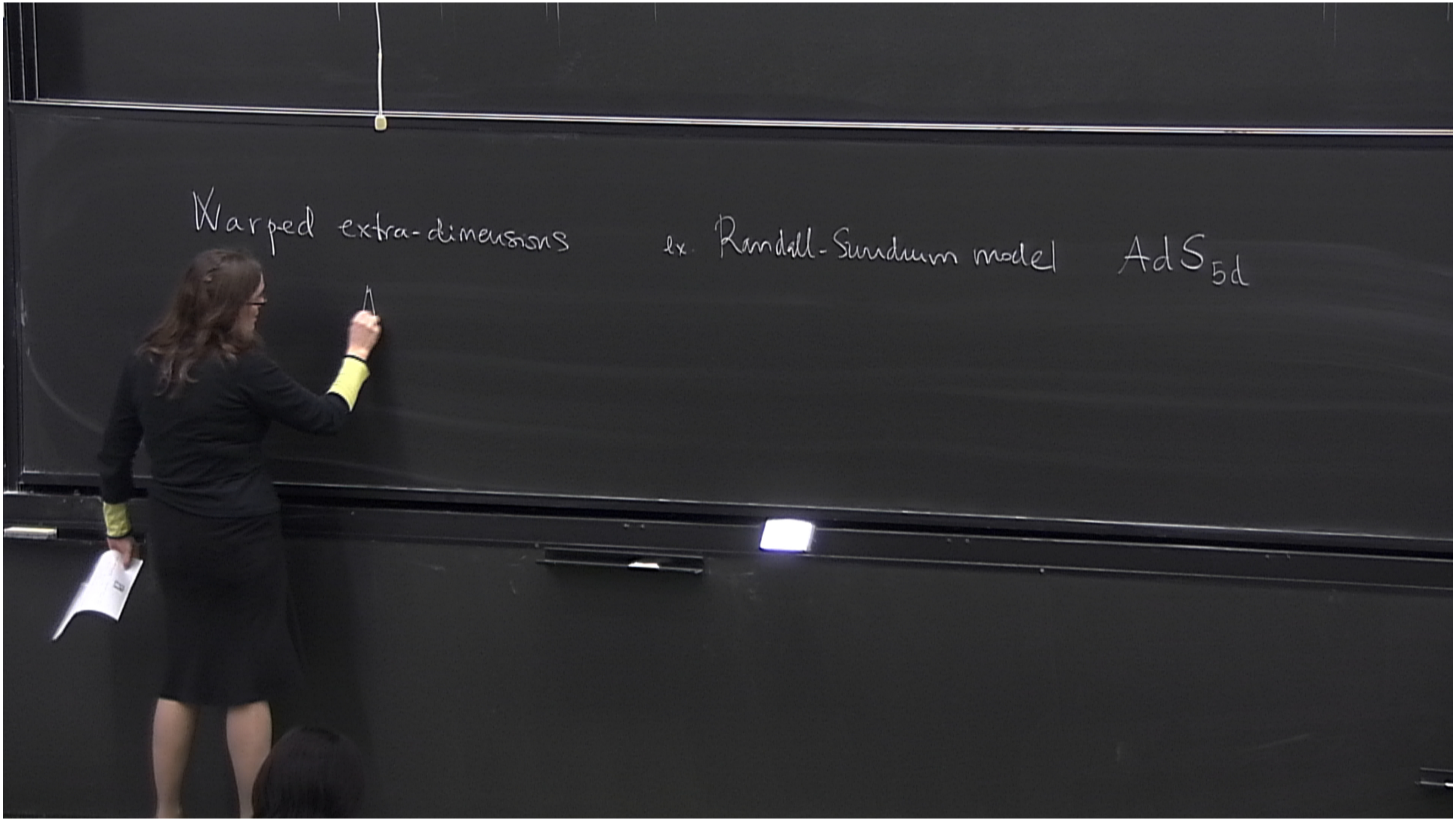
Title: Beyond the Standard Model (Review) - Lecture 13

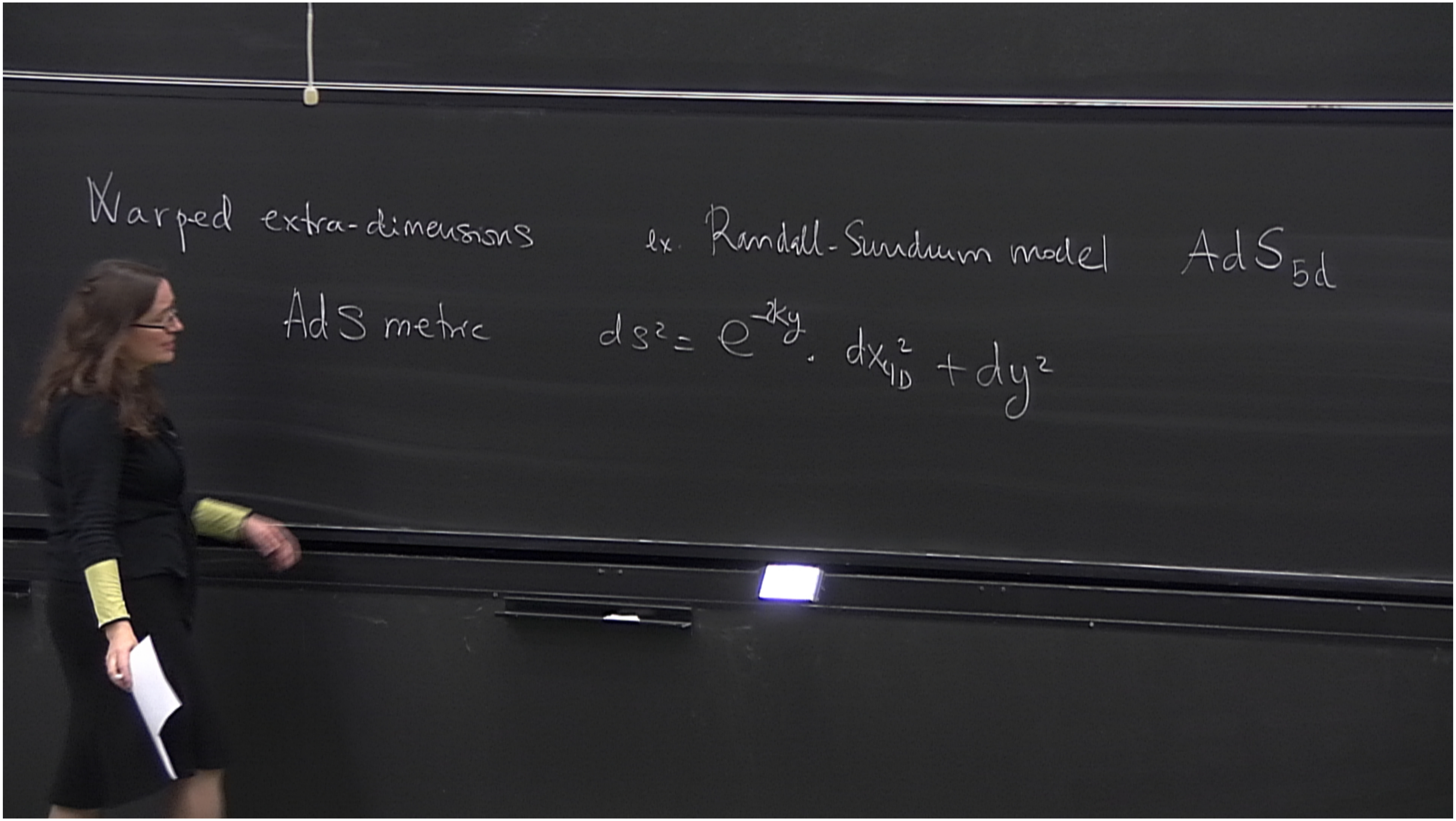
Date: Mar 01, 2012  09:00 AM

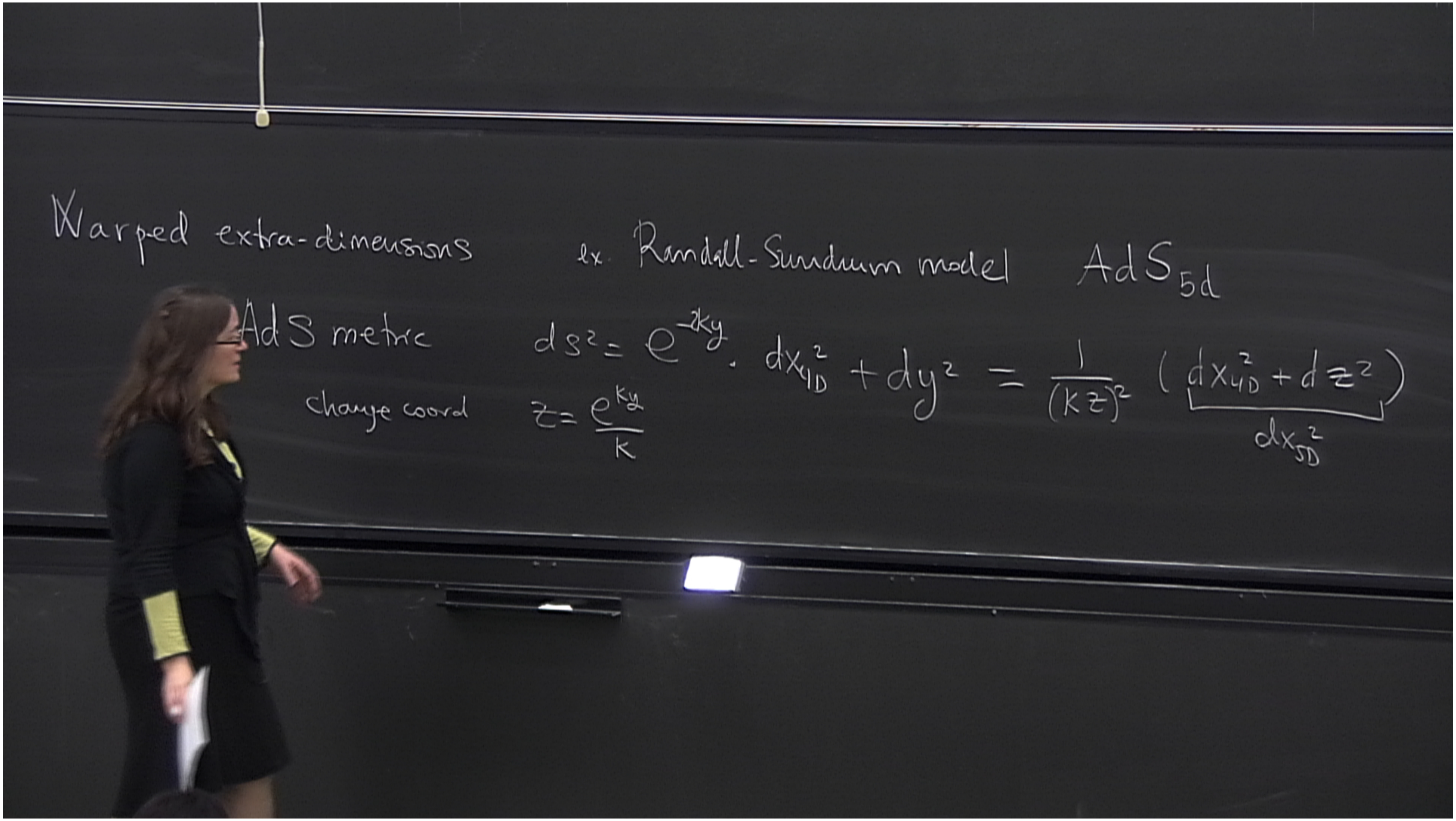
URL: http://pirsa.org/12030065

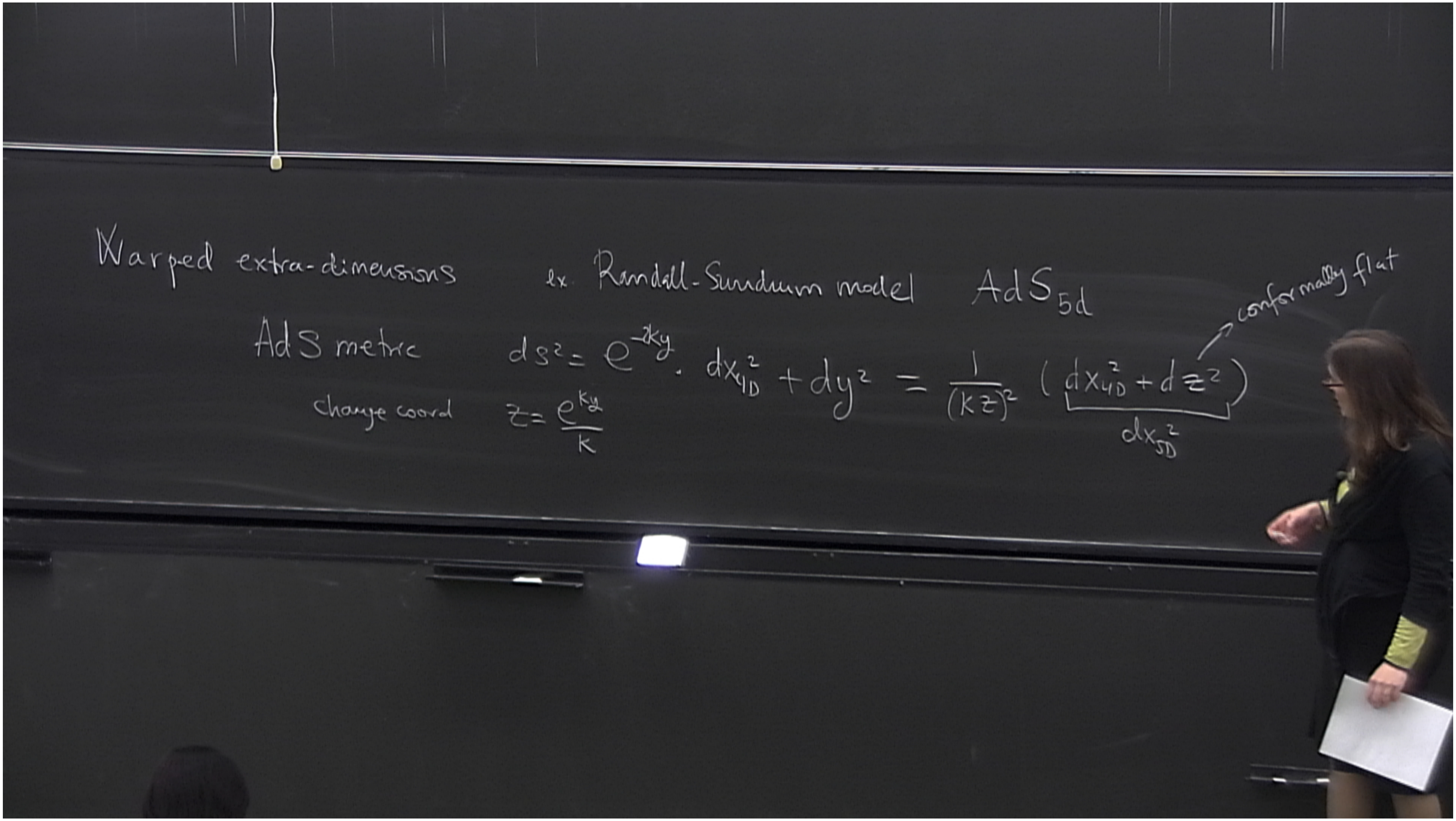
Abstract:

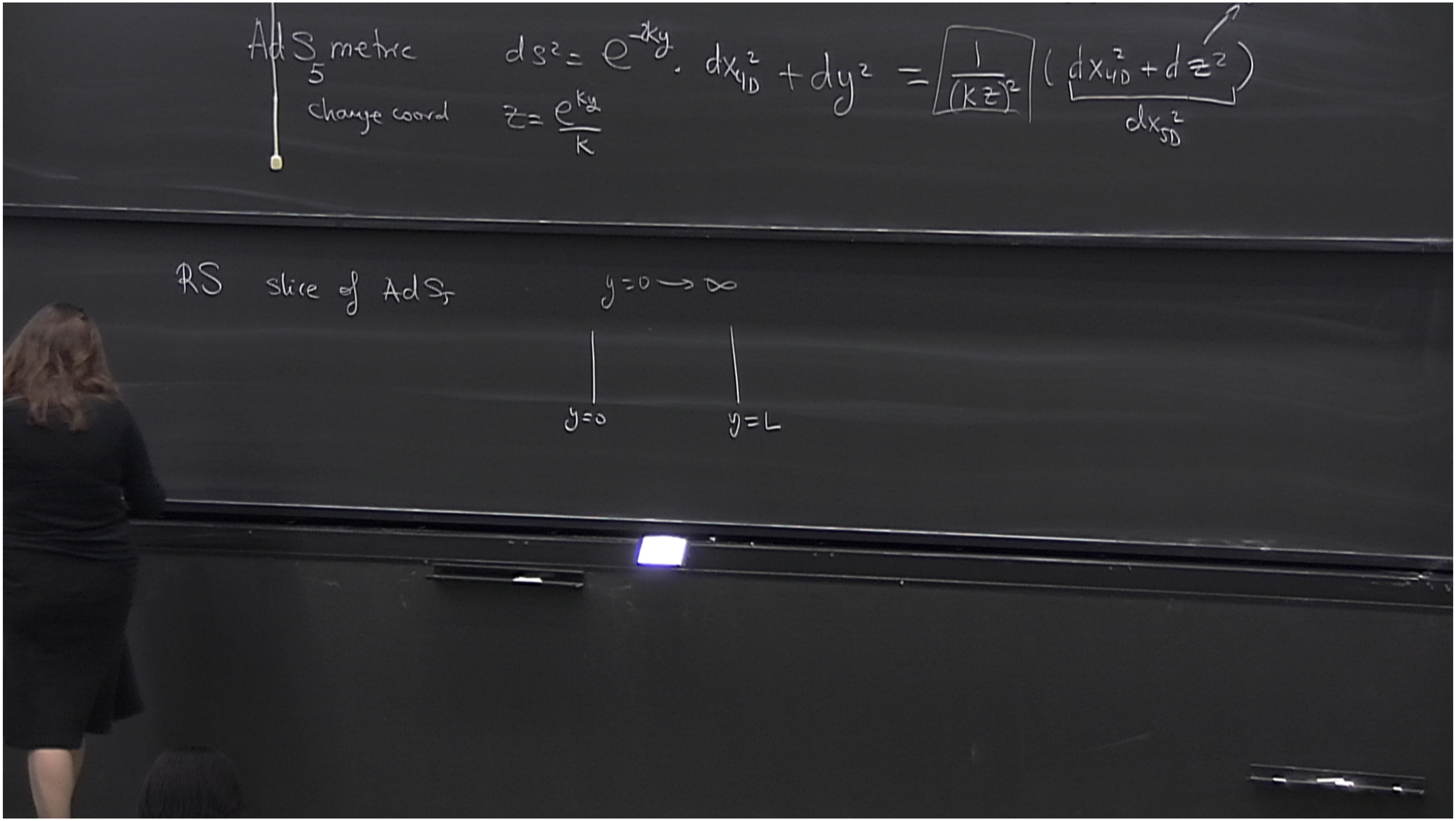

Warped extra-dimen

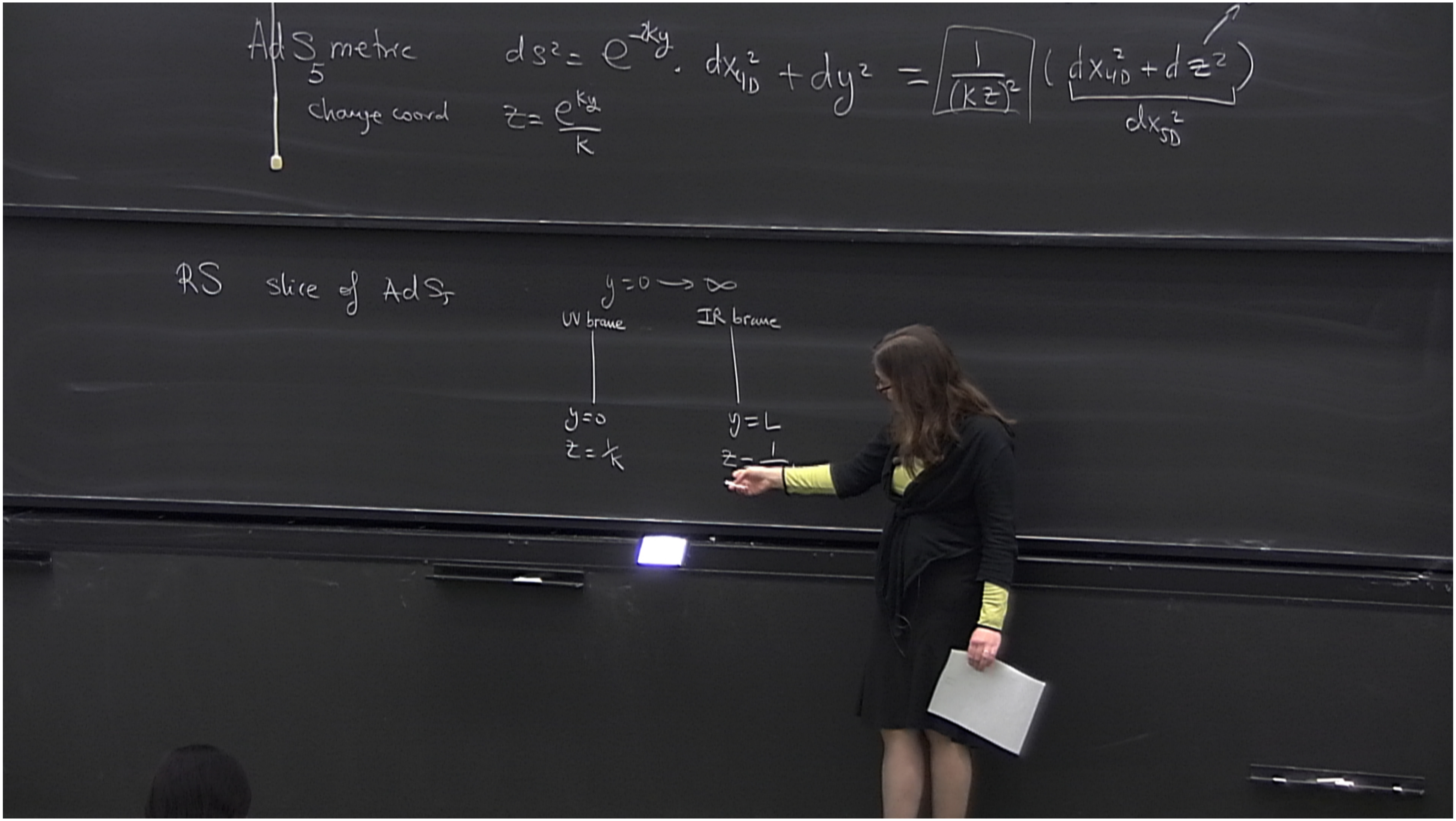

Warped extra-dimensions
ex. Randall-Sundrum model
AdS 5d

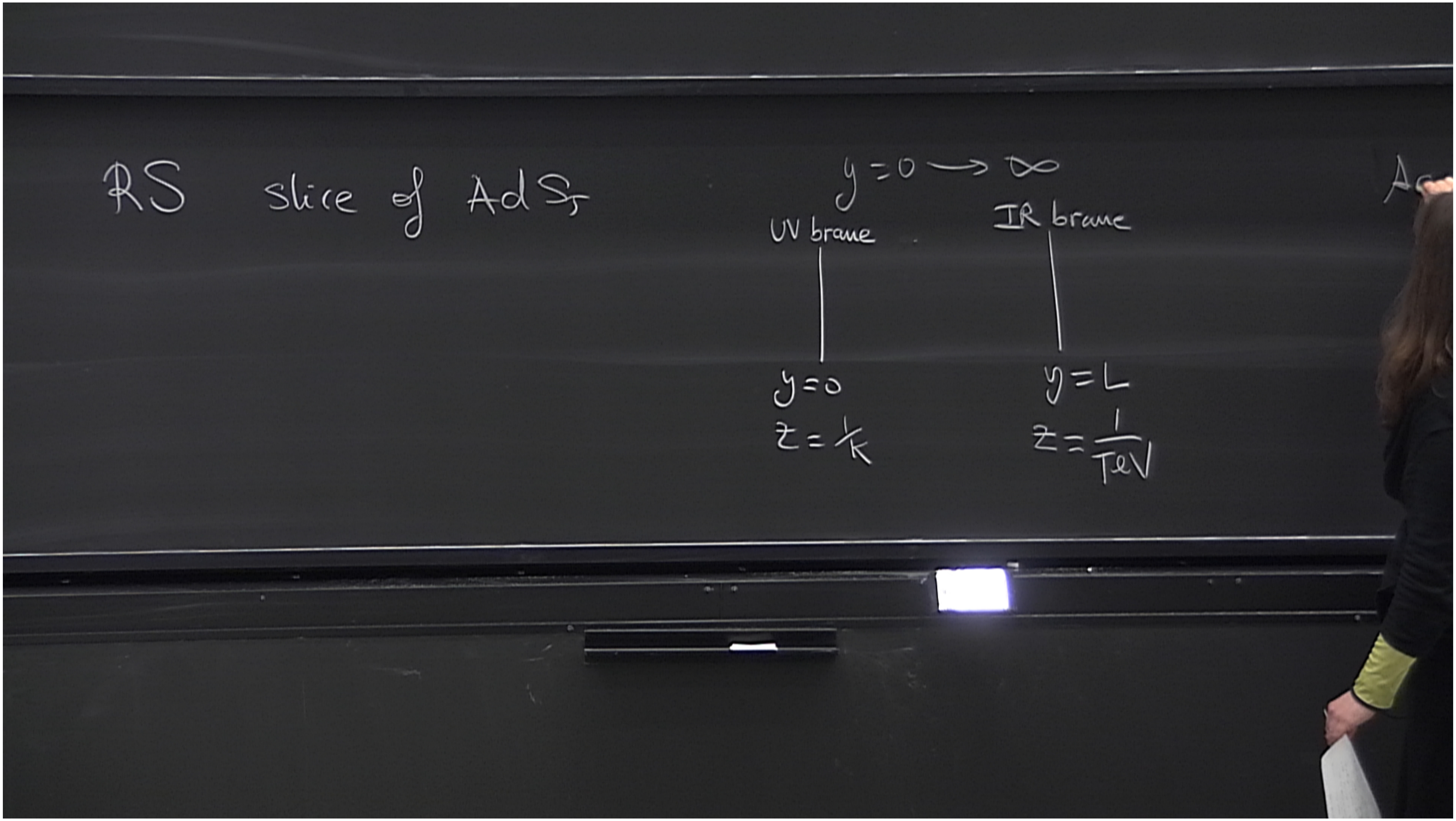

Warped extra-dimensions
ex. Randall-Sundrum model $AdS_{5d}$
AdS metric $ds^2 = e^{-2ky} \cdot dx_{4D}^2 + dy^2$

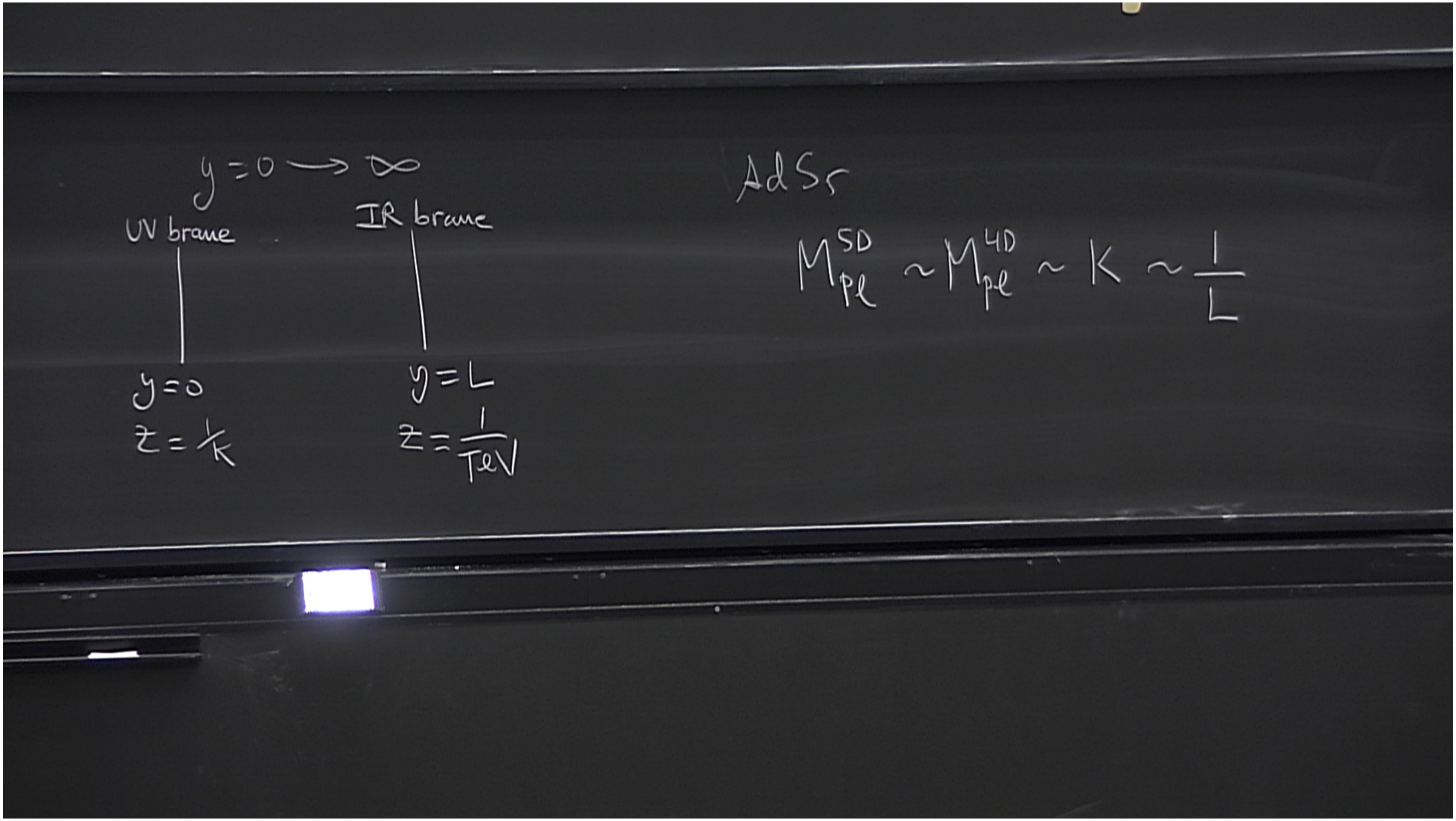

Warped extra-dimensions
ex. Randall-Sundrum model AdS 5d
AdS metric
ds² = e^{-2ky} · dx²_{4D} + dy² = 1/(kz)² (dx²_{4D} + dz²)
dx²_{5D}
change coord
z = e^{ky}/k

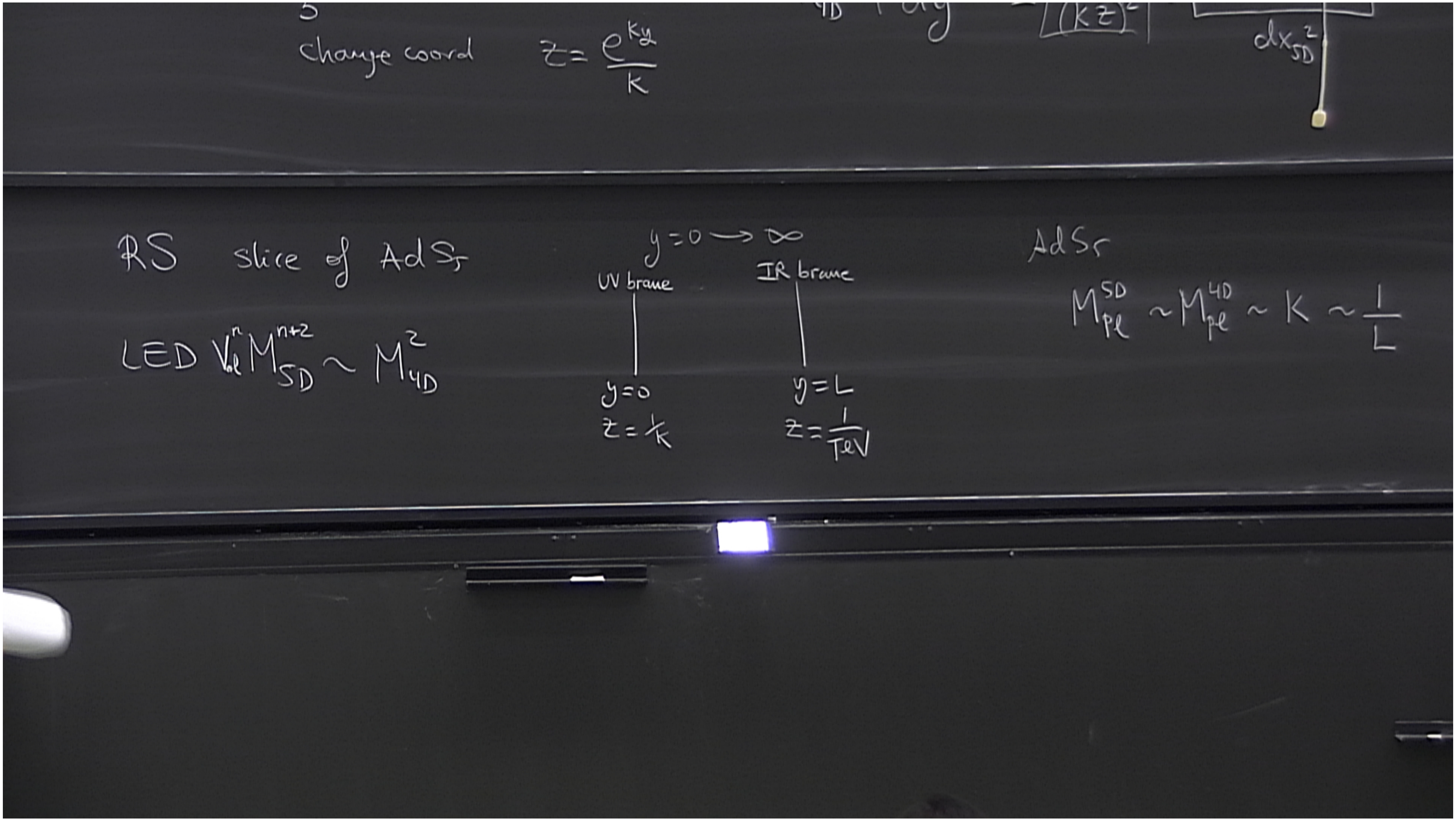

Warped extra-dimensions
ex. Randall-Sundrum model
$AdS_{5d}$
conformally flat
AdS metric
$ds^2 = e^{-2ky} \cdot dx_{4D}^2 + dy^2 = \frac{1}{(kz)^2} ( dx_{4D}^2 + dz^2 )$
$dx_{5D}^2$
change coord
$z = \frac{e^{ky}}{k}$


AdS5 metric $ds^2 = e^{-2ky} \cdot dx_{4D}^2 + dy^2 = \frac{1}{(kz)^2}(dx_{4D}^2 + dz^2)$
$dx_{5D}^2$
change coord $z = \frac{e^{ky}}{k}$
RS slice of AdS5
$y = 0 \to \infty$
$y=0$
$y=L$


AdS$_5$ metric $ds^2 = e^{-2ky} \cdot dx_{4D}^2 + dy^2 = \frac{1}{(kz)^2}(dx_{4D}^2 + dz^2)$
$dx_{5D}^2$
change coord $z = \frac{e^{ky}}{k}$
RS slice of AdS$_5$
$y = 0 \to \infty$
UV brane
IR brane
$y = 0$
$z = 1/k$
$y = L$


RS slice of AdS5
y = 0 → ∞
UV brane
IR brane
y = 0
z = 1/k
y = L
z = 1/TeV


y = 0 → ∞
UV brane
IR brane
y = 0
z = 1/k
y = L
z = 1/TeV
AdS5
M_pl^5D ~ M_pl^4D ~ k ~ 1/L


change coord $z = \frac{e^{ky}}{k}$
RS slice of $AdS_5$
LED $V_{el}^{n} M_{5D}^{n+2} \sim M_{4D}^{2}$
$y = 0 \longrightarrow \infty$
UV brane
IR brane
$y=0$
$z = 1/k$
$y = L$
$z = \frac{1}{TeV}$
$AdS_5$
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$

change coord $z = \frac{e^{ky}}{k}$

$(kz)^2$ … $dx_{5D}^2$

RS slice of $AdS_5$

LED $V_{ol}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$

$y = 0 \longrightarrow \infty$

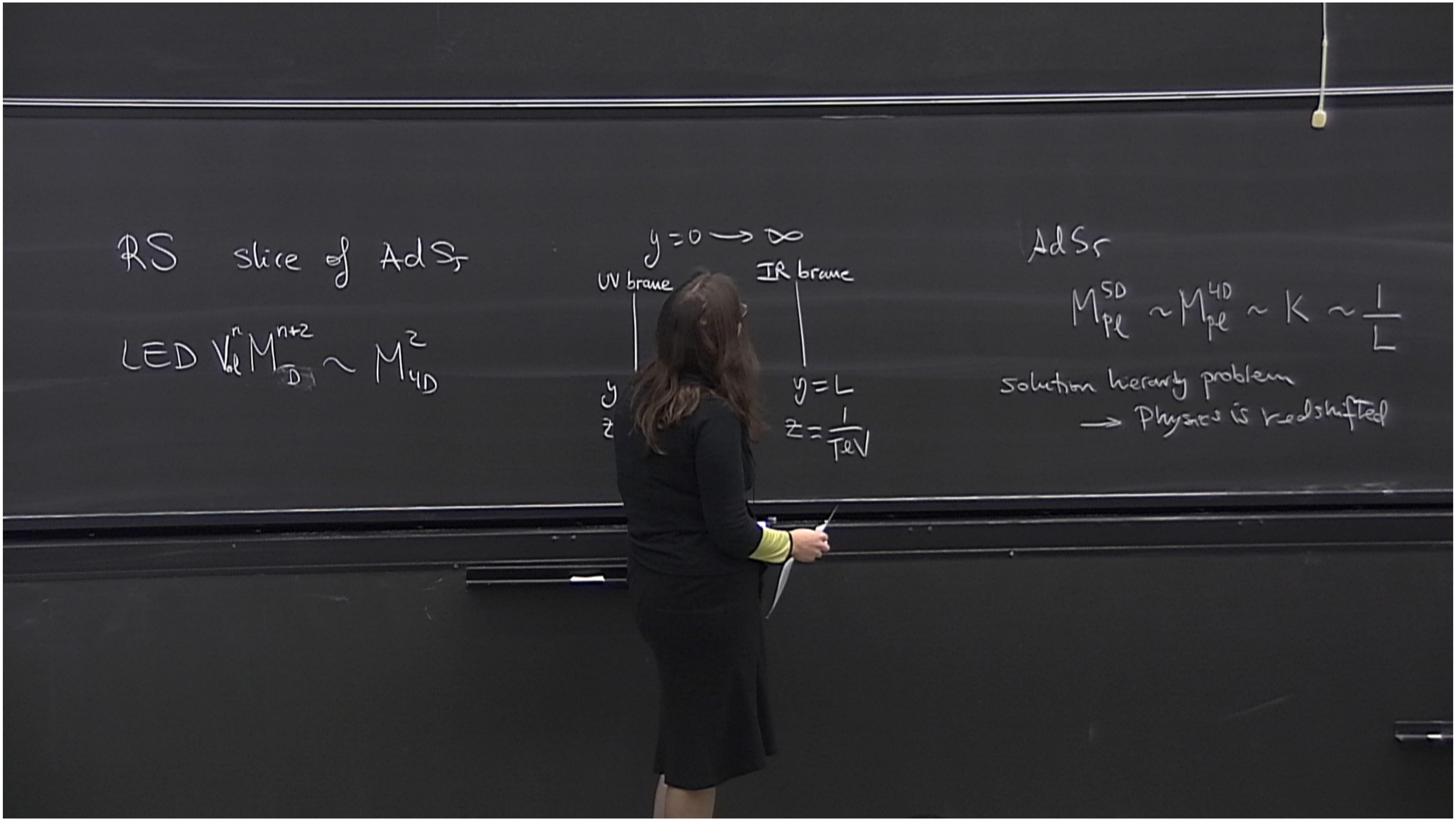
UV brane — IR brane

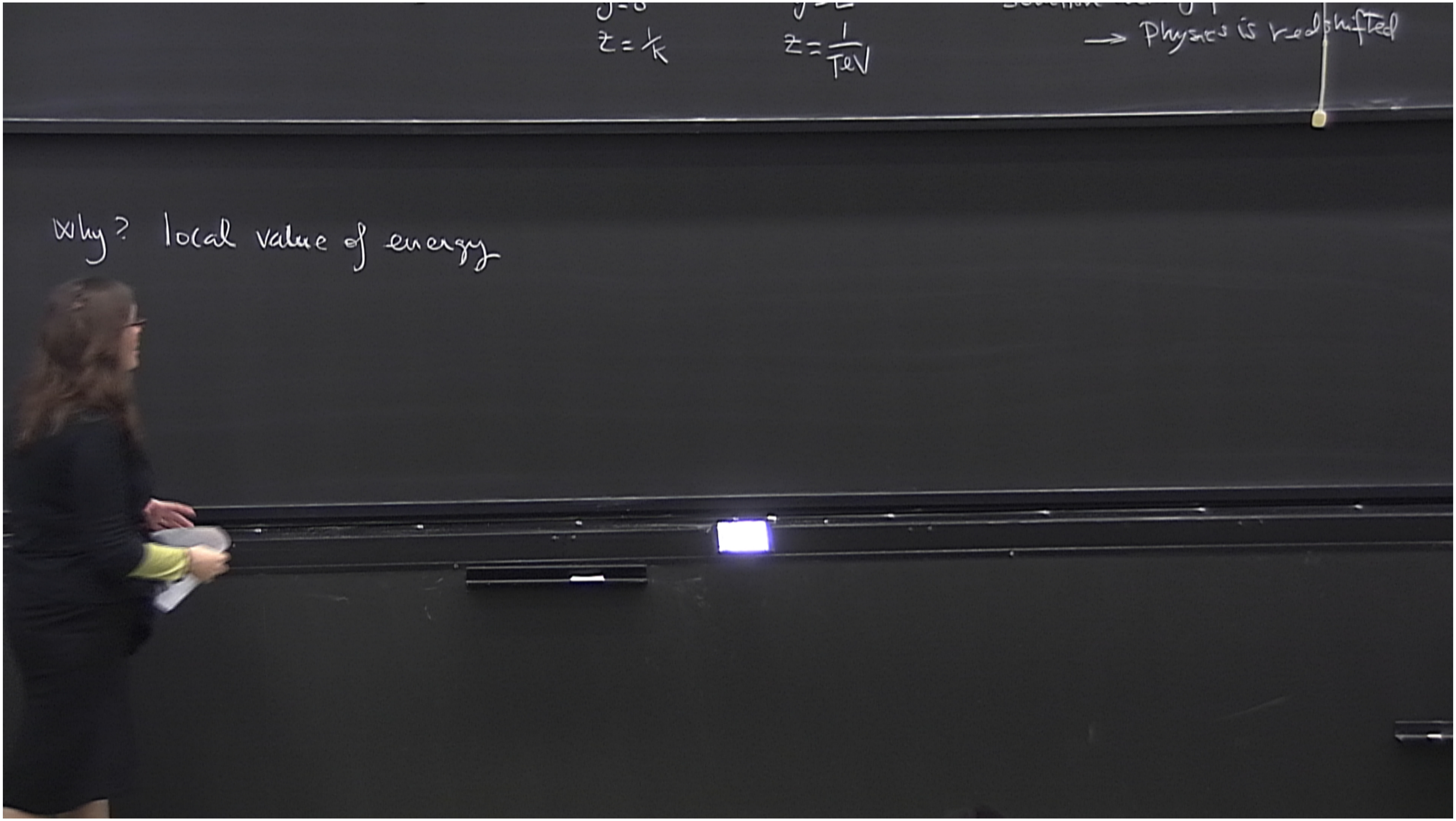
$y = 0$, $z = 1/k$

$y = L$, $z = \frac{1}{TeV}$

$AdS_5$

$M_{pl}^{5D} \sim M_{pl}^{4D} \sim k \sim \frac{1}{L}$

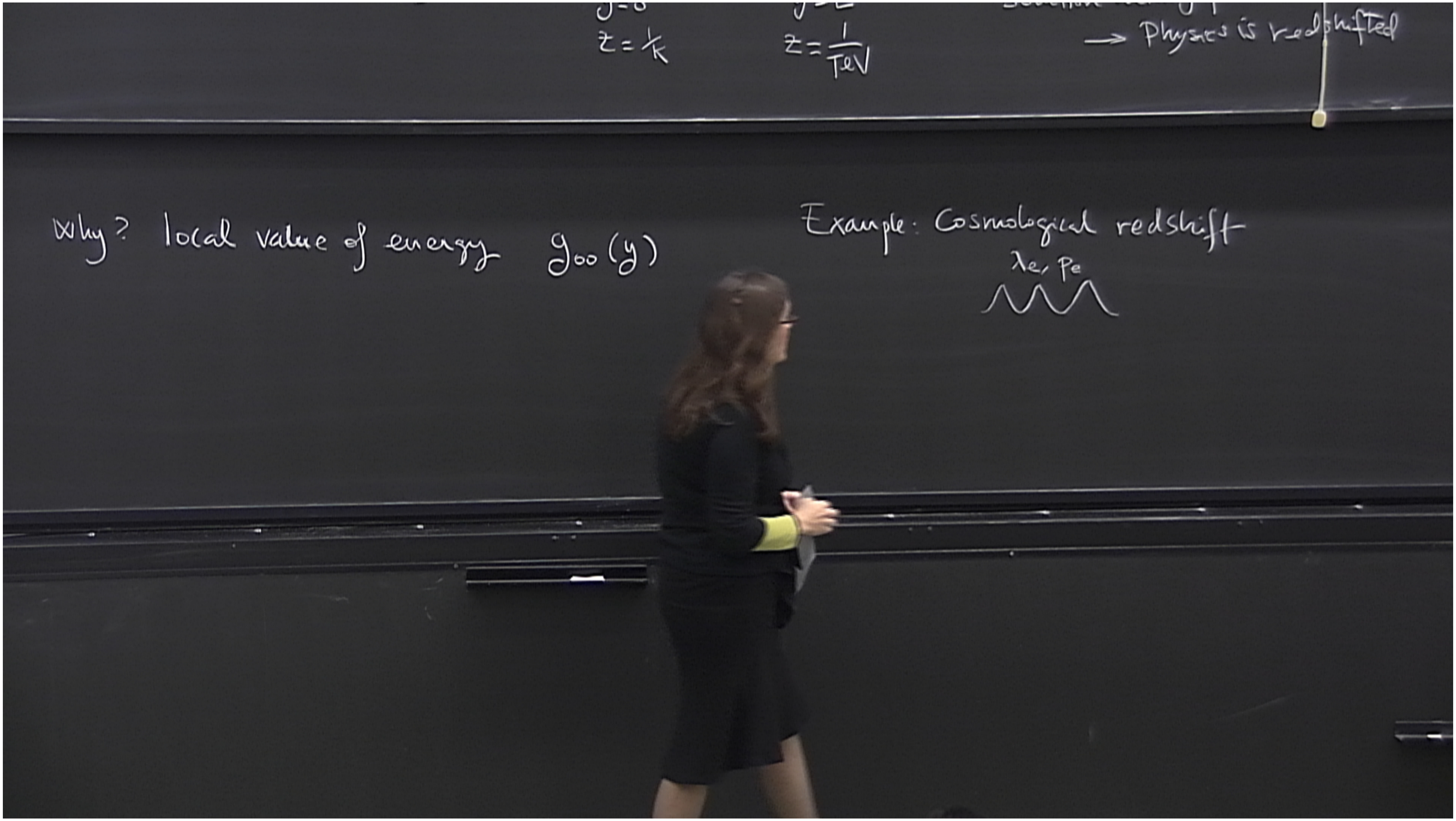

RS slice of AdS5
LED $V_{ol}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$
$y=0 \longrightarrow \infty$
UV brane
IR brane
$y=L$
$z=\frac{1}{TeV}$
AdS5
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$
solution hierarchy problem
→ Physics is redshifted

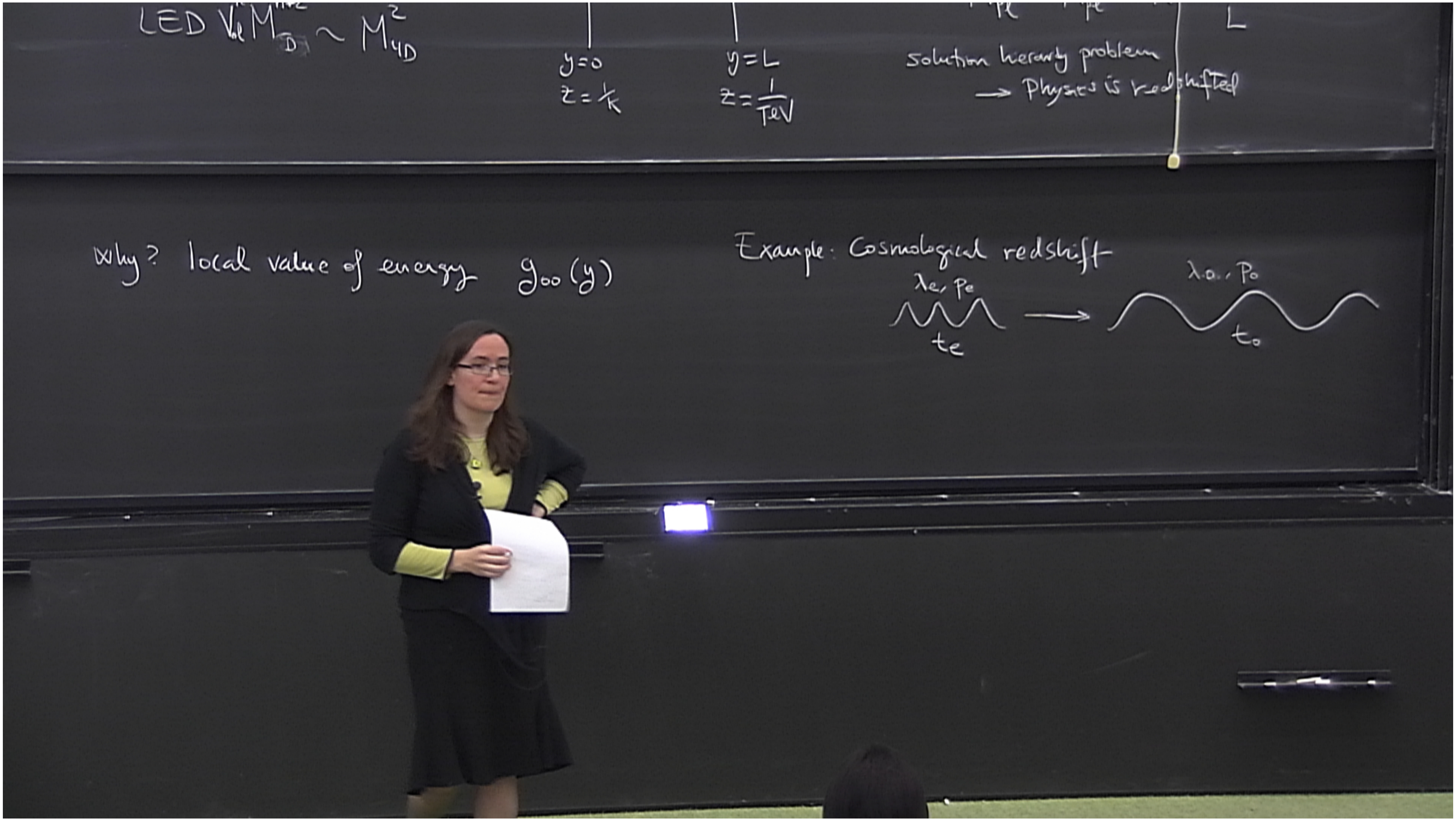

$z = 1/k$
$z = \frac{1}{TeV}$
→ Physics is redshifted
Why? local value of energy

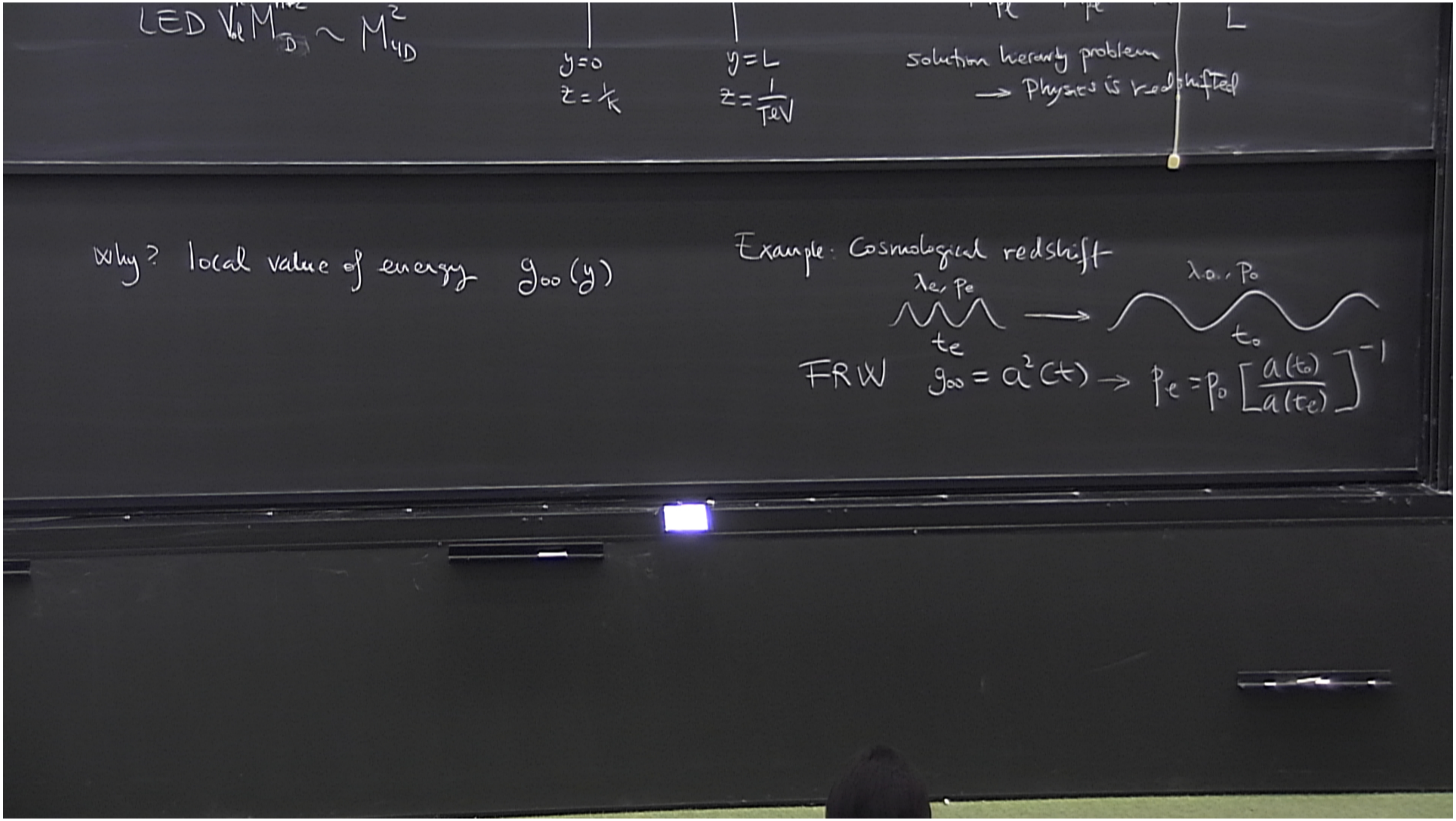
$z = \frac{1}{k}$ $\qquad$ $z = \frac{1}{TeV}$ $\qquad$ $\Longrightarrow$ Physics is redshifted

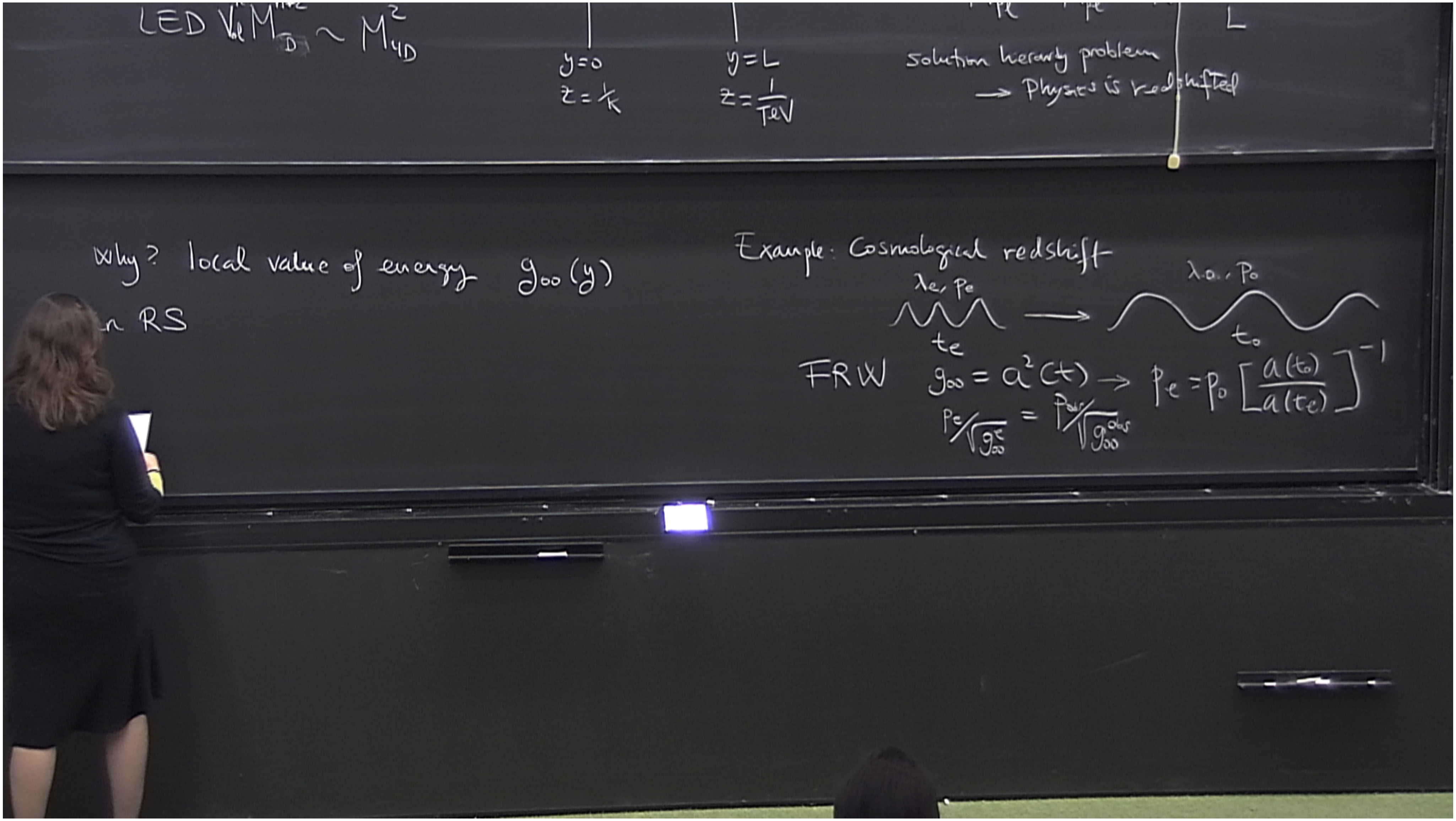
Why? local value of energy $g_{00}(y)$

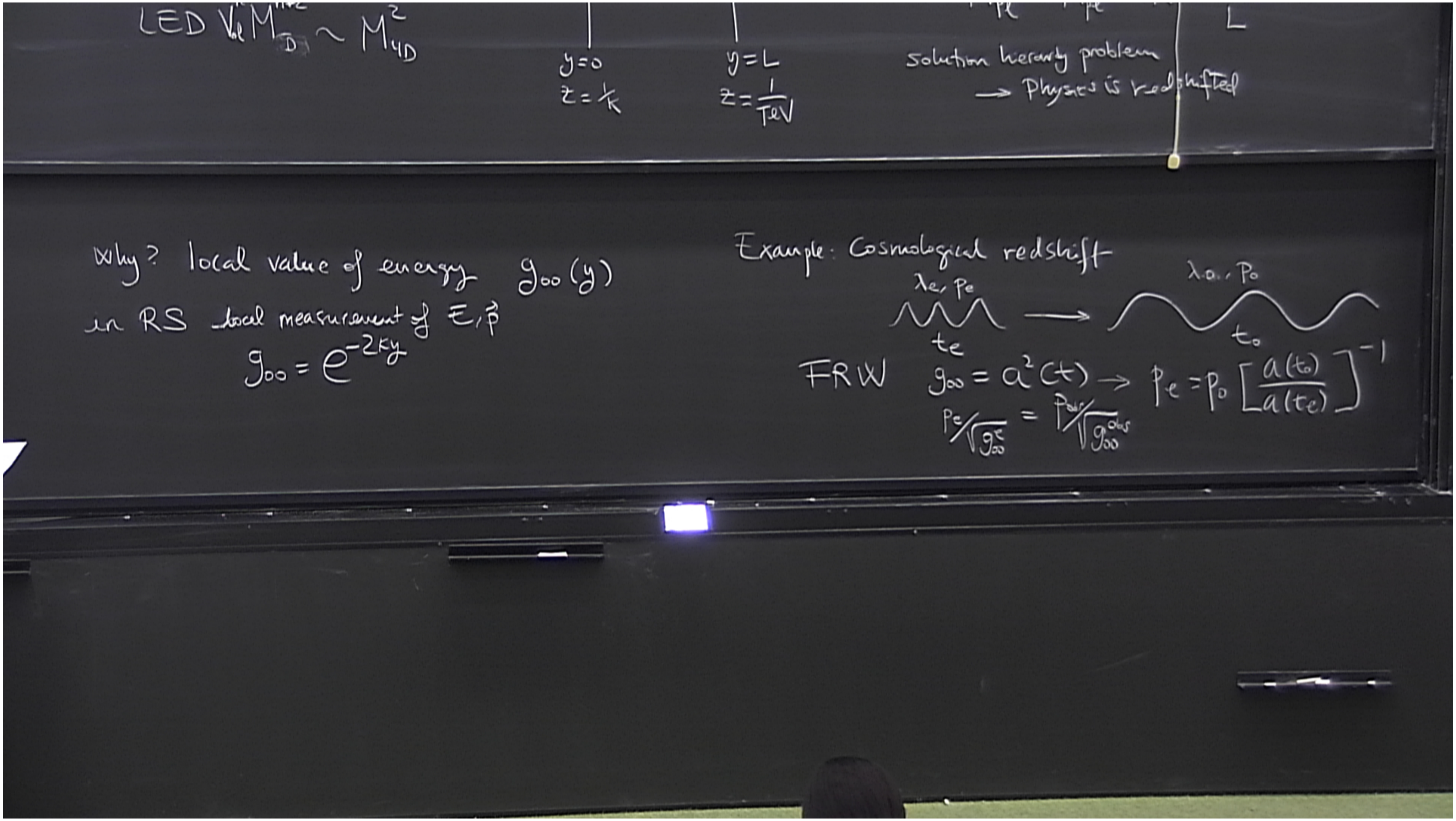
Example: Cosmological redshift

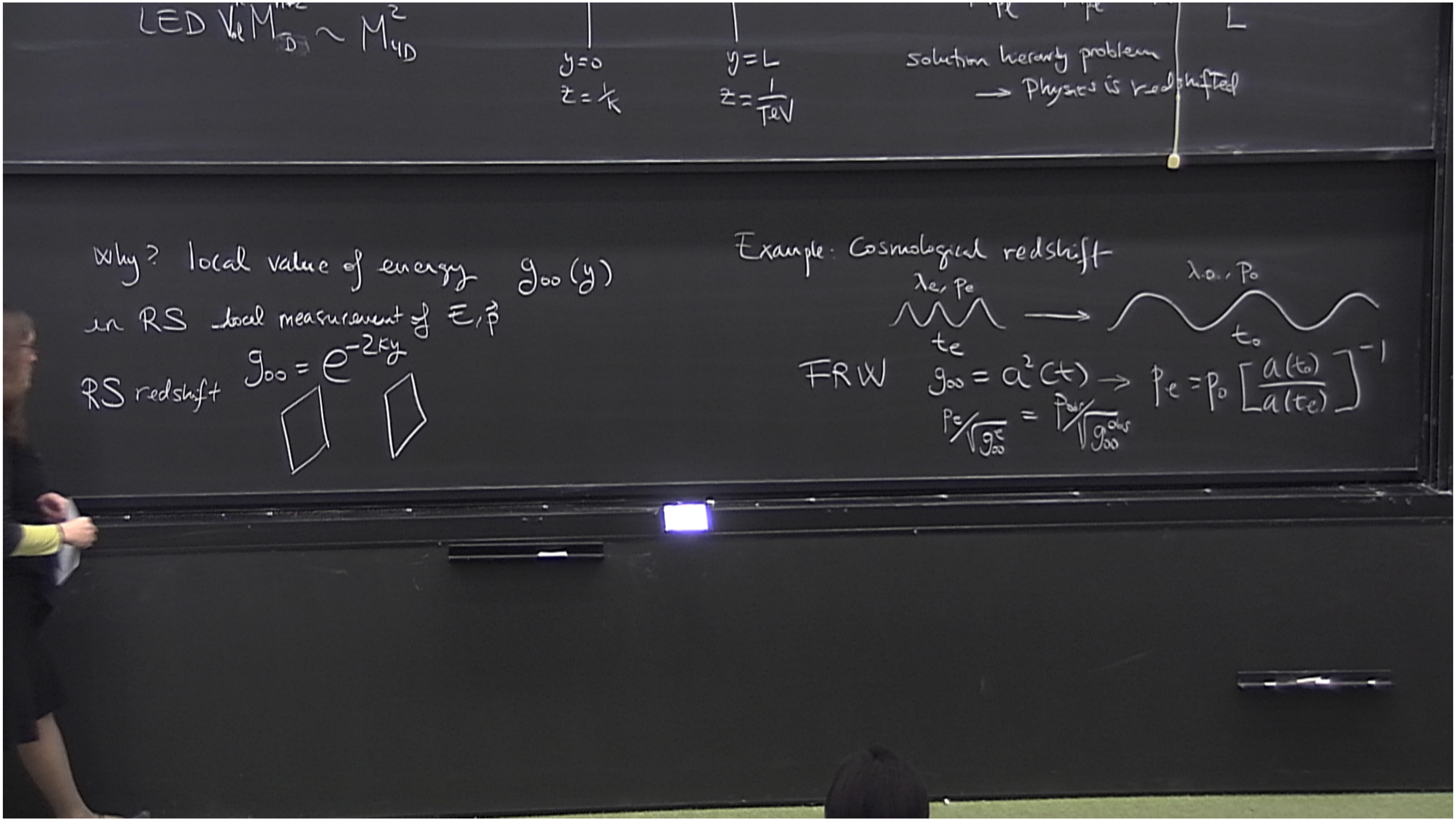

z = 1/k
z = 1/TeV
→ Physics is redshifted
Why? local value of energy g00 (y)
Example: Cosmological redshift
λe, pe

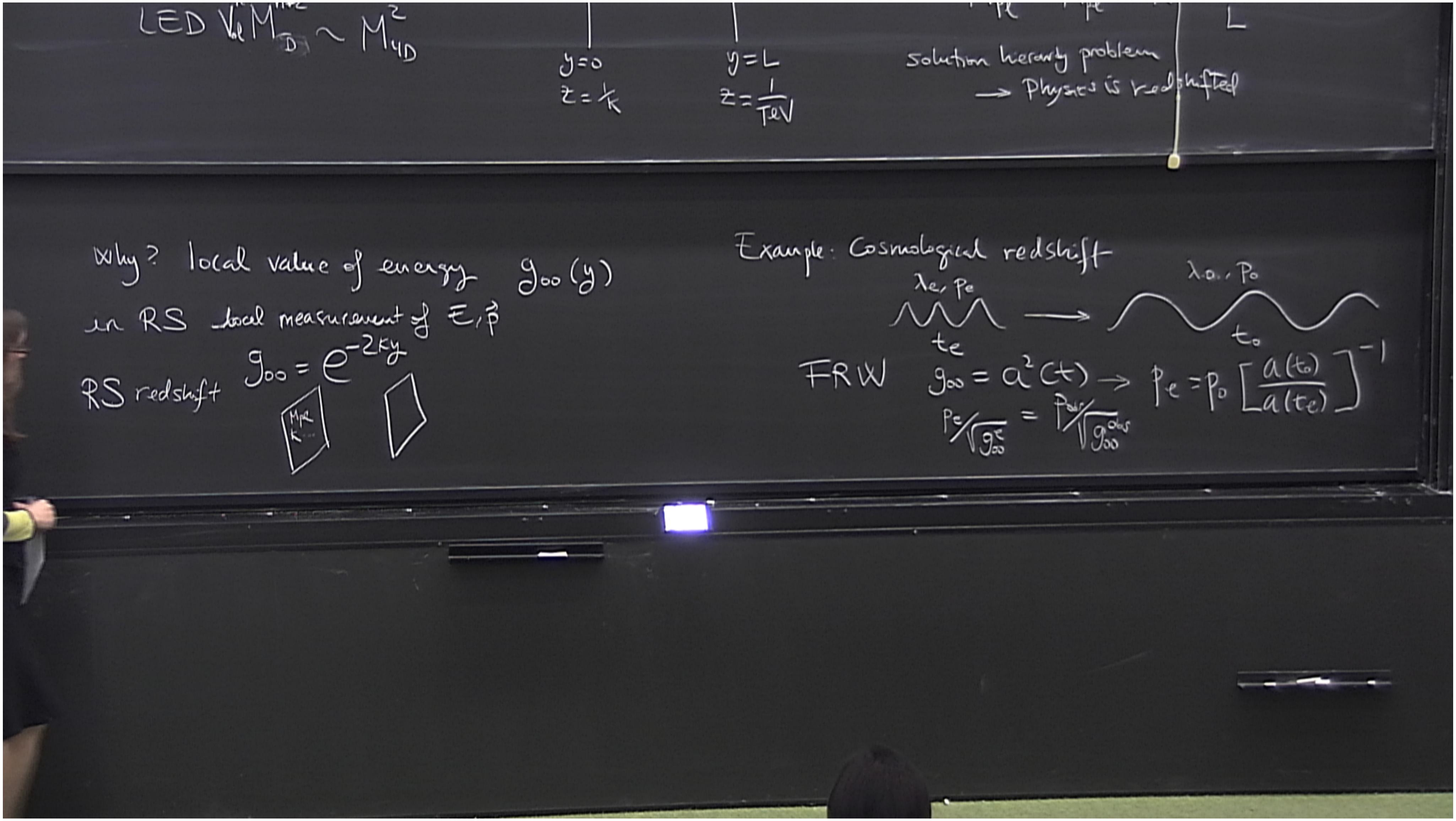

LED $V_{ol} M_D^{...} \sim M_{4D}^2$
$y=0$
$z=1/k$
$y=L$
$z=\frac{1}{TeV}$
Solution hierarchy problem
→ Physics is redshifted
L
Why? local value of energy $g_{00}(y)$
Example: Cosmological redshift
$\lambda_e, p_e$
$t_e$
$\lambda_o, p_o$
$t_o$

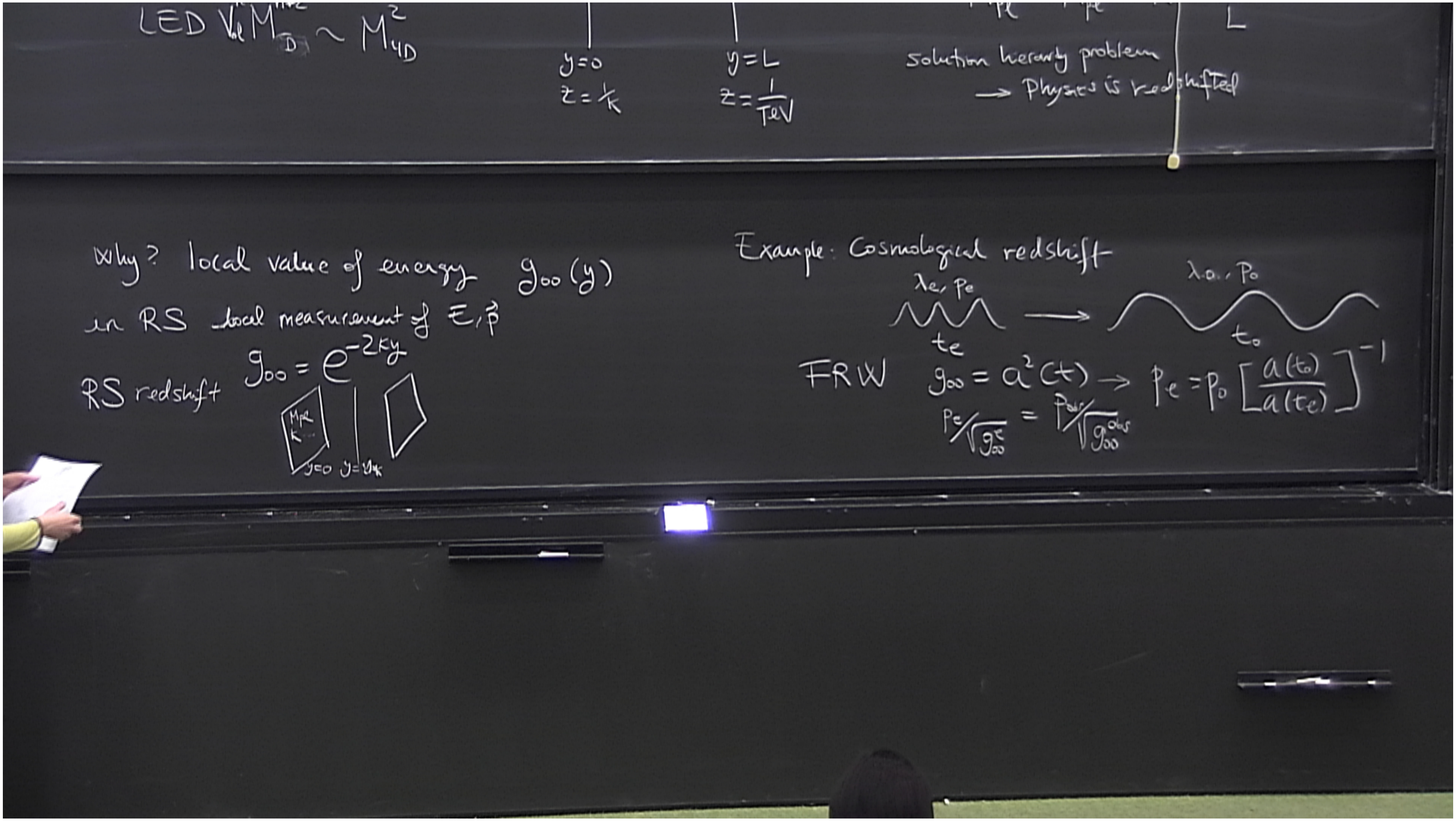

LED V M_D ~ M_4D^2
y=0
z=1/k
y=L
z=1/TeV
Solution herarcy problem
→ Physics is redshifted
L
Why? local value of energy g_00(y)
Example: Cosmological redshift
λe, pe
te
λo, po
to
FRW g_00 = a^2(t) → pe = po [a(to)/a(te)]^-1

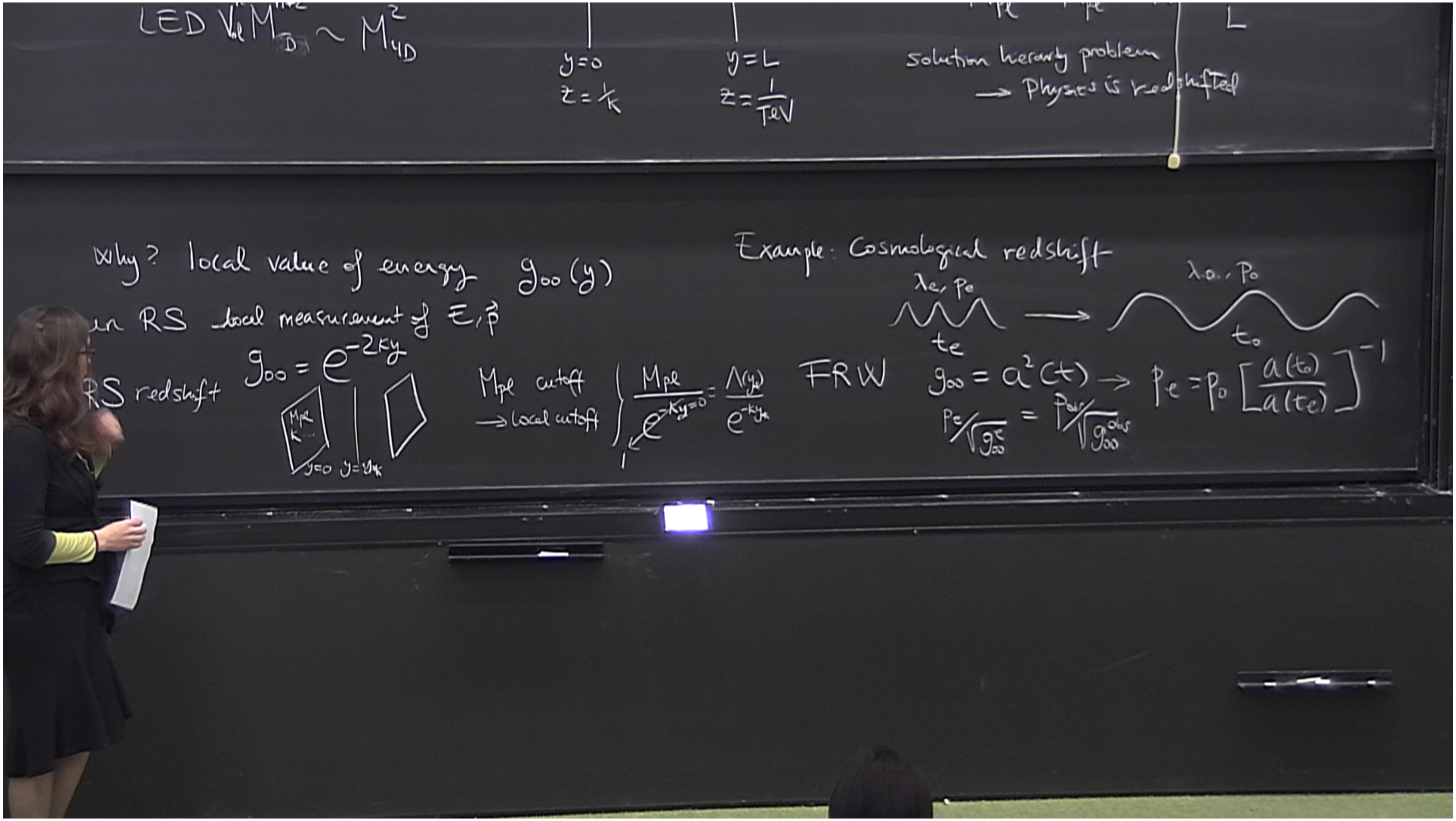

LED
y=0
y=L
L
Solution hierarchy problem
→ Physics is redshifted
Why? local value of energy g00 (y)
RS
Example: Cosmological redshift
λe, pe
λo, po
te
to
FRW g00 = a²(t) → pe = po [a(to)/a(te)]⁻¹

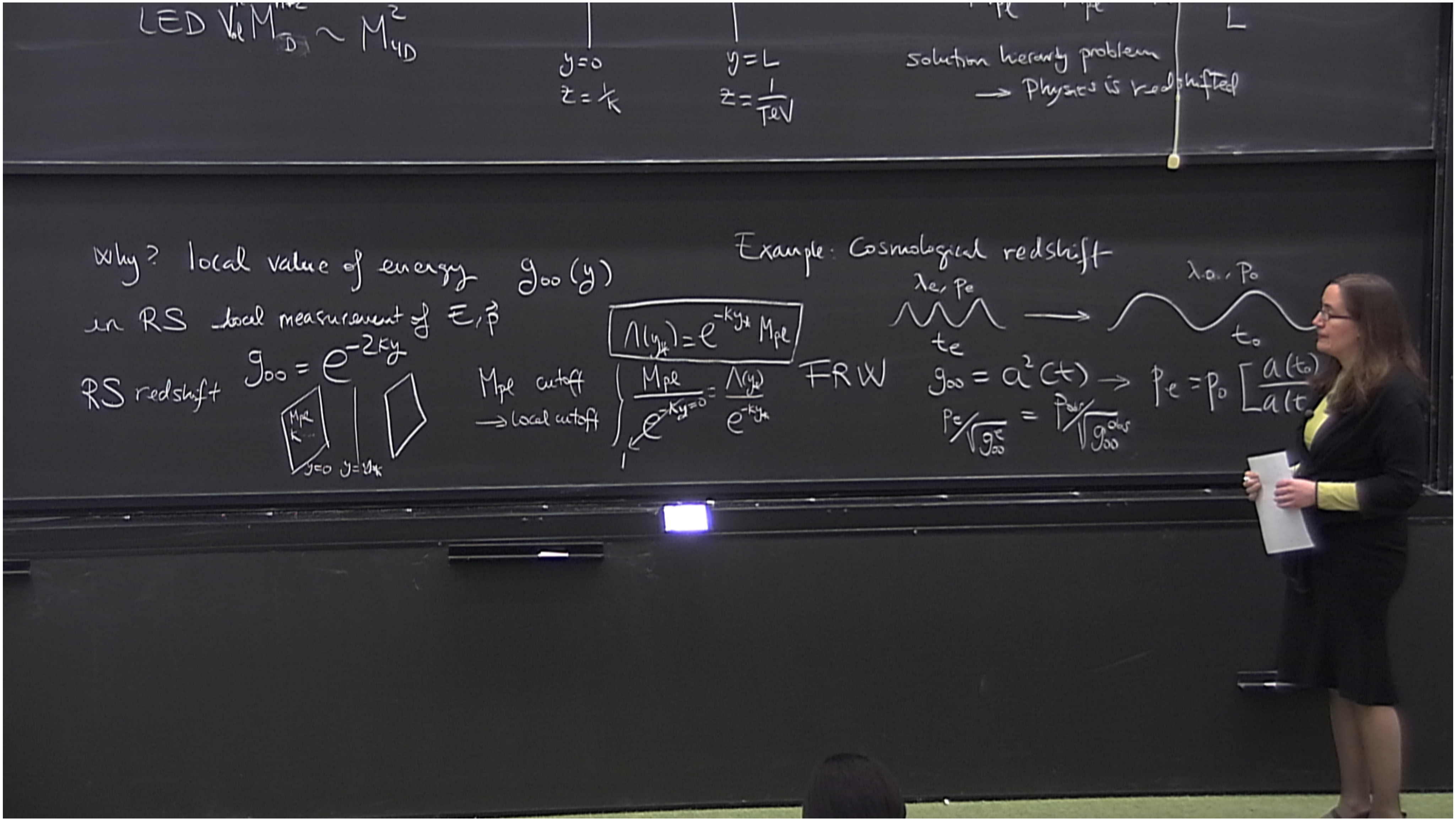

LED V M ~ M_{4D}^2
y=0
z=1/k
y=L
z=1/TeV
Solution hierarchy problem
→ Physics is redshifted
L
Why? local value of energy g_00 (y)
in RS local measurement of E, p
g_00 = e^{-2ky}
Example: Cosmological redshift
λe, pe
te
λo, po
to
FRW g_00 = a^2(t) → pe = po [a(to)/a(te)]^{-1}
pe/√g_00^e = pobs/√g_00^obs

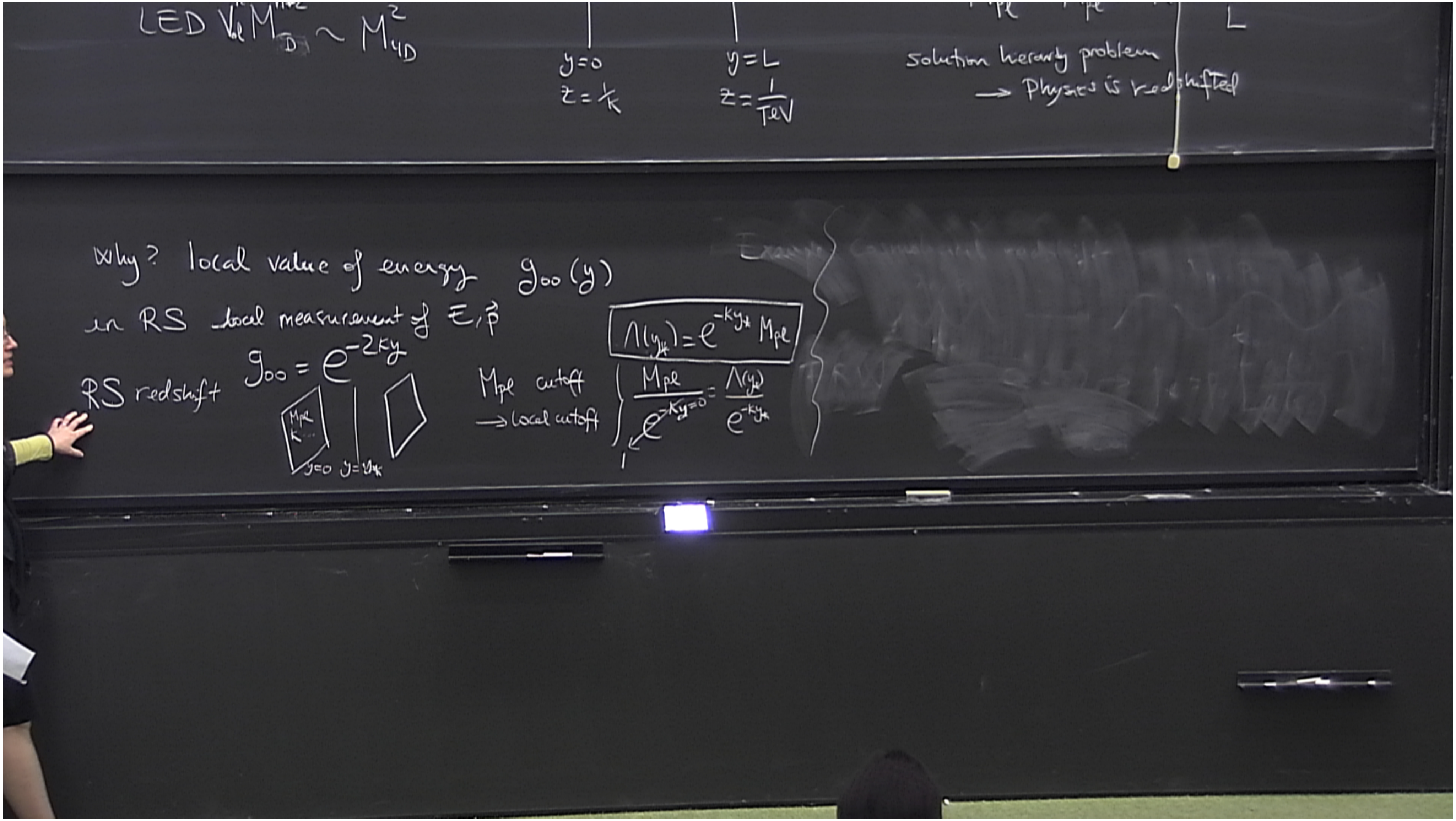

LED
y=0
z=1/k
y=L
z=1/TeV
L
solution hierarchy problem
→ Physics is redshifted
why? local value of energy $g_{00}(y)$
in RS local measurement of $E, \vec{p}$
RS redshift $g_{00} = e^{-2ky}$
Example: Cosmological redshift
$\lambda_e, p_e$
$t_e$
$\lambda_o, p_o$
$t_o$
FRW $g_{00} = a^2(t) \rightarrow p_e = p_o \left[\frac{a(t_o)}{a(t_e)}\right]^{-1}$
$p_e / \sqrt{g_{00}^e} = p_{obs} / \sqrt{g_{00}^{obs}}$

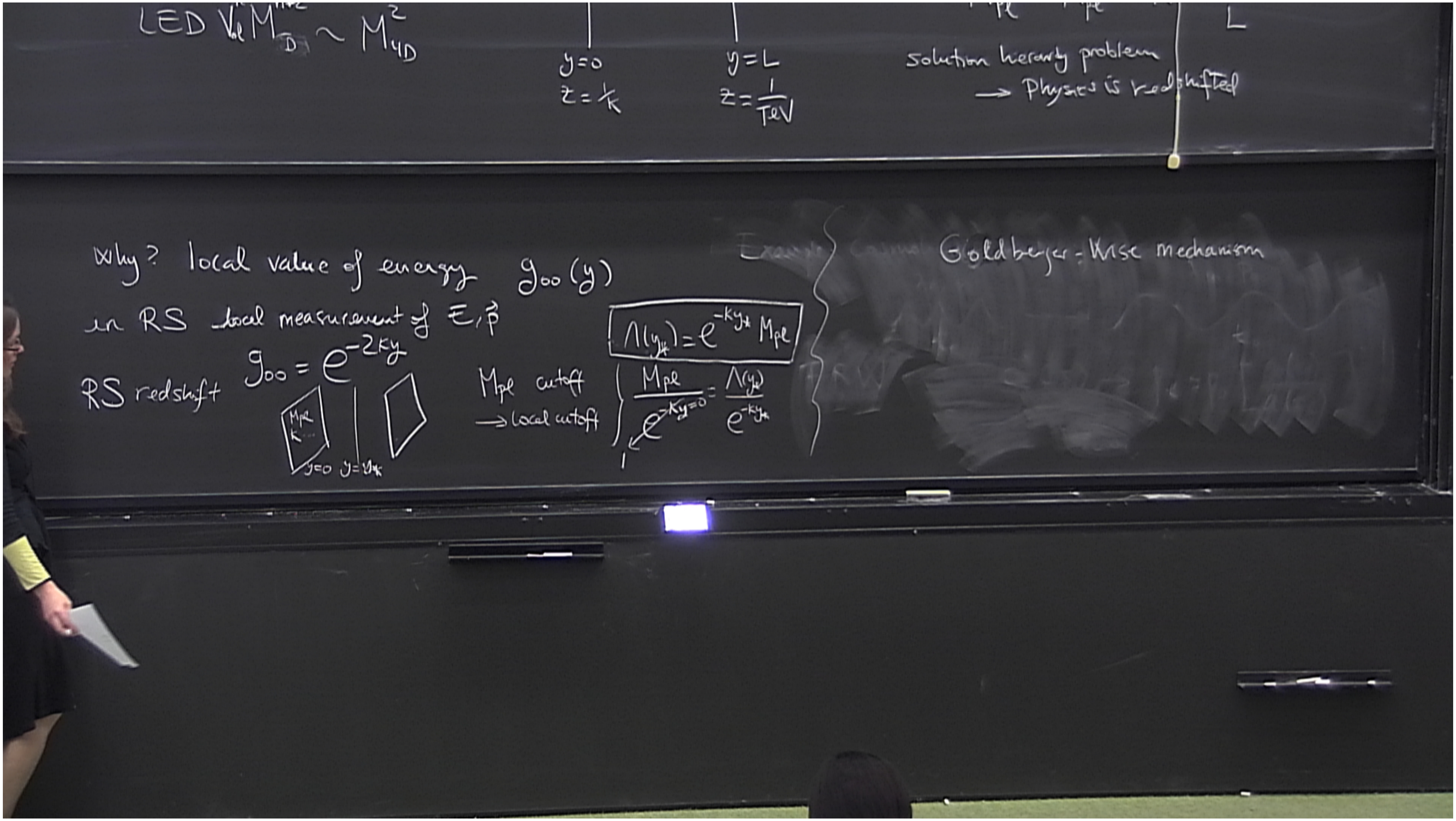

y=0
y=L
Solution hierarchy problem
→ Physics is redshifted
Why? local value of energy $g_{00}(y)$
in RS local measurement of $E, \vec{p}$
RS redshift $g_{00} = e^{-2ky}$
Example: Cosmological redshift
$\lambda_e, p_e$
$\lambda_o, p_o$
$t_e$
$t_o$
FRW $g_{00} = a^2(t) \rightarrow p_e = p_0 \left[\frac{a(t_0)}{a(t_e)}\right]^{-1}$

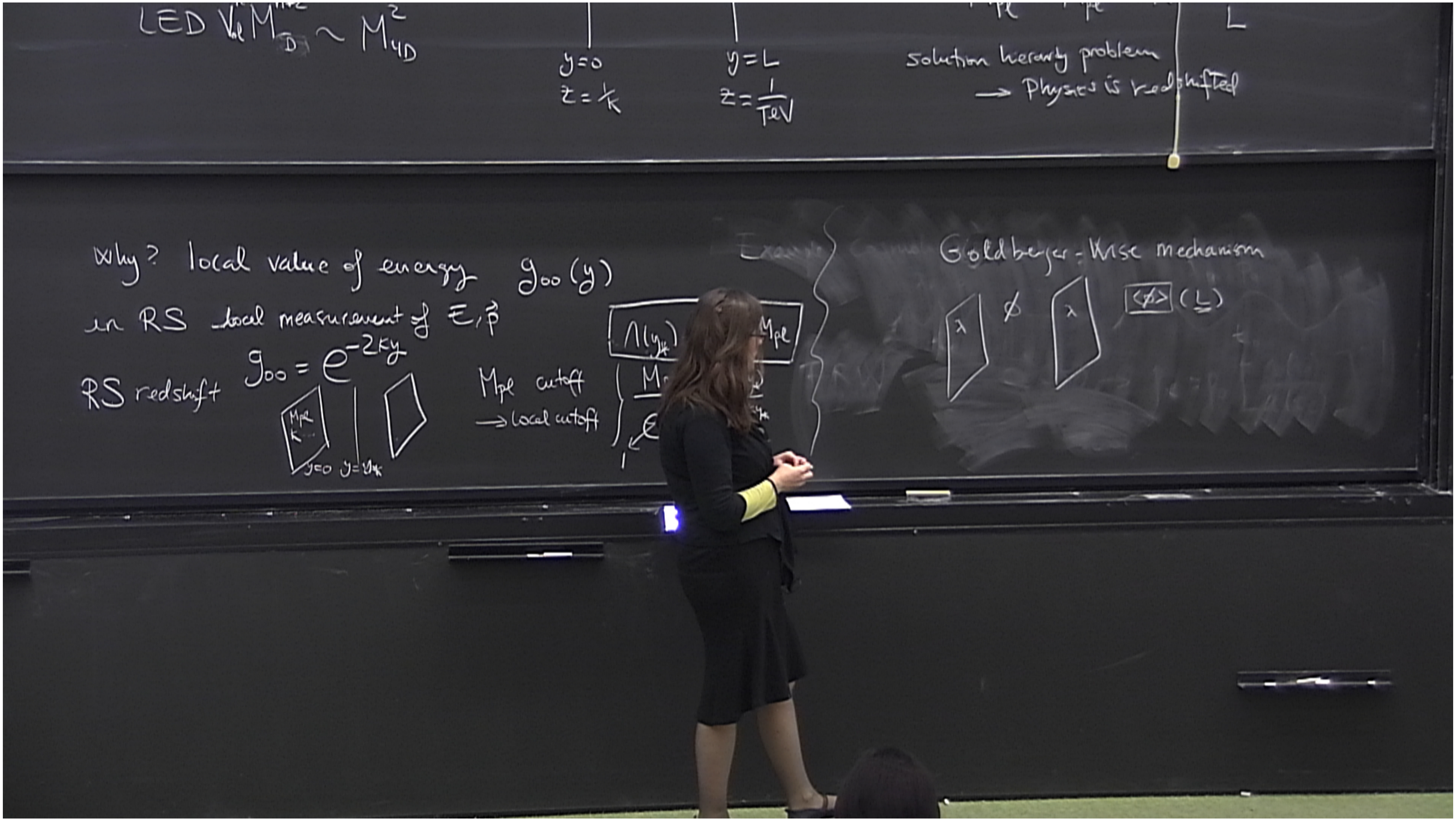

LED
y=0
z=1/k
y=L
z=1/TeV
Solution hierarchy problem
→ Physics is redshifted
Why? local value of energy g00(y)
in RS local measurement of E, p
RS redshift g00 = e^-2ky
y=0 y=y_k
Example: Cosmological redshift
λe, pe
te
λo, po
to
FRW g00 = a²(t) → pe = po [a(to)/a(te)]^-1
pe/√g00^e = pobs/√g00^obs


LED
y=0
z = 1/k
y = L
z = 1/TeV
Solution hierarchy problem
→ Physics is redshifted
Why? local value of energy g00 (y)
in RS local measurement of E, p
RS redshift g00 = e^-2ky
Mpl cutoff
→ local cutoff
Example: Cosmological redshift
λe, pe
te
λo, po
to
FRW g00 = a²(t) → pe = po [a(to)/a(te)]^-1

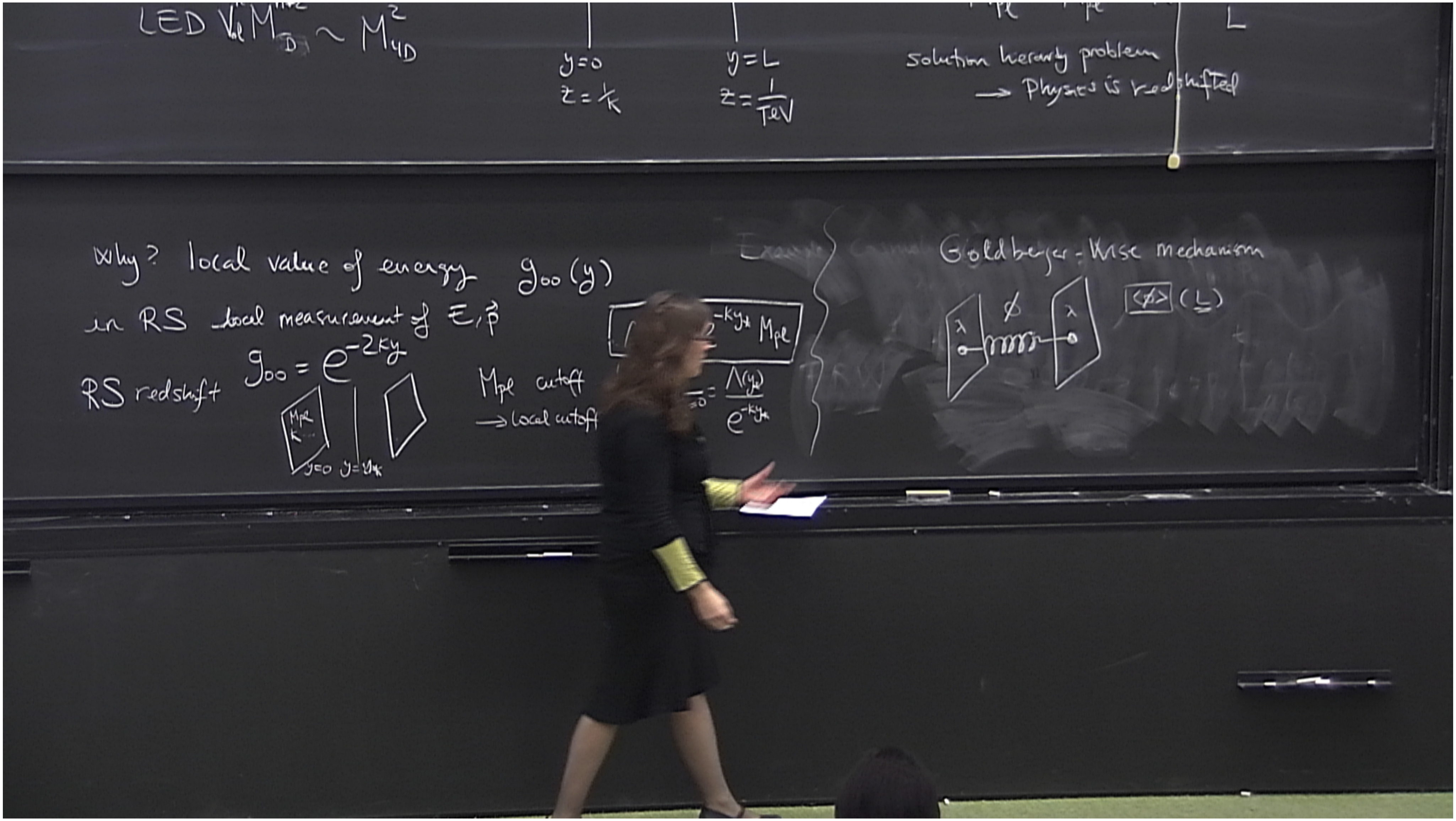

LED
y=0
y=L
z=1/k
z=1/TeV
solution hierarchy problem
→ Physics is redshifted
Why? local value of energy g00 (y)
in RS local measurement of E, p
RS redshift
Mpl cutoff
→ local cutoff
Example: Cosmological redshift
FRW


LED $V_{d} M_{D}^{n+2} \sim M_{4D}^{2}$
y=0
z=1/k
y=L
z=1/TeV
Solution hierarchy problem
→ Physics is redshifted
Why? local value of energy $g_{00}(y)$
in RS local measurement of $E, \vec{p}$
RS redshift $g_{00} = e^{-2ky}$
$M_{pl}$
k
y=0
$y=y_*$
$M_{pl}$ cutoff
→ local cutoff
$\Lambda(y_*) = e^{-ky_*} M_{pl}$
$\frac{M_{pl}}{e^{-ky=0}} = \frac{\Lambda(y_*)}{e^{-ky_*}}$
1

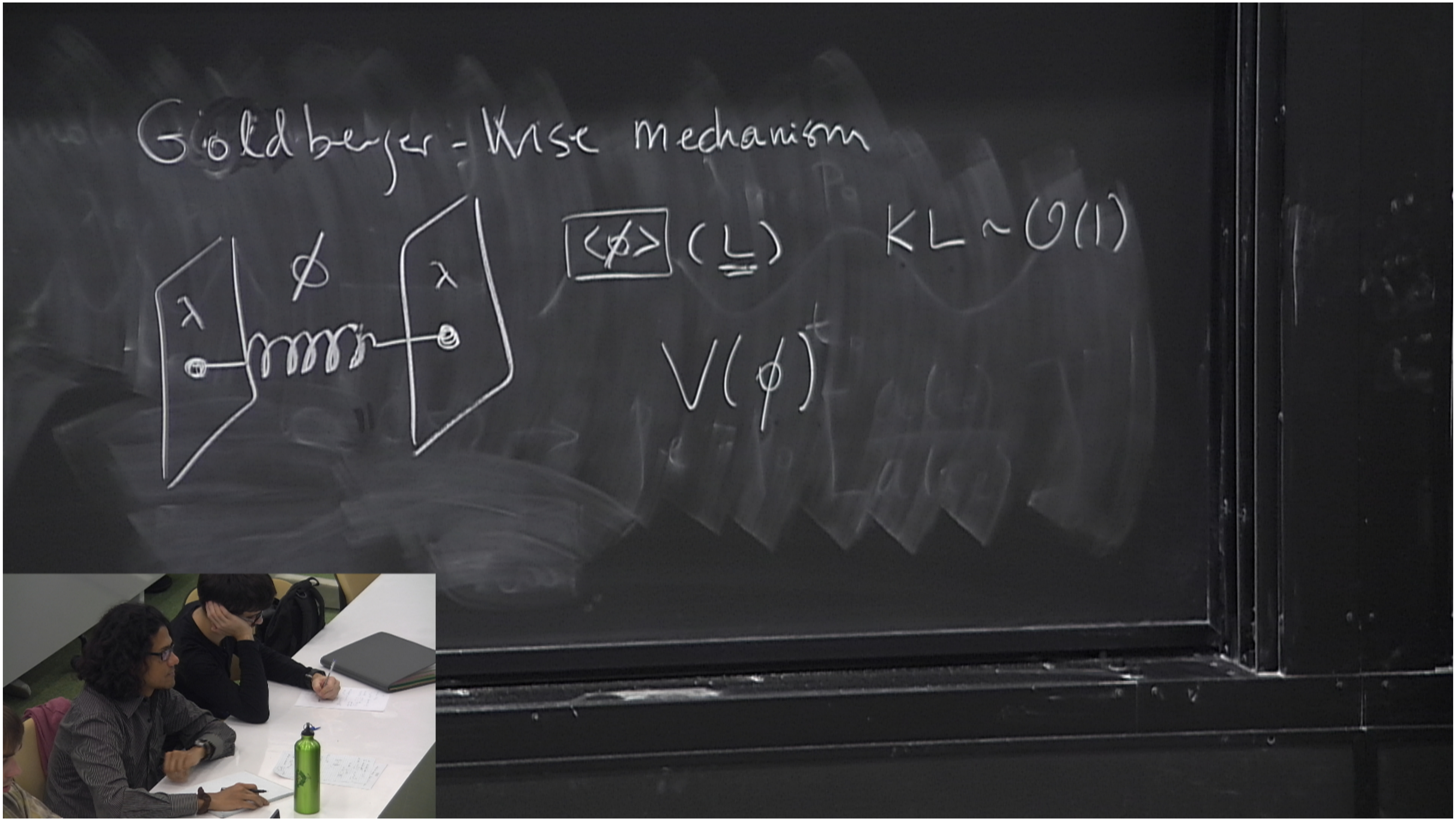

LED
y=0
z = 1/k
y=L
z = 1/TeV
Solution hierarchy problem
→ Physics is redshifted
L
Why? local value of energy $g_{00}(y)$
in RS local measurement of E, p
RS redshift $g_{00} = e^{-2ky}$
Mpl
k
y=0
Mpl cutoff
→ local cutoff
$\Lambda(y_*) = e^{-ky_*} M_{pl}$
Goldberger - Wise mechanism

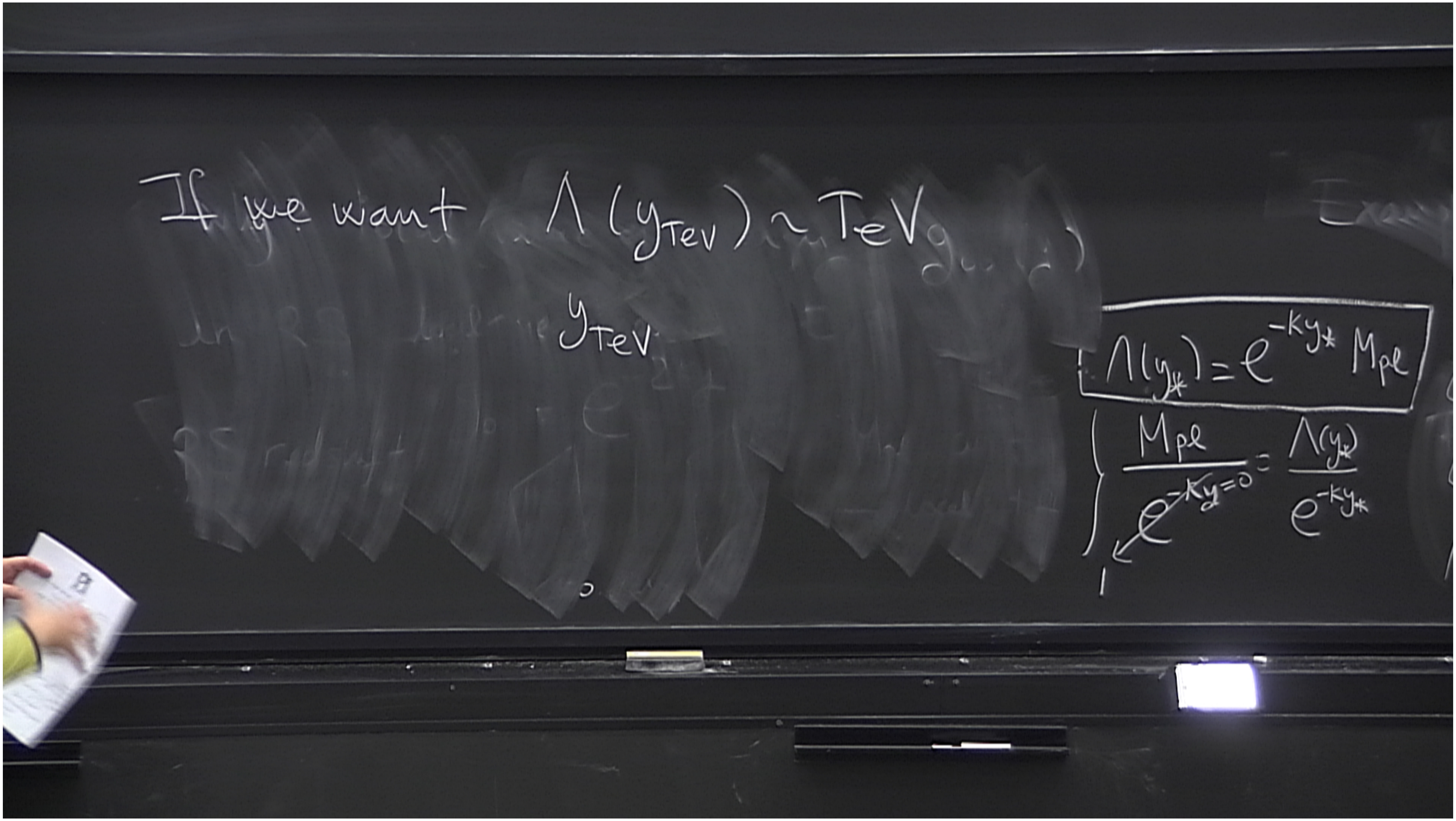


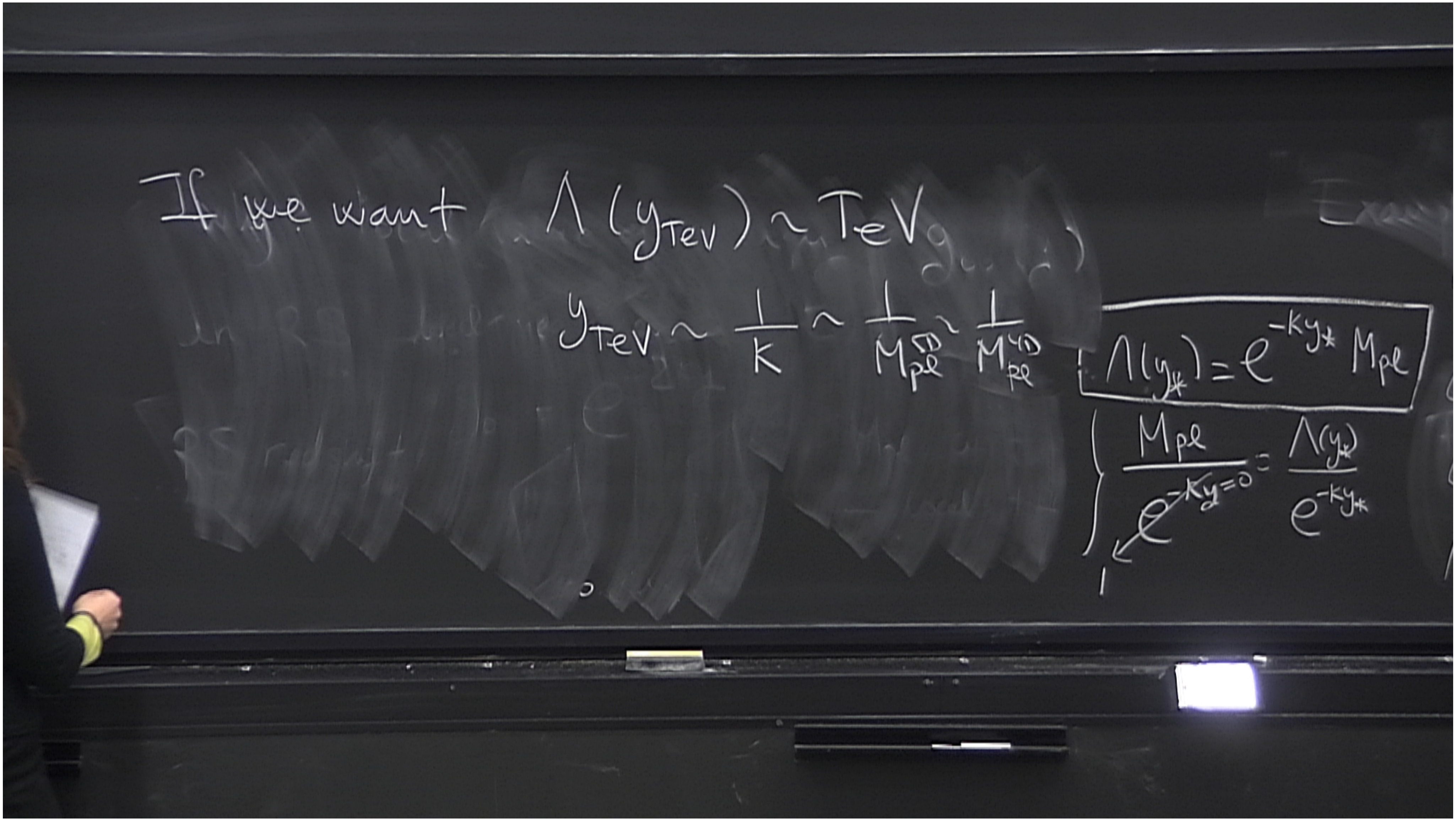
y=0
z = 1/k
y=L
z = 1/TeV
solution hierarchy problem
→ Physics is redshifted
Why? local value of energy g00(y)
in RS local measurement of E, p
RS redshift g00 = e^{-2ky}
y=0 y=y_k
Mpl cutoff
→ local cutoff
Λ(y_k)
Mpl
Goldberger-Wise mechanism
λ
φ
λ
<φ>(L)

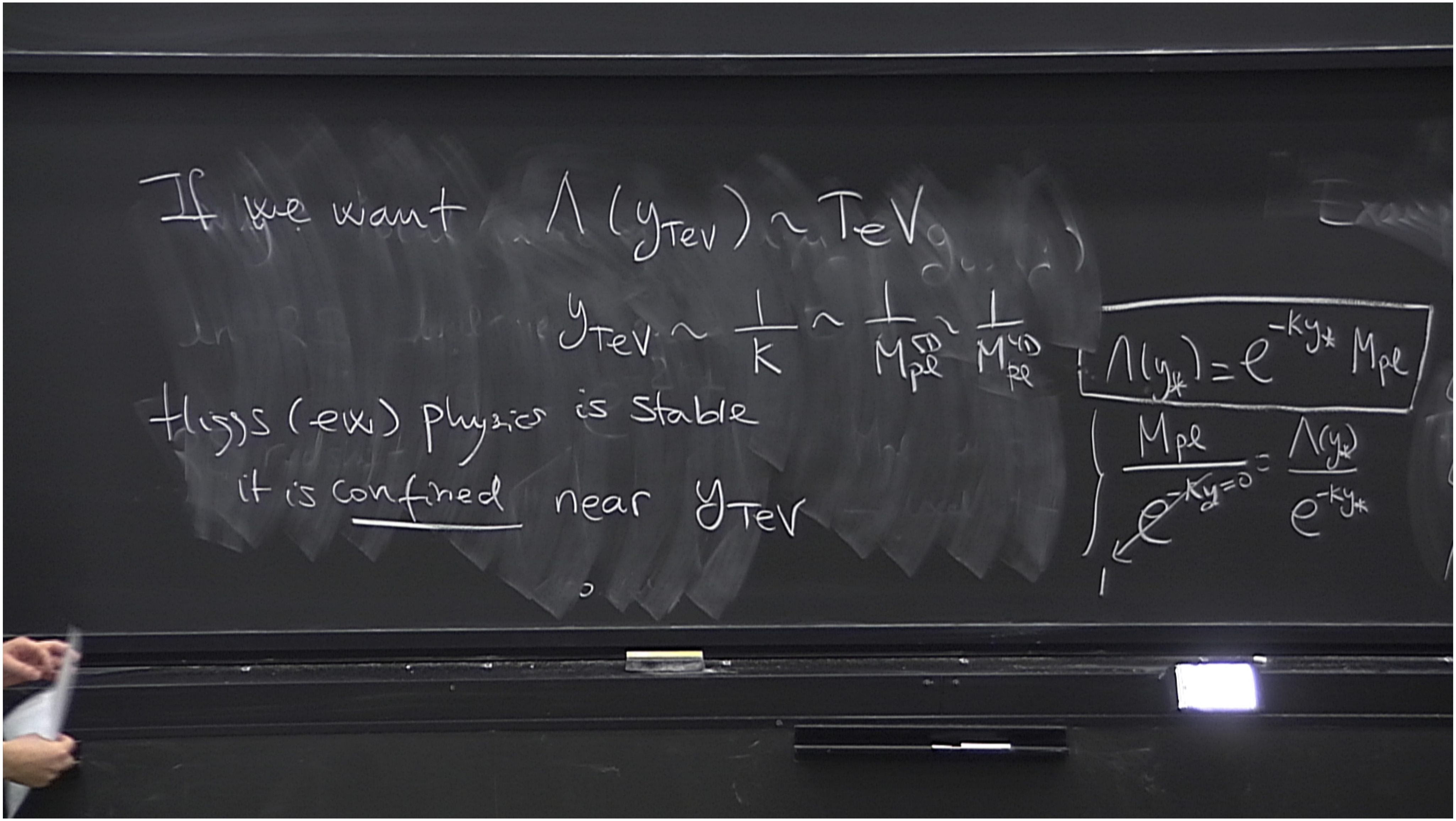


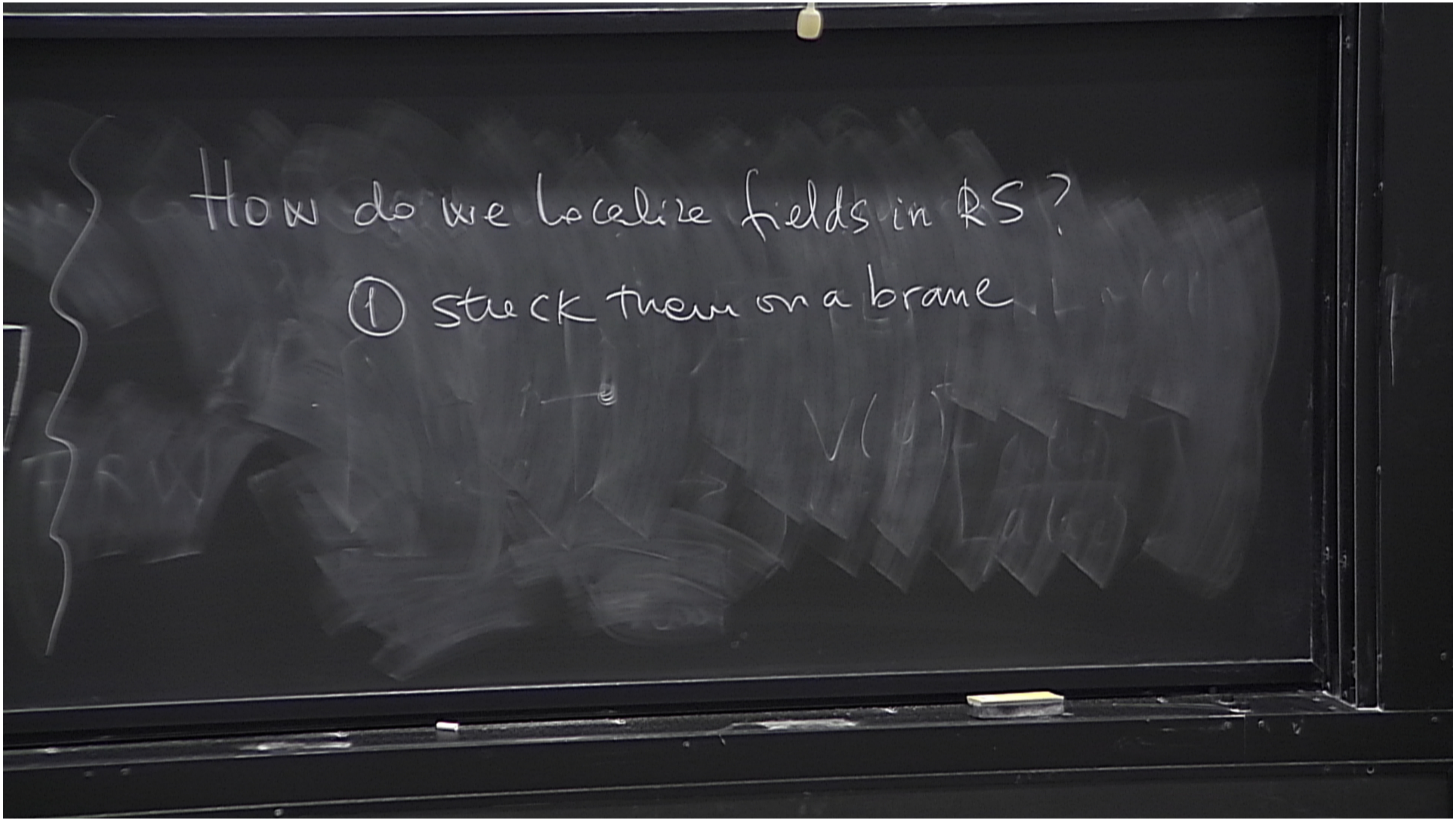
Solution herarchy problem
→ Physics is redshifted
Why? local value of energy $g_{00}(y)$
in RS local measurement of $E, \vec{p}$
RS redshift $g_{00} = e^{-2ky}$
$M_{pl}$ cutoff
→ Local cutoff
Goldberger - Wise mechanism

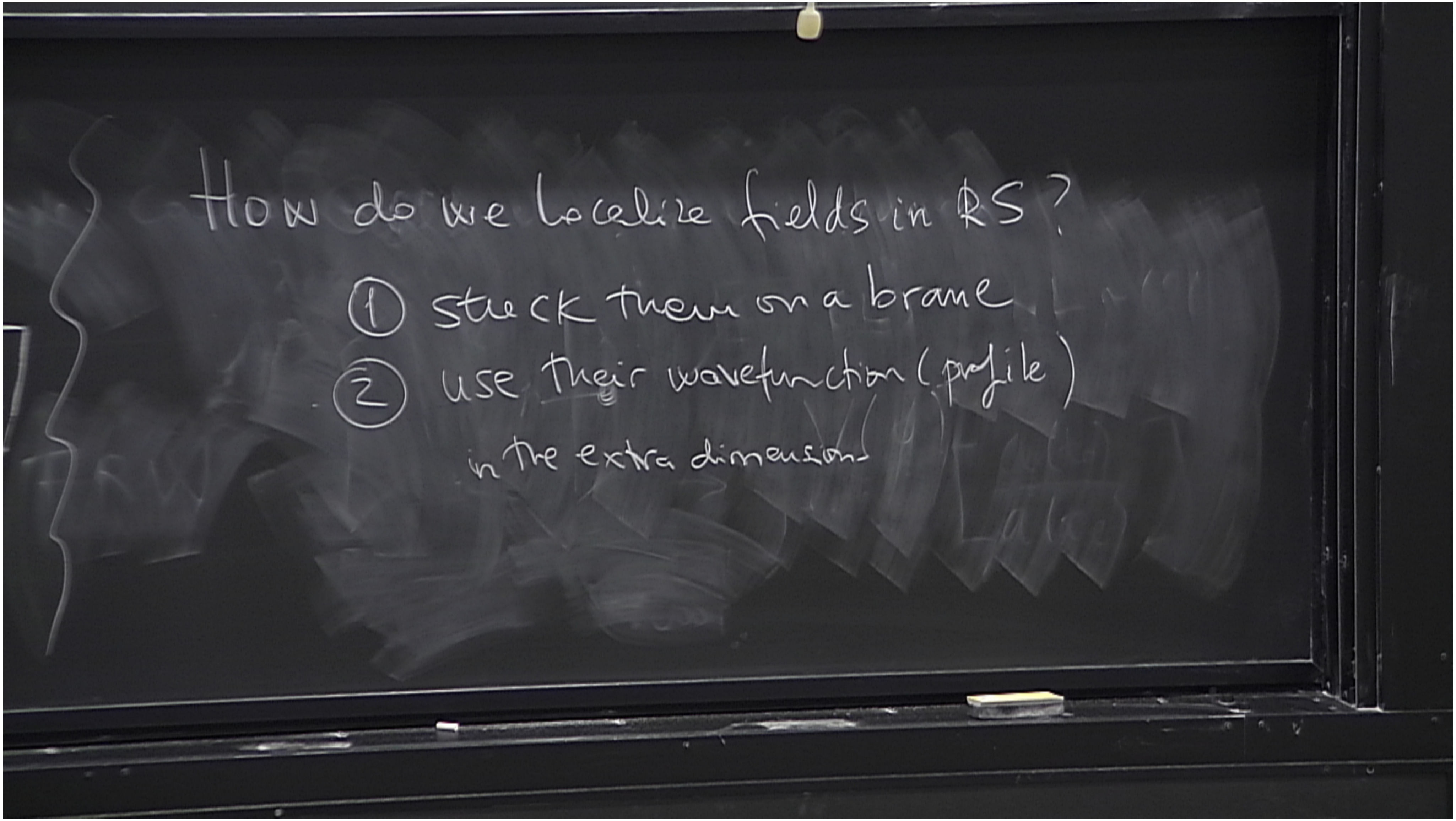

Goldberger-Wise mechanism
λ
ϕ
λ
⟨ϕ⟩ (L)
KL ~ O(1)
V(ϕ)

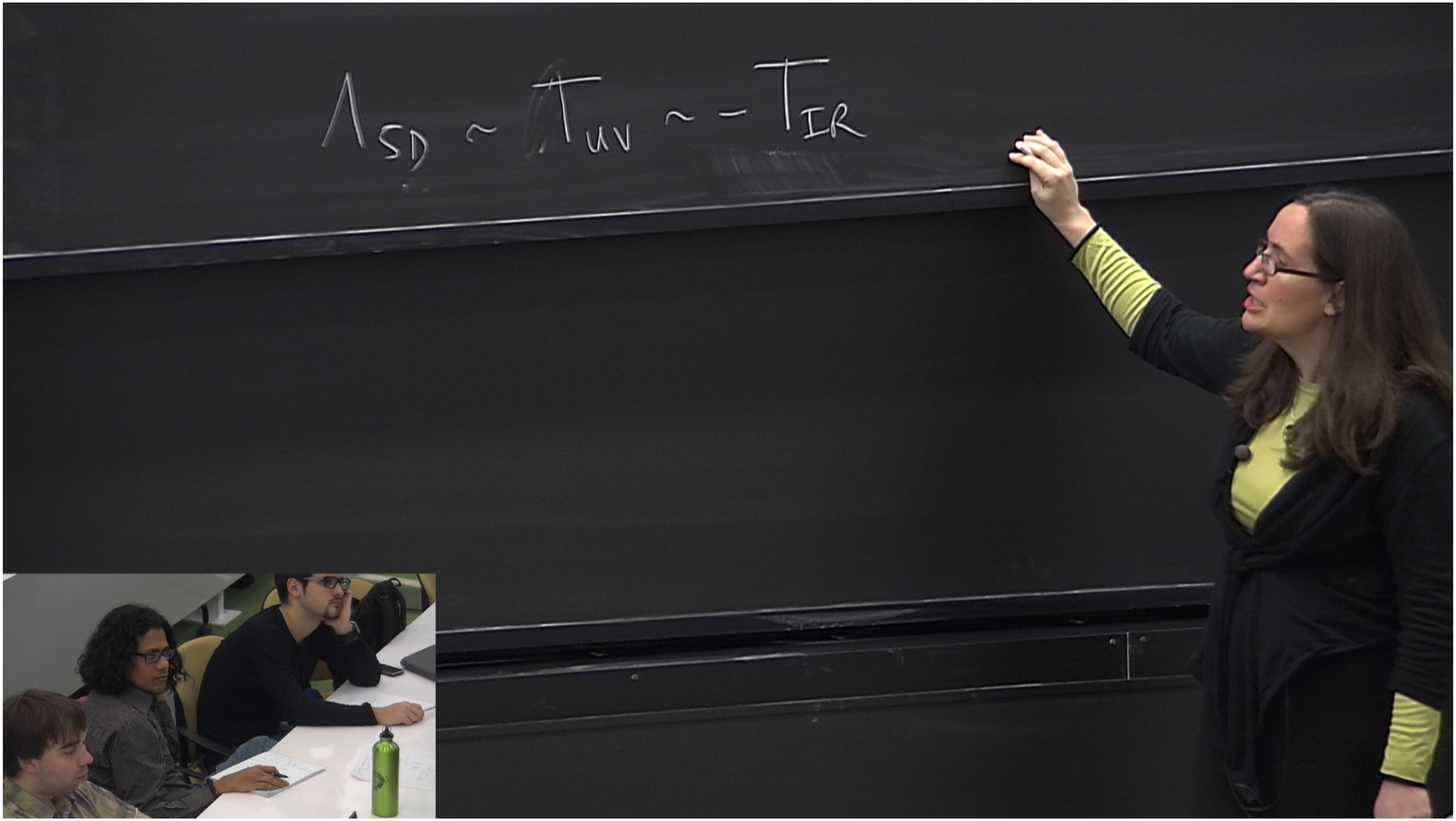

If we want Λ(y_TeV) ~ TeV
y_TeV
Λ(y_*) = e^{-ky_*} M_pl
M_pl / e^{-ky=0} = Λ(y_*) / e^{-ky_*}

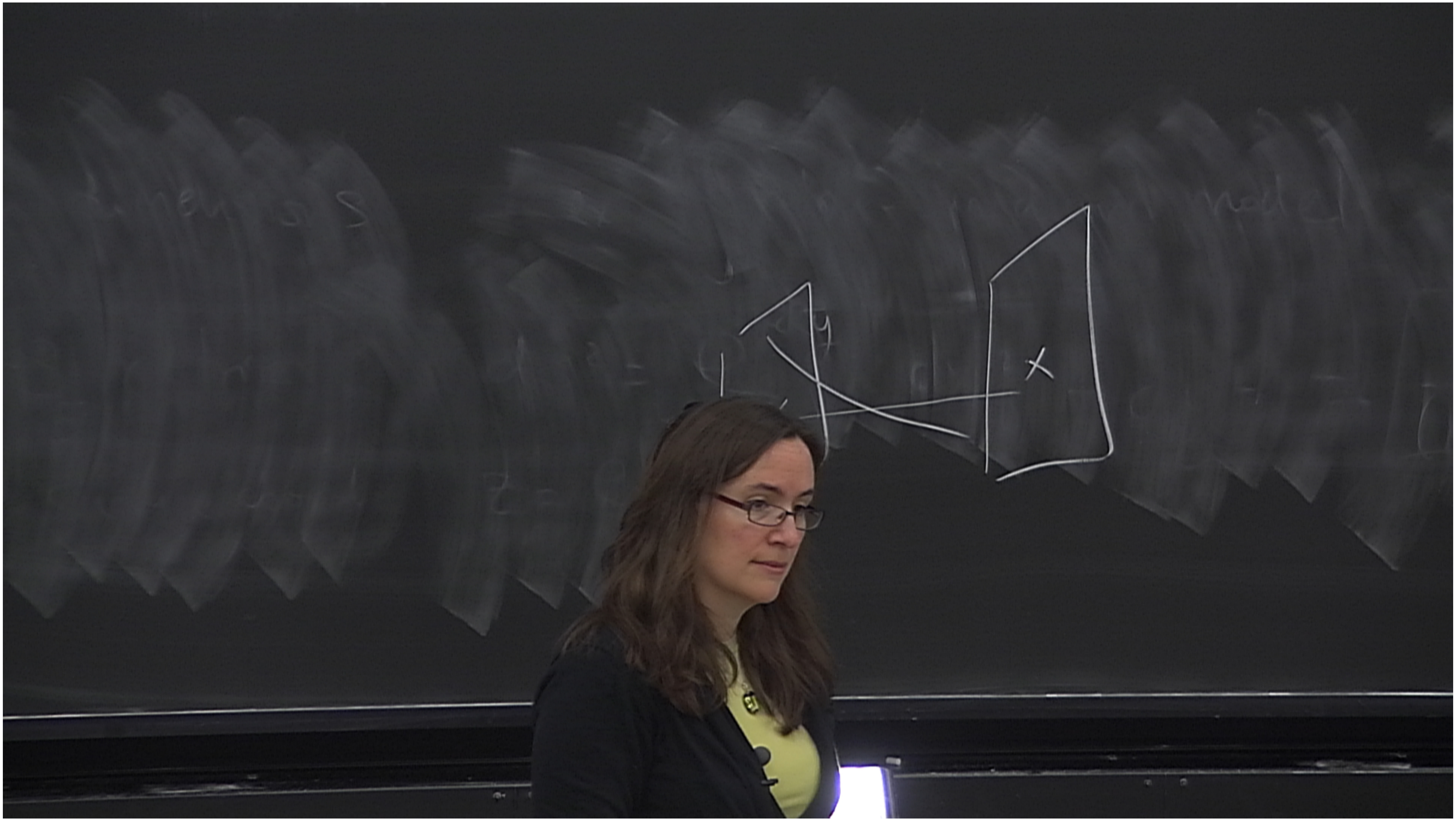

If we want Λ(y_TeV) ~ TeV
y_TeV ~ 1/k ~ 1/M_pl^(5D) ~ 1/M_pl^(4D)
Λ(y*) = e^(-ky*) M_pl
M_pl / e^(-ky=0) = Λ(y*) / e^(-ky*)
1

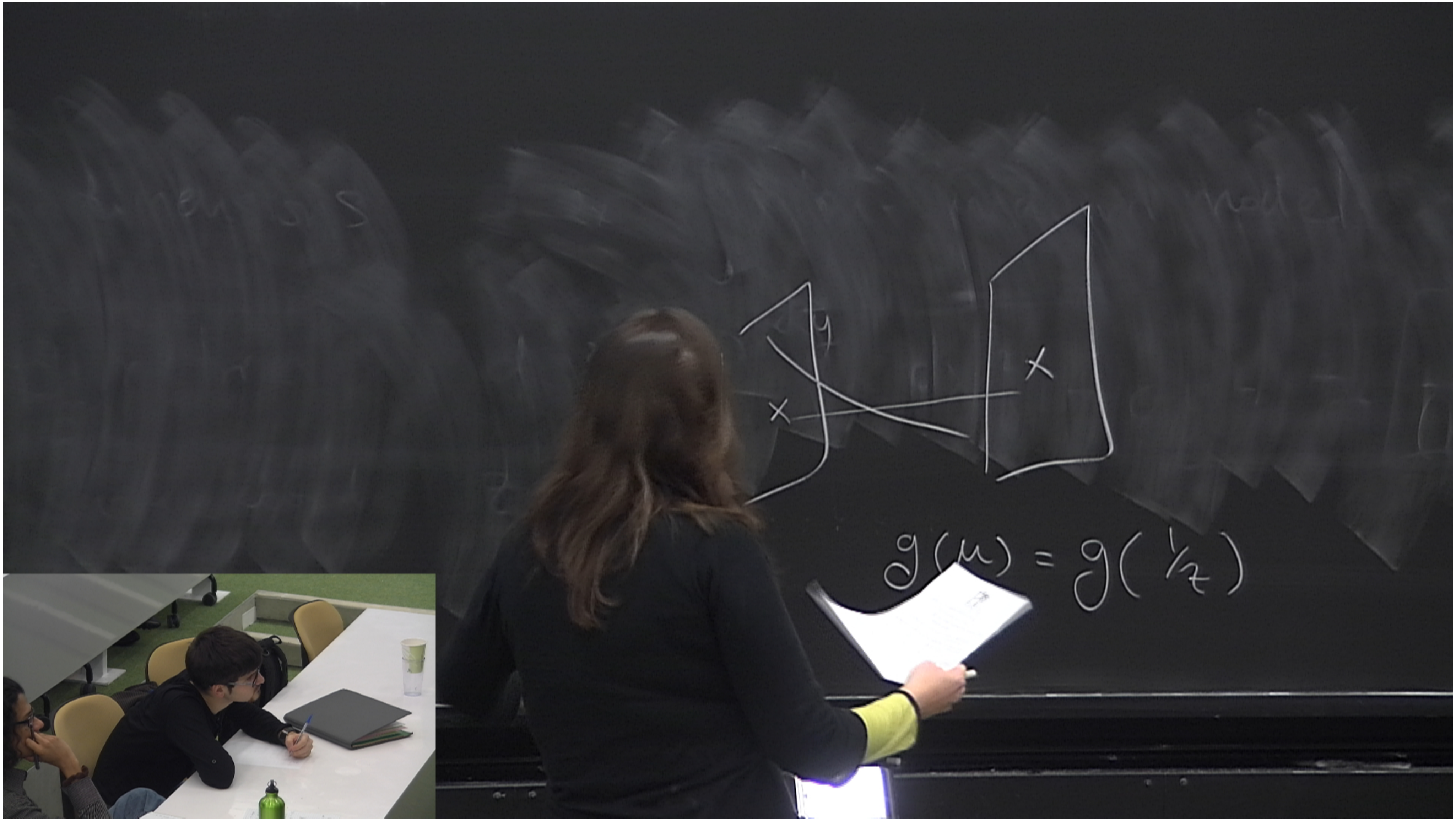

If we want Λ(y_TeV) ~ TeV
y_TeV ~ 1/K ~ 1/M_pl^(5D) ~ 1/M_pl^(4D)
Higgs (ew) physics is stable
it is confined near y_TeV
Λ(y_*) = e^(-ky_*) M_pl
M_pl / e^(-ky=0) = Λ(y_*) / e^(-ky_*)

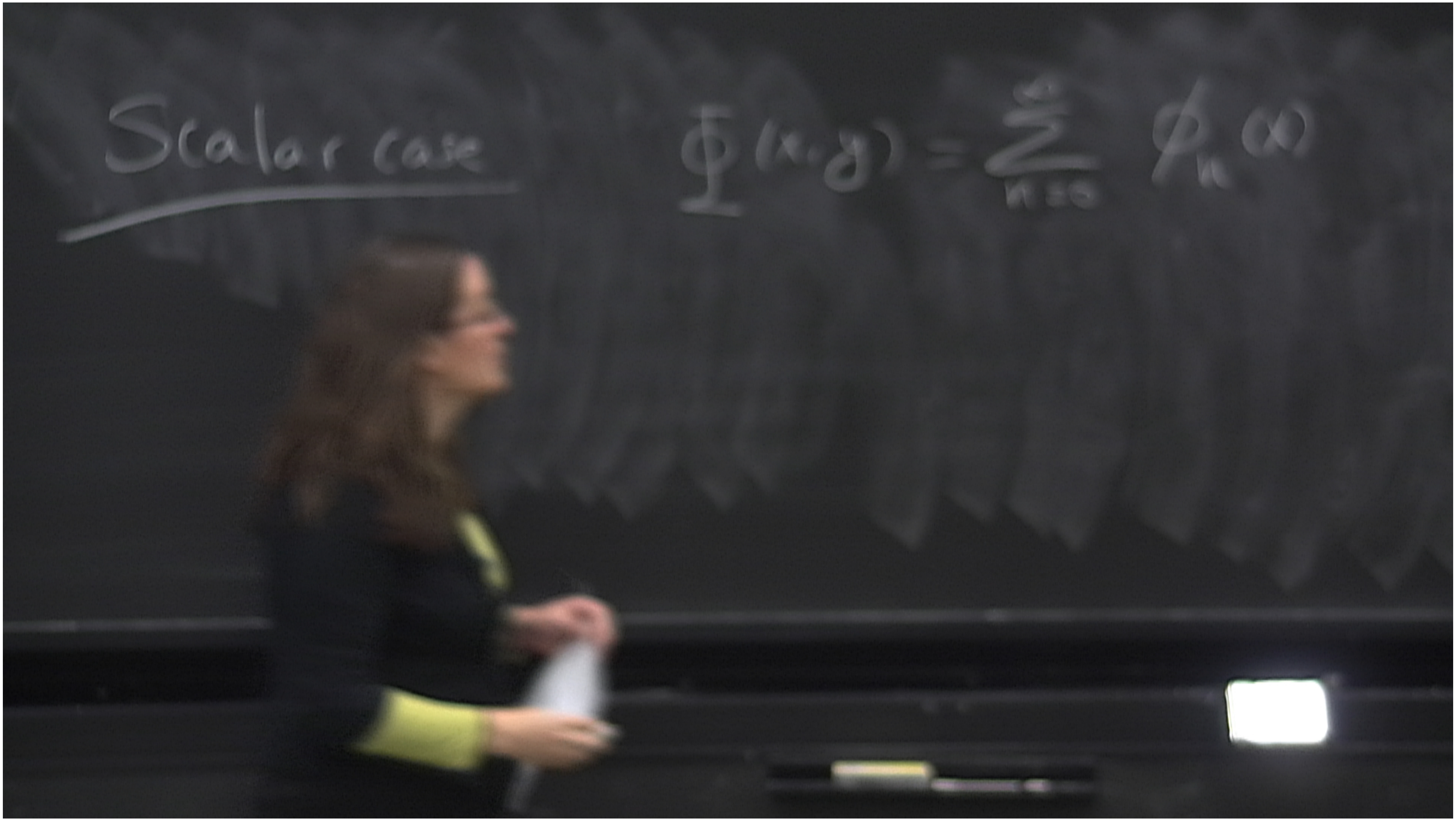

How do we localize fields in RS?
① stick them on a brane

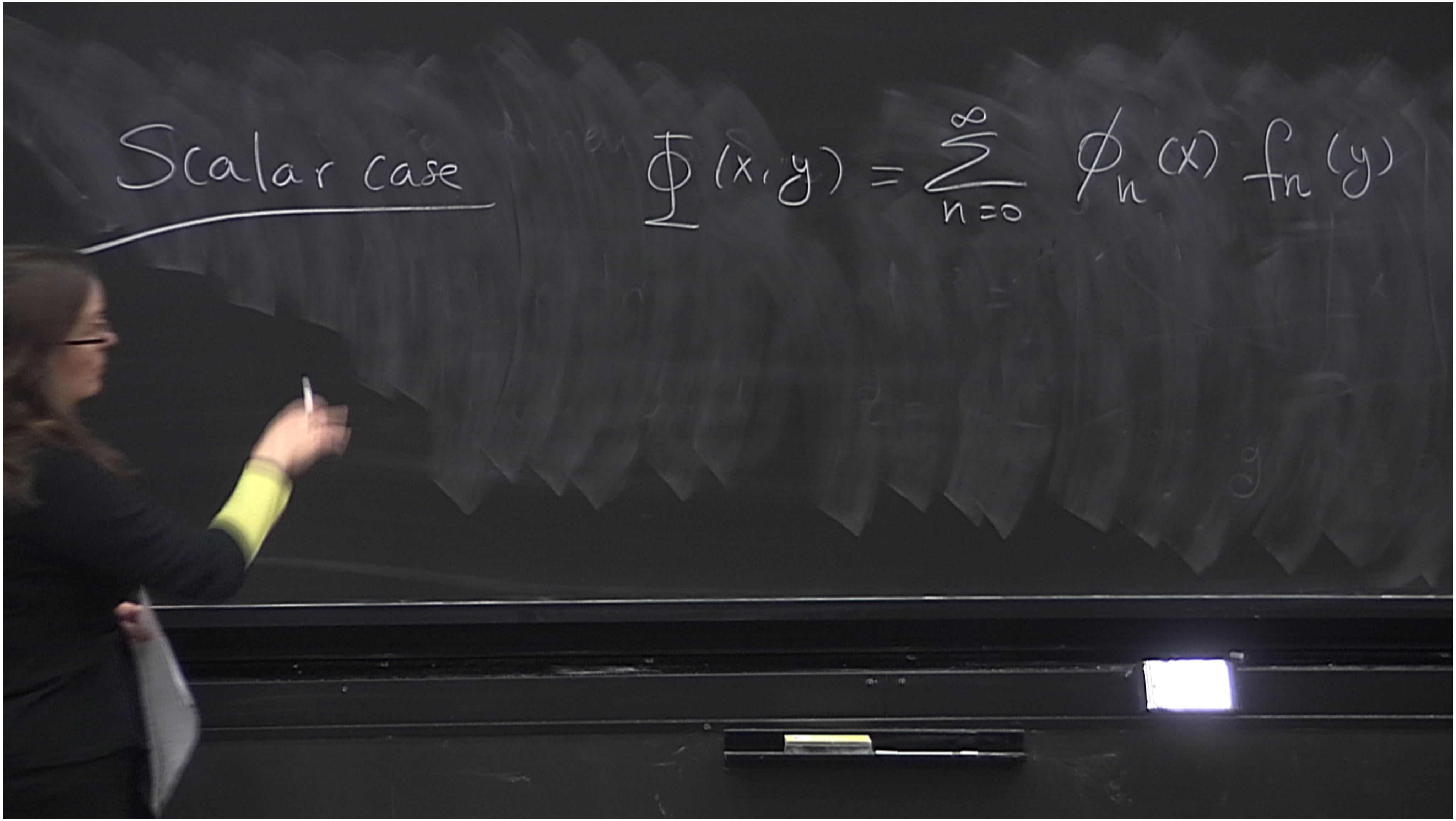

How do we localize fields in RS?
① stuck them on a brane
② use their wavefunction (profile)
in the extra dimension

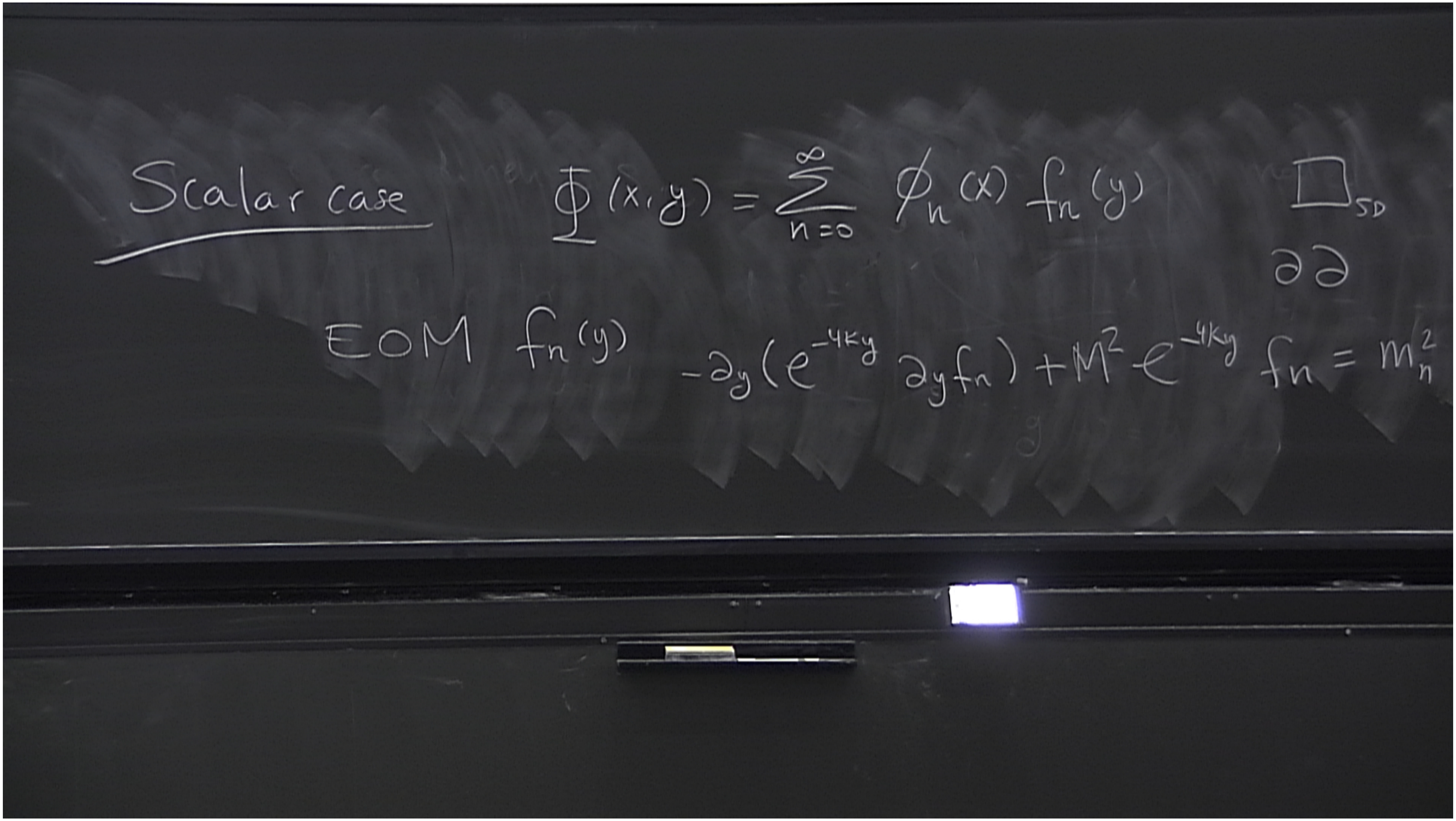

$\Lambda_{SD} \sim T_{UV} \sim -T_{IR}$

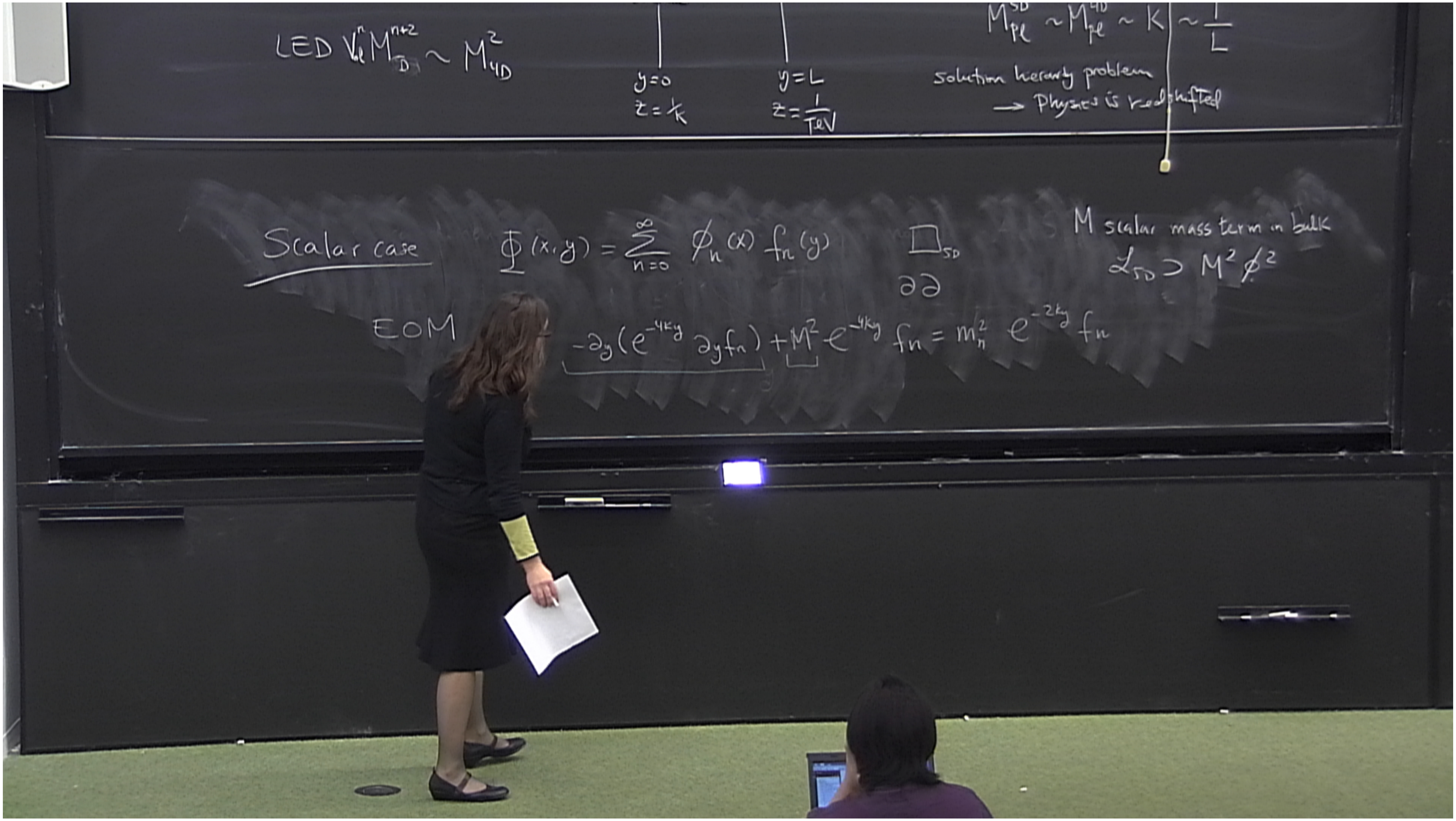


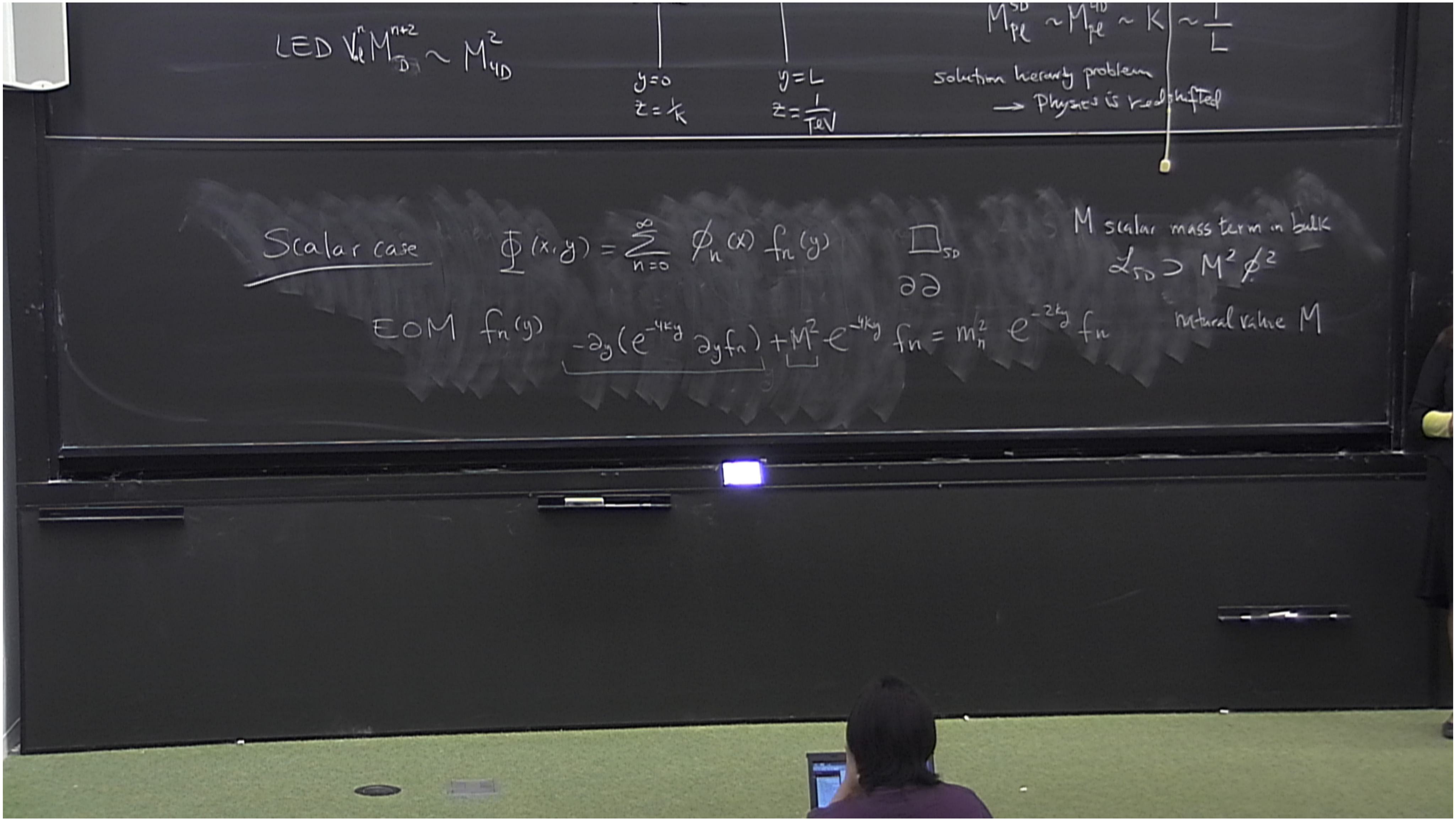

g(μ) = g(1/z)

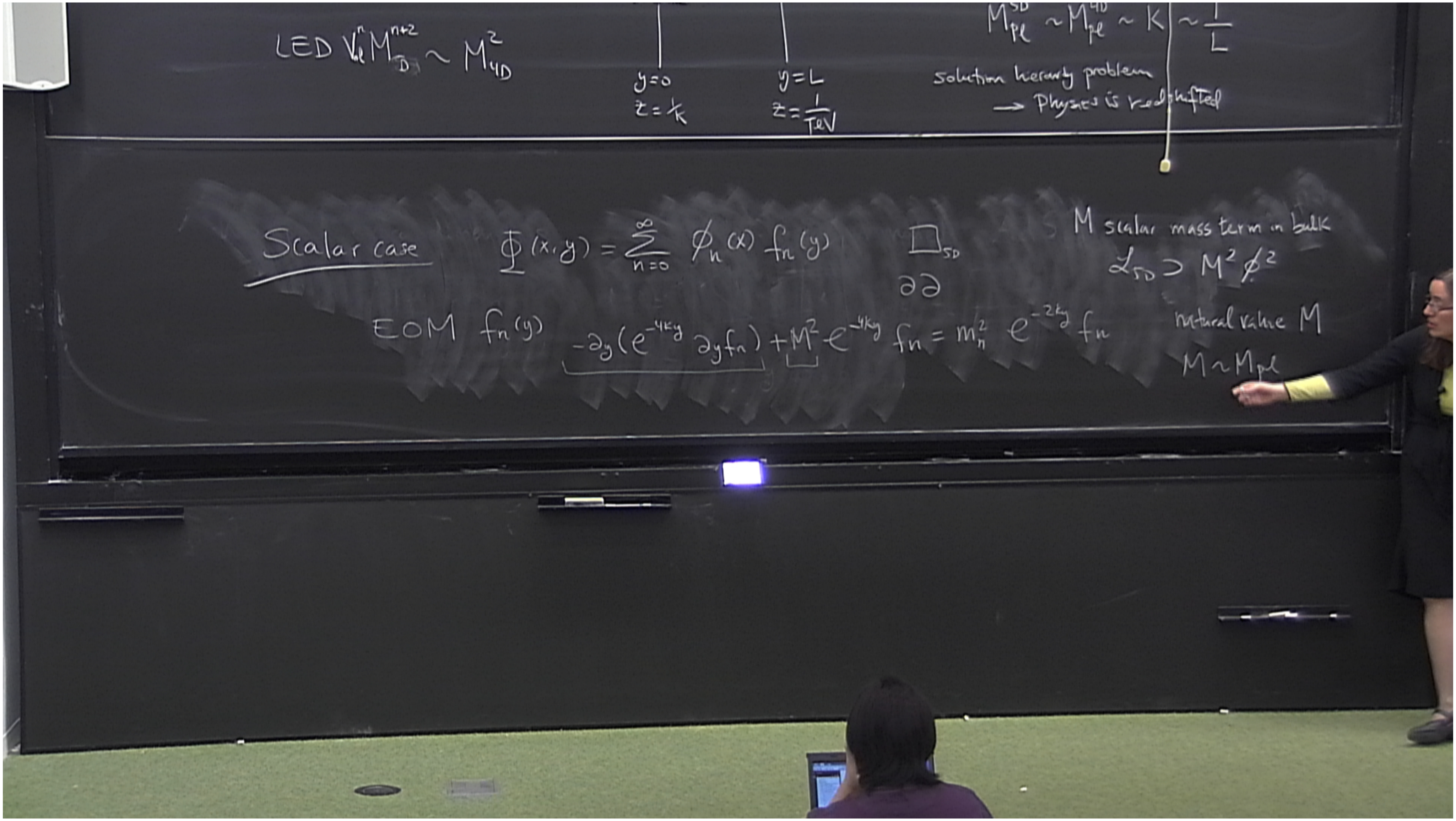

Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x)$

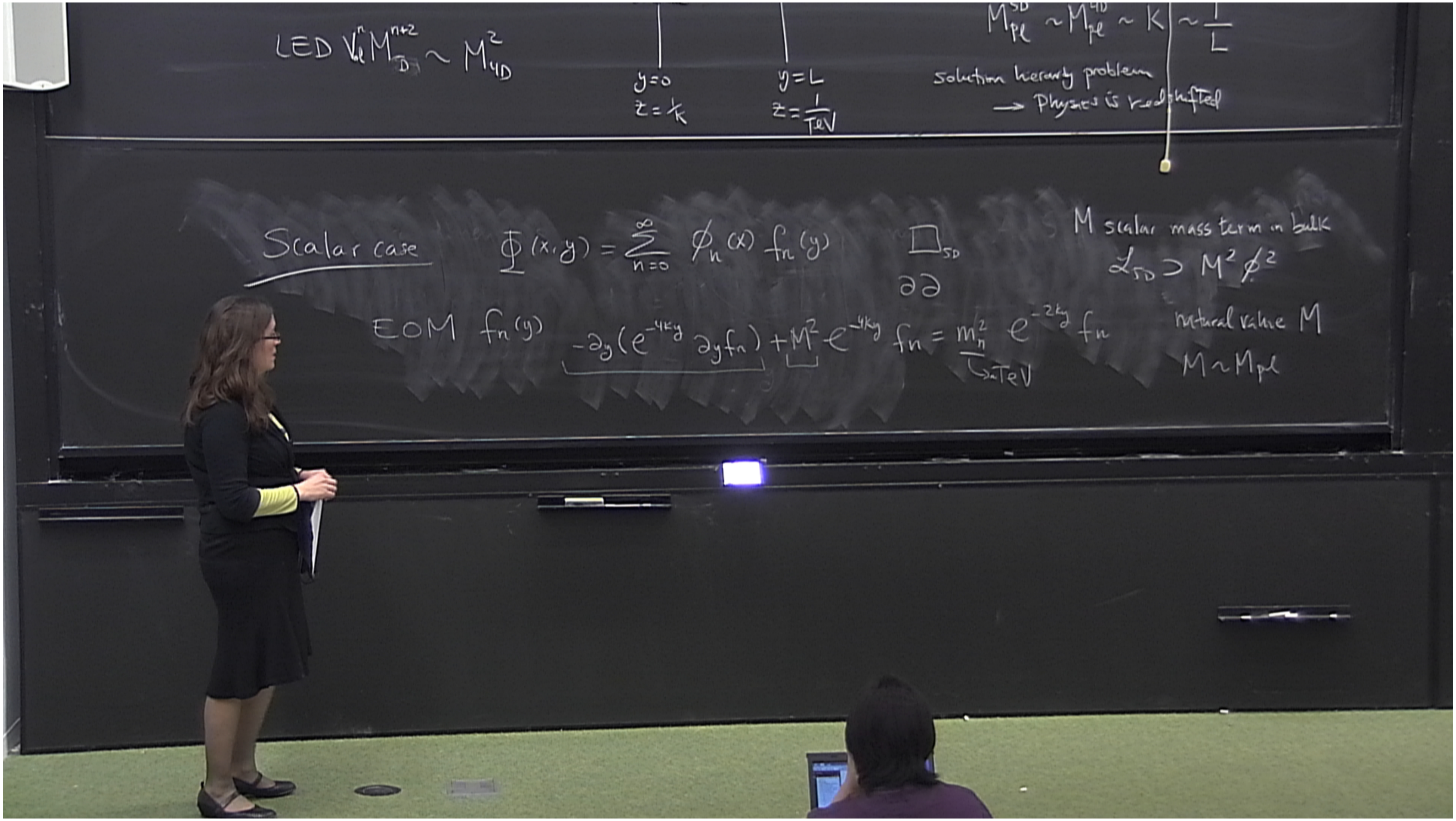

Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$

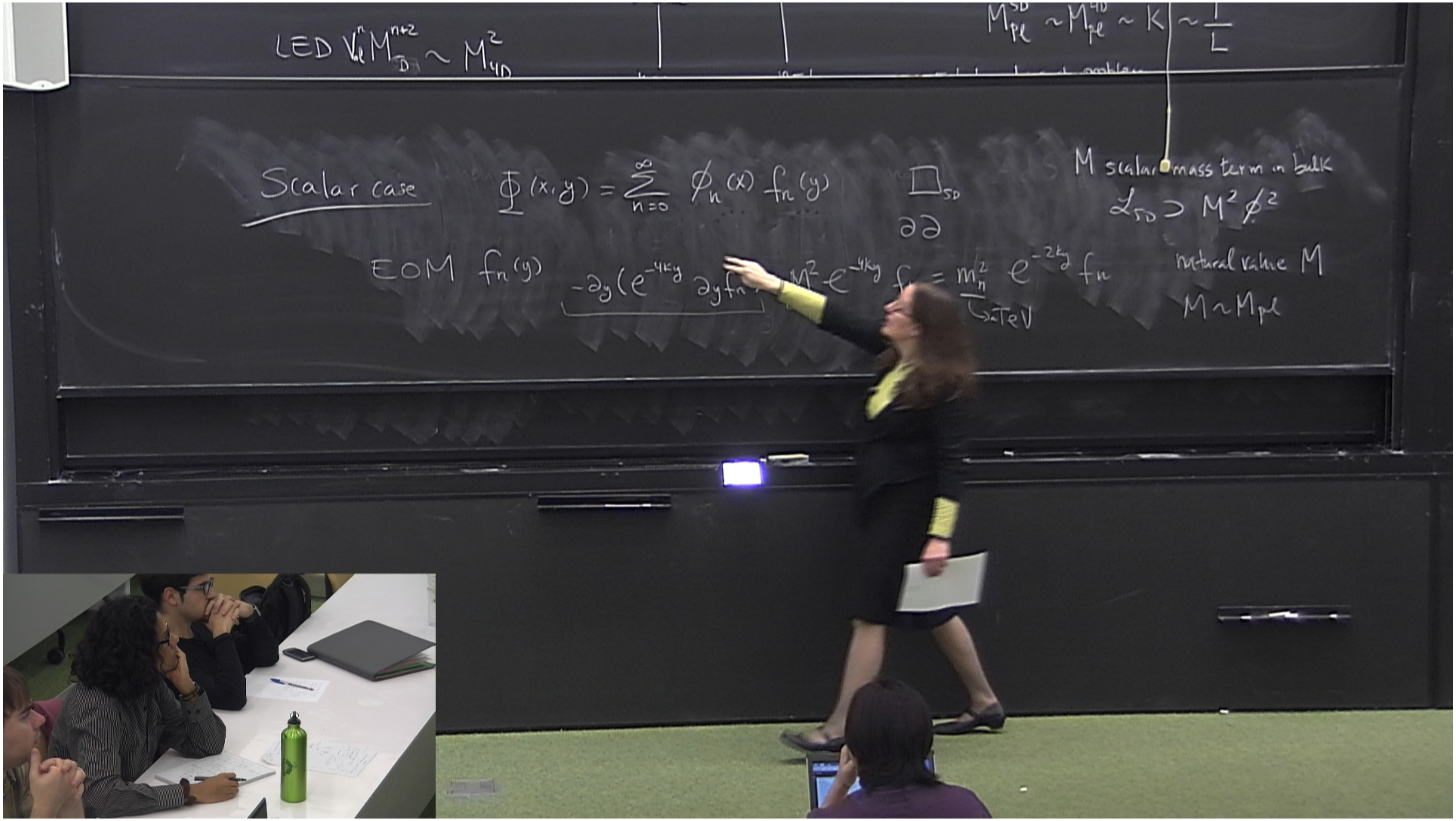

Scalar case
Φ(x,y) = Σ_{n=0}^{∞} φ_n(x) f_n(y)
□_5D
∂∂
EOM f_n(y)
−∂_y(e^{−4ky} ∂_y f_n) + M² e^{−4ky} f_n = m_n²

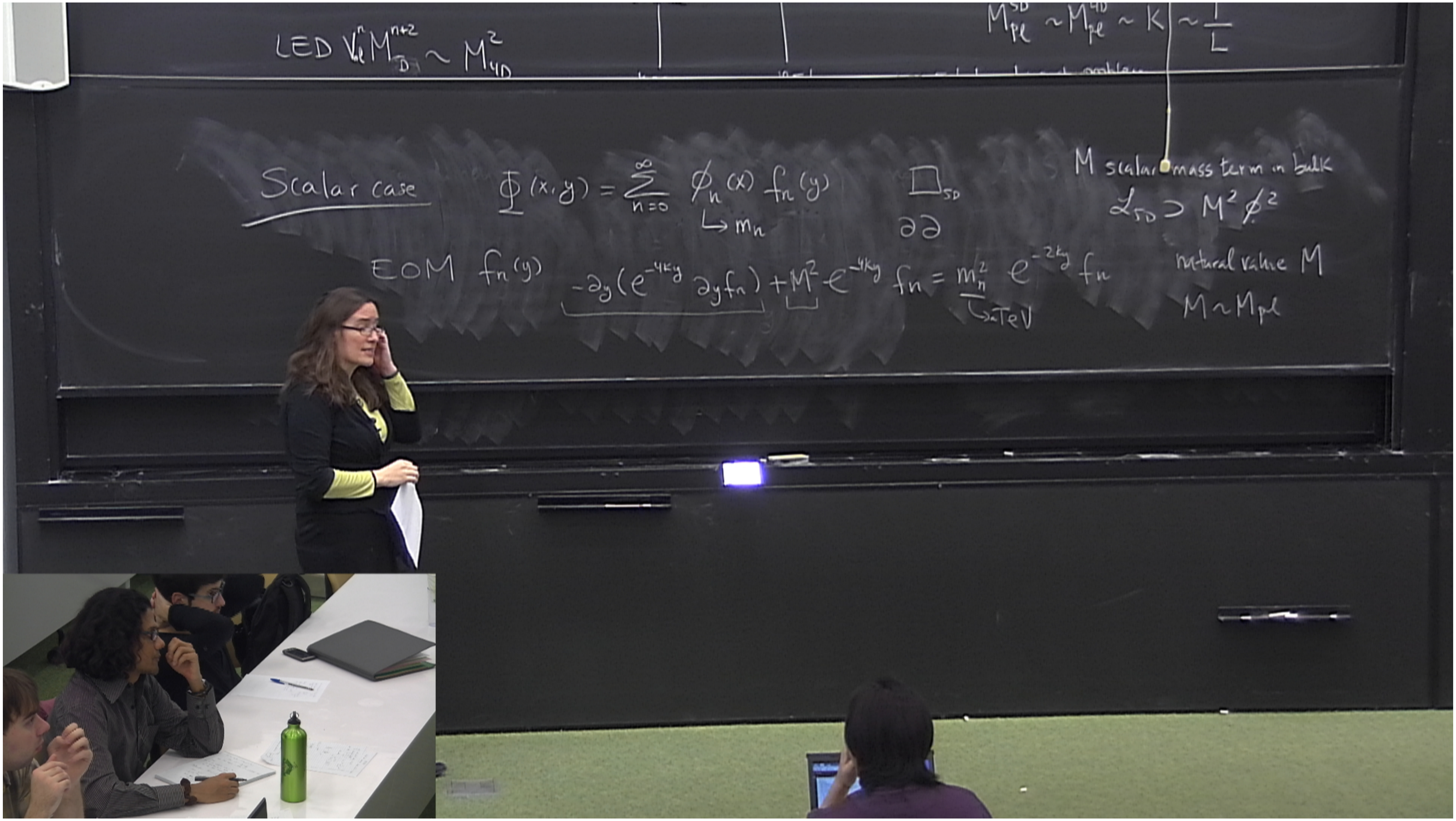

LED $V_{el}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$
y=0
z=1/k
y=L
z=1/TeV
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$
Solution hierarchy problem
→ Physics is redshifted
Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\Box_{5D}$
$\partial\partial$
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
EOM
$-\partial_y(e^{-4ky} \partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$

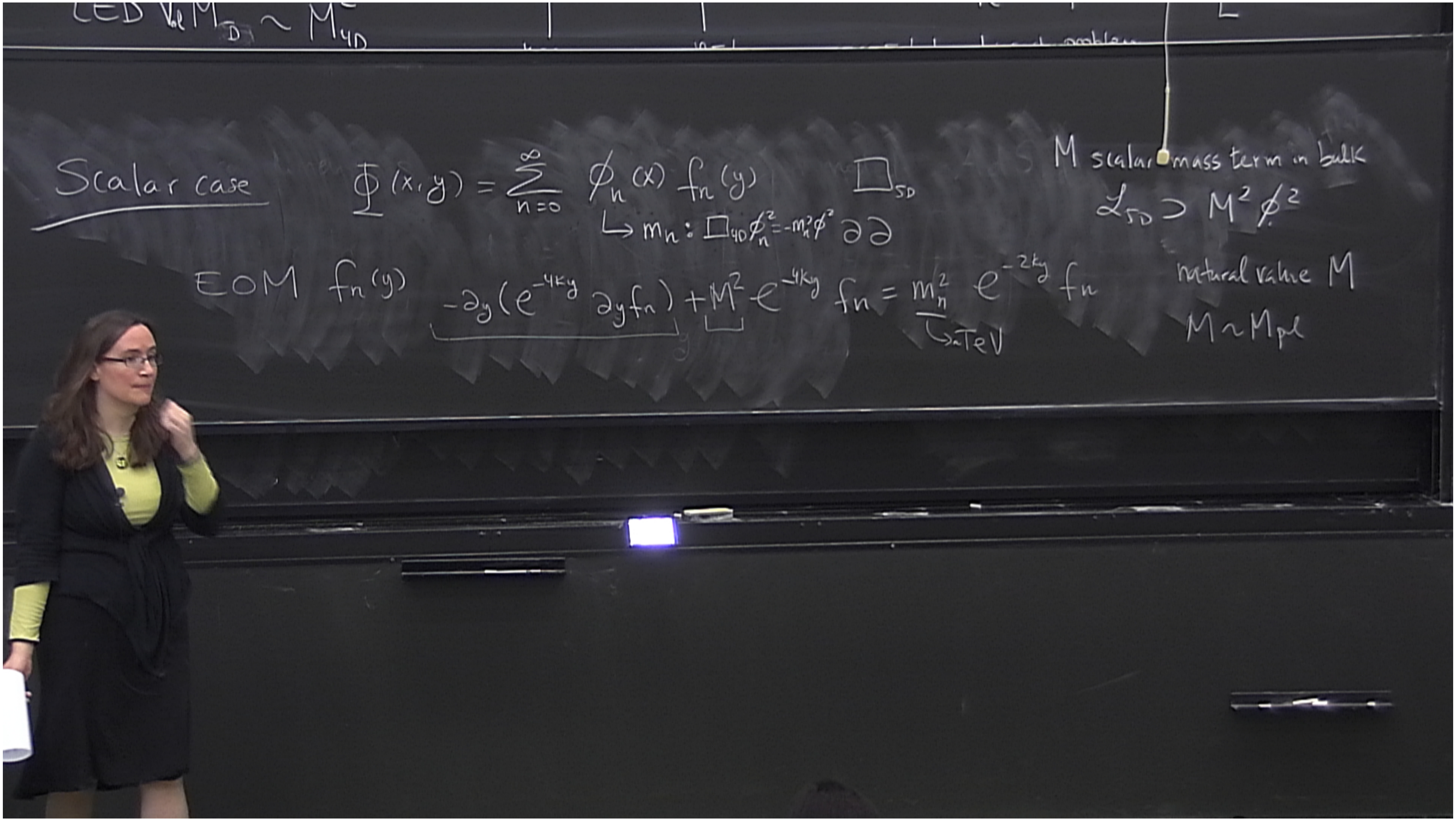

LED $V_{e}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$
y=0
z=1/k
y=L
z=1/TeV
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$
solution hierarchy problem
→ Physics is redshifted
Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\Box_{5D}$
$\partial\partial$
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
EOM $f_n(y)$
$-\partial_y(e^{-4ky} \partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$
natural value M

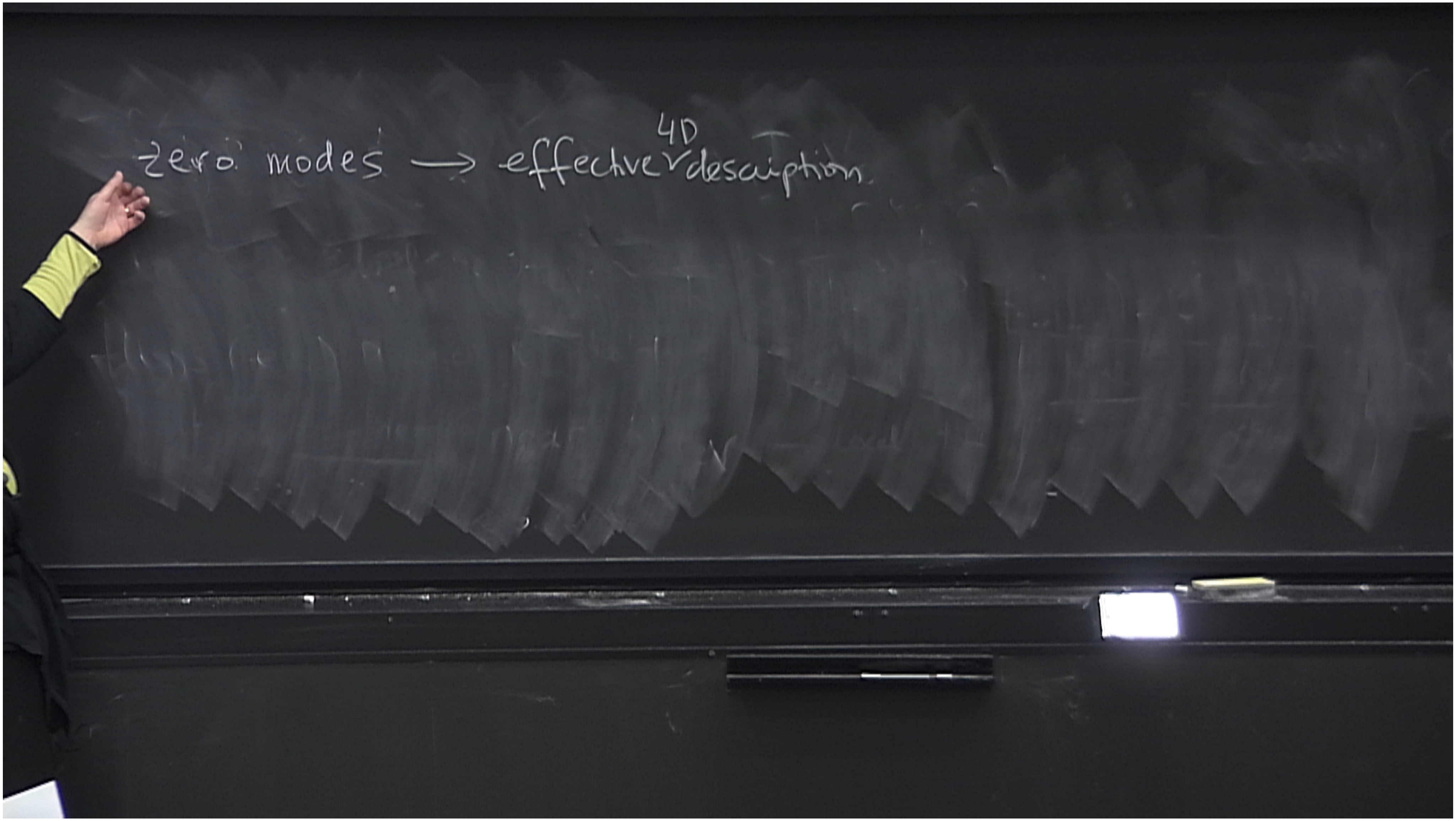

LED
y=0
y=L
solution hierarchy problem
→ Physics is redshifted
Scalar case
M scalar mass term in bulk
EOM
natural value M

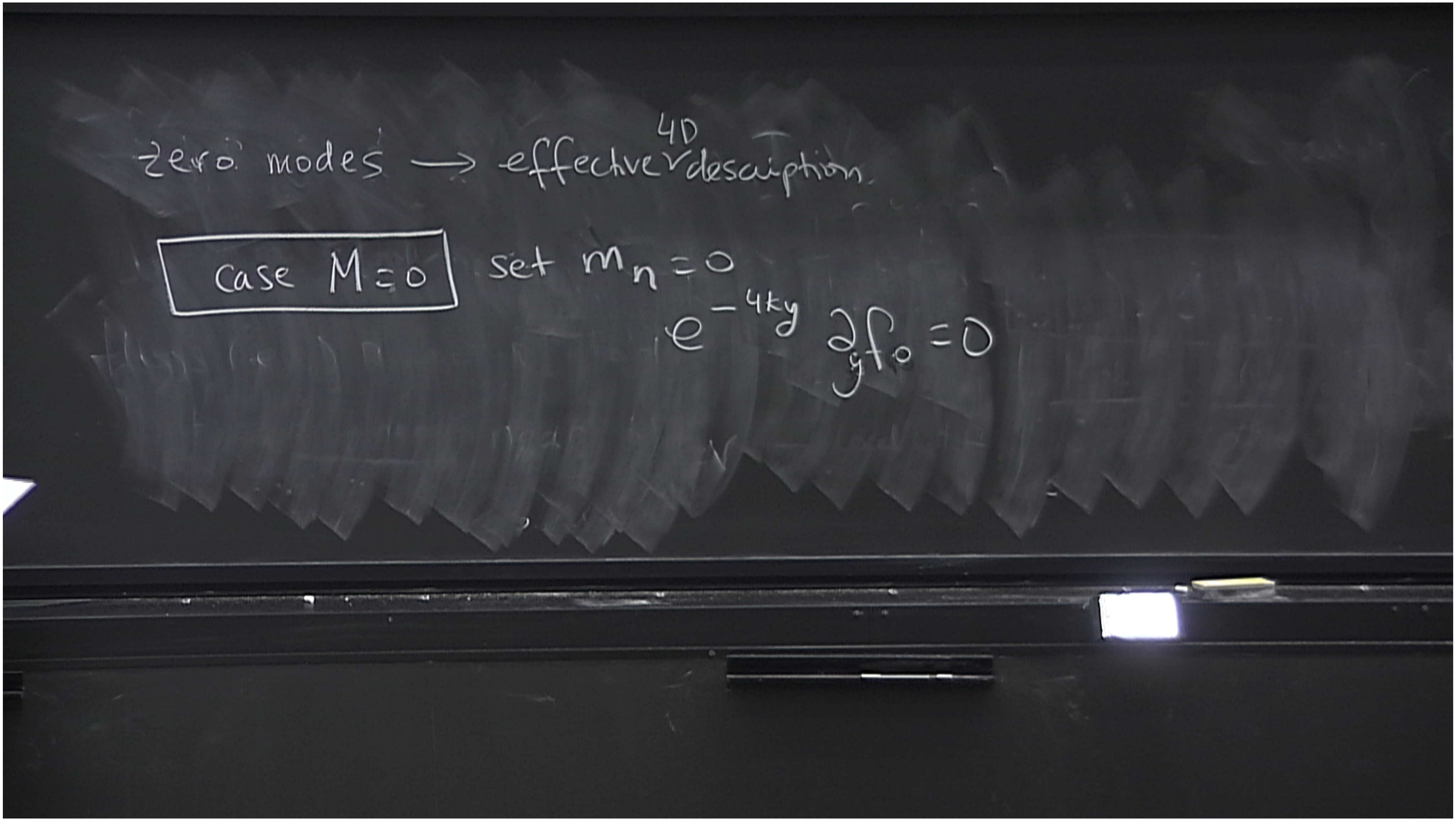

LED $V_{ol}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$
y=0
z=1/k
y=L
z=1/TeV
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$
Solution hierarchy problem
→ Physics is redshifted
Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\Box_{5D}$
$\partial\partial$
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
EOM $f_n(y)$
$-\partial_y(e^{-4ky} \partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$
$\sim$TeV
natural value M
$M \sim M_{pl}$

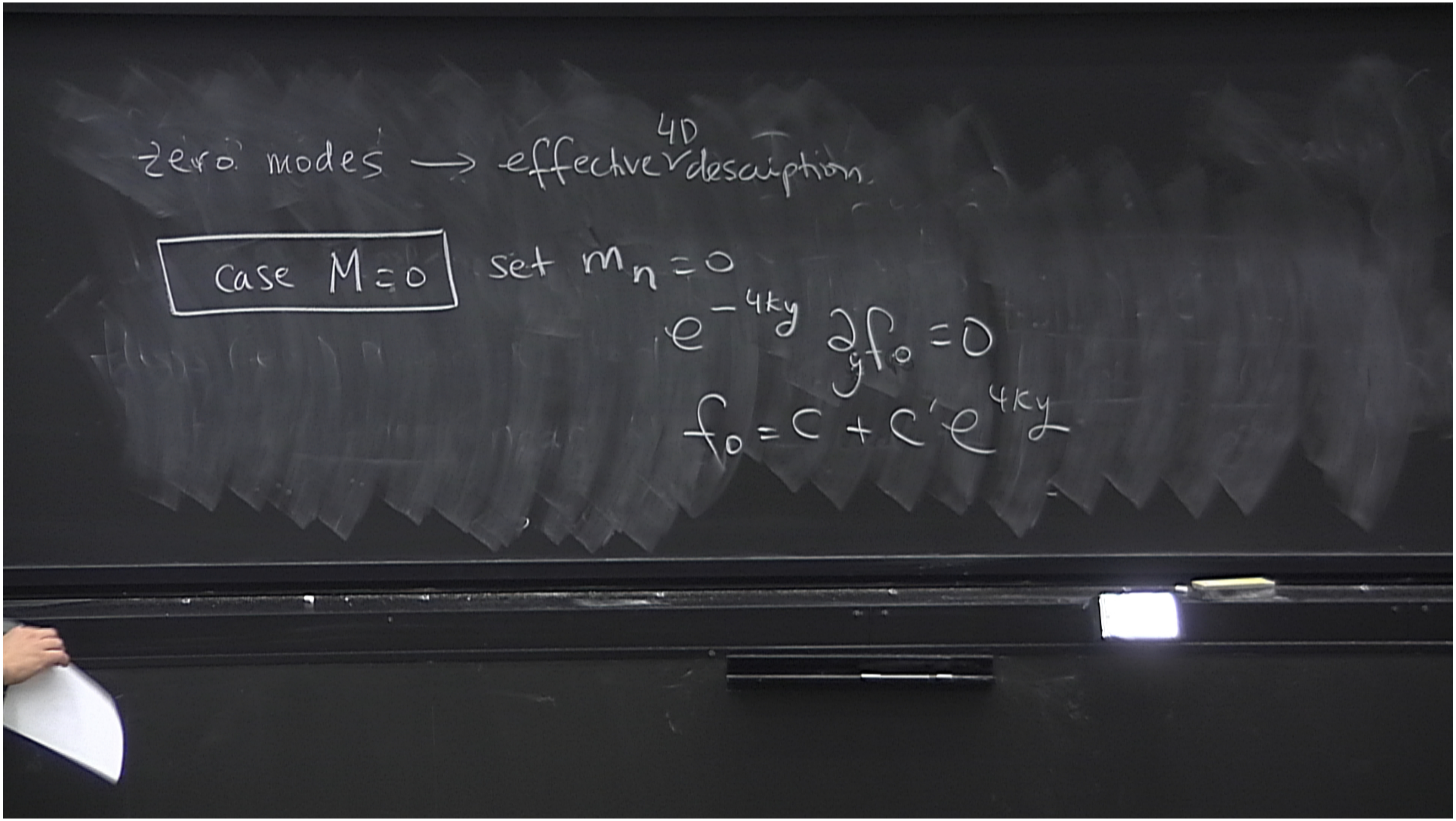

LED $V_{el}^n M_D^{n+2} \sim M_{4D}^2$
$M_{pl}^{5D} \sim M_{pl}^{4D} \sim K \sim \frac{1}{L}$
Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\Box_{5D}$
$\partial\partial$
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
EOM $f_n(y)$
$-\partial_y(e^{-4ky}\partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$
TeV
natural value M
$M \sim M_{pl}$


LED $V_{\ell}^{n} M_{D}^{n+2} \sim M_{4D}^{2}$
$M_{p\ell}^{5D} \sim M_{p\ell}^{4D} \sim k \sim \frac{1}{L}$
Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\hookrightarrow m_n$
$\Box_{5D}$
$\partial\partial$
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
EOM $f_n(y)$
$-\partial_y(e^{-4ky} \partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$
$\hookrightarrow$ TeV
natural value M
$M \sim M_{p\ell}$


Scalar case
$\Phi(x,y) = \sum_{n=0}^{\infty} \phi_n(x) f_n(y)$
$\Box_{5D}$
$\hookrightarrow m_n : \Box_{4D} \phi_n^2 = -m_n^2 \phi^2$ ∂∂
EOM $f_n(y)$
$-\partial_y (e^{-4ky} \partial_y f_n) + M^2 e^{-4ky} f_n = m_n^2 e^{-2ky} f_n$
↳ ~TeV
M scalar mass term in bulk
$\mathcal{L}_{5D} \supset M^2 \phi^2$
natural value M
$M \sim M_{pl}$


zero modes → effective 4D description


zero modes → effective 4D description
case M=0
set $m_n = 0$
$e^{-4ky} \partial_y f_0 = 0$

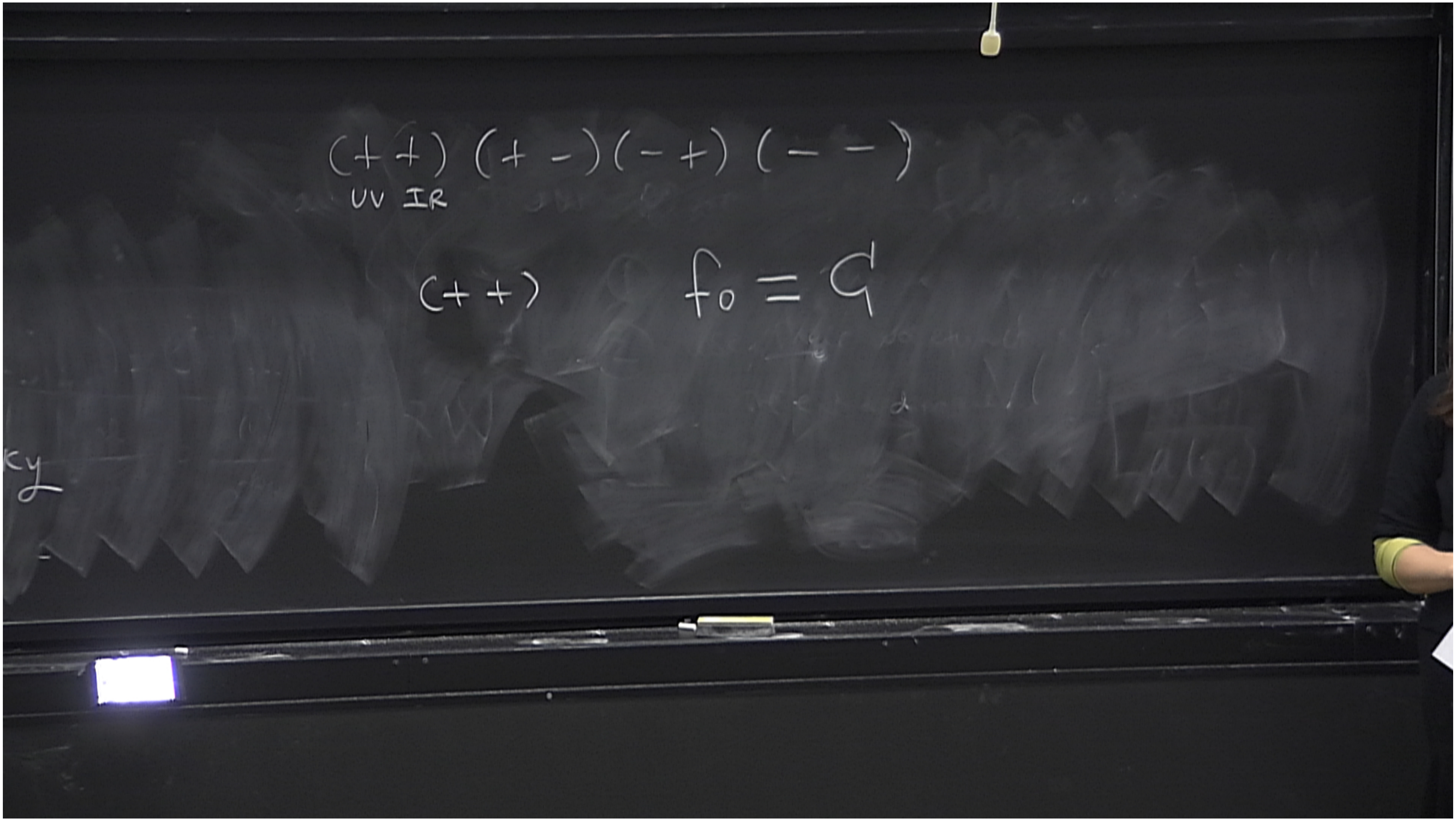

zero modes → effective 4D description
case M = 0
set $m_n = 0$
$e^{-4ky} \partial_y f_0 = 0$
$f_0 = c + c' e^{4ky}$

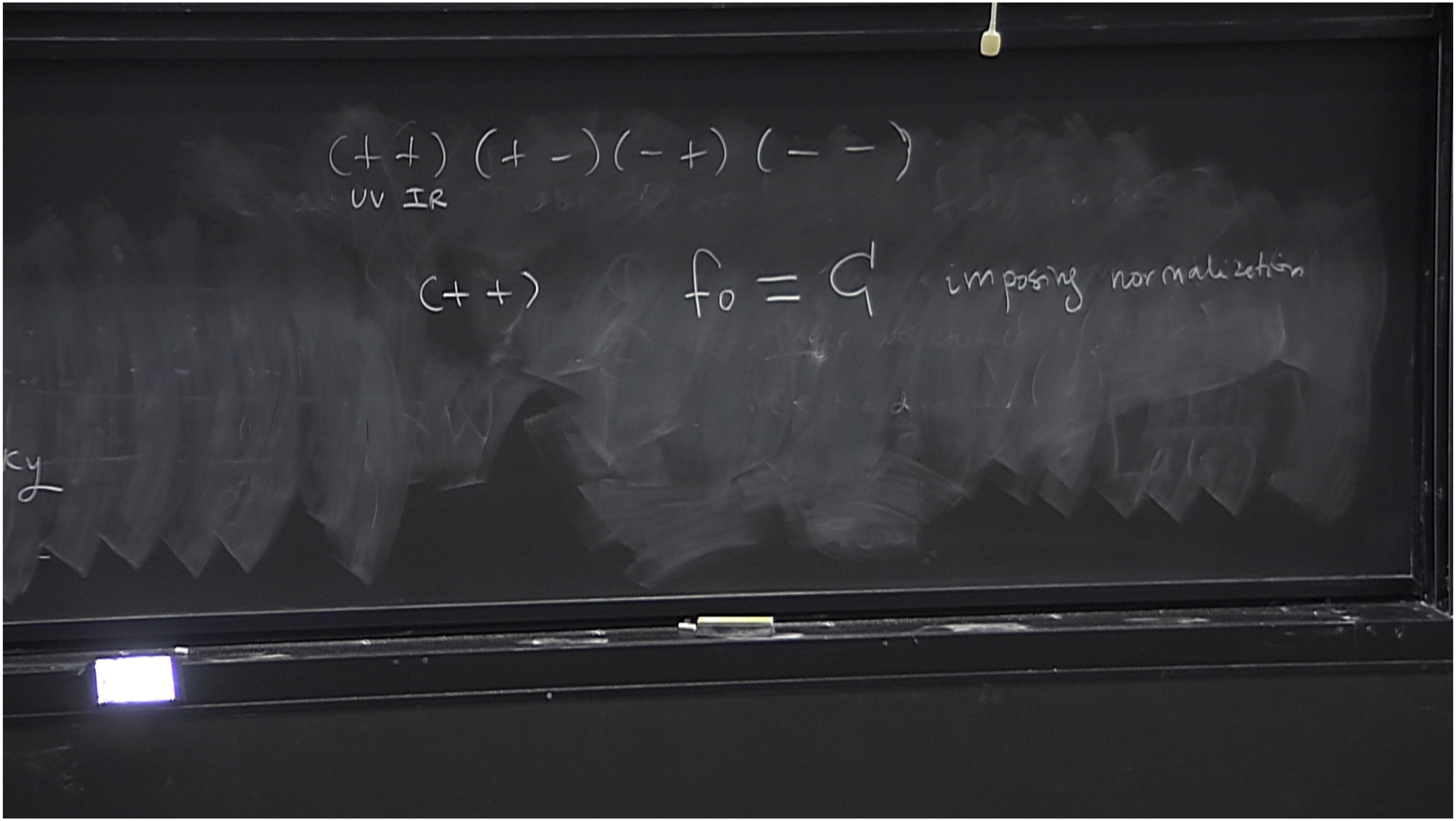
zero modes $\longrightarrow$ effective 4D description

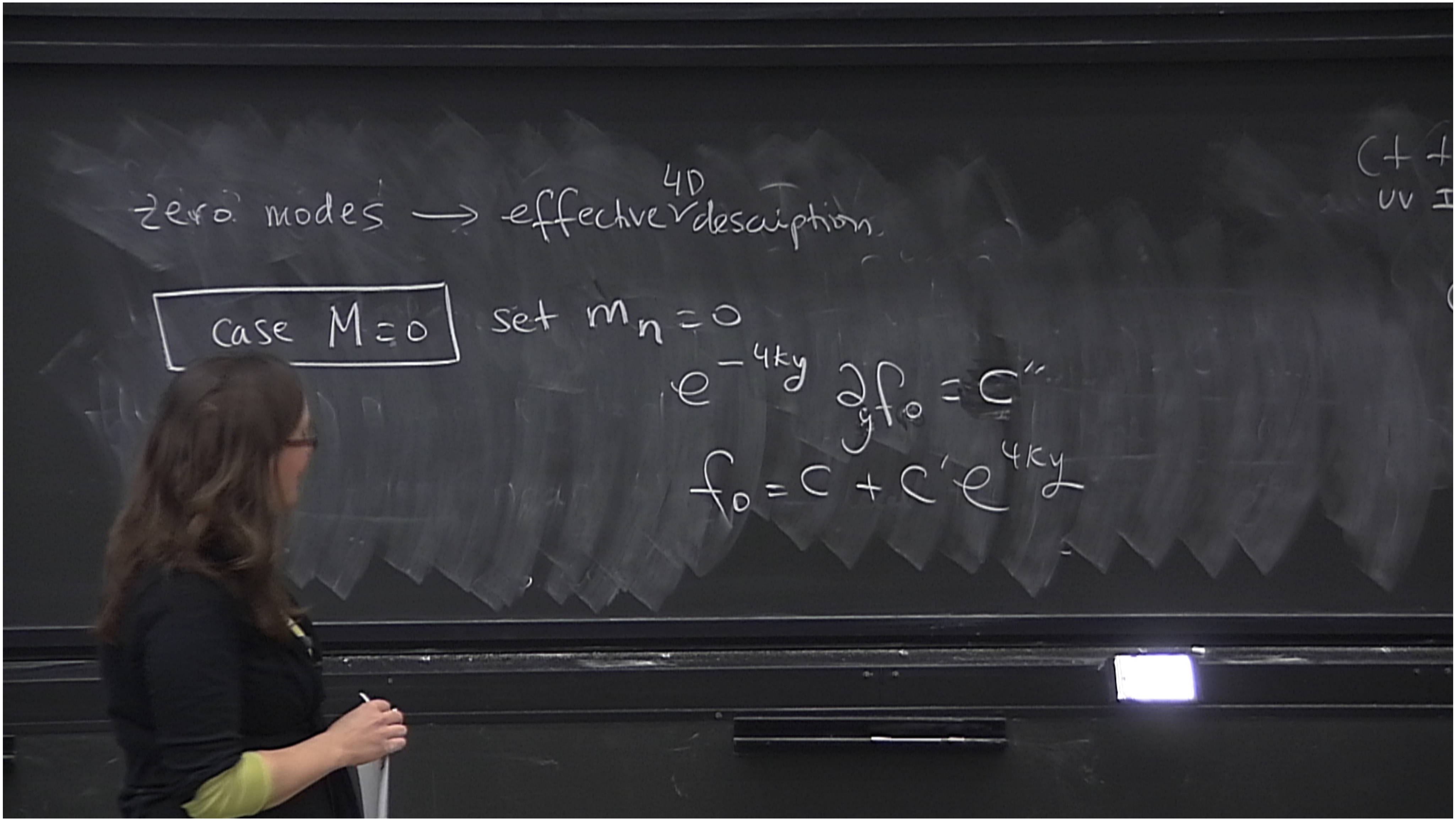
**case $M=0$** set $m_n = 0$

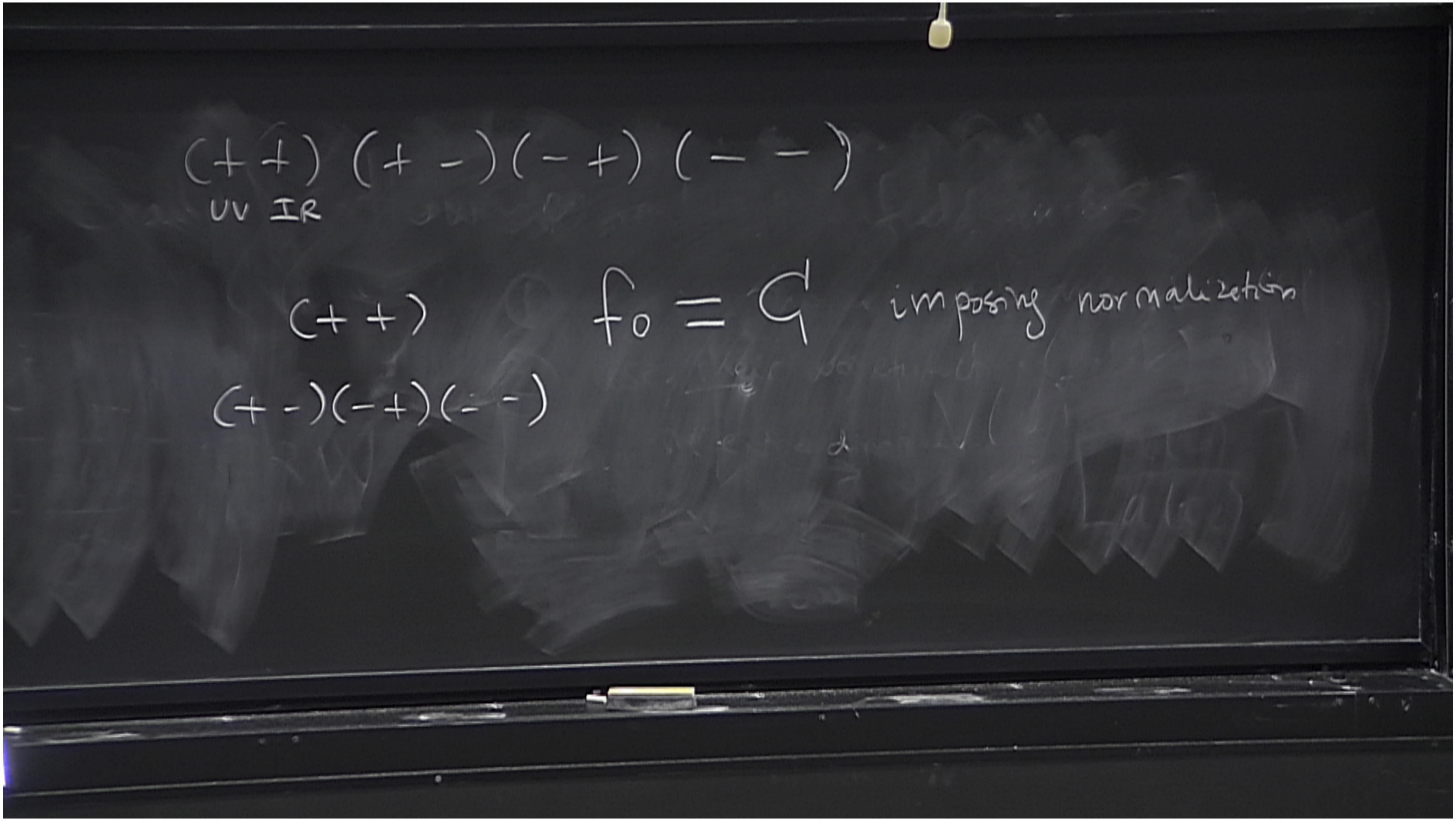
$$e^{-4ky}\,\partial_y f_0 = 0$$

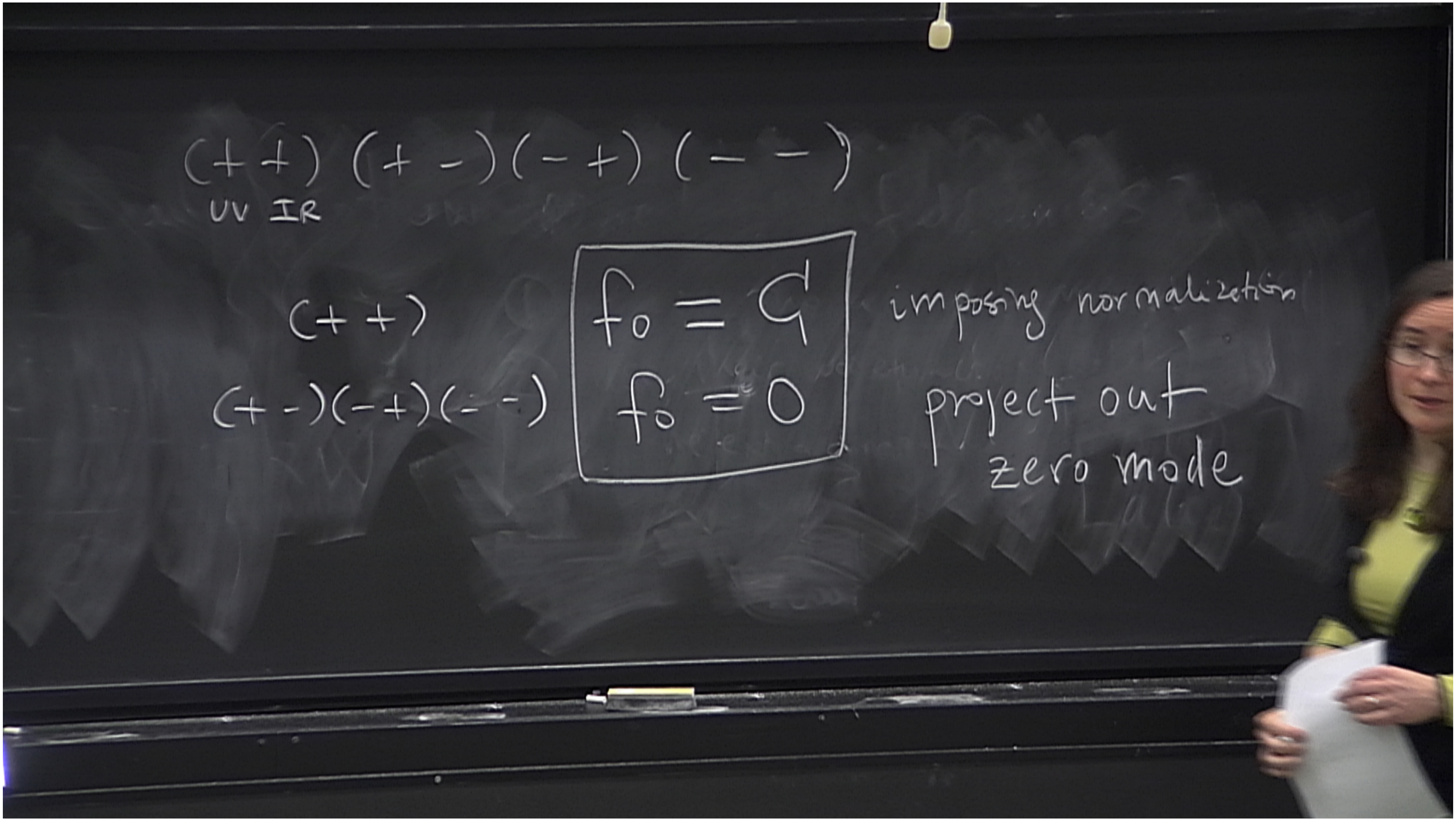
$$f_0 = c + c' e^{4ky}$$

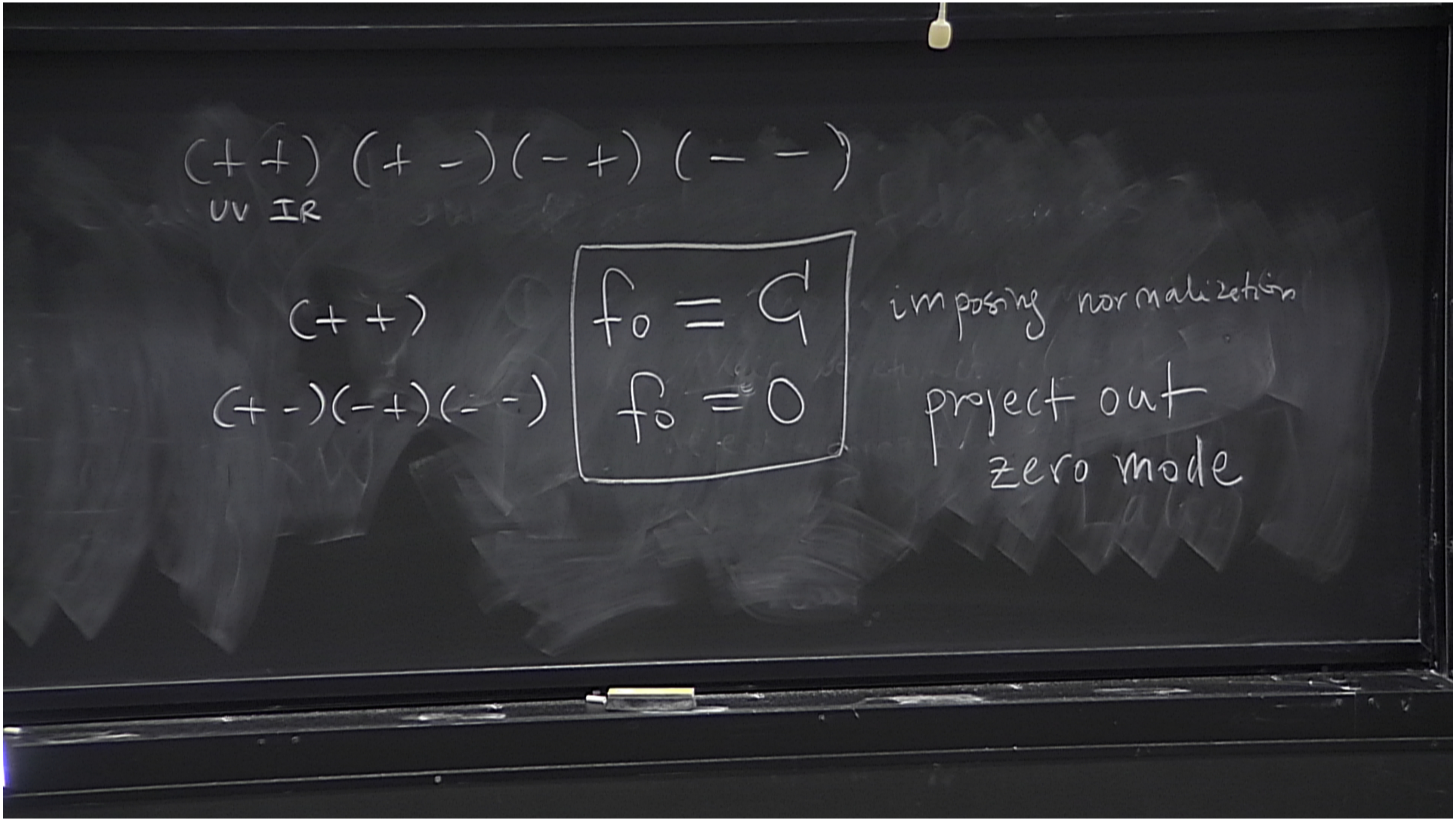

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
f0 = q

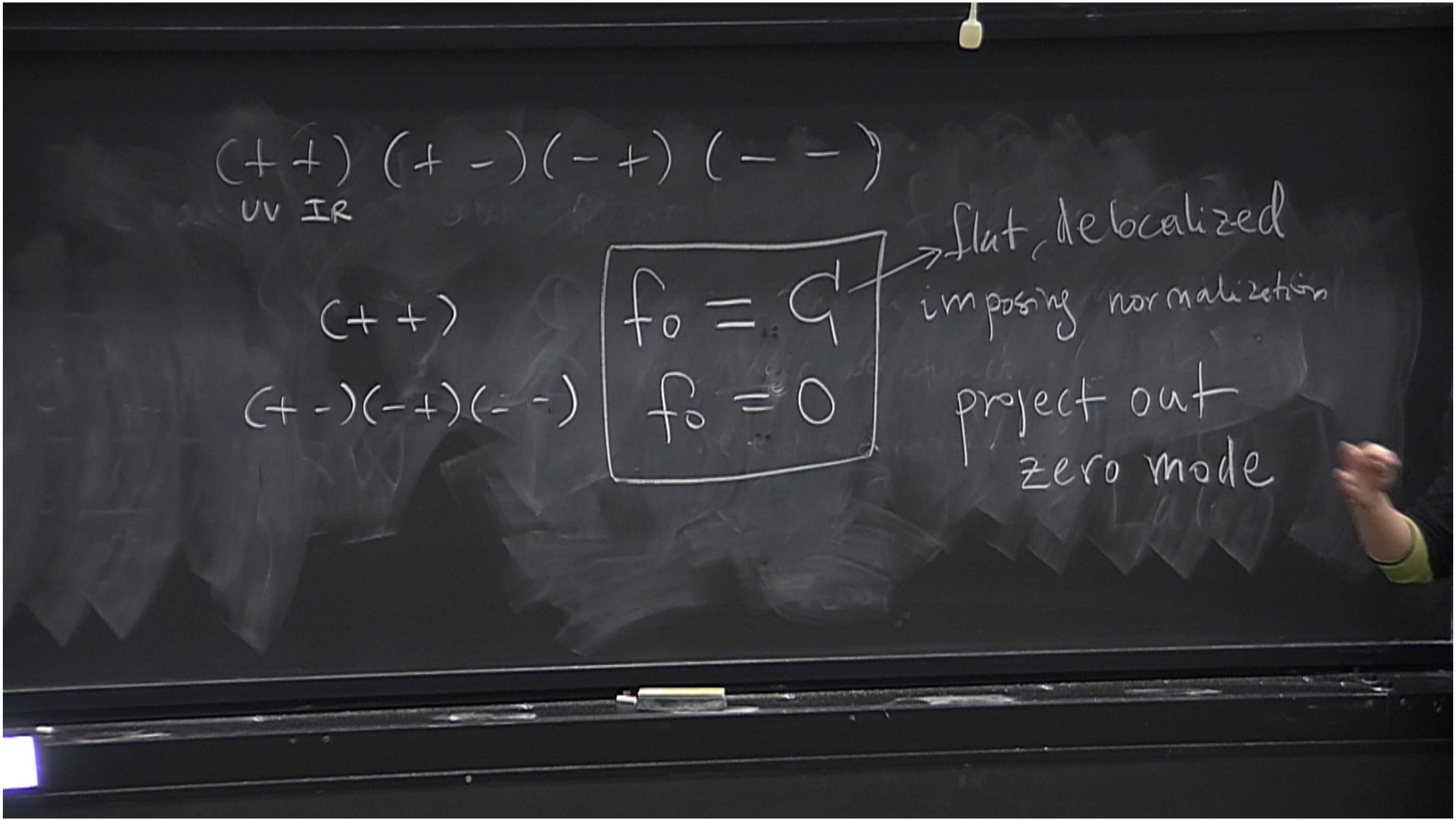

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)   $f_0 = C_1$   imposing normalization
ky

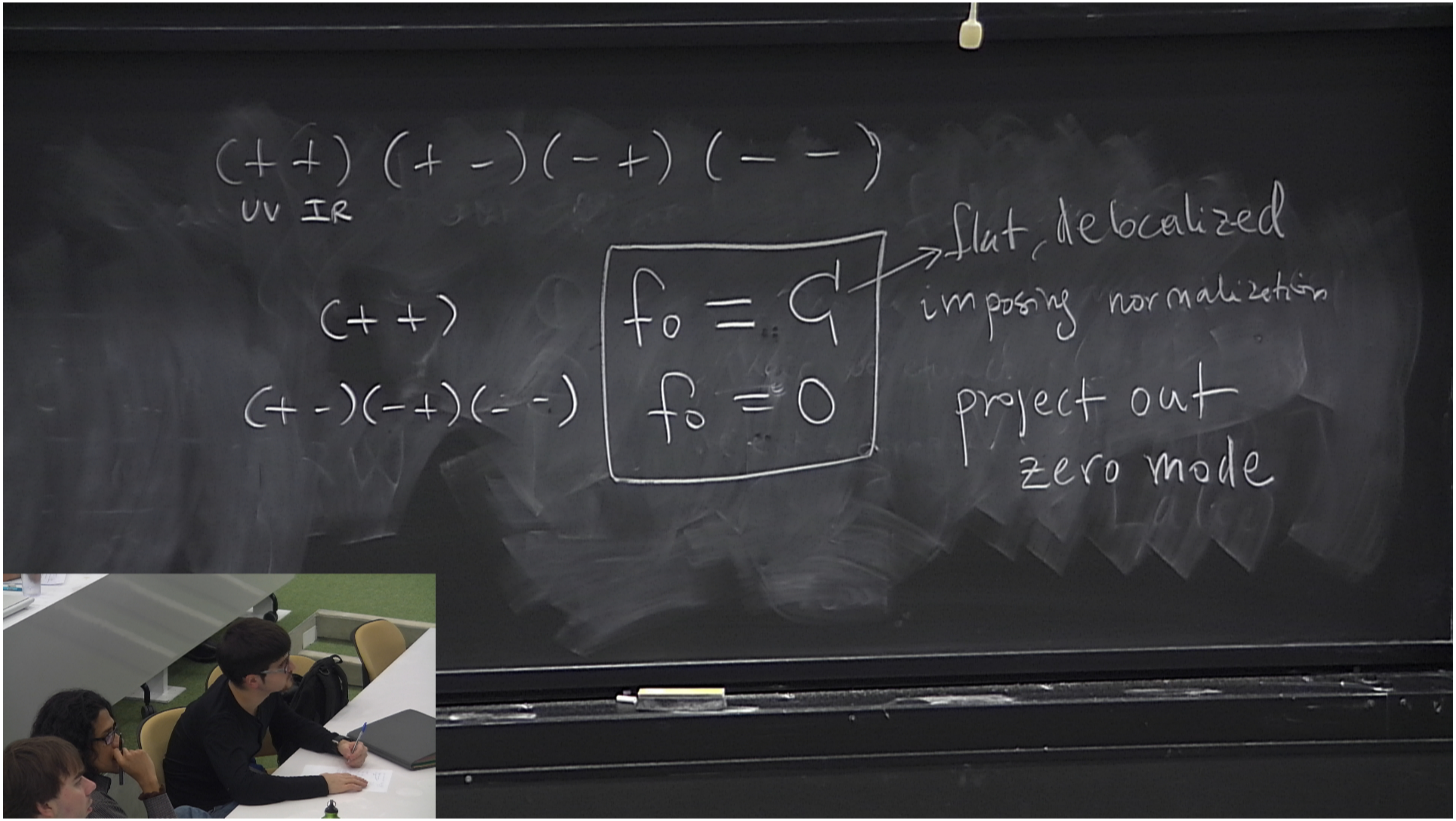

zero modes → effective 4D description
case M = 0
set $m_n = 0$
$e^{-4ky}\, \partial_y f_0 = c''$
$f_0 = c + c' e^{4ky}$

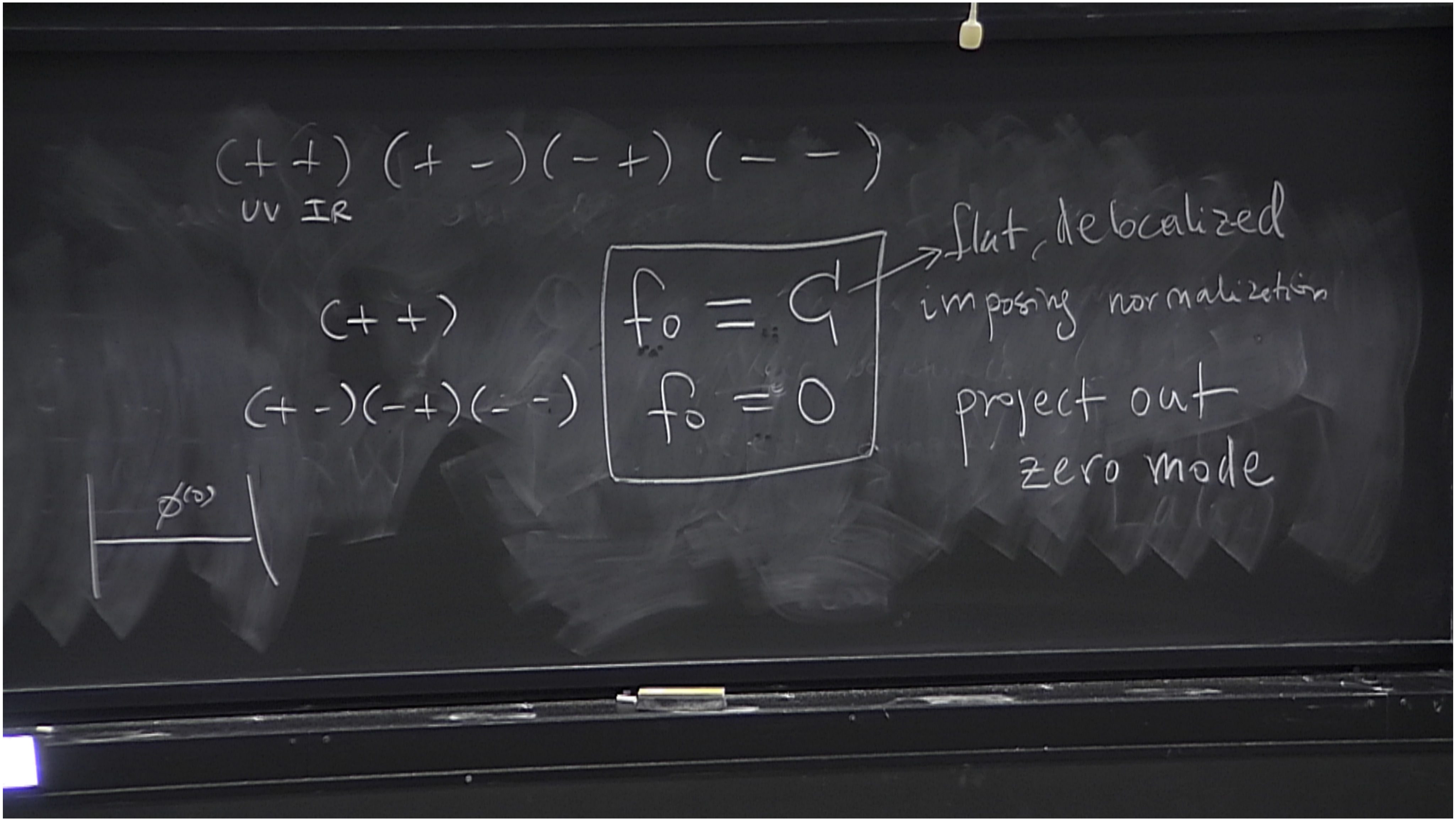

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
$f_0 = q$ imposing normalization
(+ −)(− +)(− −)

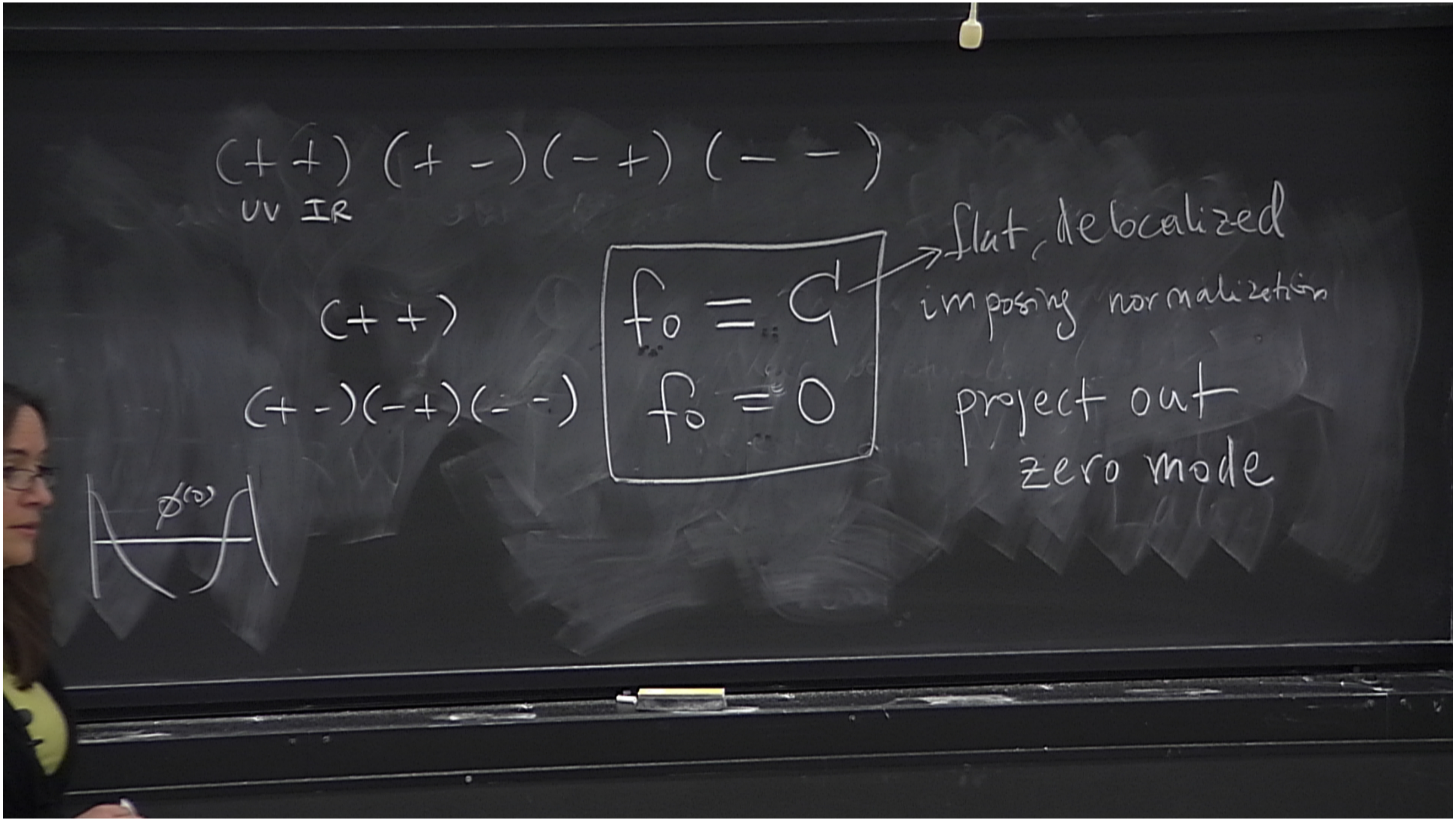

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
(+ −)(− +)(− −)
f0 = 0
imposing normalization
project out
zero mode

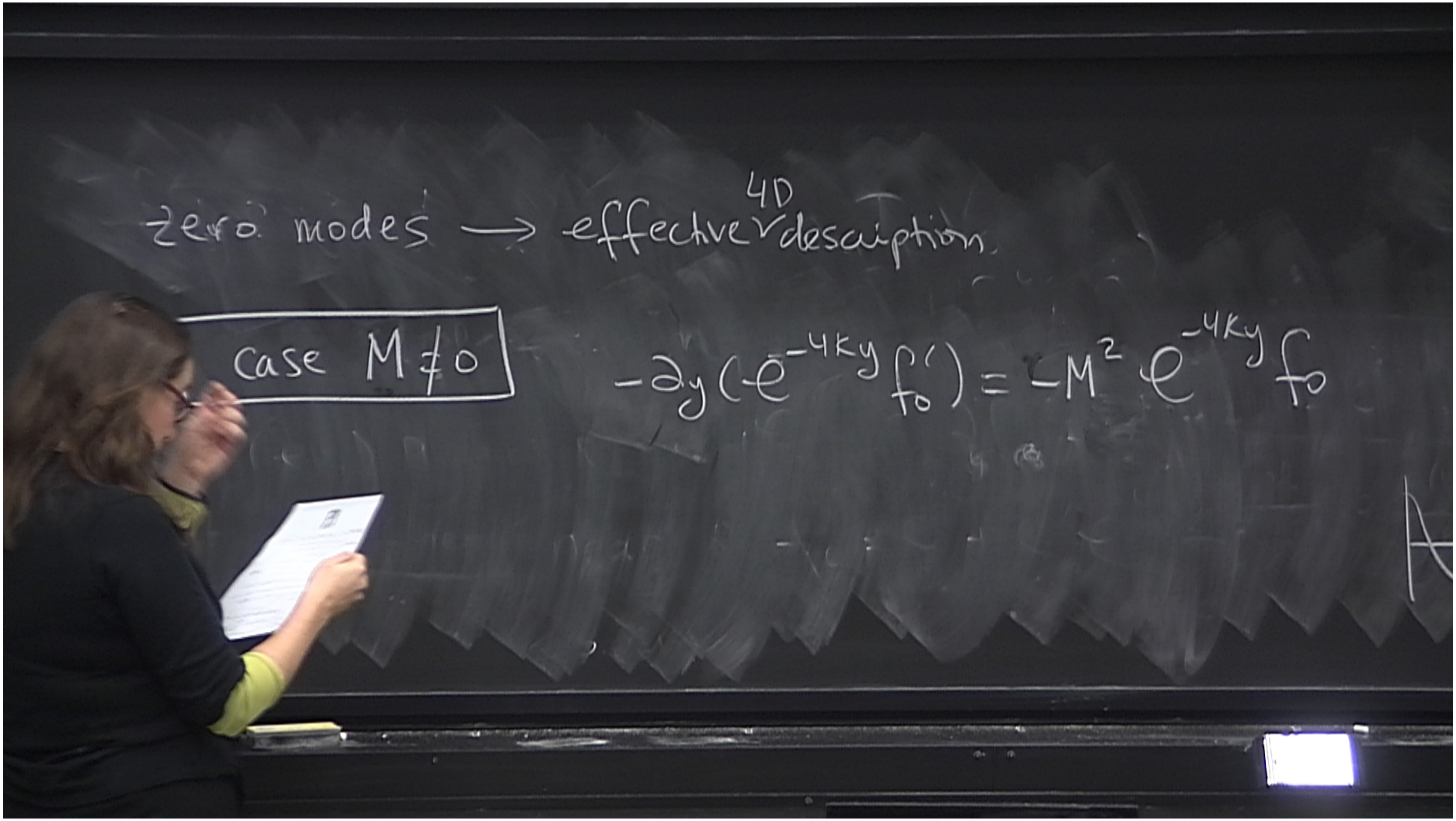

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
f0 = c
imposing normalization
(+ −)(− +)(− −)
f0 = 0
project out
zero mode

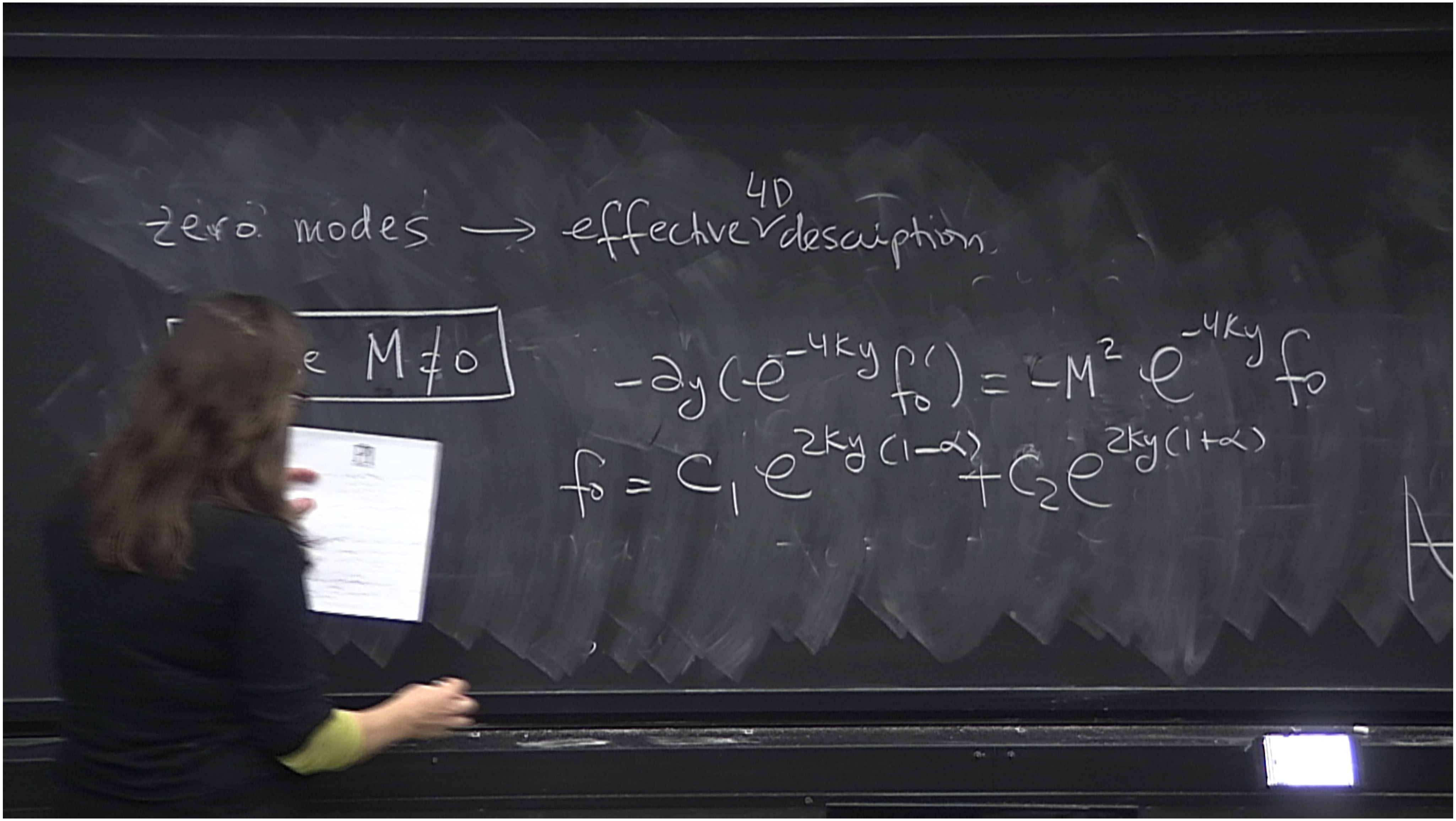

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
(+ −)(− +)(− −)
$f_0 = c$
$f_0 = 0$
flat, delocalized
imposing normalization
project out
zero mode

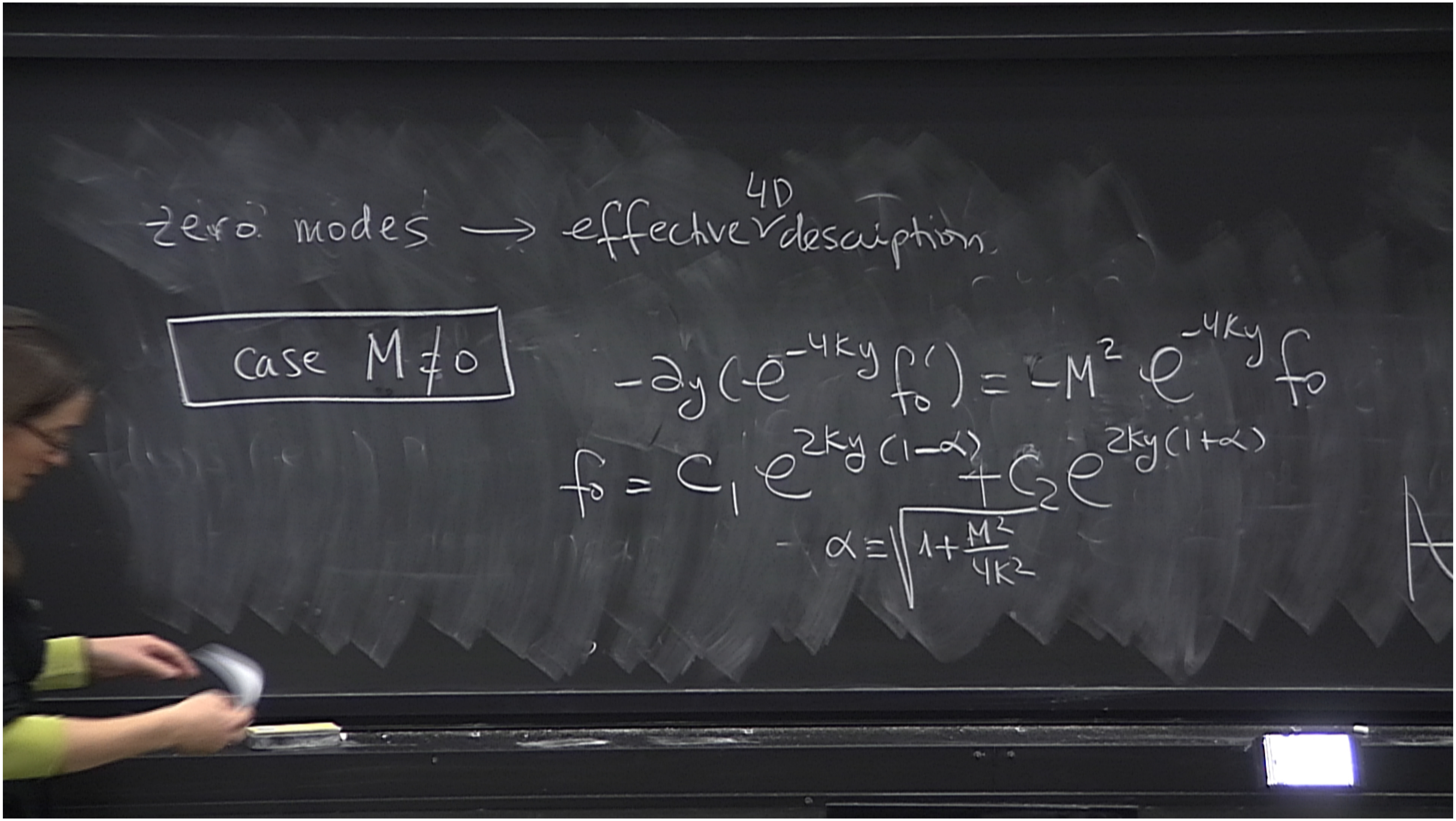

(+ +) (+ -) (- +) (- -)
UV IR
(+ +)
(+ -)(- +)(- -)
f0 = c
f0 = 0
flat, delocalized
imposing normalization
project out
zero mode

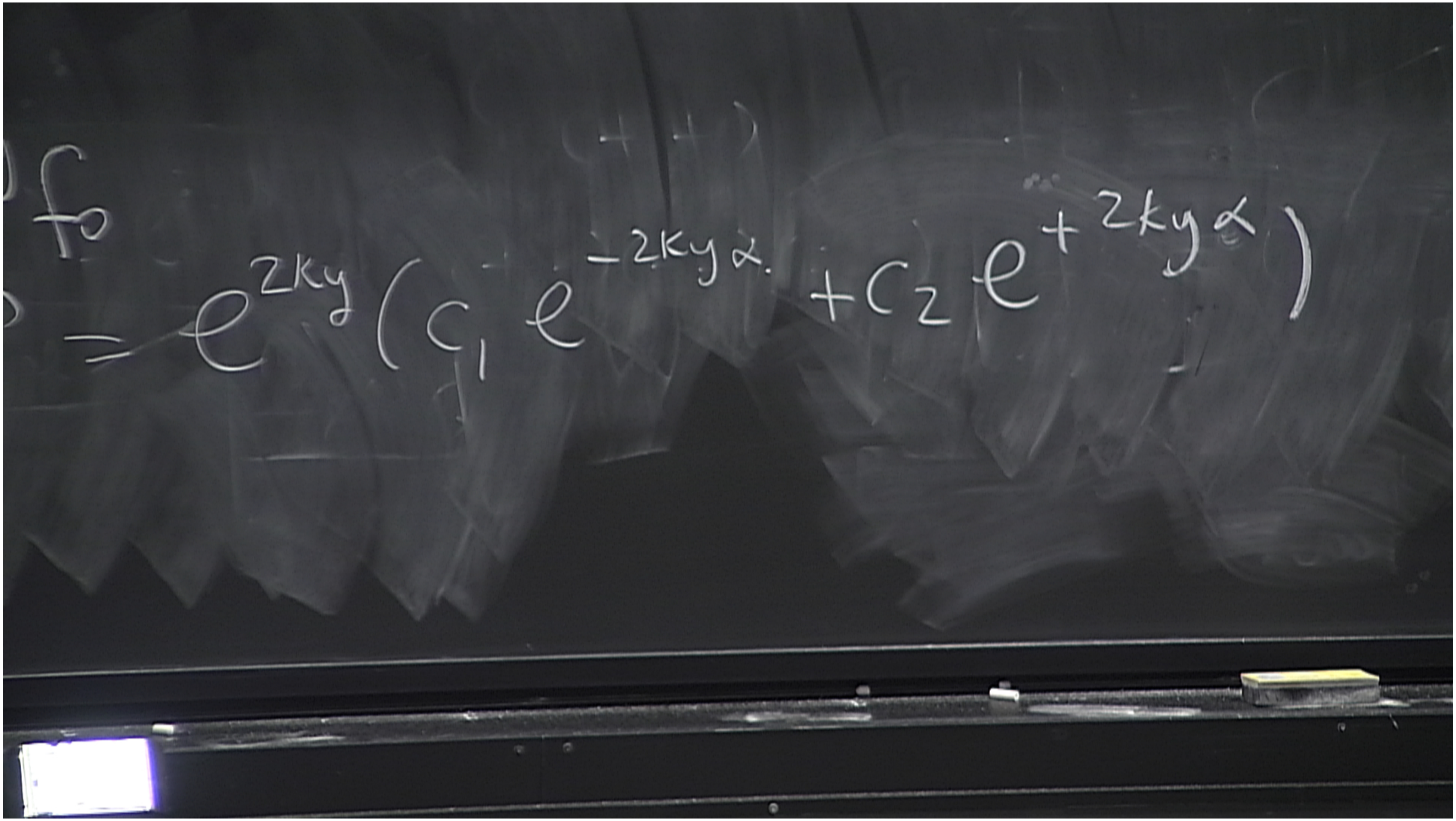

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
(+ −)(− +)(− −)
f0 = c
f0 = 0
flat, delocalized
imposing normalization
project out
zero mode
ϕ(0)

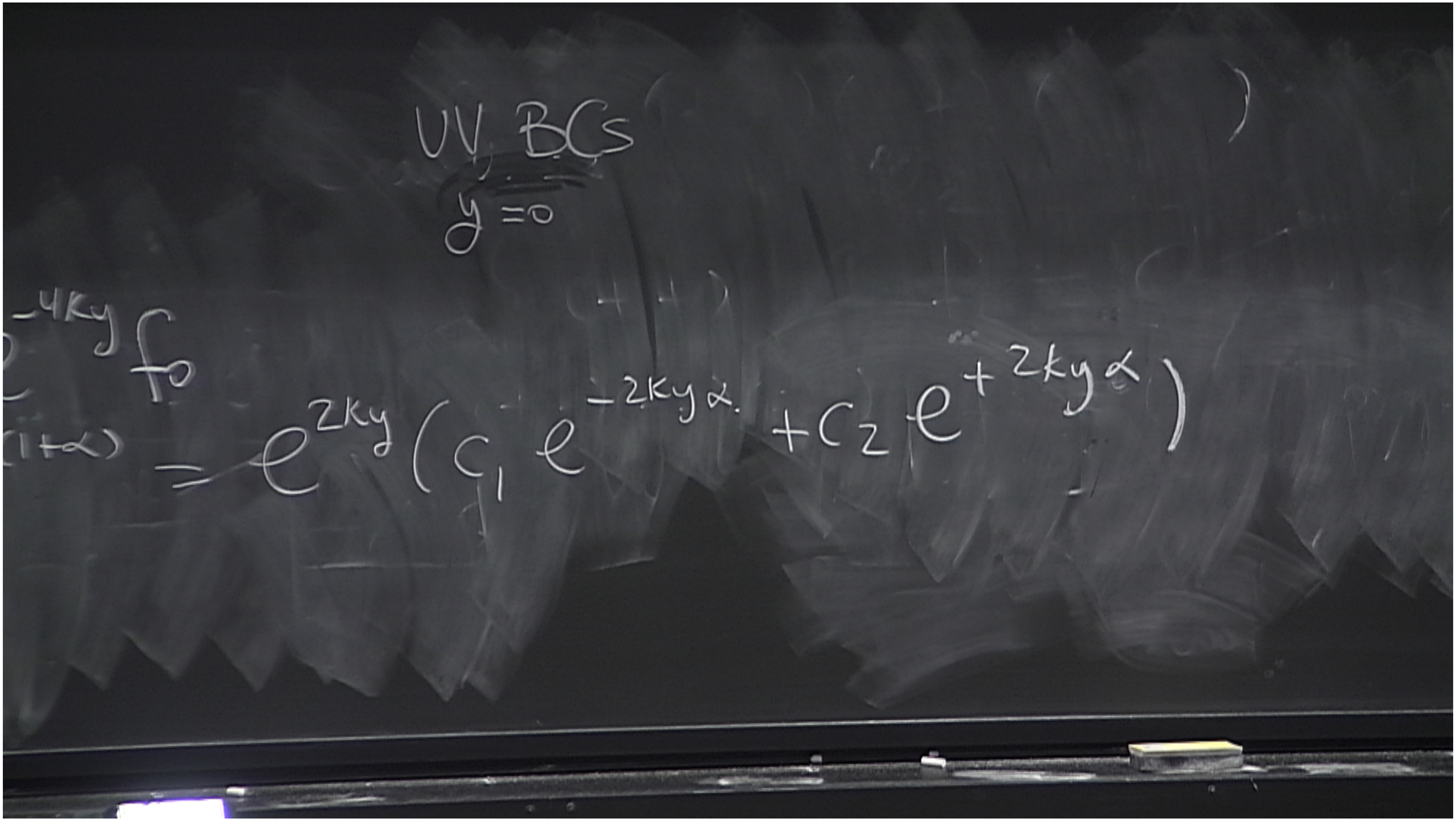

(+ +) (+ −) (− +) (− −)
UV IR
(+ +)
(+ −)(− +)(− −)
f0 = c
f0 = 0
flat, delocalized
imposing normalization
project out
zero mode
ϕ(0)

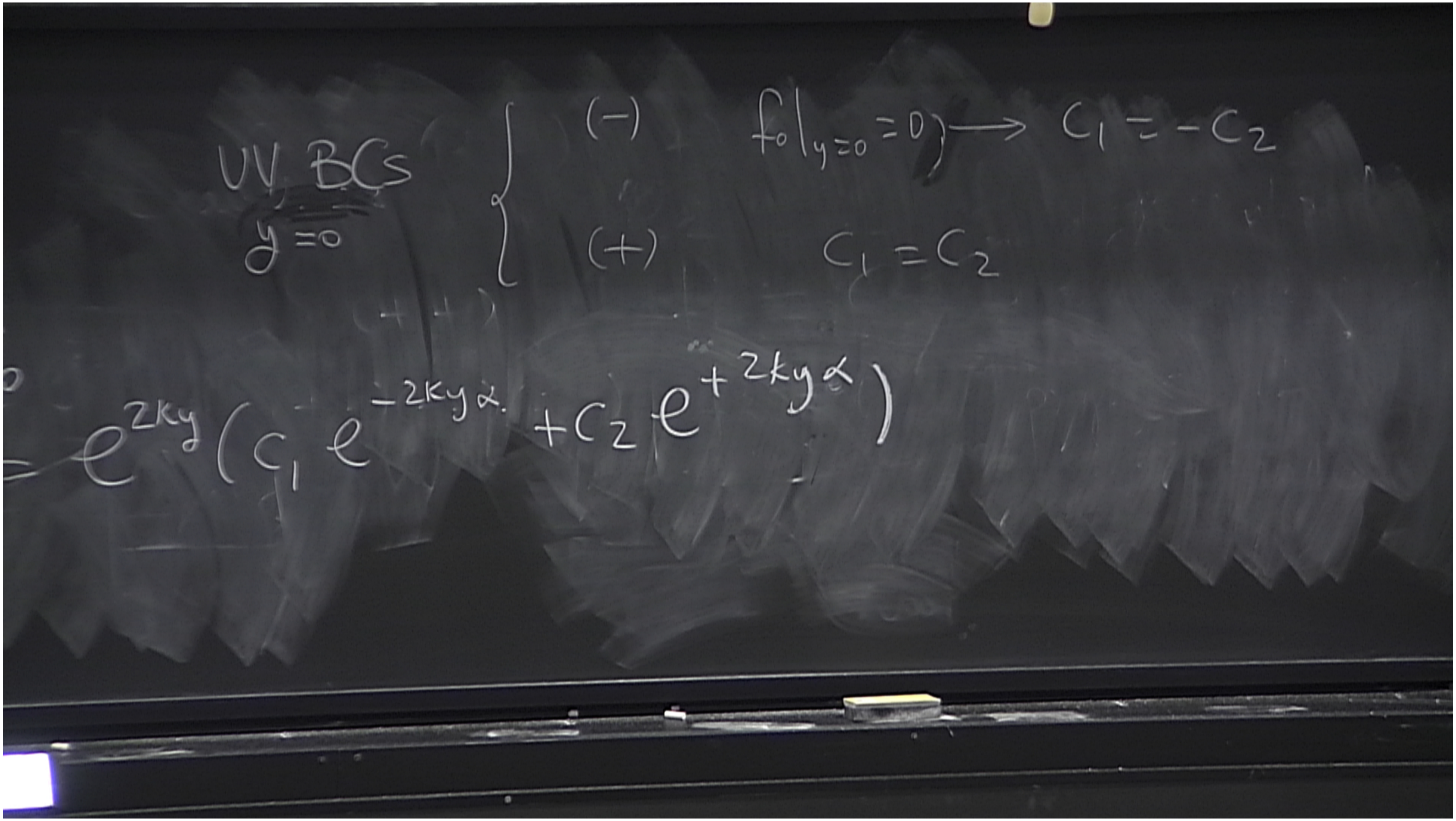

zero modes → effective 4D description
case M ≠ 0
$-\partial_y(e^{-4ky} f_0') = -M^2 e^{-4ky} f_0$

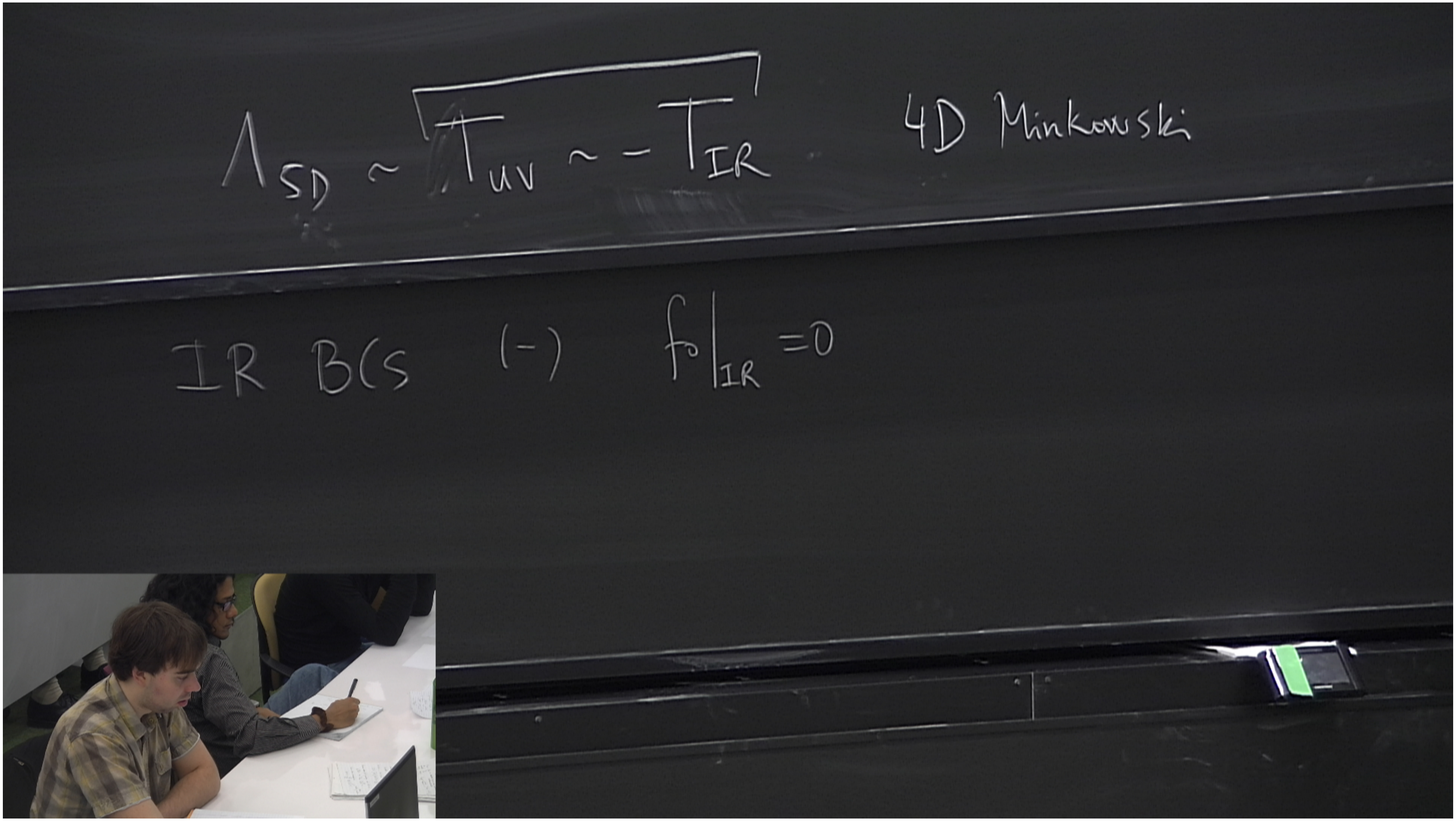

zero modes → effective 4D description
e $M \neq 0$
$-\partial_y(e^{-4ky} f_0') = M^2 e^{-4ky} f_0$
$f_0 = C_1 e^{2ky(1-\alpha)} + C_2 e^{2ky(1+\alpha)}$


zero modes → effective 4D description
case M ≠ 0
$-\partial_y(-e^{-4ky} f_0') = -M^2 e^{-4ky} f_0$
$f_0 = C_1 e^{2ky(1-\alpha)} + C_2 e^{2ky(1+\alpha)}$
$\alpha = \sqrt{1+\frac{M^2}{4k^2}}$


fo
= e^2ky (c1 e^-2kyα + c2 e^+2kyα)


UV BCs
y = 0
$e^{-4ky} f_0$
$(1+\alpha) = e^{2ky}(c_1 e^{-2ky\alpha} + c_2 e^{+2ky\alpha})$


UV BCs
y = 0
(−) f0|y=0 = 0 → c1 = −c2
(+) c1 = c2
e^2ky (c1 e^−2kyα + c2 e^+2kyα)


Λ5D ~ TUV ~ - TIR
4D Minkowski
IR BCs (-) f0|IR =0

$\Lambda_{5D} \sim \overbrace{T_{UV} \sim - T_{IR}}$ 4D Minkowski

IR BCs (−) $f_0\big|_{IR} = 0 \longrightarrow$ no sols $\rightarrow f_0 = 0$

(+) $f_0'\big|_{IR} \propto e^{2ky}\left( \alpha \begin{matrix}\cosh \\ \sinh\end{matrix} + \begin{matrix}\sinh \\ \cosh\end{matrix} \right)$

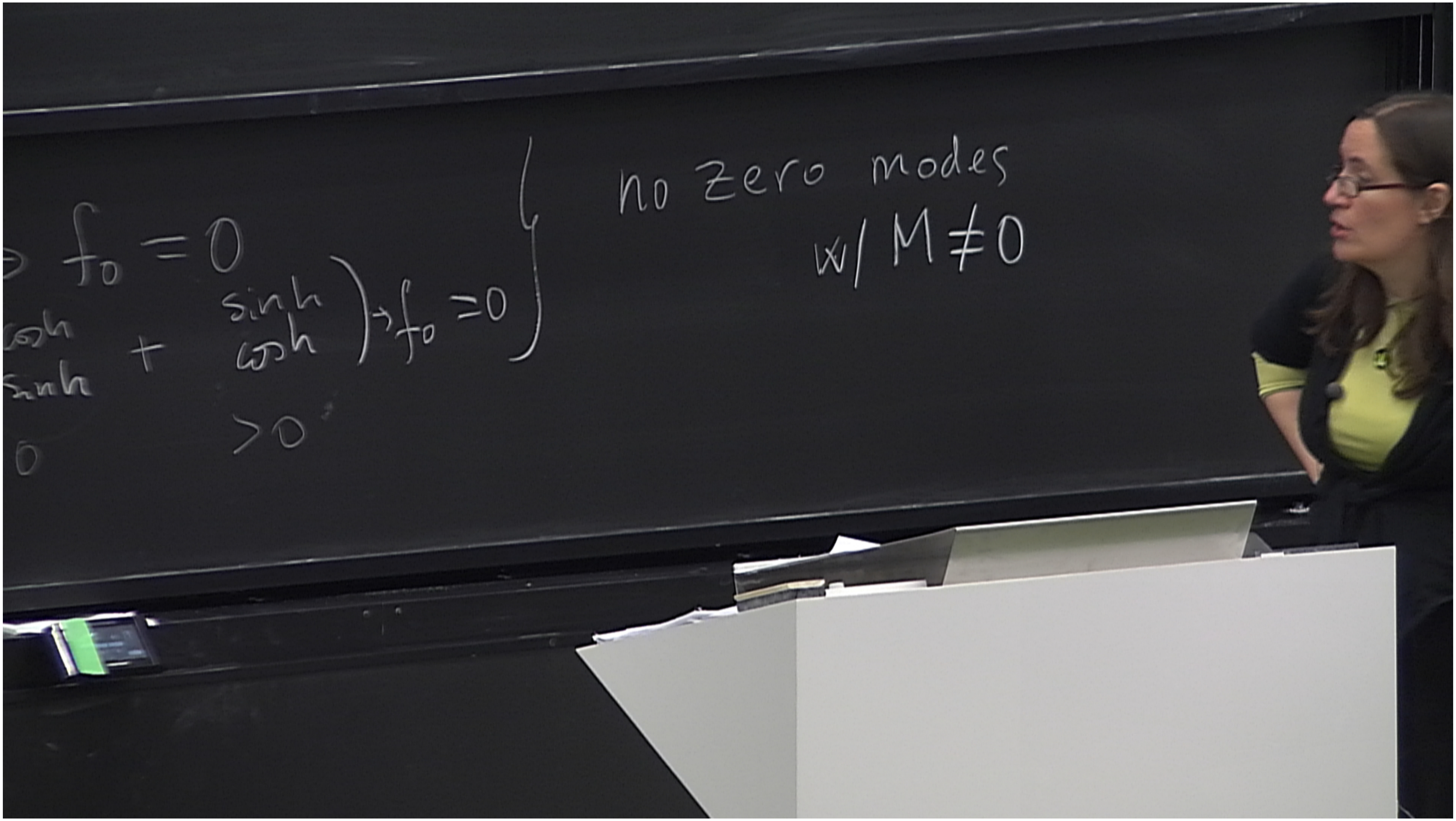
$$\Lambda_{5D} \sim \boxed{T_{UV} \sim - T_{IR}} \quad \text{4D Minkowski}$$

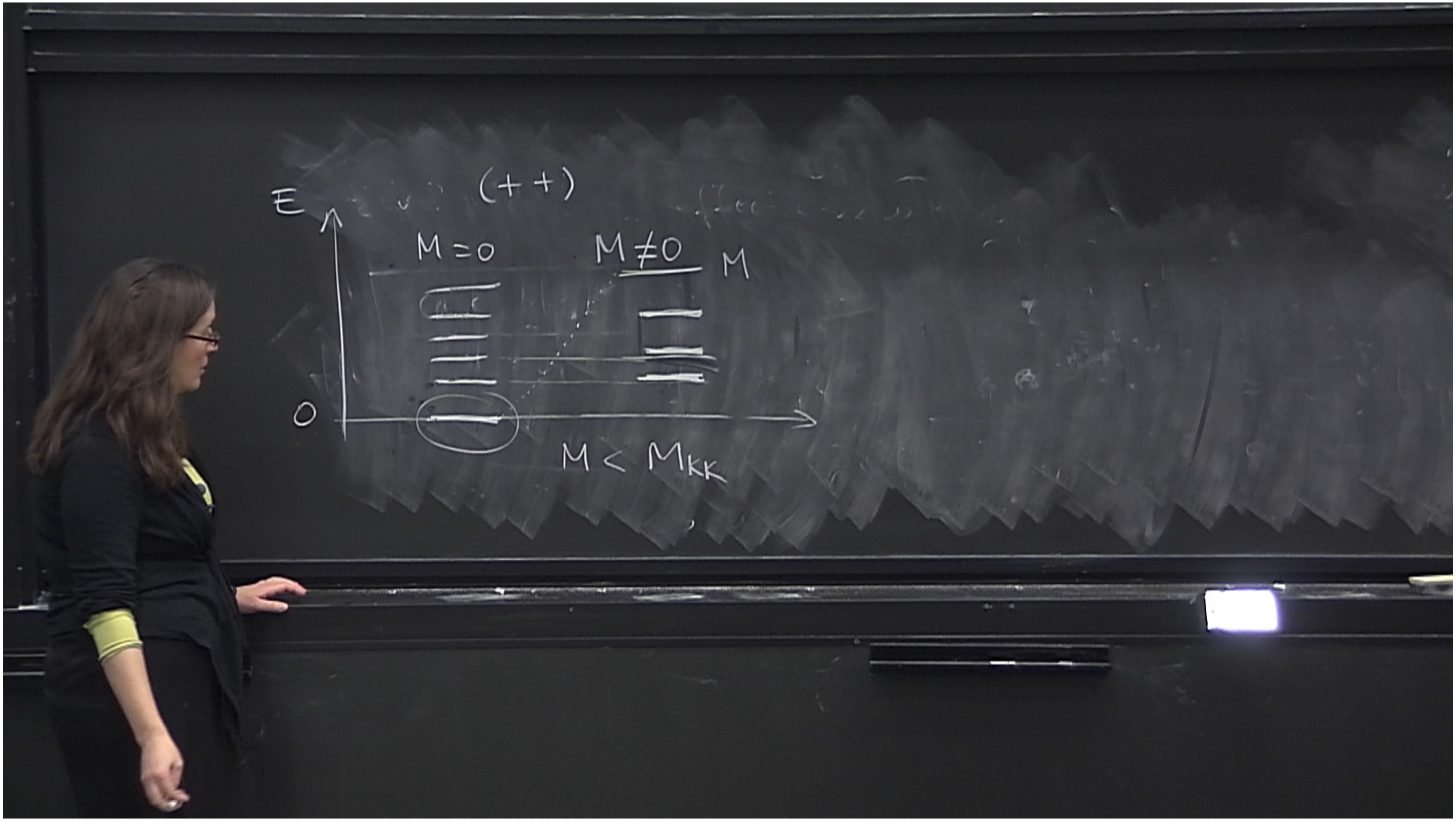
IR BCs

$(-)\quad f_0\big|_{IR} = 0 \longrightarrow \text{no sols} \rightarrow f_0 = 0$

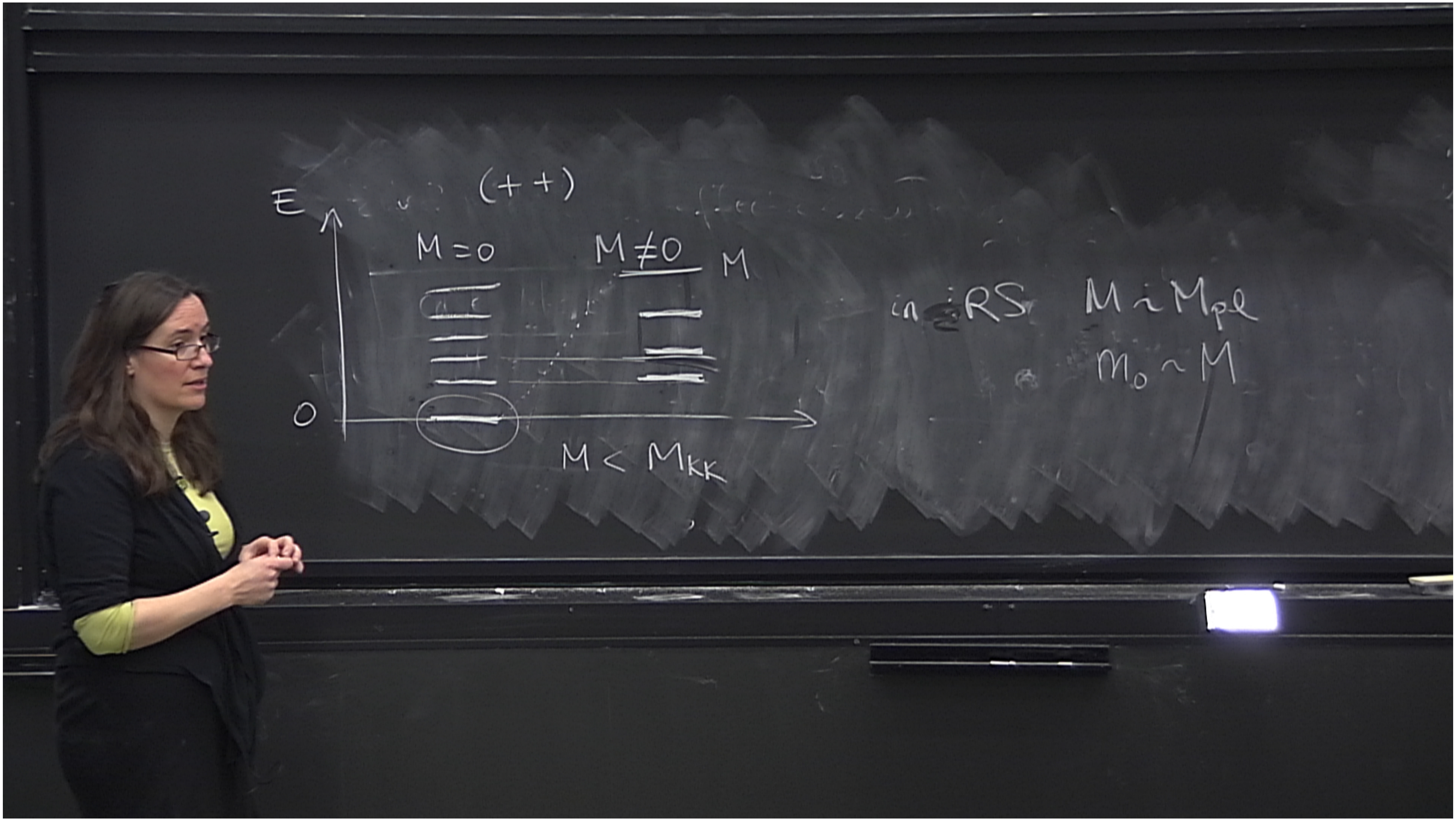
$(+)\quad f_0'\big|_{IR} \propto e^{2ky}\left(\alpha \begin{matrix}\cosh \\ \sinh\end{matrix} + \begin{matrix}\sinh \\ \cosh\end{matrix}\right)$

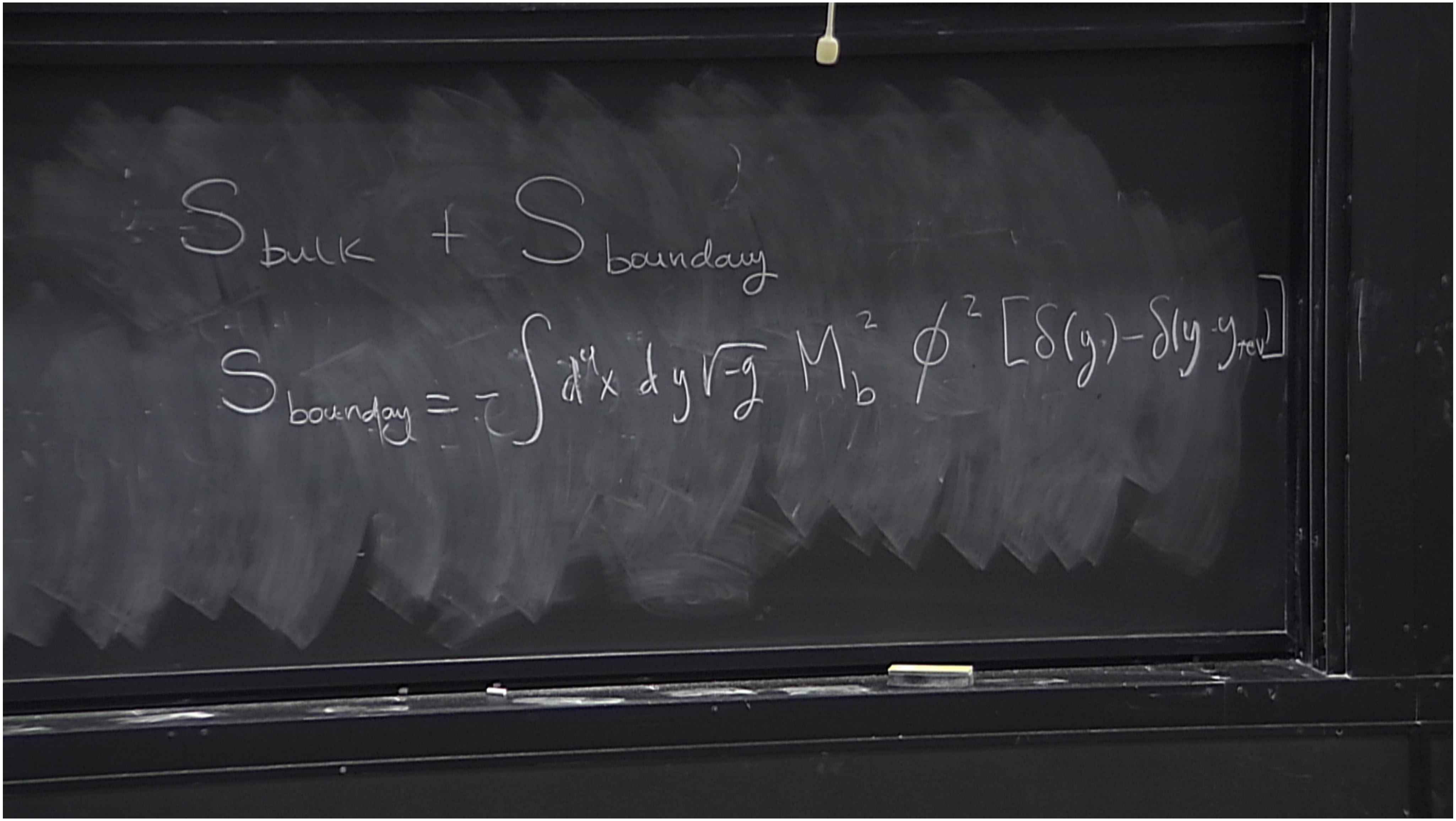
$\qquad\qquad\qquad\qquad > 0 \qquad\qquad > 0$

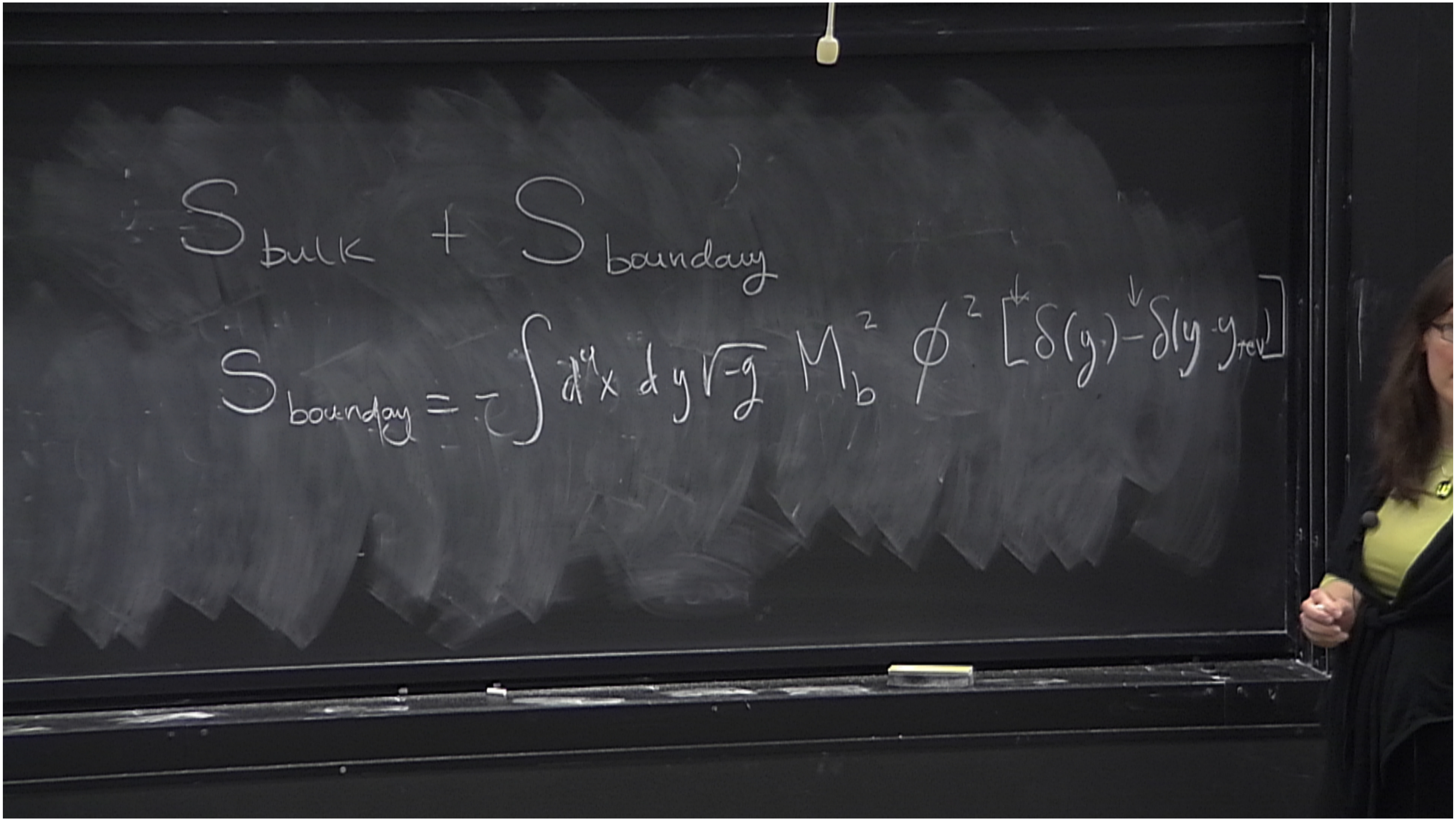

no zero modes
w/ M ≠ 0
f0 = 0
sinh
cosh
+
sinh
cosh
→ f0 = 0
>0

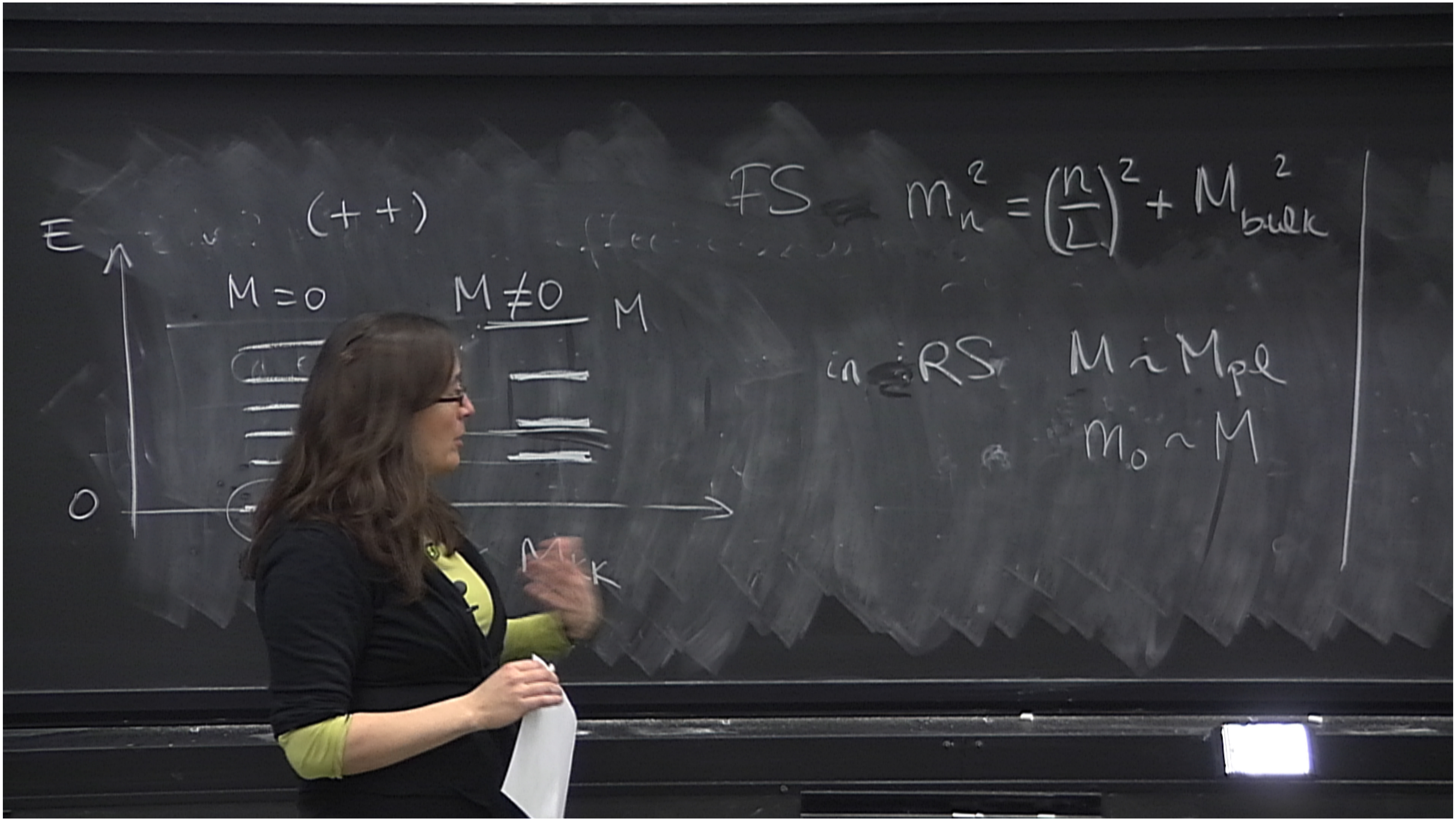


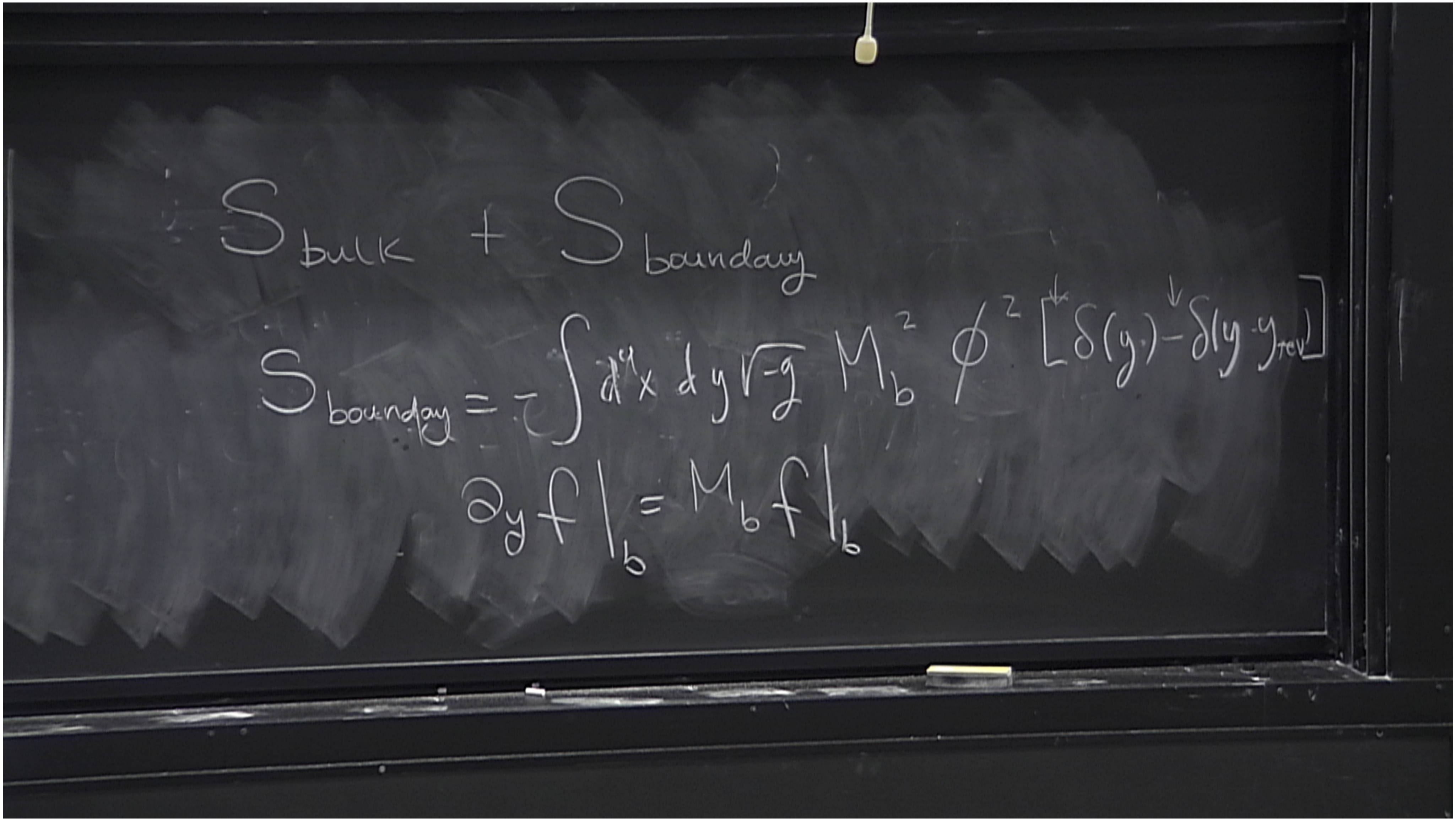
E
(+ +)
M = 0
M ≠ 0
M
0
M < M_KK

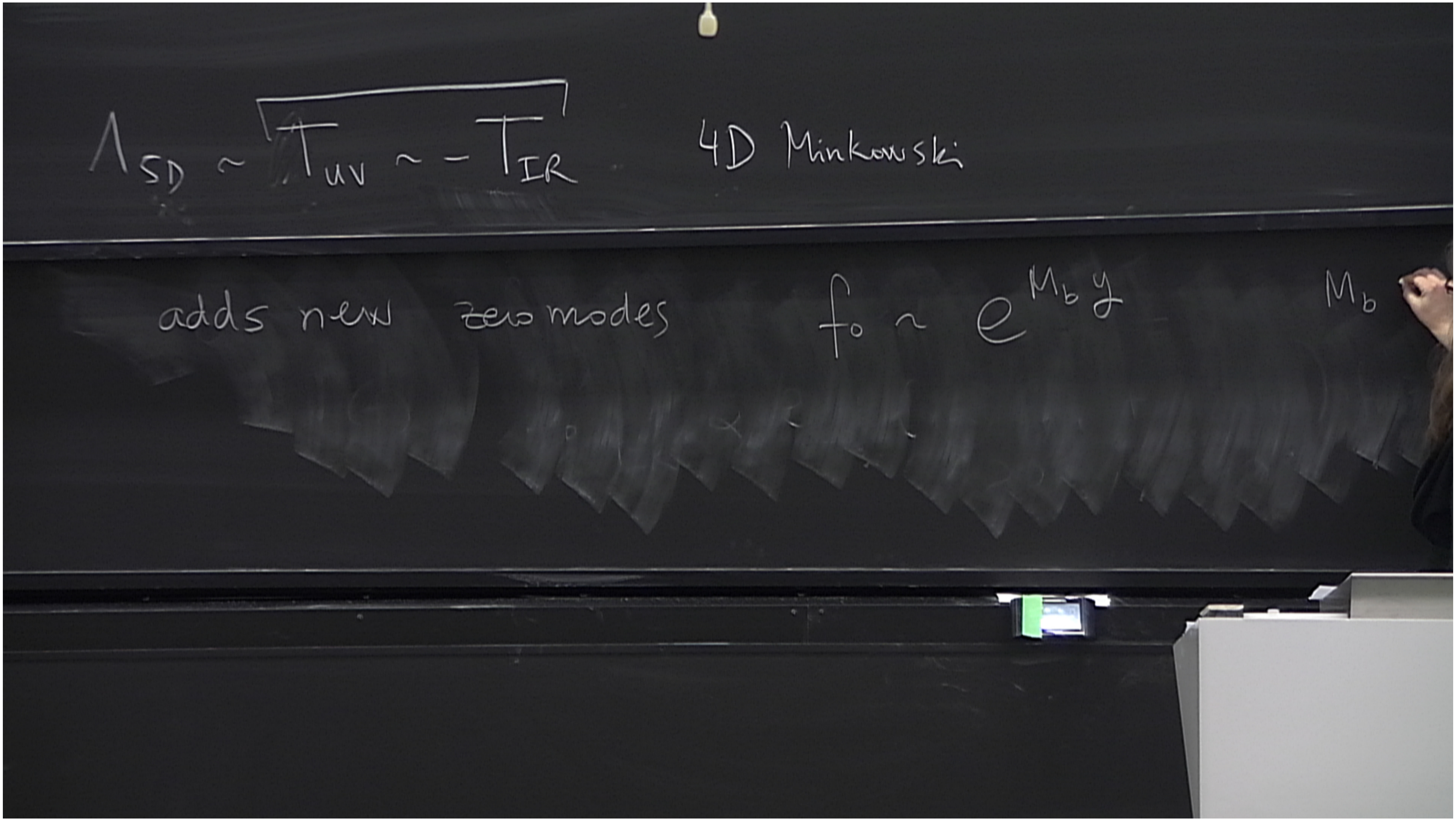

E
(+ +)
M = 0
M ≠ 0
M
0
M < M_KK
in RS
M ~ M_pl
m_0 ~ M

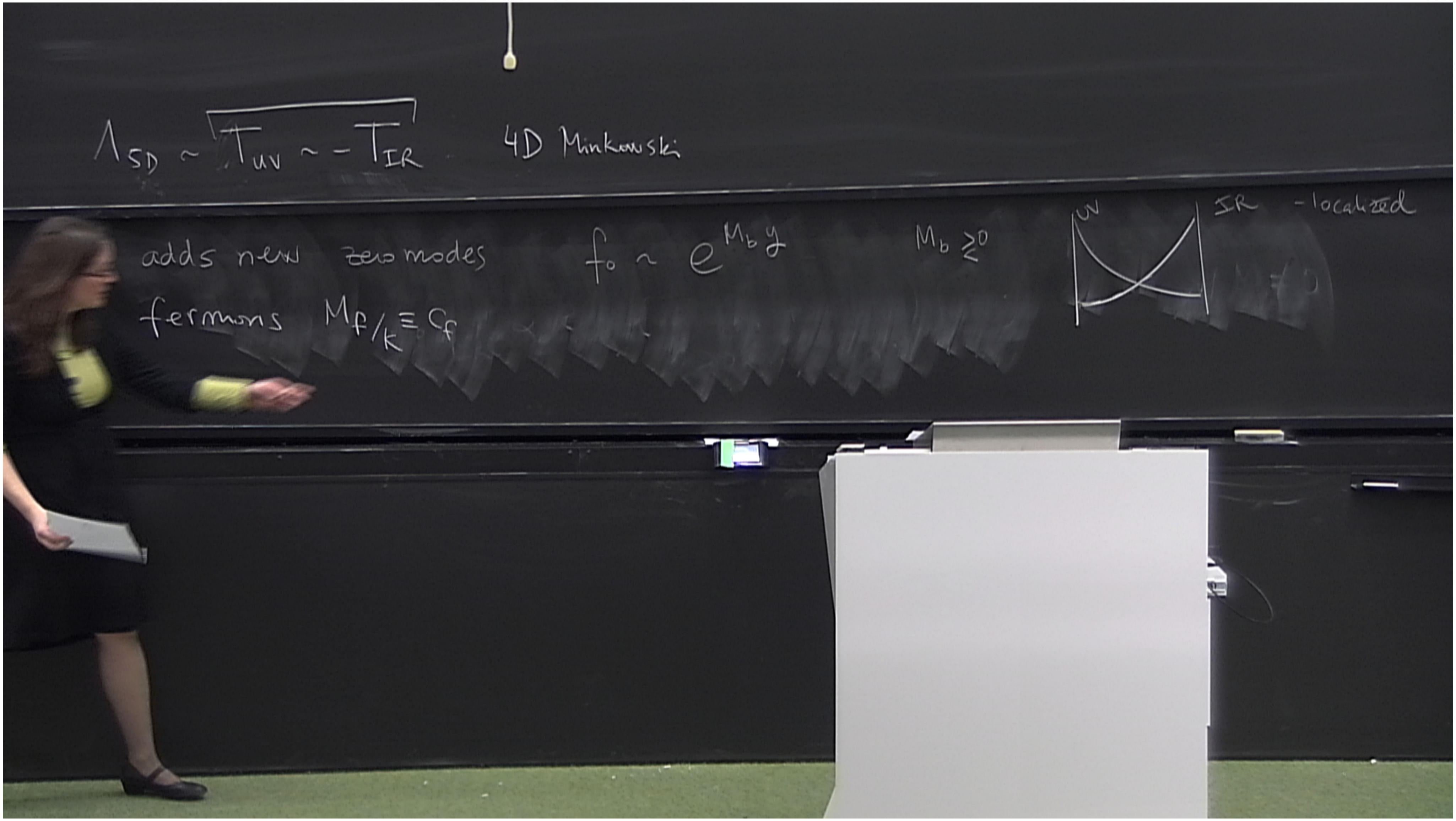

$S_{bulk} + S_{boundary}$
$S_{boundary} = -\int d^4x \, dy \sqrt{-g} \, M_b^2 \, \phi^2 \, [\delta(y) - \delta(y - y_{TeV})]$

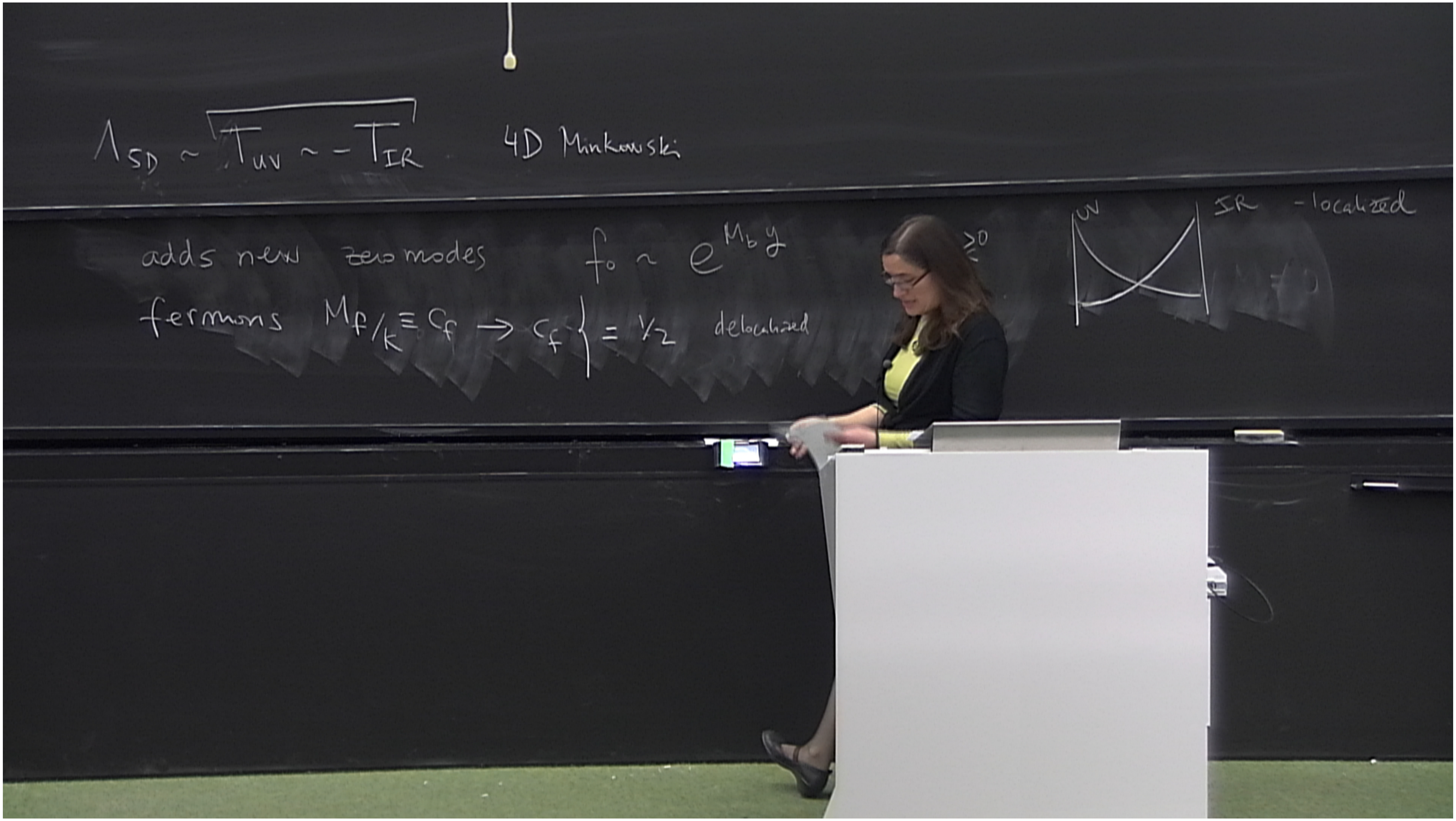

S bulk + S boundary
S boundary = -∫ d^4x dy √-g M_b^2 φ^2 [δ(y) - δ(y - y_TeV)]

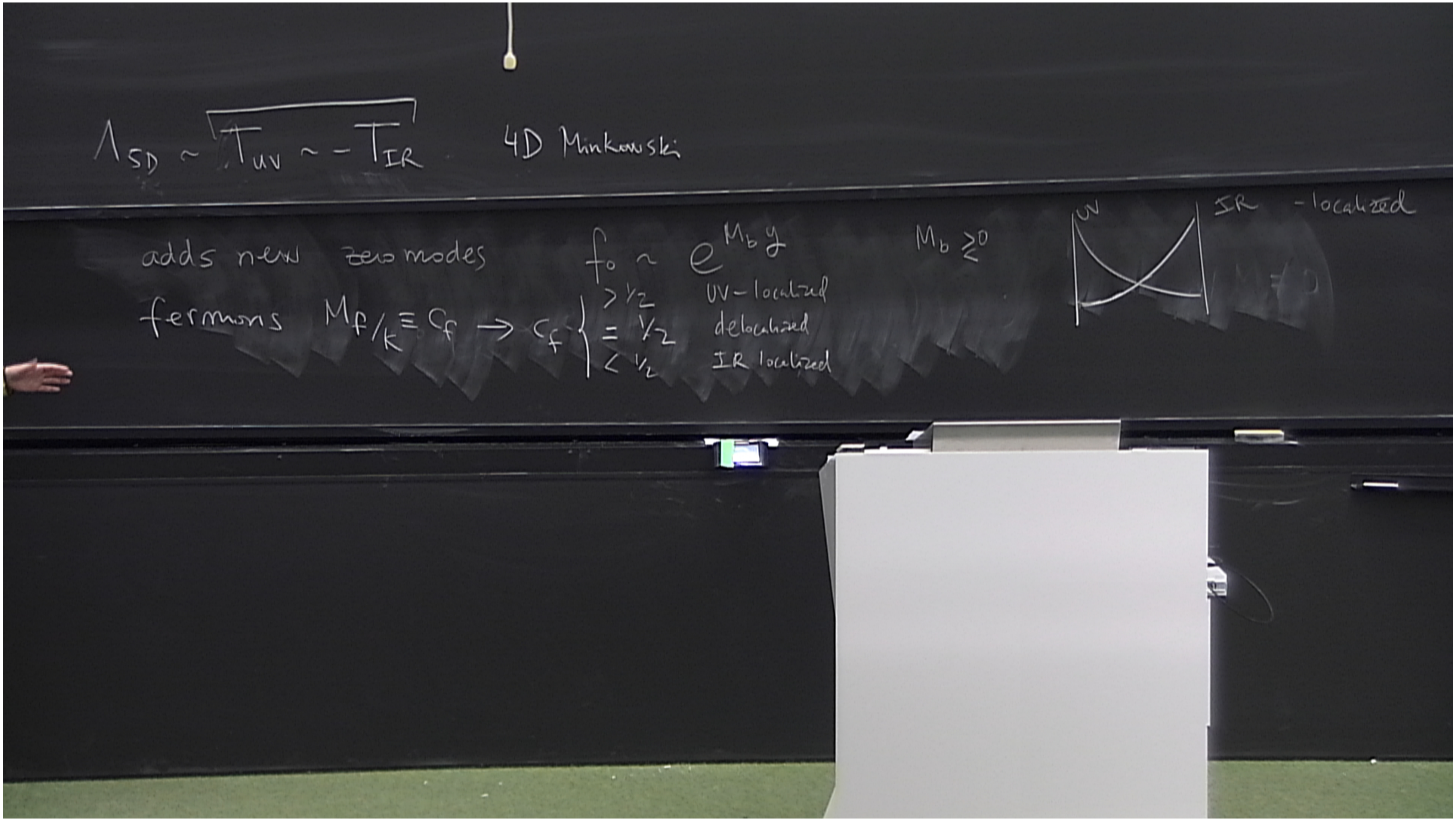

FS
$m_n^2 = \left(\frac{n}{L}\right)^2 + M_{bulk}^2$
E
(+ +)
M = 0
M ≠ 0
M
0
in RS
M ~ M_pl
m_0 ~ M

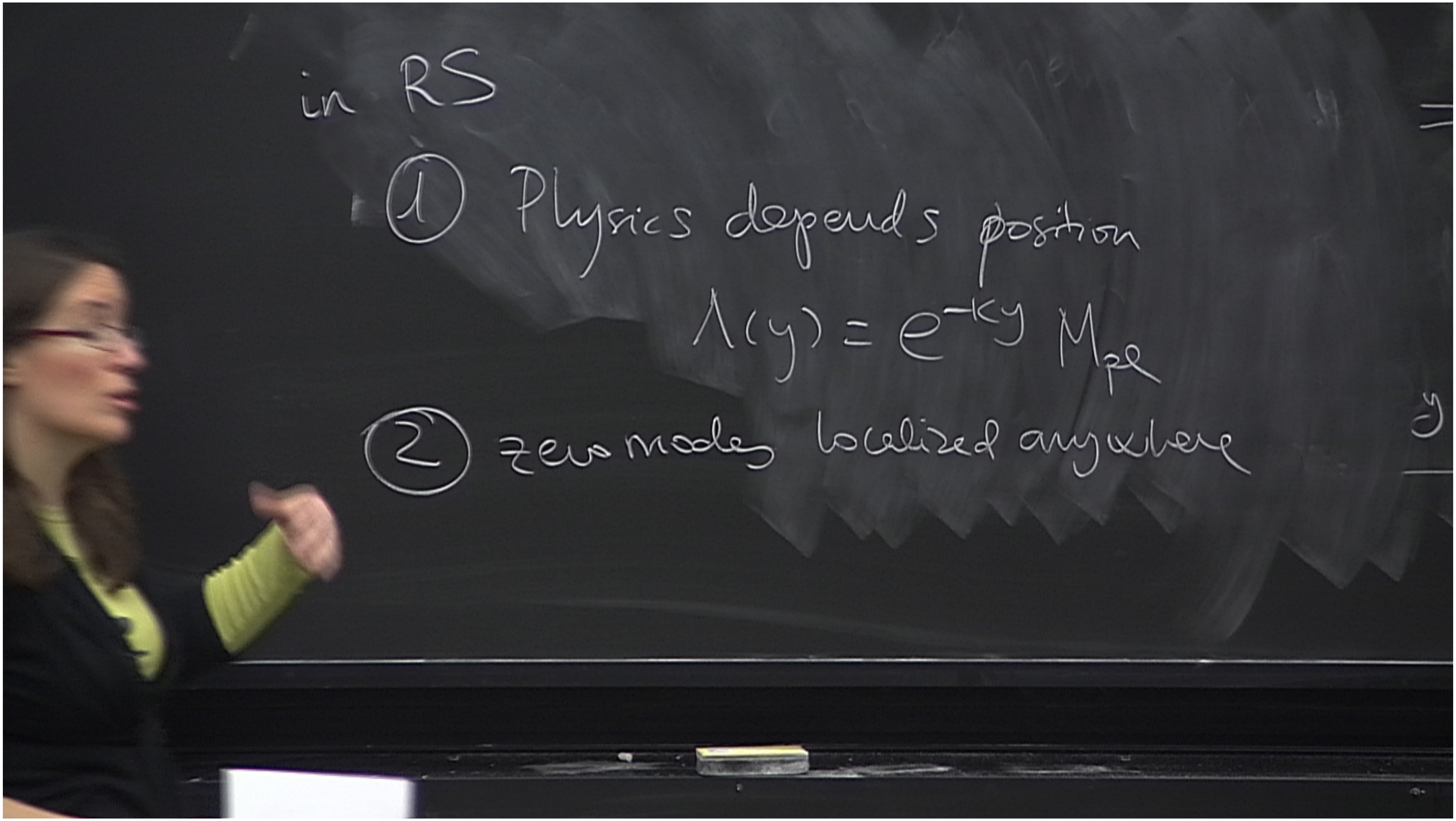

$S_{bulk} + S_{boundary}$
$S_{boundary} = -\int d^4x \, dy \sqrt{-g} \, M_b^2 \phi^2 [\delta(y) - \delta(y - y_{TeV})]$
$\partial_y f|_b = M_b f|_b$

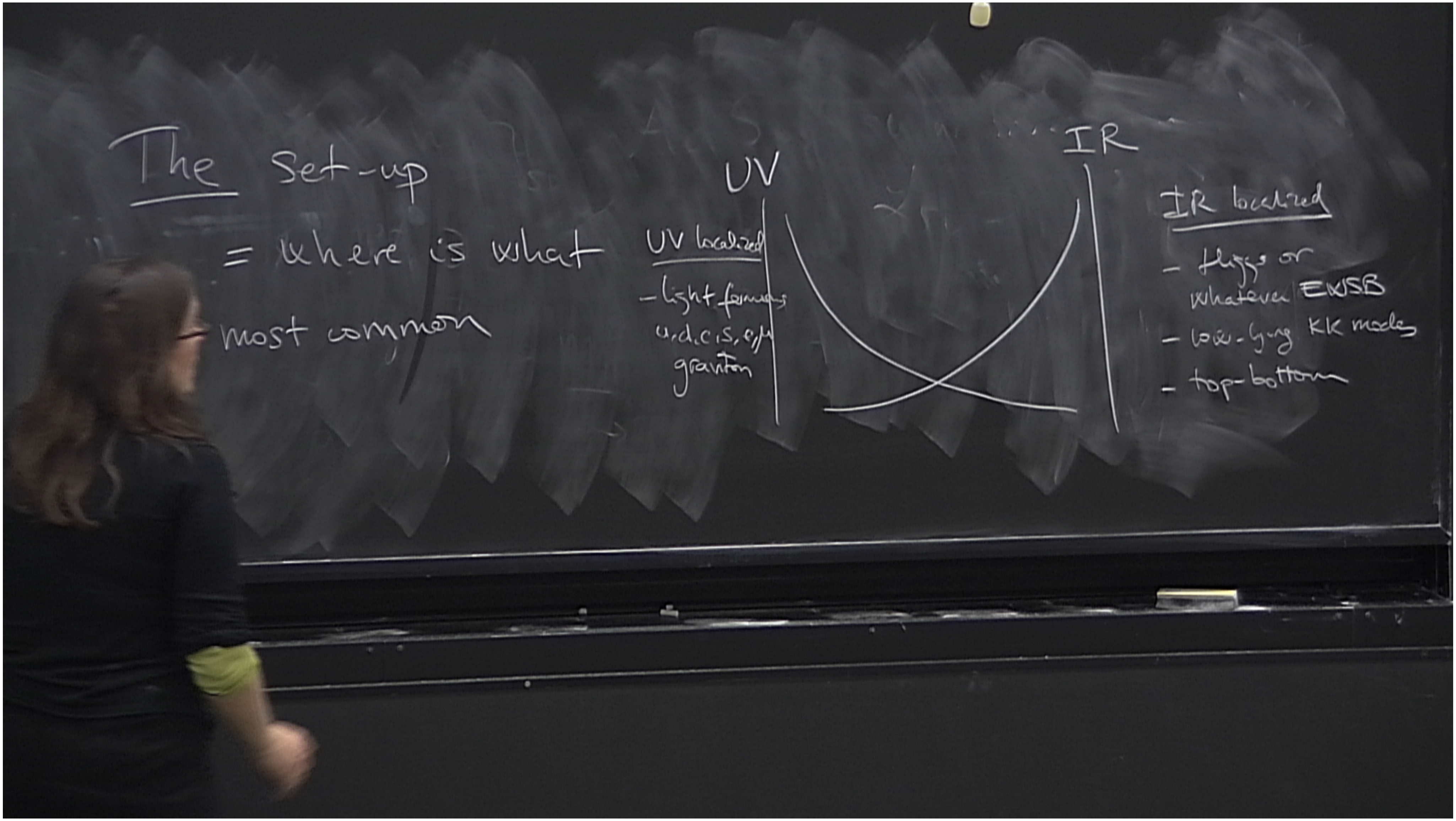

$\Lambda_{5D} \sim \sqrt{T_{UV} \sim -T_{IR}}$
4D Minkowski
adds new zero modes
$f_0 \sim e^{M_b y}$
$M_b$

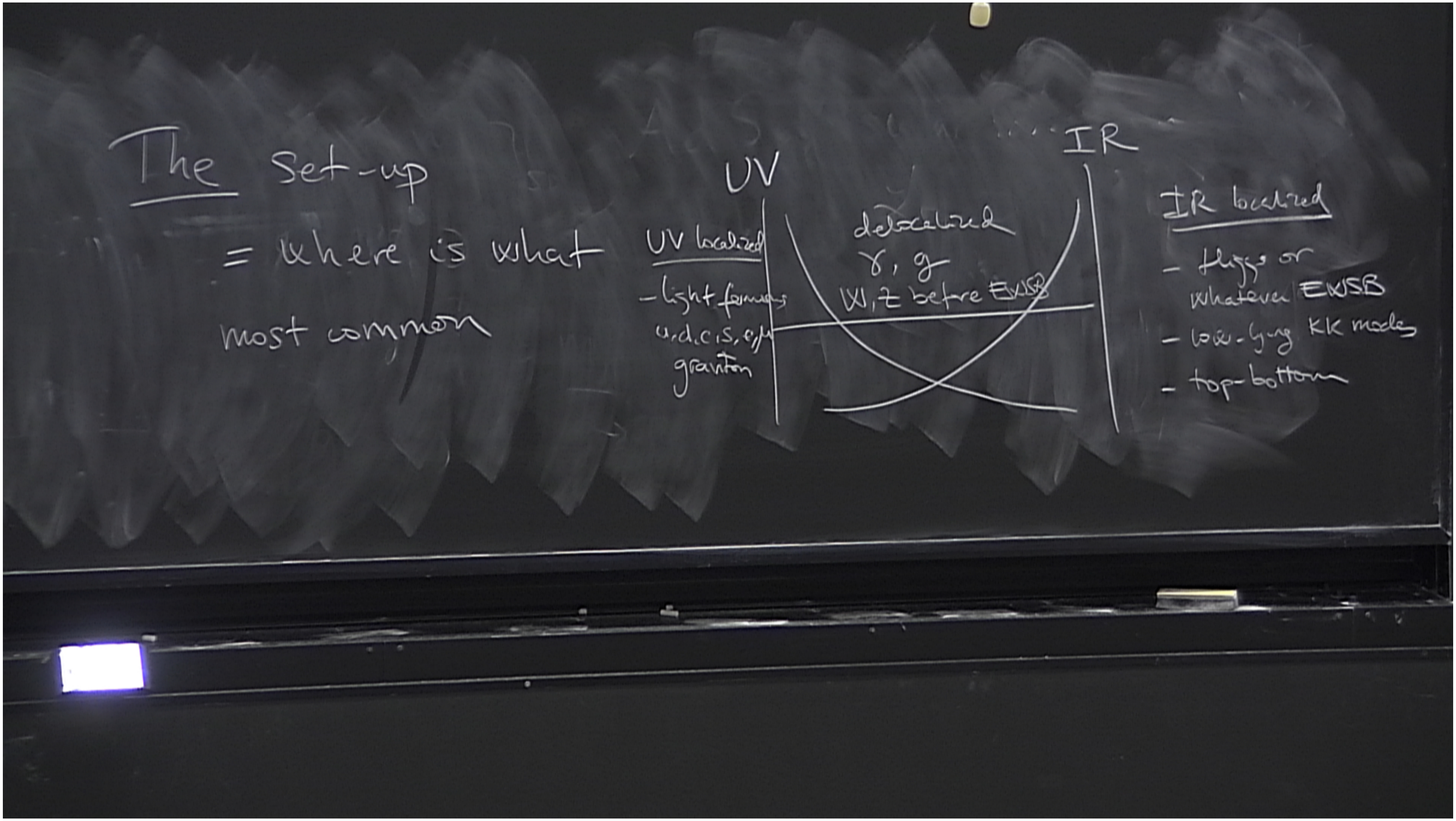

Λ5D ~ TUV ~ - TIR   4D Minkowski
adds new zero modes   f0 ~ e^(Mb y)   Mb ≥ ≤ 0
UV   IR -localized
fermions   Mf/k ≡ cf

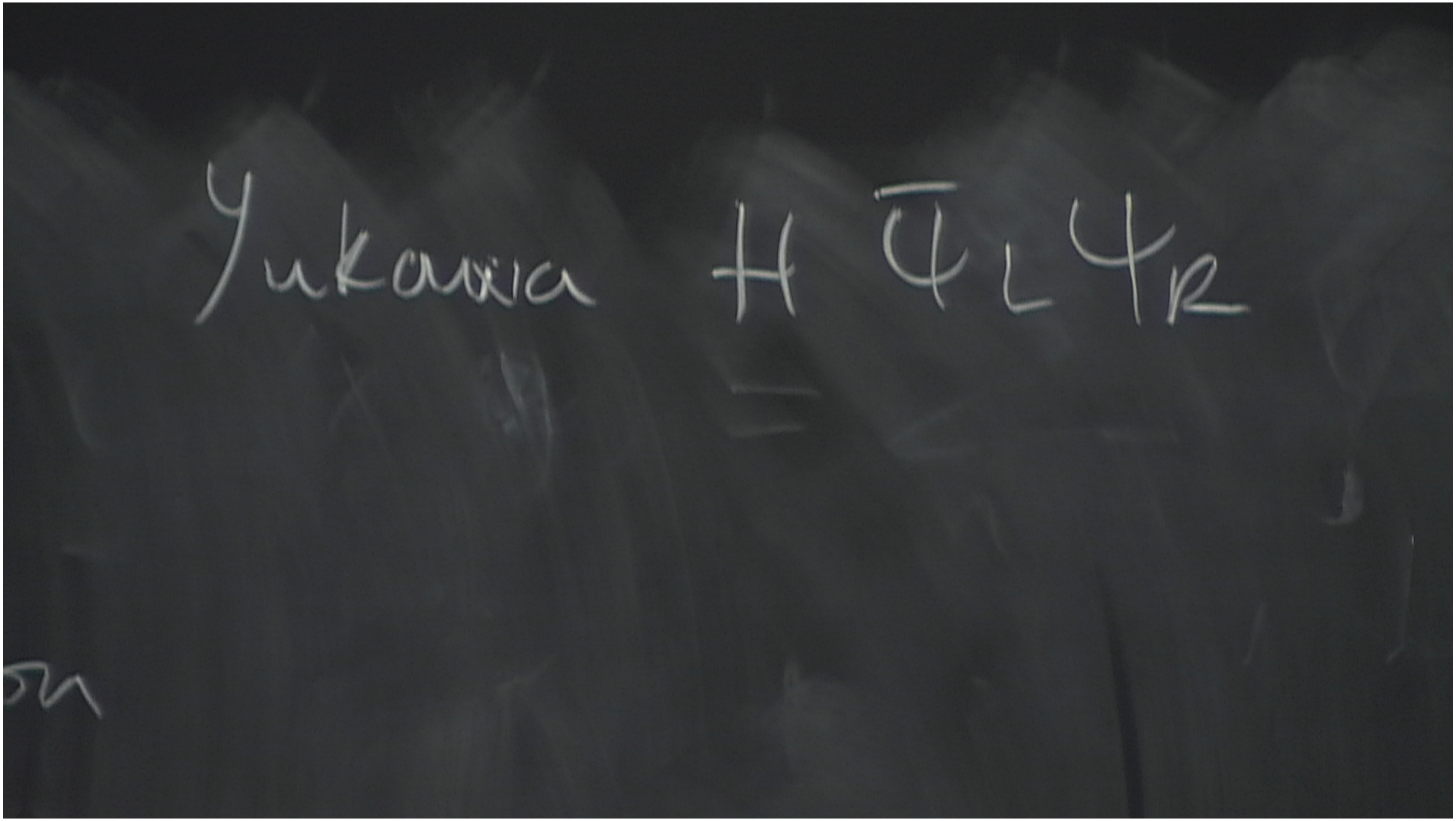

Λ5D ~ TUV ~ - TIR
4D Minkowski
UV
IR
- localized
adds new zero modes
f0 ~ e^Mb y
fermions Mf/k ≡ cf → cf { = 1/2 delocalized

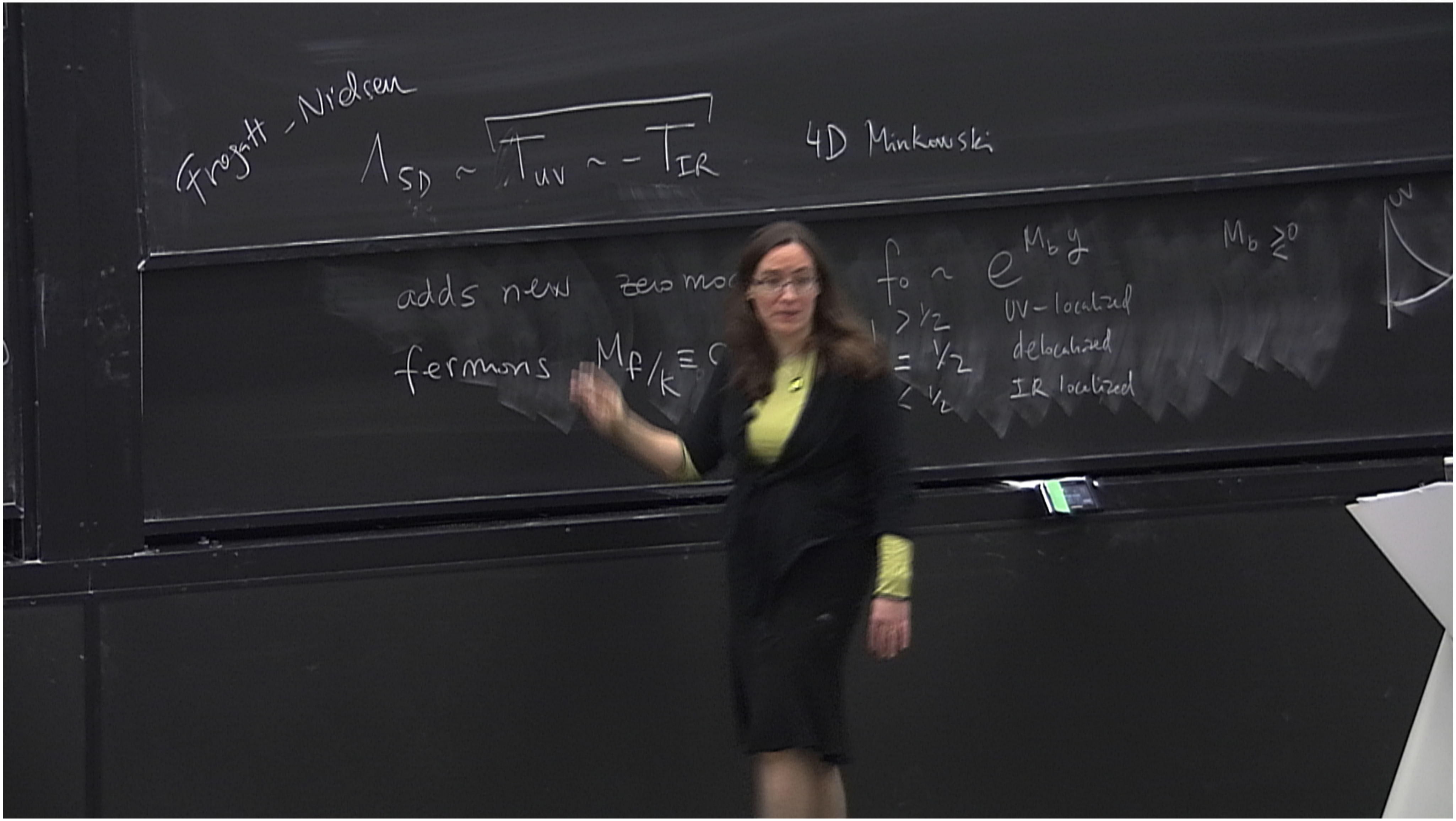

Λ5D ~ √(TUV ~ - TIR)
4D Minkowski
adds new zero modes
f0 ~ e^(Mb y)
Mb ≷ 0
UV
IR
- localized
fermions Mf/k ≡ cf → cf { > 1/2 UV-localized
= 1/2 delocalized
< 1/2 IR localized


in RS
① Physics depends position
Λ(y) = e^{-ky} M_pl
② zero modes localized anywhere


The Set-up
= where is what
most common
UV
IR
UV localized
- light fermions
u,d,c,s,e,μ
graviton
IR localized
- Higgs or
whatever EWSB
- low-lying KK modes
- top-bottom


The Set-up
= where is what
most common
UV
IR
UV localized
- light fermions
u,d,c,s,e,μ
graviton
delocalized
γ, g
W, Z before EWSB
IR localized
- Higgs or
whatever EWSB
- low-lying KK modes
- top-bottom


Yukawa H $\bar{\psi}_L \psi_R$
on


Froggatt - Nielsen
Λ5D ~ TUV ~ - TIR
4D Minkowski
adds new zero mo
fermions Mf/k ≡
f0 ~ e^{Mb y}
Mb ≷ 0
> 1/2 UV-localized
= 1/2 delocalized
< 1/2 IR localized
UV