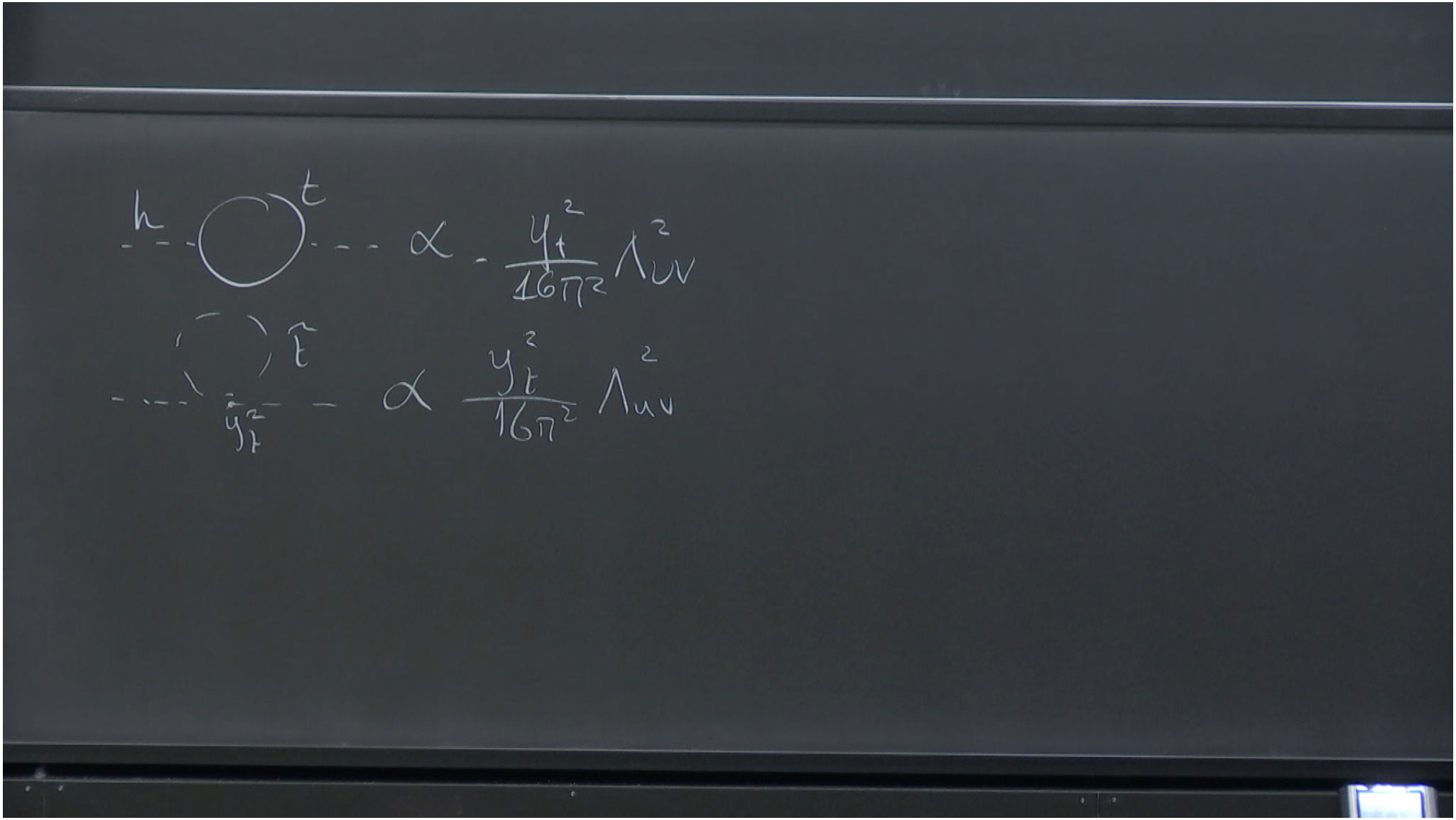
Title: Particle Physics Lecture - 230313

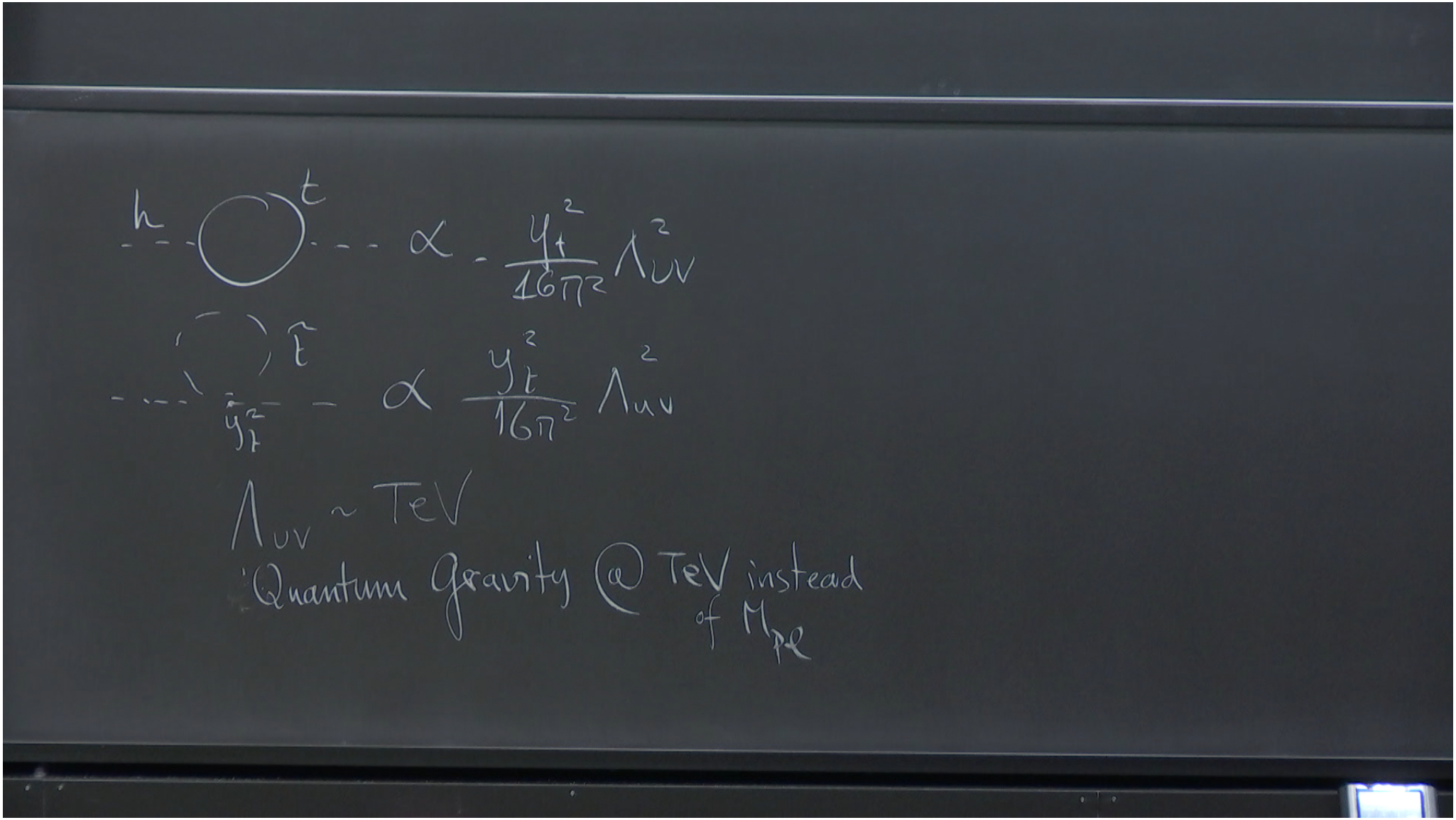
Speakers: Asimina Arvanitaki

Collection: Particle Physics (2022/2023)

Date: March 13, 2023 - 11:30 AM

URL: https://pirsa.org/23030060


h
t
$\alpha \cdot \frac{y_t^2}{16\pi^2}\Lambda_{UV}^2$
$\tilde{t}$
y_t^2
$\alpha \frac{y_t^2}{16\pi^2}\Lambda_{UV}^2$


h
t
$\alpha \cdot \frac{y_t^2}{16\pi^2} \Lambda_{UV}^2$
$\tilde{t}$
y_t^2
$\alpha \frac{y_t^2}{16\pi^2} \Lambda_{UV}^2$
$\Lambda_{UV} \sim$ TeV
'Quantum gravity @ TeV instead of M_{Pl}

Large Extra Dimensions

Arkani-Hamed, Dimopoulos, Dvali '97

$(+,-,-,\ldots)$

4 dim $\rightarrow \mu = \{0,1,2,3\}$

4+n dim $\rightarrow M$

n dim $\rightarrow$ latin characters

$$ds^2 = g_{\mu\nu}^{\ 2}\, dx^\mu dx^\nu - r^2 d\Omega_{(n)} - dr^2$$

Large Extra Dimensions

Arkani-Hamed, Dimopoulos, Dvali '97

$(+,-,-,\dots)$

4 dim $\Rightarrow \mu = \{0,1,2,3\}$

$4+n$ dim $\rightarrow M$

n dim $\rightarrow$ latin characters

$$ds^2 = g_{\mu\nu}^{2}\, dx^\mu dx^\nu - r^2 d\Omega_{(n)} - dr^2$$

r goes from 0 to R.

Large Extra Dimensions

Arkani-Hamed, Dimopoulos, Dvali '97

$(+,-,-,\dots)$

4 dim $\rightarrow \mu = \{0,1,2,3\}$

4+n dim $\rightarrow$ M

n dim $\rightarrow$ latin characters

$$ds^2 = g^{(4)}_{\mu\nu}\, dx^\mu dx^\nu - r^2 d\Omega_{(n)} - dr^2$$

r goes from 0 to R.

$$S_{4+n} = -M_*^{n+2} \int d^{4+n}x \sqrt{g^{(4+n)}}\, R^{(4+n)}$$

$$[R^{(4+n)}] = [\text{Energy}]^2$$

$$R^{(4+n)} = R^{(4)}$$

$$S_{\text{eff }4} = -\underbrace{M_*^{n+2} \int d\Omega_{(n)} r^n}_{M_{Pl}^2} \int d^4x \sqrt{g^{(4)}}\, R^{(4)}$$

$$M_{Pl}^2 = M_*^{n+2}$$

What is the size of the extra dimensions?

$$M_{Pl}^2 = M_*^{n+2} r^n \Rightarrow r^{-1} = M_* \left(\frac{M_*}{M_{Pl}}\right)^{2/n}$$

$n=1$ $\quad r^{-1} = \text{TeV} \cdot \left(10^{-16}\right)^2 = 10^{12}\,\text{eV} \cdot 10^{-32} = 10^{-20}\,\text{eV}$

$$r^{-1}_{\text{Earth-Sun}} = 10^{-18}\,\text{eV}$$

r

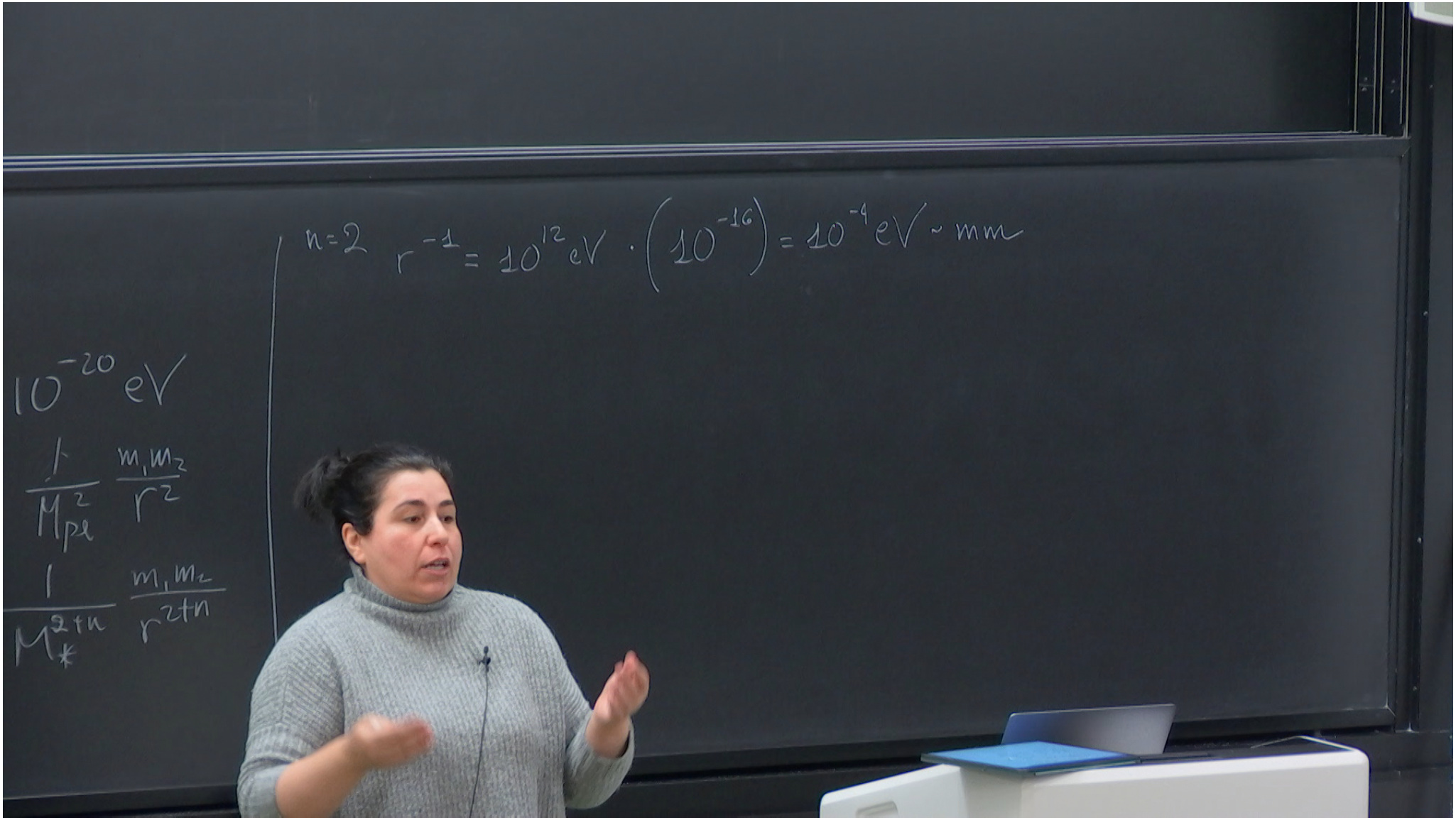
m_1 $\quad m_2$

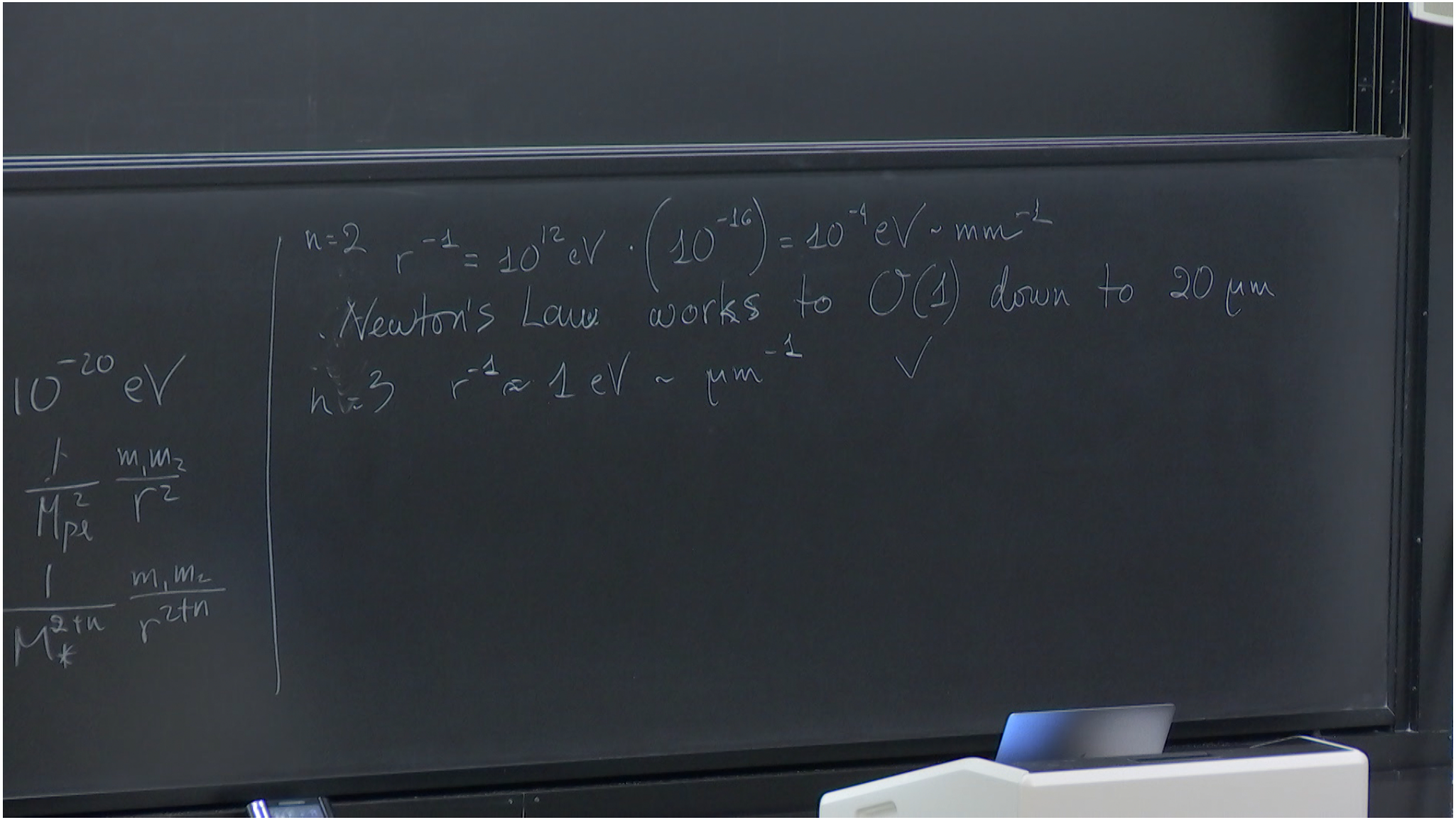
$$F_{\text{Newton}} = \frac{1}{M_{Pl}^2}\frac{m_1 m_2}{r^2}$$

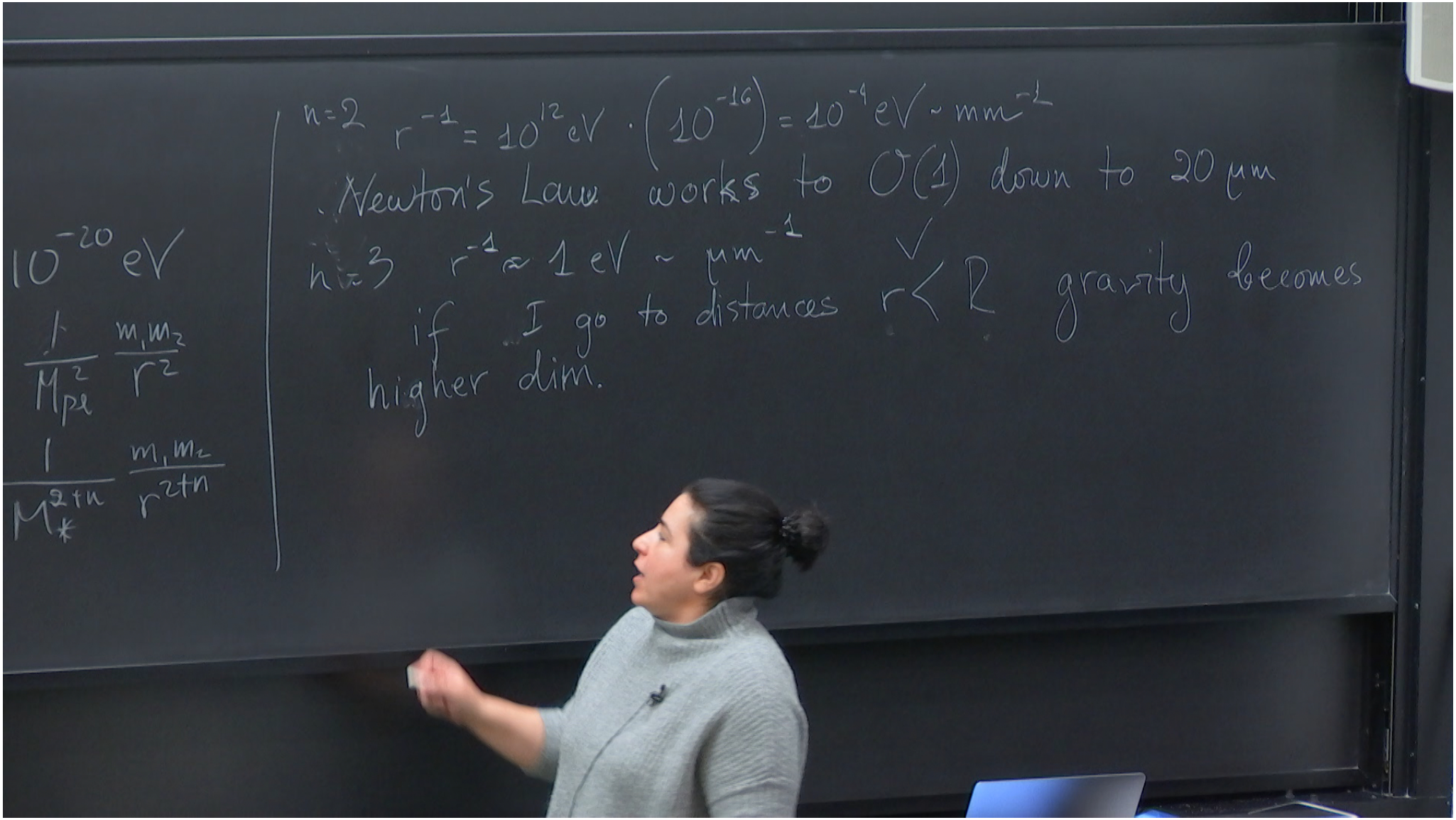
$$F^{(4+n)}_{\text{Newton}} = \frac{1}{M_*^{2+n}}\frac{m_1 m_2}{r^{2+n}}$$

#1 of LED Newton's Law

$n=2$ $\quad r$


n=2 $r^{-1} = 10^{12}\,eV \cdot (10^{-16}) = 10^{-4}\,eV \sim mm$
$10^{-20}\,eV$
$\frac{1}{M_{pl}^2}\,\frac{m_1 m_2}{r^2}$
$\frac{1}{M_*^{2+n}}\,\frac{m_1 m_2}{r^{2+n}}$


10^{-20} eV
$\frac{1}{M_{pl}^2}\frac{m_1 m_2}{r^2}$
$\frac{1}{M_*^{2+n}}\frac{m_1 m_2}{r^{2+n}}$
$n=2$ $r^{-1} = 10^{12}\,\text{eV}\cdot\left(10^{-16}\right) = 10^{-4}\,\text{eV} \sim \text{mm}^{-1}$
Newton's Law works to $O(1)$ down to 20 μm
$n=3$ $r^{-1} \approx 1\,\text{eV} \sim \mu\text{m}^{-1}$ ✓


10^{-20} eV
$\frac{1}{M_{pl}^2}\frac{m_1 m_2}{r^2}$
$\frac{1}{M_*^{2+n}}\frac{m_1 m_2}{r^{2+n}}$
$n=2$ $r^{-1} = 10^{12}$ eV $\cdot (10^{-16}) = 10^{-4}$ eV $\sim$ mm^{-1}
Newton's Law works to $O(1)$ down to 20 μm
$n=3$ $r^{-1} \simeq 1$ eV $\sim \mu$m^{-1} ✓
if I go to distances $r < R$ gravity becomes higher dim.

10^{-20} eV

$\frac{1}{M_{pl}^2} \frac{m_1 m_2}{r^2}$

$\frac{1}{M_*^{2+n}} \frac{m_1 m_2}{r^{2+n}}$

$n=2$ $r^{-1} = 10^{12}\,\text{eV} \cdot \left(10^{-16}\right) = 10^{-4}\,\text{eV} \sim \text{mm}^{-1}$

Newton's Law works to $O(1)$ down to 20 μm

$n=3$ $r^{-1} \approx 1\,\text{eV} \sim \mu\text{m}^{-1}$ ✓

if I go to distances $r < R$ gravity becomes higher dim.

$ds^2 = \left(1 - \frac{2GM}{r}\right) dt^2 - \left(1 - \frac{2GM}{r}\right)^{-1} dr^2 - r^2 d\Omega_{(n)}$

10^{-20} eV

$\frac{1}{M_{Pl}^2} \frac{m_1 m_2}{r^2}$

$\frac{1}{M_*^{2+n}} \frac{m_1 m_2}{r^{2+n}}$

$n=2 \quad r^{-1} = 10^{12}\,\text{eV} \cdot \left(10^{-16}\right) = 10^{-4}\,\text{eV} \sim \text{mm}^{-1}$

. Newton's Law works to $O(1)$ down to 20 μm

$n=3 \quad r^{-1} \simeq 1\,\text{eV} \sim \mu\text{m}^{-1}$ ✓

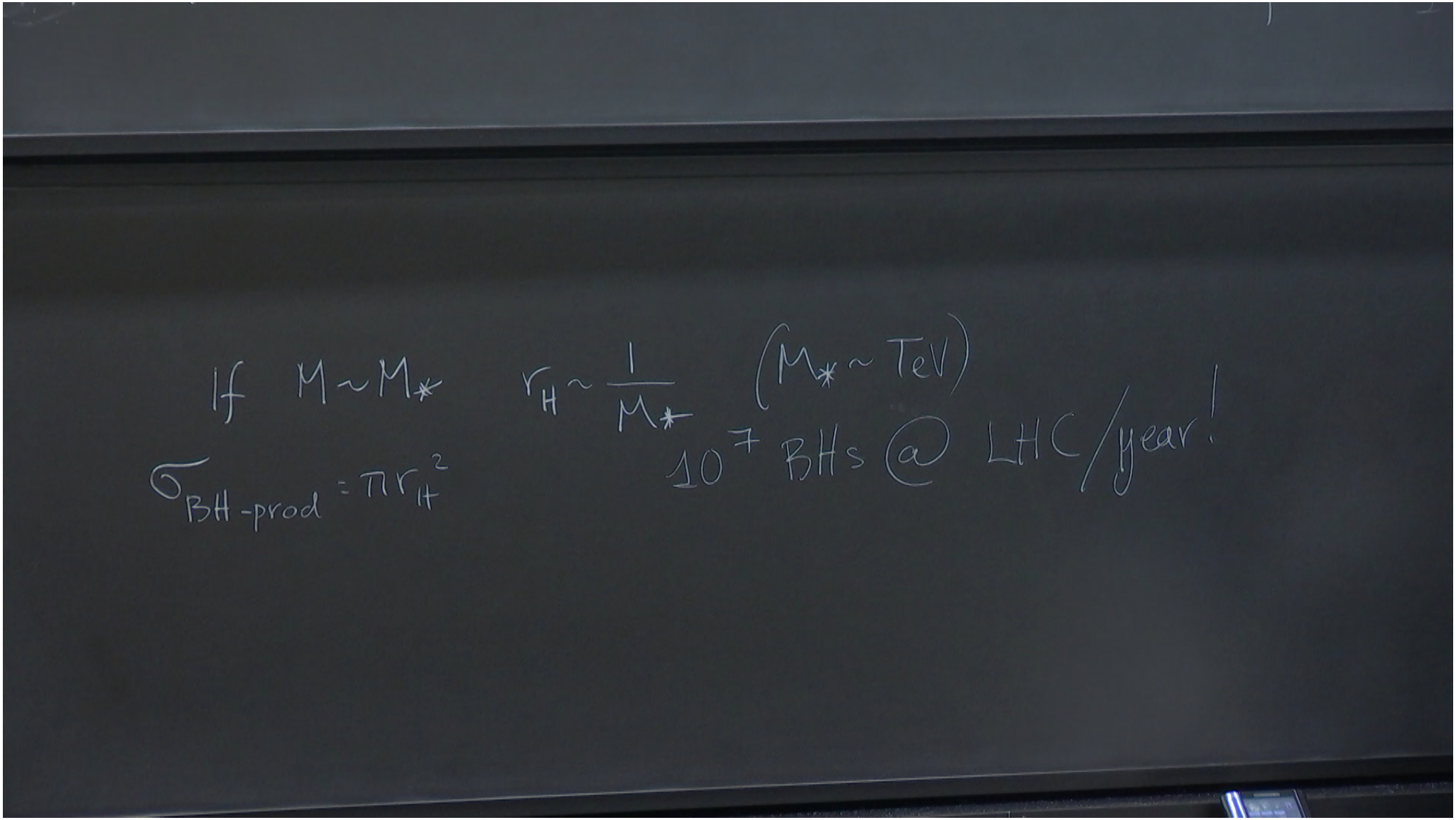
if I go to distances $r < R$ gravity becomes higher dim.

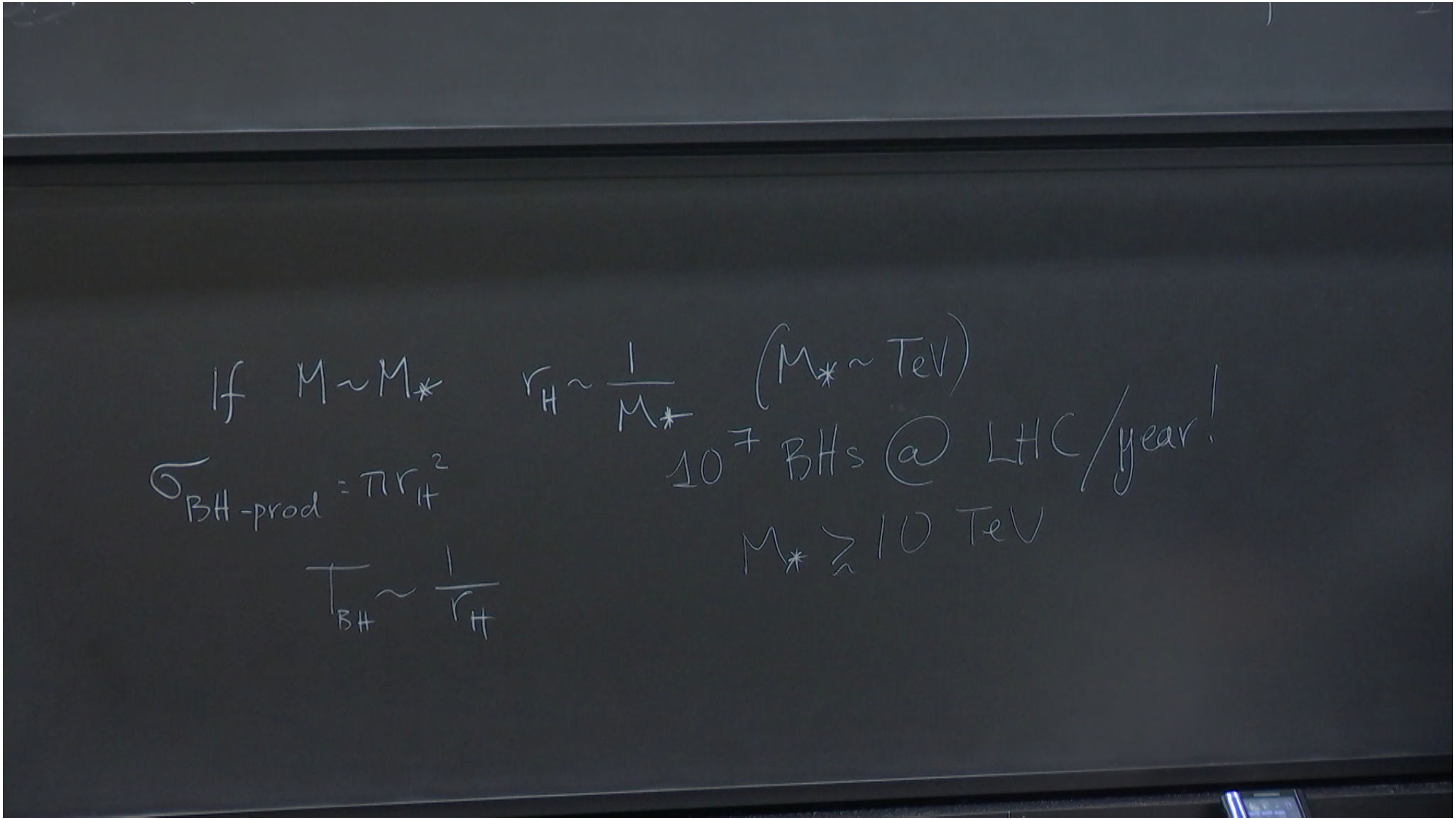
$$ds^2 = \left(1 - \frac{2GM}{M_{Pl}^2 r}\right) dt^2 - \left(1 - \frac{2GM}{M_{Pl}^2 r}\right)^{-1} dr^2 - r^2 d\Omega_{(n)}$$

$$1 - \frac{2GM}{M_{Pl}^2 r} \longrightarrow 1 - \frac{M}{M_*^{2+n} r^{1+n}} \Rightarrow$$

Horizon Size:

$$r_H \sim \left(\frac{M}{M_*}\right)^{1/1+n} \frac{1}{M_*}$$


If $M \sim M_*$ $r_H \sim \frac{1}{M_*}$ $(M_* \sim TeV)$
$\sigma_{BH\text{-}prod} = \pi r_H^2$
10^7 BHs @ LHC/year!


If $M \sim M_*$ $r_H \sim \frac{1}{M_*}$ $(M_* \sim \text{TeV})$
$\sigma_{BH\text{-}prod} = \pi r_H^2$
10^7 BHs @ LHC/year!
$M_* \gtrsim 10$ TeV
$T_{BH} \sim \frac{1}{r_H}$

mensions (LED)

poulos, Dvali '97

4 dim → $\mu = \{0,1,2,3\}$

4+n dim → M

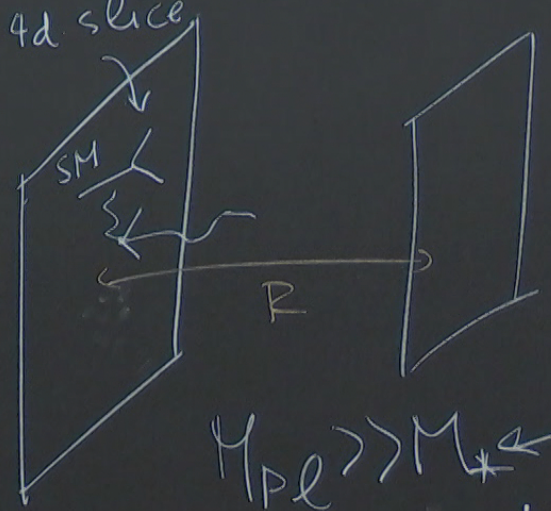
n dim → latin characters

$d\Omega_{(n)} - dr^2$ r goes from 0 to R.

$M_*^{n+2} \int d^{4+n}x \sqrt{g^{(4+n)}} R^{(4+n)}$

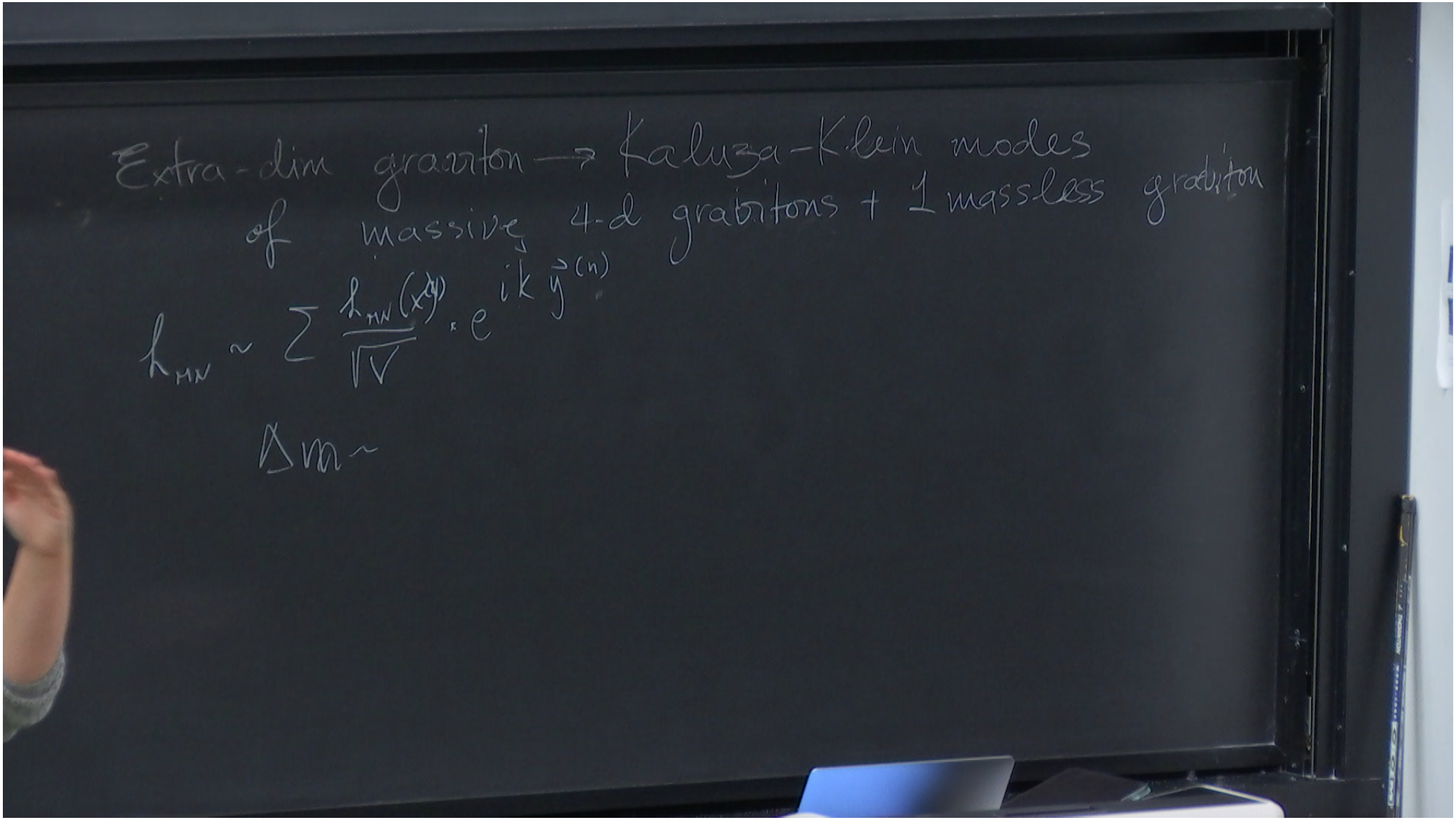
$S_{eff\,4} = -\underbrace{M_*^{n+2} \int d\Omega_{(n)} r^n}_{M_{pl}^2} \int d^4x \sqrt{g^{(4)}} R^{(4)}$

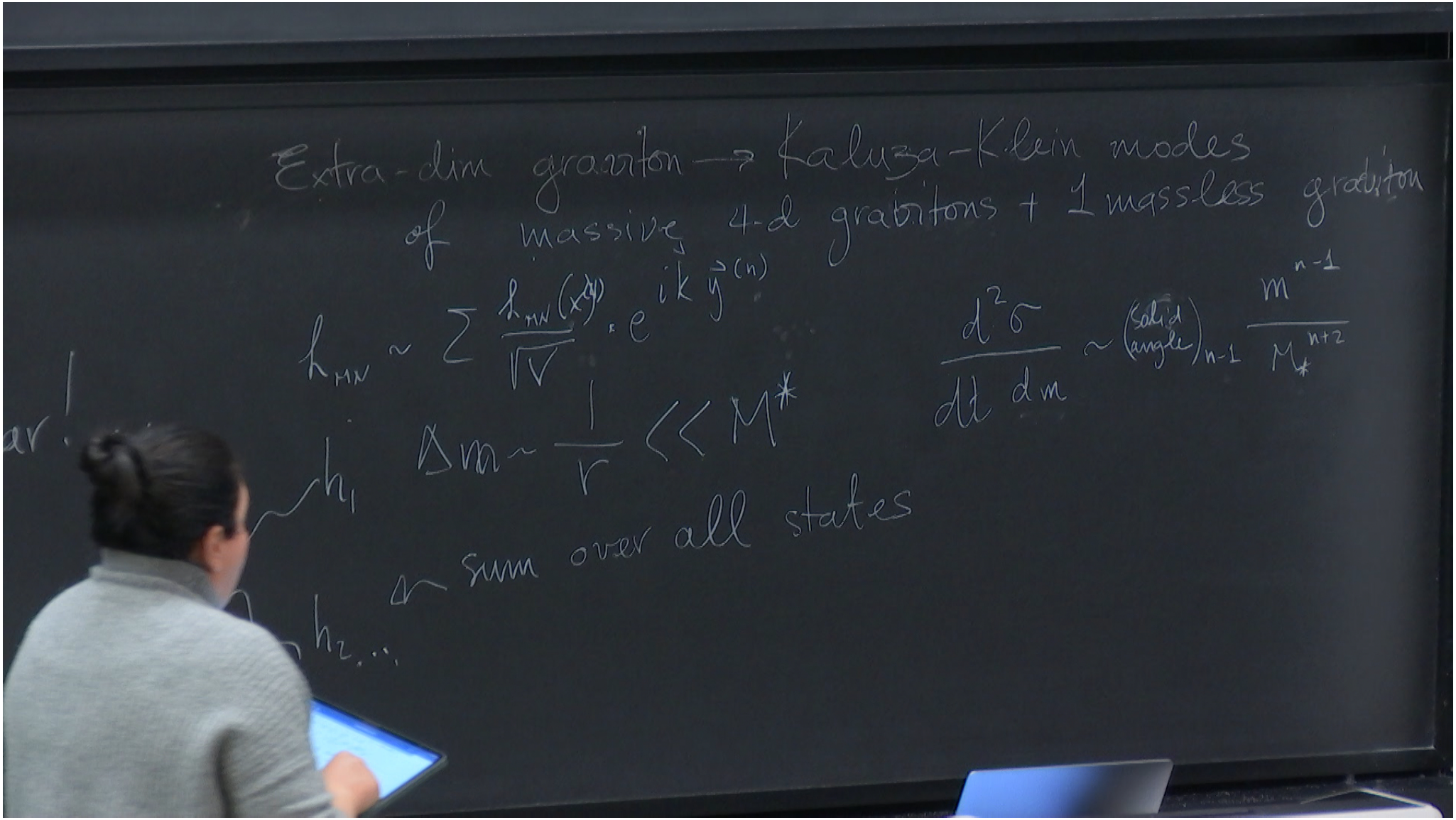
$M_{pl}^2 = M_*^{n+2} \underline{\underline{V^{(n)}}}$



$M_{pl} >> M_*$

Extra dimensions dilute gravity to give "!"


Extra-dim graviton → Kaluza-Klein modes
of massive 4-d gravitons + 1 massless graviton
$h_{\mu\nu} \sim \sum \frac{h_{\mu\nu}(x)}{\sqrt{V}} \cdot e^{ik\vec{y}^{(n)}}$
$\Delta m \sim$

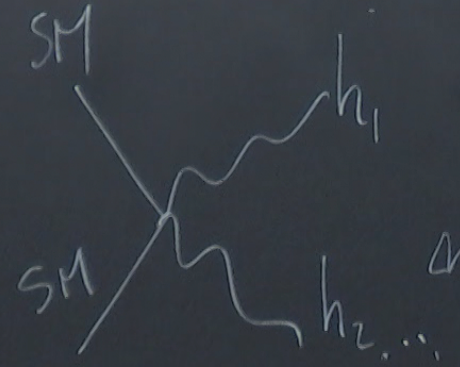

Extra-dim graviton → Kaluza-Klein modes
of massive 4-d gravitons + 1 massless graviton
$h_{\mu\nu} \sim \sum \frac{h_{\mu\nu}(x)}{\sqrt{r}} \cdot e^{i k \vec{y}^{(n)}}$
$\frac{d^2\sigma}{dt\, dm} \sim \left(\text{solid angle}\right)_{n-1} \frac{m^{n-1}}{M_*^{n+2}}$
$\Delta m \sim \frac{1}{r} \ll M^*$
h_1
sum over all states
$h_2 \ldots$

Extra-dim graviton → Kaluza-Klein modes
of massive 4-d gravitons + 1 massless graviton

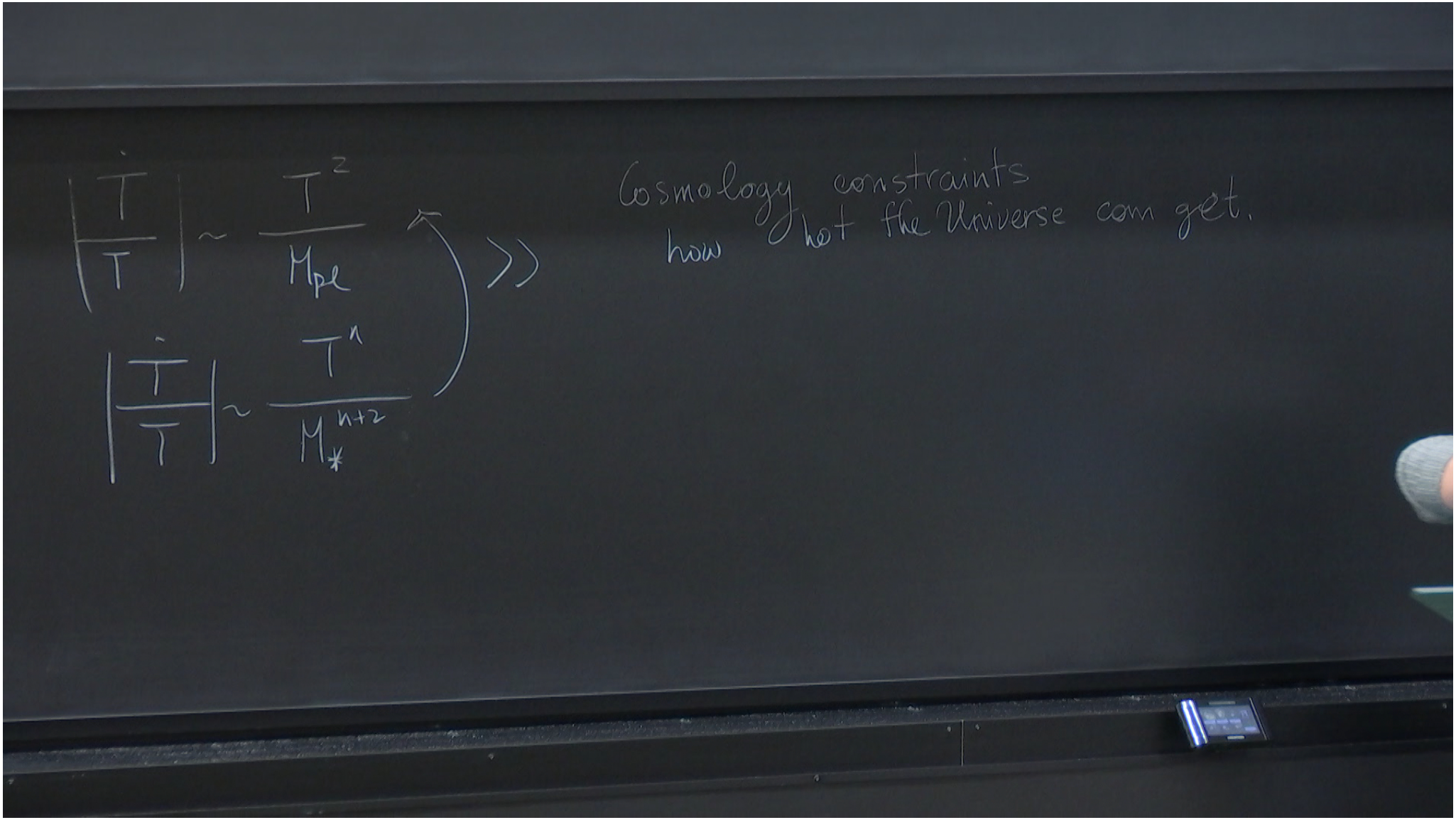
$$h_{\mu\nu} \sim \sum \frac{h_{\mu\nu}(x)}{\sqrt{V}} \cdot e^{i k \vec{y}^{(n)}}$$

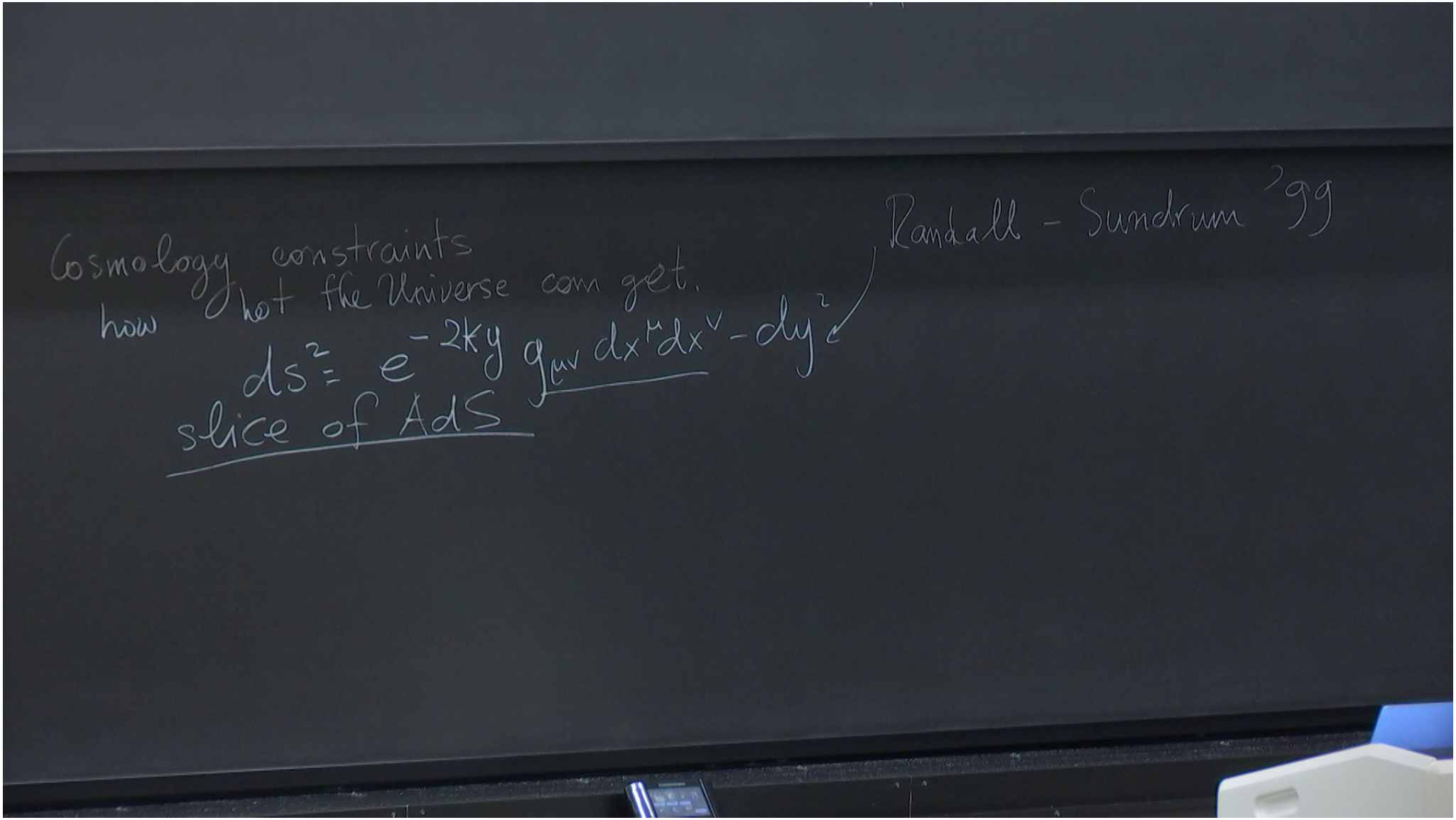
$$\frac{d^2\sigma}{dt\, dm} \sim (\text{solid angle})_{n-1} \frac{m^{n-1}}{M_*^{n+2}}$$

$$\Delta m \sim \frac{1}{r} \ll M^*$$

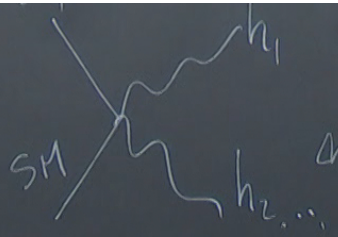


↳ sum over all states


$\left|\frac{\dot{T}}{T}\right| \sim \frac{T^2}{M_{pl}}$
$\left|\frac{\dot{T}}{T}\right| \sim \frac{T^n}{M_*^{n+2}}$
>>
Cosmology constraints how hot the Universe can get.

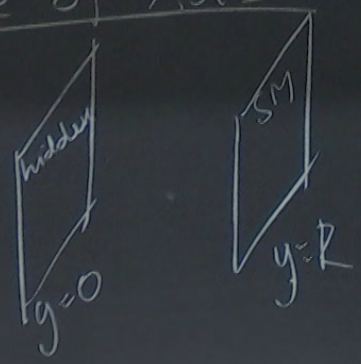

Cosmology constraints
how hot the Universe can get.
$ds^2 = e^{-2ky} g_{\mu\nu} dx^\mu dx^\nu - dy^2$
slice of AdS
Randall - Sundrum '99

$M_* \gtrsim 10$ TeV



σ sum over all states

slice of AdS



$$M_{Pl}^2 = \frac{M_*^3}{k}\left[1 - e^{-2kR}\right]$$

$$g_{\mu\nu SM} = e^{-2kR}\,\bar{g}_{\mu\nu}$$

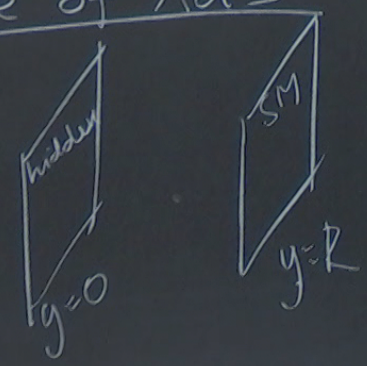
AdS/CFT on SM brane means that you have compositeness eg. theories of Technicolor

logy constraints
hot the Universe can get.

Randall - Sundrum 2 gg

$ds^2 = e^{-2ky} g_{\mu\nu} dx^\mu dx^\nu - dy^2$

slice of AdS



$M_{Pl}^2 = \frac{M_*^3}{k}\left[1 - e^{-2kR}\right]$

$g_{\mu\nu SM} = e^{-2kR}\,\bar{g}_{\mu\nu}$

$kR \sim 30$

$S_{vis} \rightarrow$

$\tilde{v} = e^{-kR} v_0$

$\tilde{m} = e^{-kR} m_0$

AdS/CFT on SM brane

means that you have compositeness

eg. theories of Technicolor

smology constraints
how hot the Universe can get.

Randall - Sundrum 2 gg

$ds^2 = e^{-2ky} g_{\mu\nu} dx^\mu dx^\nu - dy^2$

slice of AdS

$M_{Pl}^2 = \frac{M_*^3}{k}\left[1 - e^{-2kR}\right]$

$g_{\mu\nu SM} = e^{-2kR}\,\bar{g}_{\mu\nu}$

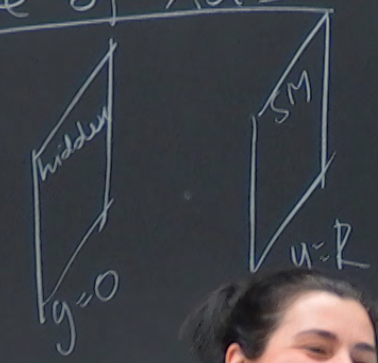
$kR \sim 30$

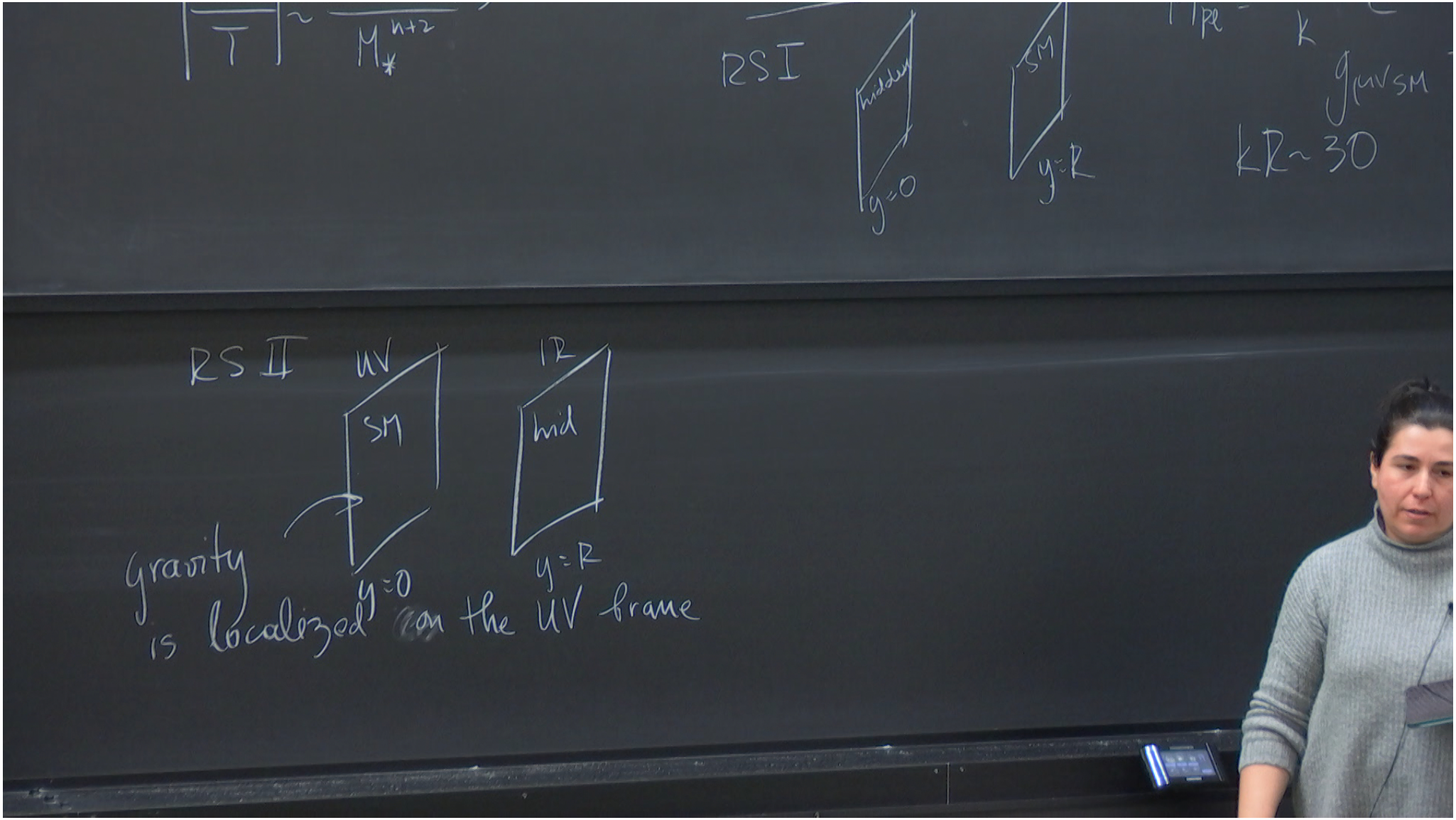
$S_{vis} \rightarrow$

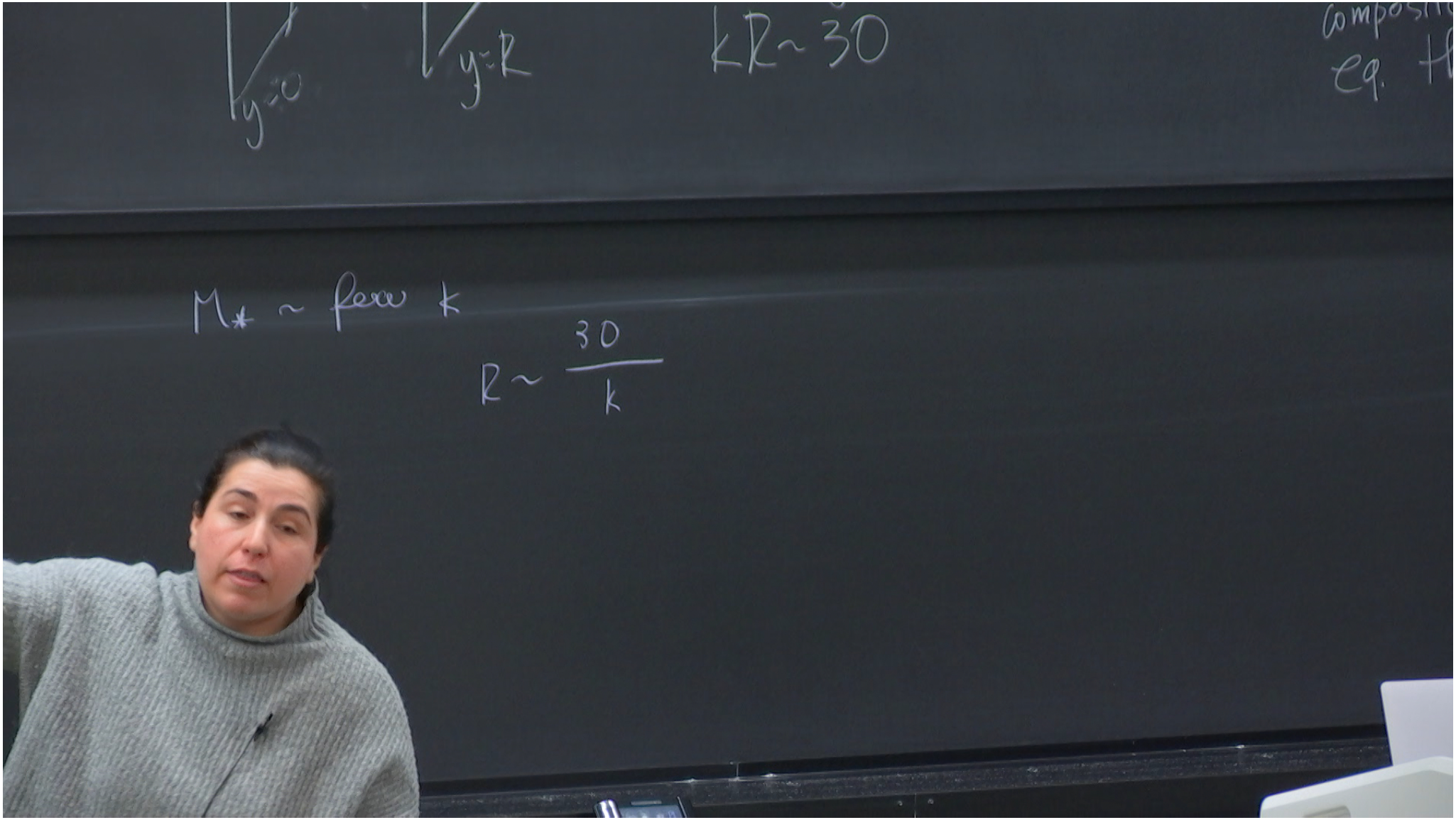
$\tilde{v} = e^{-kR} v_0$

$\tilde{m} = e^{-kR} m_0$

AdS/CFT on SM brane means that you have compositeness eg. theories of Technicolor




RS II
UV
IR
SM
hid
y=0
y=R
Gravity is localized on the UV frame
RSI
hidden
SM
y=0
y=R
kR~30


y=0
y=R
kR~30
M* ~ few k
R~ 30/k