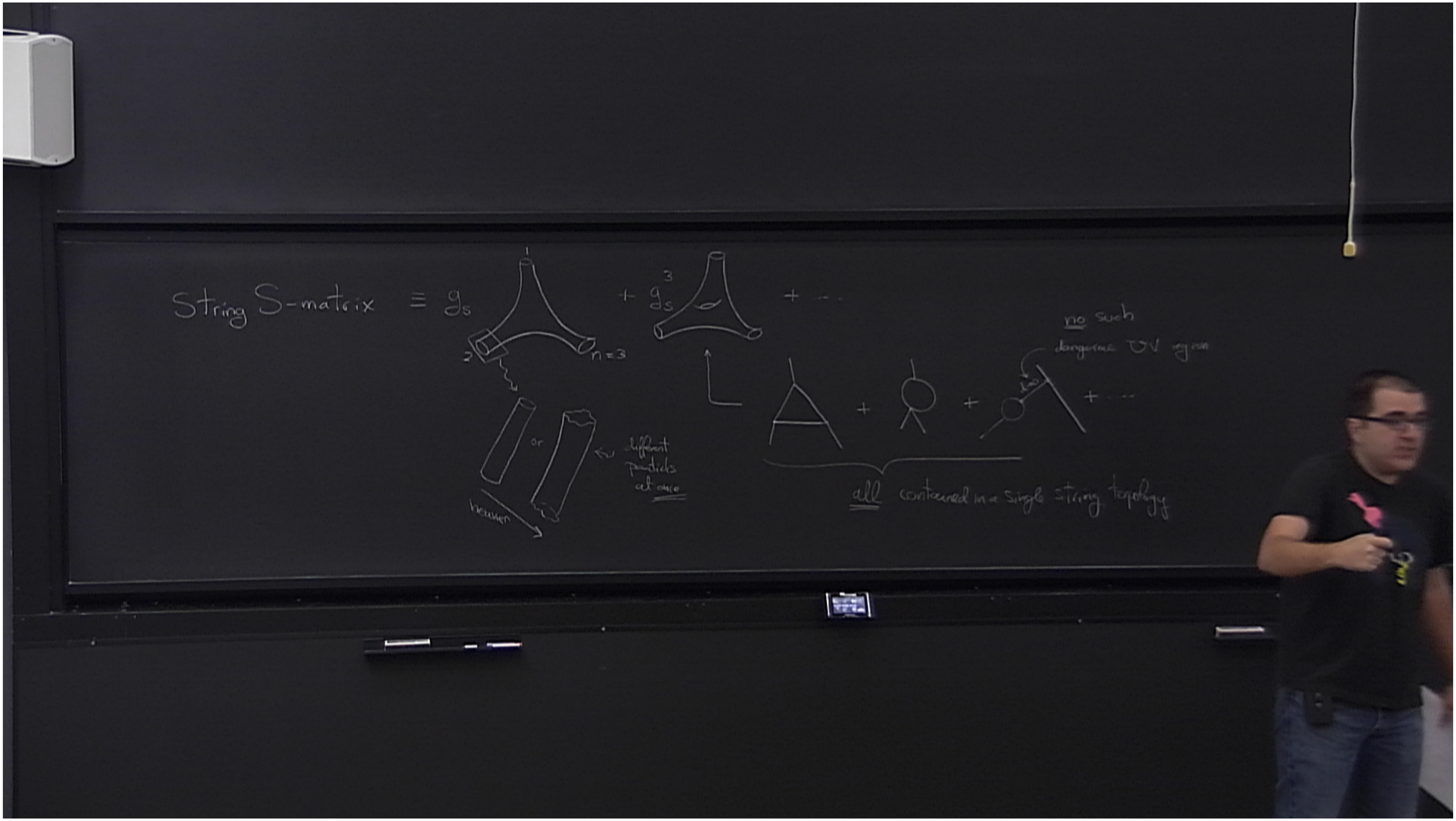
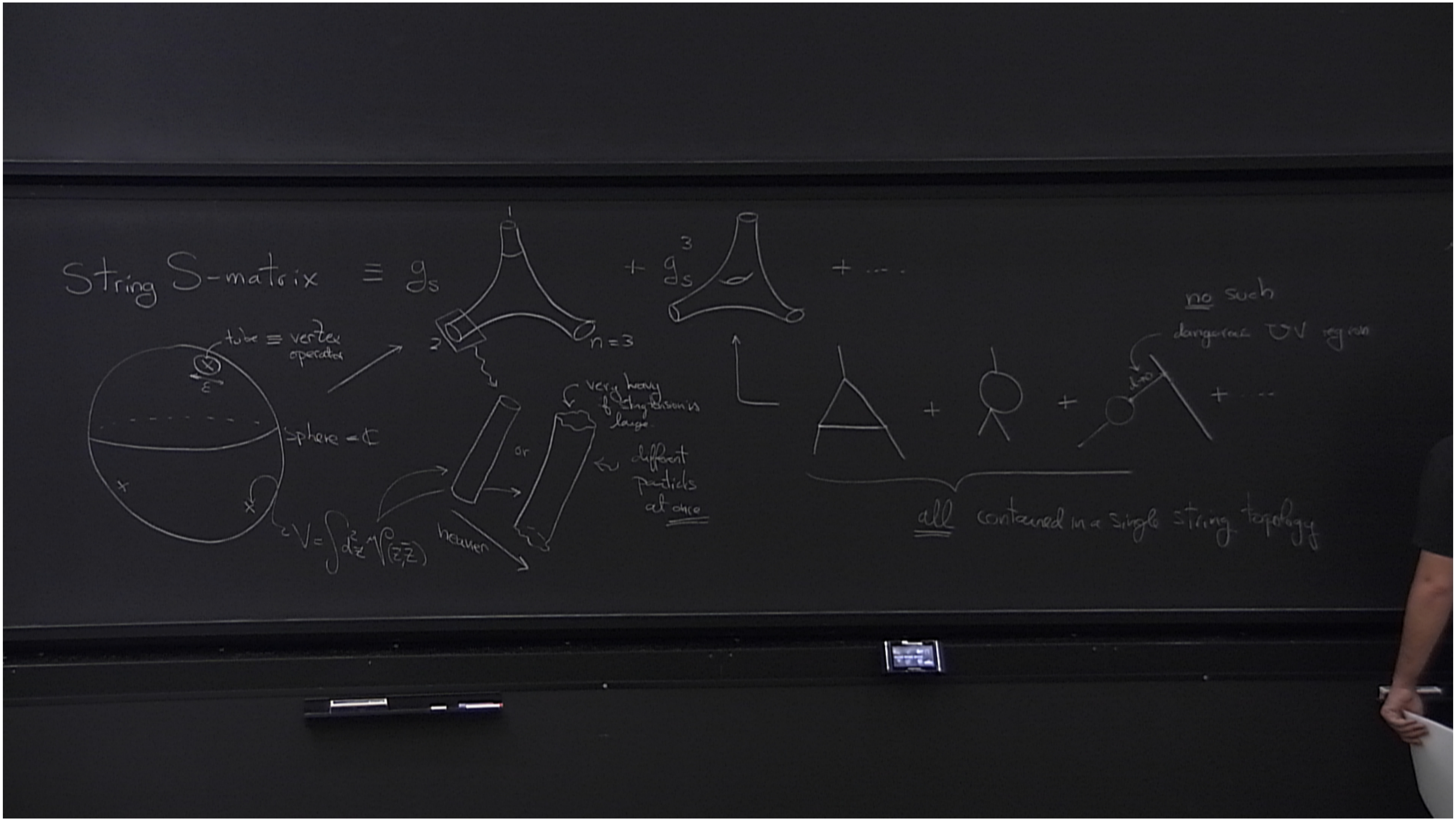
Title: PSI 2015/2016 Explorations in String Theory - Pedro Vieira - 1

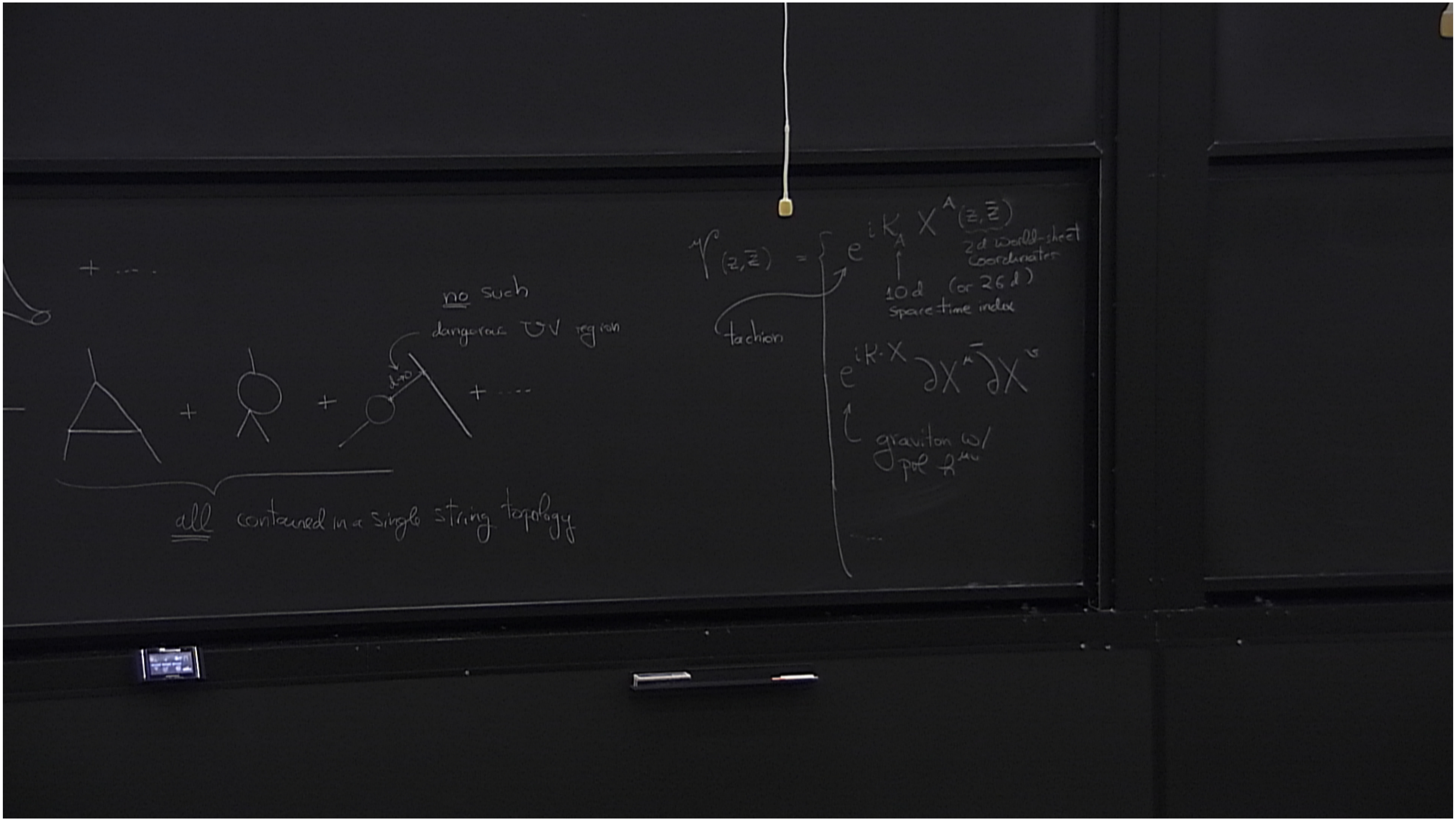
Date: Mar 21, 2016 11:30 AM

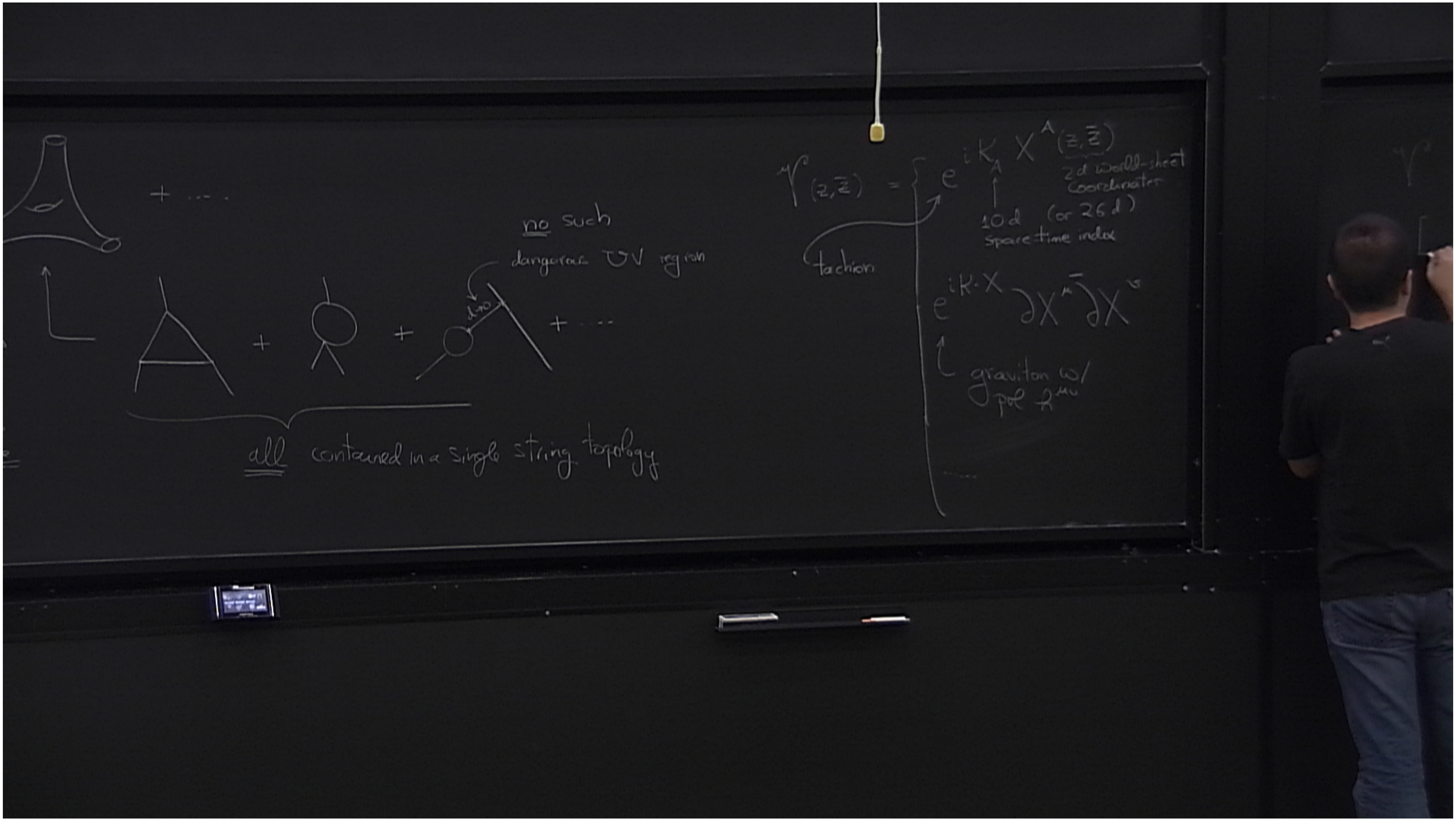
URL: http://pirsa.org/16030063

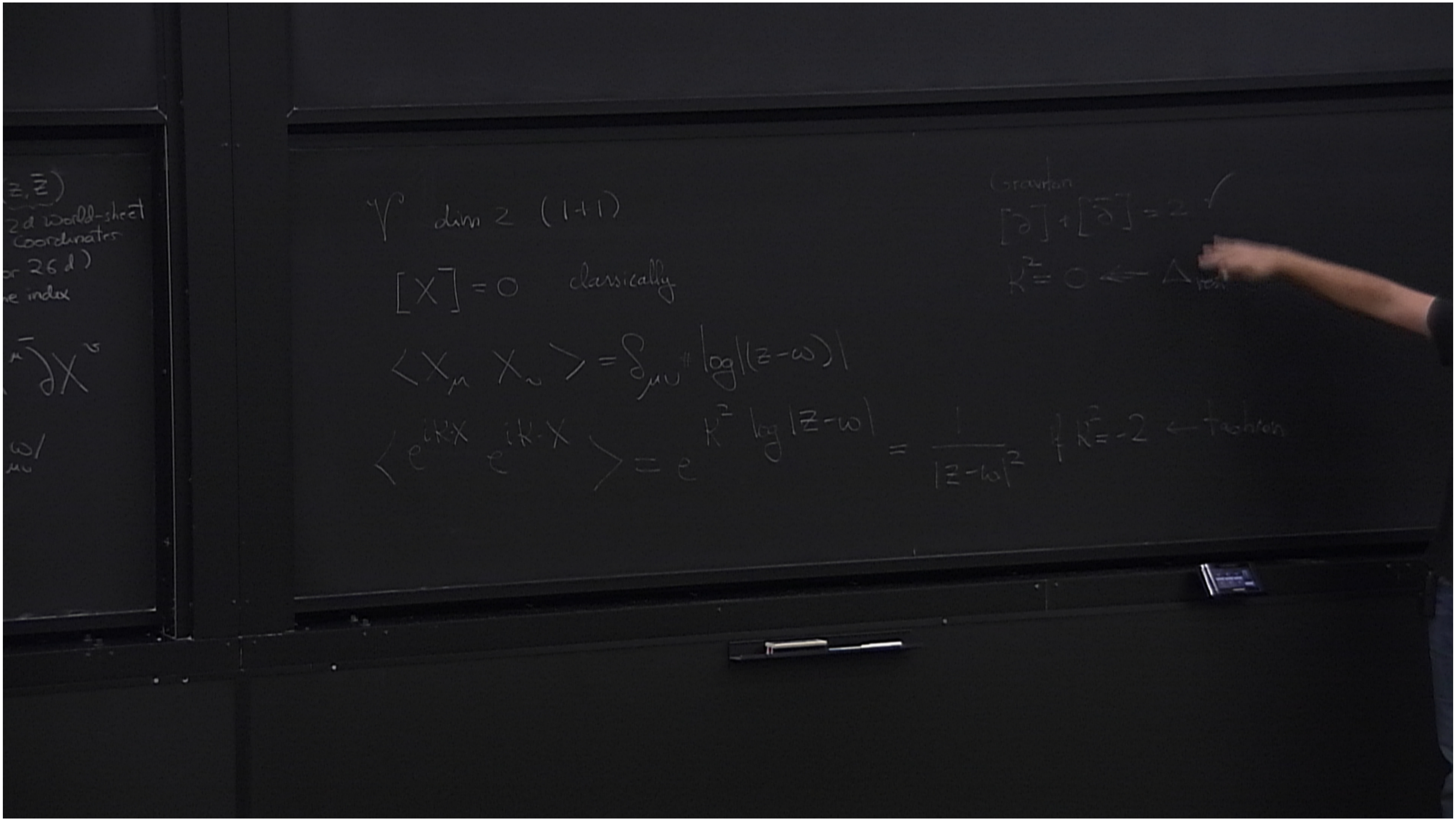
Abstract:


String S-matrix ≡ g_s
+ g_s^3
+ ...
n=3
or
different particles at once
heavier
no such dangerous UV region
all contained in a single string topology


String S-matrix ≡ g_s + g_s^3 + ...
tube ≡ vertex operator
ε
sphere ≈ ℂ
V = ∫d²z V(z, z̄)
n = 3
very heavy
or
different particles at once
heavier
no such dangerous UV region
+ ...
all contained in a single string topology


no such
dangerous UV region
all contained in a single string topology
V(z, z̄) = e^{iK_A X^A(z, z̄)}
2d world-sheet coordinates
10d (or 26d) space-time index
tachion
e^{iK·X} ∂X^μ ∂̄X^ν
graviton w/ pol ε^{μν}


no such
dangerous UV region
all contained in a single string topology
$V(z,\bar{z}) = \{ e^{iK_A X^A(z,\bar{z})}$
tachion
2d world-sheet coordinates
10 d (or 26 d)
space-time index
$e^{ik\cdot X}\,\partial X^\mu \bar{\partial} X^\nu$
graviton w/ pol $\epsilon^{\mu\nu}$



(z, z̄)
2d world-sheet coordinates
or 26 d)
e index
dim 2 (1+1)
[X] = 0 classically
⟨X_μ X_ν⟩ = δ_μν log|(z−ω)|
⟨e^{ik·X} e^{ik·X}⟩ = e^{k² log|z−ω|} = 1/|z−ω|² if k² = −2 ← tachyon
Graviton
[∂] + [∂̄] = 2
k² = 0 ←

γ dim 2 (1+1)

$[X] = 0$ classically

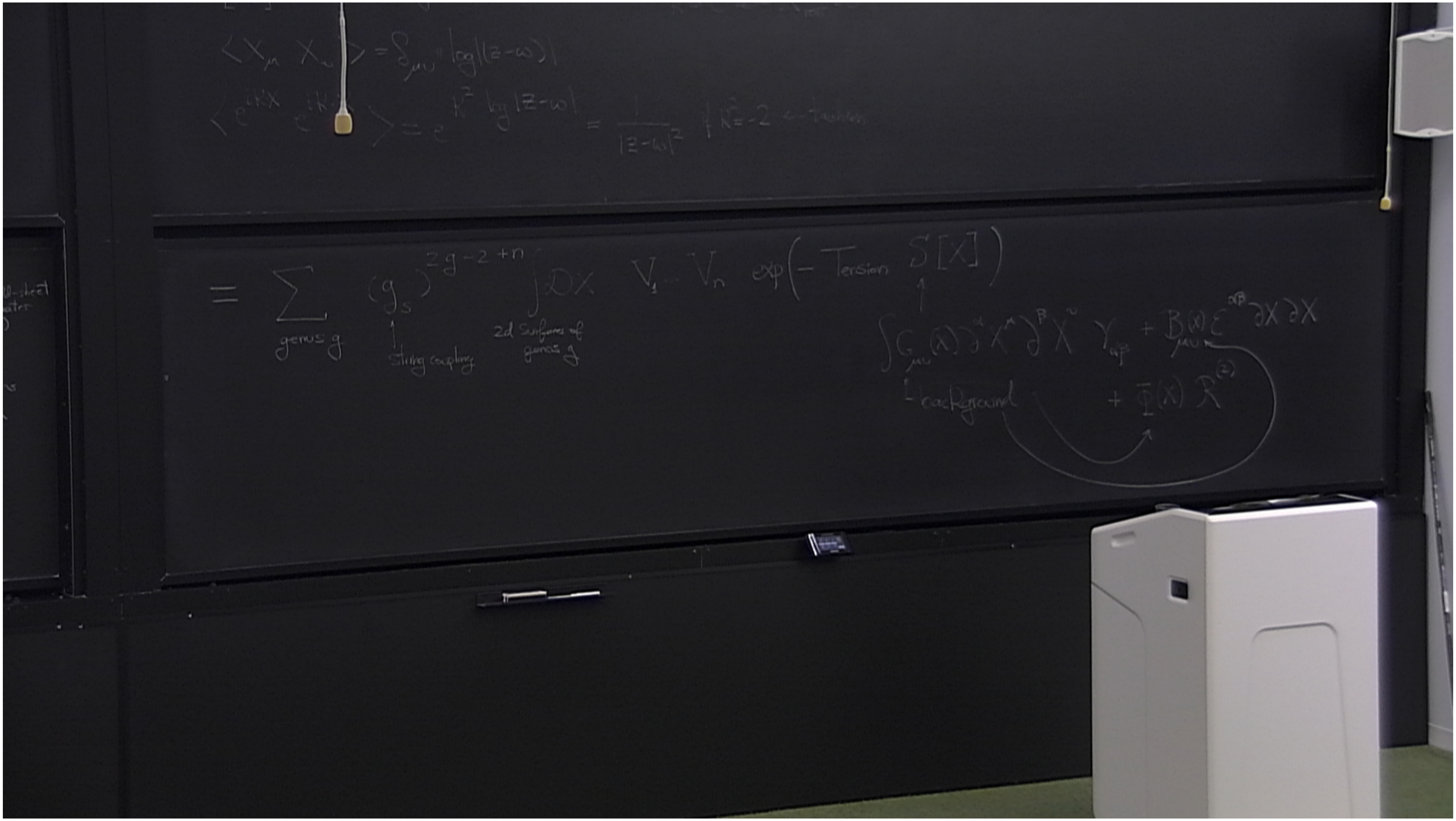
$\langle X_\mu X_\nu \rangle = \delta_{\mu\nu} \# \log|(z-\omega)|$

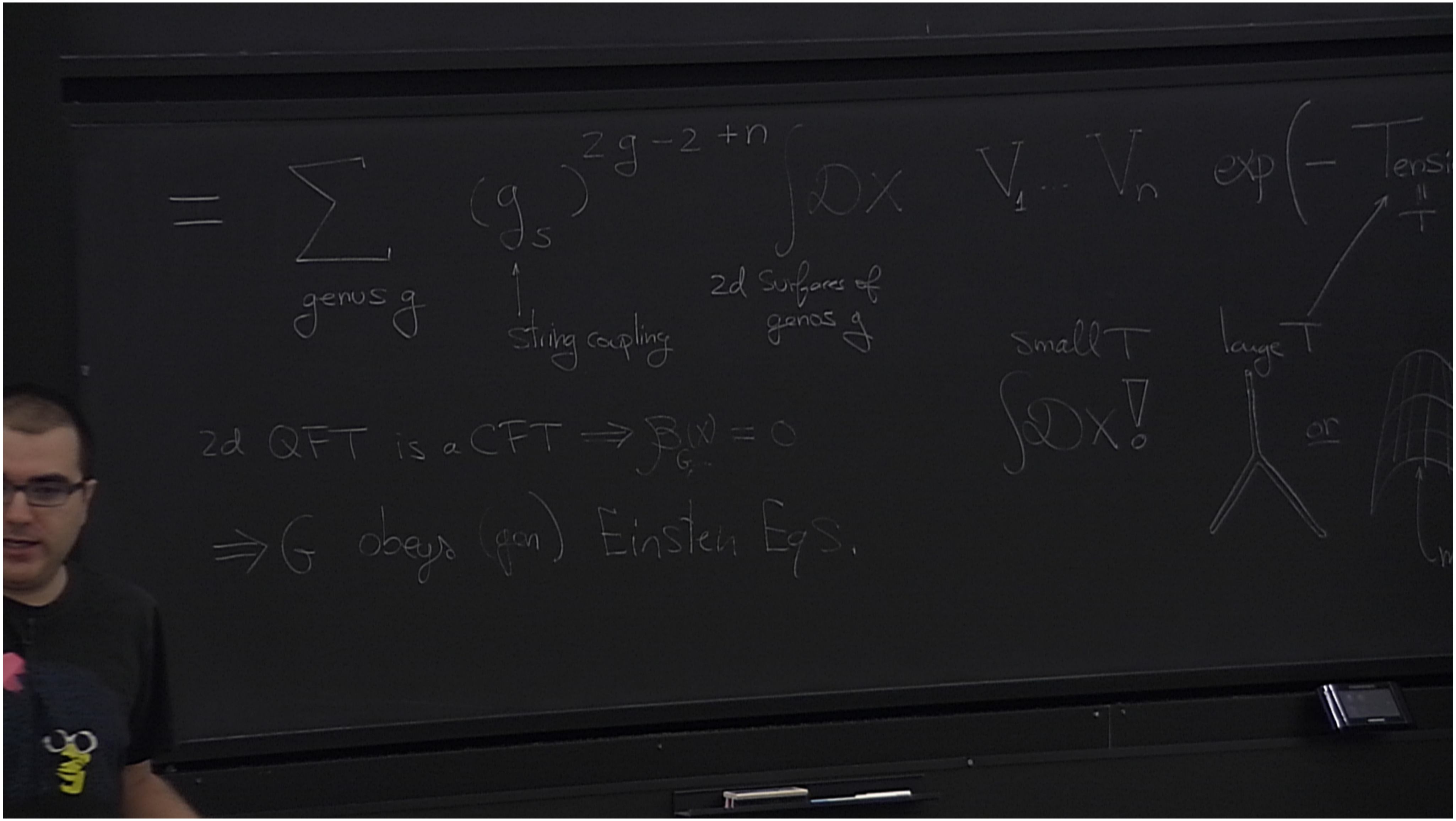
$\langle e^{ik\cdot X} e^{ik\cdot X} \rangle = e^{k^2 \log|z-\omega|} = \frac{1}{|z-\omega|^2}$ if $k^2 = -2 \leftarrow$ tachyon

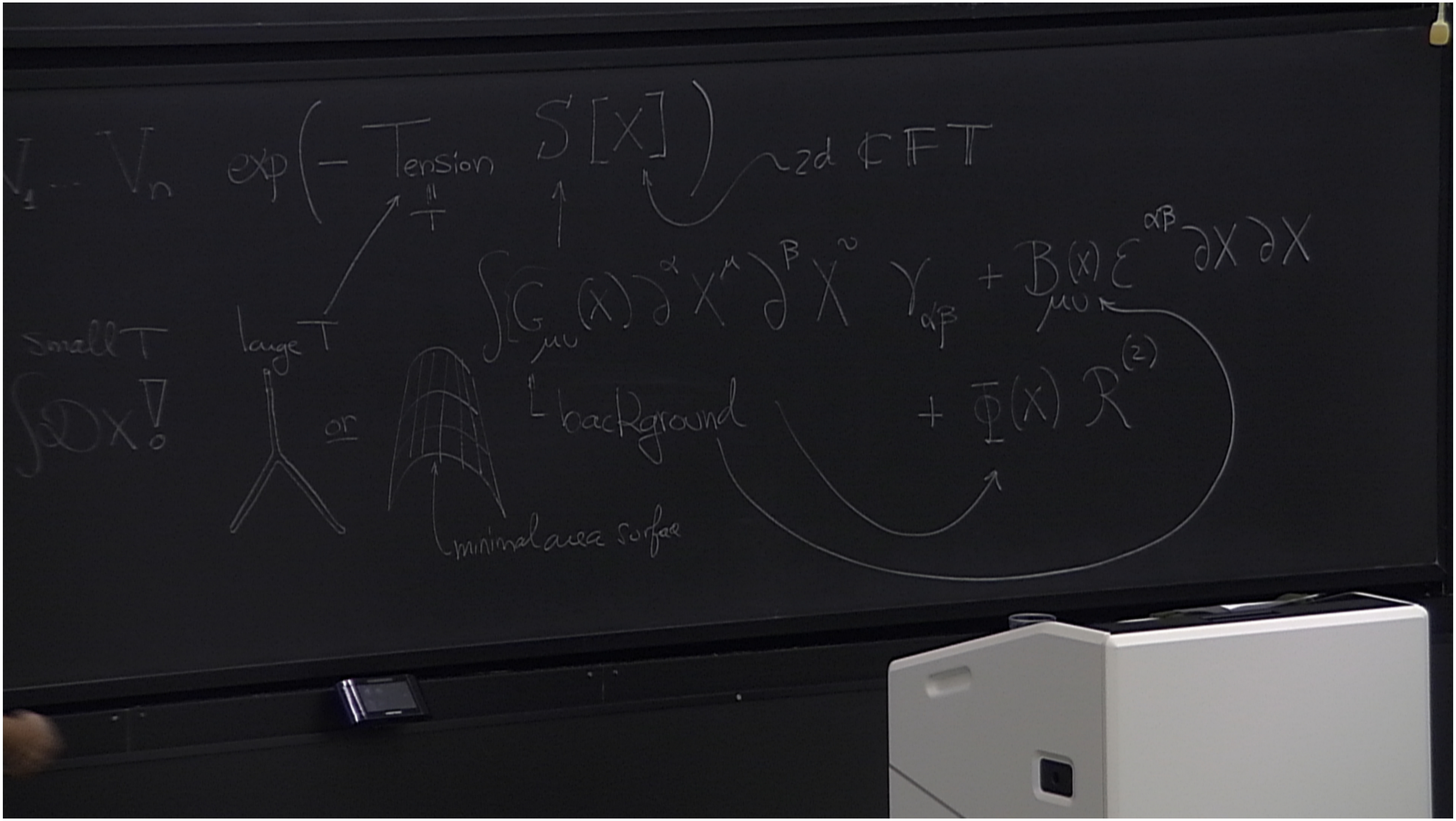
Graviton

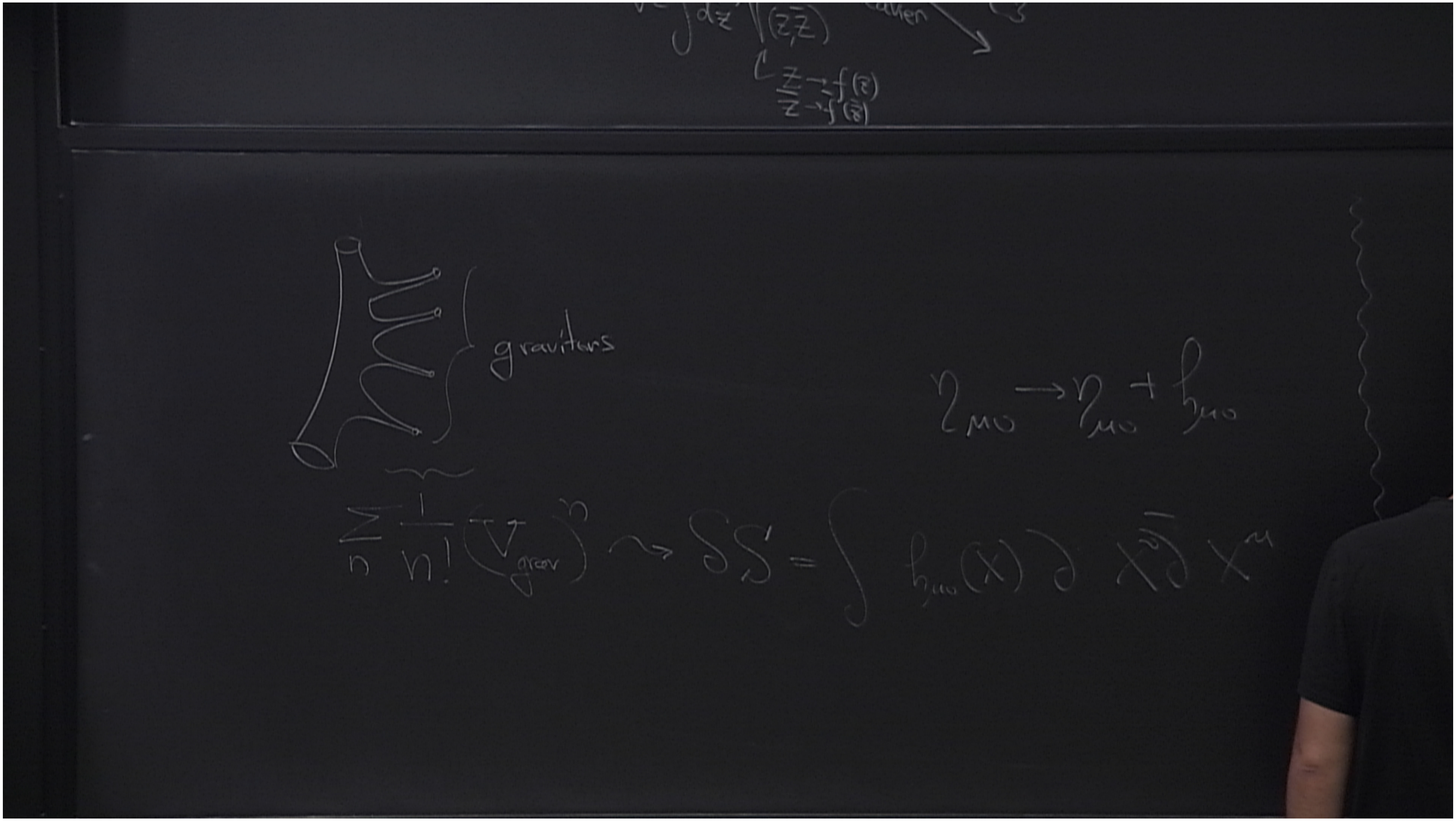
$[\partial] + [\bar{\partial}] = 2$ ✓

$k^2 = 0 \Leftarrow \Delta_{rest} = 0$

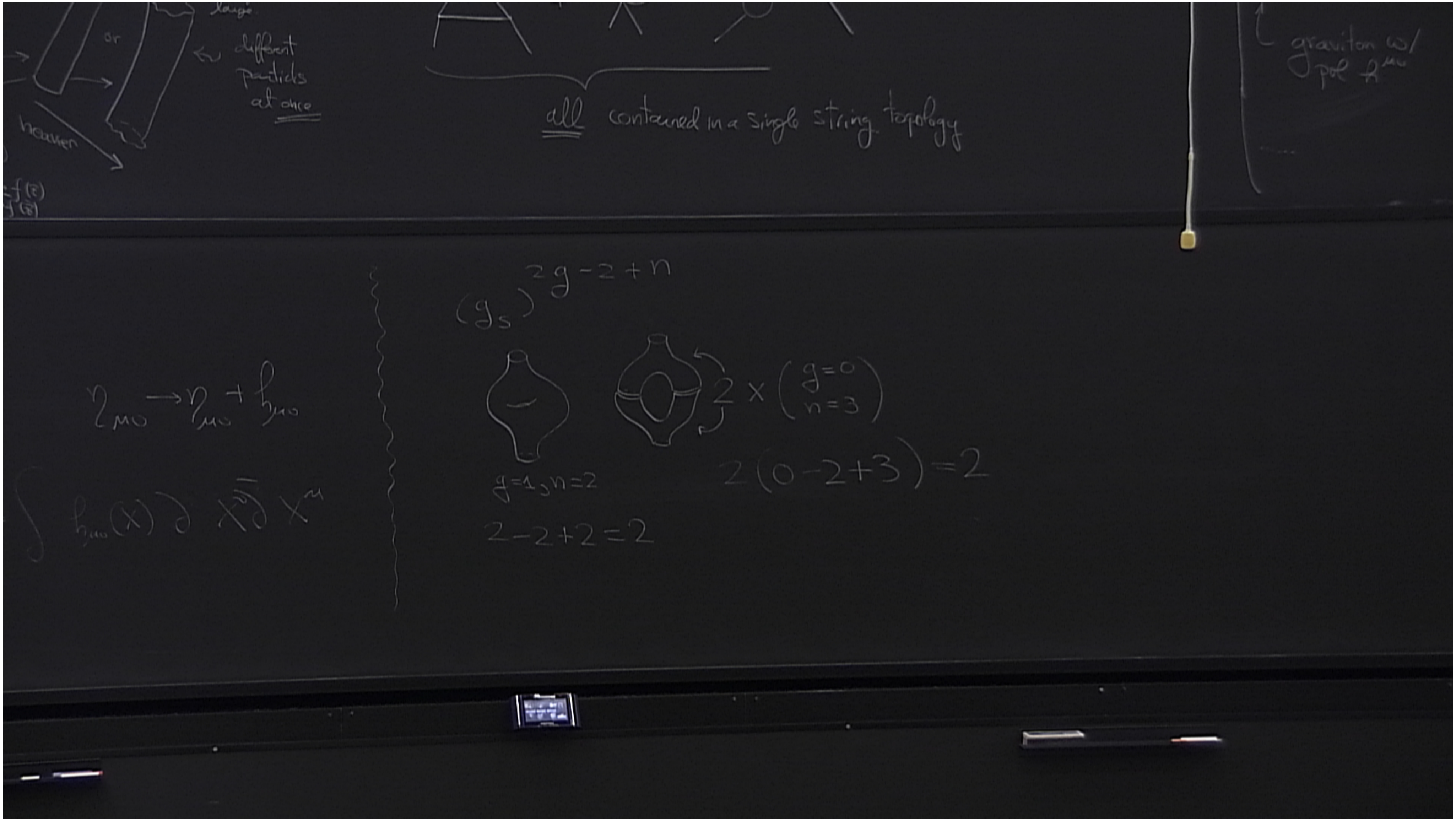

⟨X_μ X_ν⟩ = δ_μν log|z−ω|
⟨e^{ikX} e^{ikX}⟩ = e^{k² log|z−ω|} = 1/|z−ω|² if k² = −2 ← tachyon
= Σ_{genus g} (g_s)^{2g−2+n} ∫DX V_1 … V_n exp(− Tension S[X])
genus g
string coupling
2d Surfaces of genus g
∫ G_μν(X) ∂^α X^μ ∂^β X^ν γ_αβ + B_μν(X) ε^{αβ} ∂X ∂X
+ Φ(X) R^(2)
background

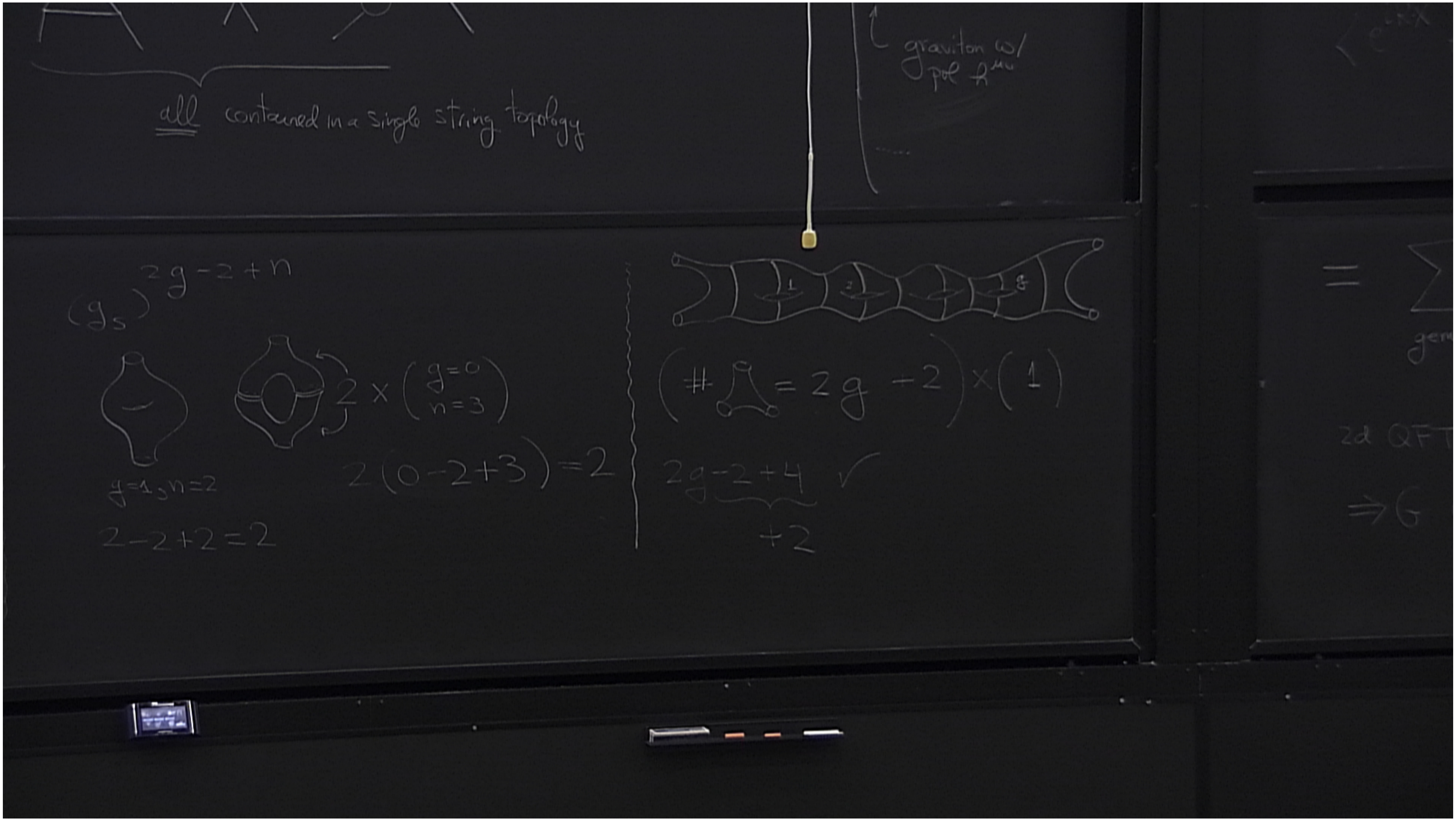

= Σ (g_s)^{2g-2+n} ∫DX V_1 ... V_n exp(- Tensi
genus g
string coupling
2d Surfaces of genus g
small T
large T
∫DX!
or
2d QFT is a CFT ⇒ β_{G,...}(X) = 0
⇒ G obeys (gen) Einsten Eqs.

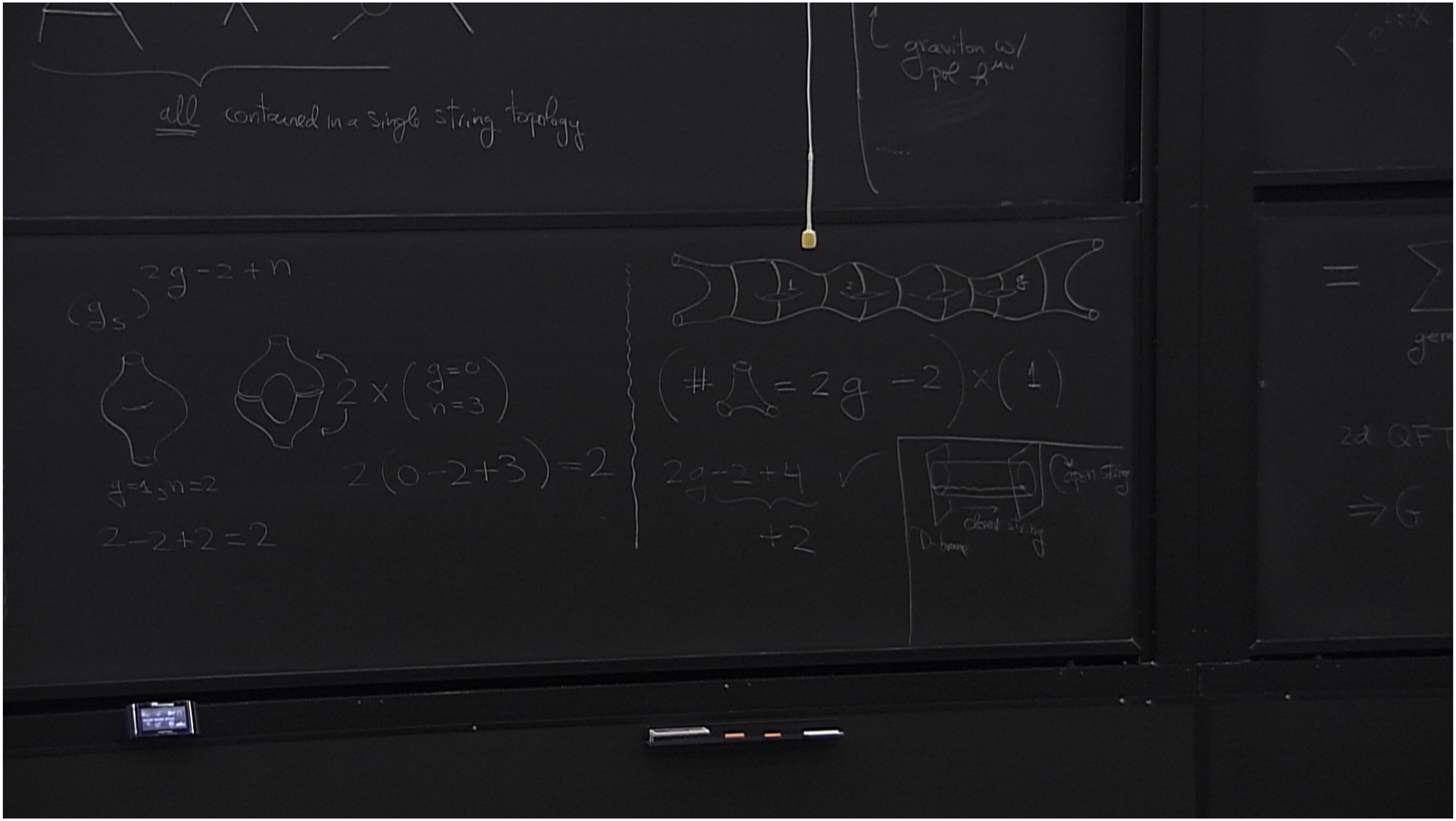

$V_1 \ldots V_n \exp(-\text{Tension}\, S[X])$
2d CFT
$\frac{1}{T}$
small T
$\int \mathcal{D}X$!
large T
or
minimal area surface
$\int [G_{\mu\nu}(X)\partial^\alpha X^\mu \partial^\beta X^\nu \gamma_{\alpha\beta} + B_{\mu\nu}(X)\varepsilon^{\alpha\beta}\partial X \partial X + \Phi(X) R^{(2)}$
background

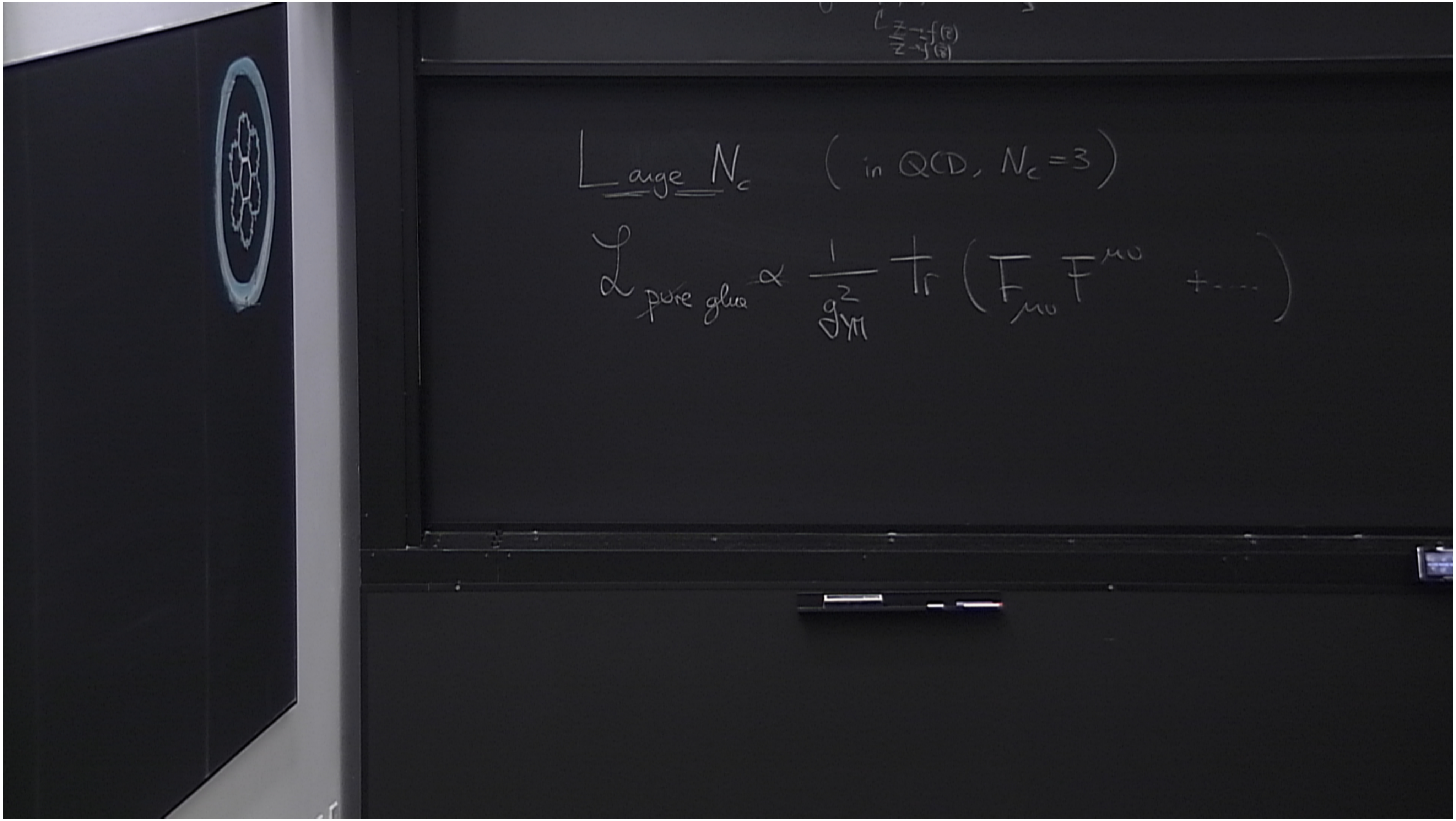


$\int dz\, V(z,\bar{z})$
$z \to f(z)$
$\bar{z} \to \bar{f}(\bar{z})$
gravitons
$\eta_{\mu\nu} \to \eta_{\mu\nu} + h_{\mu\nu}$
$\sum_n \frac{1}{n!}(V_{grav})^n \rightsquigarrow \delta S' = \int h_{\mu\nu}(X)\, \partial X^\nu \bar{\partial} X^\mu$


or
different
particles
at once
heavier
all contained in a single string topology
graviton w/
pol
(g_s)^{2g-2+n}
g=1, n=2
2-2+2=2
2 x (g=0, n=3)
2(0-2+3)=2


all contained in a single string topology
graviton w/ pol
(gs)^2g-2+n
2 × (g=0 n=3)
g=1, n=2
2-2+2=2
2(0-2+3)=2
(# = 2g -2) × (1)
2g-2+4
+2
2d QFT


all contained in a single string topology
graviton w/ pol
$(g_s)^{2g-2+n}$
$g=1, n=2$
$2-2+2=2$
$2 \times \begin{pmatrix} g=0 \\ n=3 \end{pmatrix}$
$2(0-2+3)=2$
$2g-2+4$
$+2$
$= 2g-2$
open string
closed string
D-brane
2d QFT



Large N_c (in QCD, $N_c = 3$)
$\mathcal{L}_{\text{pure glue}} \propto \frac{1}{g_{YM}^2} \mathrm{tr}\left(F_{\mu\nu}F^{\mu\nu} + \ldots\right)$

$\ldots \left(\ldots + \cdots \right)$

$$\mu \frac{d}{d\mu} g_{YM} = \frac{g_{YM}^3 N_c}{16\pi^2}\left(-\frac{11}{3} + \cdots\right)$$

$g_{YM} \to 0$ small

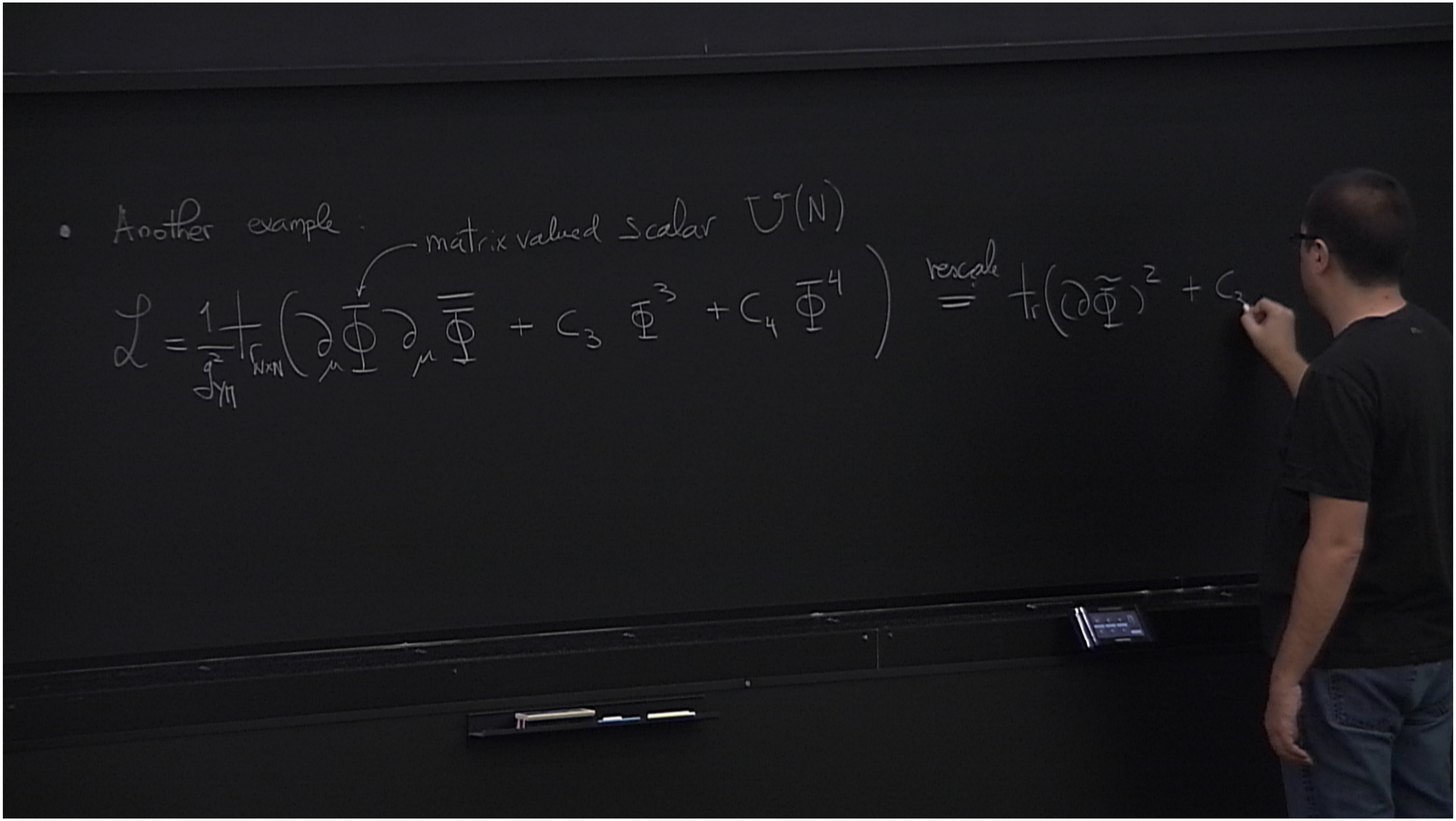
but N_c large

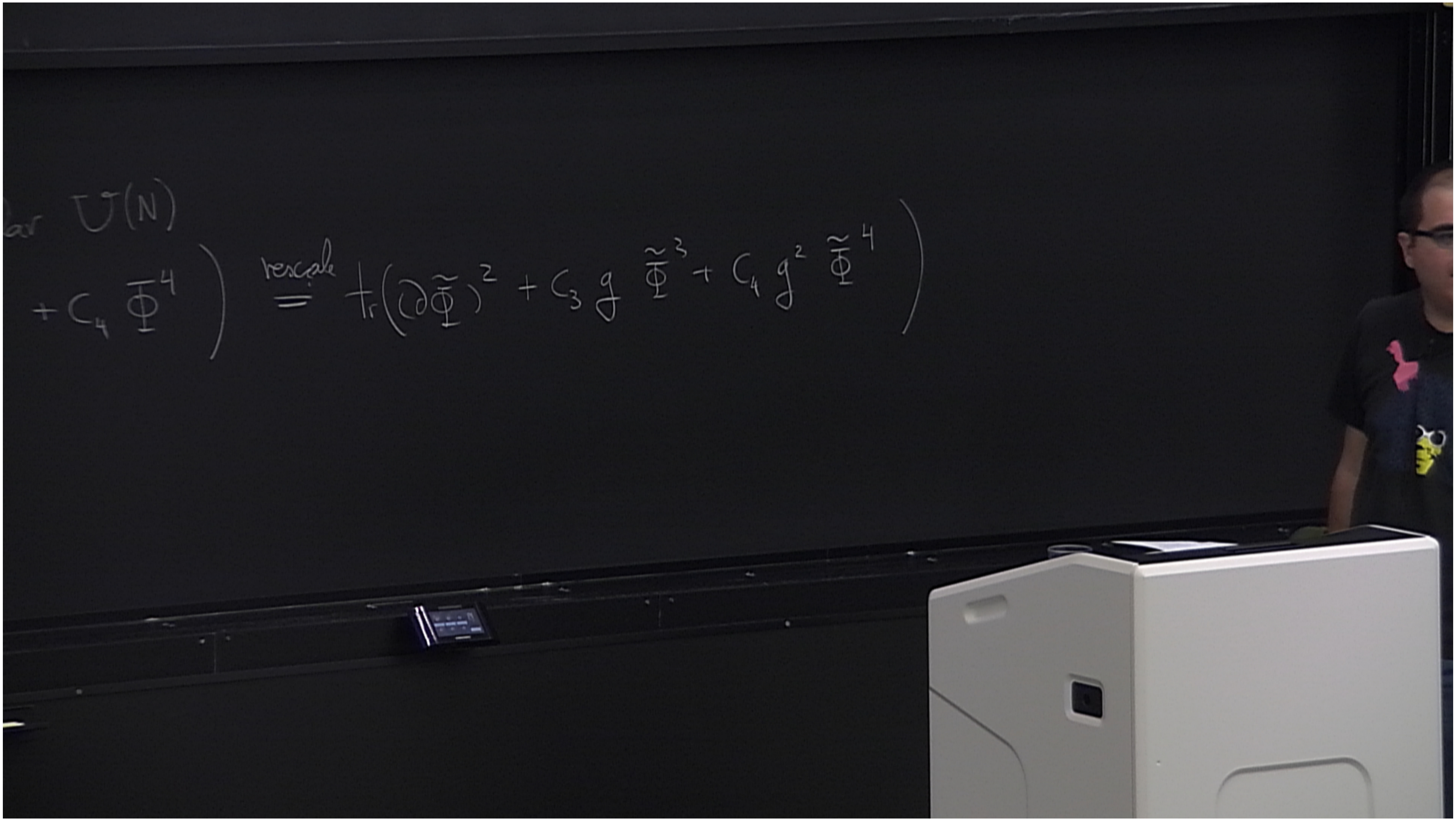
$\hookrightarrow \infty$

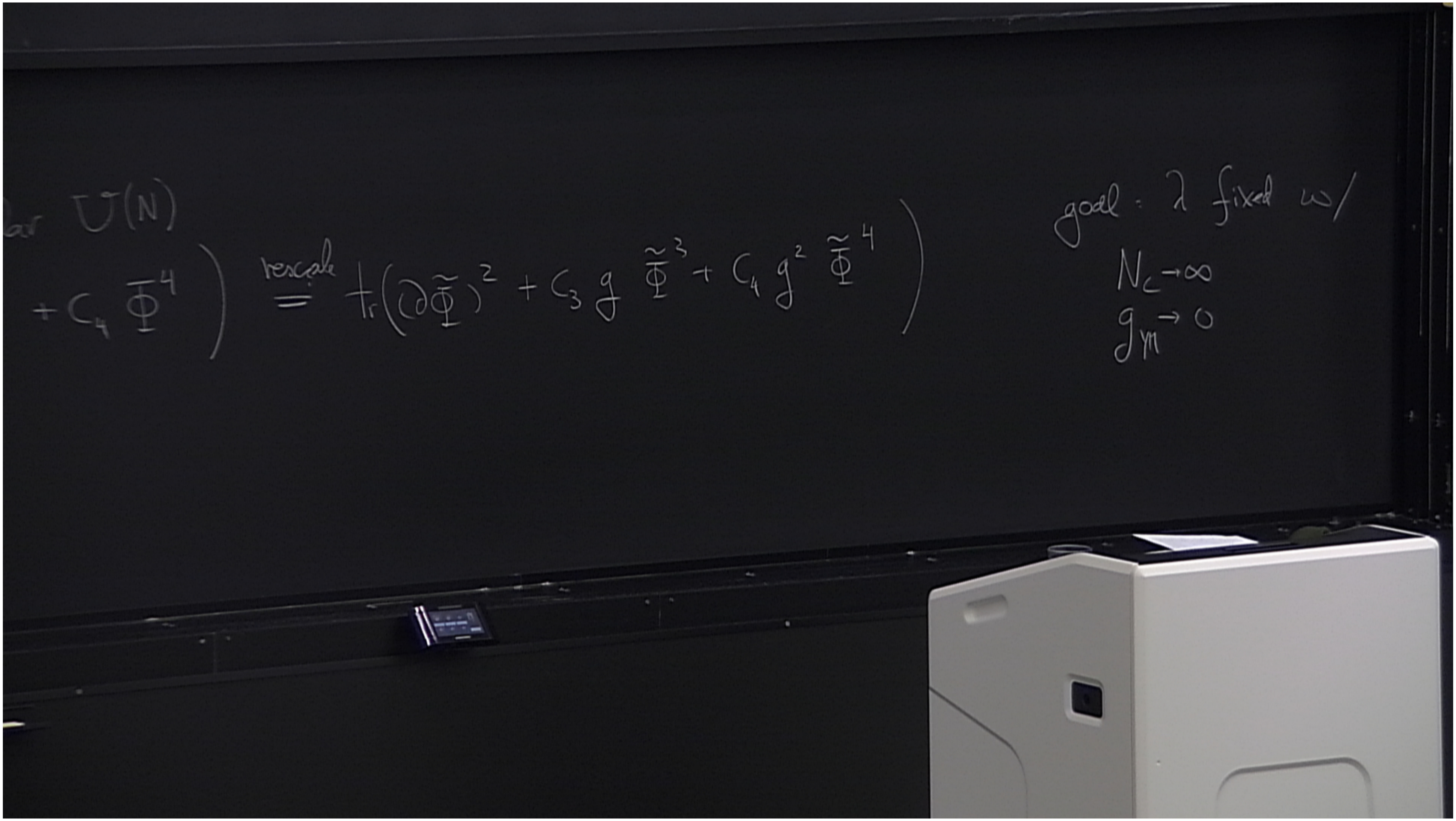
$$\mu \frac{d}{d\mu}\lambda = \# \lambda^2 \qquad \boxed{\lambda = g_{YM}^2 N_c}$$

't Hooft coupling

λ fixed


• Another example: matrix valued scalar U(N)
L = 1/g_YM^2 tr_NxN (∂_μ Φ ∂_μ Φ + c_3 Φ^3 + c_4 Φ^4) rescale = tr((∂Φ̃)^2 + c_3

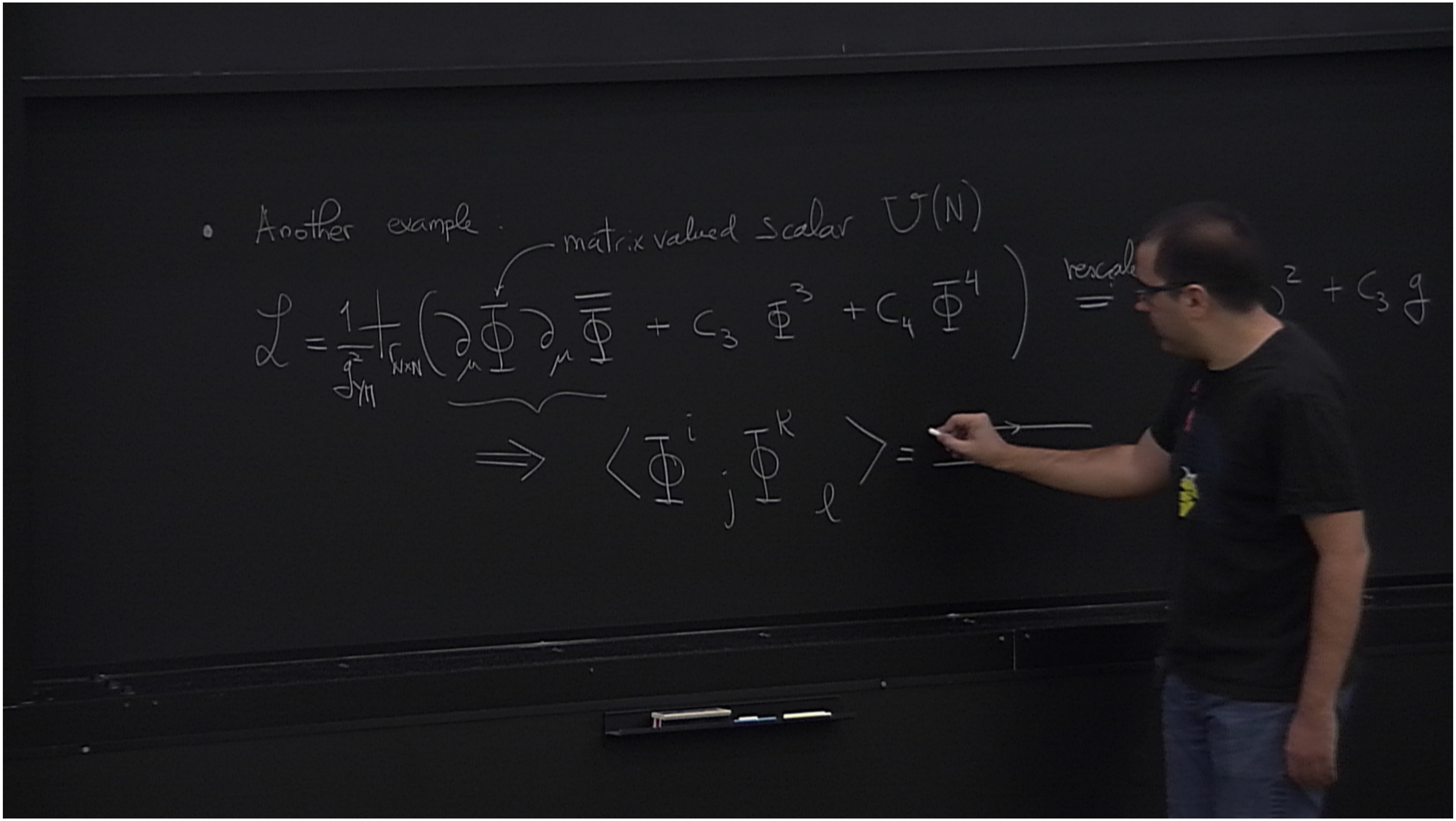

lar $U(N)$
$+ C_4 \Phi^4 \Big) \overset{\text{rescale}}{=} \mathrm{tr}\Big((\partial\tilde{\Phi})^2 + c_3\, g\, \tilde{\Phi}^3 + c_4\, g^2\, \tilde{\Phi}^4 \Big)$

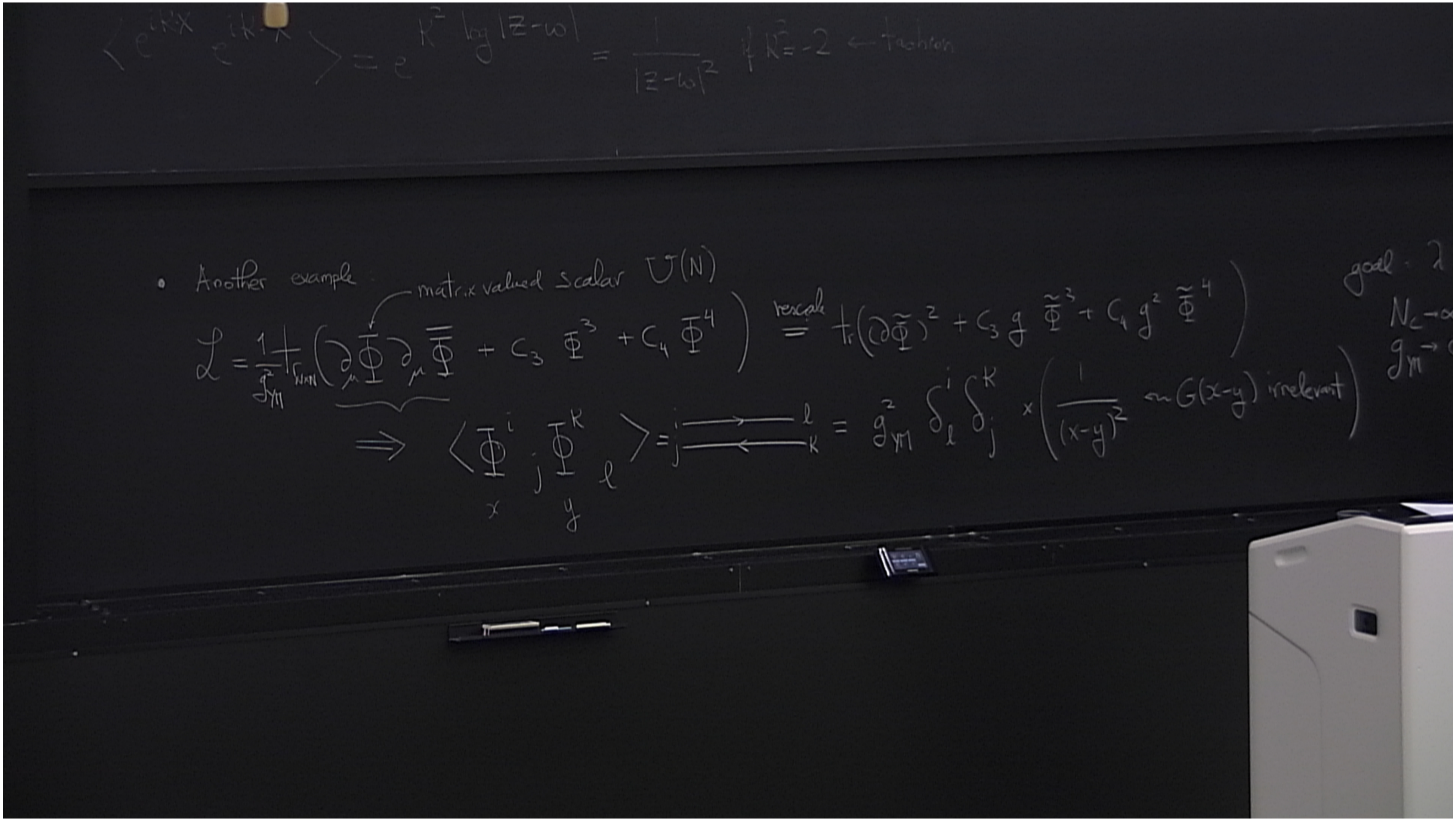

lar $U(N)$
$+ c_4 \Phi^4)$
$\overset{\text{rescale}}{=} \mathrm{tr}\left((\partial \tilde{\Phi})^2 + c_3 g \tilde{\Phi}^3 + c_4 g^2 \tilde{\Phi}^4 \right)$
goal: λ fixed w/
$N_c \to \infty$
$g_{YM} \to 0$

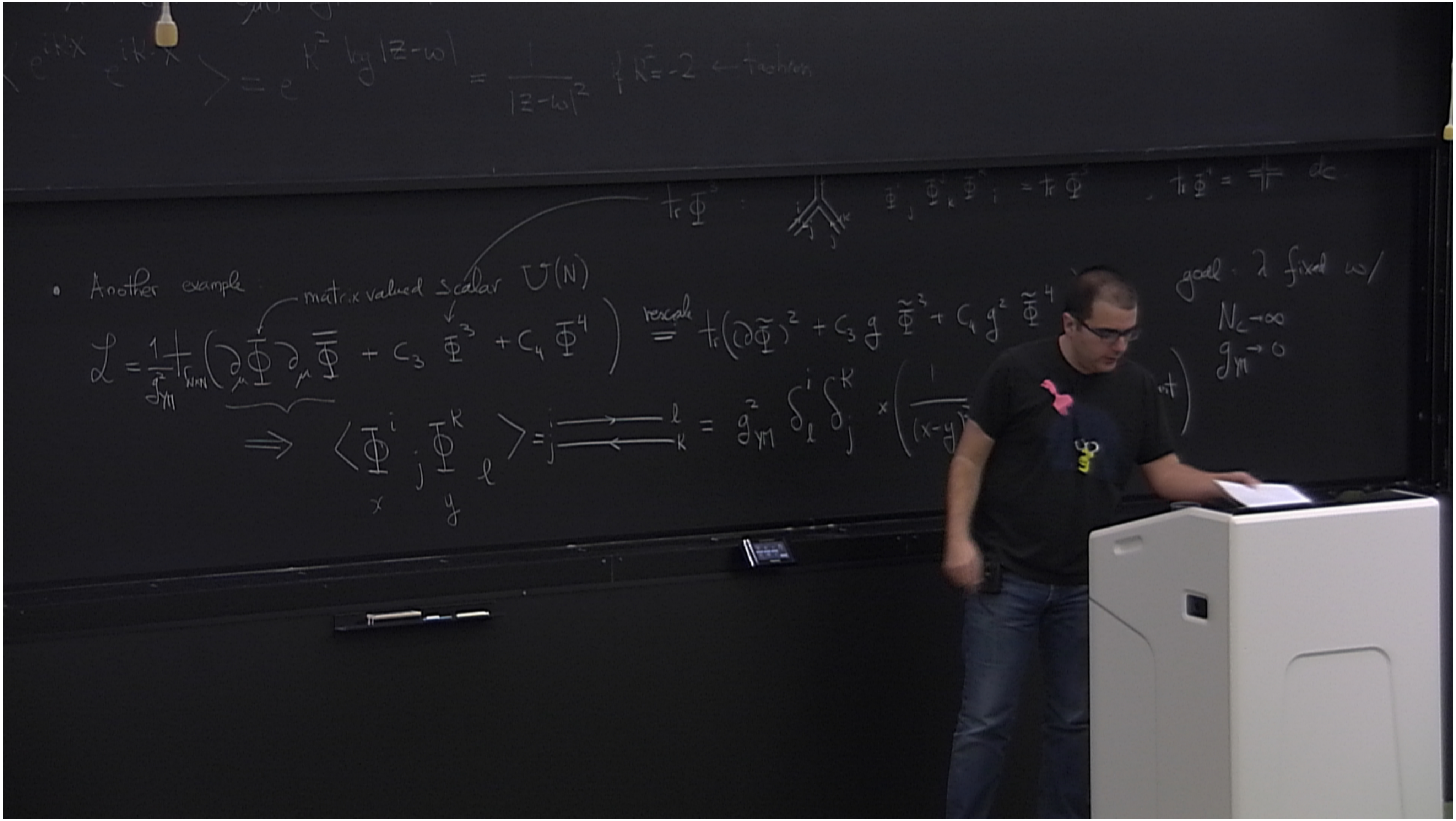
- Another example: matrix valued scalar $U(N)$

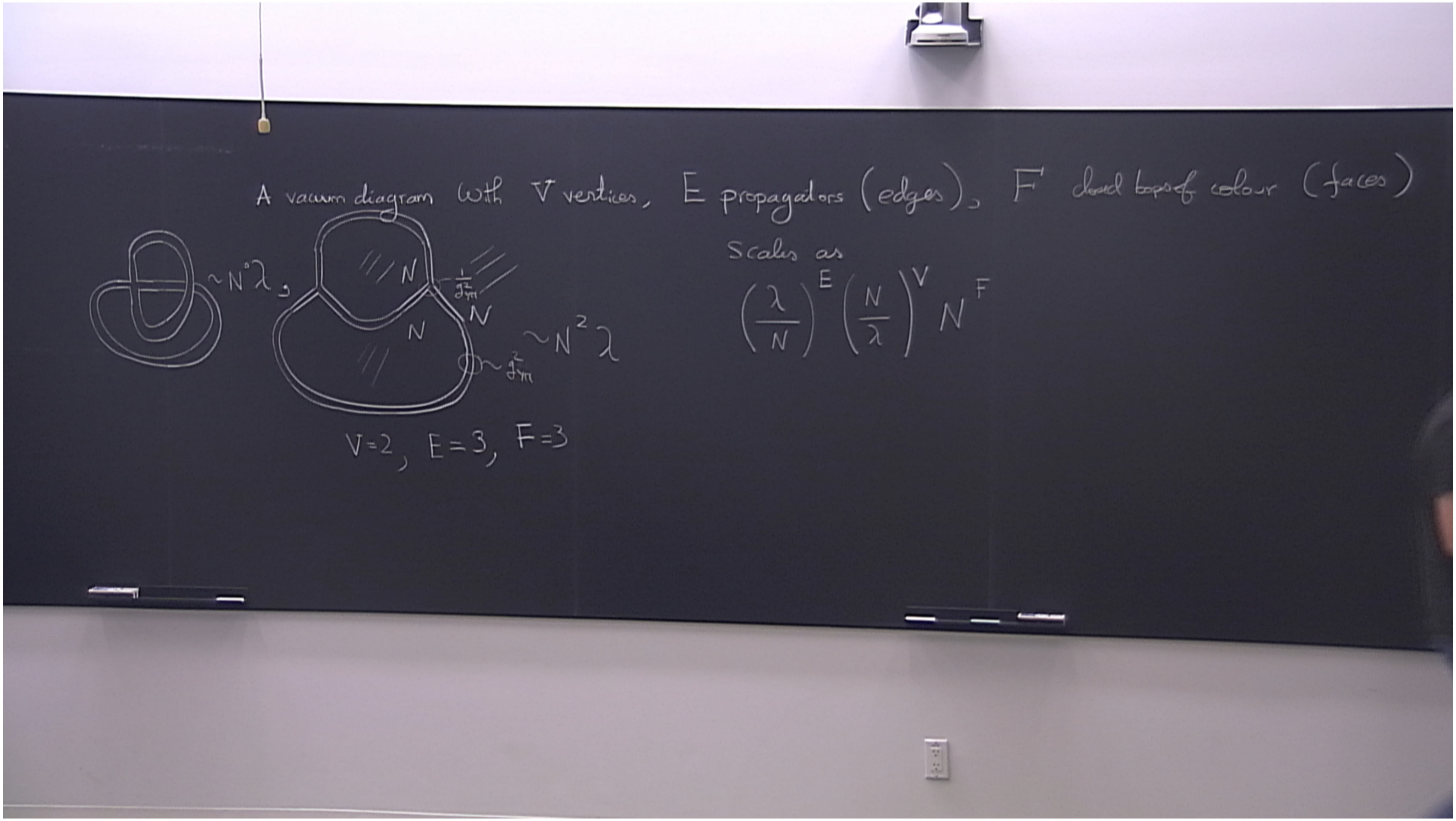
$$\mathcal{L} = \frac{1}{g_{YM}^2} \mathrm{tr}_{N\times N}\left(\underbrace{\partial_\mu \Phi\, \partial_\mu \bar{\Phi}} + c_3\, \Phi^3 + c_4\, \Phi^4 \right) \overset{\text{rescale}}{=} \mathrm{tr}(\partial \tilde{\Phi})^2 + c_3\, g$$

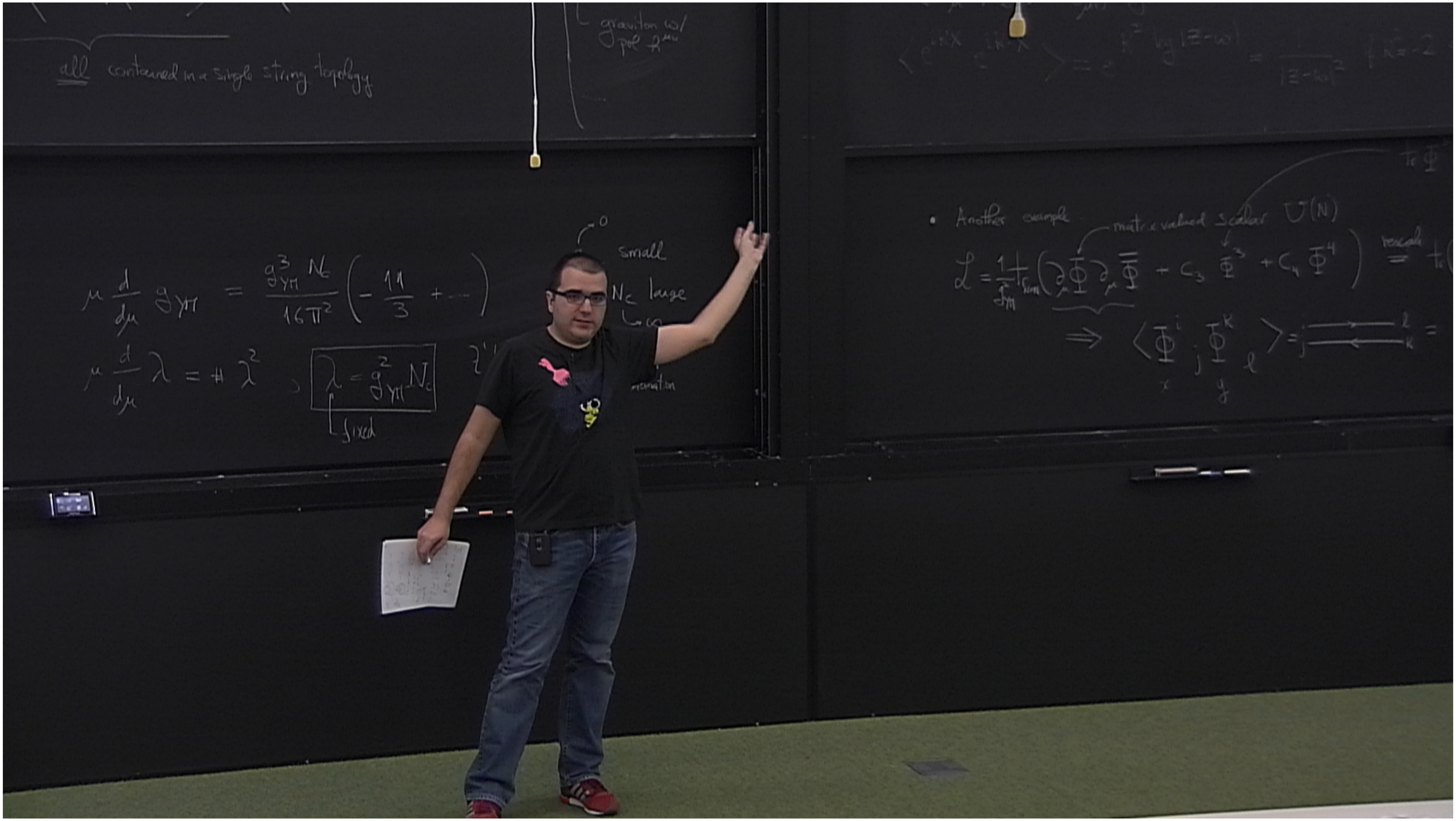
$$\Longrightarrow \langle \Phi^i{}_j\, \Phi^k{}_l$$

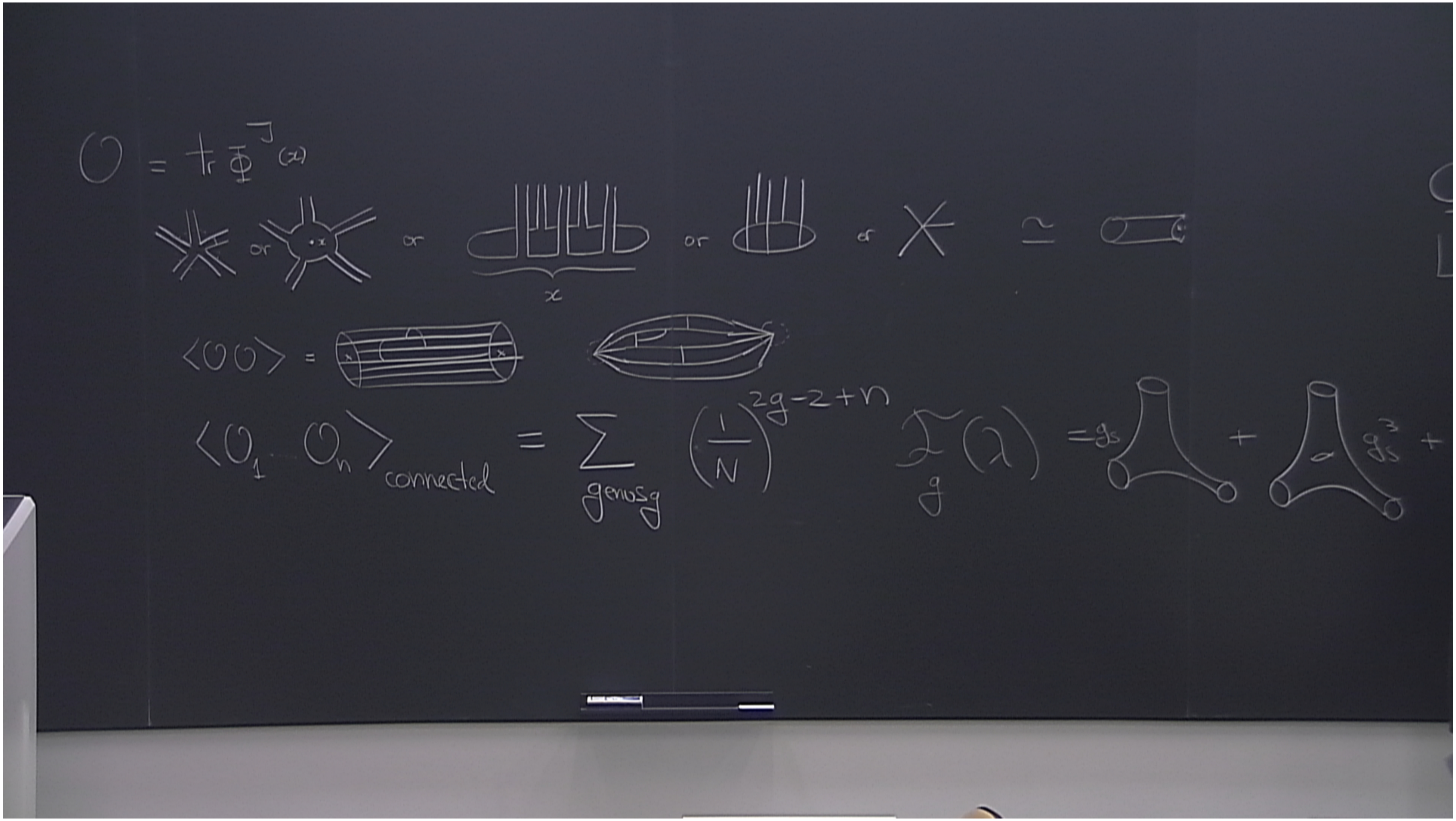

• Another example.
matrix valued scalar U(N)
$\mathcal{L} = \frac{1}{g_{YM}^2} \mathrm{tr}_{N\times N}\left(\partial_\mu \Phi \partial_\mu \Phi + c_3 \Phi^3 + c_4 \Phi^4\right)$
rescale
$)^2 + c_3 g$
$\Rightarrow \langle \Phi^i{}_j \Phi^k{}_l \rangle =$


$\langle e^{ik\cdot x} e^{ik\cdot x} \rangle = e^{k^2 \log|z-w|} = \frac{1}{|z-w|^2}$ if $k^2=-2$ ← tachyon
• Another example: matrix valued scalar $U(N)$
$\mathcal{L} = \frac{1}{g_{YM}^2} \mathrm{tr}_{N\times N}\left(\partial_\mu \Phi \partial_\mu \Phi + c_3 \Phi^3 + c_4 \Phi^4\right) \overset{\text{rescale}}{=} \mathrm{tr}\left((\partial\tilde{\Phi})^2 + c_3 g \tilde{\Phi}^3 + c_4 g^2 \tilde{\Phi}^4\right)$
$\Rightarrow \langle \Phi^i{}_j(x) \Phi^k{}_l(y) \rangle = g_{YM}^2 \delta^i_l \delta^k_j \times \left(\frac{1}{(x-y)^2} \sim G(x-y) \text{ irrelevant}\right)$
goal: λ
$N_c \to \infty$
$g_{YM} \to$

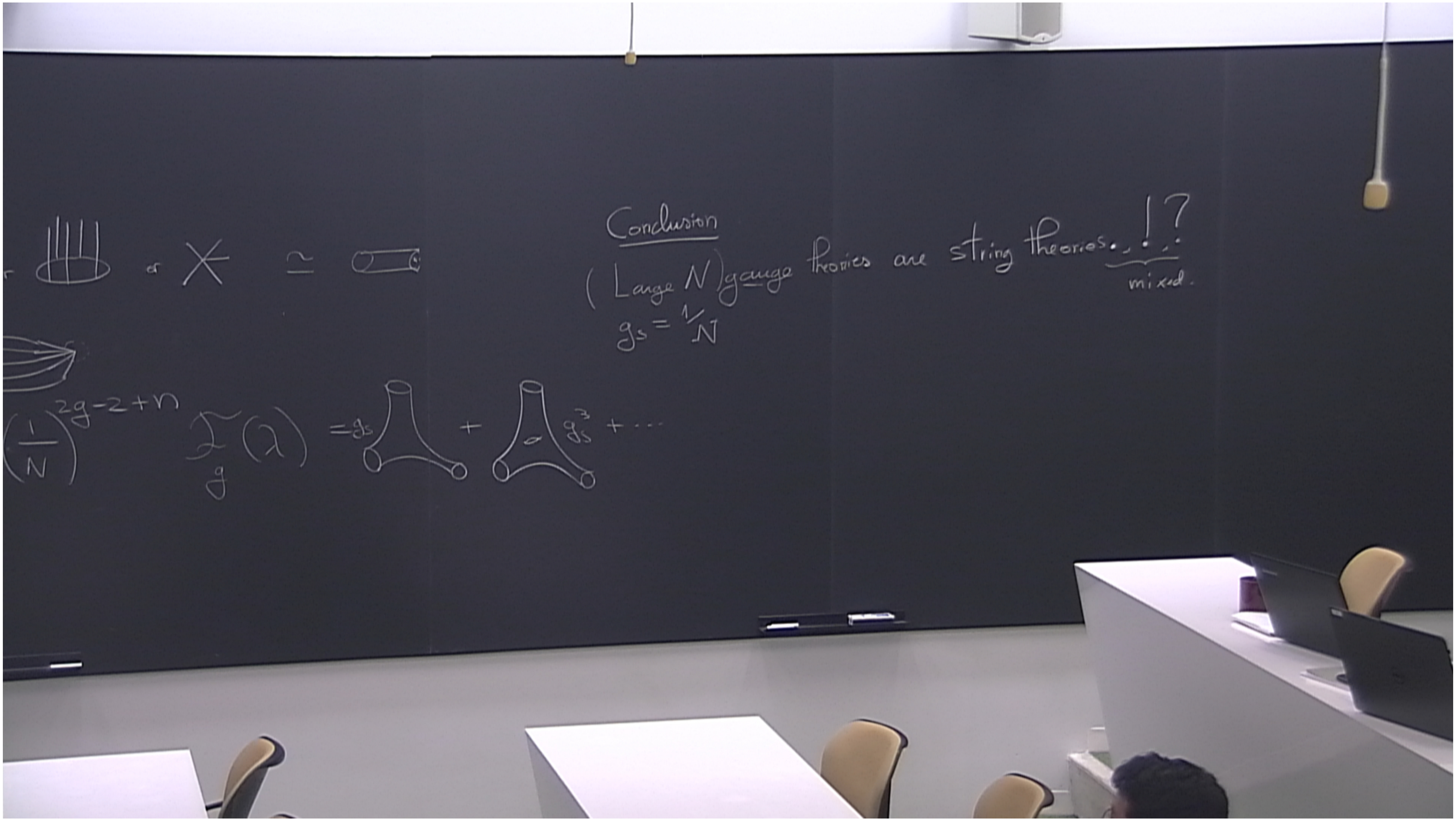

Another example: matrix valued scalar U(N)
goal: λ fixed w/
N_c → ∞
g_YM → 0
rescale
tachyon

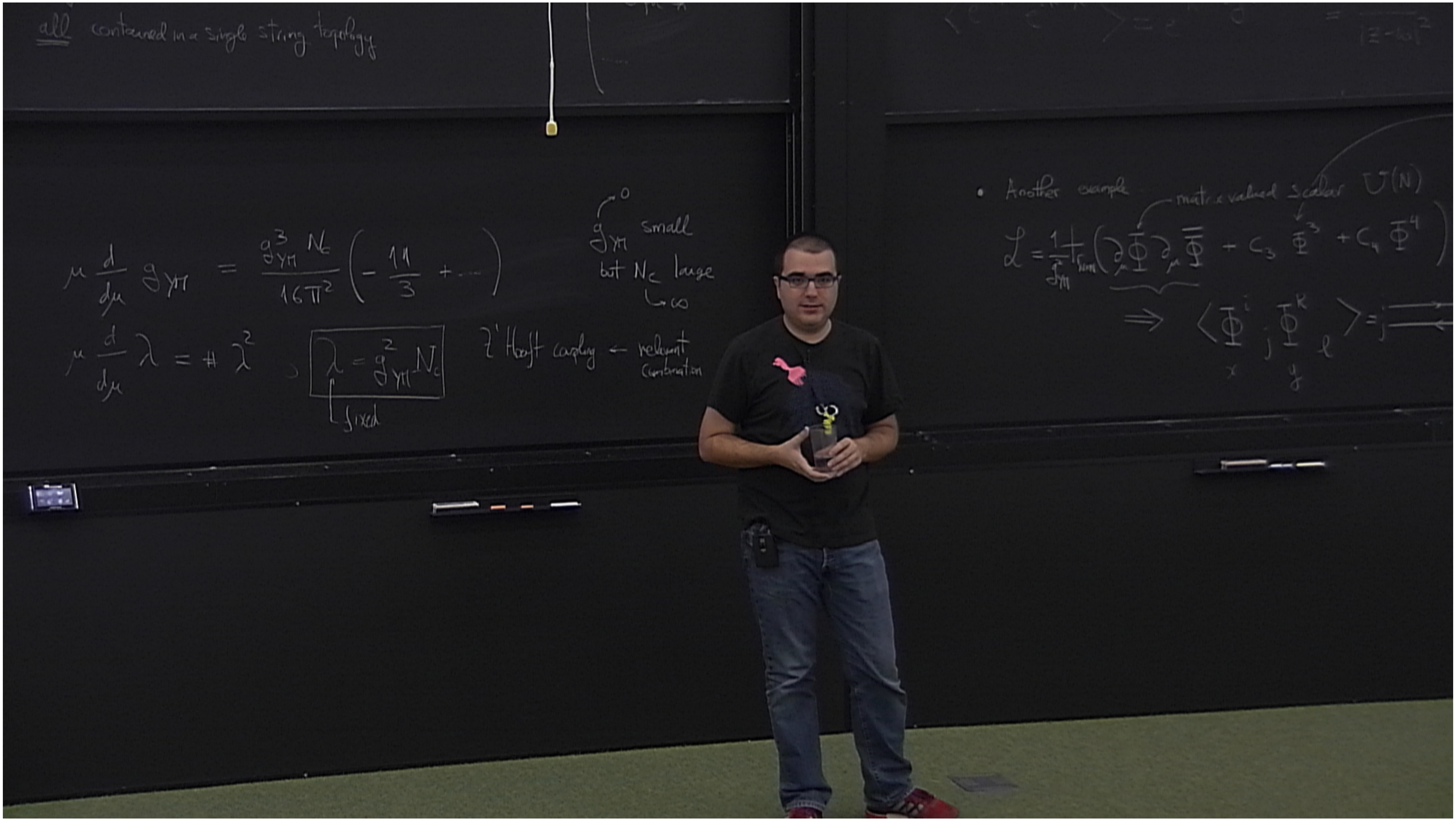

A vacuum diagram with V vertices, E propagators (edges), F closed loops of colour (faces)
$\sim N^0 \lambda$,
N
$\frac{1}{g^2_{YM}}$
N
N
$\sim N^2 \lambda$
$\sim g^2_{YM}$
V=2, E=3, F=3
Scales as
$\left(\frac{\lambda}{N}\right)^E \left(\frac{N}{\lambda}\right)^V N^F$


all contained in a single string topology
graviton w/
small
N_c large
fixed
Another example
matrix valued scalar
U(N)



$\mathcal{O} = \mathrm{tr}\,\Phi^J(x)$
or
or
or
or
$\simeq$
x
$\langle \mathcal{O}\mathcal{O} \rangle =$
$\langle \mathcal{O}_1 \cdots \mathcal{O}_n \rangle_{\text{connected}} = \sum_{\text{genus } g} \left(\frac{1}{N}\right)^{2g-2+n} \mathcal{F}_g(\lambda)$
$= g_s$
$+$
g_s^3
$+$


Conclusion
(Large N) gauge theories are string theories...!?
mixed.
$g_s = 1/N$
$\left(\frac{1}{N}\right)^{2g-2+n}$
$\sum_g (\lambda) = g_s$
$+$
$g_s^3 + \cdots$


all contained in a single string topology
small
but N_c large
't Hooft coupling
relevant combination
fixed
Another example
matrix valued scalar
U(N)