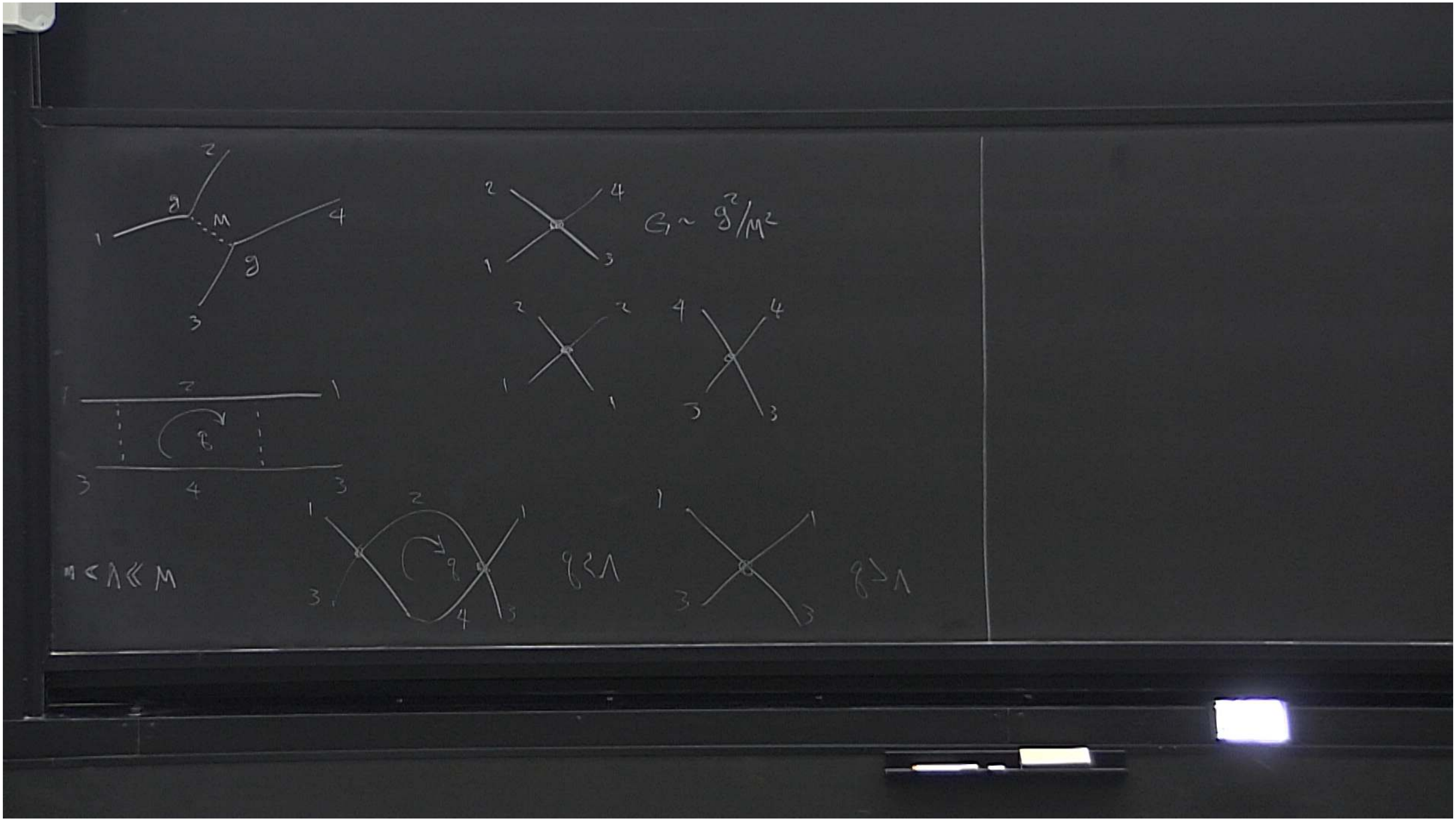
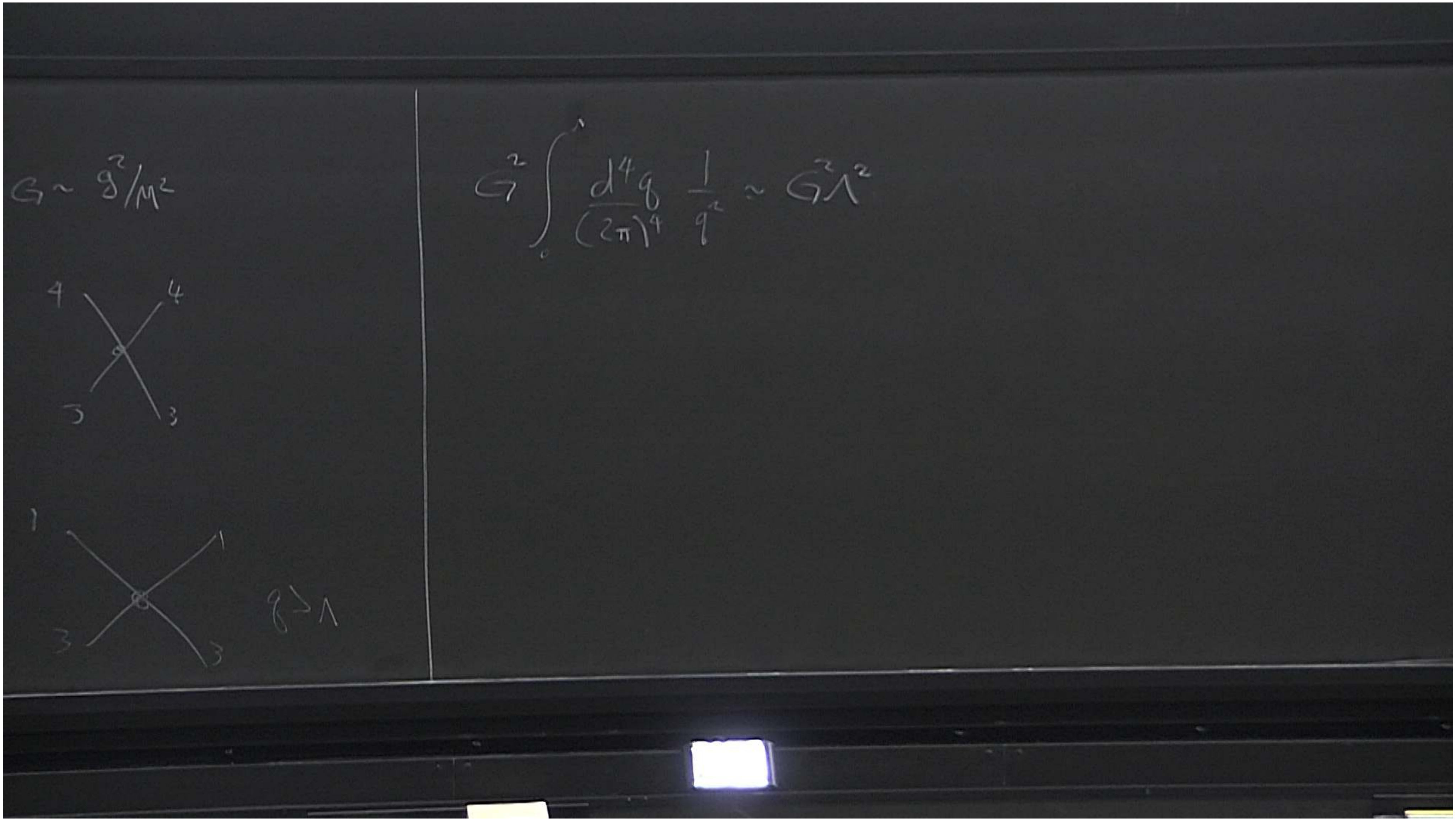
Title: PSI 17/18 - Beyond Standard Model - lecture 7

Date: Feb 27, 2018 09:00 AM

URL: http://pirsa.org/18020107

Abstract:

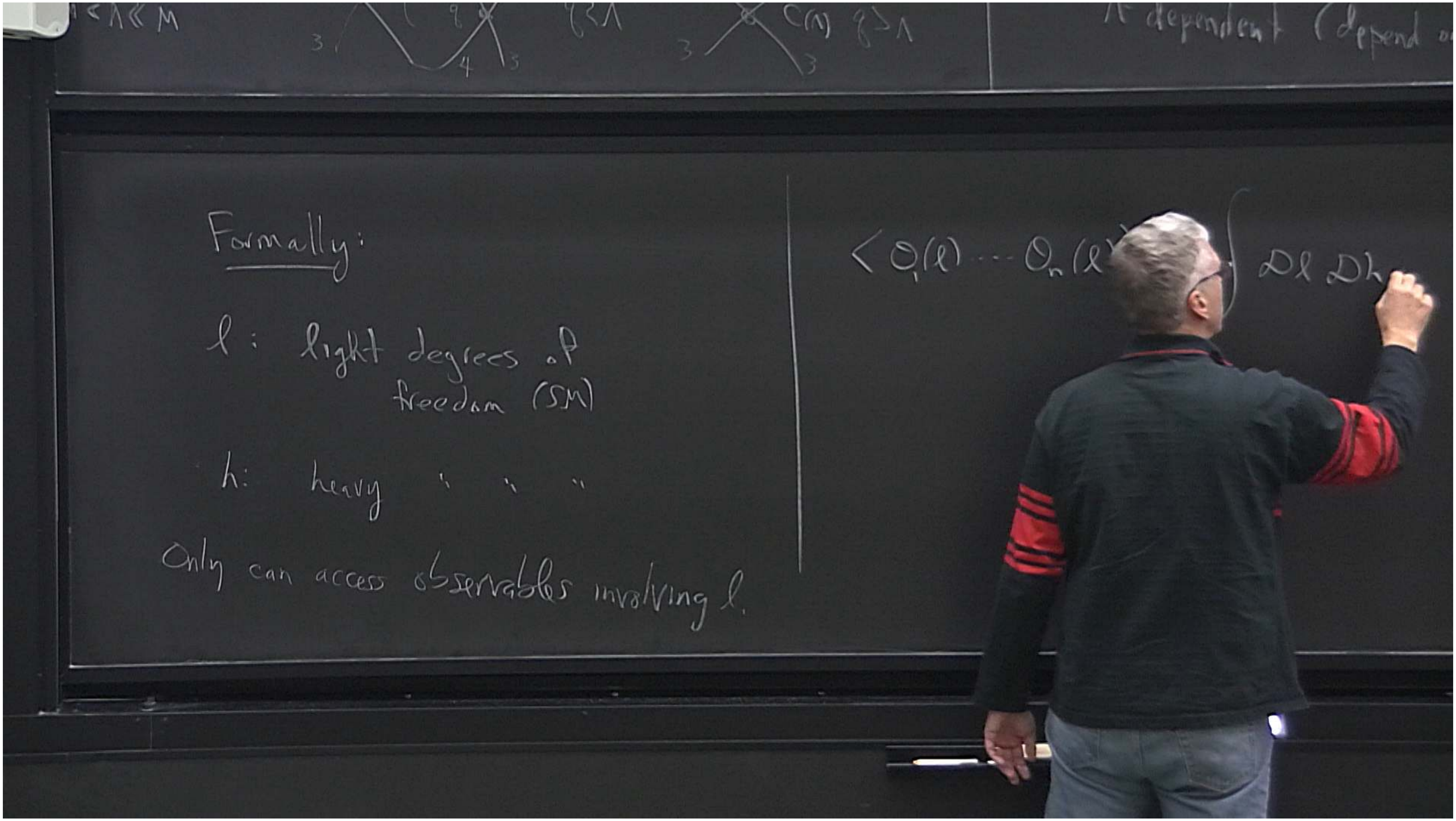

G ~ g²/M²
m < Λ ≪ M
q < Λ
q > Λ


$G \sim g^2/M^2$
$G^2 \int_0^\Lambda \frac{d^4q}{(2\pi)^4} \frac{1}{q^2} \sim G^2\Lambda^2$
4
4
3
3
1
1
3
3
$q > \Lambda$

$$G^2 \int_0^{\Lambda} \frac{d^4q}{(2\pi)^4} \frac{1}{q^2} \sim G^2\Lambda^2$$

the effective couplings
describing low-energy implications
of high-energy states must be
Λ-dependent (depend on details of

$\rightarrow$ low-high energy split.


Formally:
l : light degrees of freedom (SM)
h: heavy " " "
Only can access observables involving l.
< O1(l) ... On(l) > = ∫ Dl Dh

$C(\Lambda)$ $E > \Lambda$

Λ-dependent (depend on details of

$$\langle T^*[O_1(\ell) \cdots O_n(\ell)] \rangle = \int \mathcal{D}\ell\, \mathcal{D}h\, e^{iS(\ell,h)}\, O_1(\ell) \cdots O_n(\ell)$$

involving ℓ.

$C(\Lambda)\quad q > \Lambda$

Λ-dependent (depend on details of

$$\langle T^*[O_1(\ell)\cdots O_n(\ell)]\rangle = \int \mathcal{D}\ell\, \boxed{\mathcal{D}h\; e^{iS(\ell,h)}}\, O_1(\ell)\cdots O_n(\ell)$$

involving ℓ.

$C(\Lambda)\, g^3 \Lambda$

Λ dependent (depend on details of

$$\langle T^*[O_1(\ell)\cdots O_n(\ell)]\rangle = \int \mathcal{D}\ell \boxed{\mathcal{D}h\; e^{iS(\ell,h)}}\, O_1(\ell)\cdots O_n(\ell)$$

$$e^{i\underbrace{S_W(\ell)}_{\text{Wilson action}}} = \int \mathcal{D}h\; e^{iS(\ell,h)}$$

nvolving ℓ.

... dependent (depend on details of ...

$$\ldots \mathcal{O}_n(\ell)\rangle = \int \mathcal{D}\ell \boxed{\int \mathcal{D}h\, e^{iS(\ell,h)}}\, \mathcal{O}_1(\ell)\cdots\mathcal{O}_n(\ell) = \int \mathcal{D}\ell\, e^{iS_w(\ell)}\, \mathcal{O}_1(\ell)\cdots\mathcal{O}_n(\ell)$$

$$e^{i\underbrace{S_w(\ell)}_{\text{...on action}}} = \int \mathcal{D}h\, e^{iS(\ell,h)}$$

dependent (depend on details of

$$\left.\mathcal{O}_n(\ell)\right]\rangle = \int \mathcal{D}\ell_\Lambda \boxed{\mathcal{D}h_\Lambda\, e^{iS(\ell,h)}}\, \mathcal{O}_1(\ell) \cdots \mathcal{O}_n(\ell) = \int \mathcal{D}\ell\; e^{iS_W(\ell)}\, \mathcal{O}_1(\ell) \cdots \mathcal{O}_n(\ell)$$

$$e^{iS_W(\ell)} = \int \mathcal{D}h\, e^{iS(\ell,h)}$$

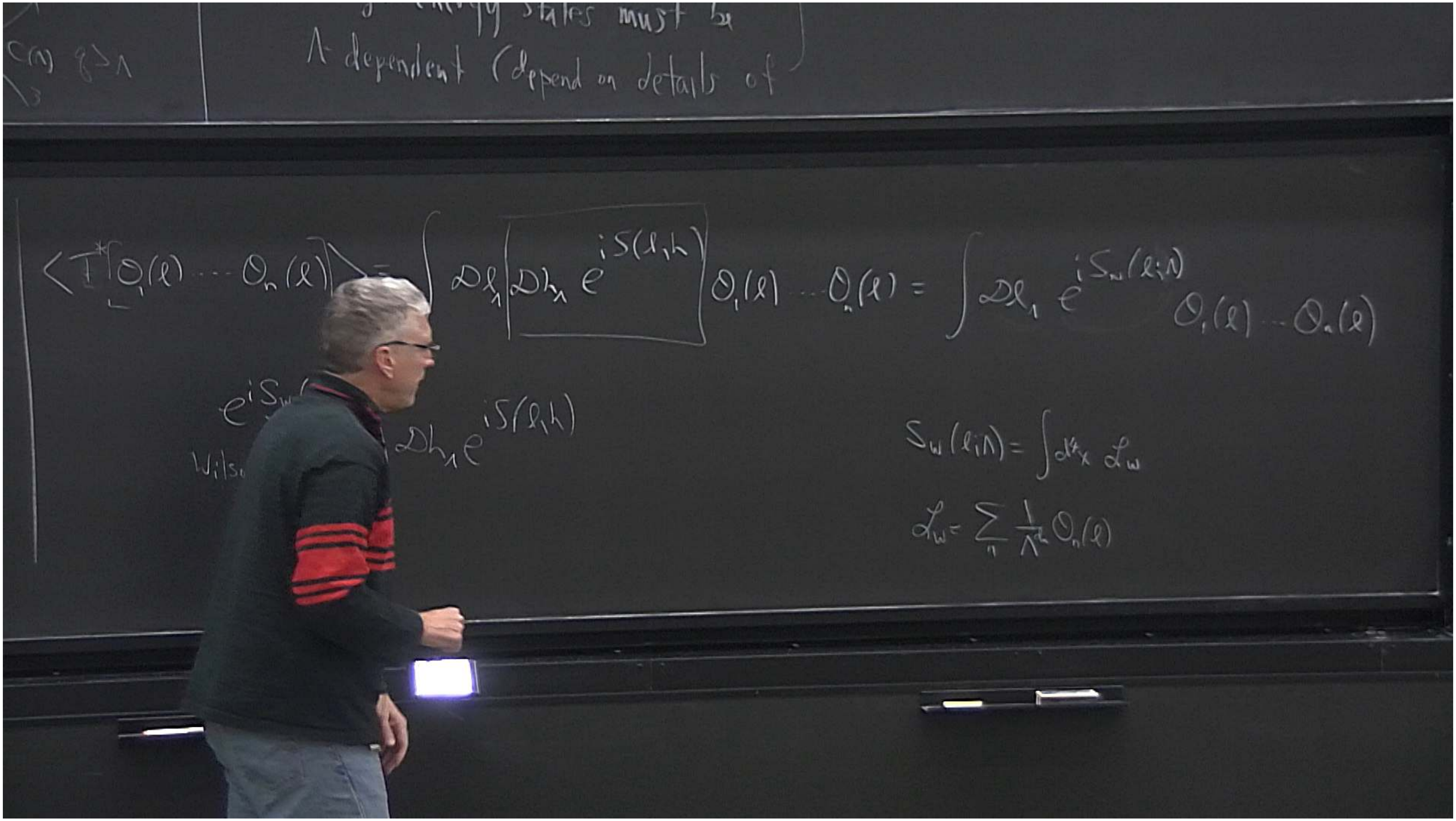
...on action

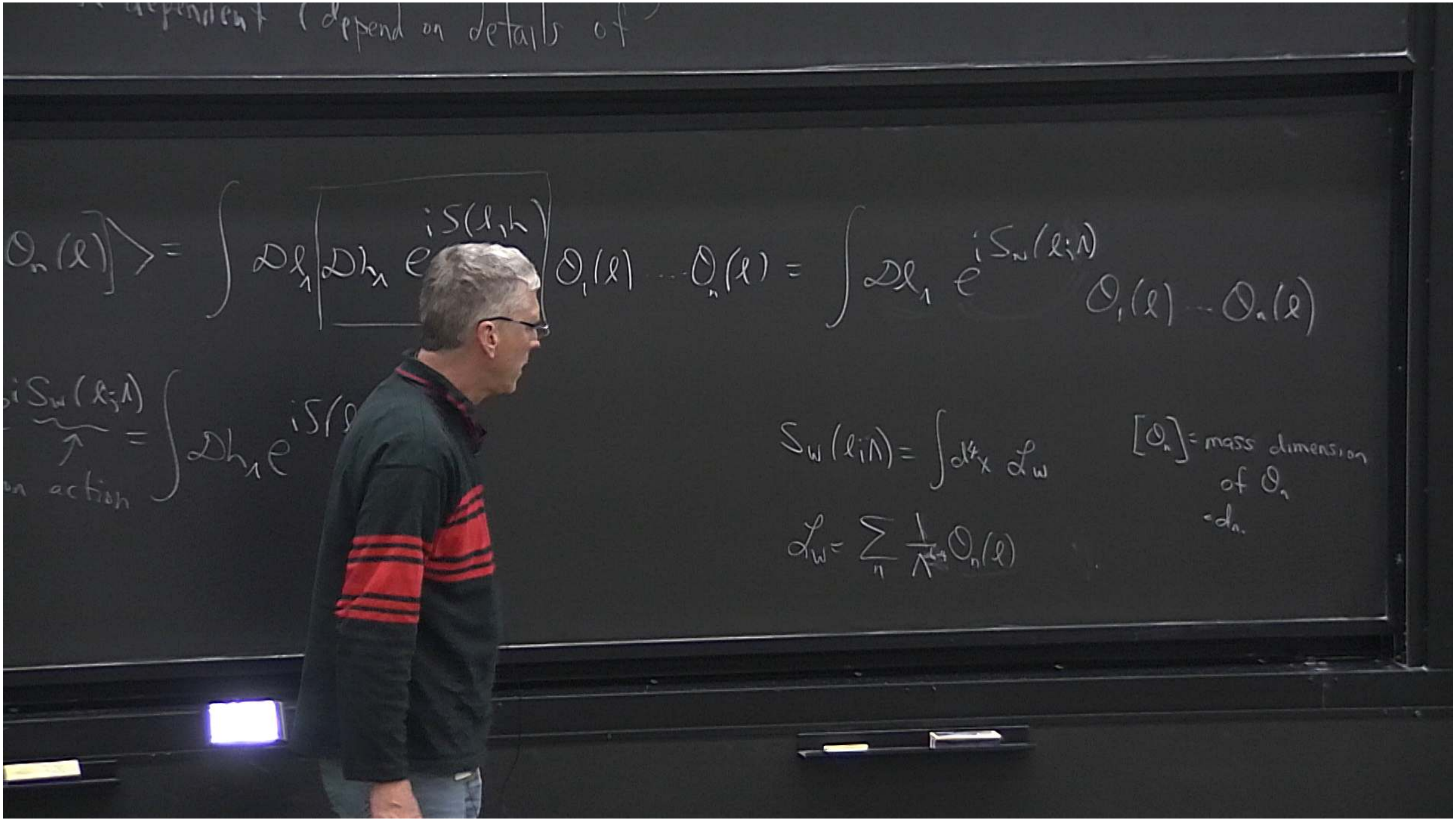
... states must be
Λ-dependent (depend on details of

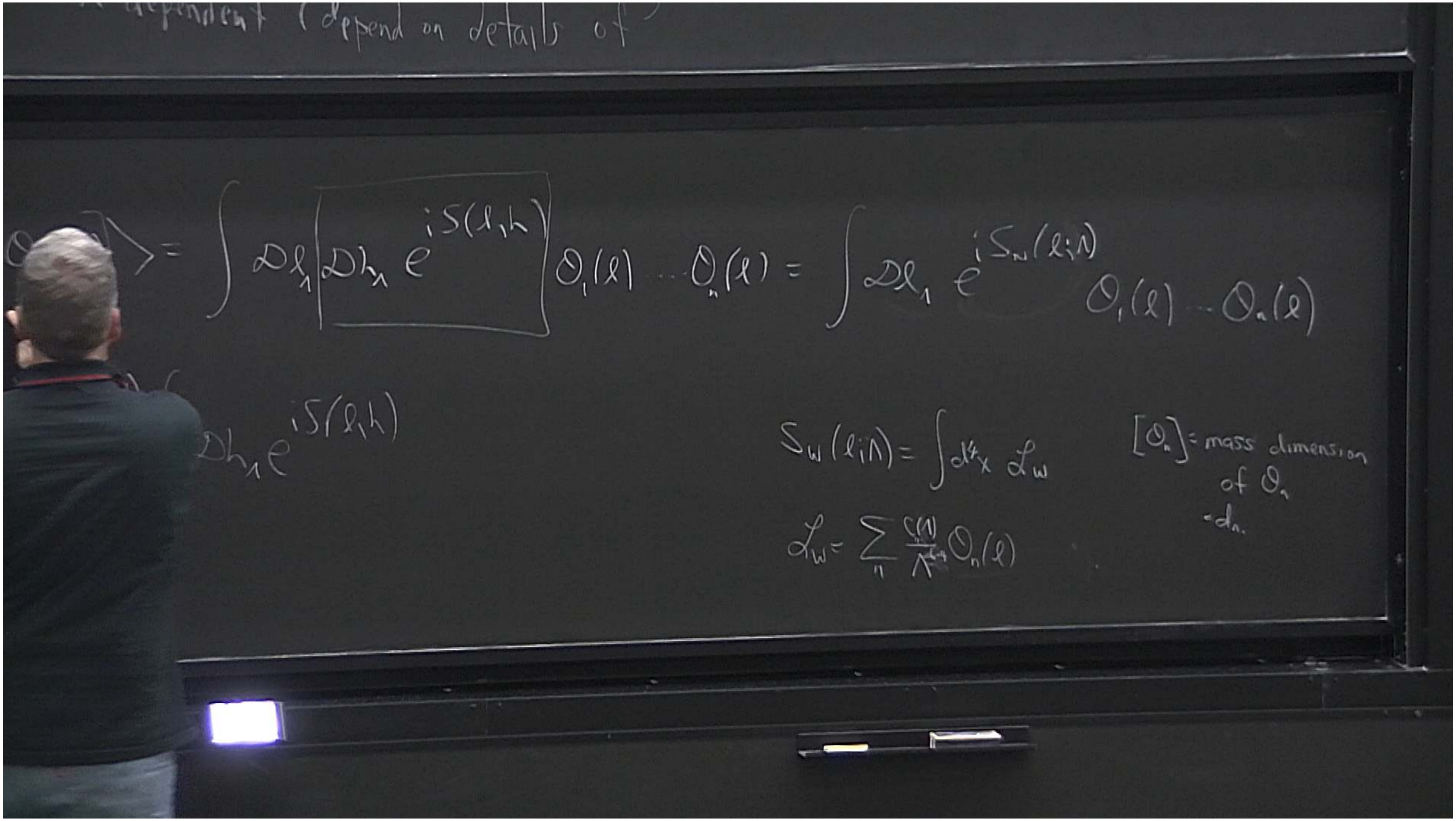
$C(\Lambda)$ $\xi > \Lambda$

$$\langle T^*[O_1(\ell)\cdots O_n(\ell)]\rangle = \int \mathcal{D}\ell_\Lambda \boxed{\mathcal{D}h_\Lambda\, e^{iS(\ell,h)}}\, O_1(\ell)\cdots O_n(\ell) = \int \mathcal{D}\ell_\Lambda\, e^{iS_W(\ell;\Lambda)}\, O_1(\ell)\cdots O_n(\ell)$$

$$e^{i\underbrace{S_W(\ell;\Lambda)}_{\text{Wilson action}}} = \int \mathcal{D}h_\Lambda\, e^{iS(\ell,h)}$$

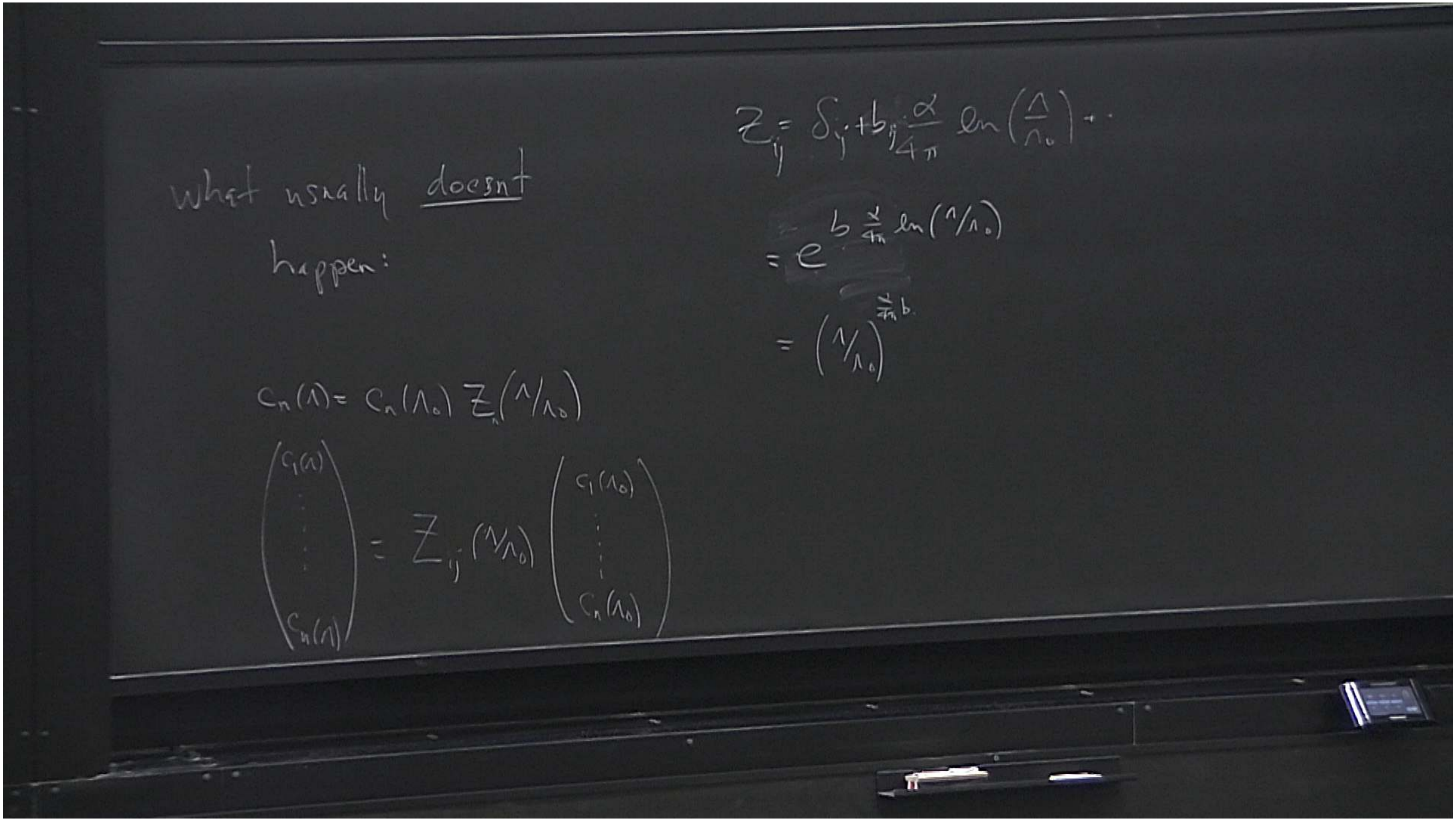

states must be
Λ-dependent (depend on details of
S_W(l;Λ) = ∫d⁴x L_W
L_W = Σ_n 1/Λ^k O_n(l)


dependent (depend on details of
$\mathcal{O}_n(\ell)]\rangle = \int \mathcal{D}\ell_\Lambda \boxed{\mathcal{D}h_\Lambda\, e^{iS(\ell,h)}}\, \mathcal{O}_1(\ell)\cdots\mathcal{O}_n(\ell) = \int \mathcal{D}\ell_\Lambda\, e^{iS_w(\ell;\Lambda)}\, \mathcal{O}_1(\ell)\cdots\mathcal{O}_n(\ell)$
$e^{iS_w(\ell;\Lambda)} = \int \mathcal{D}h_\Lambda e^{iS(\ell}$
on action
$S_w(\ell;\Lambda) = \int d^4x\, \mathcal{L}_w$
$\mathcal{L}_w = \sum_n \frac{1}{\Lambda^{d_n-4}}\mathcal{O}_n(\ell)$
$[\mathcal{O}_n]$ = mass dimension of $\mathcal{O}_n$
$= d_n$.

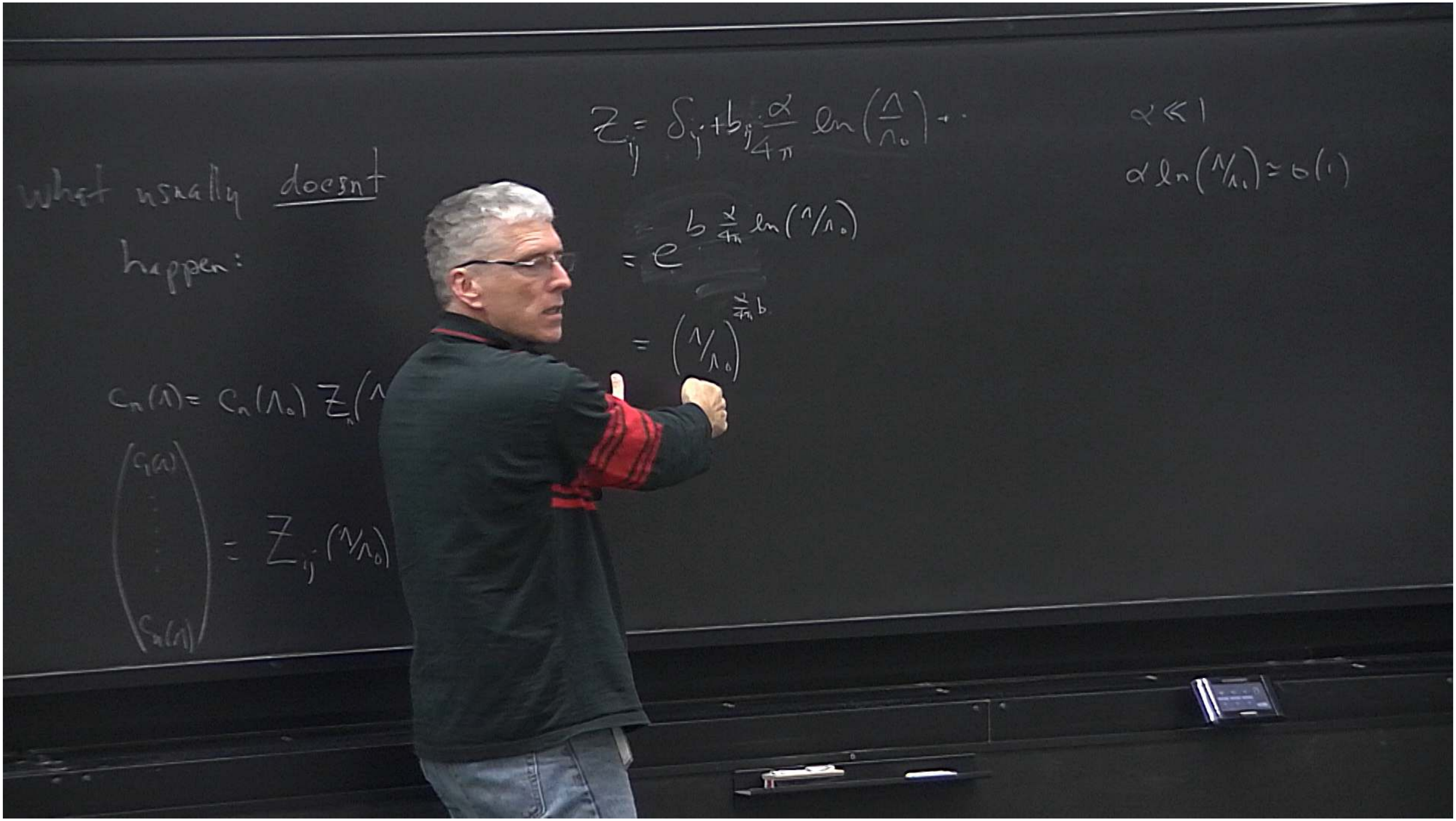

dependent (depend on details of
$\langle \mathcal{O} \ldots \rangle = \int \mathcal{D}l_\Lambda \boxed{\int \mathcal{D}h_\Lambda\, e^{iS(l,h)}}\, \mathcal{O}_1(l) \cdots \mathcal{O}_n(l) = \int \mathcal{D}l_\Lambda\, e^{iS_W(l;\Lambda)}\, \mathcal{O}_1(l) \cdots \mathcal{O}_n(l)$
$\mathcal{D}h_\Lambda\, e^{iS(l,h)}$
$S_W(l;\Lambda) = \int d^4x\, \mathcal{L}_W$
$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} \mathcal{O}_n(l)$
$[\mathcal{O}_n]$ = mass dimension of $\mathcal{O}_n$ $= d_n$.

what usually <u>doesn't</u> happen:

$$c_n(\Lambda) = c_n(\Lambda_0)\, Z_n(\Lambda/\Lambda_0)$$



$Z_{ij} = \delta_{ij} + b_{ij}\frac{\alpha}{4\pi}\ln\left(\frac{\Lambda}{\Lambda_0}\right) + \cdots$
$= e^{b\frac{\alpha}{4\pi}\ln(\Lambda/\Lambda_0)}$
$= \left(\Lambda/\Lambda_0\right)^{\frac{\alpha}{4\pi}b}$
what usually doesn't happen:
$c_n(\Lambda) = c_n(\Lambda_0)\, Z_n(\Lambda/\Lambda_0)$
$\begin{pmatrix} c_1(\Lambda) \\ \vdots \\ c_n(\Lambda) \end{pmatrix} = Z_{ij}(\Lambda/\Lambda_0) \begin{pmatrix} c_1(\Lambda_0) \\ \vdots \\ c_n(\Lambda_0) \end{pmatrix}$


what usually doesnt happen:
$Z_{ij} = \delta_{ij} + b_{ij} \frac{\alpha}{4\pi} \ln\left(\frac{\Lambda}{\Lambda_0}\right) + \cdots$
$\alpha \ll 1$
$\alpha \ln(\Lambda/\Lambda_0) \simeq O(1)$
$= e^{b \frac{\alpha}{4\pi} \ln(\Lambda/\Lambda_0)}$
$= (\Lambda/\Lambda_0)^{\frac{\alpha}{4\pi} b}$
$= Z_{ij} (\Lambda/\Lambda_0)$

What usually <u>doesnt</u> happen:

$$c_n(\Lambda) = c_n(\Lambda_0)\, Z_n(\Lambda/\Lambda_0)$$

$$\begin{pmatrix} c_1(\Lambda) \\ \vdots \\ c_n(\Lambda) \end{pmatrix} = Z_{ij}(\Lambda/\Lambda_0) \begin{pmatrix} c_1(\Lambda_0) \\ \vdots \\ c_n(\Lambda_0) \end{pmatrix}$$

$$Z_{ij} = \delta_{ij} + b_{ij}\frac{\alpha}{4\pi}\ln\left(\frac{\Lambda}{\Lambda_0}\right) + \cdots$$

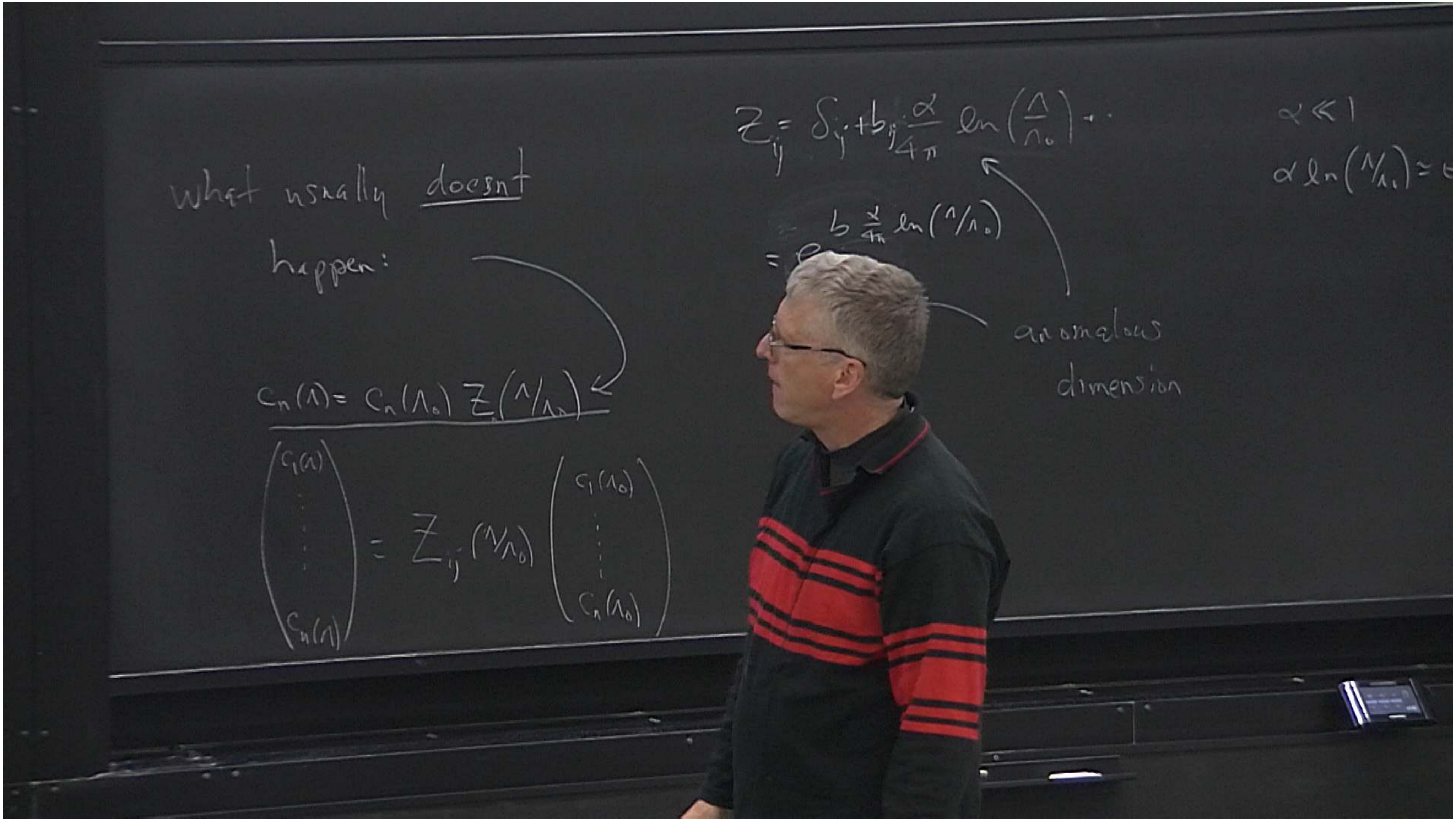
$$= e^{b\frac{\alpha}{4\pi}\ln(\Lambda/\Lambda_0)}$$

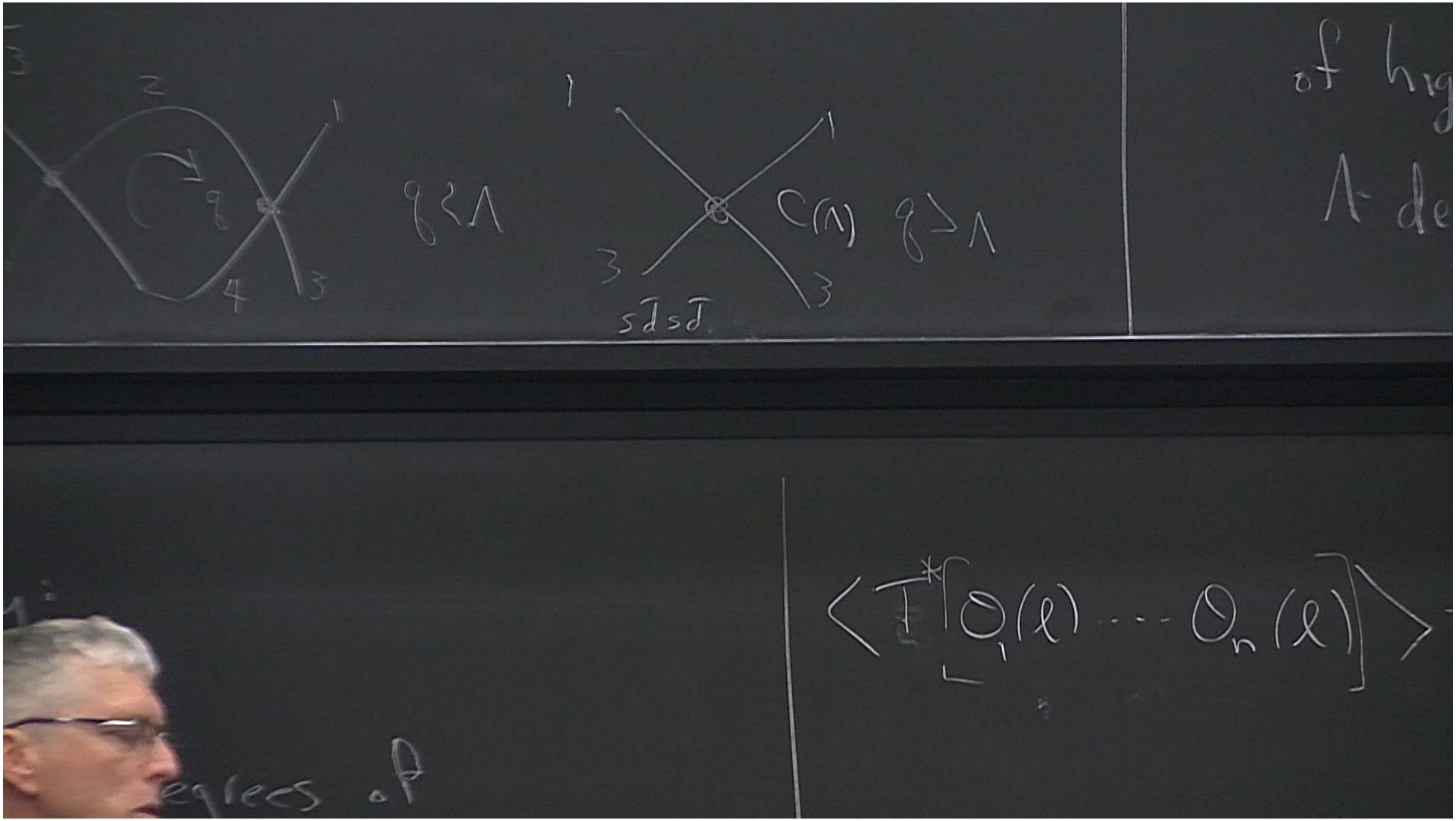
$$= \left(\Lambda/\Lambda_0\right)^{\frac{\alpha}{4\pi}b}$$

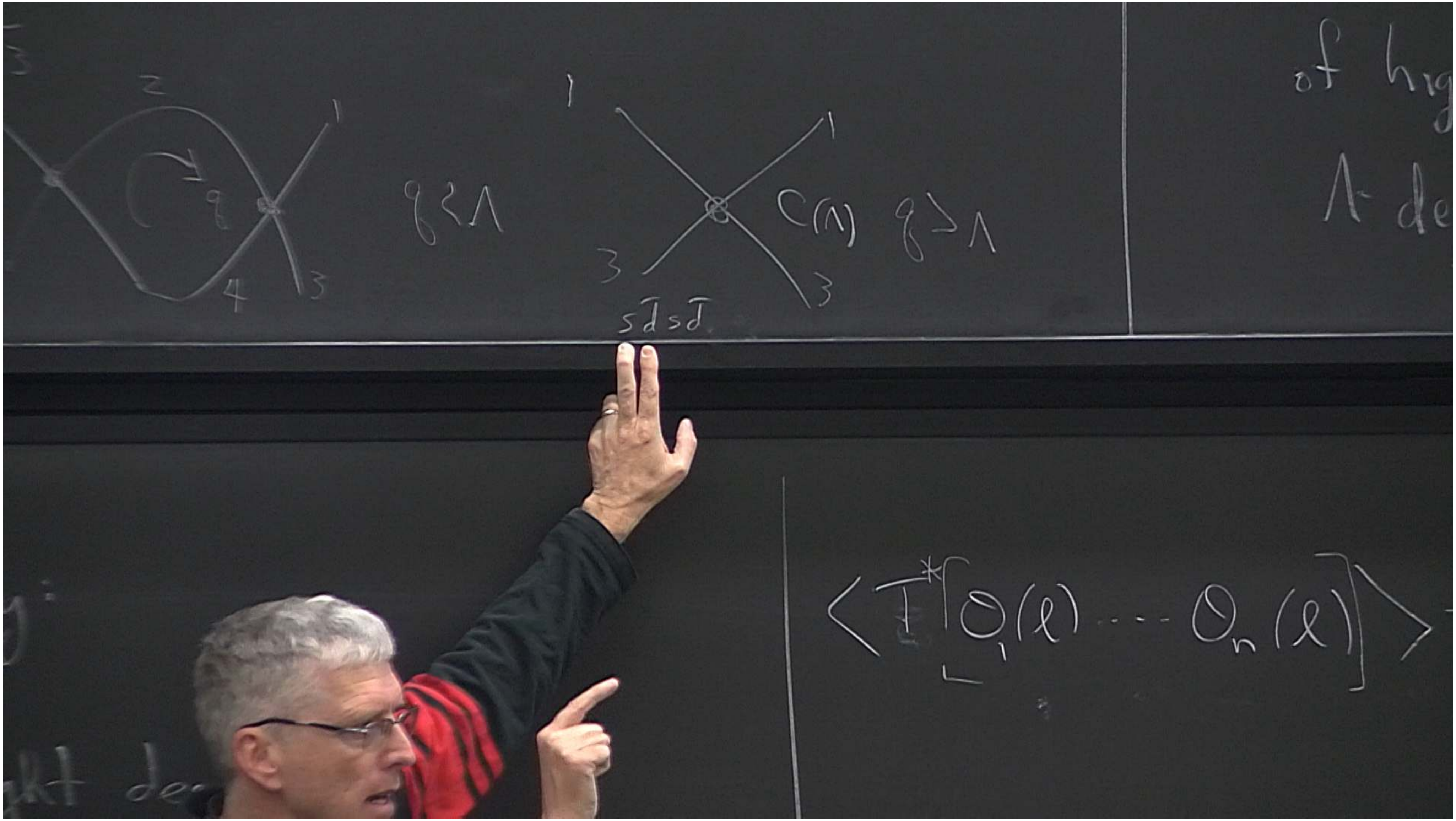
anomalous dimension

$\alpha \ll 1$

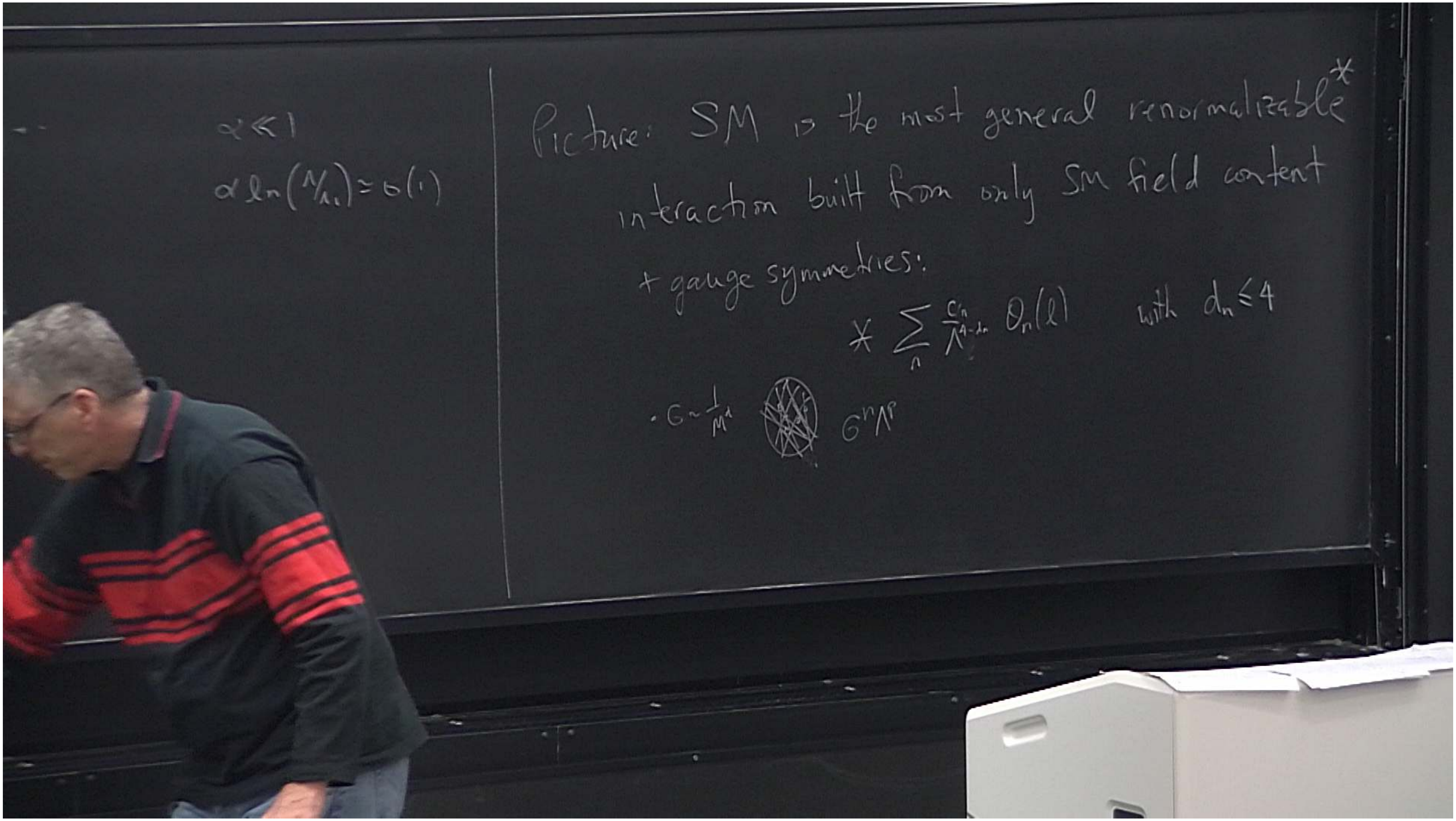
$\alpha \ln(\Lambda/\Lambda_1) \simeq O(1)$

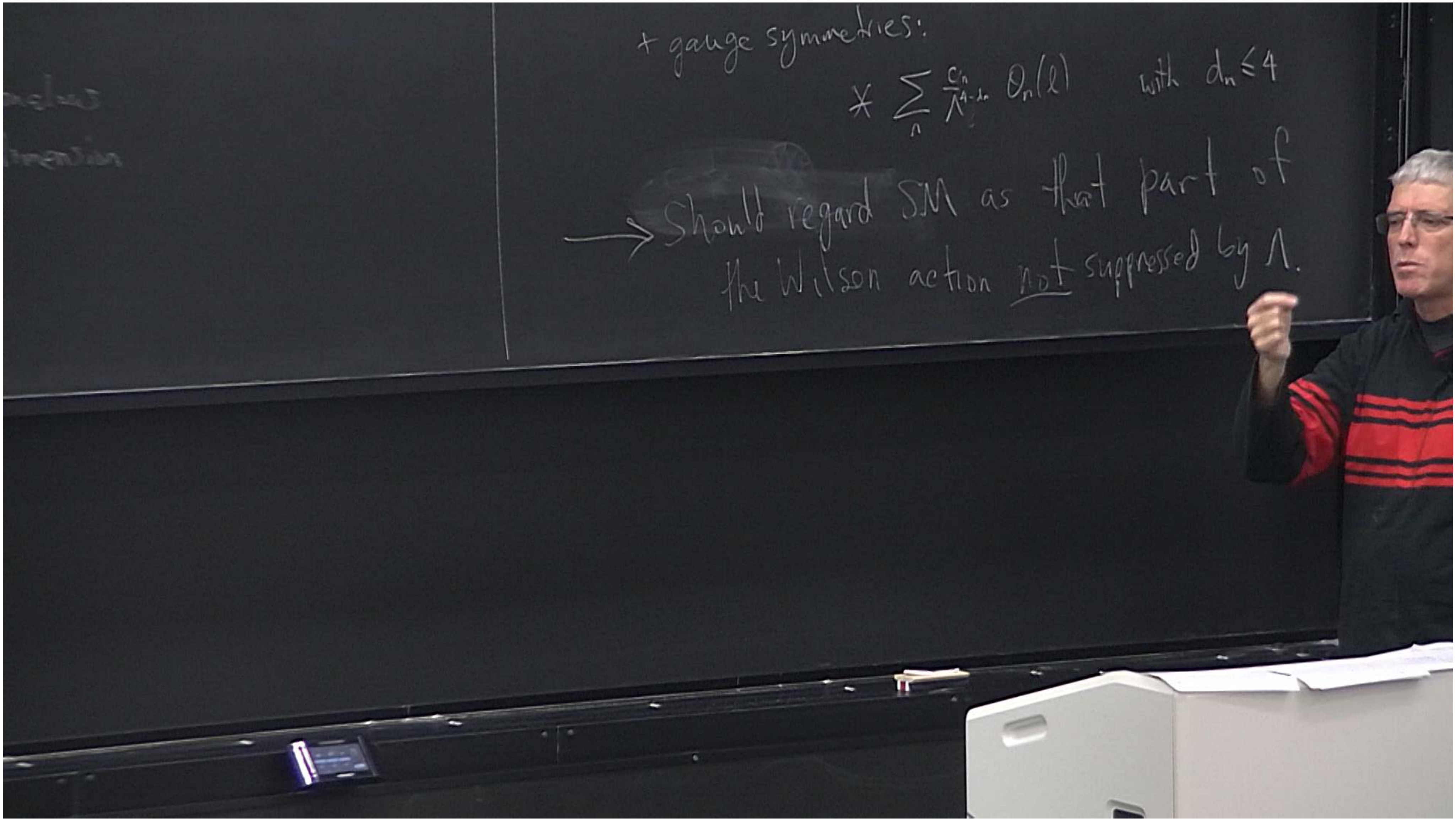

what usually doesn't happen:
$c_n(\Lambda) = c_n(\Lambda_0)\, Z(\Lambda/\Lambda_0)$
$\begin{pmatrix} c_1(\Lambda) \\ \vdots \\ c_n(\Lambda) \end{pmatrix} = Z_{ij}(\Lambda/\Lambda_0) \begin{pmatrix} c_1(\Lambda_0) \\ \vdots \\ c_n(\Lambda_0) \end{pmatrix}$
$Z_{ij} = \delta_{ij} + b_{ij} \frac{\alpha}{4\pi} \ln\left(\frac{\Lambda}{\Lambda_0}\right) + \dots$
$= e^{b \frac{\alpha}{4\pi} \ln(\Lambda/\Lambda_0)}$
anomalous dimension
$\alpha \ll 1$
$\alpha \ln(\Lambda/\Lambda_0) \simeq$

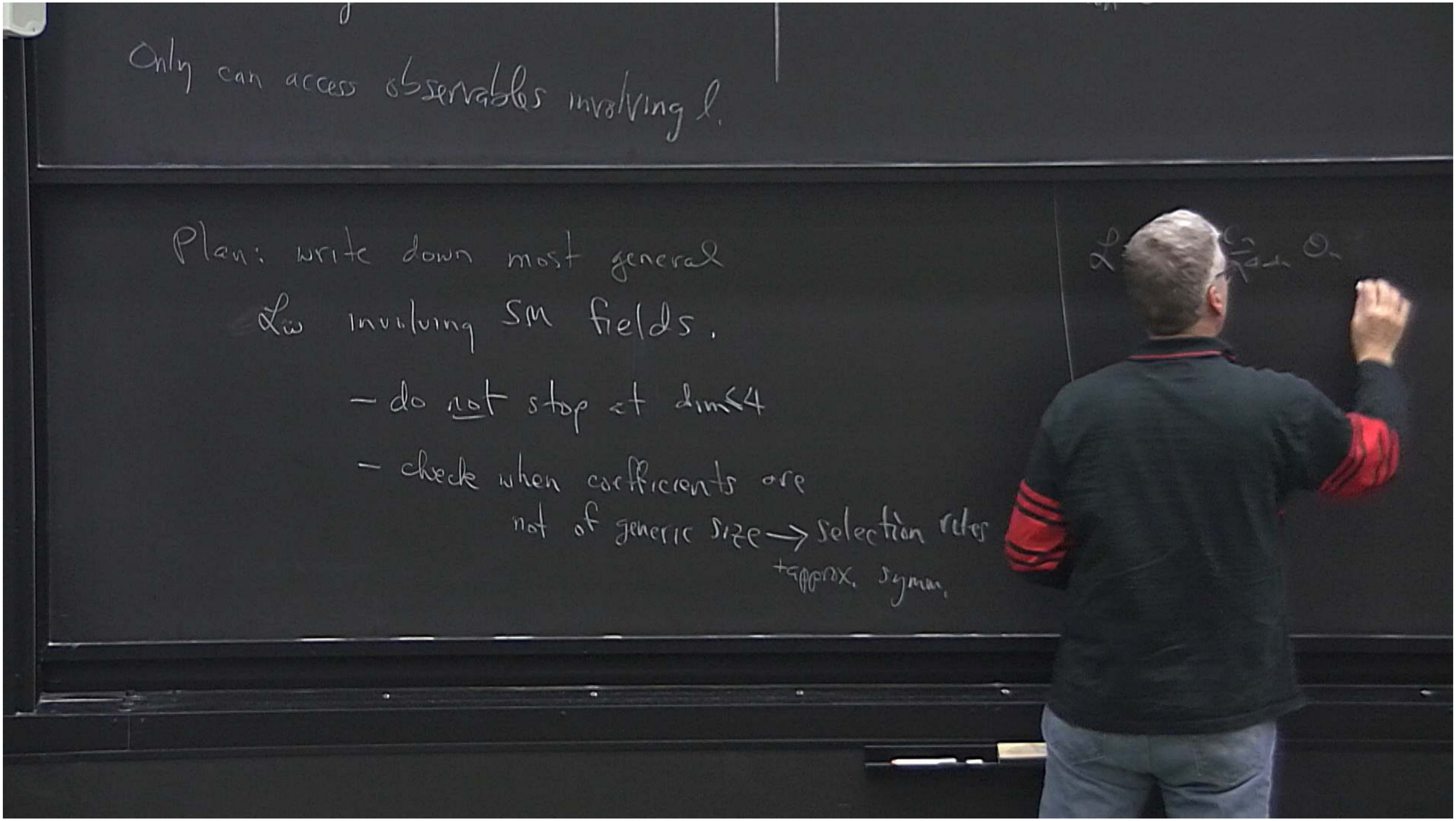

q < Λ
C(Λ) q > Λ
⟨T*[O_1(ℓ) .... O_n(ℓ)]⟩



$q < \Lambda$
$C(\Lambda)$ $q > \Lambda$
$s\bar{d}s\bar{d}$
of hig
Λ de
$\langle T^* [O_1(\ell) \cdots O_n(\ell)] \rangle$


$\alpha \ll 1$
$\alpha \ln(\Lambda/\Lambda_1) \simeq O(1)$
Picture: SM is the most general renormalizable*
interaction built from only SM field content
+ gauge symmetries:
$* \sum_n \frac{c_n}{\Lambda^{4-d_n}} O_n(\ell)$ with $d_n \leq 4$
$G \sim \frac{1}{M^2}$ $G^n \Lambda^p$


+ gauge symmetries:
$* \sum_n \frac{c_n}{\Lambda^{4-d_n}} O_n(\ell)$ with $d_n \leq 4$
Should regard SM as that part of
the Wilson action not suppressed by Λ.


Only can access observables involving l.
Plan: write down most general
Lω involving SM fields.
- do not stop at dim≤4
- check when coefficients are
not of generic size → selection rules
+approx. symm.

$$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} O_n(\ell)$$

$= d_n.$

$$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} O_n$$

dim 0: 1 $(\sqrt{-g})$ cosmological constant (Dark Energy) c.f. Λ^4 (cosmolog const prob)

if coeff $\approx (10^{-3}\,\mathrm{eV})^4$

dim 2: $\mu^2 \phi^\dagger \phi$ $\quad \mu \approx 100$ GeV (Higgs mass, G_F) $\quad \Lambda^2$ (electroweak hierarchy)

dim 4: $(\phi^\dagger\phi)^2 \quad ff\phi \quad F_{\mu\nu}^2 \quad f \not{D} f \quad (D\phi)^\dagger (D\phi)$

$$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} O_n(\ell)$$

$= d_n$

$$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} O_n$$

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dim 2: $\mu^2 \phi^\dagger \phi$ $\mu \approx 100$ GeV (Higgs mass, G_F) Λ^2 (electroweak hierarchy)

dim 4: $(\phi^\dagger\phi)^2$ $ff\phi$ $F_{\mu\nu}^2$ $f \not{D} f$ $(D\phi)^\dagger(D\phi)$ | $\theta \epsilon^{\mu\nu\lambda\rho} \underline{F_{\mu\nu} F_{\lambda\rho}}$

$$\mathcal{L}_W = \sum_n \frac{c(\Lambda)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$$

$= d_n$

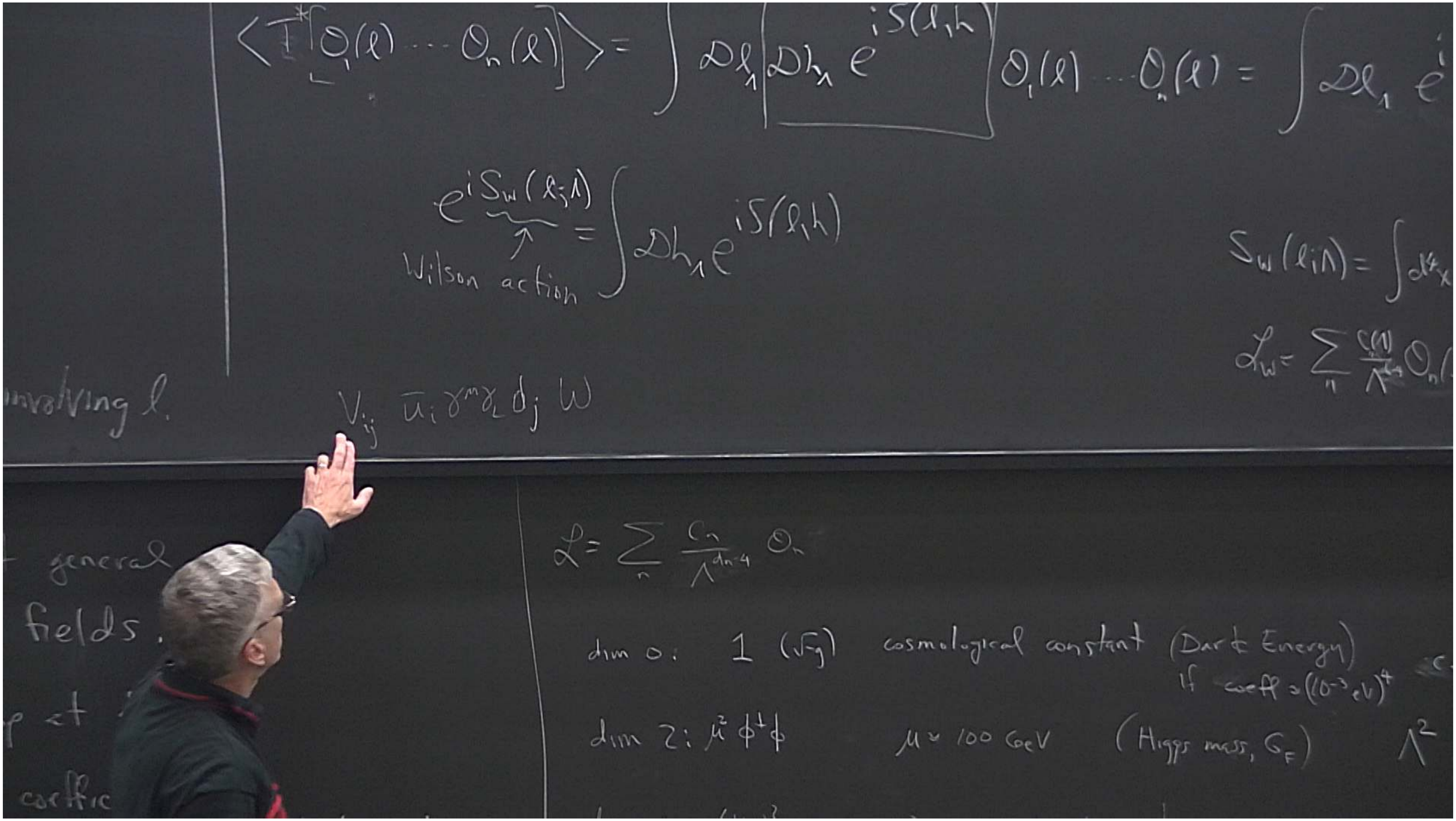
$$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} \mathcal{O}_n$$

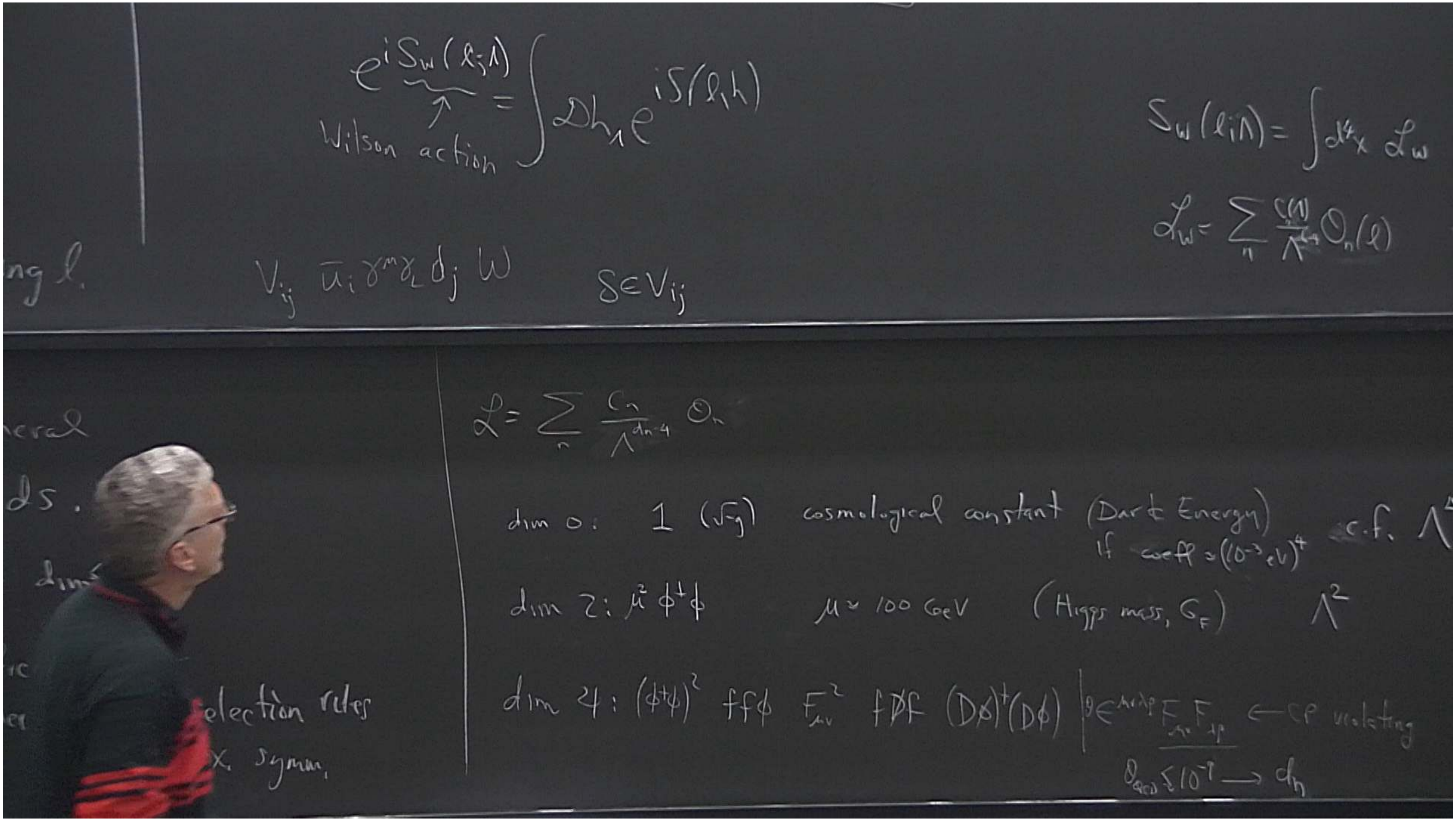
dim 0: 1 ($\sqrt{-g}$) cosmological constant (Dark Energy) c.f. Λ^4 (cosmolog const prob)
if coeff $\approx (10^{-3}\,\mathrm{eV})^4$

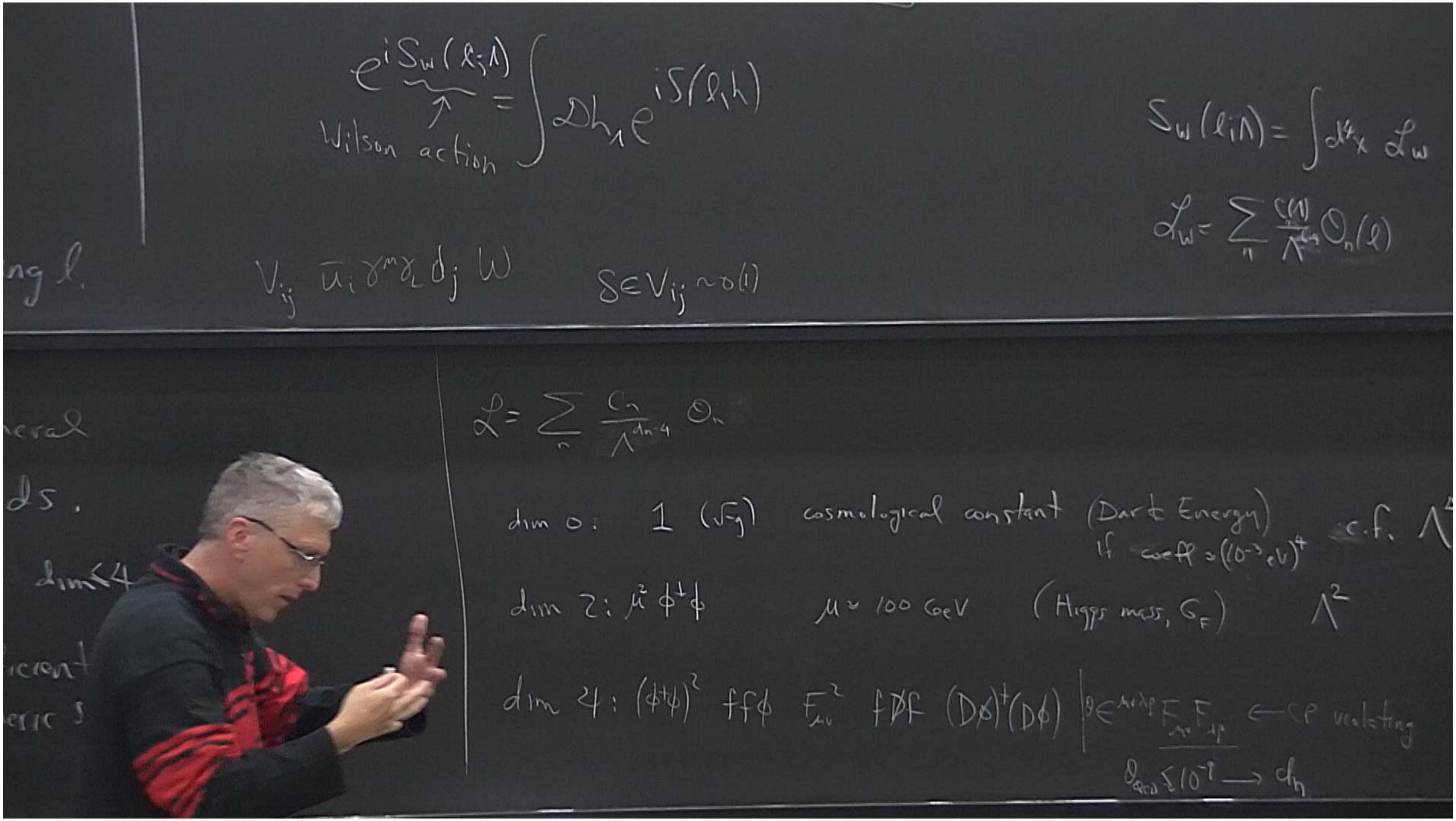
dim 2: $\mu^2 \phi^\dagger \phi$ $\mu \approx 100$ GeV (Higgs mass, G_F) Λ^2 (electroweak hierarchy)

dim 4: $(\phi^\dagger\phi)^2$ $ff\phi$ $F_{\mu\nu}^2$ $f\not{D}f$ $(D\phi)^\dagger(D\phi)$ | $\theta\,\epsilon^{\mu\nu\lambda\rho}\underline{F_{\mu\nu}F_{\lambda\rho}}$ $\leftarrow$ CP violating (Strong CP problem)

$\theta_{QCD} \lesssim 10^{-9} \longrightarrow d_n$


Wilson action
involving l.
general
fields.
dim 0: 1
cosmological constant (Dark Energy)
dim 2:
μ ≈ 100 GeV
(Higgs mass, G_F)


$e^{iS_W(\ell;\Lambda)} = \int \mathcal{D}h_\Lambda e^{iS(\ell,h)}$
Wilson action
$S_W(\ell;\Lambda) = \int d^4x\, \mathcal{L}_W$
$\mathcal{L}_W = \sum_n \frac{c(\Lambda)}{\Lambda^{d_n-4}} O_n(\ell)$
ng ℓ.
$V_{ij}\ \bar{u}_i \gamma^\mu \gamma_L d_j W$
$\delta \in V_{ij}$
$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} O_n$
dim 0: 1 $(\sqrt{-g})$ cosmological constant (Dark Energy)
if coeff $= (10^{-3}\,eV)^4$
c.f. Λ^4
dim 2: $\mu^2 \phi^\dagger \phi$ $\mu \approx 100$ GeV (Higgs mass, G_F) Λ^2
dim 4: $(\phi^\dagger\phi)^2$ $ff\phi$ $F_{\mu\nu}^2$ $f\not{D}f$ $(D\phi)^\dagger(D\phi)$
$\theta\epsilon^{\mu\nu\lambda\rho} F_{\mu\nu} F_{\lambda\rho}$ ← CP violating
$\theta_{QCD} \lesssim 10^{-9} \longrightarrow d_n$
election rules
x. symm.


e^{iS_W(l;Λ)} = ∫ Dh_Λ e^{iS(l,h)}
Wilson action
S_W(l;Λ) = ∫d⁴x L_W
L_W = Σ_n c_n(Λ)/Λ^{d_n-4} O_n(l)
V_ij ū_i γ^μ γ_L d_j W
δ ∈ V_ij ~ o(1)
L = Σ_n c_n/Λ^{d_n-4} O_n
dim 0: 1 (√-g) cosmological constant (Dark Energy) c.f. Λ⁴
if coeff ≈ (10⁻³ eV)⁴
dim 2: μ² φ†φ μ ≈ 100 GeV (Higgs mass, G_F) Λ²
dim 4: (φ†φ)² ffφ F_μν² fDf (Dφ)†(Dφ) θ ε^{μνλρ} F_μν F_λρ ← CP violating
θ_QCD ≲ 10⁻⁹ → d_n
ng l.
neral
ds.
dim ≤ 4
ferent
eric

d_j W $\quad \delta \epsilon V_{ij} \sim o(1)$

$$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$$

$\cdot d_n.$

$$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} \mathcal{O}_n$$

dim 0: 1 $(\sqrt{-g})$ cosmological constant (Dark Energy) c.f. Λ^4 (cosmolog const prob)

if coeff $\approx (10^{-3}\,\text{eV})^4$

dim 2: $\mu^2 \phi^\dagger \phi$ $\quad \mu \approx 100$ GeV (Higgs mass, G_F) $\quad \Lambda^2$ (electroweak hierarchy)

dim 4: $(\phi^\dagger\phi)^2$ $\;ff\phi$ $\;F_{\mu\nu}^2$ $\;f\not{D}f$ $\;(D\phi)^\dagger(D\phi)$ $\;\Big|\;$ $\theta \epsilon^{\mu\nu\lambda\rho} \underline{F_{\mu\nu} F_{\lambda\rho}}$ $\leftarrow$ CP violating (Strong CP problem)

$\theta_{QCD} \lesssim 10^{-9} \longrightarrow d_n \lesssim 10^{-26}$ e-cm

$$\mathcal{L}_W = \sum_n \frac{c(n)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$$

$= d_n$.

$d_j \, W$ $\qquad \delta \in V_{ij} \sim o(1)$

$$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} \mathcal{O}_n$$

dim 0: 1 $(\sqrt{-g})$ cosmological constant (Dark Energy) c.f. Λ^4 (cosmolog const prob)

if coeff $\approx (10^{-3}\,\mathrm{eV})^4$

dim 2: $\mu^2 \phi^\dagger \phi$ $\qquad \mu \approx 100$ GeV (Higgs mass, G_F) $\quad \Lambda^2$ (electroweak hierarchy)

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$\theta_{QCD} \lesssim 10^{-9} \longrightarrow d_n \lesssim 10^{-26}$ e-cm $\sim e (10^{12}\,\mathrm{GeV})^{-1}$

$\mathcal{L}_W = \sum_n \frac{c_n(\ell)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$

W $\quad \delta \in V_{ij} \sim O(1)$

$\mathcal{L} = \sum_n \frac{c_n}{\Lambda^{d_n-4}} \mathcal{O}_n \qquad T_{\mu\nu} = \lambda g_{\mu\nu} \leftarrow p = -\rho = -\lambda$

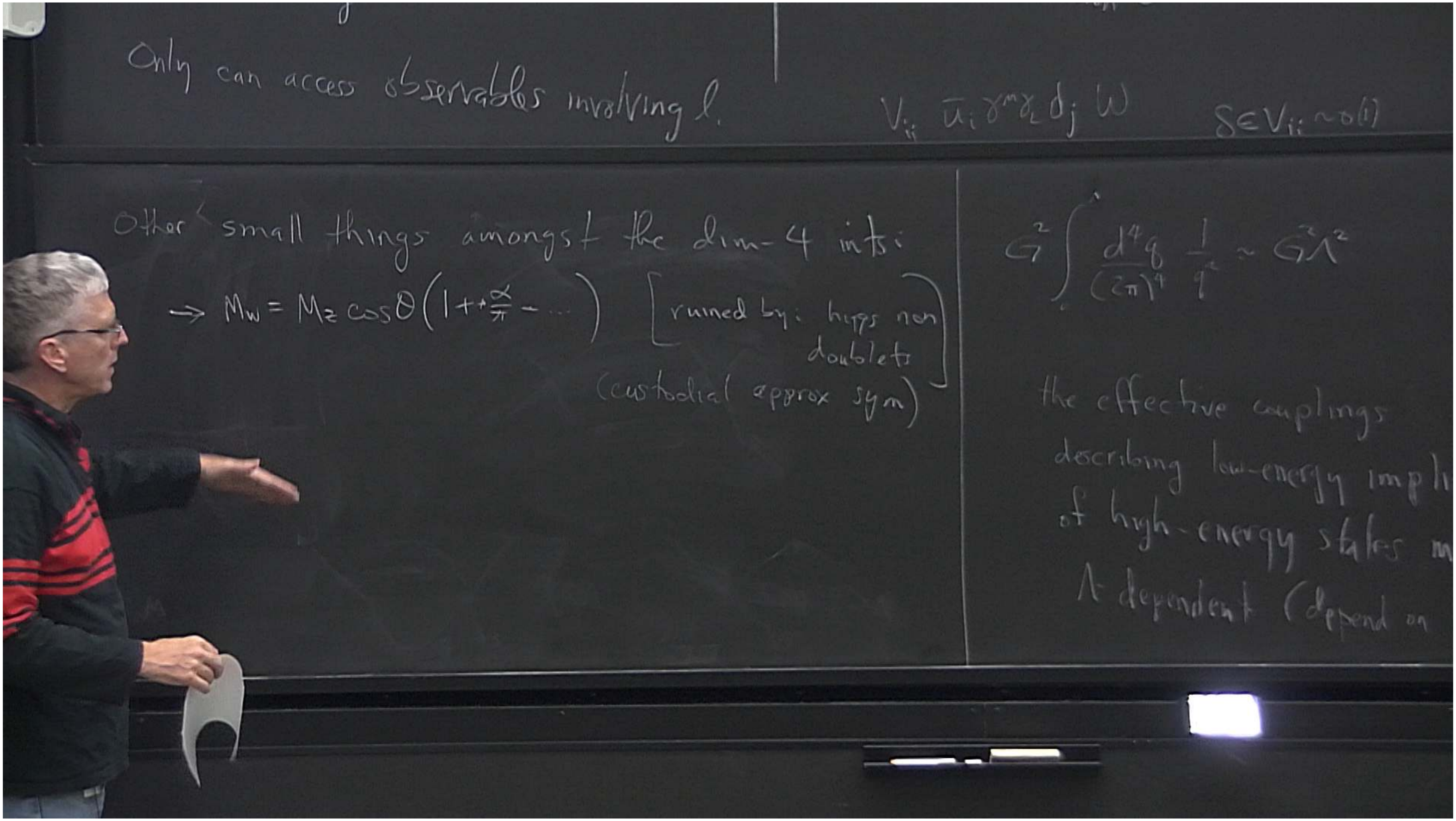
dim 0: $\lambda \; (\sqrt{-g})$ cosmological constant (Dark Energy) c.f. Λ^4 (cosmolog const prob)

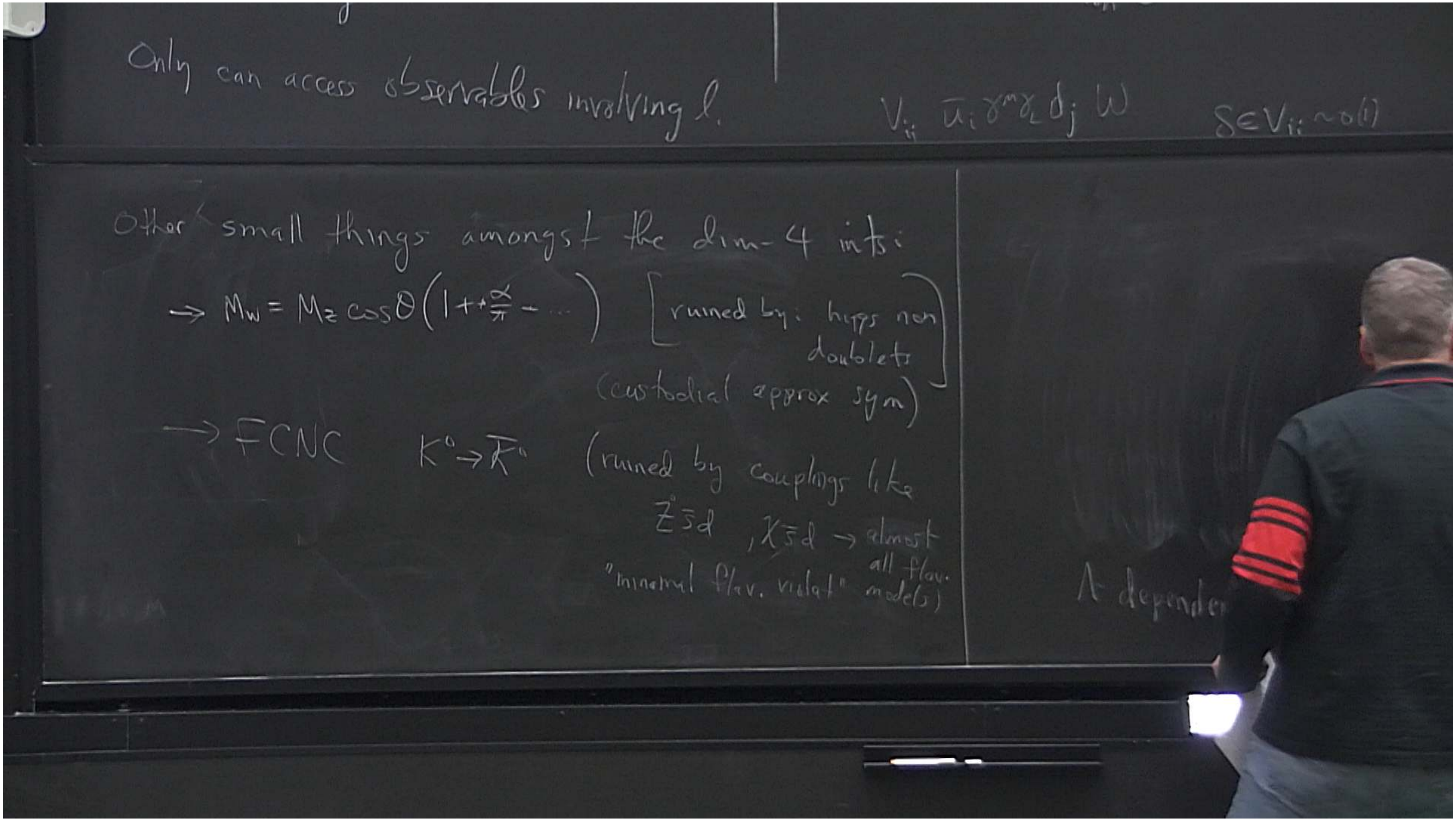
if coeff $\approx (10^{-3}\,\mathrm{eV})^4$

dim 2: $\mu^2 \phi^\dagger \phi \qquad \mu \approx 100$ GeV (Higgs mass, G_F) $\quad \Lambda^2$ (electroweak hierarchy)

dim 4: $(\phi^\dagger\phi)^2 \quad ff\phi \quad F_{\mu\nu}^2 \quad f\not{D}f \quad (D\phi)^\dagger(D\phi) \;\Big|\; \underline{\theta\,\epsilon^{\mu\nu\lambda\rho} F_{\mu\nu} F_{\lambda\rho}} \leftarrow$ CP violating (Strong CP problem)

$\theta_{QCD} \lesssim 10^{-9} \longrightarrow d_n \lesssim 10^{-26}$ e-cm $\sim e(10^{12}\,\mathrm{GeV})^{-1}$


Only can access observables involving l.
$V_{ij}\, \bar{u}_i \gamma^\mu \gamma_L d_j W$
$\delta \in V_{ij} \sim o(1)$
Other small things amongst the dim-4 ints:
$\rightarrow M_W = M_Z \cos\theta \left(1 + \frac{\alpha}{\pi} - \dots\right)$
[ruined by: higgs non doublets]
(custodial approx sym)
$G^2 \int \frac{d^4q}{(2\pi)^4} \frac{1}{q^2} \sim G^2 \Lambda^2$
the effective couplings
describing low-energy impl
of high-energy states
Λ-dependent (depend on


Only can access observables involving l.
V_ij ū_i γ^μ γ_L d_j W
δ∈V_ij ~ o(1)
Other small things amongst the dim-4 ints:
→ M_W = M_Z cosθ (1 + α/π − ...)
[ruined by: higgs non doublets]
(custodial approx sym)
→ FCNC K^0 → K̄^0
(ruined by couplings like
Z^0 s̄d , χ s̄d → almost all flav.
"minimal flav. violat" models)
Λ dependen

$$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$$

$\bar{u}_i \gamma^\mu \gamma_L d_j W$ $\quad \delta \in V_{ij} \sim o(1)$

(c) Z - coupling well known
(LEP)

(d) accidental symmetries

$\bar{u}_i \gamma^\mu \gamma_L d_j W$ $\quad \delta \in V_{ij} \sim o(1)$ $\quad \mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} O_n(\ell)$

(c) Z - coupling well known
(LEP)

(d) "accidental symmetries"

although not an input, conservation of
B, L_e, L_μ, L_τ, are accidentally valid

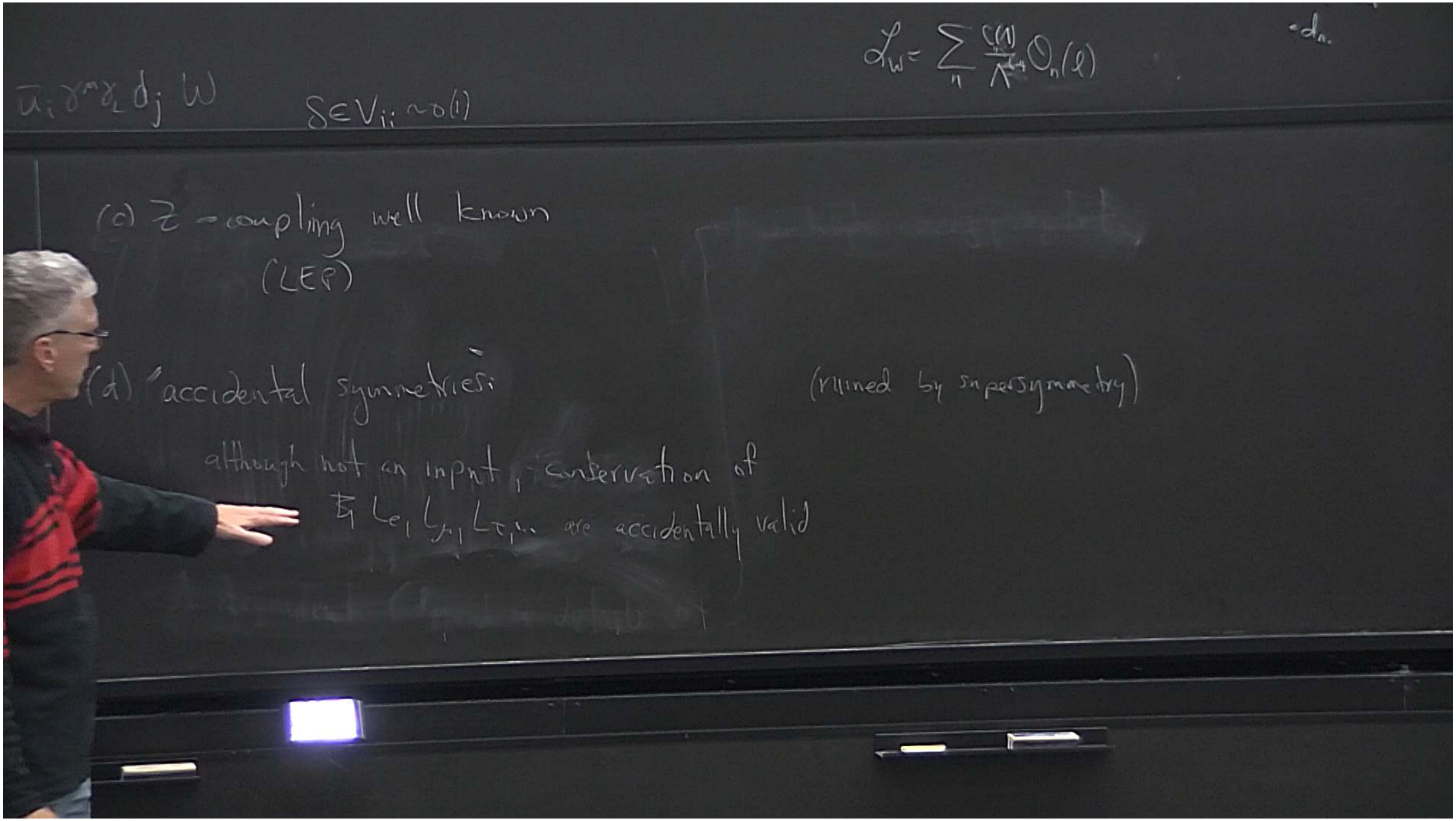
$$\mathcal{L}_W = \sum_n \frac{c(n)}{\Lambda^{d_n-4}} O_n(\ell)$$

$\bar{u}_i \gamma^\mu \gamma_L d_j W$ $\qquad \delta \epsilon V_{ij} \sim o(1)$

(c) Z - coupling well known (LEP)

(d) 'accidental' symmetries:

although not an input, conservation of B, L_e, L_μ, L_τ, ... are accidentally valid


$\mathcal{L}_W = \sum_n \frac{c(n)}{\Lambda^{d-4}} O_n(\ell)$
$\bar{u}_i \gamma^\mu \gamma_L d_j W$
$\delta \epsilon V_{ij} \sim O(1)$
(c) Z - coupling well known
(LEP)
(d) "accidental symmetries"
(ruined by supersymmetry)
although not an input, conservation of
B, Le, Lμ, Lτ,.. are accidentally valid

$\bar{u}_i \gamma^\mu \gamma_L d_j W$ $\delta \in V_{ij} \sim o(1)$

$\mathcal{L}_W = \sum_n \frac{c(n)}{\Lambda^{d-4}} O_n(\ell)$

(c) Z - coupling well known (LEP)

(d) 'accidental symmetries'

although not an input, conservation of B, L_e, L_μ, L_τ, .. are accidentally valid

(e) CP violation is small + involves all generations

(f) ...ence of ...entz-violat...

(ruined by supersymmetry) (" " "

$\chi_L d_j W$ $\delta \epsilon V_{ii} \sim o(1)$

$$\mathcal{L}_W = \sum_n \frac{c_n(\Lambda)}{\Lambda^{d_n-4}} \mathcal{O}_n(\ell)$$

$-d_n.$

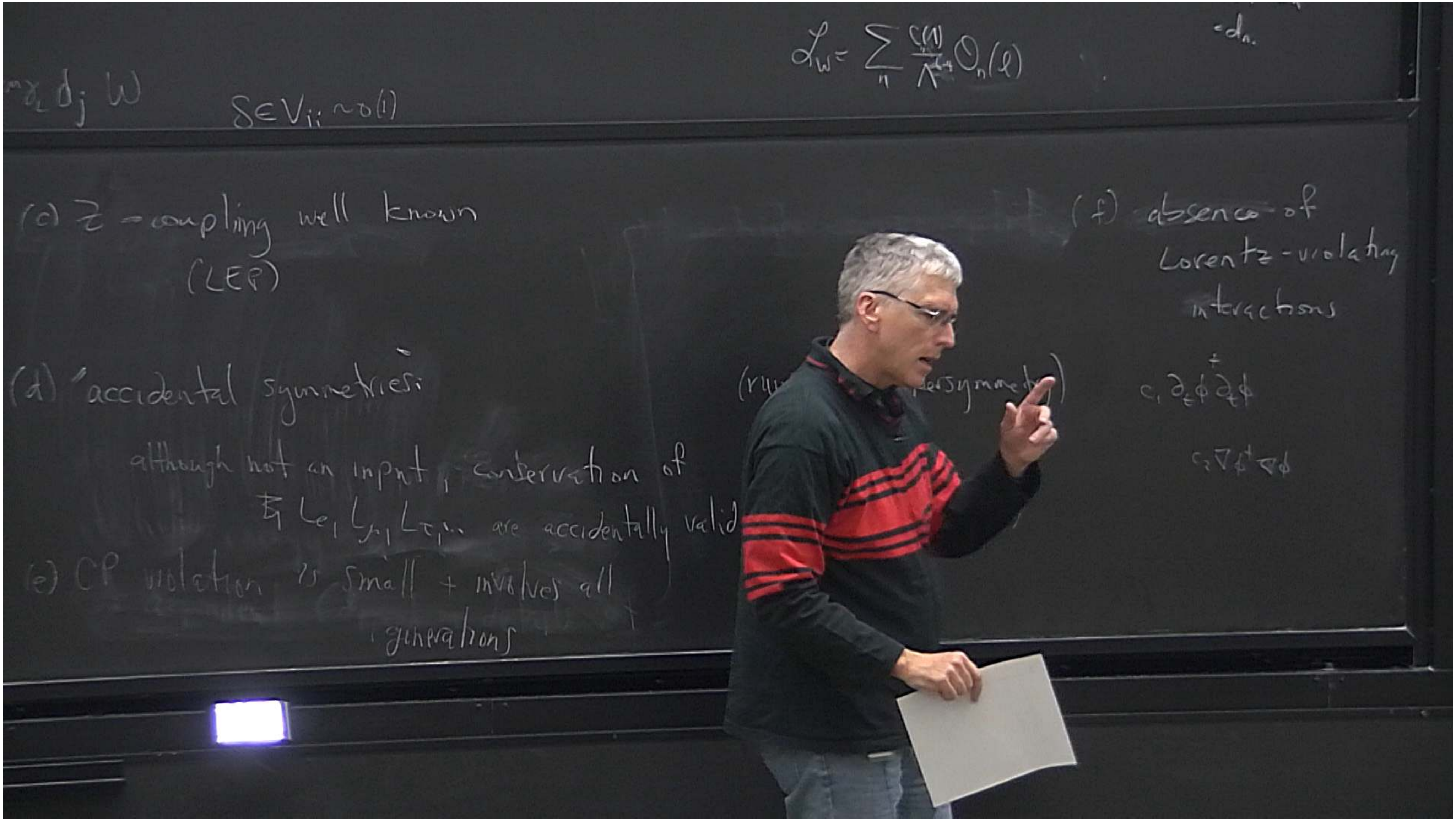
(c) Z-coupling well known (LEP)

(f) absence of Lorentz-violating interactions

(d) "accidental symmetries: (ruined by supersymmetry)

although not an input, conservation of $B, L_e, L_\mu, L_\tau, \ldots$ are accidentally valid (" " ")

(e) CP violation is small + involves all generations



$\mathcal{L}_W = \sum_n \frac{C(\Lambda)}{\Lambda^{d-4}} O_n(\ell)$
$\delta \in V_{ii} \sim o(1)$
(c) Z - coupling well known
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although not an input, conservation of
B, L_e, L_μ, L_τ, .. are accidentally valid
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$c_1 \partial_t \phi^\dagger \partial_t \phi$
$c_2 \nabla \phi^\dagger \nabla \phi$

Only can access observables involving l.

$V_{ij}\ \bar{u}_i \gamma^\mu \chi_L d_j W$

$\delta \in V_{ij} \sim o(1)$

Other small things amongst the dim-4 ints:

$\rightarrow M_W = M_Z \cos\theta \left(1 + \frac{\alpha}{\pi} - \cdots\right)$ [ruined by: higgs non doublets] (custodial approx sym)

$\longrightarrow$ FCNC $K^0 \to \bar{K}^0$ (ruined by couplings like $Z^0 \bar{s} d$, $\chi \bar{s} d$ → almost all flav. models) "minimal flav. violat"

$\mathcal{L}_5$ (1 oper.) $\Delta L = 2$

$\mathcal{L}_6$ (B-viol) $\Delta B = \Delta L$

(c) Z-coupling well known (LEP)

(d) "accidental symmetries: although not an input, ... Eg $L_e, L_\mu, L_\tau, \ldots$

(e) CP violation is small + ... generally