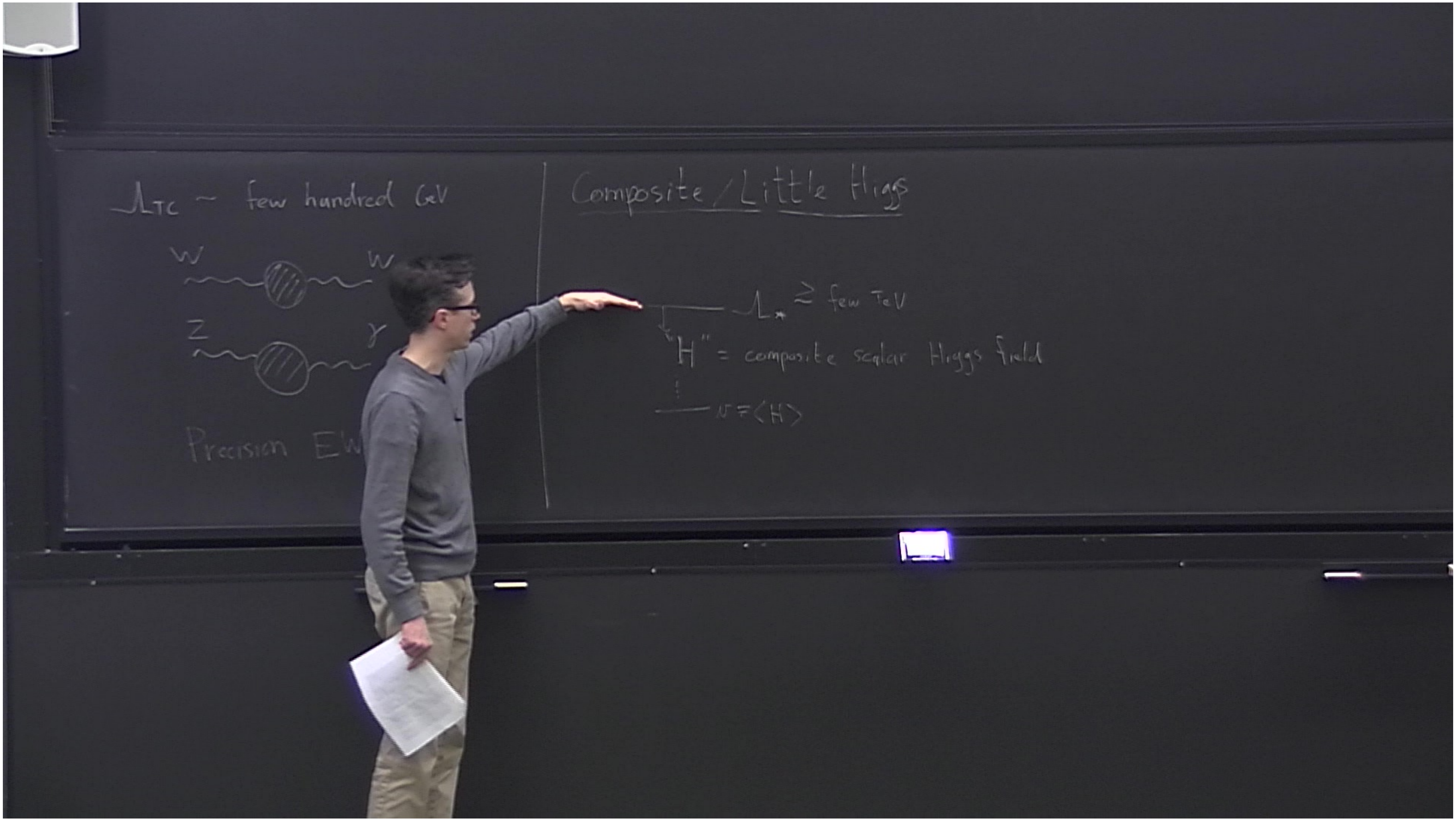
Title: Beyond Standard Model-12

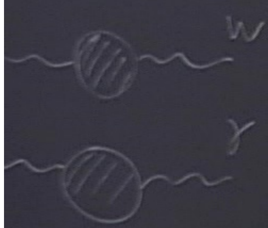
Date: Mar 04, 2015 09:00 AM

URL: http://pirsa.org/15030003

Abstract:


Λ_TC ~ few hundred GeV
W
W
Z
γ
Precision EW
Composite / Little Higgs
Λ* ≳ few TeV
"H" = composite scalar Higgs field
v = ⟨H⟩

few hundred GeV



ecision EW Test

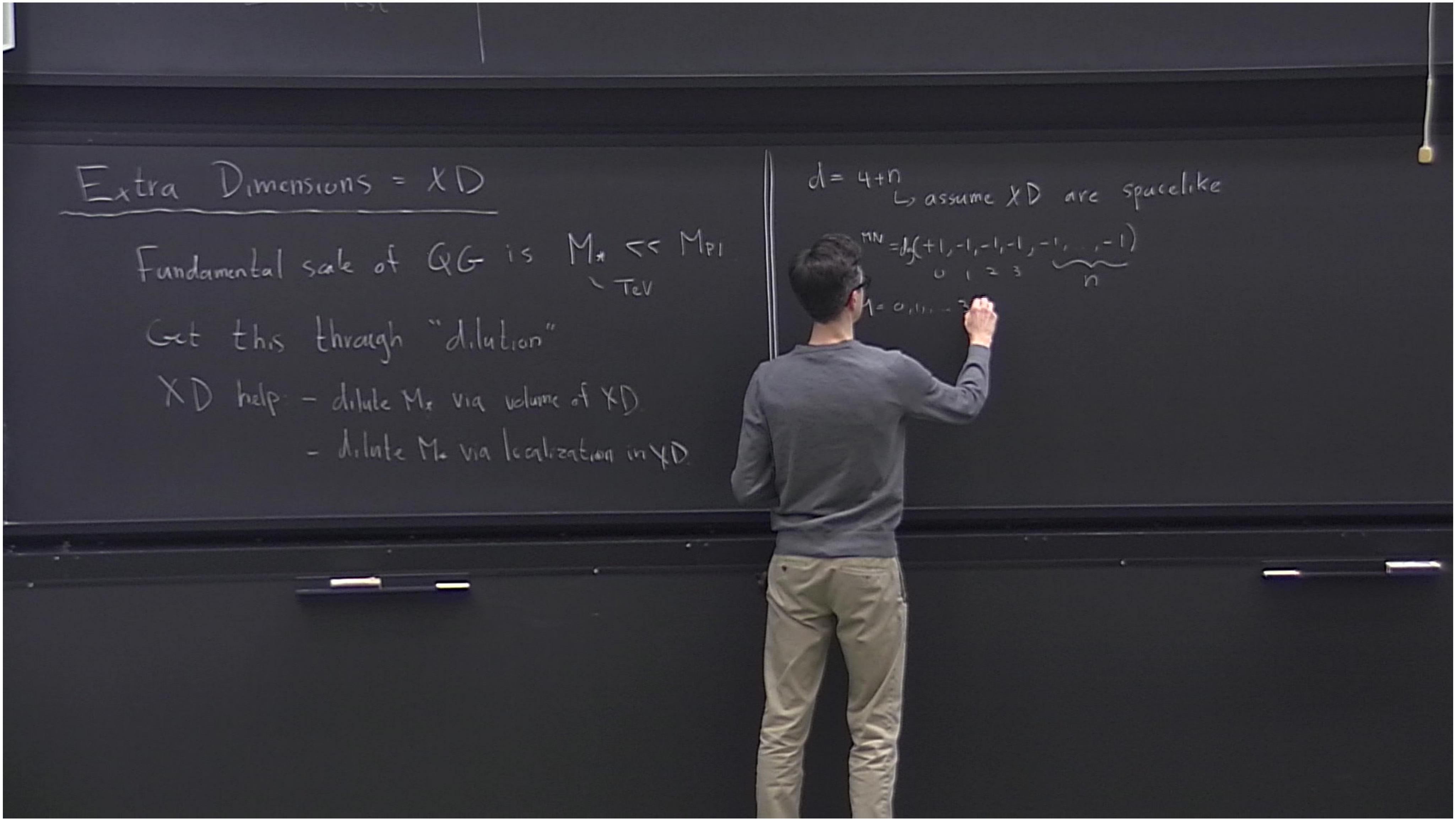
Composite / Little Higgs

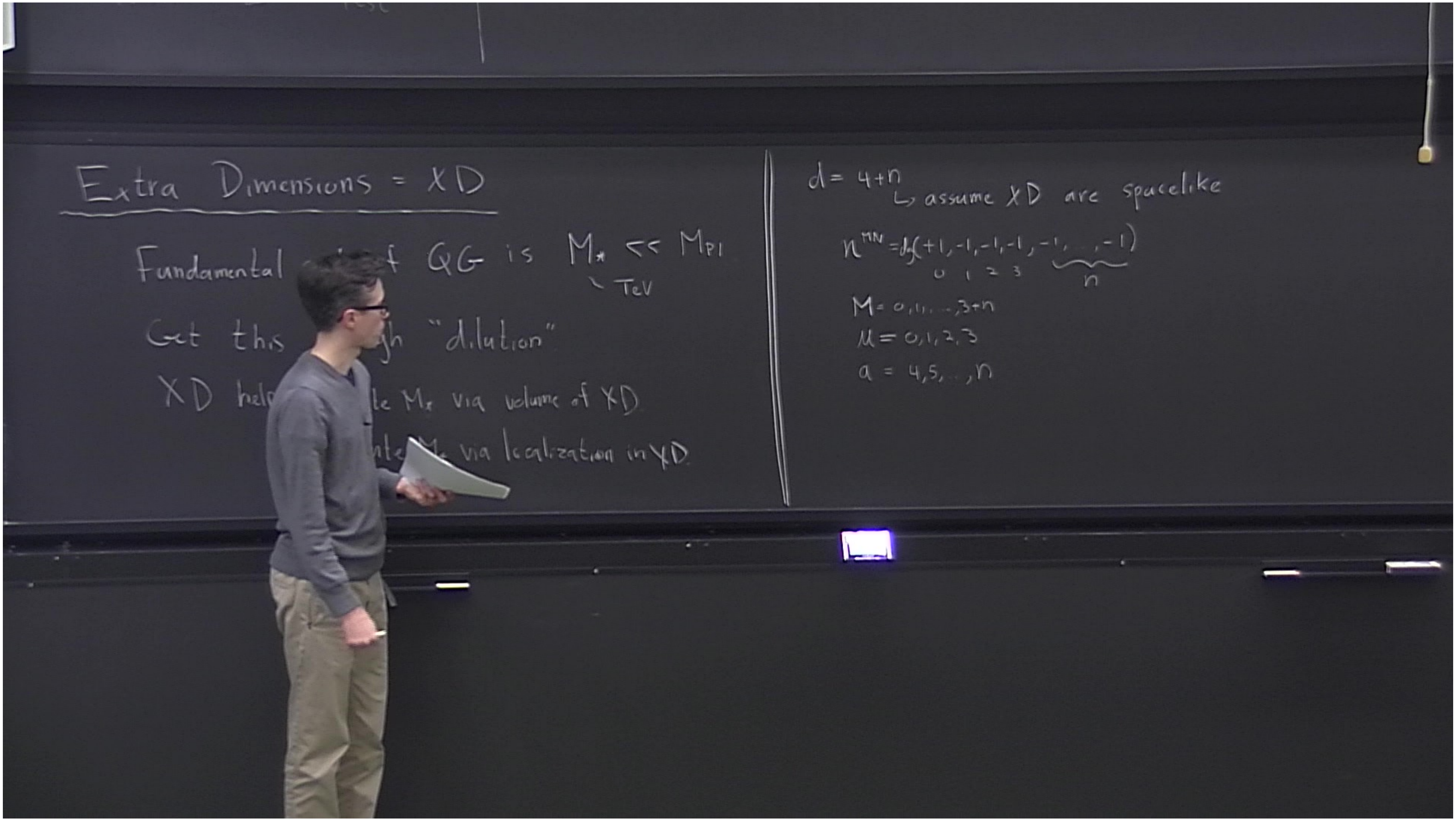
$\Lambda_* \gtrsim$ few TeV

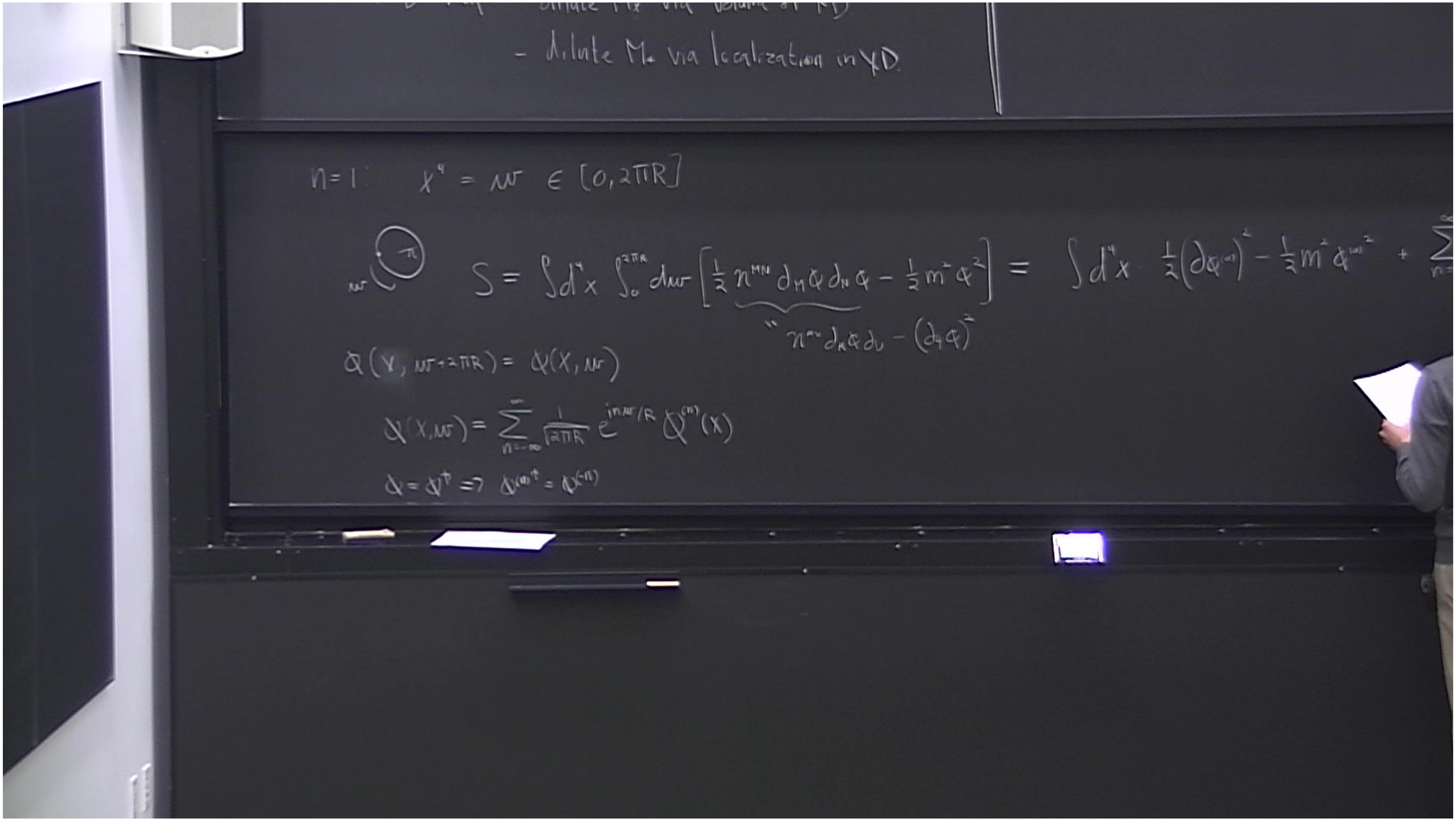
"H" = composite scalar Higgs field

$v = \langle H \rangle$

Composite Higgs ~ approximate NGB


Extra Dimensions = XD
Fundamental scale of QG is M* << MPl
~ TeV
Get this through "dilution"
XD help - dilute M* via volume of XD
- dilute M* via localization in XD
d = 4+n
↳ assume XD are spacelike
MN = diag(+1, -1, -1, -1, -1, ..., -1)
0 1 2 3
n
M = 0, 1, ...


Extra Dimensions = XD
Fundamental
f QG is M* << MPl
~ TeV
Get this
gh "dilution"
XD help
te M* via volume of XD
te
via localization in XD
d = 4+n
↳ assume XD are spacelike
η^MN = diag(+1,-1,-1,-1,-1,...,-1)
0 1 2 3
n
M = 0,1,...,3+n
μ = 0,1,2,3
a = 4,5,...,n


- dilute M_* via localization in XD
$n=1$: $x^4 = w \in [0, 2\pi R]$
$S = \int d^4x \int_0^{2\pi R} dw \left[\frac{1}{2} \eta^{MN} \partial_M \phi \partial_N \phi - \frac{1}{2} m^2 \phi^2 \right] = \int d^4x \ \frac{1}{2}(\partial \phi^{(0)})^2 - \frac{1}{2} m^2 \phi^{(0)2} + \sum$
$\eta^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - (\partial_4 \phi)^2$
$\phi(x, w + 2\pi R) = \phi(x, w)$
$\phi(x, w) = \sum_{n=-\infty}^{\infty} \frac{1}{\sqrt{2\pi R}} e^{inw/R} \phi^{(n)}(x)$
$\phi = \phi^\dagger \Rightarrow \phi^{(n)\dagger} = \phi^{(-n)}$

- dilute M_* via localization in XD

$w \in [0, 2\pi R]$

$$= \int d^4x \int_0^{2\pi R} dw \left[\frac{1}{2} \underbrace{\eta^{MN} \partial_M \phi \, \partial_N \phi}_{\text{“} \eta^{\mu\nu} \partial_\mu \phi \, \partial_\nu - (\partial_4 \phi)^2} - \frac{1}{2} m^2 \phi^2 \right] = \int d^4x \left(\underbrace{\frac{1}{2} (\partial \phi^{(0)})^2 - \frac{1}{2} m^2 \phi^{(0)2}}_{\text{“zero mode scalar”}} + \sum_{n=1}^{\infty} \underbrace{\left[\partial_\mu \phi^{(n)\dagger} \partial^\mu \phi^{(n)} - \left(m^2 + \frac{n^2}{R^2} \right) \phi^{(n)\dagger} \phi^{(n)} \right]}_{\text{Kaluza-Klein modes (KK)}} \right)$$

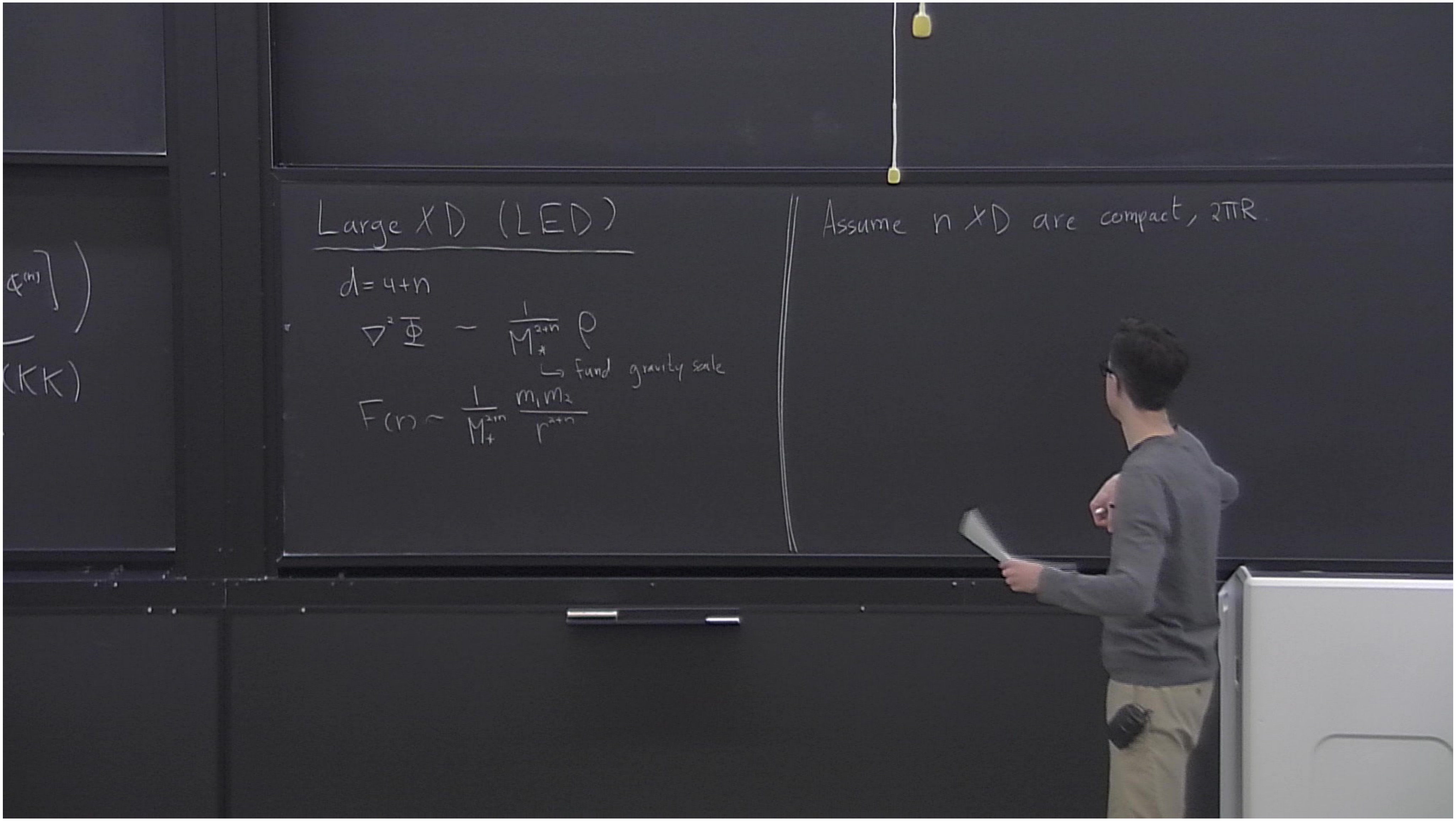
$m_0^2 = m^2$

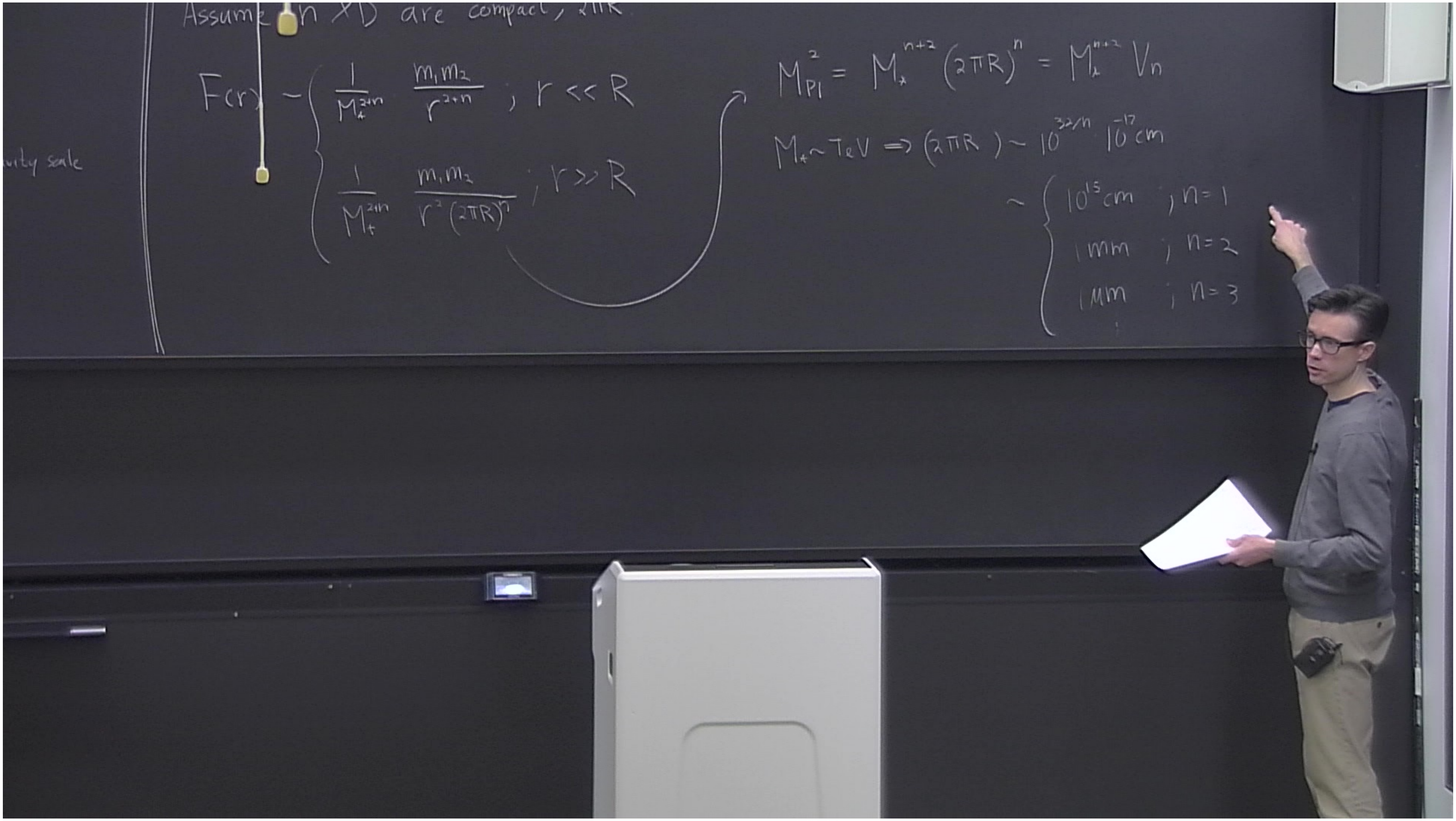
$m_n^2 = m^2 + n^2/R^2$

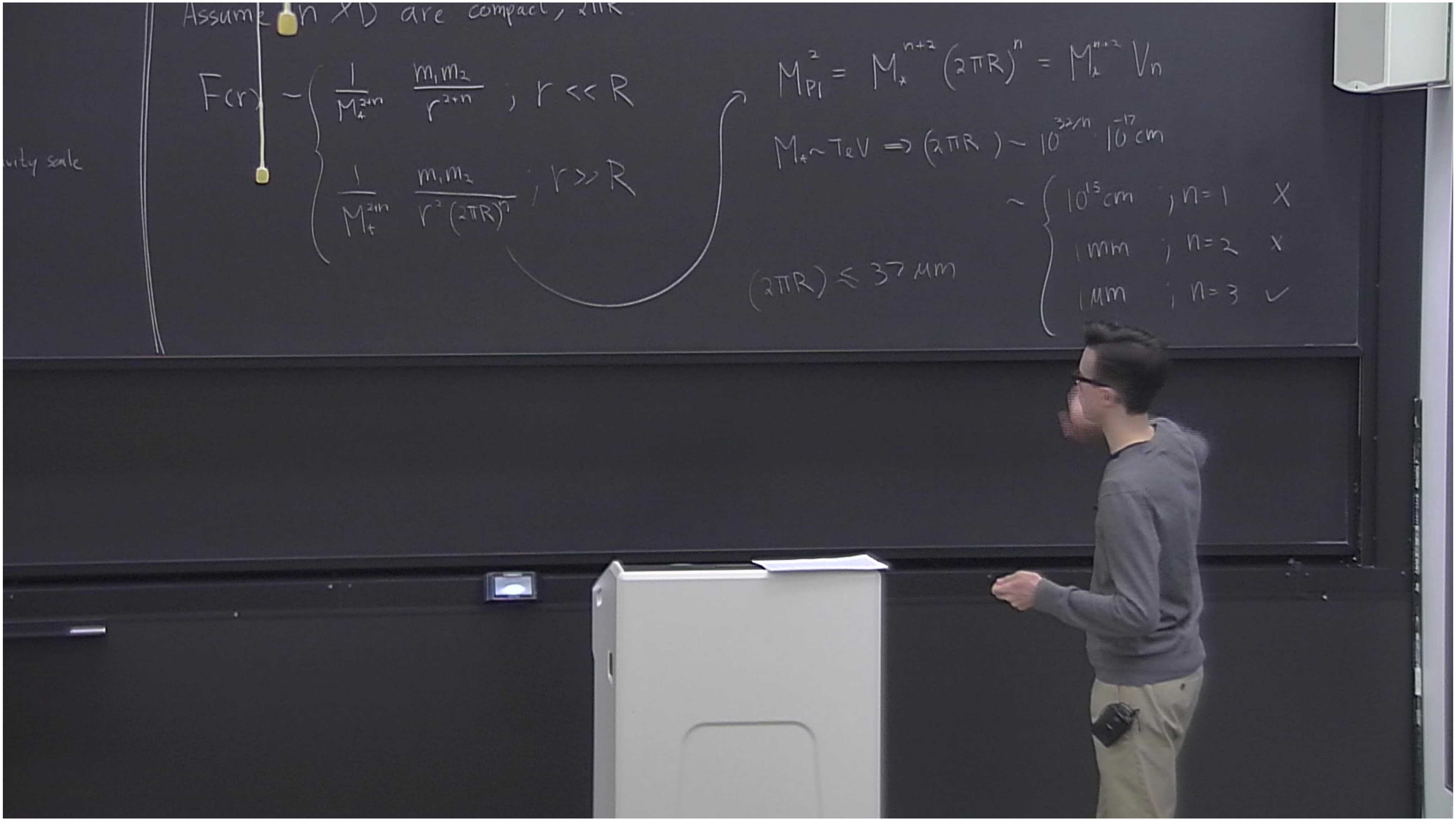
$) = \phi(X, w)$

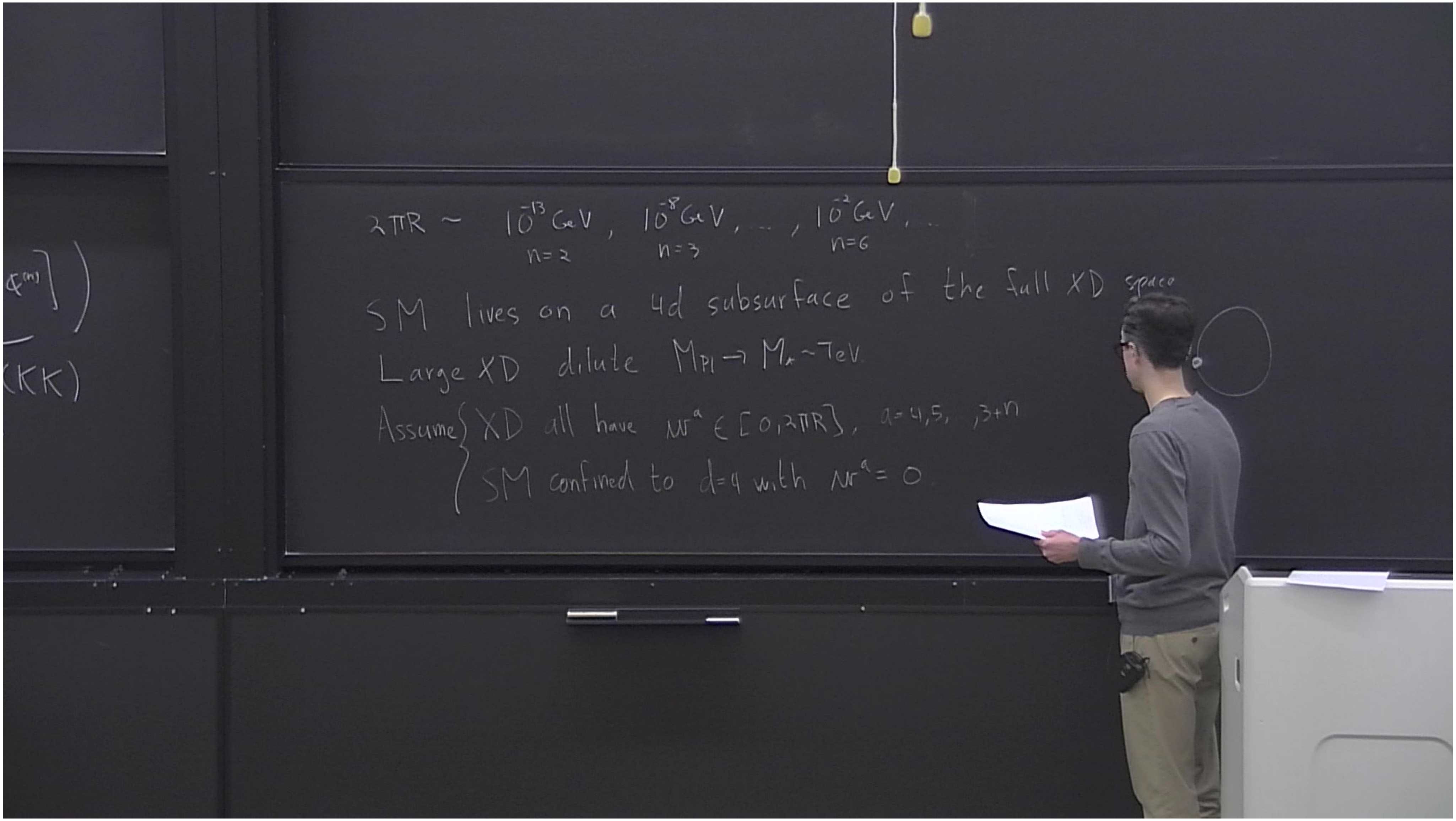
$$\sum_{n=-\infty}^{\infty} \frac{1}{\sqrt{2\pi R}} e^{inw/R} \phi^{(n)}(X)$$

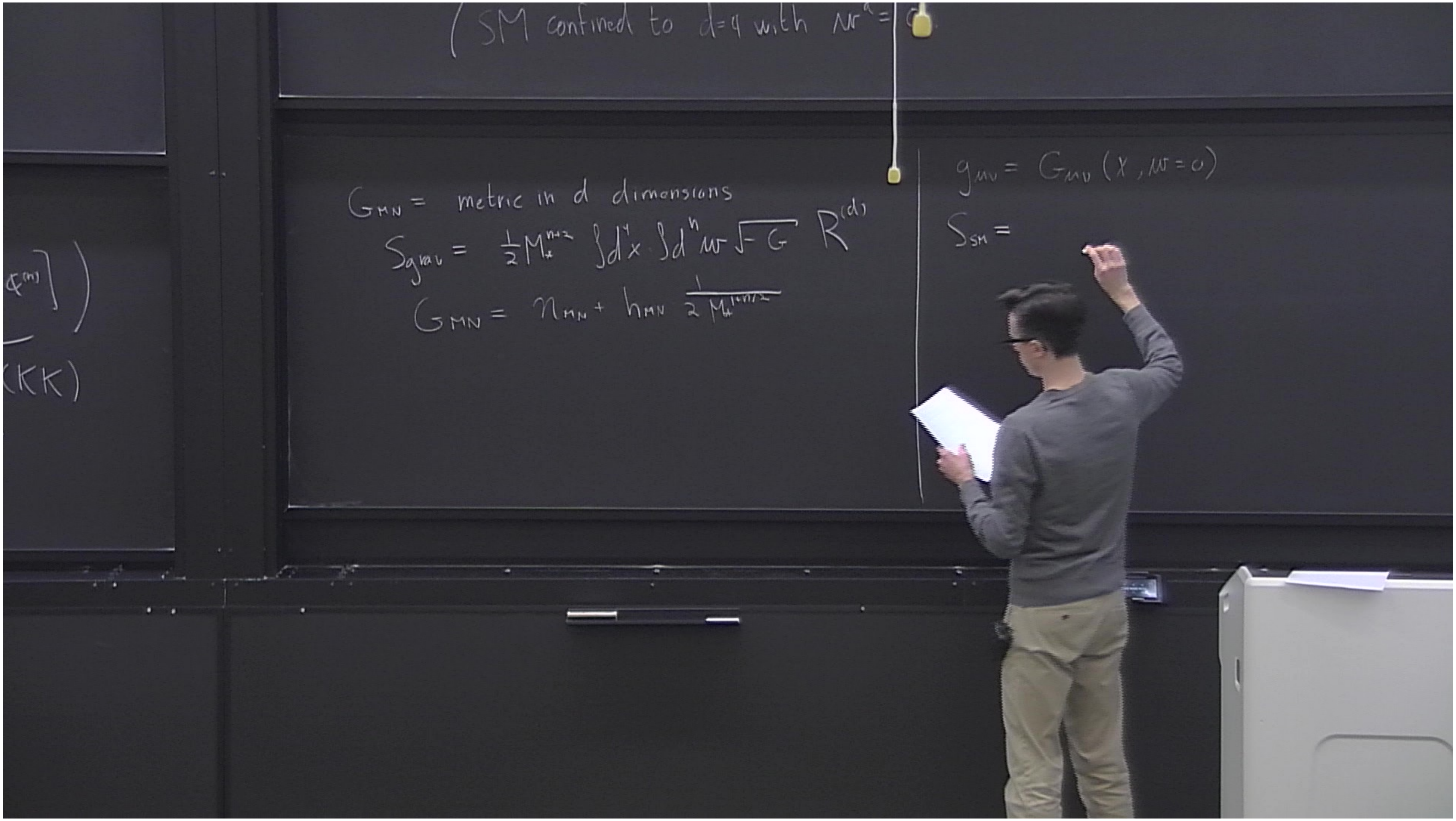
$\phi^{(n)\dagger} = \phi^{(-n)}$

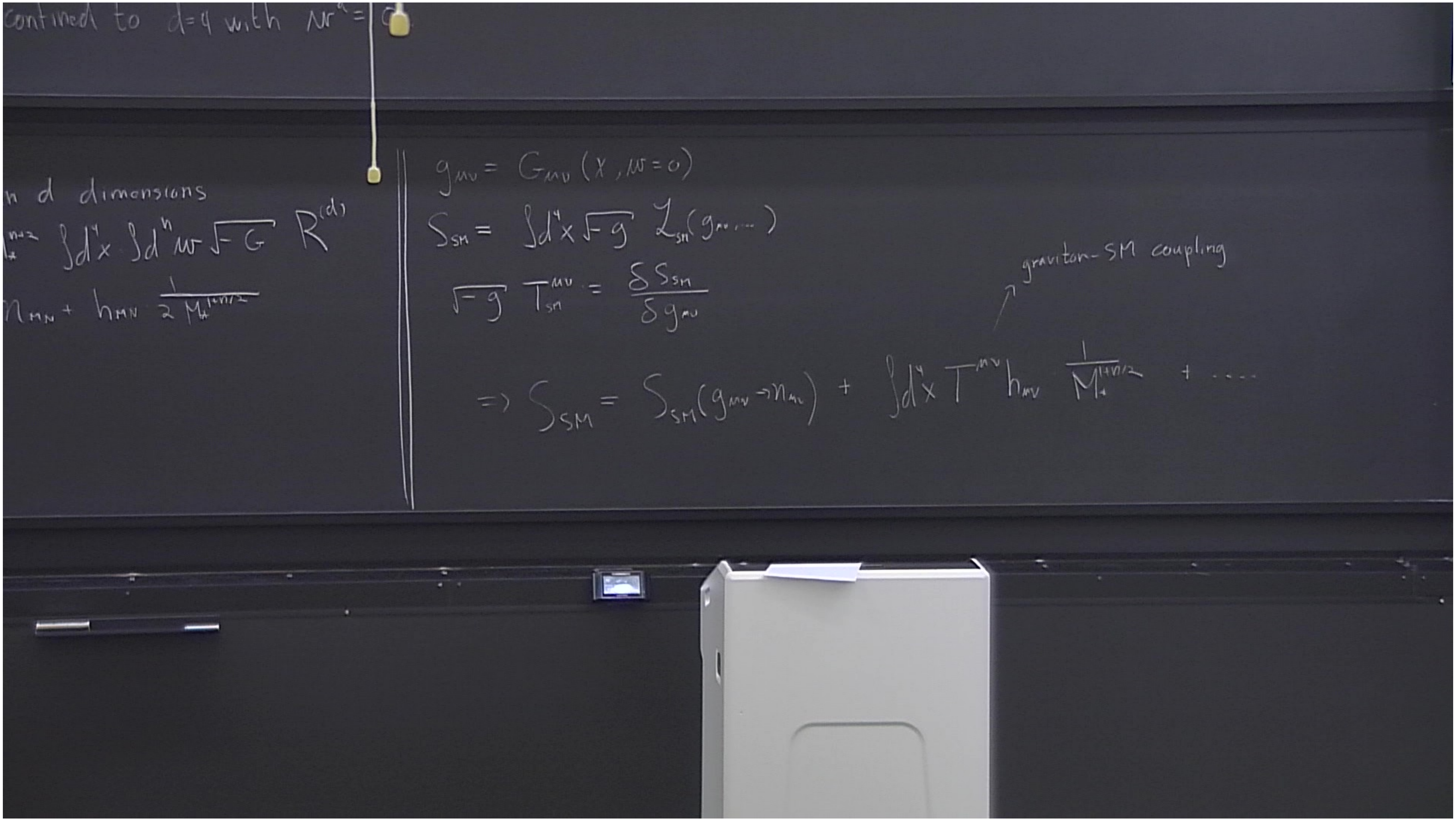

Large XD (LED)
d = 4+n
∇²Φ ~ 1/M*^(2+n) ρ
↳ fund gravity scale
F(r) ~ 1/M*^(2+n) m1m2/r^(2+n)
Assume n XD are compact, 2πR
(KK)


Assume n XD are compact, 2πR
F(r) ~ 1/M*^{2+n} m1m2/r^{2+n} ; r << R
1/M*^{2+n} m1m2/r^2(2πR)^n ; r >> R
M_Pl^2 = M*^{n+2} (2πR)^n = M*^{n+2} V_n
M* ~ TeV ⇒ (2πR) ~ 10^{32/n} 10^{-17} cm
~ 10^15 cm ; n=1
1mm ; n=2
1μm ; n=3
vity scale


Assume n XD are compact, 2πR
$F(r) \sim \frac{1}{M_*^{2+n}} \frac{m_1 m_2}{r^{2+n}}$; $r \ll R$
$\frac{1}{M_*^{2+n}} \frac{m_1 m_2}{r^2 (2\pi R)^n}$; $r \gg R$
$M_{Pl}^2 = M_*^{n+2} (2\pi R)^n = M_*^{n+2} V_n$
$M_* \sim \text{TeV} \Rightarrow (2\pi R) \sim 10^{32/n} \cdot 10^{-17}$ cm
$\sim 10^{15}$ cm ; n=1 X
1 mm ; n=2 X
1 μm ; n=3 ✓
$(2\pi R) \lesssim 37\ \mu m$


2πR ~ 10^-13 GeV, 10^-8 GeV, ..., 10^-2 GeV, ...
n=2 n=3 n=6
SM lives on a 4d subsurface of the full XD space
Large XD dilute M_Pl → M_* ~ TeV
Assume XD all have Δr^a ∈ [0, 2πR], a=4,5, ,3+n
SM confined to d=4 with Δr^a = 0


(SM confined to d=4 with w^a =
G_MN = metric in d dimensions
S_grav = 1/2 M_*^(n+2) ∫d^4x ∫d^n w √-G R^(d)
G_MN = η_MN + h_MN 1/(2 M_*^(1+n/2))
g_μν = G_μν (x, w = 0)
S_SM =
(KK)


confined to $d=4$ with $w^a = 0$
n d dimensions
$M_*^{n+2} \int d^4x \int d^n w \sqrt{-G}\, R^{(d)}$
$\eta_{MN} + h_{MN} \frac{1}{2 M_*^{1+n/2}}$
$g_{\mu\nu} = G_{\mu\nu}(x, w=0)$
$S_{SM} = \int d^4x \sqrt{-g}\, \mathcal{L}_{SM}(g_{\mu\nu}, \dots)$
$\sqrt{-g}\, T^{\mu\nu}_{SM} = \frac{\delta S_{SM}}{\delta g_{\mu\nu}}$
graviton-SM coupling
$\Rightarrow S_{SM} = S_{SM}(g_{\mu\nu} \to \eta_{\mu\nu}) + \int d^4x\, T^{\mu\nu} h_{\mu\nu} \frac{1}{M_*^{1+n/2}} + \dots$

$$\phi(x,w) = \sum_{n=-\infty} \frac{1}{\sqrt{2\pi R}} e \quad \phi^{(n)}(x)$$

$$\phi = \phi^\dagger \Rightarrow \phi^{(n)\dagger} = \phi^{(-n)}$$

$N \times D.$

$$h_{MN}(x,w) = \sum_{n_1=-\infty}^{\infty} \cdots \sum_{n_N=-\infty}^{\infty} \frac{1}{(2\pi R)^{N/2}} e^{i\vec{n}\cdot\vec{w}/R} \, h^{(\vec{n})}_{MN}(x)$$

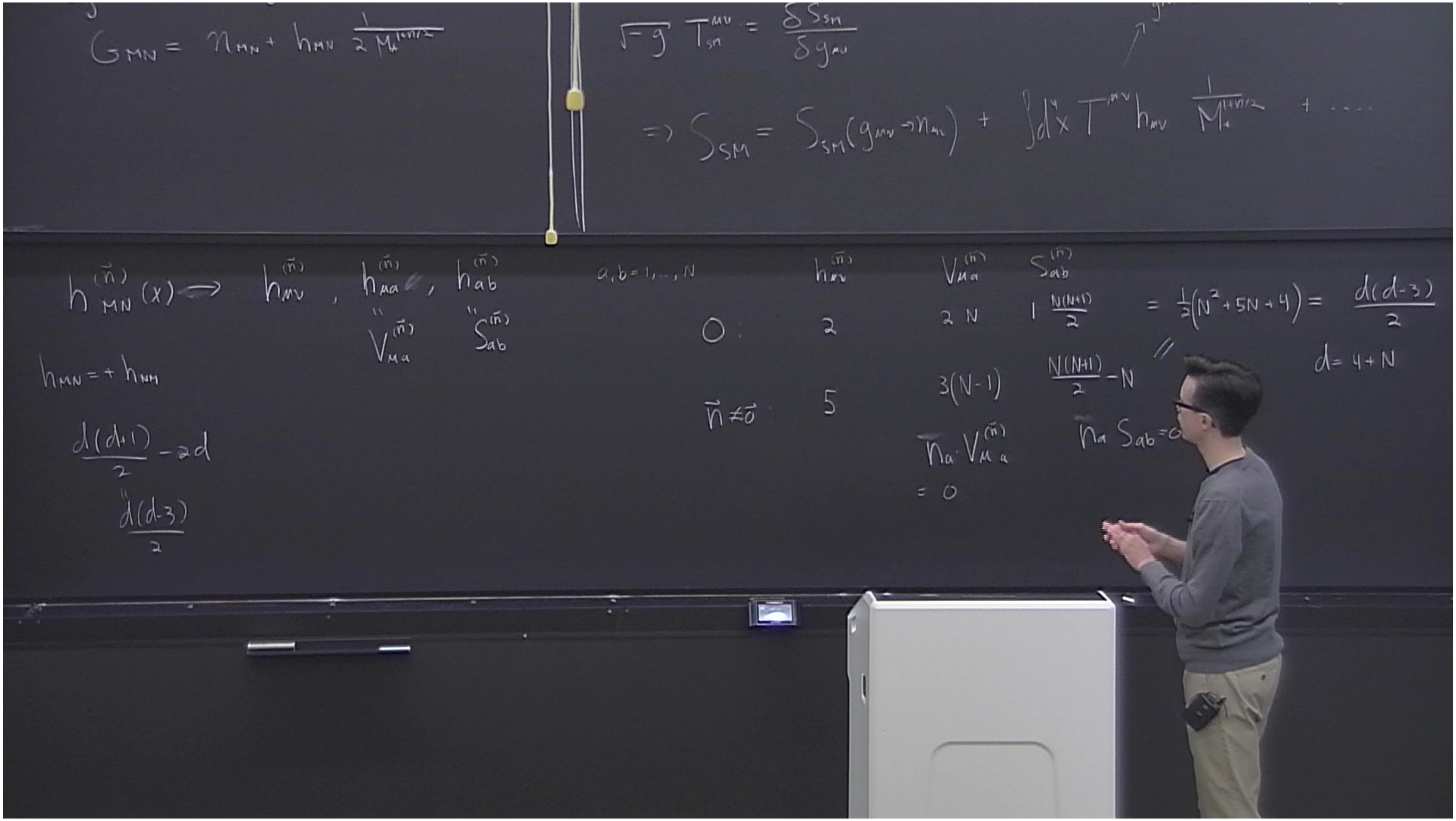
x^μ

$w^a \quad a = 1, 2, \ldots, N$

$$\vec{n} = (n_1, n_2, \ldots, n_N)$$

$$\vec{n}\cdot\vec{w} = n_1 w^1 + \ldots + n_N w^N$$

$$\Rightarrow S_{SM} = S_{SM}(\eta_{\mu\nu}) + \int d^4x \, \underbrace{\frac{1}{M_*^{1+N/2}} \frac{1}{(2\pi R)^{N/2}}}_{\frac{1}{M_{Pl}}} \sum_{\vec{n}} h^{(\vec{n})}_{\mu\nu} T^{\mu\nu}_{SM}.$$



G_MN = η_MN + h_MN 1/(2 M^(1+N/2))
√-g T^μν_SM = δS_SM / δg_μν
=> S_SM = S_SM(g_μν → η_μν) + ∫d^4x T^μν h_μν 1/M^(1+N/2) + ...
h^(n)_MN (x) → h^(n)_μν , h^(n)_μa , h^(n)_ab
V^(n)_μa S^(n)_ab
h_MN = + h_NM
d(d+1)/2 - 2d = d(d-3)/2
a,b = 1,...,N
h^(n)_μν V^(n)_μa S^(n)_ab
0 : 2 2N 1 N(N+1)/2 = 1/2 (N^2 + 5N + 4) = d(d-3)/2
n ≠ 0 : 5 3(N-1) N(N+1)/2 - N
d = 4 + N
n_a V^(n)_μa = 0
n_a S_ab = 0