Title: Particle Physics Lecture - 230301

Speakers: Asimina Arvanitaki

Collection: Particle Physics (2022/2023)

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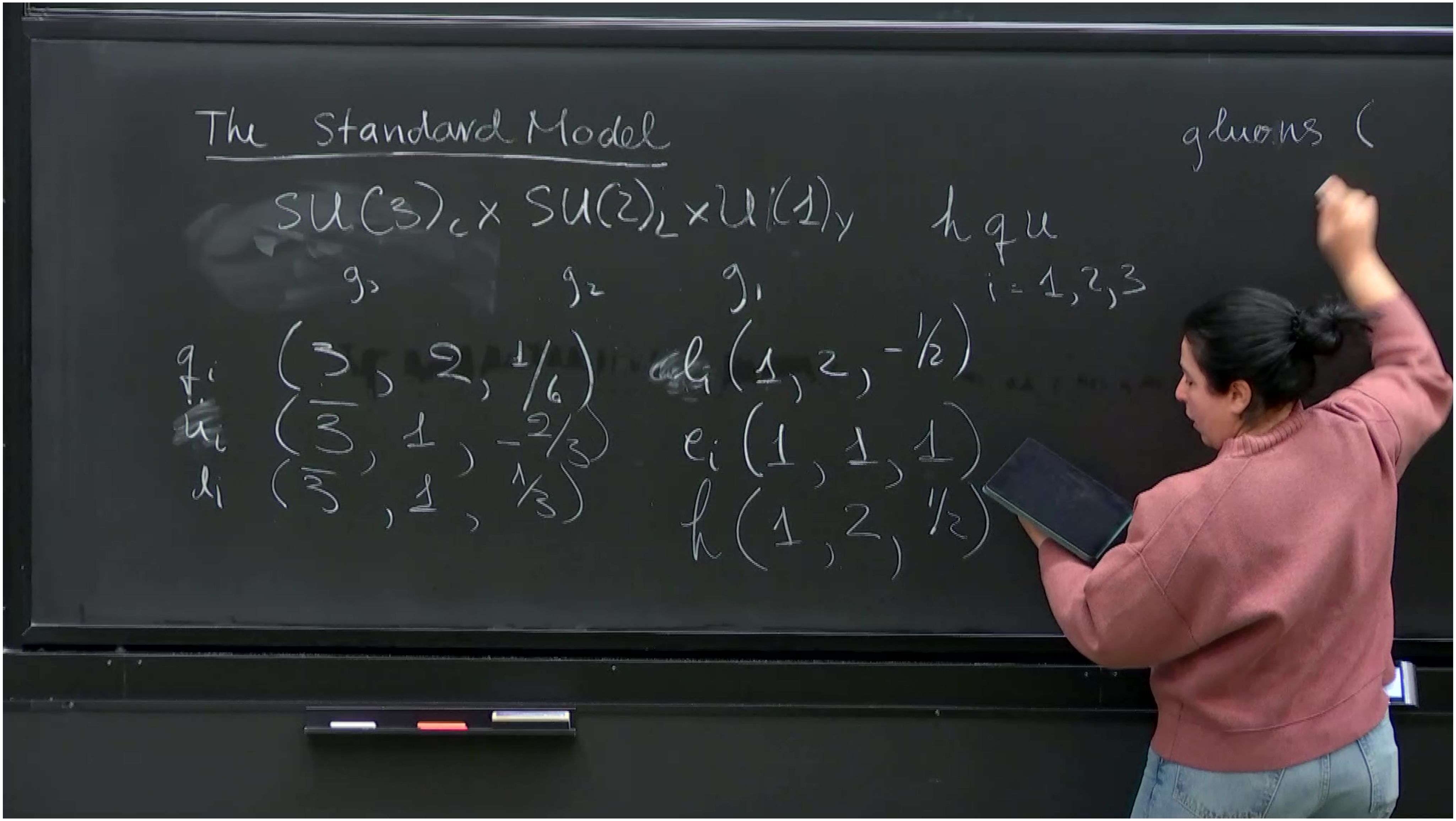

The Standard Model
SU(3)c × SU(2)L × U(1)Y
h q u
g3 g2 g1
i = 1,2,3
qi (3, 2, 1/6)
ui (3̄, 1, -2/3)
di (3̄, 1, 1/3)
li (1, 2, -1/2)
ei (1, 1, 1)
h (1, 2, 1/2)
gluons (

$1)_Y$ $\quad h\, q\, u$

$i = 1,2,3$

$2, -\frac{1}{2})$

$, \underline{1}, 1)$

$, 2, \frac{1}{2})$

$,)$

gluons $(8, \underline{1}, 0)$

$W_{1,2,3}$ $(1, 3, 0)$

B $(1, 1, 0)$

$m_u = 2$ MeV $\qquad m_e = 0.5$ MeV

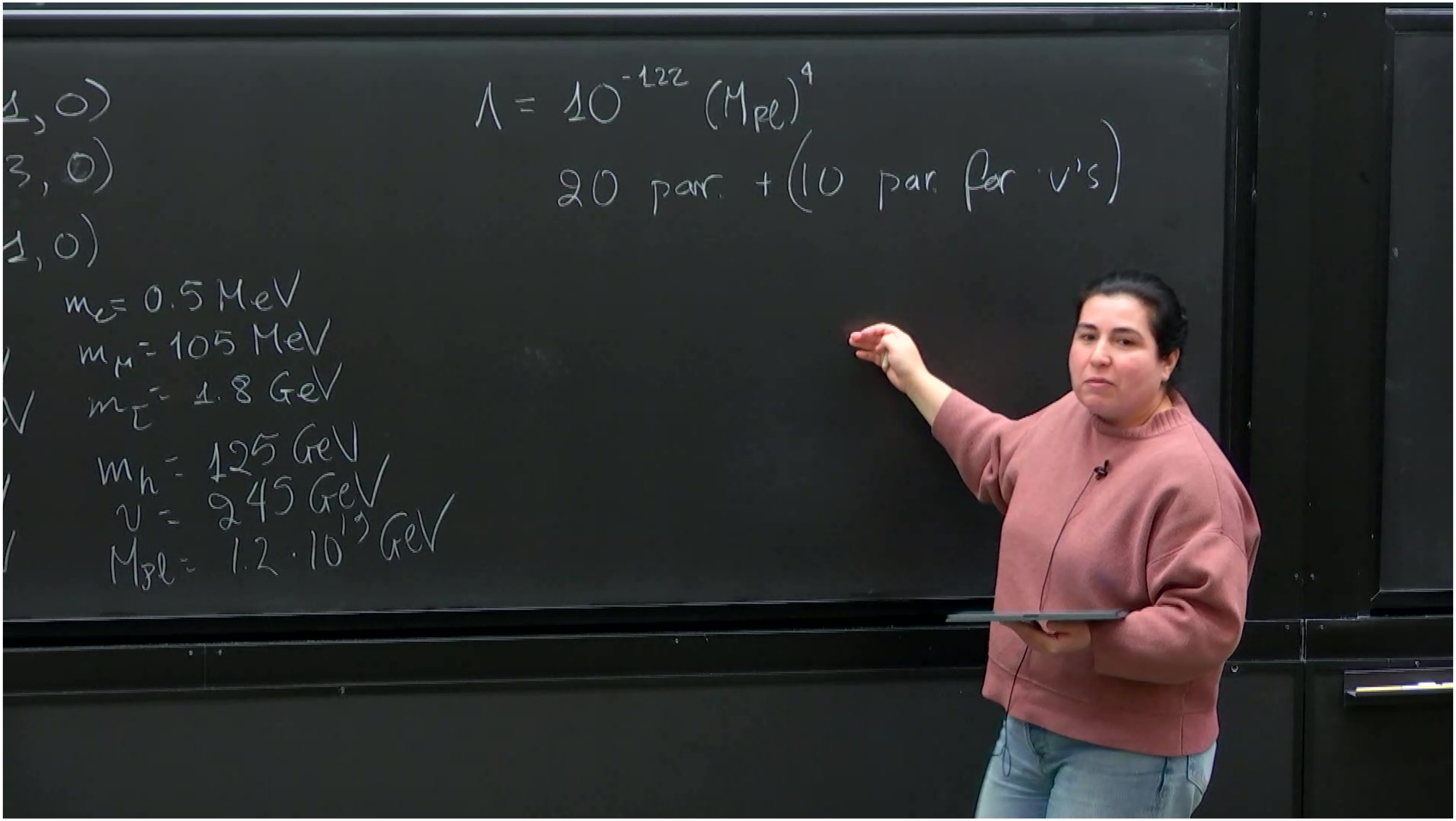
$m_c = 1.3$ GeV $\qquad m_\mu = 105$ MeV

$m_t = 173$ GeV $\qquad m_\tau = 1.8$ GeV

$m_d = 5$ MeV

$m_s = 96$ MeV

$m_b = 4.2$ GeV


Λ = 10^-122 (M_Pl)^4
20 par. + (10 par. for ν's)
m_e = 0.5 MeV
m_μ = 105 MeV
m_τ = 1.8 GeV
m_h = 125 GeV
v = 245 GeV
M_Pl = 1.2 · 10^19 GeV

$1, 0)$

$3, 0)$

$1, 0)$

$m_e = 0.5$ MeV

$m_\mu = 105$ MeV

$m_\tau = 1.8$ GeV

$m_h = 125$ GeV

$v = 245$ GeV

$M_{Pl} = 1.2 \cdot 10^{19}$ GeV

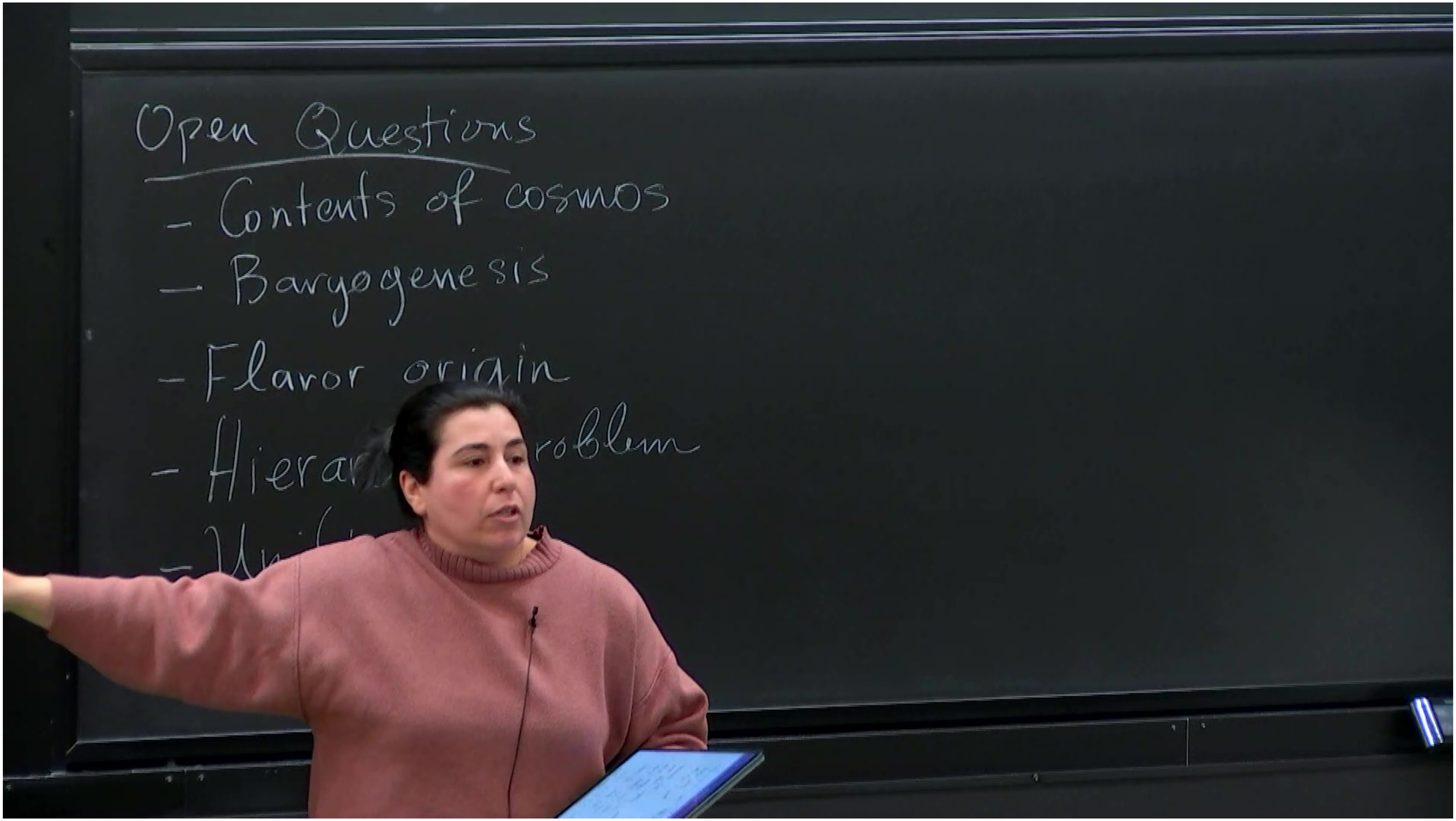
$\Lambda = 10^{-122} (M_{Pl})^4$

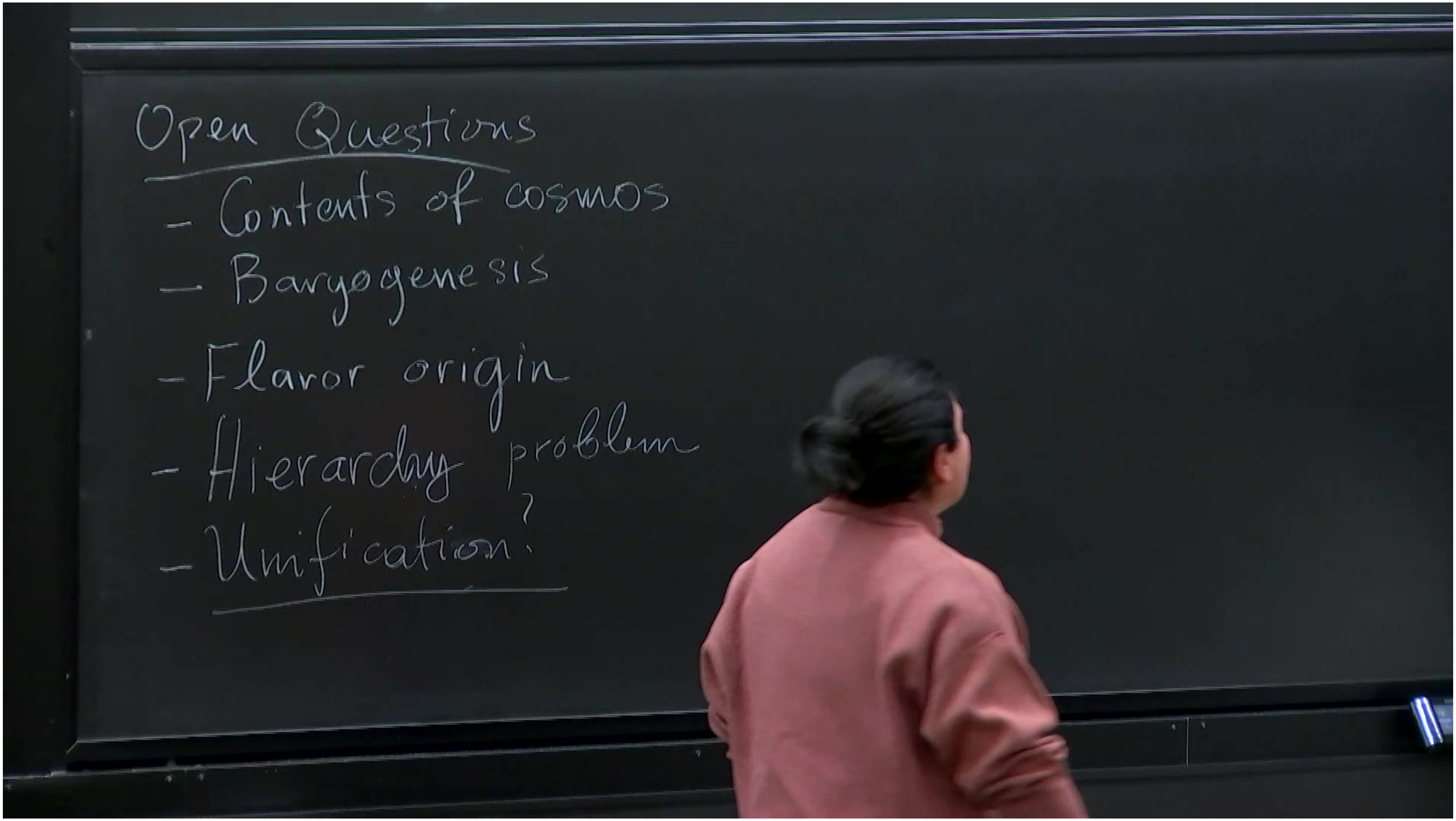
20 par. + (10 par. for ν's)

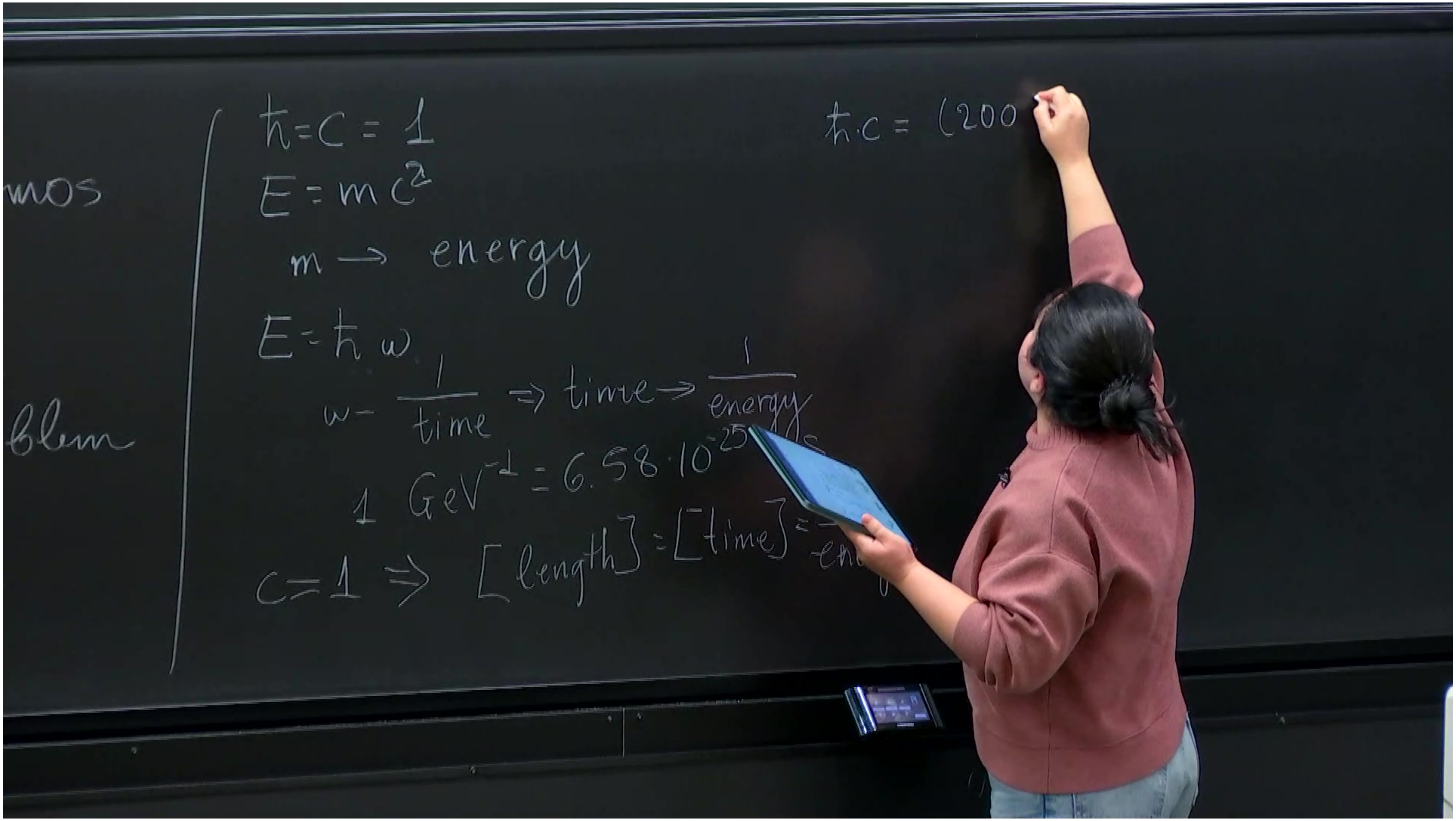
5% of energy budget

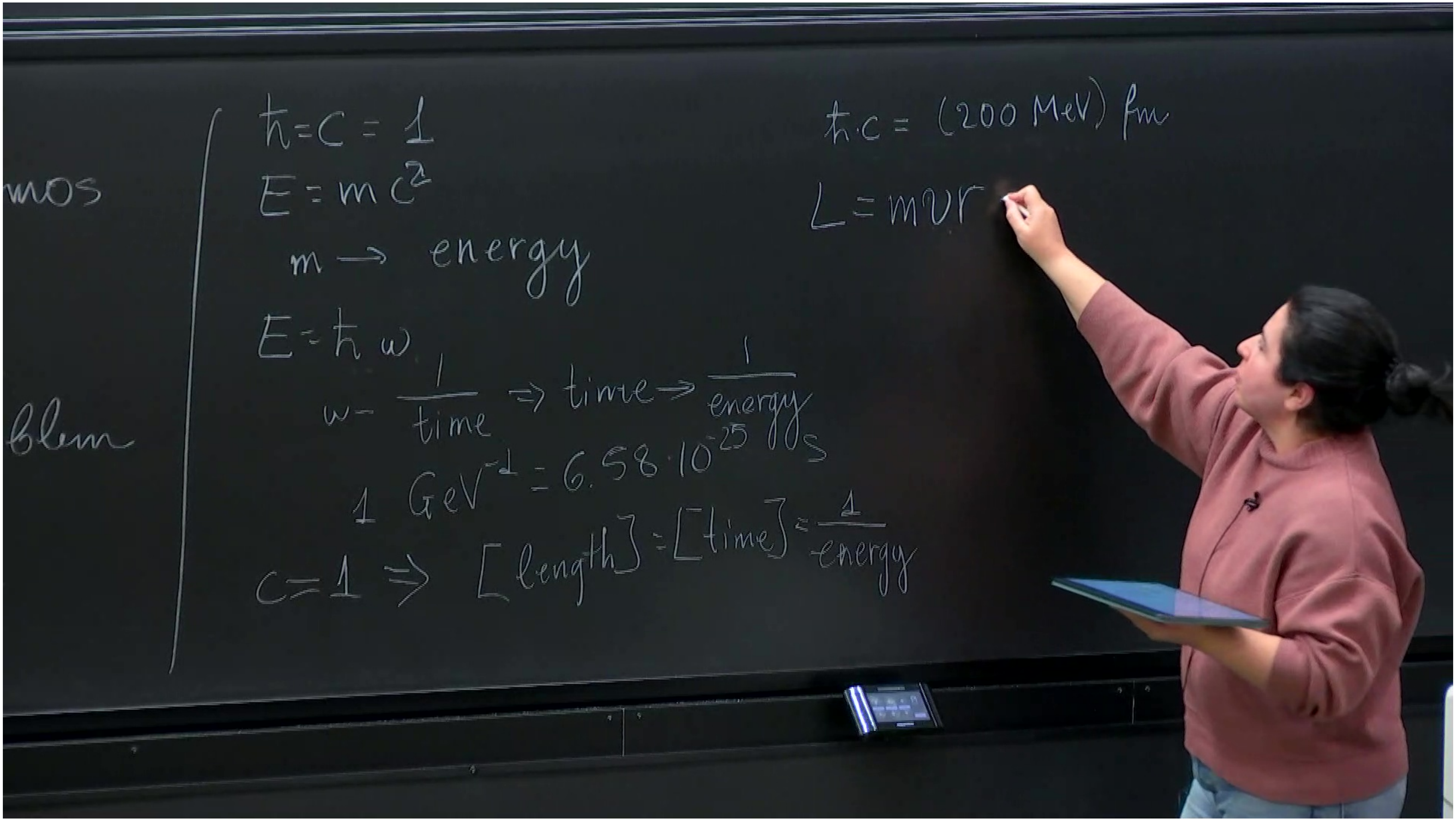
25% Dark Matter (?)

$\sim 70\%$ Λ (?)

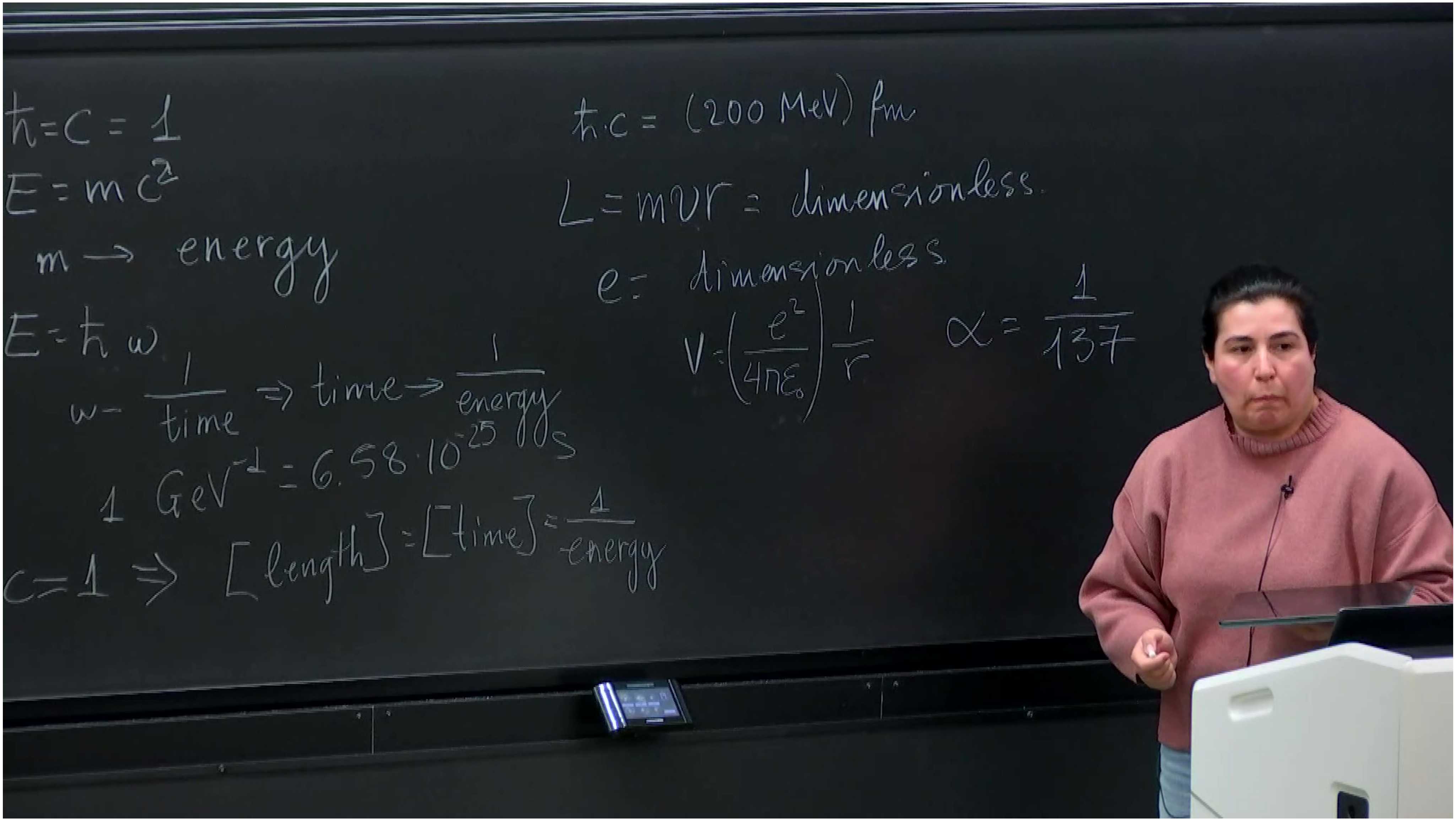

Open Questions
- Contents of cosmos
- Baryogenesis
- Flavor origin

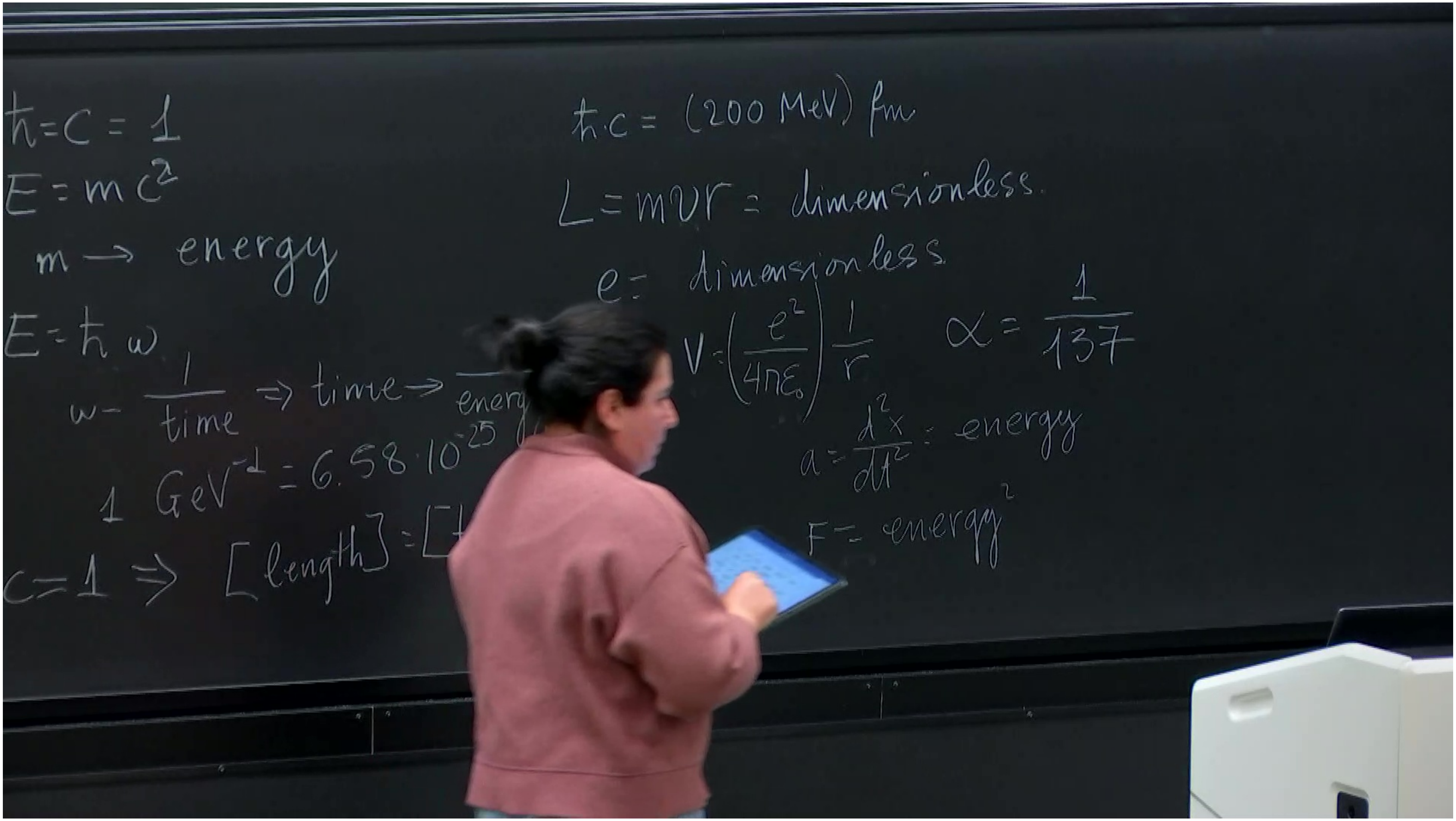

Open Questions
- Contents of cosmos
- Baryogenesis
- Flavor origin
- Hierarchy problem
- Unification?


ħ=c=1
E=mc²
m → energy
E=ħω
ω ~ 1/time ⇒ time → 1/energy
1 GeV⁻¹ = 6.58·10⁻²⁵
c=1 ⇒ [length] = [time] =
ħ·c = (200



mos
blem
ħ = c = 1
E = mc²
m → energy
E = ħω
ω ~ 1/time ⇒ time → 1/energy
1 GeV⁻¹ = 6.58·10⁻²⁵ s
c = 1 ⇒ [length] = [time] = 1/energy
ħ·c = (200 MeV) fm
L = mvr

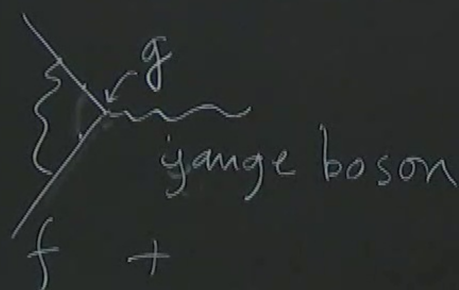

$\hbar = c = 1$
$E = mc^2$
$m \longrightarrow$ energy
$E = \hbar\omega$
$\omega \sim \frac{1}{\text{time}} \Rightarrow \text{time} \rightarrow \frac{1}{\text{energy}}$
$1\ \text{GeV}^{-1} = 6.58 \cdot 10^{-25}\ \text{s}$
$c = 1 \Rightarrow [\text{length}] = [\text{time}] = \frac{1}{\text{energy}}$
$\hbar \cdot c = (200\ \text{MeV})\ \text{fm}$
$L = mvr =$ dimensionless.
$e =$ dimensionless.
$V = \left(\frac{e^2}{4\pi\varepsilon_0}\right)\frac{1}{r}$
$\alpha = \frac{1}{137}$


ħ = c = 1
E = mc²
m → energy
E = ħω
ω ~ 1/time ⇒ time → 1/energ
1 GeV⁻¹ = 6.58·10⁻²⁵
c = 1 ⇒ [length] = [t
ħ·c = (200 MeV) fm
L = mvr = dimensionless
e = dimensionless
V = (e²/4πε₀) 1/r
α = 1/137
a = d²x/dt² = energy
F = energy²

Georgi & Glashow (1974)

$$SU(3_c) \times SU(2)_L \times U(1)_Y \to SU(5)$$

$$g_3 \qquad g_2 \qquad g_1 \qquad g_5$$



$+ \; \ldots$

$$\mu \frac{dg(\mu)}{d\mu} = \frac{b_0 g^3}{16\pi^2}$$

$$t = \ln \mu \qquad x = \frac{16\pi^2}{g^2} = \frac{4\pi}{\alpha}$$

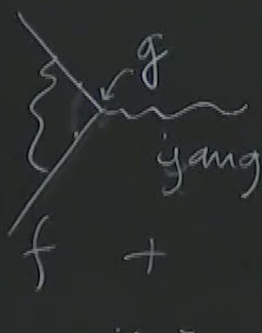
$$\frac{dx}{dt} = -2 b_0$$

$$x(t) = x(0) - 2 b_0 t$$

Georgi & Glashow (1974)

$$SU(3_c)\times SU(2)_L\times U(1)_Y \to SU(5)$$

$$g_3 \qquad g_2 \qquad g_1 \qquad g_5$$



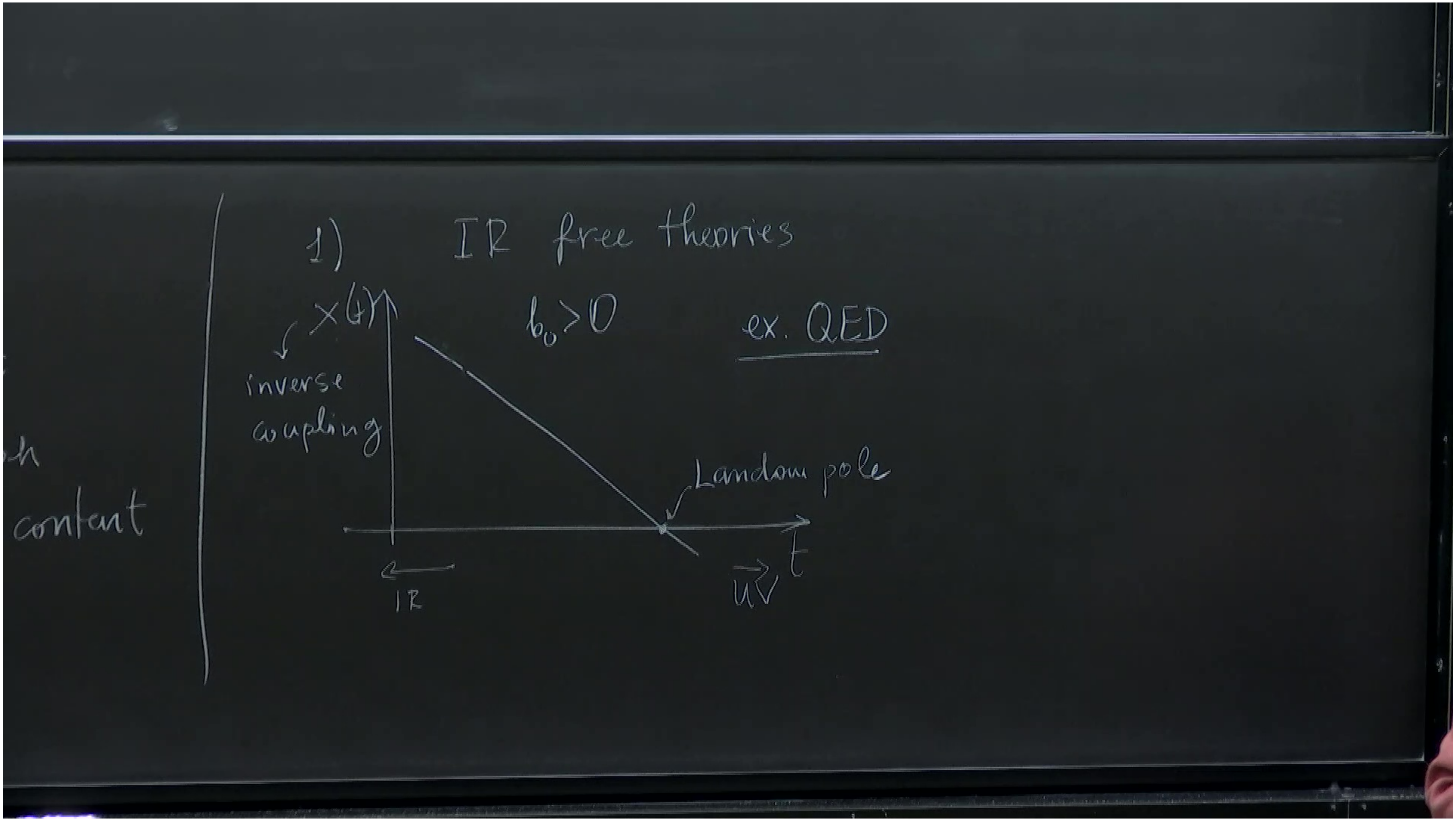
$$\mu \frac{dg(\mu)}{d\mu} = \frac{b_0 g^3}{16\pi^2}$$

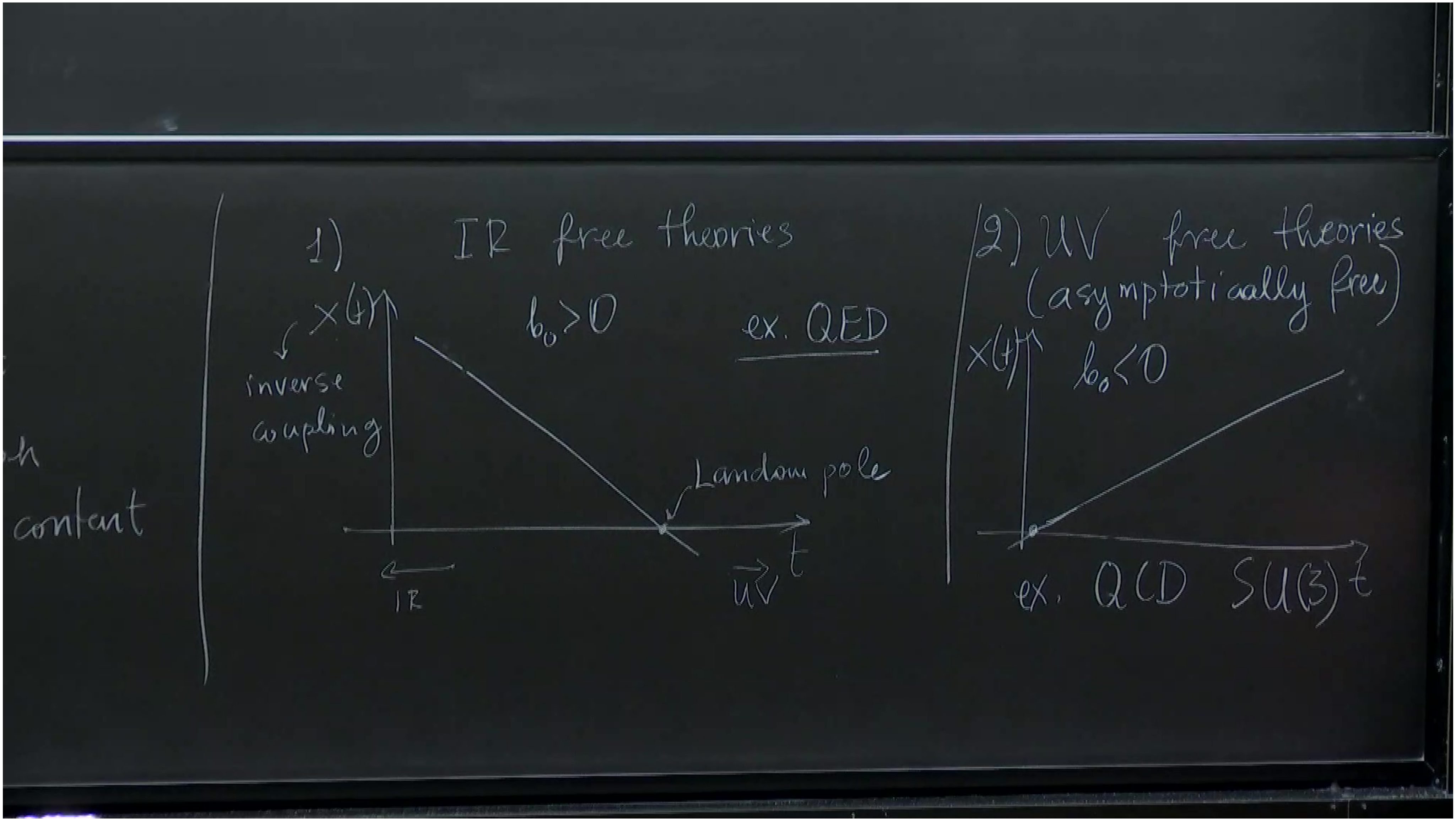
$$t = \ln\mu \qquad x = \frac{16\pi^2}{g^2} = \frac{4\pi}{\alpha}$$

$$\frac{dx}{dt} = -2b_0$$

$$x(t) = x(0) - 2b_0 t$$

b_0: depends on the particle content


1) IR free theories
$b_0 > 0$
ex. QED
$x(t)$
inverse coupling
Landau pole
t
IR
UV
content


1) IR free theories
x(t)
inverse coupling
b0>0
ex. QED
Landau pole
IR
UV
t
2) UV free theories
(asymptotically free)
x(t)
b0<0
t
ex. QCD SU(3)
content

SU(N) pure Yang Mills

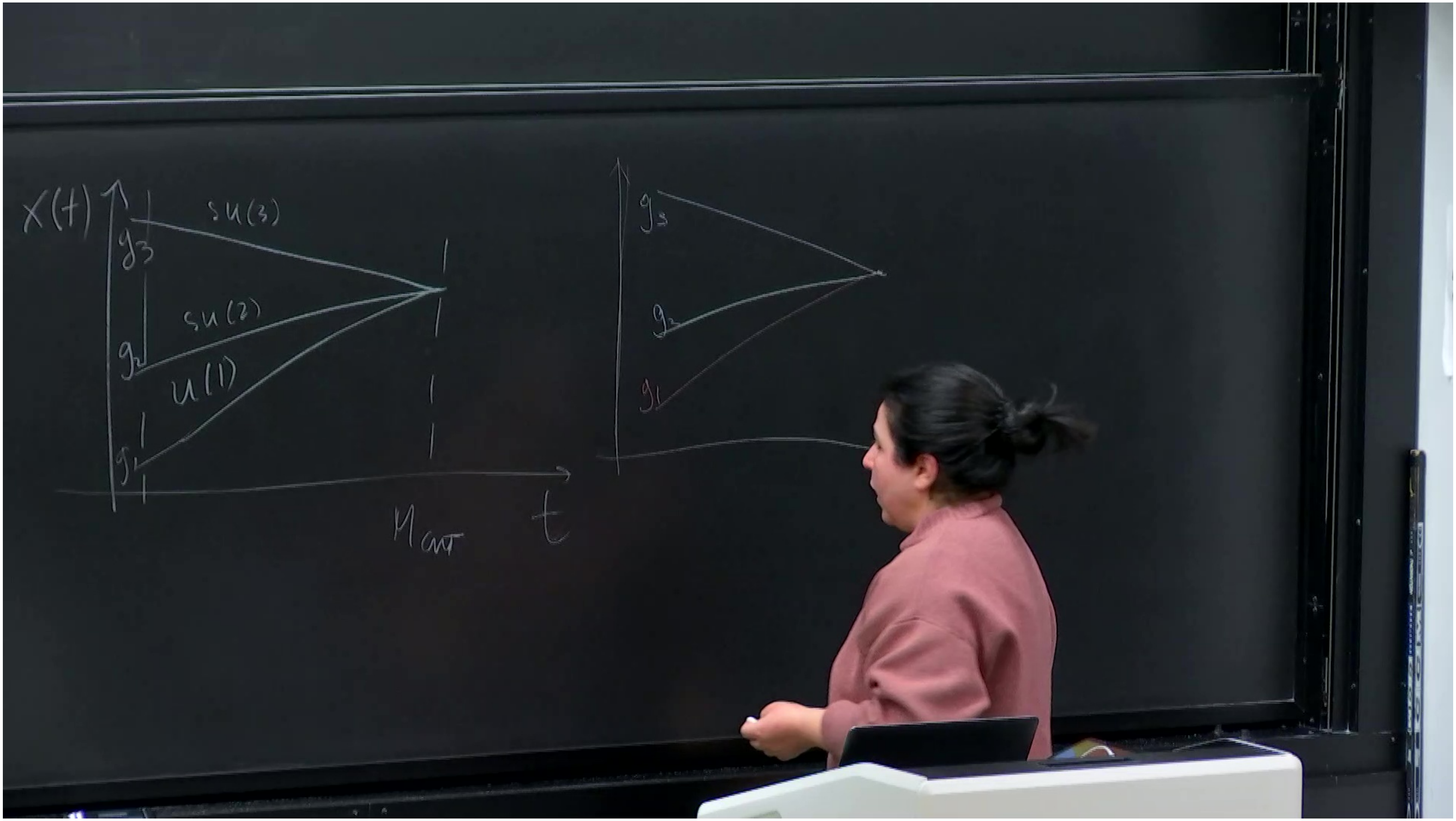
$$b_0 = -\frac{11}{3} C_2(\text{adj})$$

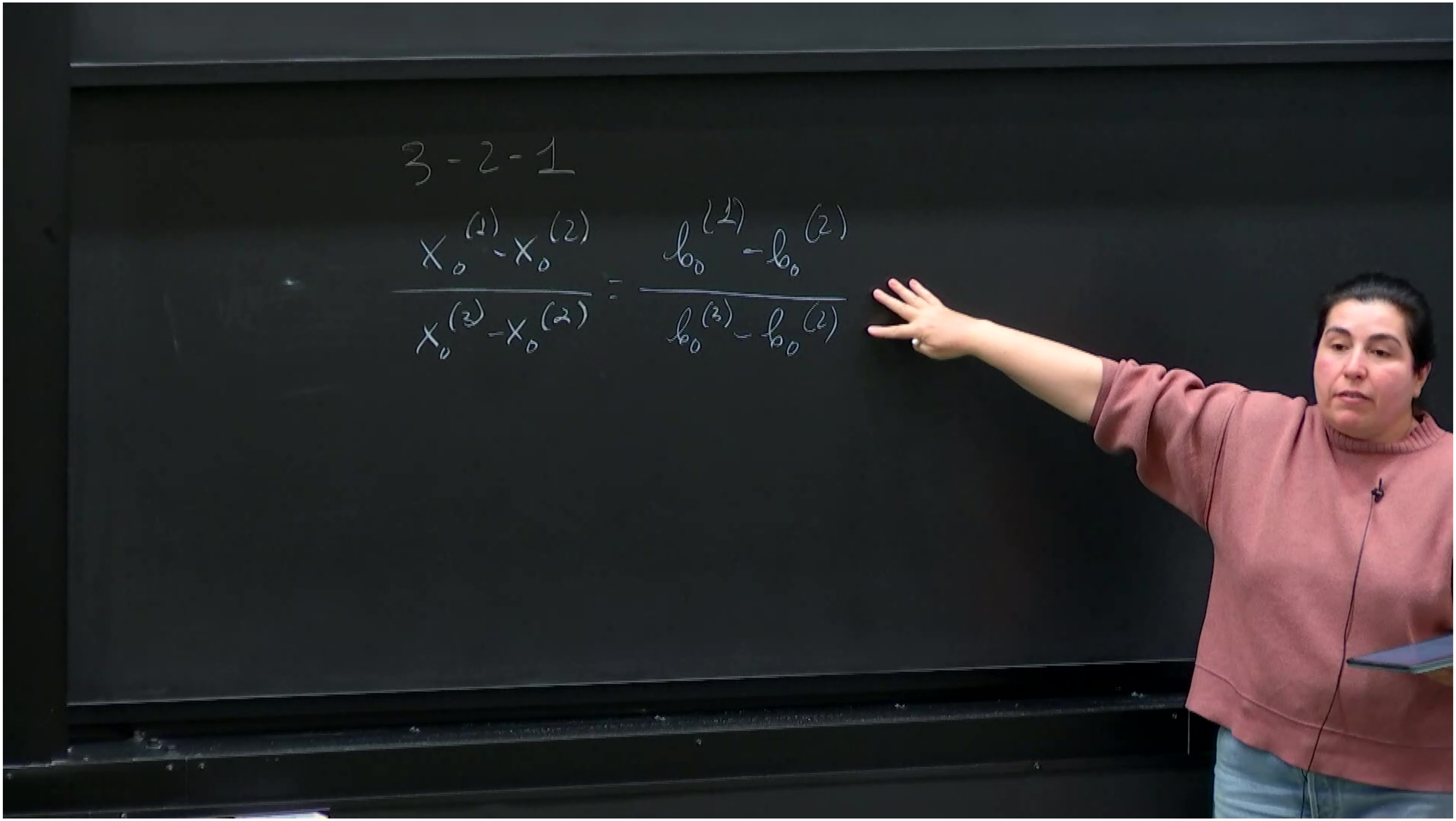
$$C_2(\text{adj}) = N$$

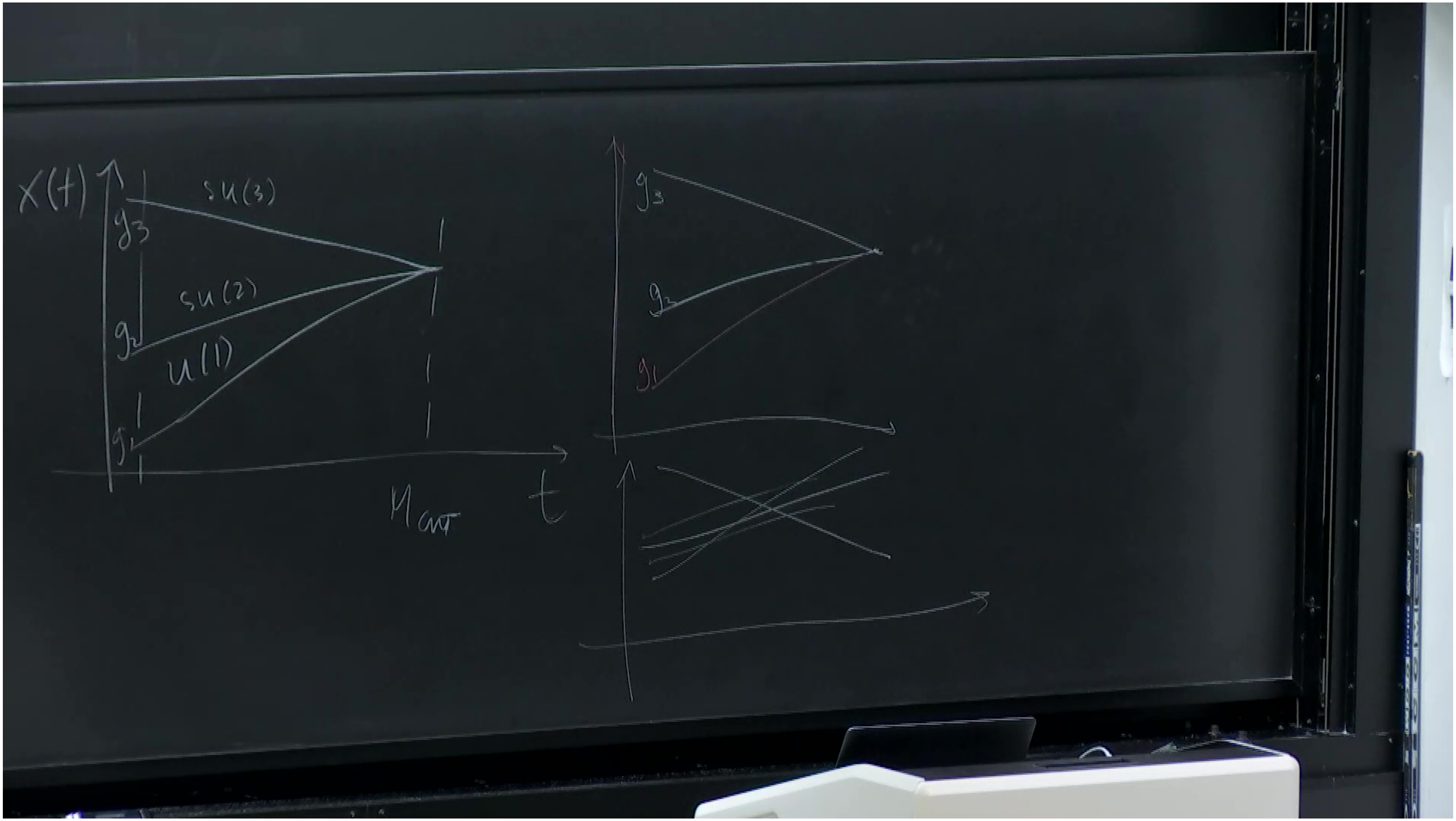
R scalar: $b_0 = \frac{1}{3} T(R)$ fermion: $b_0 = \frac{2}{3} T(R)$

$$T(N) = T(\bar{N}) = \frac{1}{2}$$

U(1) $T(q) = q^2$


X(t)
su(3)
su(2)
u(1)
g_3
g_2
g_1
M_{GUT}
t


3-2-1
$$\frac{x_0^{(1)}-x_0^{(2)}}{x_0^{(3)}-x_0^{(2)}}=\frac{b_0^{(1)}-b_0^{(2)}}{b_0^{(3)}-b_0^{(2)}}$$


X(t)
g3
g2
g1
su(3)
su(2)
u(1)
M_GUT
t
g3
g2
g1