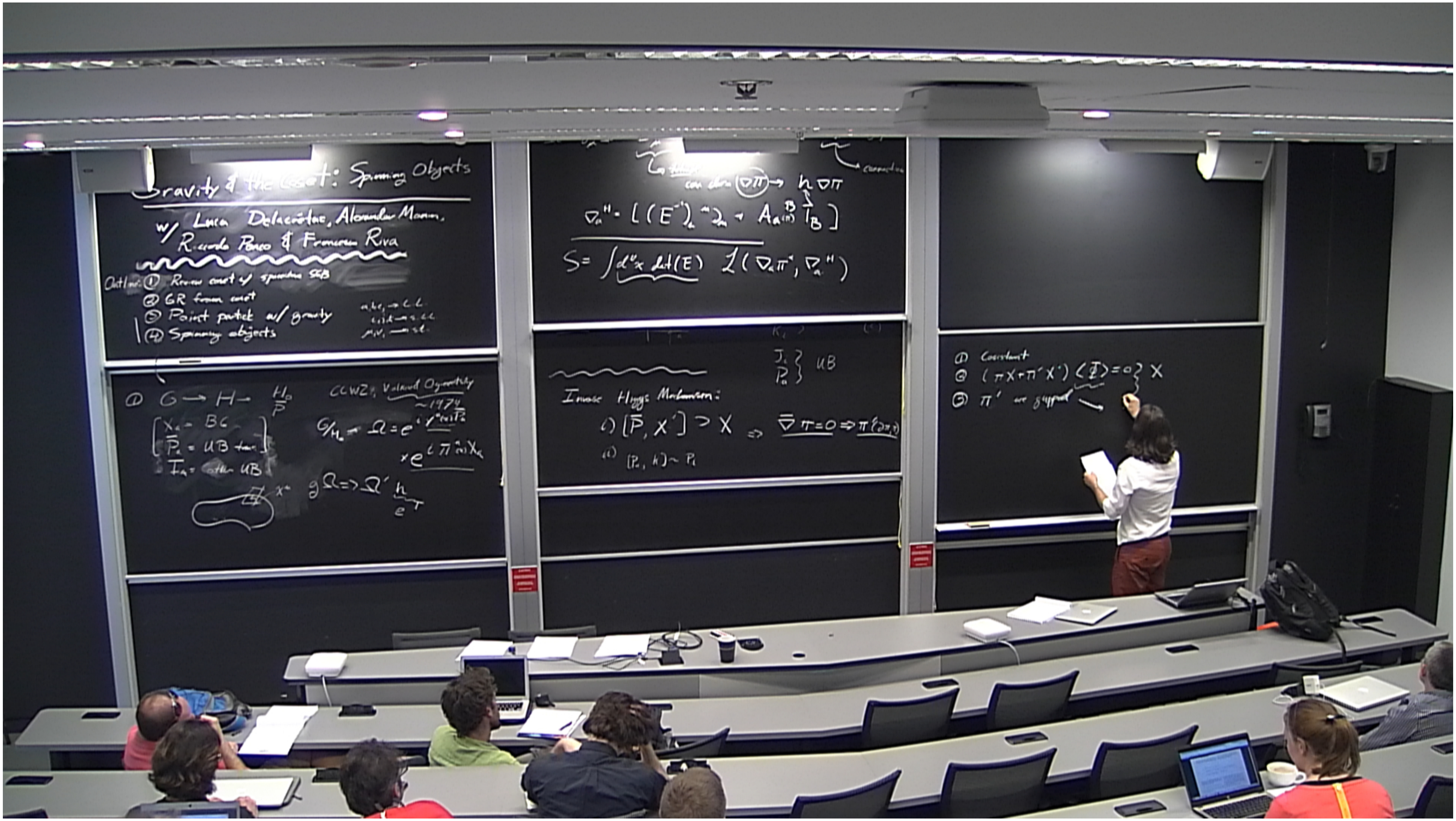

P.P. :
S.S.B S.T
⟹
P_i, K_i } BG 6 GB (2)
J_i, P_a } UB
Higgs Mechanism :
i)
Ogievetsky
~1974
$e^{i \pi^a(x) X_a}$


Ogievetsky
~1974
P.P. :
S.S.B ST
Pi
Ki
6 GB
Ji
UB
Inverse Higgs Mechanism:
i) [P̄, X'] ⊃ X ⇒
ii)


Ogievetsky
~1974
P.P.:
S.S.B
BG
GB
UB
Inverse Higgs Mechanism:
i) [P̄, X'] ⊃ X
ii)


Ogievetsky
~1974
Inverse Higgs Mechanism:
i) [P̄, X'] ⊃ X ⇒ ∇̄π = 0 ⇒ π(∂π, π)
ii) [P, K] ~ P
UB
CAUTION
CAUTION


UB
π = 0 ⇒ π(∂π, π)
① Cosistant
② (πX + π′X′) ⟨Φ⟩ = 0 } X
③ π′ are gapped
CAUTION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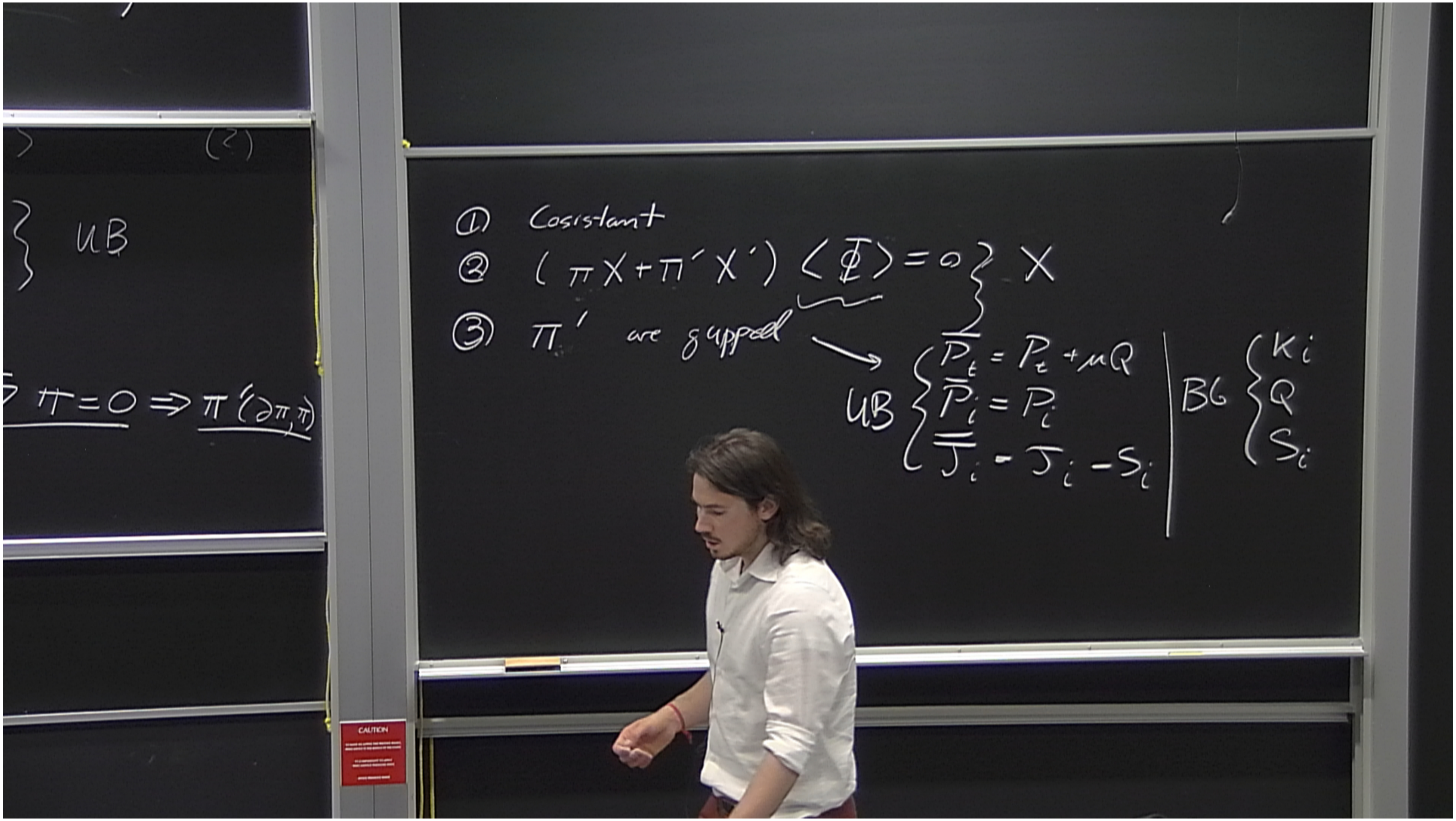
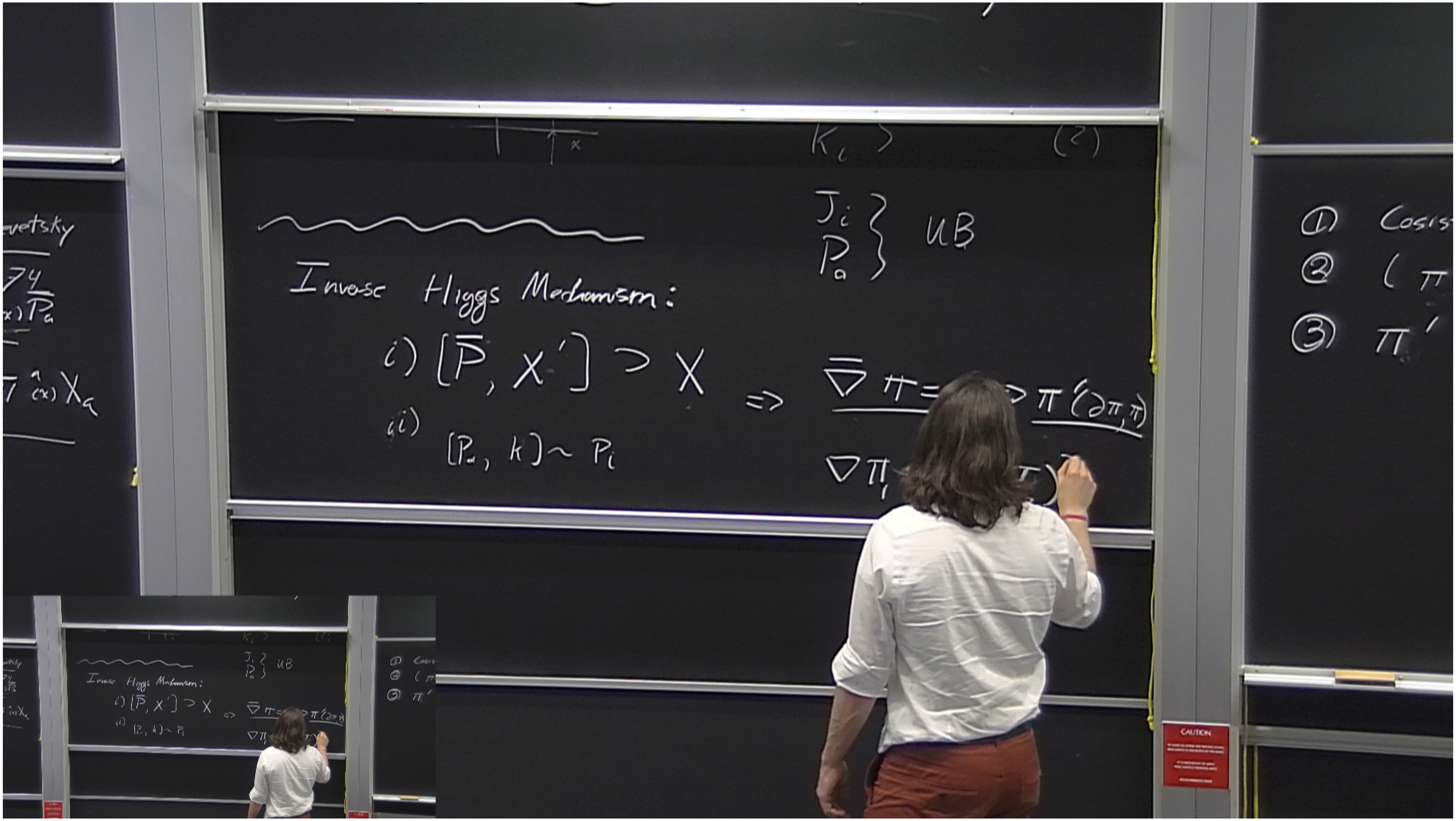
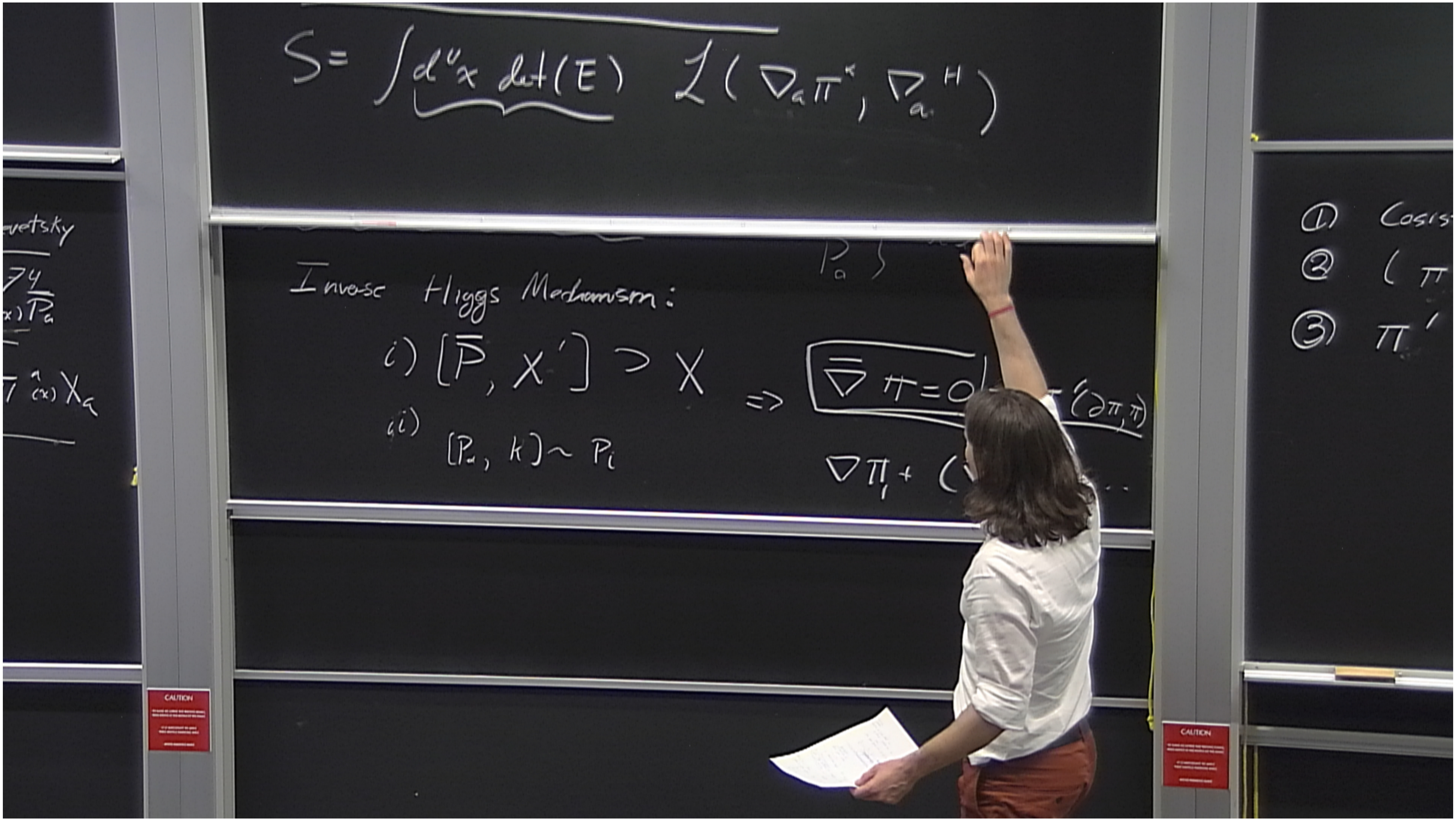
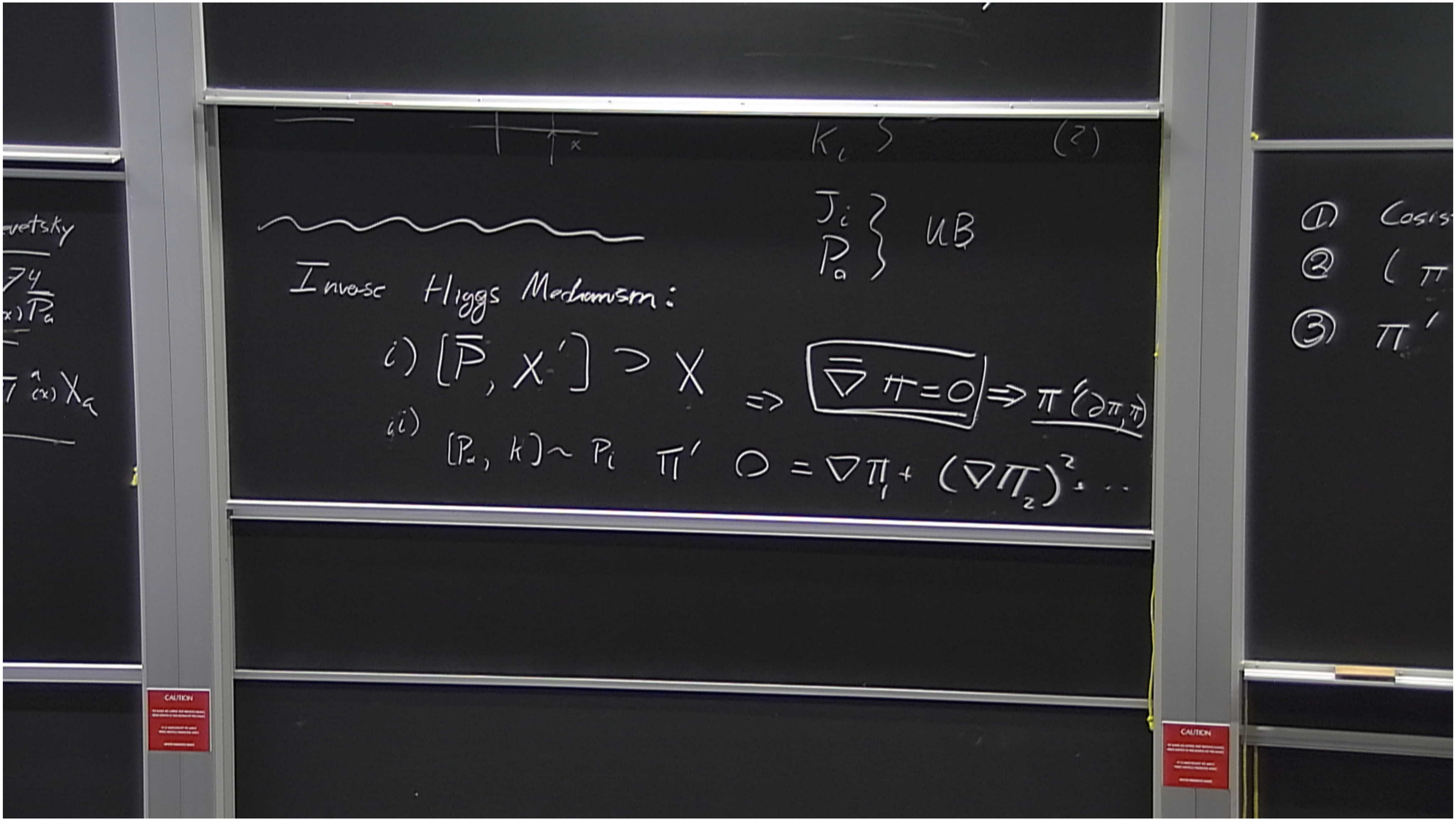
CCWZ; Volkov; Ogievetsky ~1974
Inverse Higgs Mechanism:
① Constraint
③ π' are gapped

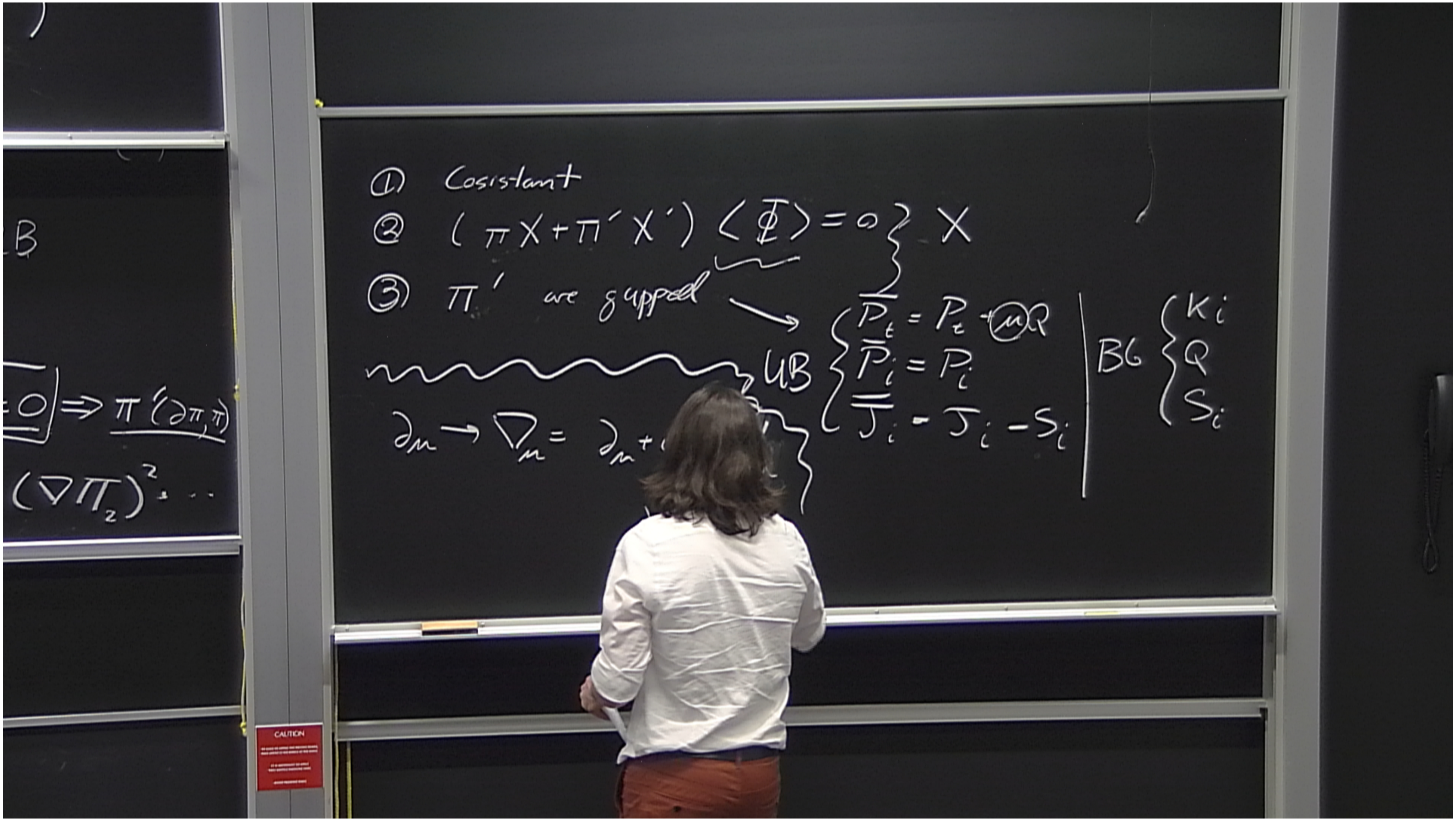

UB
① Cosistant
② (π X + π' X') ⟨ Φ ⟩ = 0 } X
③ π' are gapped
UB
P̄_t = P_t + μQ
P̄_i = P_i
J̄_i = J_i − S_i
BG
K_i
Q
S_i
CAUTION

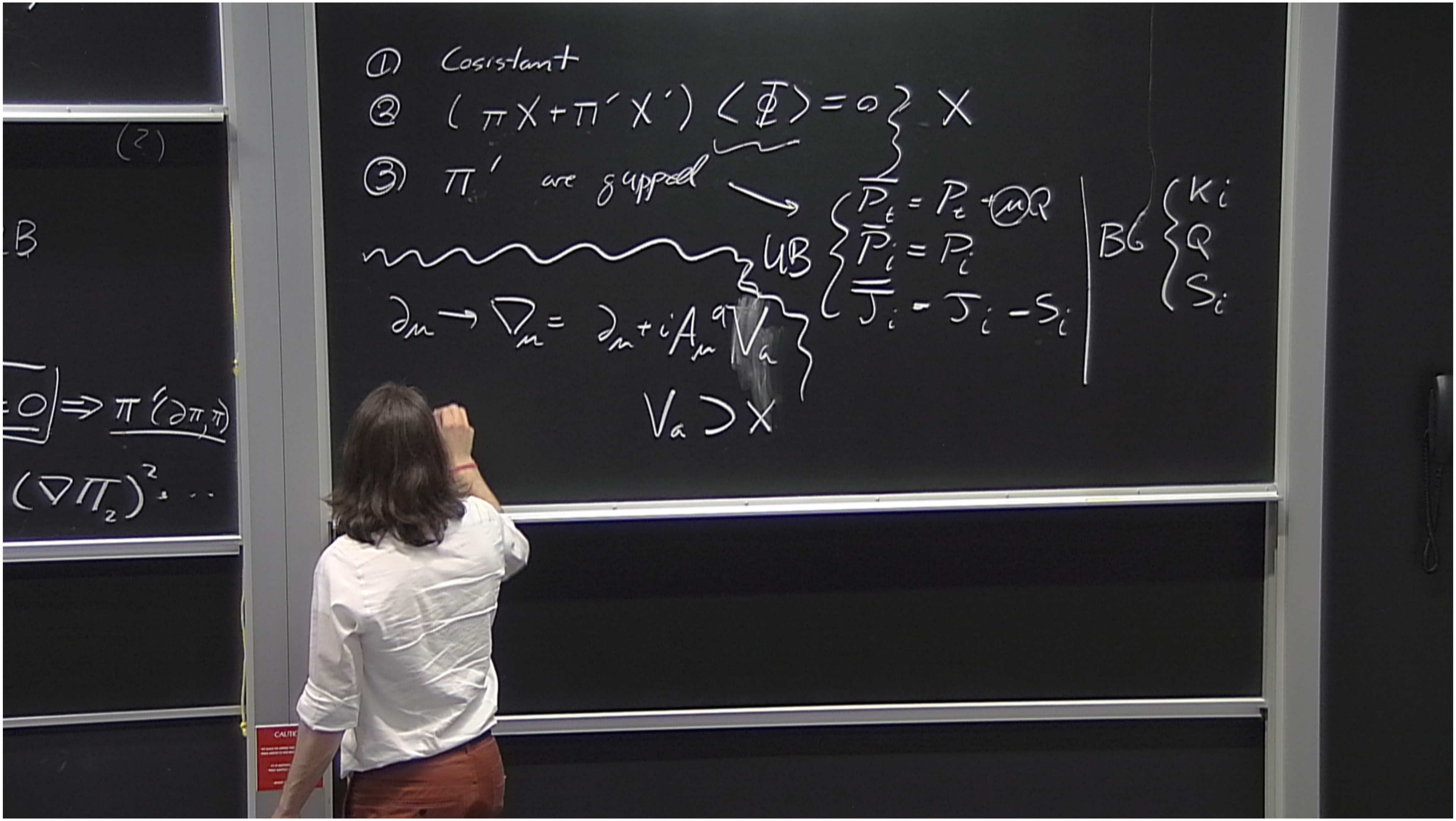

Inverse Higgs Mechanism:
i) [P̄, X′] ⊃ X
ii) [P_a, K] ~ P_i
⇒
J_i
P_a
UB
K_i
① Cosist
② (π
③ π′
CAUTION

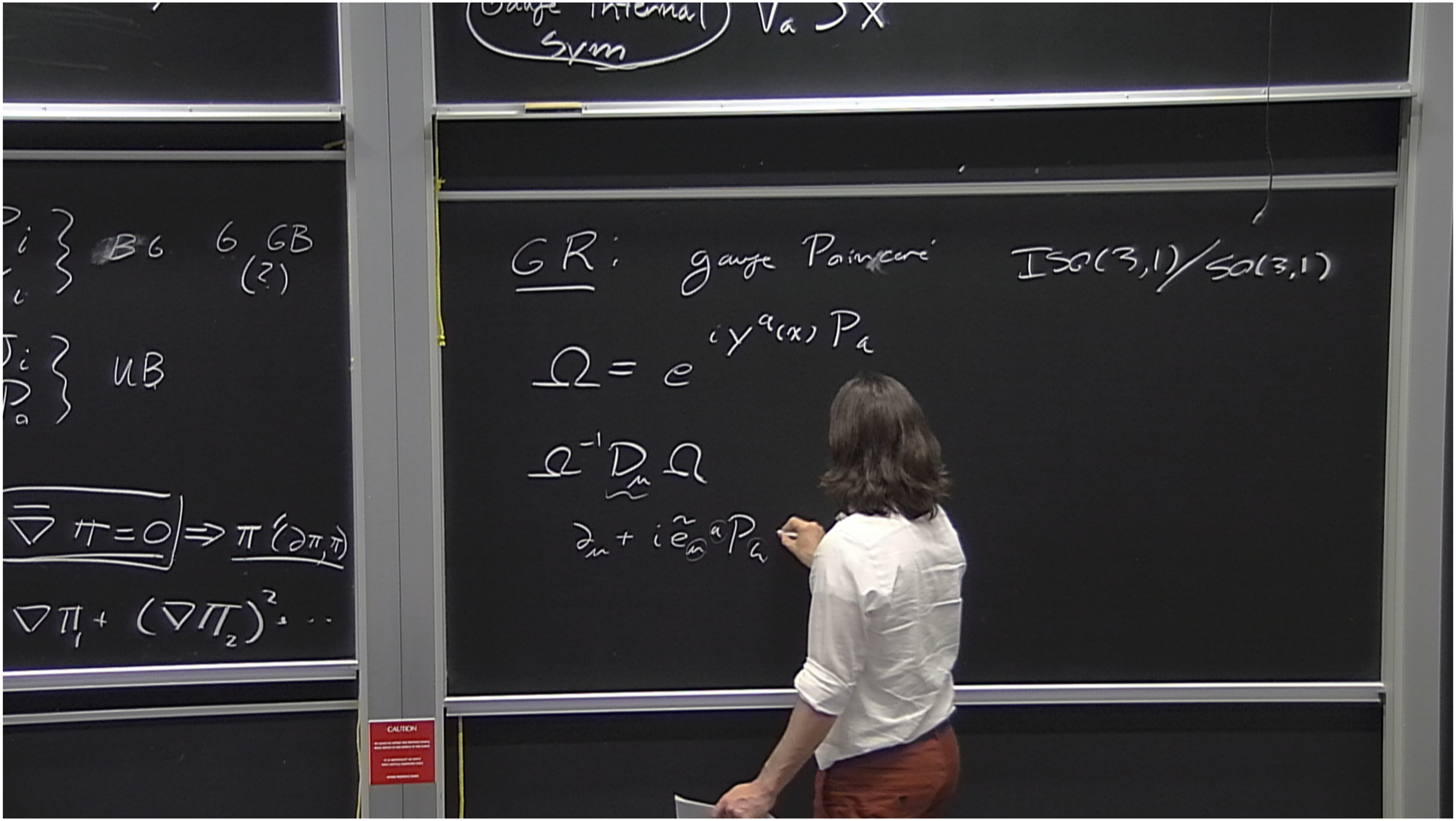


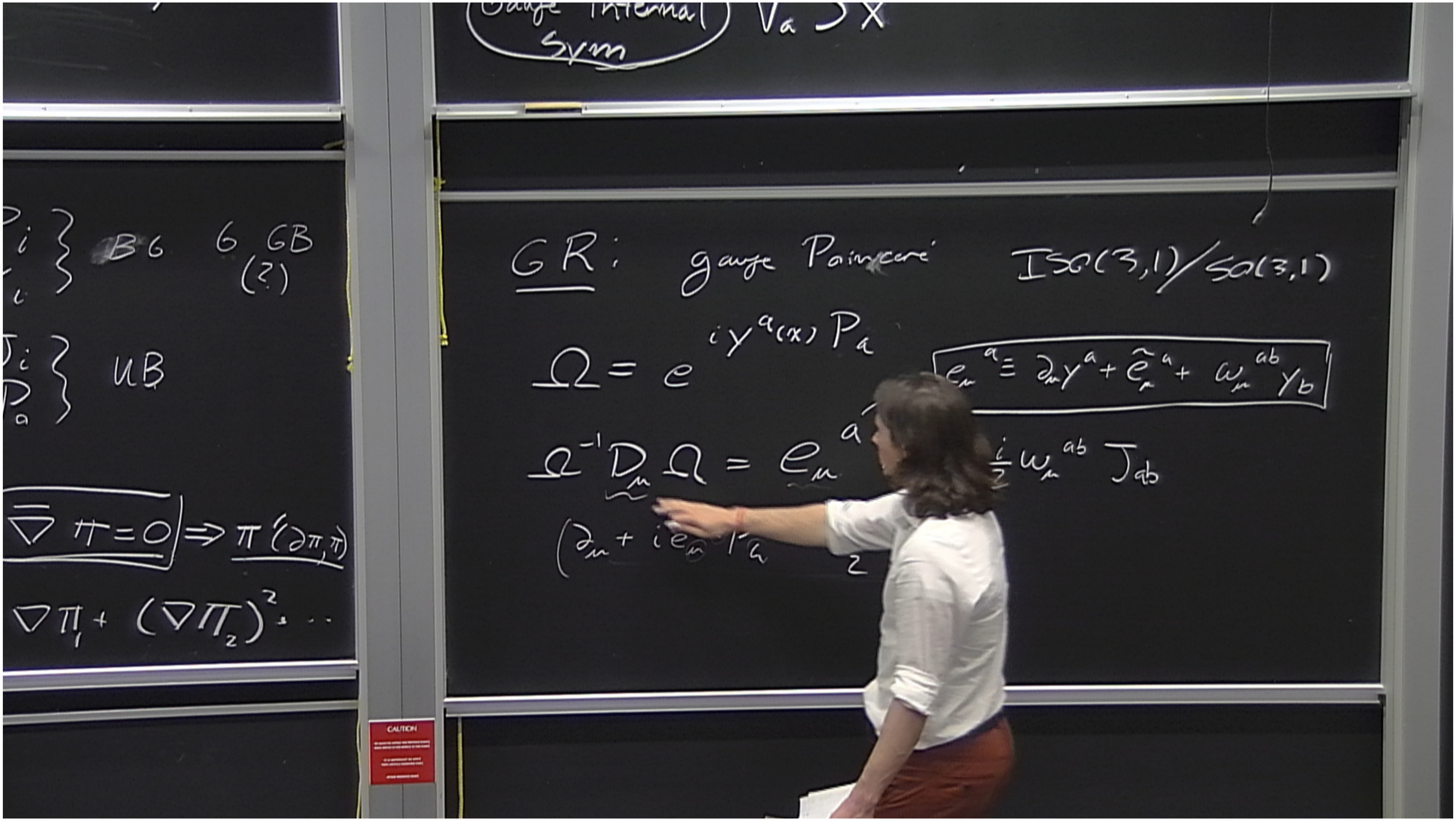
S= ∫d^4x det(E) L(∇_a π^α, ∇_a H)
Inverse Higgs Mechanism:
i) [P̄, X'] ⊃ X
ii) [P_a, K] ~ P_i
=> ∇̄π = 0

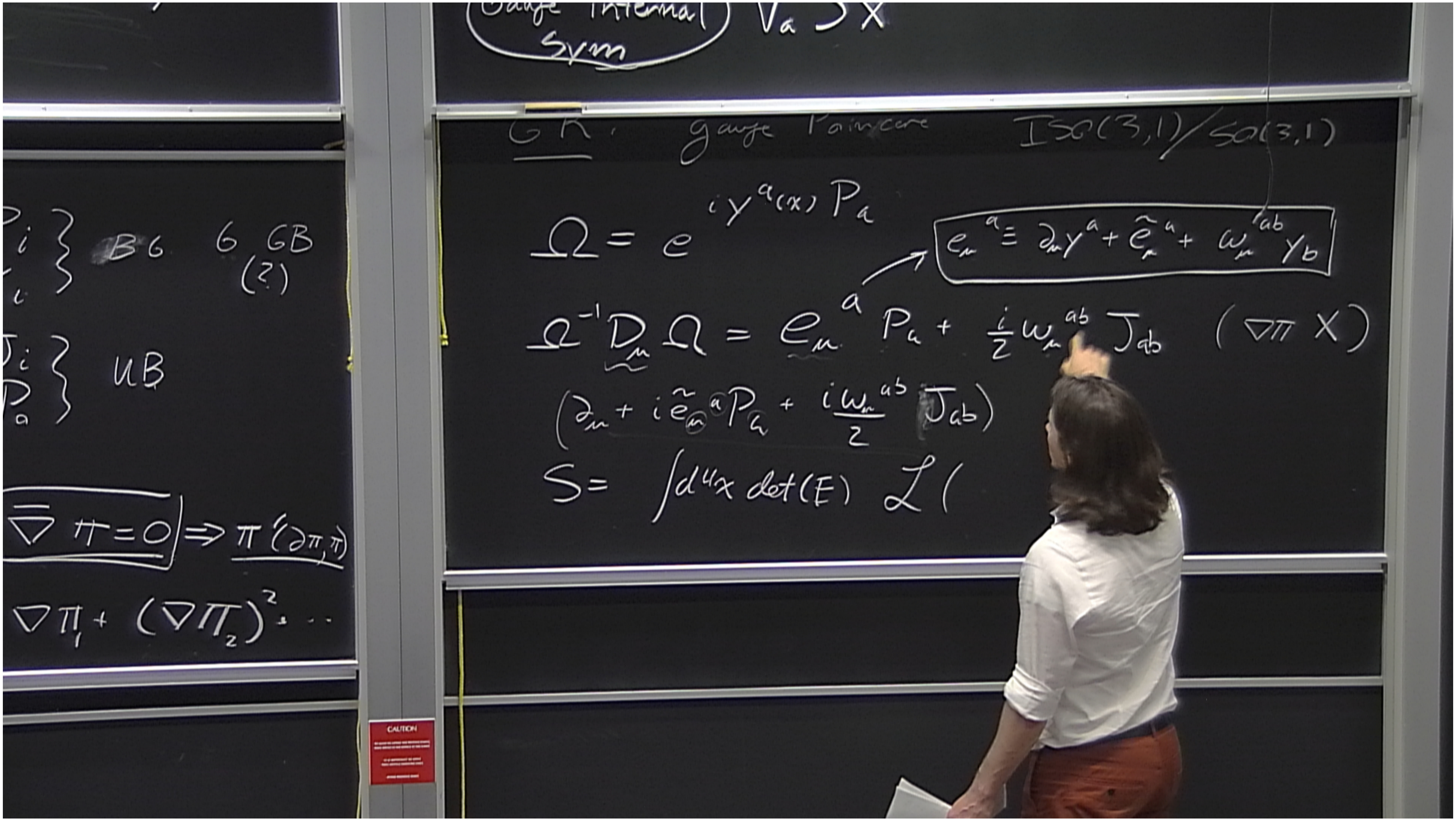

Inverse Higgs Mechanism:
i) [P̄, X'] ⊃ X ⇒ ∇̄π = 0 ⇒ π'(∂π, π)
ii) [P_a, K] ~ P_i π'
O = ∇π_1 + (∇π_2)^2 ...
K_i }
J_i
P_a } UB

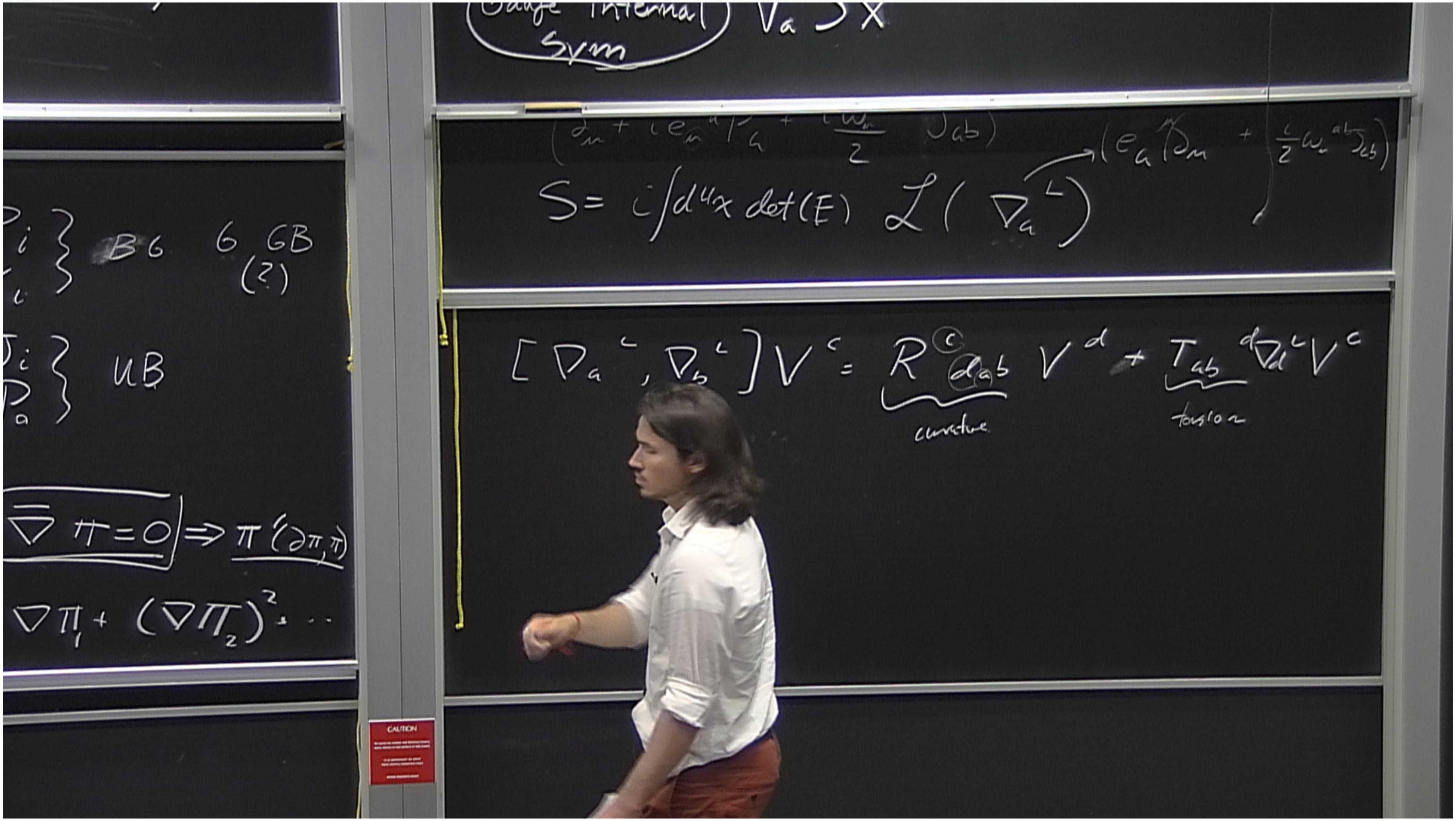

① Cosistant
③ π' are gapped
UB
BG
Ki
Q
Si

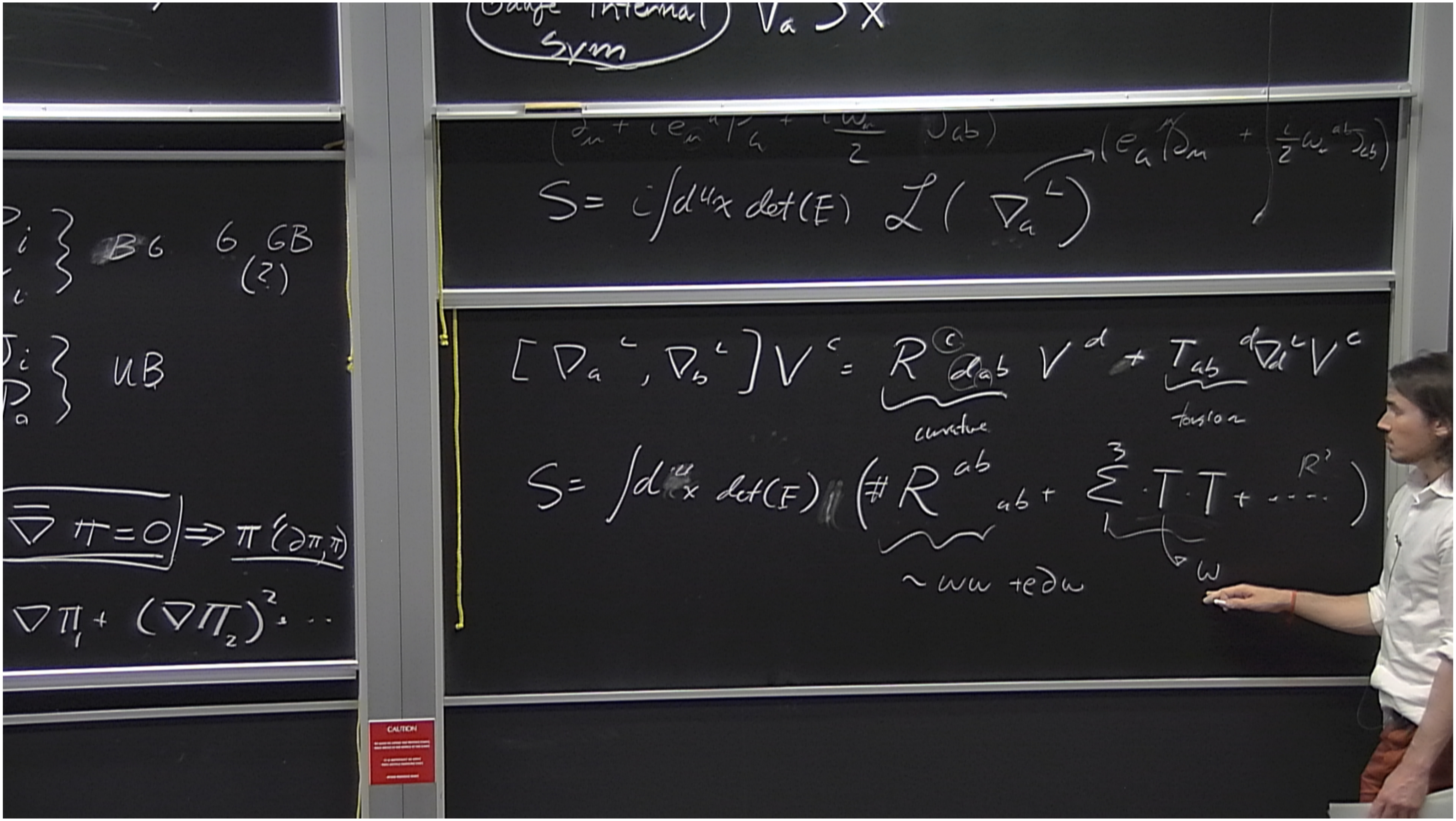

① Cosistant
② (π X + π' X') < Φ > = 0 } X
③ π' are gapped
UB
BG
Ki
Q
Si
Va ⊃ X

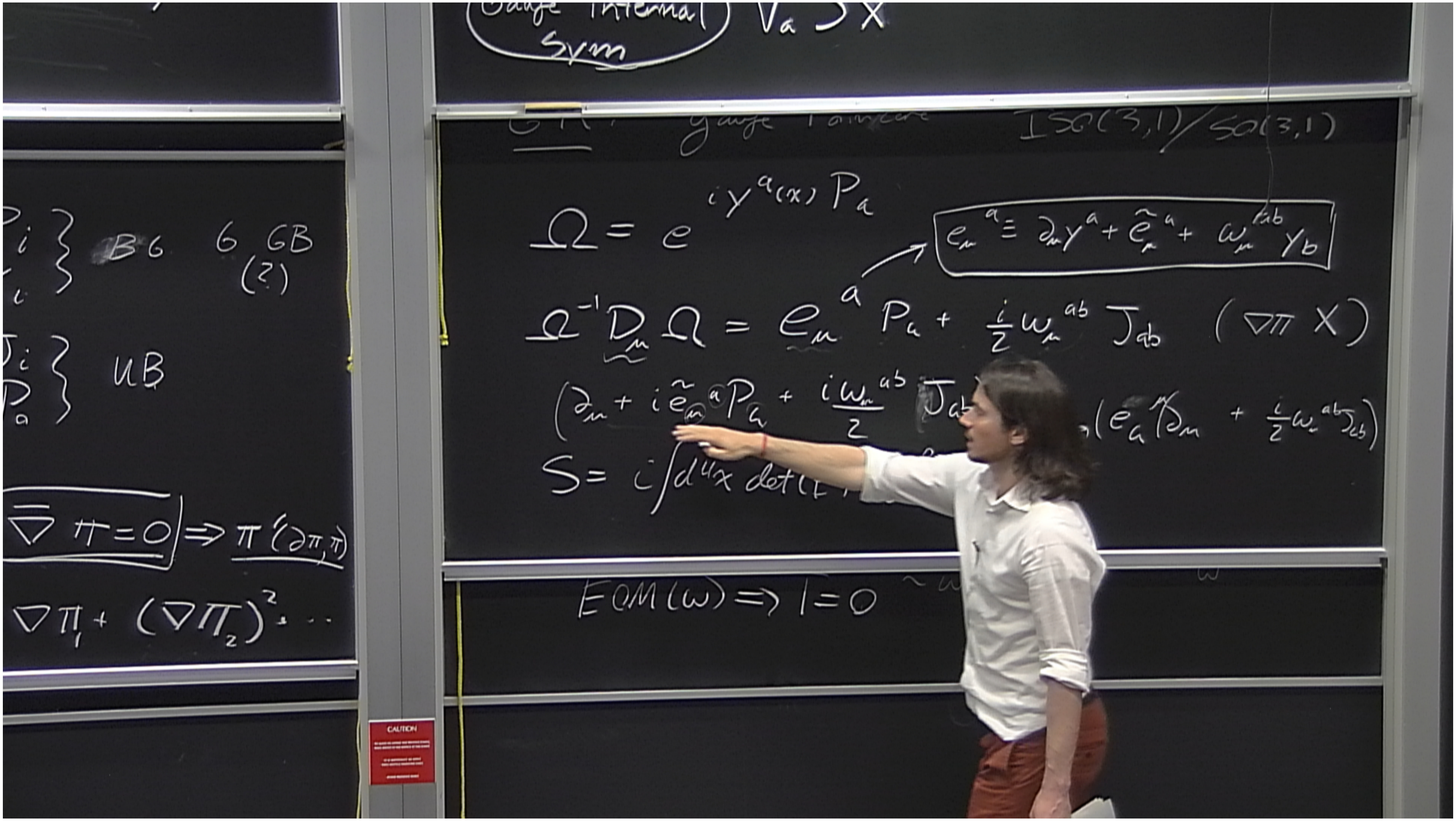

Sym
GR: gauge Poincaré
ISO(3,1)/SO(3,1)
Ω = e^{iy^a(x) P_a}
Ω^{-1} D_μ Ω
∂_μ + i ẽ_μ^a P_a
UB
CAUTION

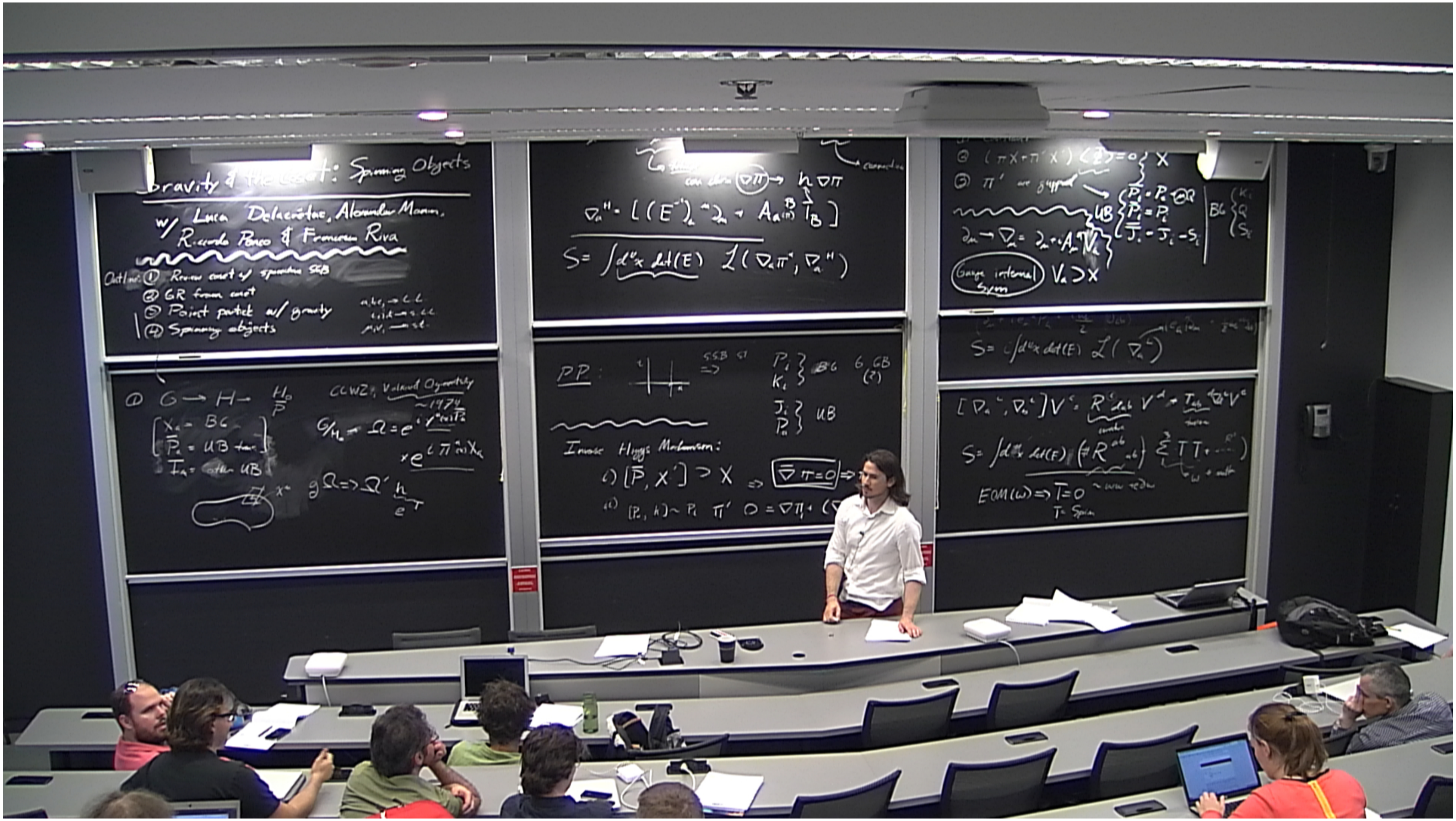

Gauge Internal Sym
GR: gauge Poincaré ISO(3,1)/SO(3,1)
B 6
6 6B (?)
UB
CAUTION


GR: gauge Poincare
ISO(3,1)/SO(3,1)
UB
S= ∫d⁴x det(E) L(


Sym
S= i∫d⁴x det(E) ℒ(∇a)
curvature
torsion
UB
6 GB
(?)


Gauge Internal Sym
$\nabla_a \supset X$
$S = i\int d^4x \, \det(E) \, \mathcal{L}(\nabla_a^L)$
$[\nabla_a^L, \nabla_b^L] V^c = R^c{}_{dab} V^d + T_{ab}{}^d \nabla_d^L V^c$
curvature
torsion
$S = \int d^4x \, \det(E) \, (\# R^{ab}{}_{ab} + \sum_1^3 \cdot T \cdot T + \ldots R^2)$
$\sim \omega\omega + e\partial\omega$
ω
UB
$\nabla \pi = 0 \Rightarrow \pi(\partial\pi, \pi)$
$\nabla\pi_1 + (\nabla\pi_2)^2 + \ldots$
CAUTION


Sym
ISO(3,1)/SO(3,1)
Ω = e^{i y^a(x) P_a}
e_μ^a ≡ ∂_μ y^a + ẽ_μ^a + ω_μ^ab y_b
Ω^{-1} D_μ Ω = e_μ^a P_a + (i/2) ω_μ^ab J_ab
(∇π X)
S = i ∫ d^4x det(
EOM(ω) ⇒ I = 0
UB
∇π = 0 ⇒ π(∂π, π)
∇π_1 + (∇π_2)^2 + ...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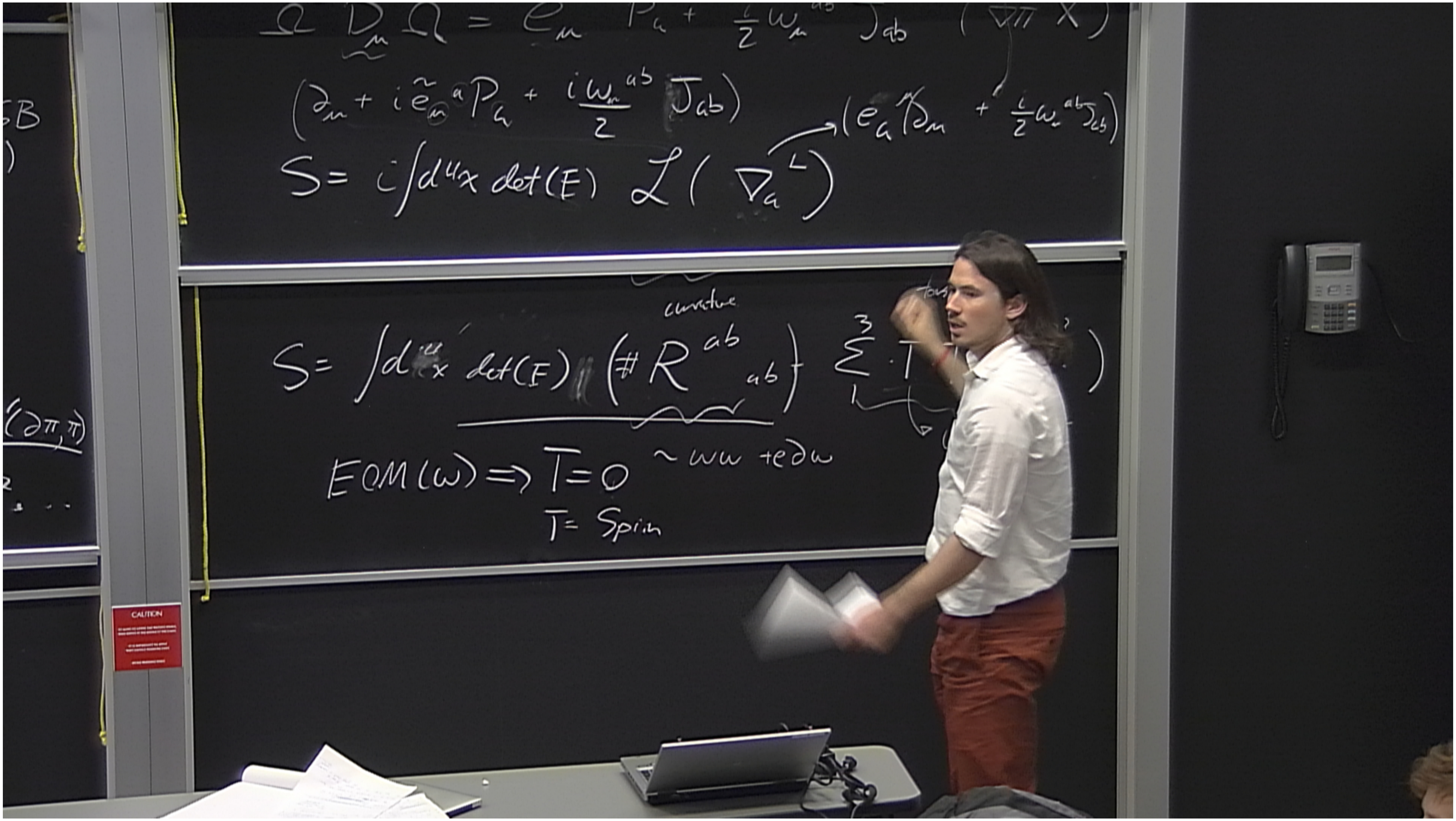
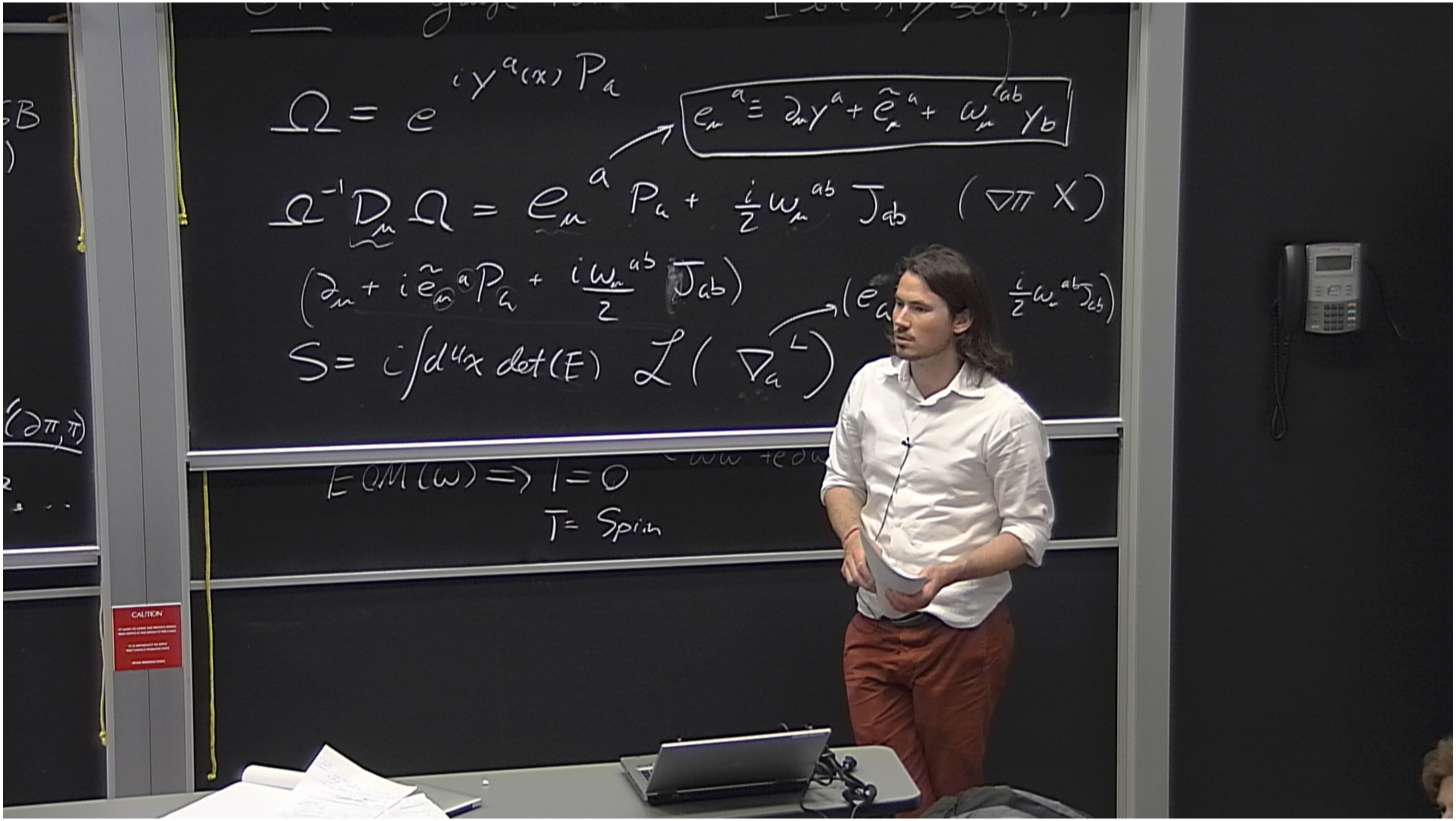
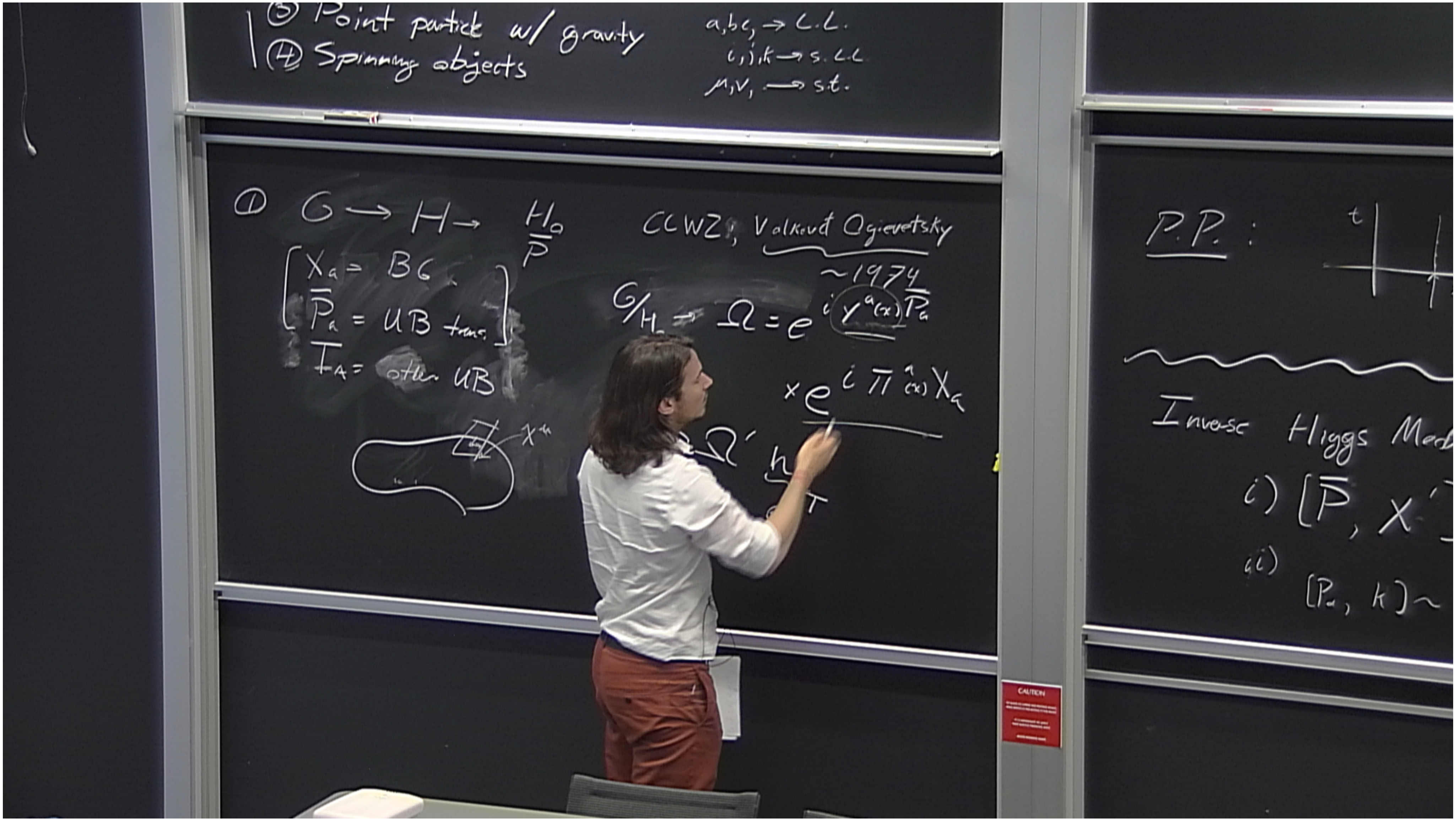
Inverse Higgs Mechanism:
Gauge internal Sym


curvature
EOM(ω) ⇒ T=0
T= Spin
CAUTION


CAUTION
EOM (ω) ⇒ T=0
T= Spin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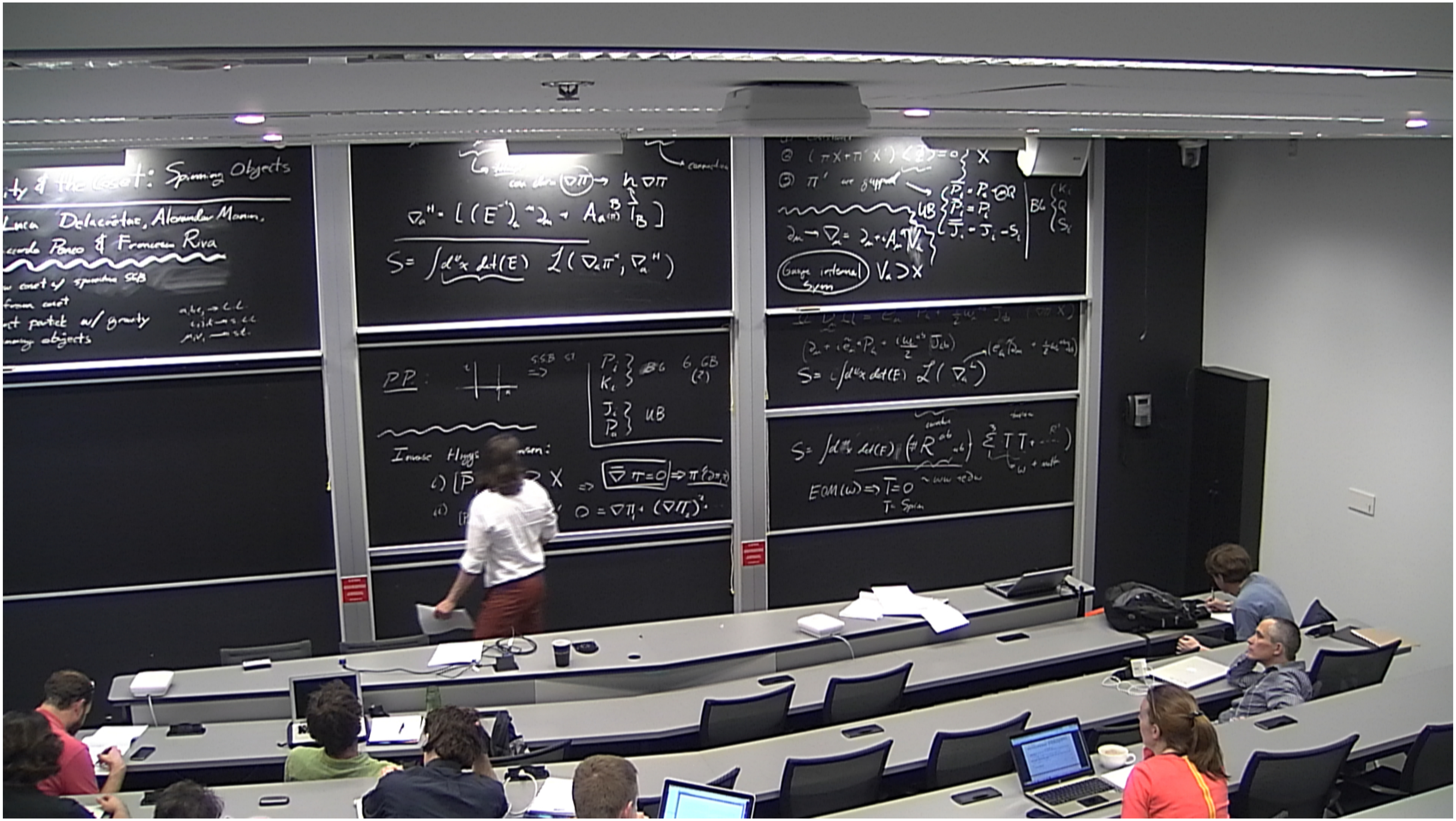
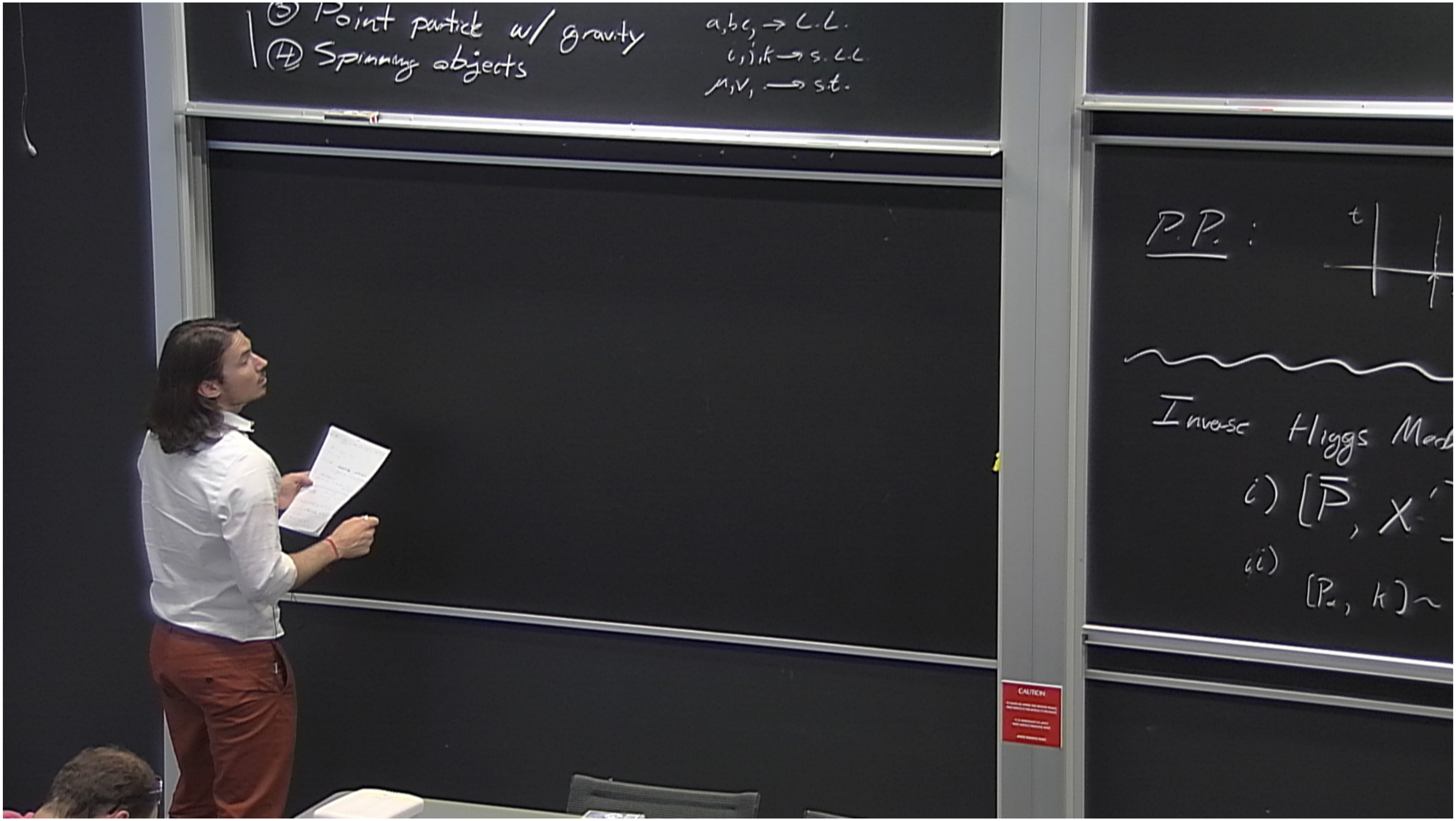
i,j,k → s.L.L
μ,ν, → s.t.
① G → H →
CCWZ, Volkov & Ogievetsky
~1974
[X_a = BG
P̄_a = UB trans.]
I_A = other UB
G/H → Ω = e^{i Y^a(x) P̄_a}
× e^{i π^a(x) X_a}
P.P. :
Inverse Higgs Mech
i) [P̄, X
ii)
[P_a, k] ~
CAUTION


Spinning Objects
Luca Delacrétaz, Alexander Monin,
Francesco Riva
PP:
Inverse Higgs
UB
EOM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④ Spinning objects
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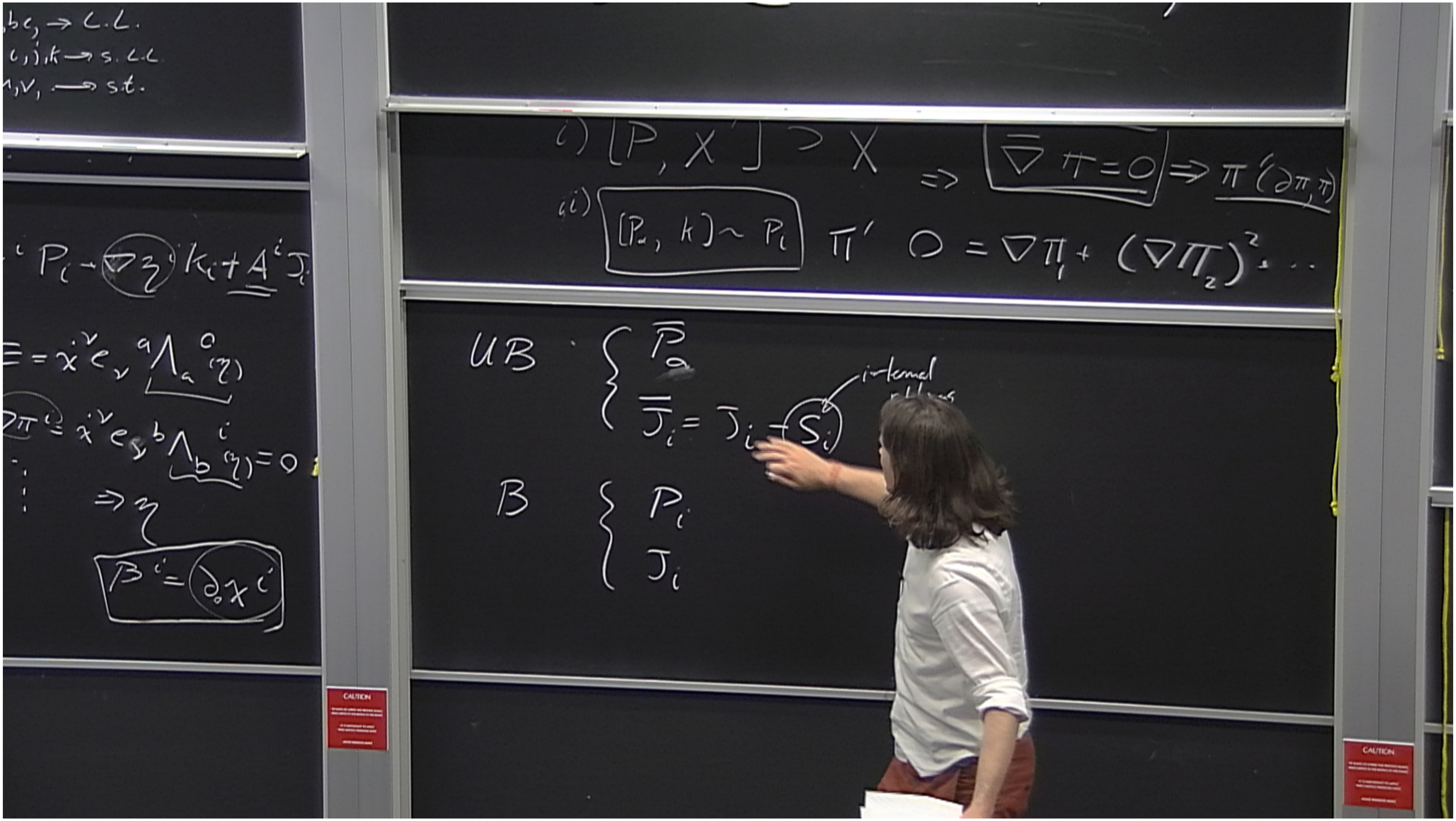
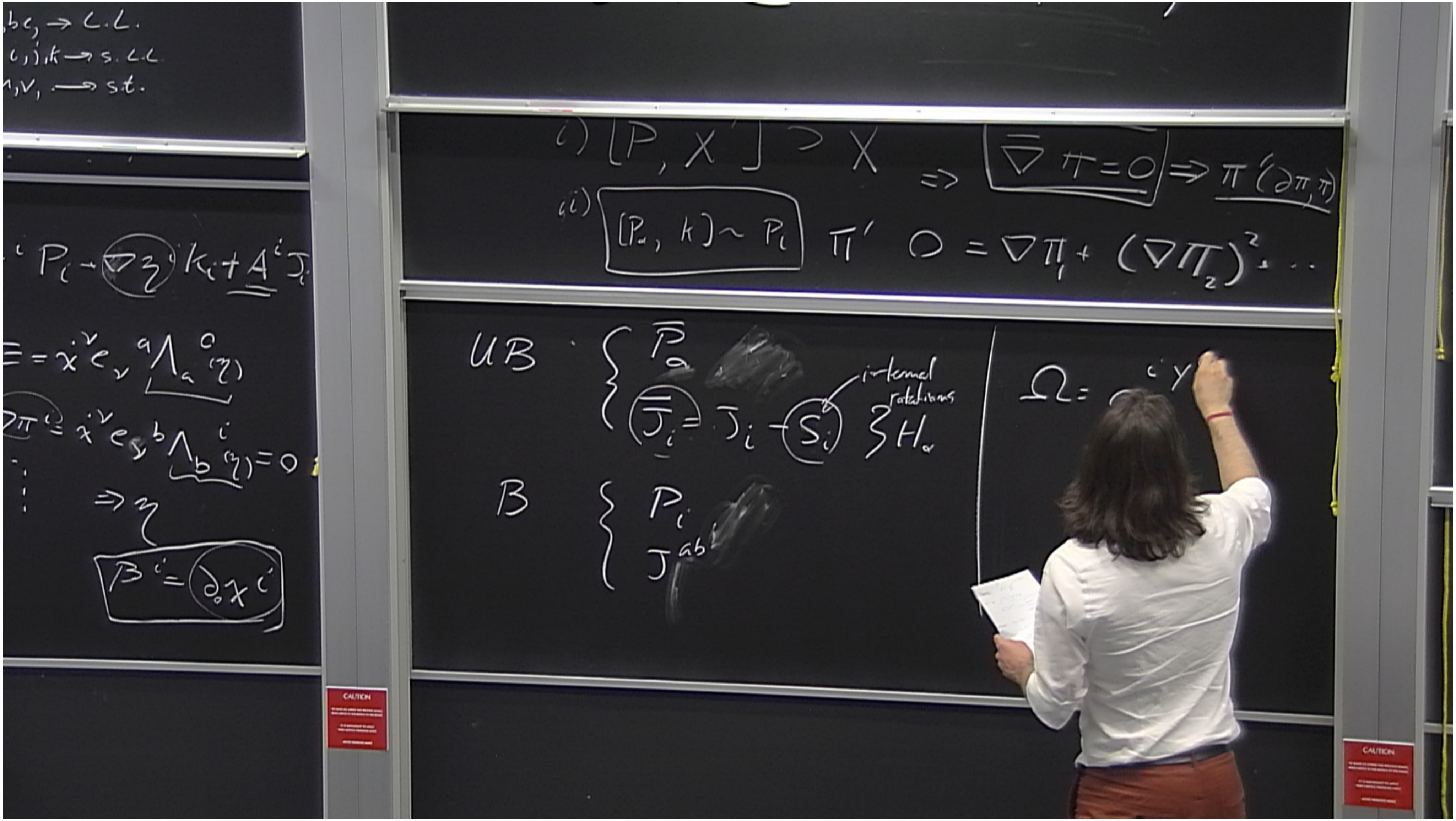
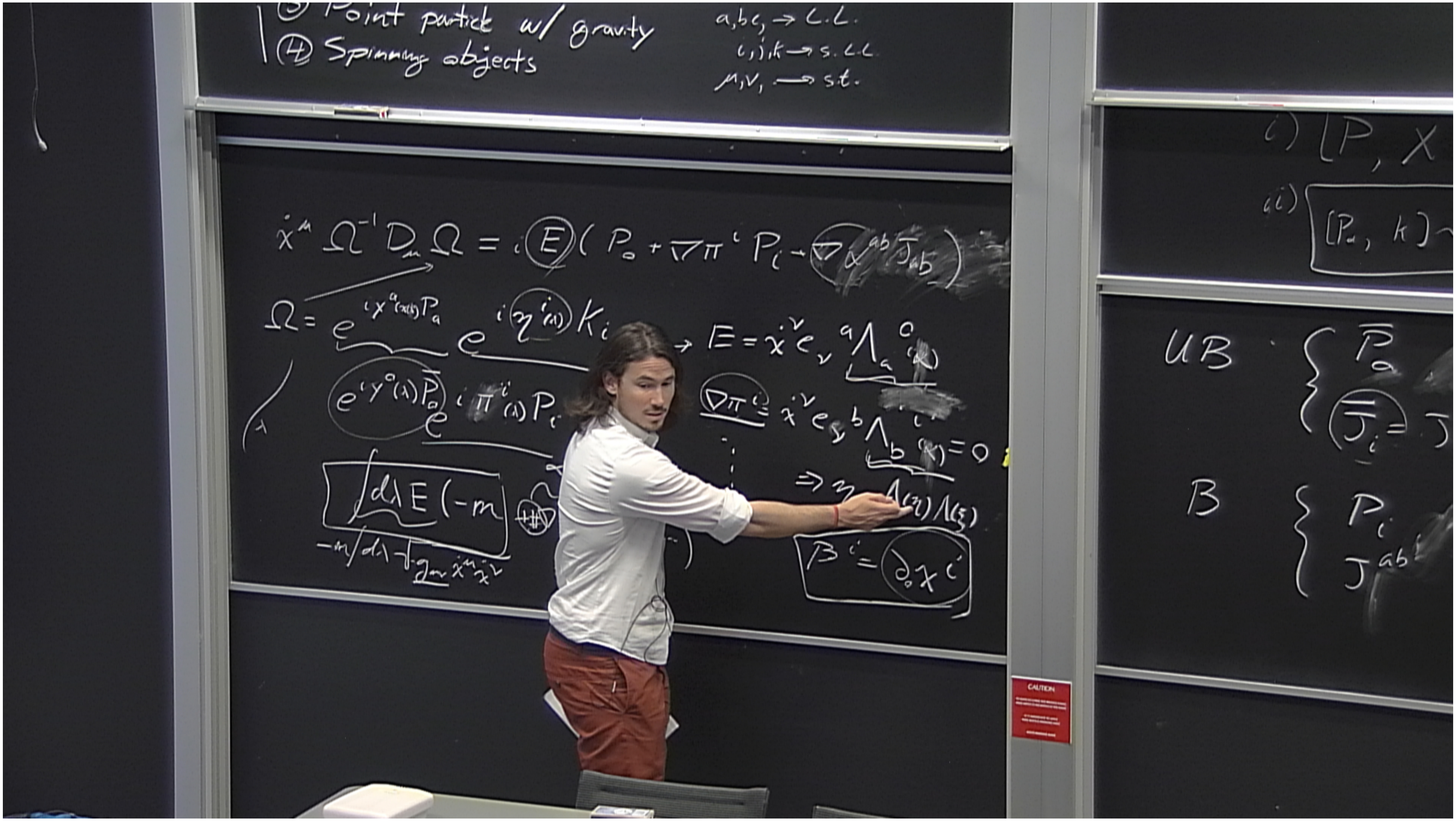
i,j,k → s.L.L
μ,ν, → s.t.
P.P. :
t
Inverse Higgs


UB
B
internal


internal rotations


Point particle w/ gravity
④ Spinning objects
a,b,c, → L.L.
i,j,k → s.L.L.
μ,ν, → s.t.
UB
B