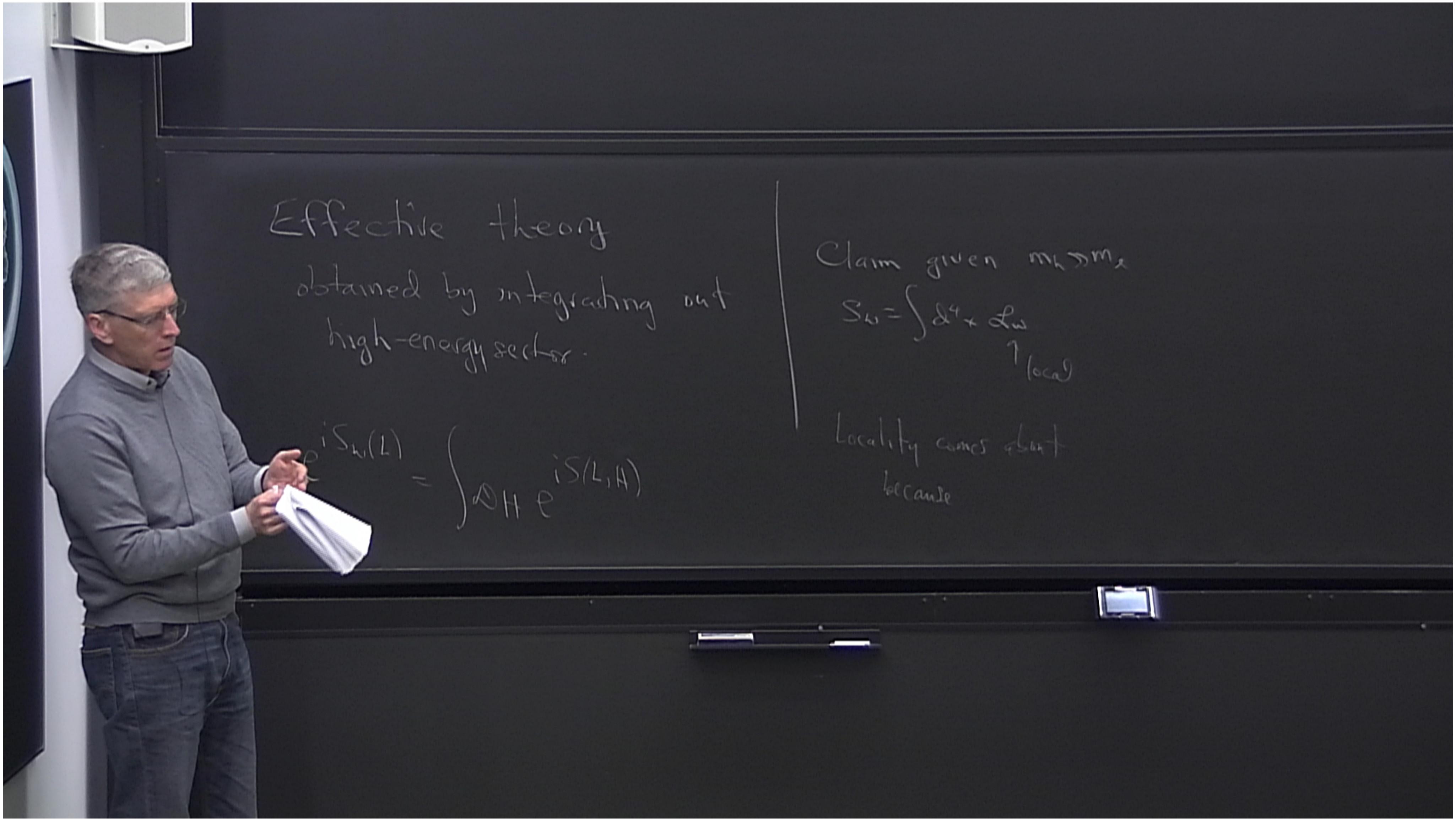
Title: PSI 2015/2016 Explorations in Particle Theory - Burgess - 13

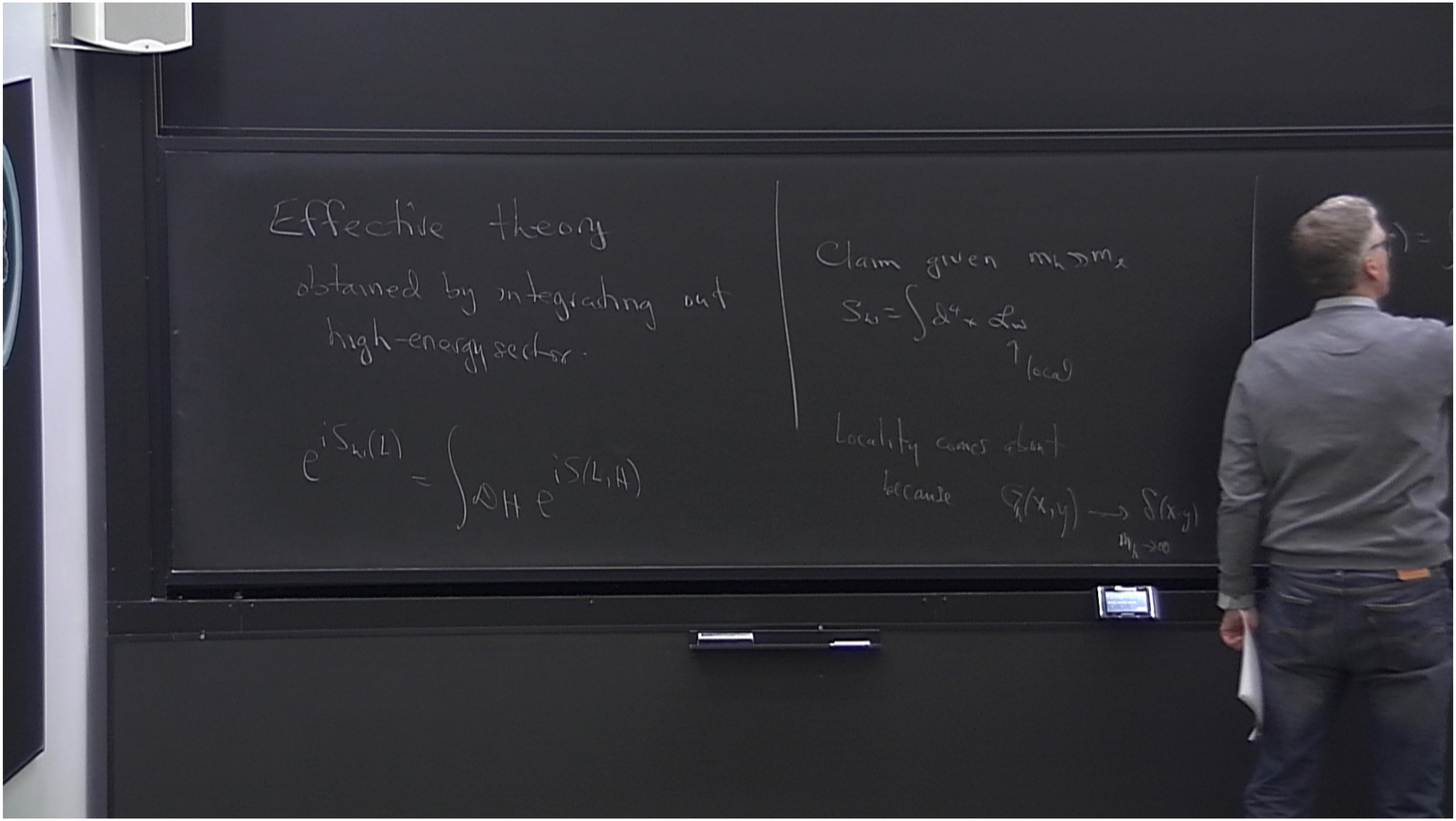
Date: Apr 27, 2016 09:00 AM

URL: http://pirsa.org/16040032

Abstract:



Effective theory
obtained by integrating out
high-energy sector.
$e^{iS_w(L)} = \int \mathcal{D}H \, e^{iS(L,H)}$
Claim given $m_h \gg m_\ell$
$S_w = \int d^4x \, \mathcal{L}_w$
local
Locality comes about
because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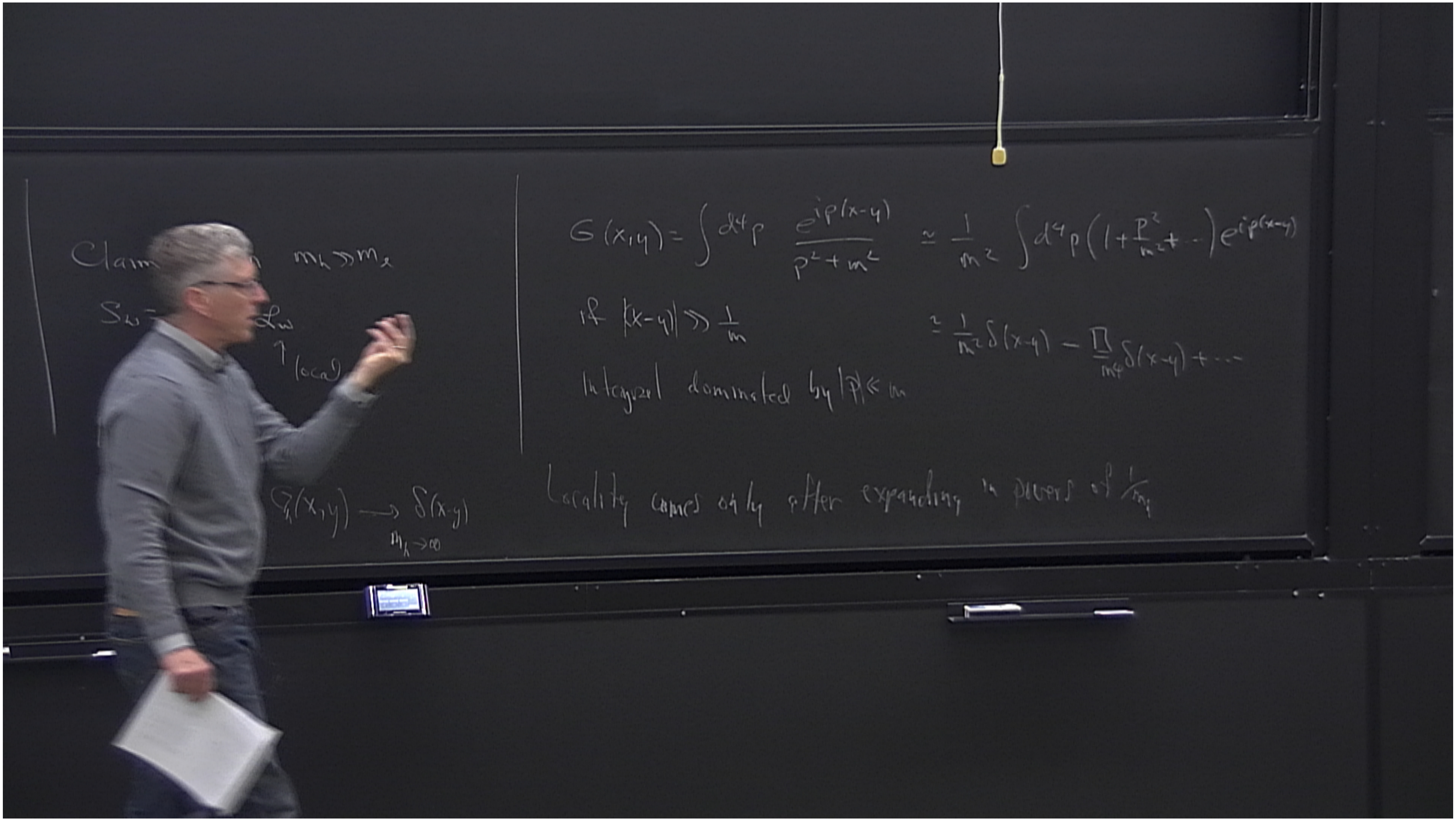

Claim $m_h \gg m_\ell$
S_W $\mathcal{L}_W$
local
$G_h(x,y) \xrightarrow[m_h\to\infty]{} \delta(x-y)$
$G(x,y) = \int d^4p \, \frac{e^{ip(x-y)}}{p^2+m^2} \simeq \frac{1}{m^2}\int d^4p \left(1+\frac{p^2}{m^2}+\dots\right) e^{ip(x-y)}$
if $|x-y| \gg \frac{1}{m}$
$= \frac{1}{m^2}\delta(x-y) - \frac{\Box}{m^4}\delta(x-y) + \dots$
Integral dominated by $|p| \ll m$
Locality comes only after expanding in powers of $1/m_h$

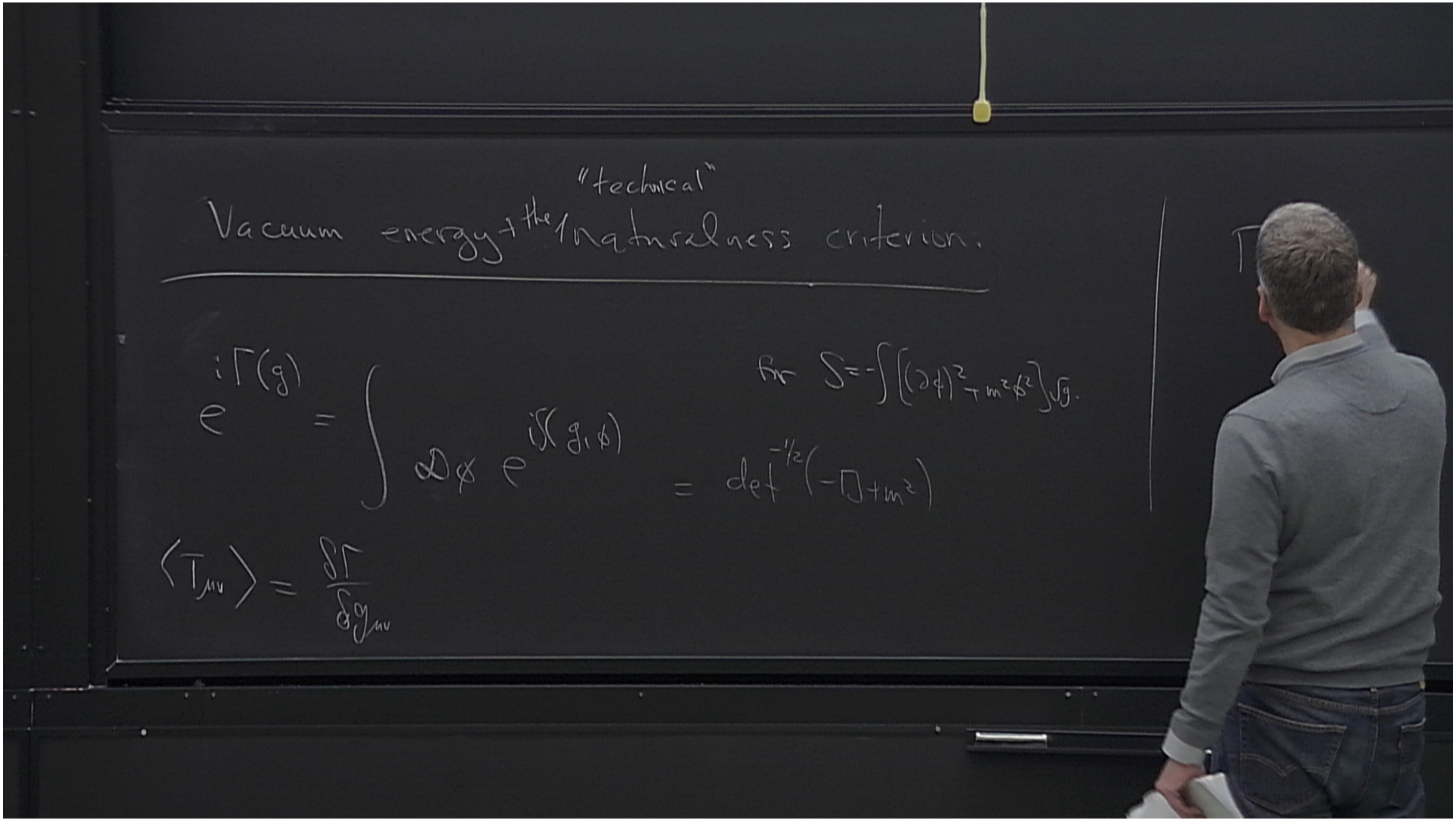
Vacuum energy + the "technical" naturalness criterion:

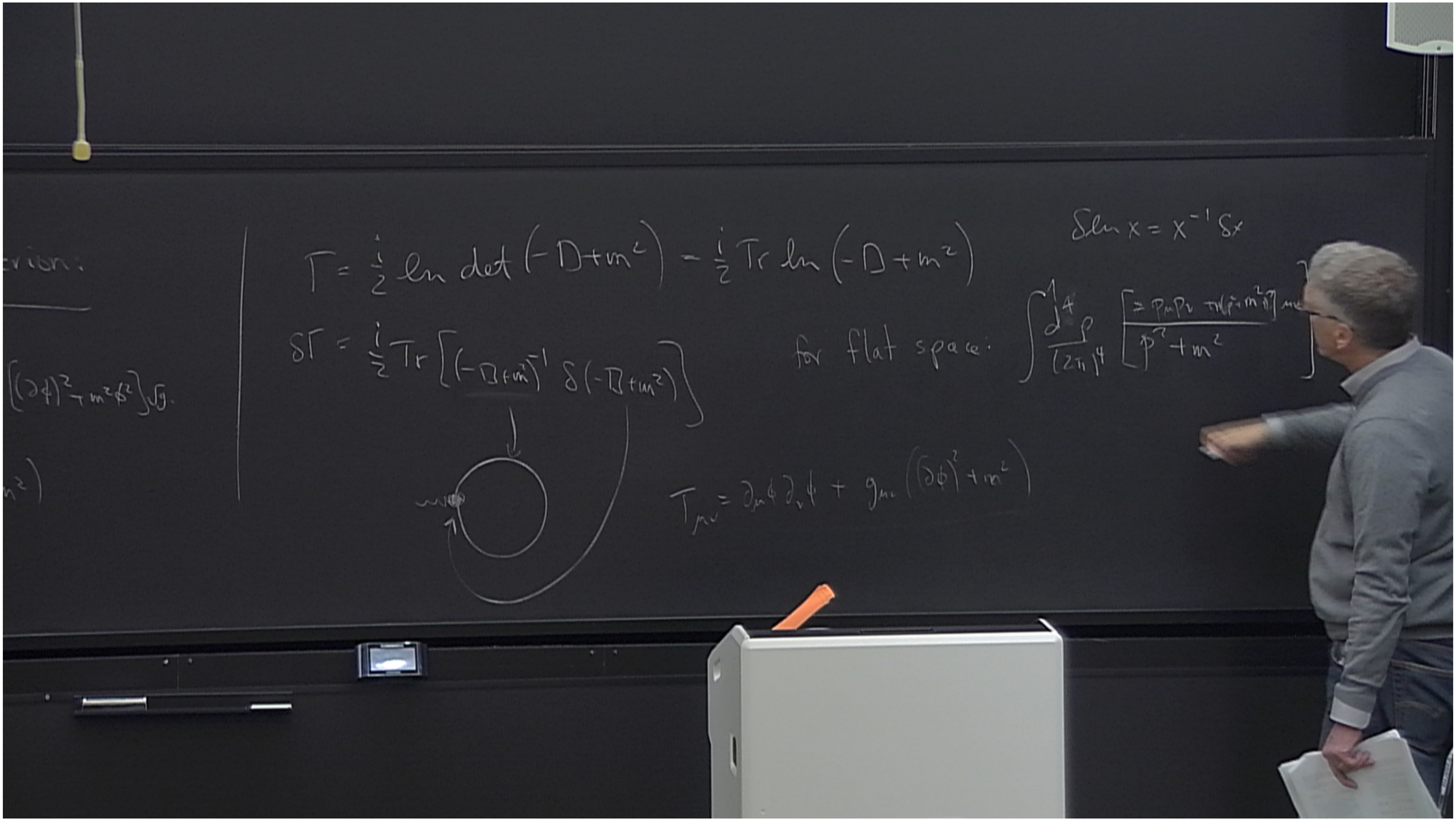
$$e^{i\Gamma(g)} = \int \mathcal{D}\phi \, e^{iS(g,\phi)}$$

for $S = -\int \left[(\partial\phi)^2 + m^2\phi^2\right]\sqrt{g}$.

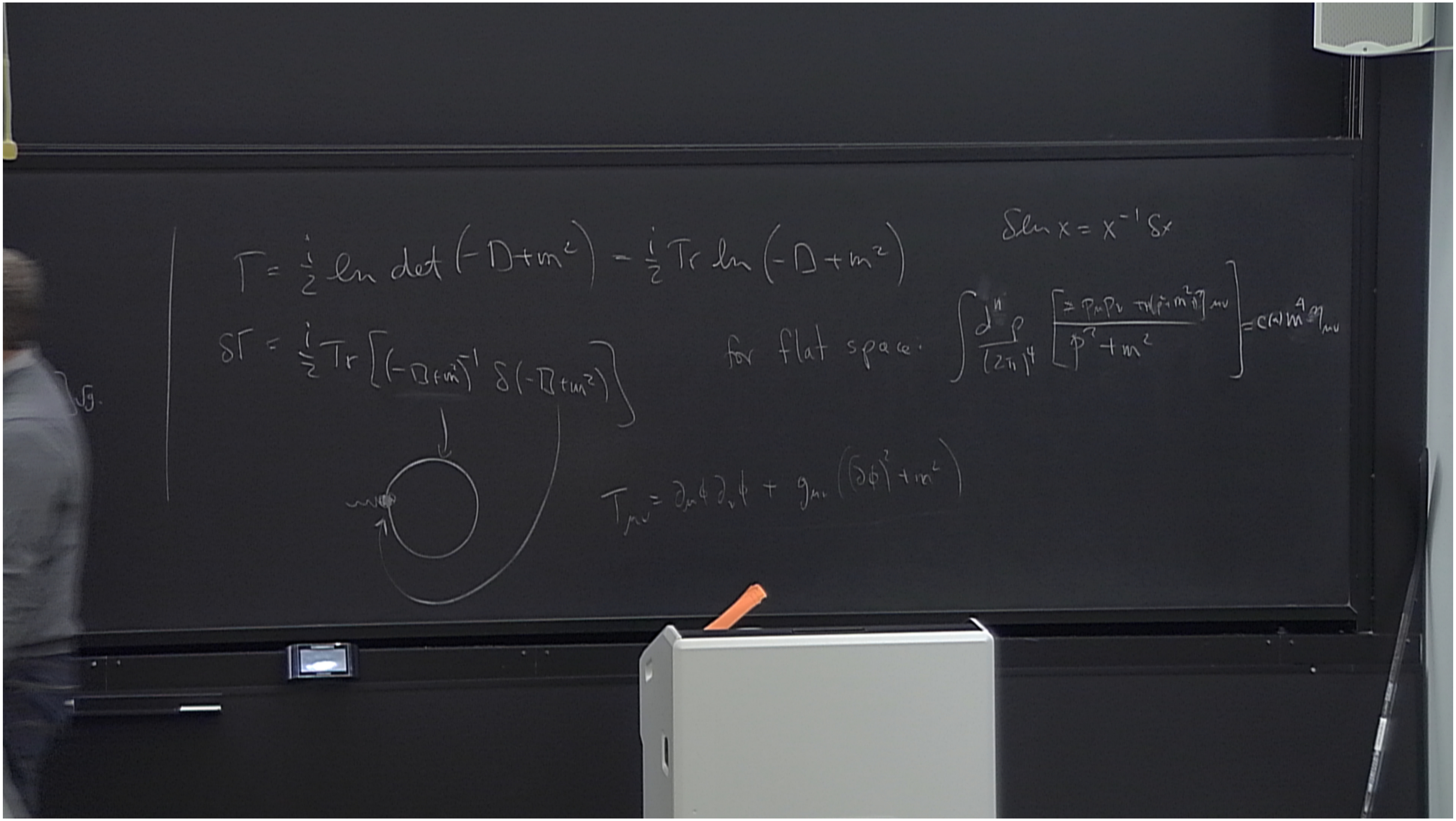
$$= \det{}^{-1/2}\left(-\Box + m^2\right)$$

$$\langle T_{\mu\nu} \rangle$$


"technical"
Vacuum energy + the naturalness criterion.
$e^{i\Gamma(g)} = \int \mathcal{D}\phi \, e^{iS(g,\phi)}$
for $S = -\int [(\partial\phi)^2 + m^2\phi^2]\sqrt{g}$.
$= \det^{-1/2}(-\Box + m^2)$
$\langle T_{\mu\nu} \rangle = \frac{\delta\Gamma}{\delta g_{\mu\nu}}$



$\delta \ln X = X^{-1} \delta X$
$\Gamma = \frac{i}{2} \ln \det(-\Box + m^2) = \frac{i}{2} \mathrm{Tr} \ln(-\Box + m^2)$
$\delta\Gamma = \frac{i}{2} \mathrm{Tr}\left[(-\Box + m^2)^{-1} \delta(-\Box + m^2)\right]$
for flat space:
$\int \frac{d^4 p}{(2\pi)^4} \left[\frac{p_\mu p_\nu}{p^2 + m^2}\right]$
$T_{\mu\nu} = \partial_\mu \phi \partial_\nu \phi + g_{\mu\nu}((\partial\phi)^2 + m^2)$



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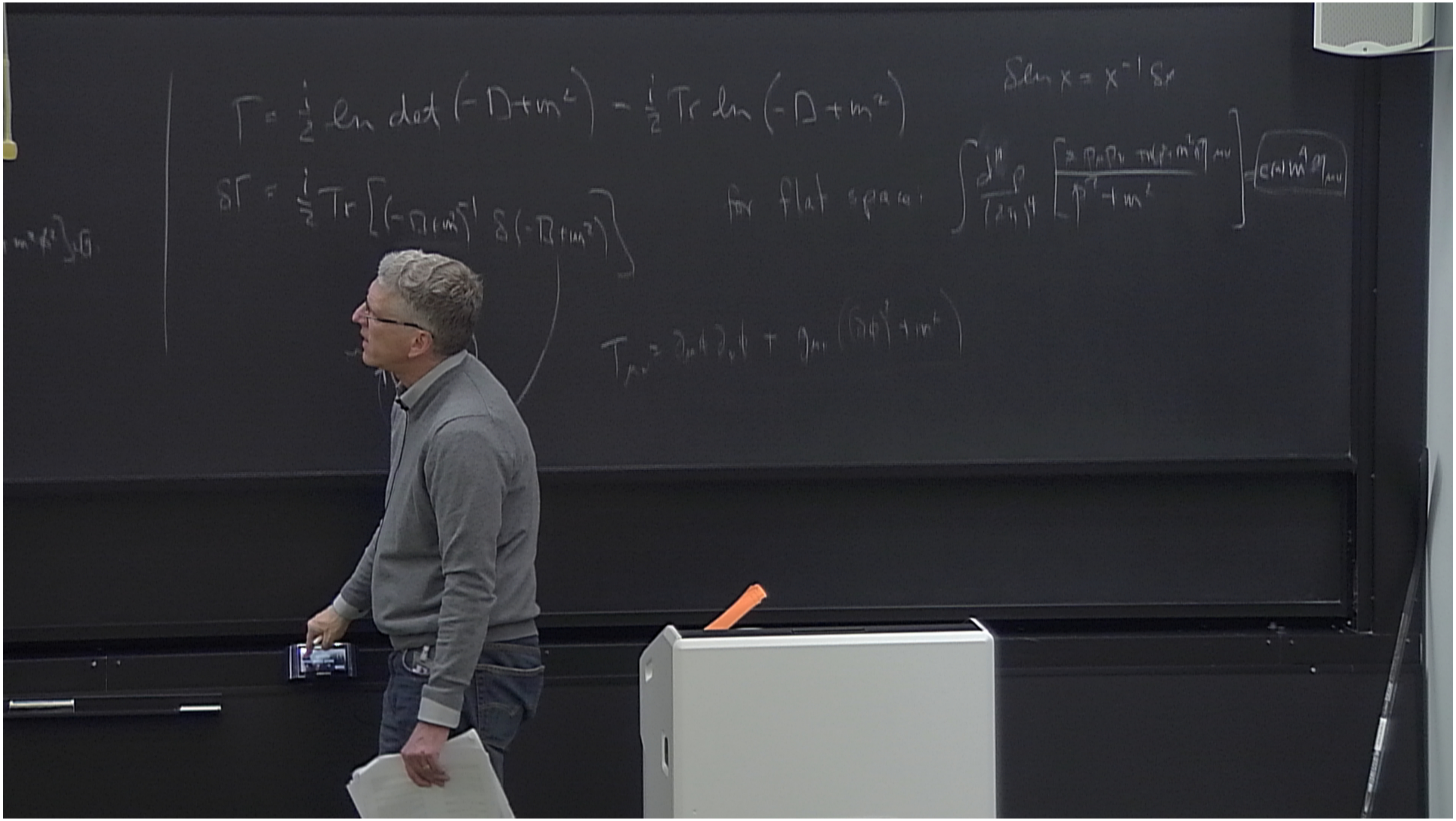
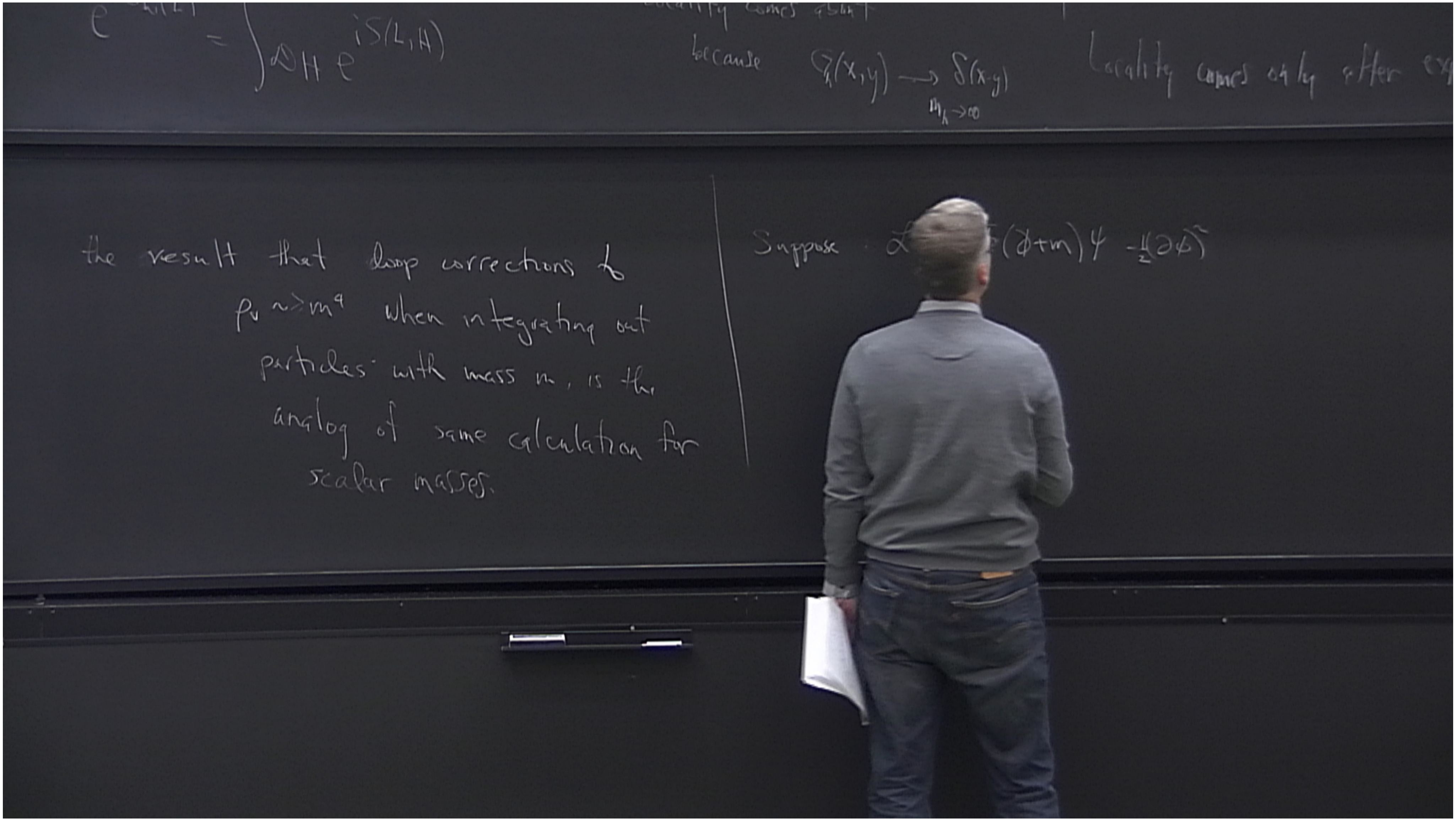
for flat space:
$\int \frac{d^n p}{(2\pi)^4} \left[\frac{\ldots p_\mu p_\nu \ldots (p^2 + m^2)\eta_{\mu\nu}}{p^2 + m^2}\right] = c(n) m^4 \eta_{\mu\nu}$
$T_{\mu\nu} = \partial_\mu\phi \partial_\nu\phi + g_{\mu\nu}\left((\partial\phi)^2 + m^2\right)$
$\sqrt{g}$.


Γ = i/2 ln det (−□+m²) − i/2 Tr ln (−□+m²)
δΓ = i/2 Tr [(−□+m²)⁻¹ δ(−□+m²)]
δ ln x = x⁻¹ δx
for flat space:
Tμν = ∂μφ ∂νφ + gμν ((∂φ)² + m²


= ∫DH e^iS(L,H)
because G(x,y) → δ(x-y)
Locality comes only after
the result that loop corrections to
ρv ~> m^4 when integrating out
particles with mass m, is the
analog of same calculation for
scalar masses.
Suppose

because $G_h(x,y) \xrightarrow[m_h \to \infty]{} \delta(x-y)$ Locality comes only after expanding in powers of $1/m_h$

...s $\mathcal{L}$

...ting out

..., is the

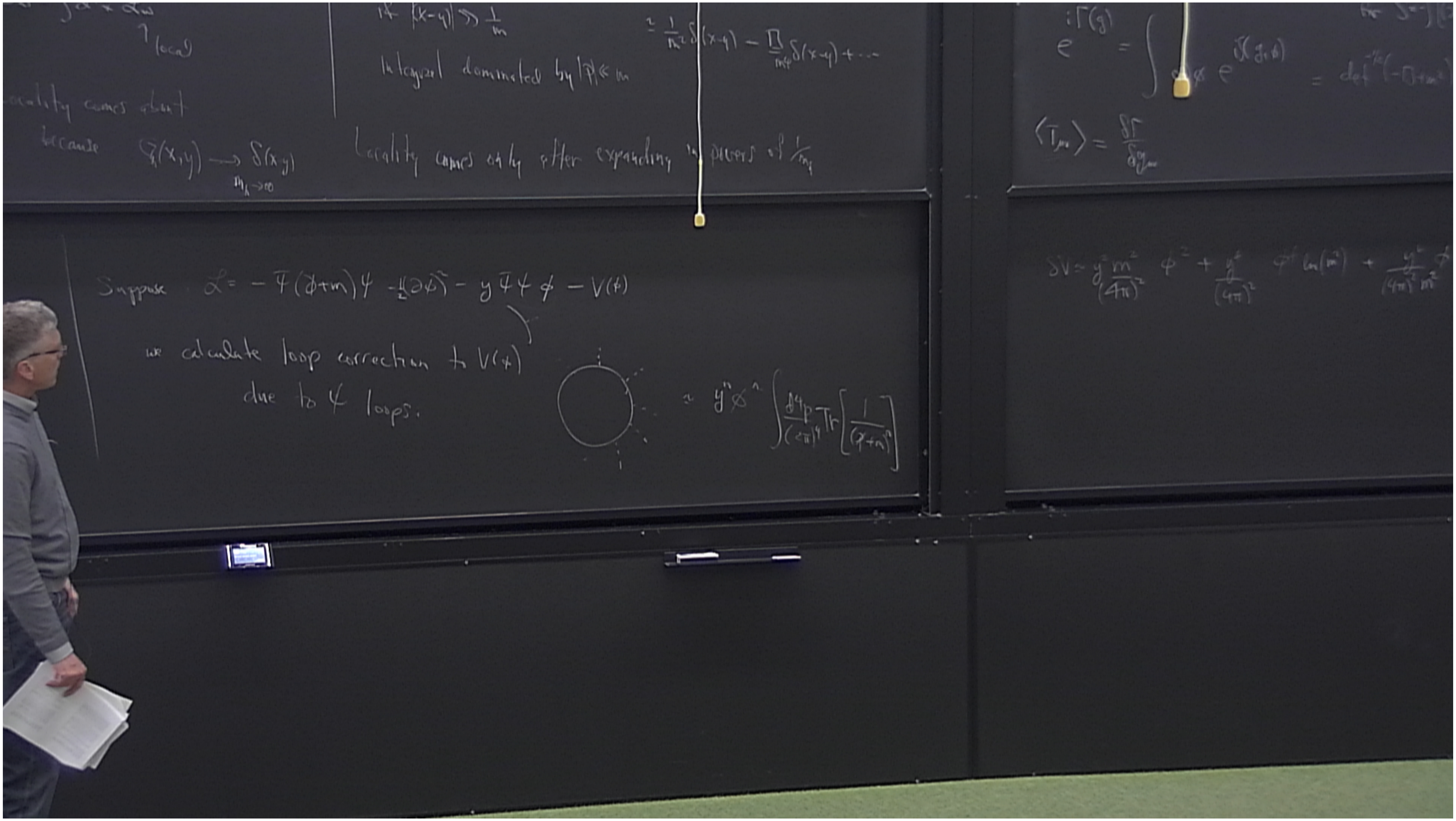
...ulation for

Suppose : $\mathcal{L} = -\bar{\psi}(\partial\!\!\!/ + m)\psi - \frac{1}{2}(\partial\phi)^2 - y\bar{\psi}\psi\phi - V(\phi)$

we calculate loop correction to $V(\phi)$

due to ψ loops:

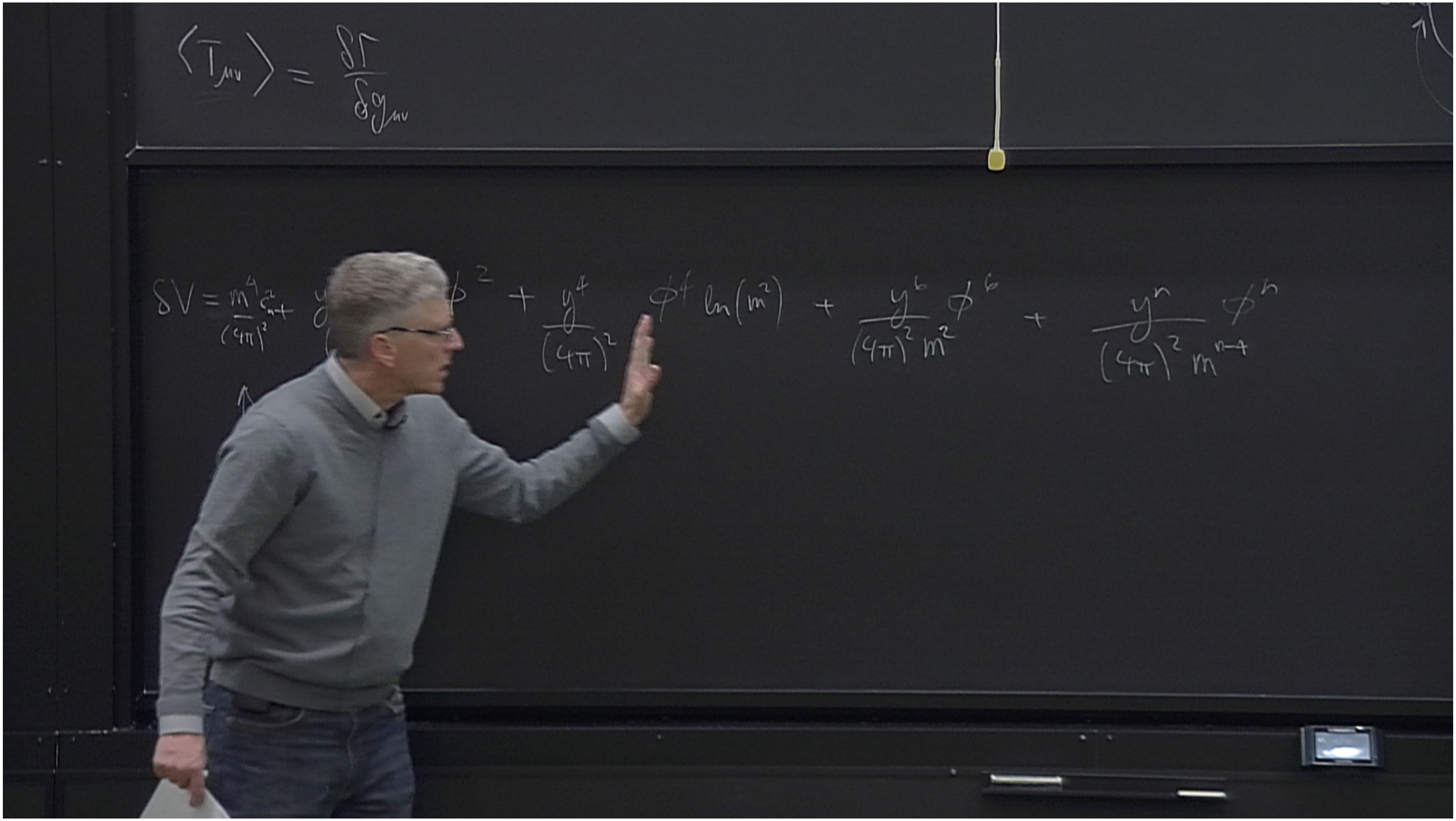
$\sim y^n \phi^n \int \frac{d^4p}{(2\pi)^4} \mathrm{Tr}\left[\frac{1}{(p\!\!\!/ + m)^n}\right]$



Locality comes about because
Integral dominated by |p| ≪ m
Locality comes only after expanding in powers of 1/m
Suppose
we calculate loop correction to V(φ)
due to ψ loops.

$$\langle T_{\mu\nu} \rangle = \frac{\delta \Gamma}{\delta g_{\mu\nu}}$$

$$\delta V \simeq y^2 \frac{m^2}{(4\pi)^2} c_n \phi^2 + \frac{y^4}{(4\pi)^2} \phi^4 \ln(m^2) + \frac{y^6}{(4\pi)^2 m^2} \phi^6 + \frac{y^n}{(4\pi)^2 m^{n-4}} \phi^n$$



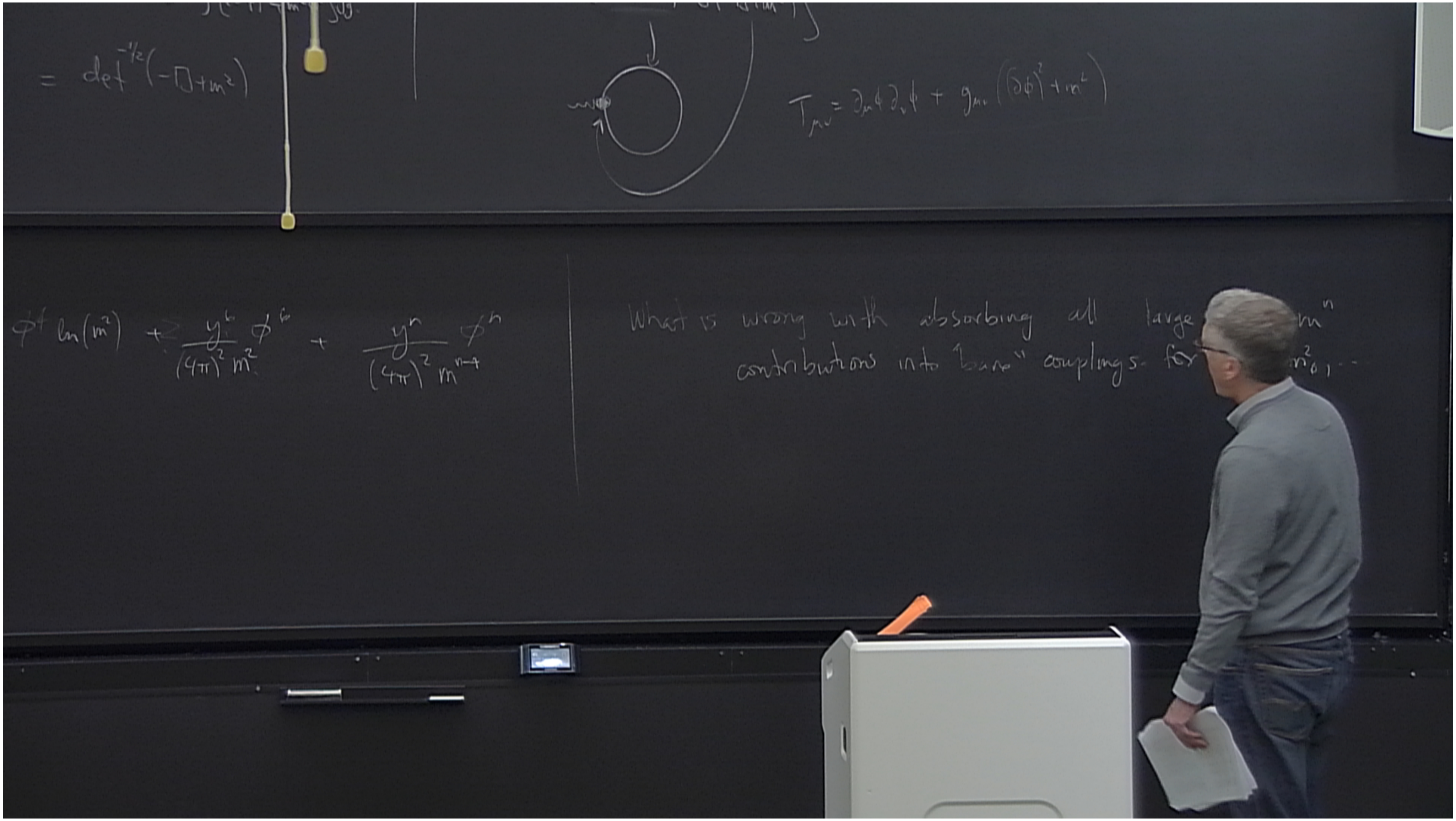
$\langle T_{\mu\nu} \rangle = \frac{\delta \Gamma}{\delta g_{\mu\nu}}$
$\delta V = \frac{m^4}{(4\pi)^2}$
$+ \frac{y^4}{(4\pi)^2} \phi^4 \ln(m^2) + \frac{y^6}{(4\pi)^2 m^2} \phi^6 + \frac{y^n}{(4\pi)^2 m^{n-4}} \phi^n$

$$\langle T_{\mu\nu} \rangle = \frac{\delta \Gamma}{\delta g_{\mu\nu}}$$

$$\delta V = \frac{m^4}{(4\pi)^2} c_n^2 + \frac{y^2 m^2}{(4\pi)^2} c_n \phi^2 + \frac{y^4}{(4\pi)^2} \phi^4 \ln(m^2) + \frac{y^6}{(4\pi)^2 m^2} \phi^6 + \frac{y^n}{(4\pi)^2 m^{n-4}} \phi^n$$

"relevant" interaction

$$+ \frac{m^2}{(4\pi)^2} \sqrt{g} R$$


$= \det^{-1/2}(-\Box+m^2)$
$T_{\mu\nu} = \partial_\mu\phi\,\partial_\nu\phi + g_{\mu\nu}\left((\partial\phi)^2+m^2\right)$
$\phi^4 \ln(m^2) + \frac{y^6}{(4\pi)^2 m^2}\phi^6 + \frac{y^n}{(4\pi)^2 m^{n-4}}\phi^n$
What is wrong with absorbing all large
contributions into "bare" couplings for

Given the couplings in $\mathcal{L}_{W_1}$

can compute " " $\mathcal{L}_{W_n}$ $n>1$

ρ_i = vacuum energy param in $\mathcal{L}_{W_i}$

m_i^2 = scalar mass " " "

For each $\mathcal{L}_{W_i}$, choose ρ_i to ensure ρ_{phys} has the right value

$(10^{-3}eV)^4$.

$$\underset{(10^{-3}eV)^4}{\rho_{phys}} = \underset{\text{learn}}{\rho_S} + \sum_{p \in \mathcal{L}_{W_3}} \frac{m_p^4}{64\pi^2} \ln\left(\frac{m_p^2}{\Lambda^2}\right)$$

$m_p \lesssim 10^{-3} eV$ for $\mathcal{L}_{W_3}$

Same calculation for $\mathcal{L}_{W_3}$:

$$\rho_{phys} = \rho_3 + \underbrace{\sum_{p\in\mathcal{L}_{W_2}} \frac{m_p^4}{64\pi^2}\ln\left(\frac{m^2}{\mu^2}\right)}_{} + \cdots$$

$$\underbrace{\sum_{p\in\mathcal{L}_4}}_{\rho_4} + \frac{m_e^4}{64\pi^2}\ln\left(\frac{m_e^2}{\mu^2}\right) + \cdots$$

$$\overset{10^{-12}\,eV^4}{\downarrow}$$

$$\rho_4 = \overbrace{\rho_3 + \overbrace{\frac{m_e^4}{64\pi^2}\ln\left(\frac{m_e^2}{\mu^2}\right)}^{10^{22}\,eV^4}}^{10^{22}\,eV^4}$$

$$\rho_3 = \rho_2 + \sum_{\substack{p\in 2\\ p\notin 3}} \frac{m_p^4}{64\pi^2}\ln\left(\frac{m^2}{\mu^2}\right)$$

when integrating out particles with mass m, is the analog of same calculation for scalar masses.

we calculate lo...

due t...

SM
$a_0^{-1} \simeq \alpha_{SM} m_{eSM}$
$r_n \simeq \frac{1}{\Lambda_{QCD}}$

atoms > nuclei ? $a_0 \simeq \frac{1}{\alpha m_e}$ $r_n \sim \frac{1}{m_p}$

M_p

E

10^{8} GeV

TeV

M_W

m_e

eV

$m_e \sim m_{e_{SM}} + \alpha m_e \ln\left(\frac{m_n}{m_e}\right)$

— $\mathcal{L}_{W_1}$

— $\mathcal{L}_{W_2} \ (\simeq \mathcal{L}_{SM})$

— $\mathcal{L}_{W_3}$

— $\mathcal{L}_{W_4}$

Given the couplings in $\mathcal{L}_{W_1}$
can compute " " $\mathcal{L}_{W_n}$ $n>1$

ρ_i = vacuum energy param in $\mathcal{L}_{W_i}$
m_i^2 = scalar mass " " "

"Technically unnatural"

Technically natural:

1) Why does Ed think it is true at Planck scale

2) Why does it stay true as you integrate out physics to scales where it is measured?