Title: Causality constraints in gravitational theories

Date: Apr 22, 2014 02:00 PM

URL: http://pirsa.org/14040116

Abstract:

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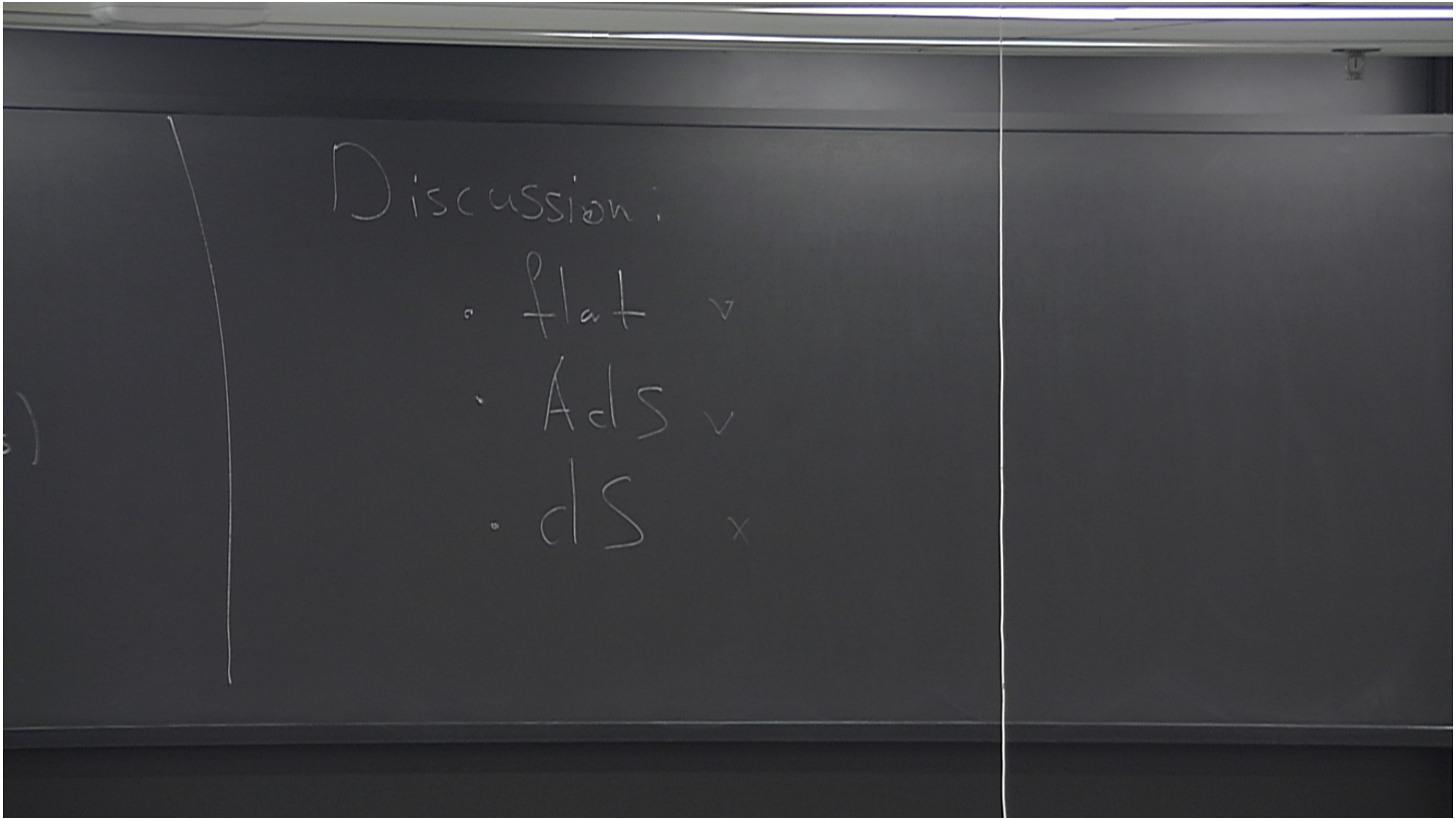
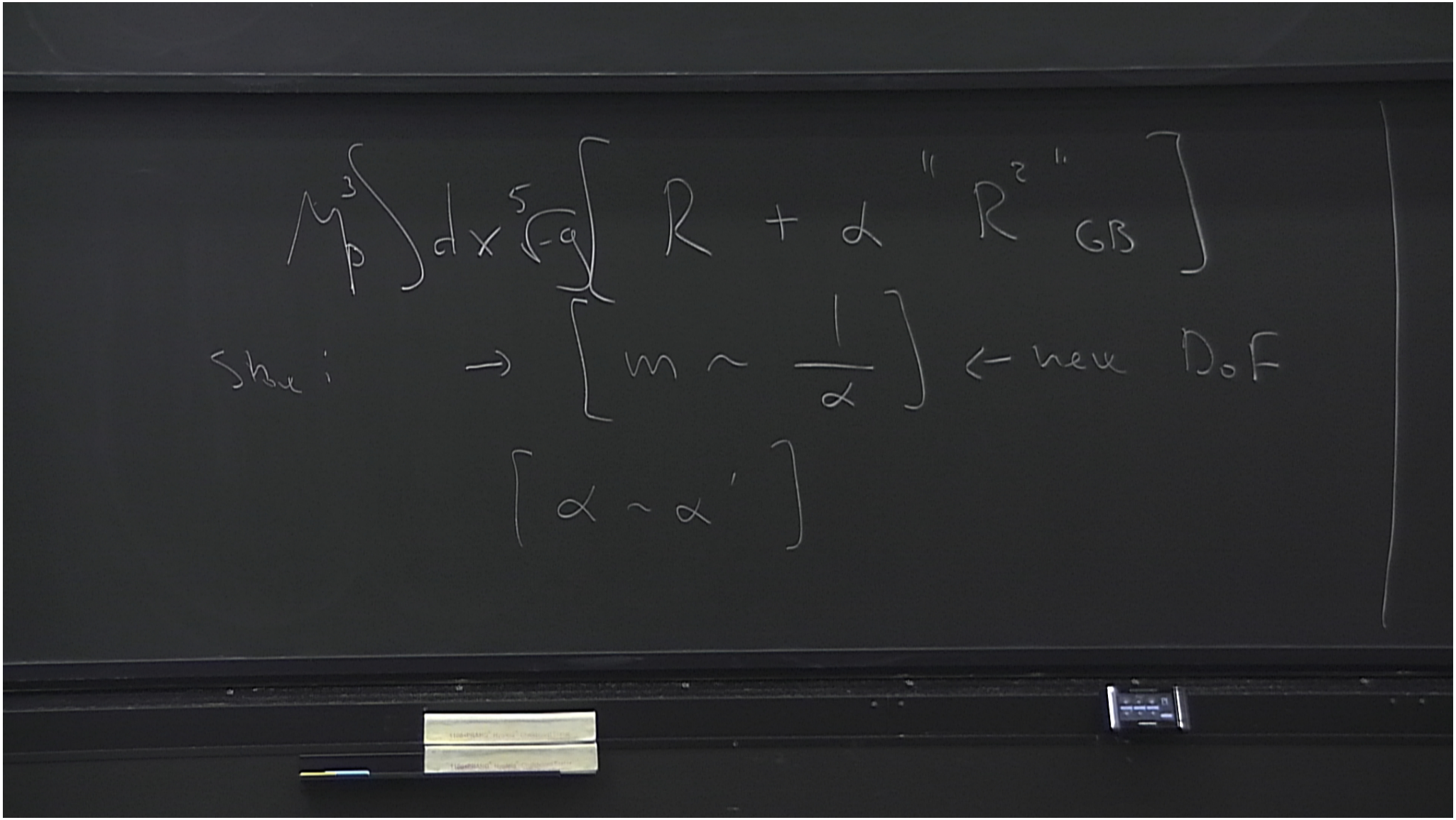
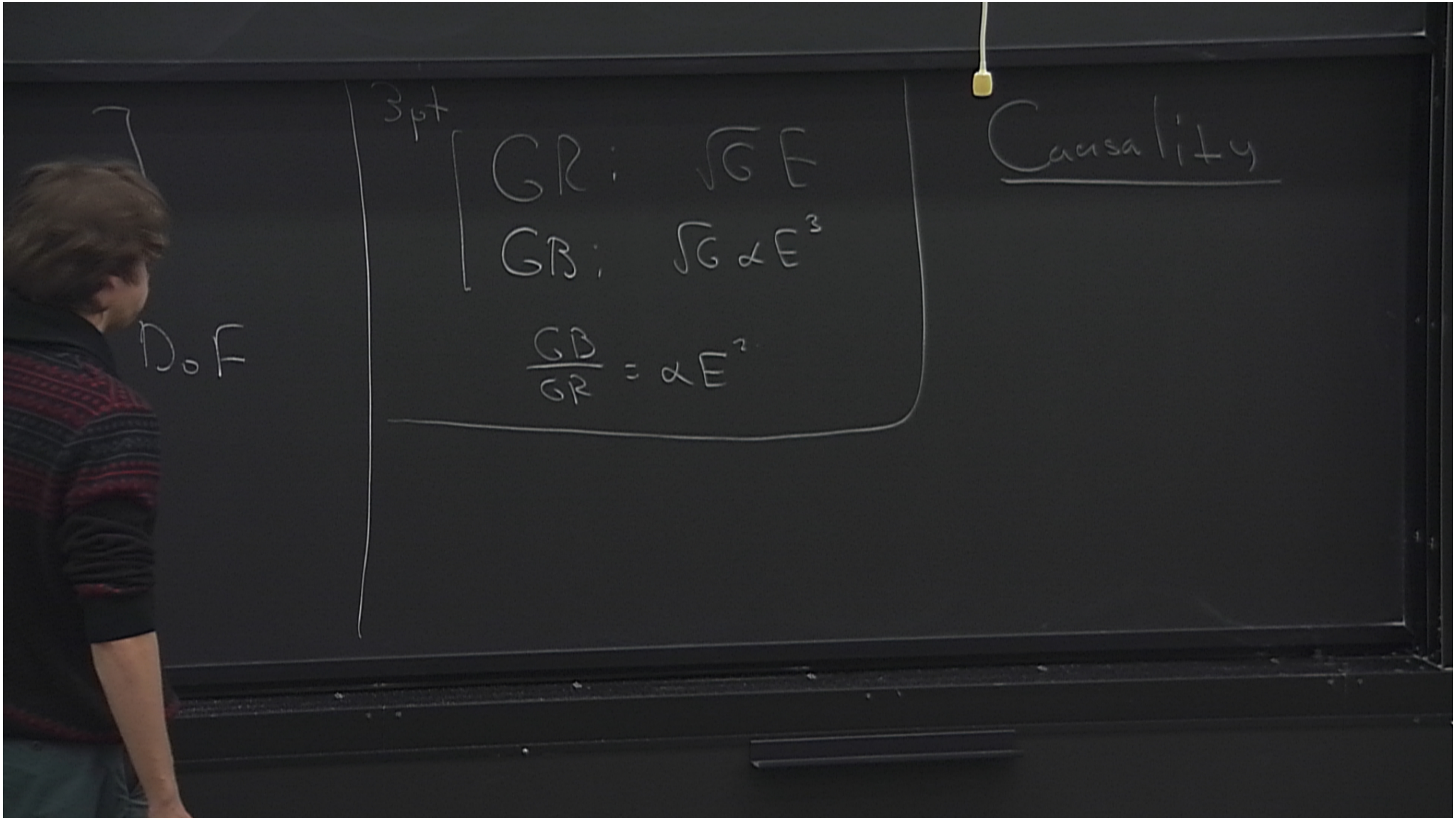
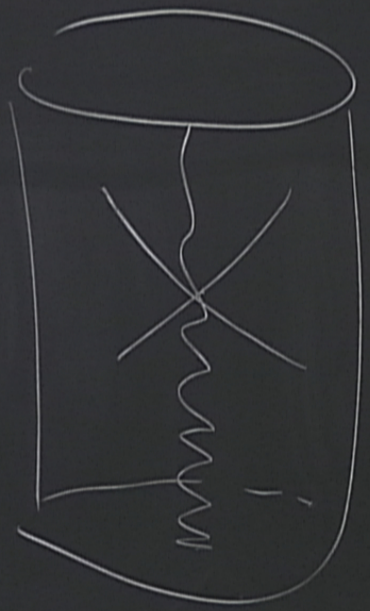
- gravitational theory
- weakly coupled (no loops)
- higher der. corr to GR.


Discussion:
· flat ✓
· AdS ✓
· dS ✗


$M_p^3 \int d^5x \sqrt{-g} \left[R + \alpha \text{ "} R^2 \text{"}_{GB} \right]$
Shu: $\rightarrow \left[m \sim \frac{1}{\alpha} \right]$ ← new D.F
$[\alpha \sim \alpha']$

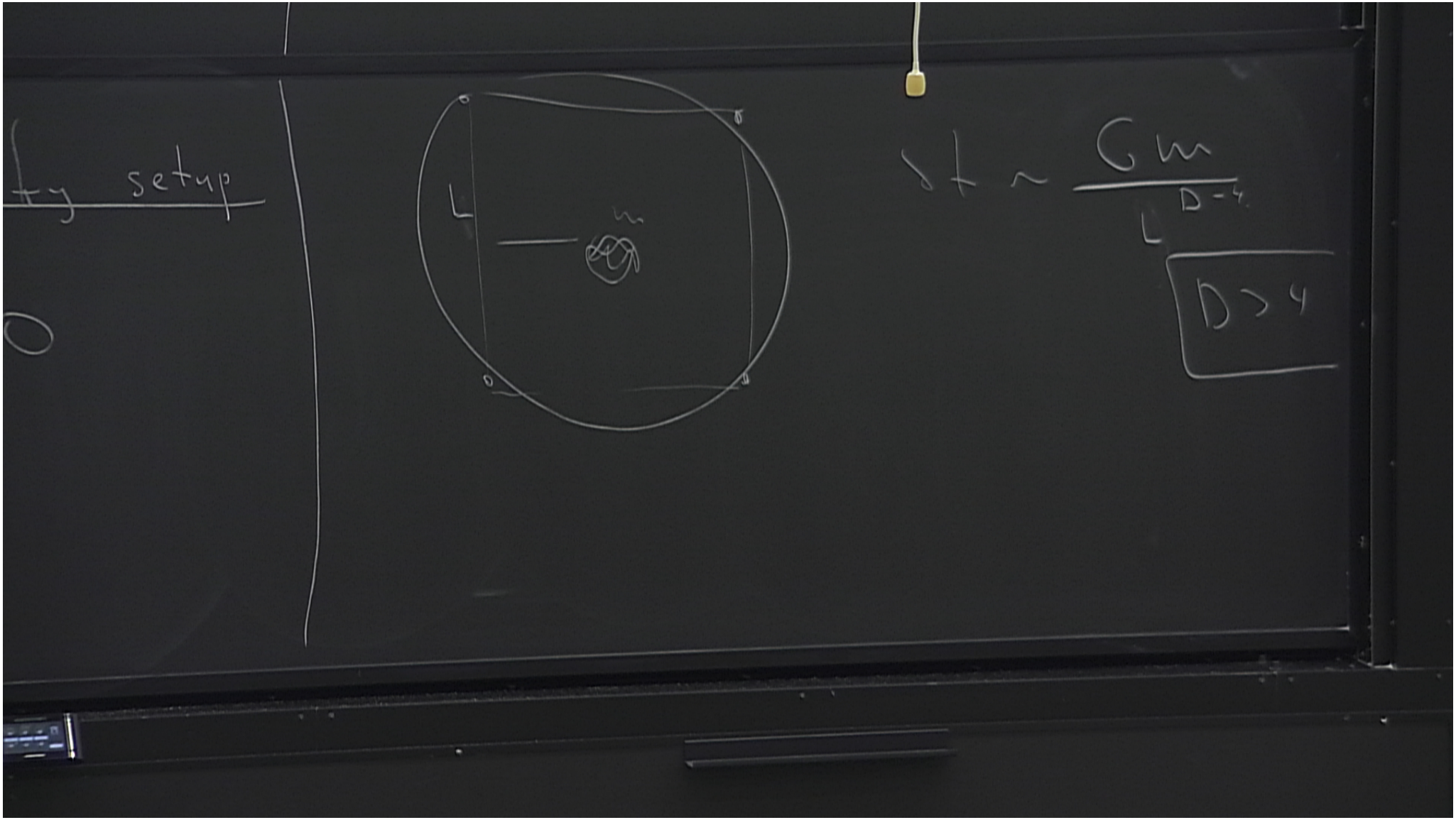

D.o.F
3pt
GR: $\sqrt{G}E$
GB: $\sqrt{G}\alpha E^3$
$\frac{GB}{GR} = \alpha E^2$
Causality

Causality setup

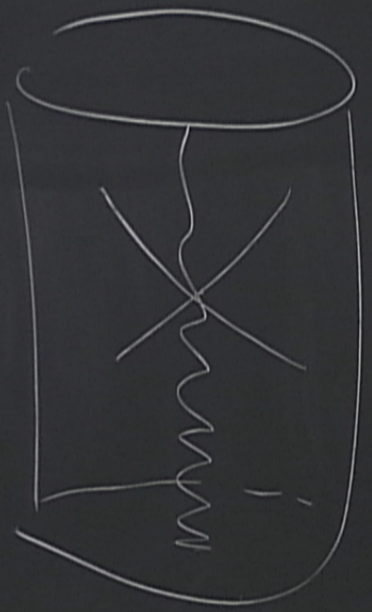


$$\langle \Psi | [T_{\mu\nu}(x), T_{\rho\sigma}(0)] | \Psi \rangle = 0$$

x^2 - spacelike.


ty setup
L
m
$\delta t \sim \frac{Gm}{L^{D-4}}$
D > 4

Causality setup



$$\langle \Psi | [T_{\mu\nu}(x), T_{\rho\sigma}(0)] | \Psi \rangle = 0$$

x^2 - spacelike.

GR: Yoolgar

Wald-Guv.

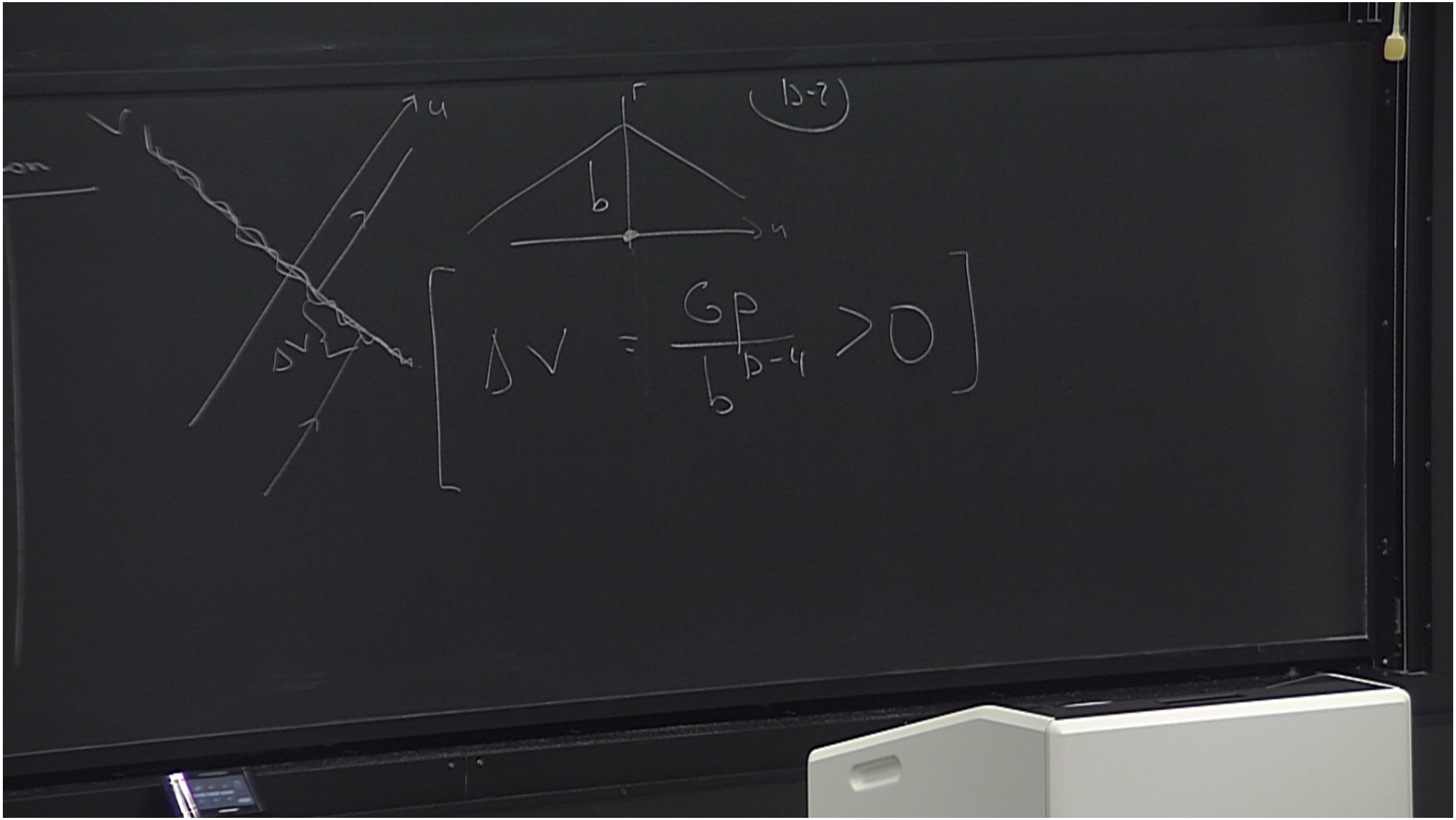
Shock wave geom

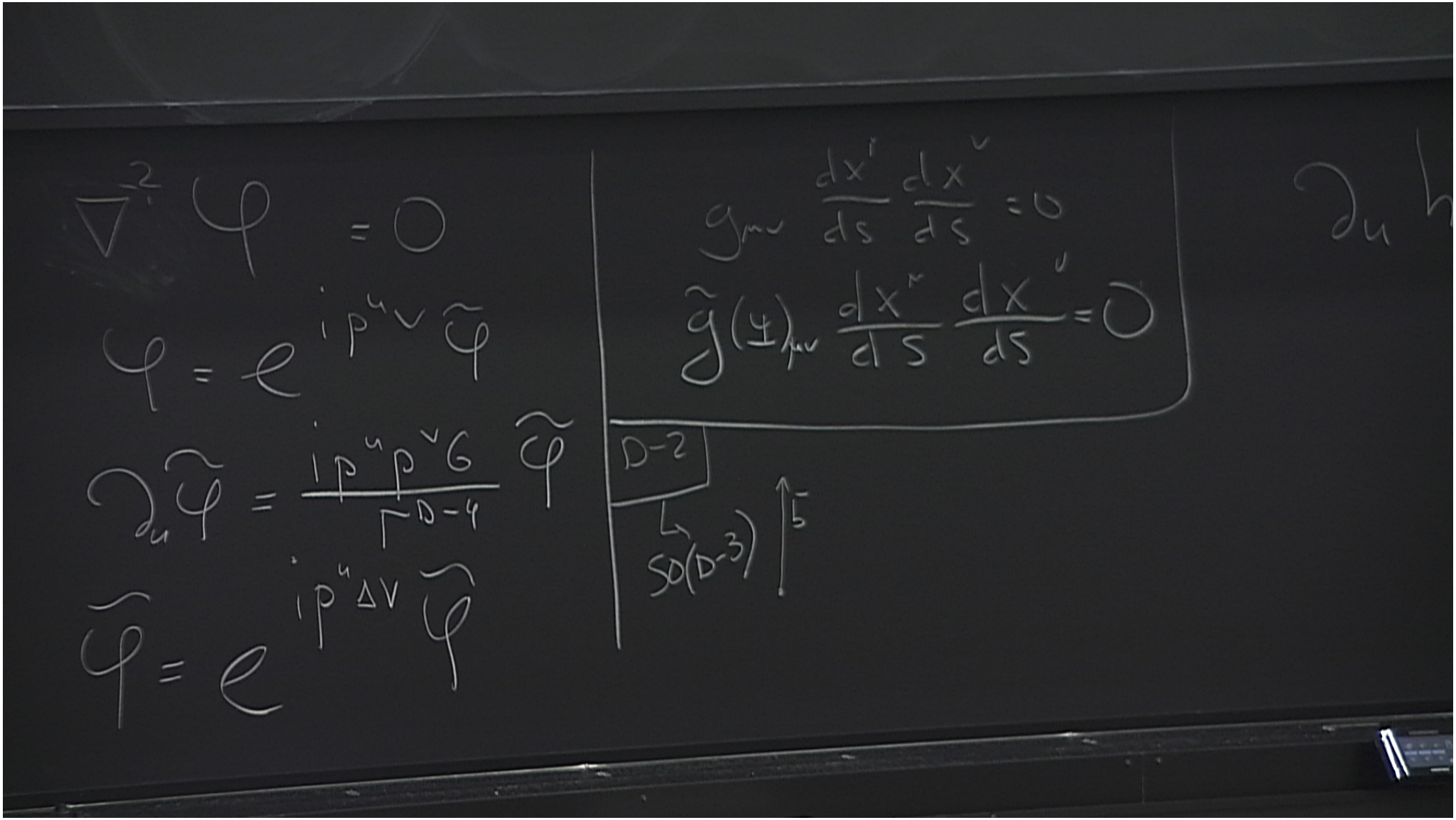
Plane wave:

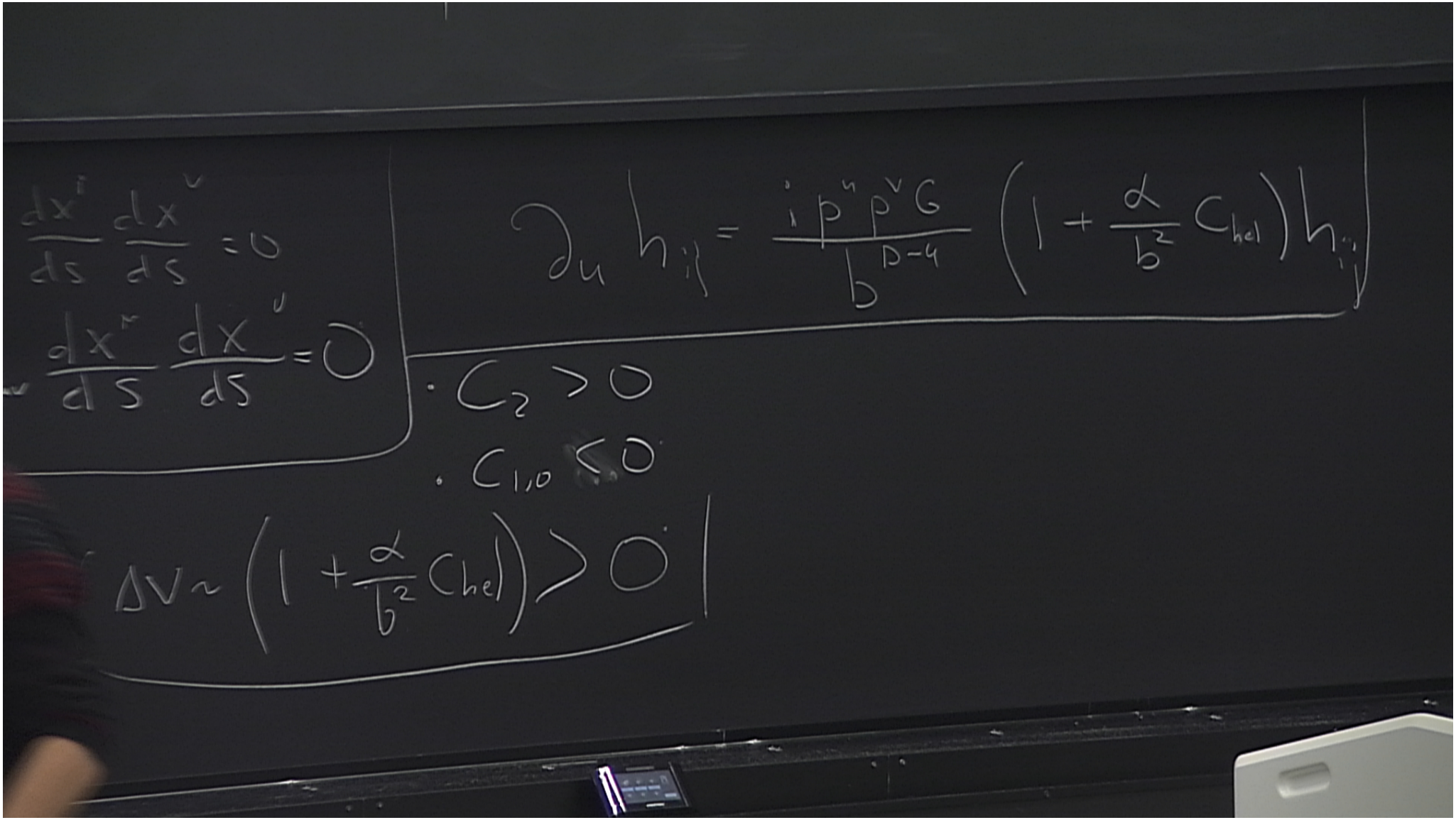
highly boosted p

$$ds^2 = -du\,dv + h(u,x^i)\,du^2 + \sum_{i=1}^{D-2} dx^i$$

$$\partial_\perp^2 h = \delta(r) \qquad h = \delta(u)\frac{G_p}{r^{D-4}}$$


(D-2)
b
$\Delta v = \frac{GP}{b^{D-4}} > 0$


$\nabla^2 \varphi = 0$
$\varphi = e^{ip^\mu x_\nu} \tilde{\varphi}$
$\partial_\mu \varphi = \frac{ip^\mu p^\nu G}{r^{D-4}} \tilde{\varphi}$
$\tilde{\varphi} = e^{ip^\mu \Delta x_\nu} \tilde{\varphi}$
$g_{\mu\nu} \frac{dx^\mu}{ds} \frac{dx^\nu}{ds} = 0$
$\tilde{g}(\pm)_{\mu\nu} \frac{dx^\mu}{ds} \frac{dx^\nu}{ds} = 0$
D-2
SO(D-3)
5
$\partial_\mu h$


$\frac{dx^i}{ds}\frac{dx^\nu}{ds}=0$
$\frac{dx^\mu}{ds}\frac{dx^\nu}{ds}=0$
$\partial_u h_{ij} = \frac{i p^u p^v G}{b^{D-4}}\left(1+\frac{\alpha}{b^2}c_{hel}\right)h_{ij}$
$\cdot c_2 > 0$
$\cdot c_{1,0} \leq 0$
$\Delta V \sim \left(1+\frac{\alpha}{b^2}c_{hel}\right) > 0$

$(\alpha \sim \alpha)$

On-shell language

$$\delta(s,b) = \frac{1}{s}\int d^{D-2}\bar{q}_\perp \, e^{-i\bar{b}\bar{q}_{D-2}} A^{\text{tree}}(s,-\bar{q}^2) = \frac{Cs}{b^{D-4}}$$

$$A = \frac{s^2}{t}$$

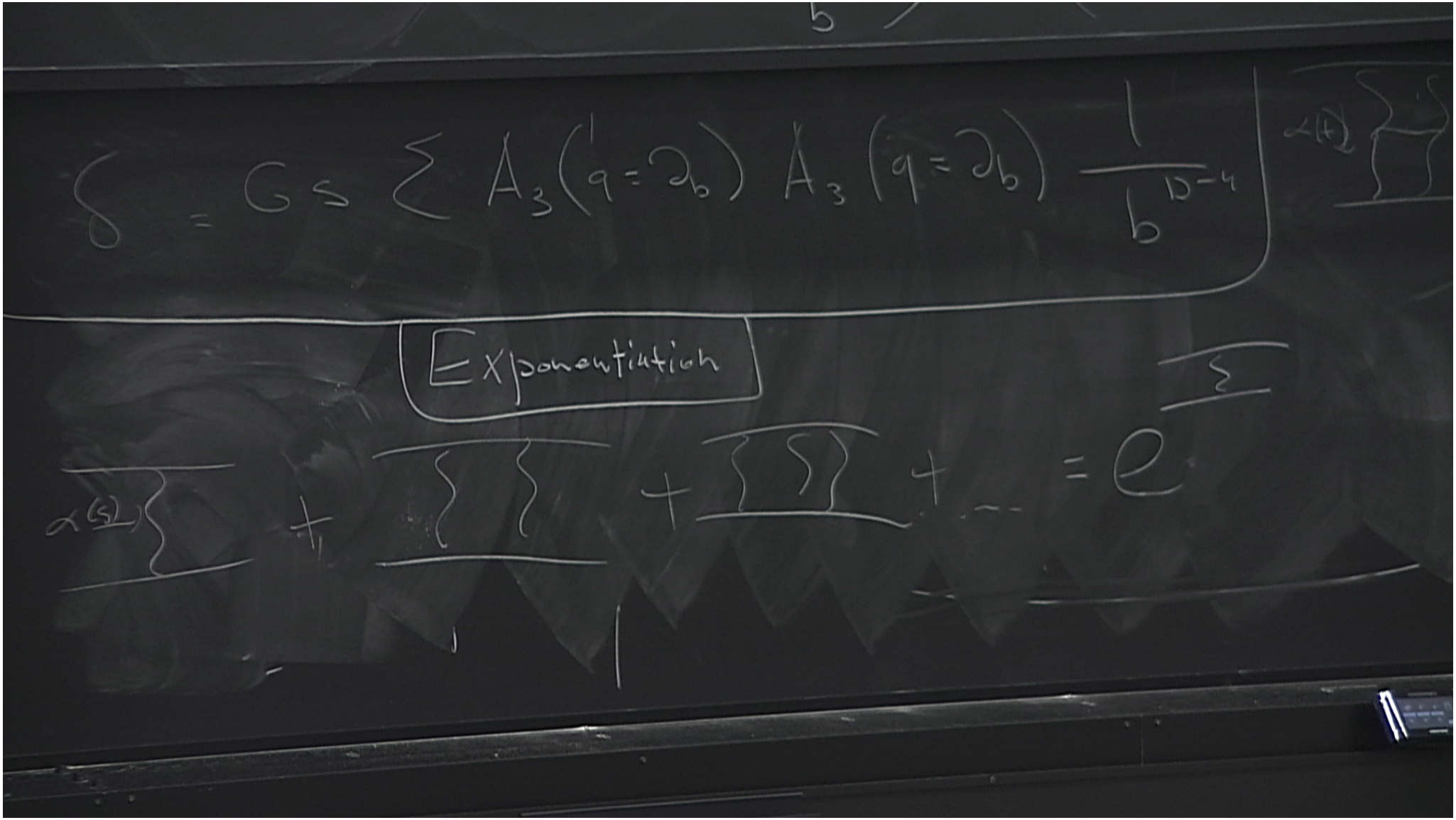
$[\alpha \sim \alpha']$

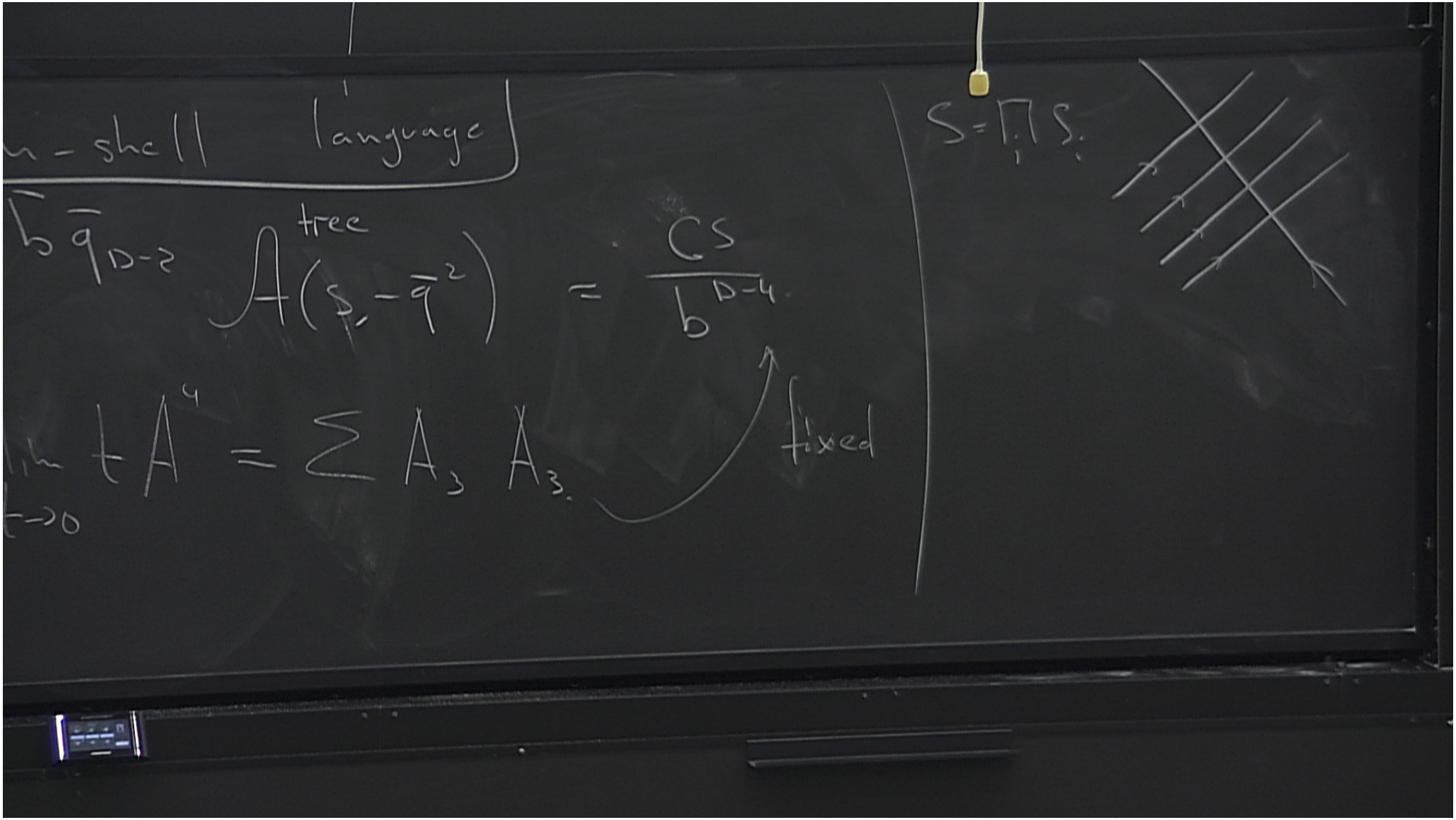
On-shell language

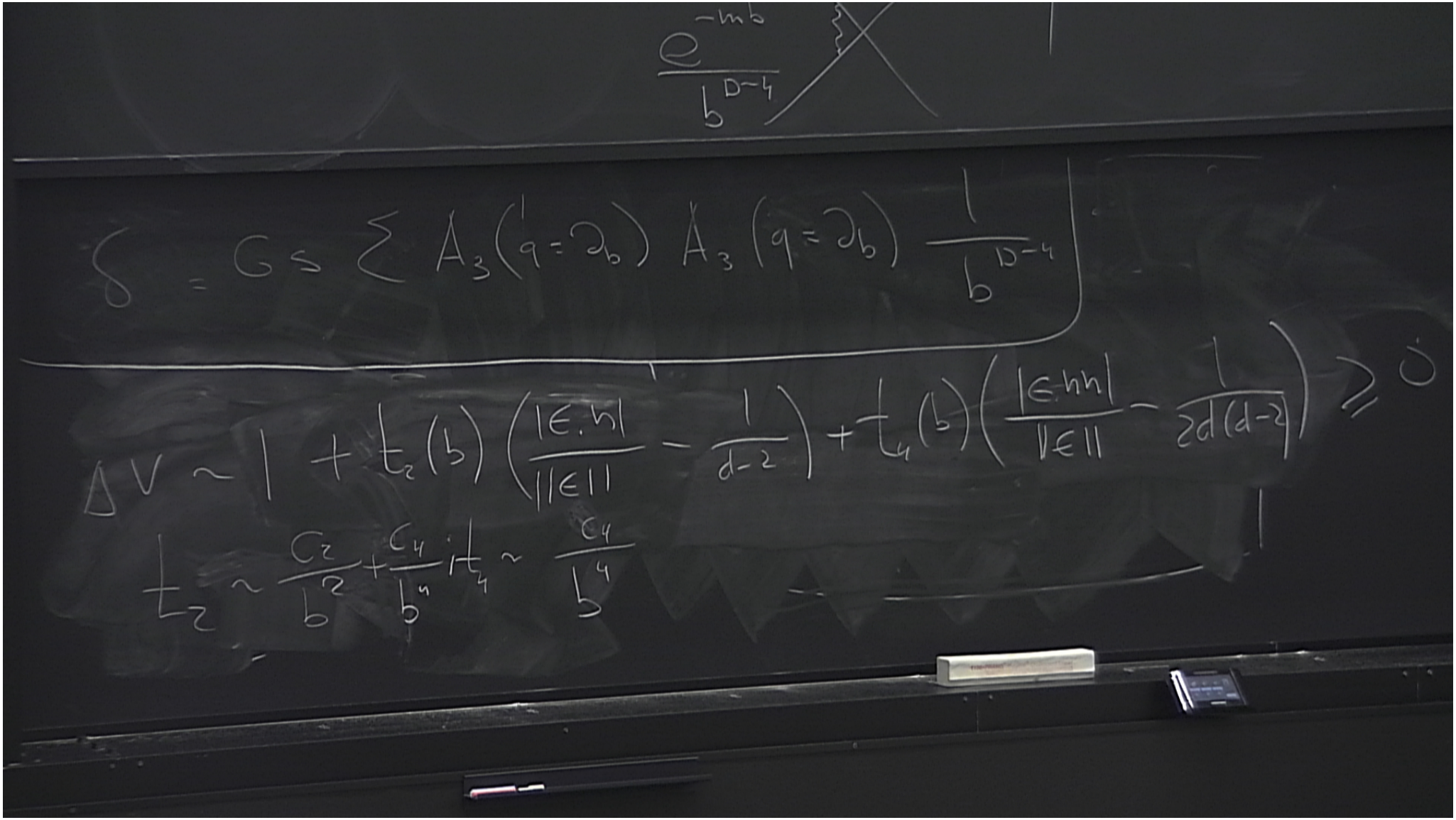
$$\delta(s,b) = \frac{1}{s}\int d^{D-2}\bar{q}_\perp \, e^{-ib\bar{q}_{D-2}} A^{\text{tree}}(s,-\bar{q}^2) = \frac{Cs}{b^{D-4}}$$

$$A = \frac{s^2}{t} \qquad \lim_{t\to 0} tA^4 = \sum A_3 A_3$$

fixed

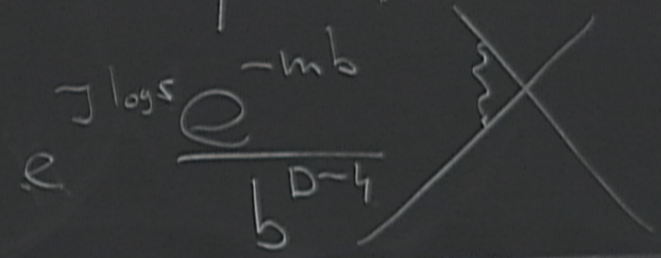

Exponentiation


n - shell
language
$\vec{b}\,\vec{q}_{D-2}$
$A^{tree}(s, -\vec{q}^2) = \frac{cs}{b^{D-4}}$
$\lim_{t\to 0} tA^4 = \sum A_3 A_3$
fixed
$S = \prod_i S_i$


$\frac{e^{-mb}}{b^{D-4}}$
$\delta = G_S \sum A_3(q=2_b)\, A_3(q=2_b)\, \frac{1}{b^{D-4}}$
$\Delta V \sim 1 + t_2(b)\left(\frac{|\epsilon\cdot n|}{\|\epsilon\|} - \frac{1}{d-2}\right) + t_4(b)\left(\frac{|\epsilon\cdot n|}{\|\epsilon\|} - \frac{1}{2d(d-2)}\right) \geq 0$
$t_2 \sim \frac{c_2}{b^2} + \frac{c_4}{b^4}$ $t_4 \sim \frac{c_4}{b^4}$

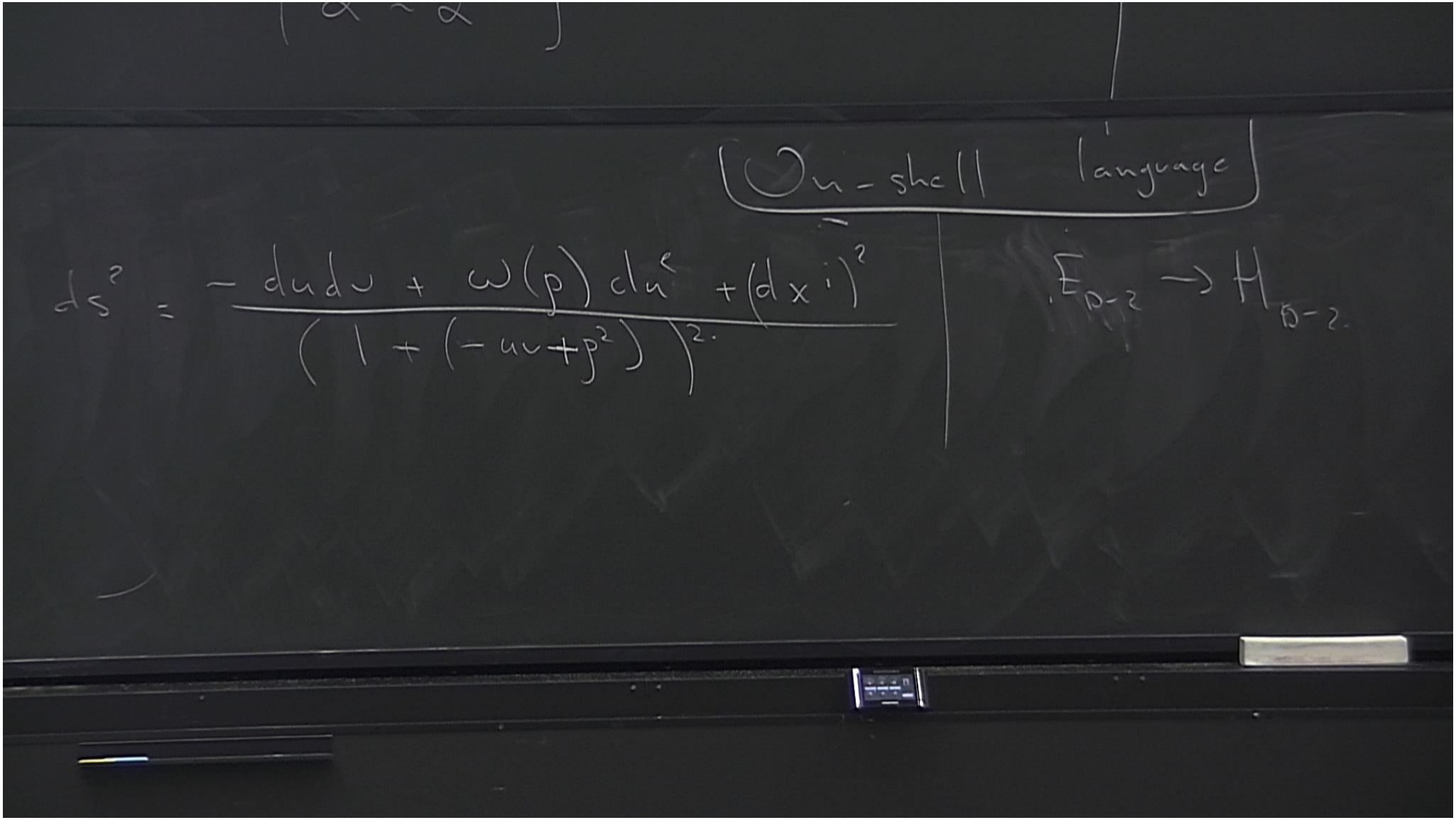
$$\partial_\perp^2 h = \delta(r) \quad h = \delta(u) \frac{G_D}{r^{D-4}}$$

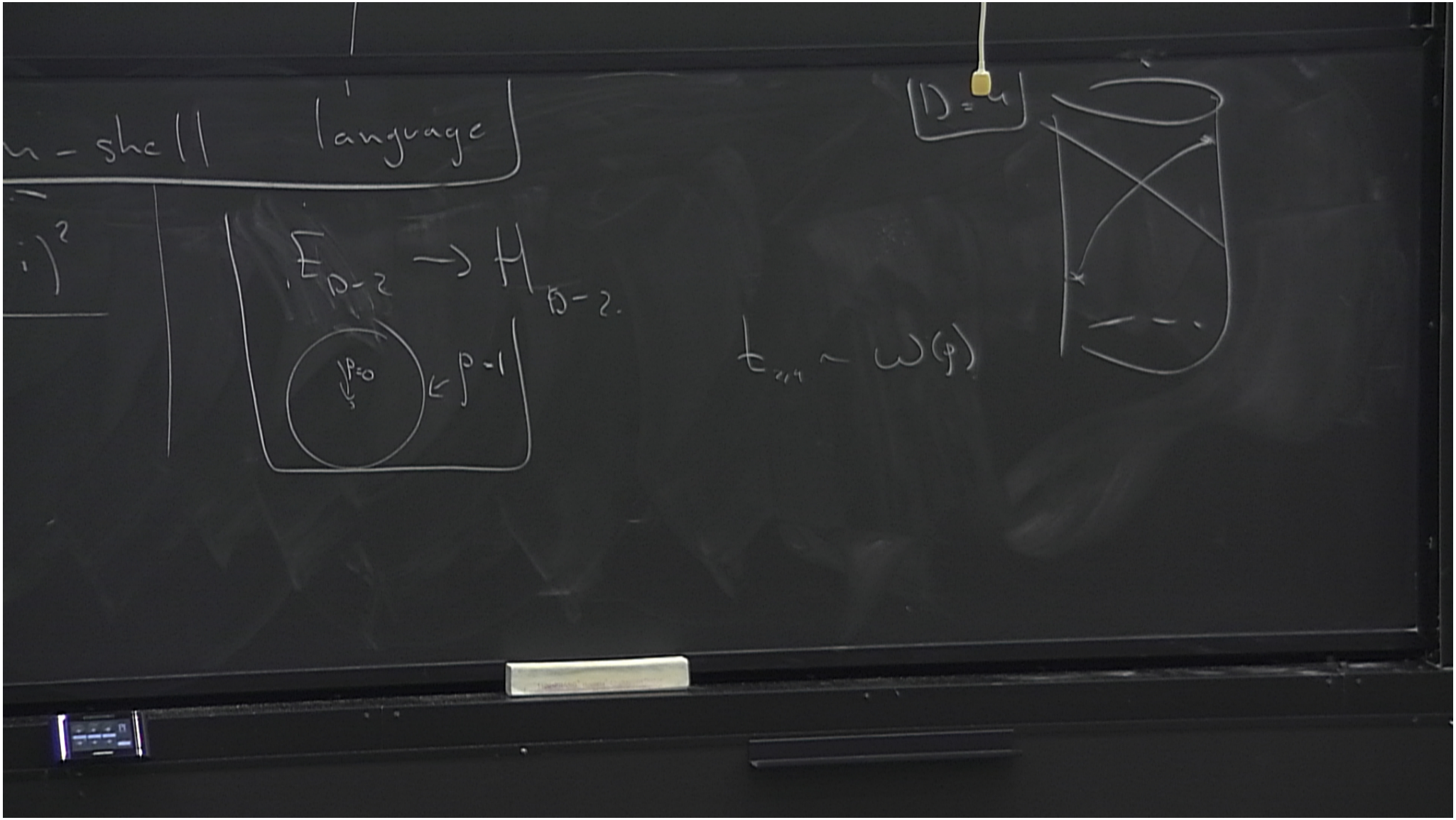
$$e^{\int \log s} \frac{e^{-mb}}{b^{D-4}}$$

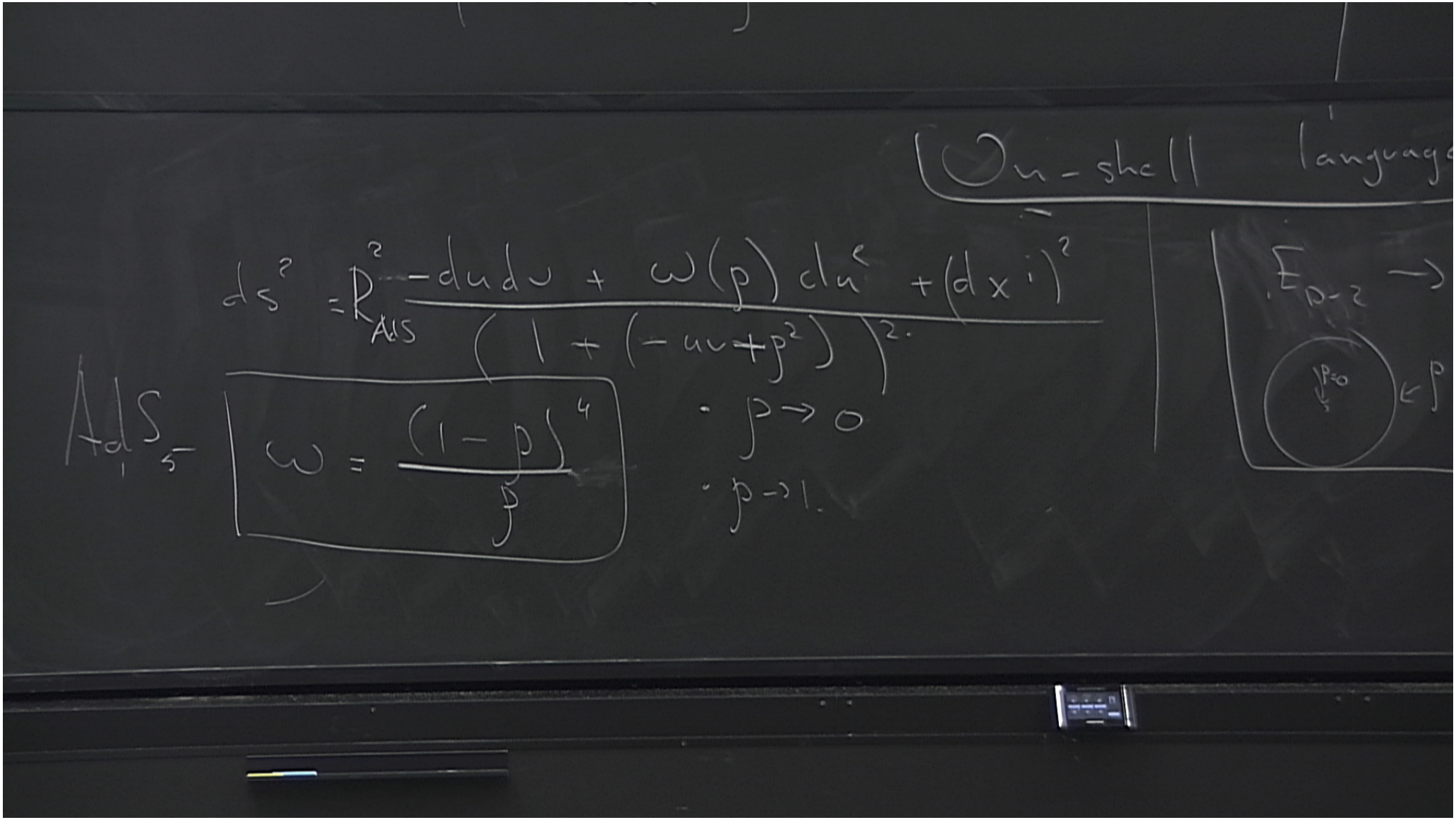


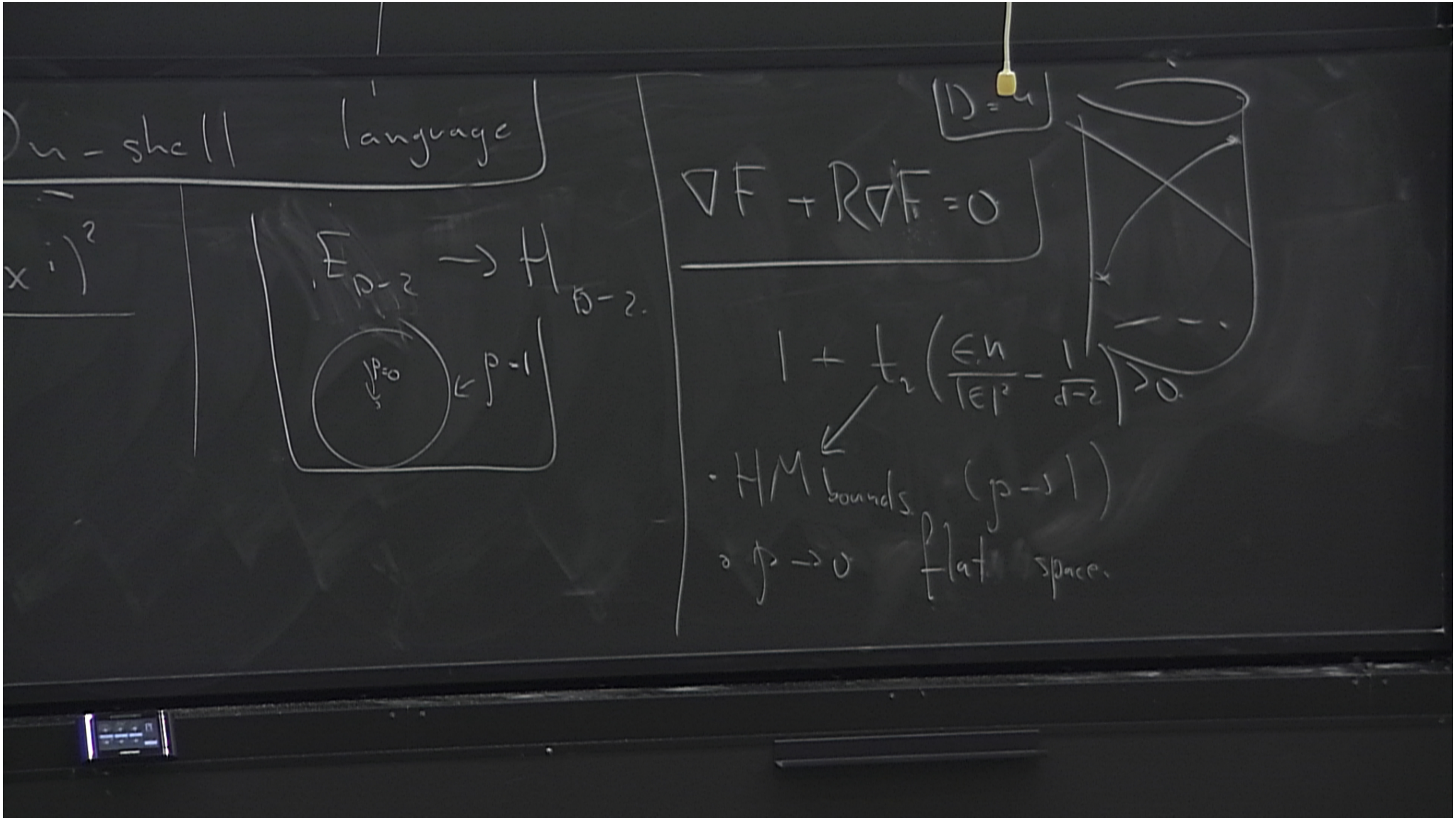
$$\delta = G_s = \sum A_3(q=2_b)\, A_3(q=2_b)\, \frac{1}{b^{D-4}}$$

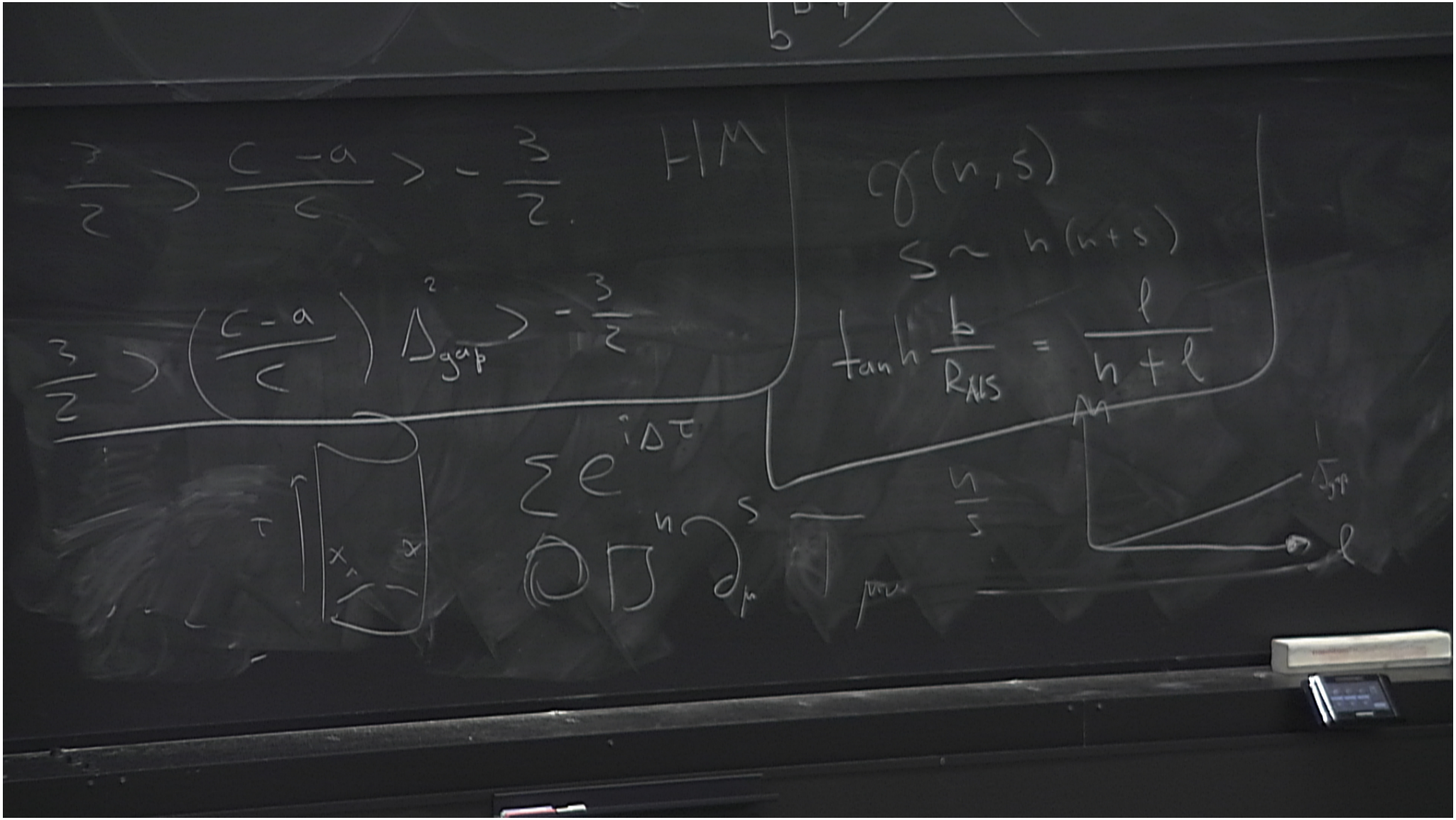
$$\Delta V \sim 1 + t_2(b)\left(\frac{|\epsilon\cdot n|}{\|\epsilon\|} - \frac{1}{d-2}\right) + t_4(b)\left(\frac{|\epsilon\cdot n n|}{\|\epsilon\|} - \frac{1}{2d}\right.$$

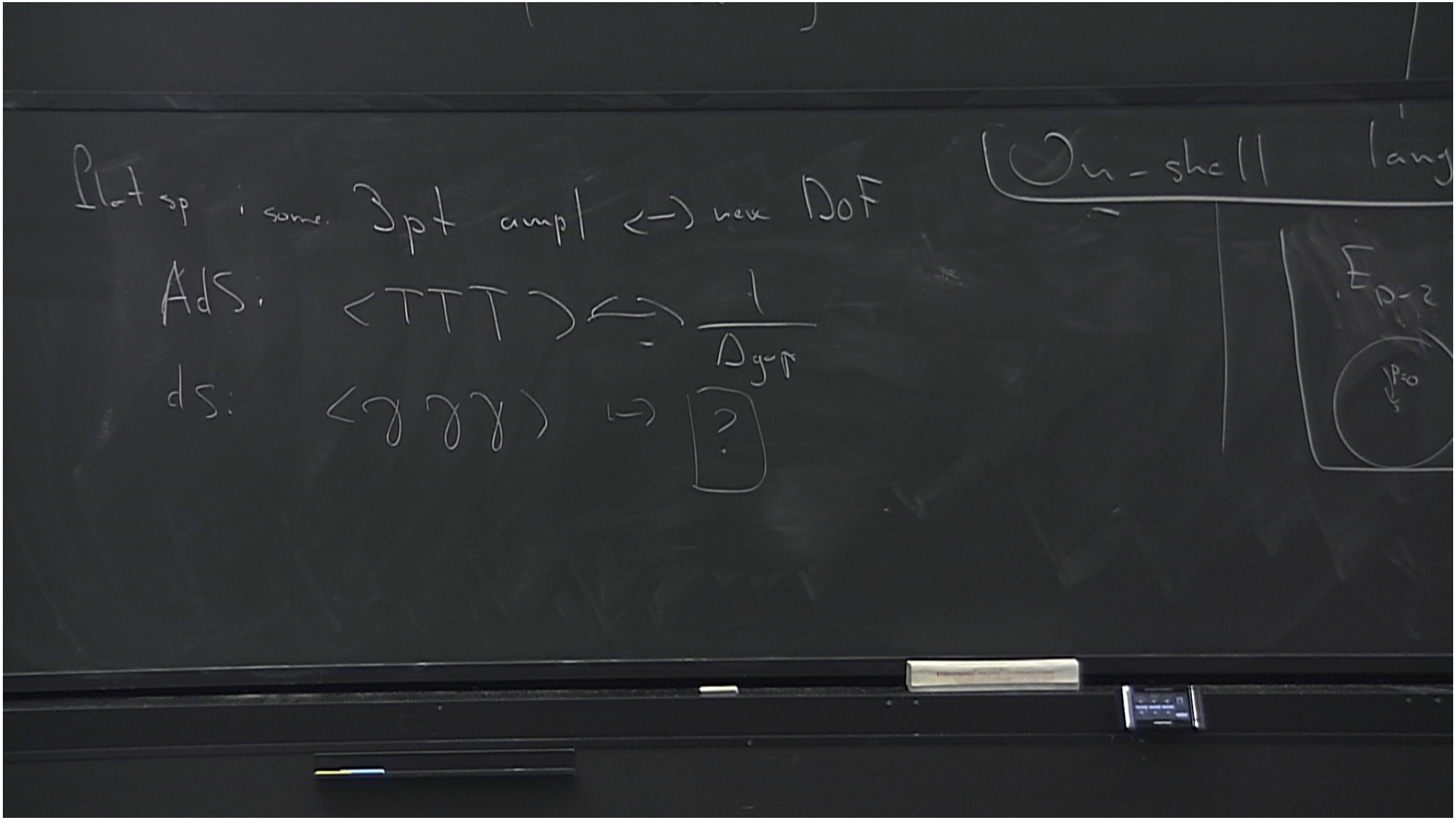

On-shell language
$ds^2 = \frac{-dudv + \omega(p)\,du^2 + (dx^i)^2}{\left(1 + (-uv + p^2)\right)^2}$
$E_{D-2} \to H_{D-2}$


n-shell
language
D=4
$E_{D-2} \to H_{D-2}$
p=0
p-1
$t_{\mu\nu} \sim \omega(\varphi)$


On-shell
$ds^2 = R_{AdS}^2 \frac{-dudv + \omega(p)\,du^2 + (dx^i)^2}{\left(1 + (-uv + p^2)\right)^2}$
AdS_{d+1}
$\omega = \frac{(1-p)^4}{p^2}$
$p \to 0$
$p \to 1$
$E_{p-2} \to$
$p=0$
$\leftarrow p$


n-shell
language
$E_{D-2} \to H_{D-2}$
p=0
p-1
$\nabla F + R \nabla F = 0$
D=4
$1 + t_2 \left(\frac{\epsilon n}{|\epsilon|^2} - \frac{1}{d-2} \right) > 0$
HM_{bounds} (p-1)
$p \to 0$ flat space.


HM
$\frac{3}{2} > \frac{c-a}{c} > -\frac{3}{2}$
$\frac{3}{2} > \left(\frac{c-a}{c}\right)^2 \Delta_{gap} > -\frac{3}{2}$
$g(n,s)$
$s \sim n(n+s)$
$\tanh \frac{b}{R_{AdS}} = \frac{l}{n+l}$
$\Sigma e^{i\Delta\tau}$
$\mathcal{O} J^n \partial_\mu^s$
$\frac{n}{s}$


flat sp : some 3pt ampl ⟷ new DoF
AdS: ⟨TTT⟩ ⟷ 1/Δ_grav
ds: ⟨γγγ⟩ ↦ ?
On-shell
E_{D-2}
p=0