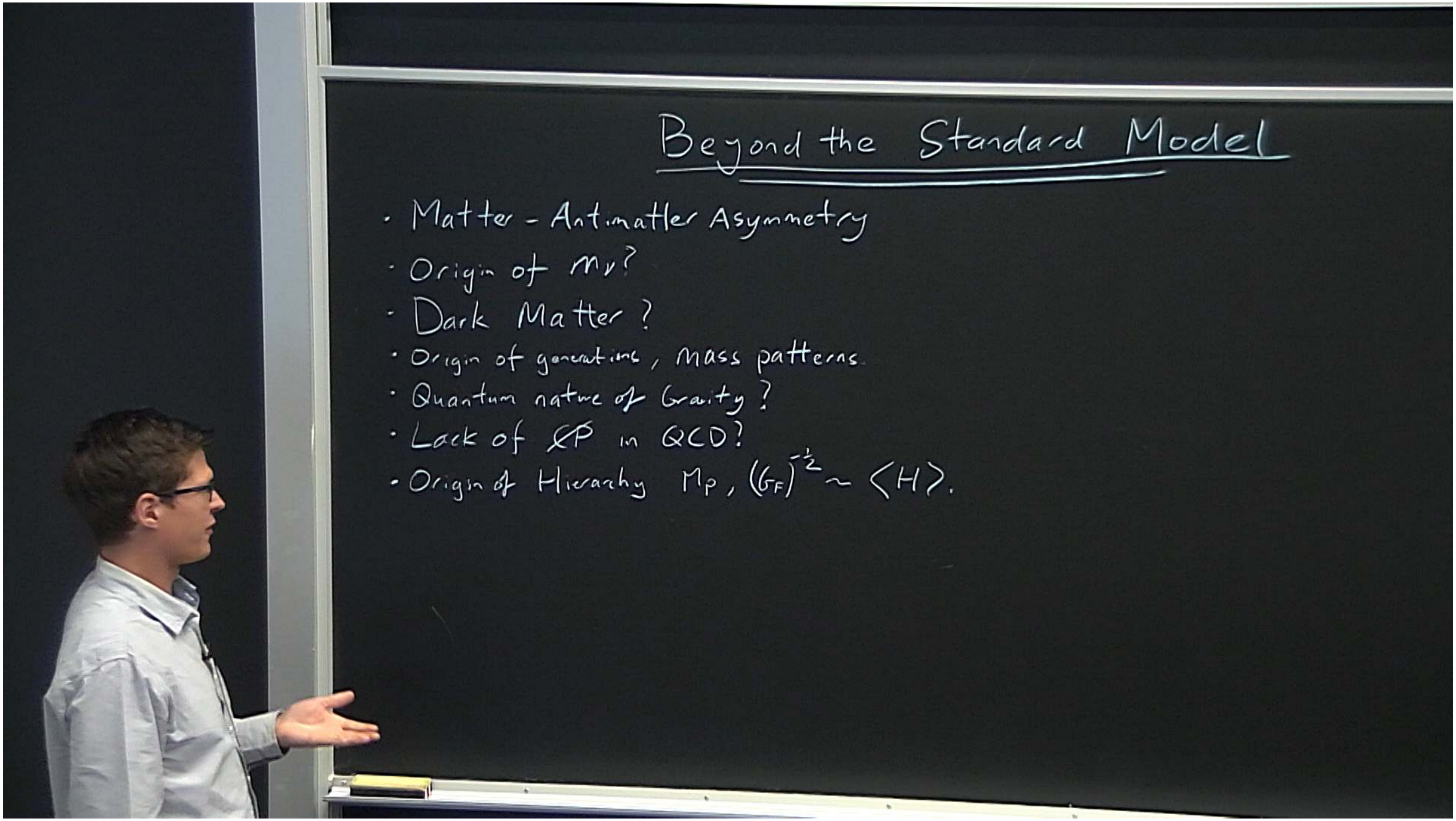
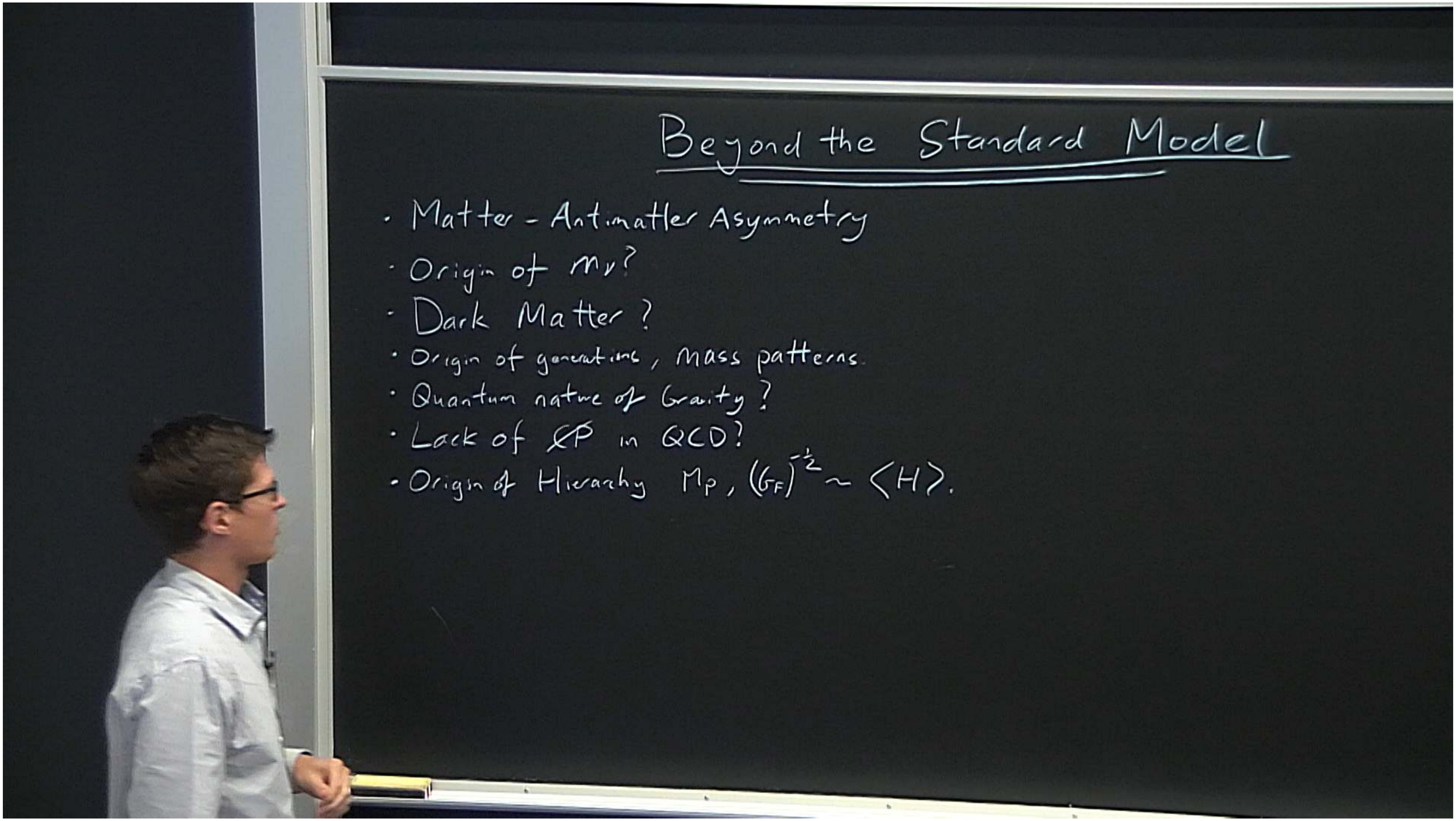
Title: BSM Theory 1

Date: Jul 11, 2018 01:00 PM

URL: http://pirsa.org/18070011

Abstract:


Beyond the Standard Model
· Matter - Antimatter Asymmetry
· Origin of m_ν?
· Dark Matter ?
· Origin of generations, mass patterns
· Quantum nature of Gravity ?
· Lack of $\not{CP}$ in QCD?
· Origin of Hierarchy M_P, $(G_F)^{-\frac{1}{2}} \sim \langle H \rangle$.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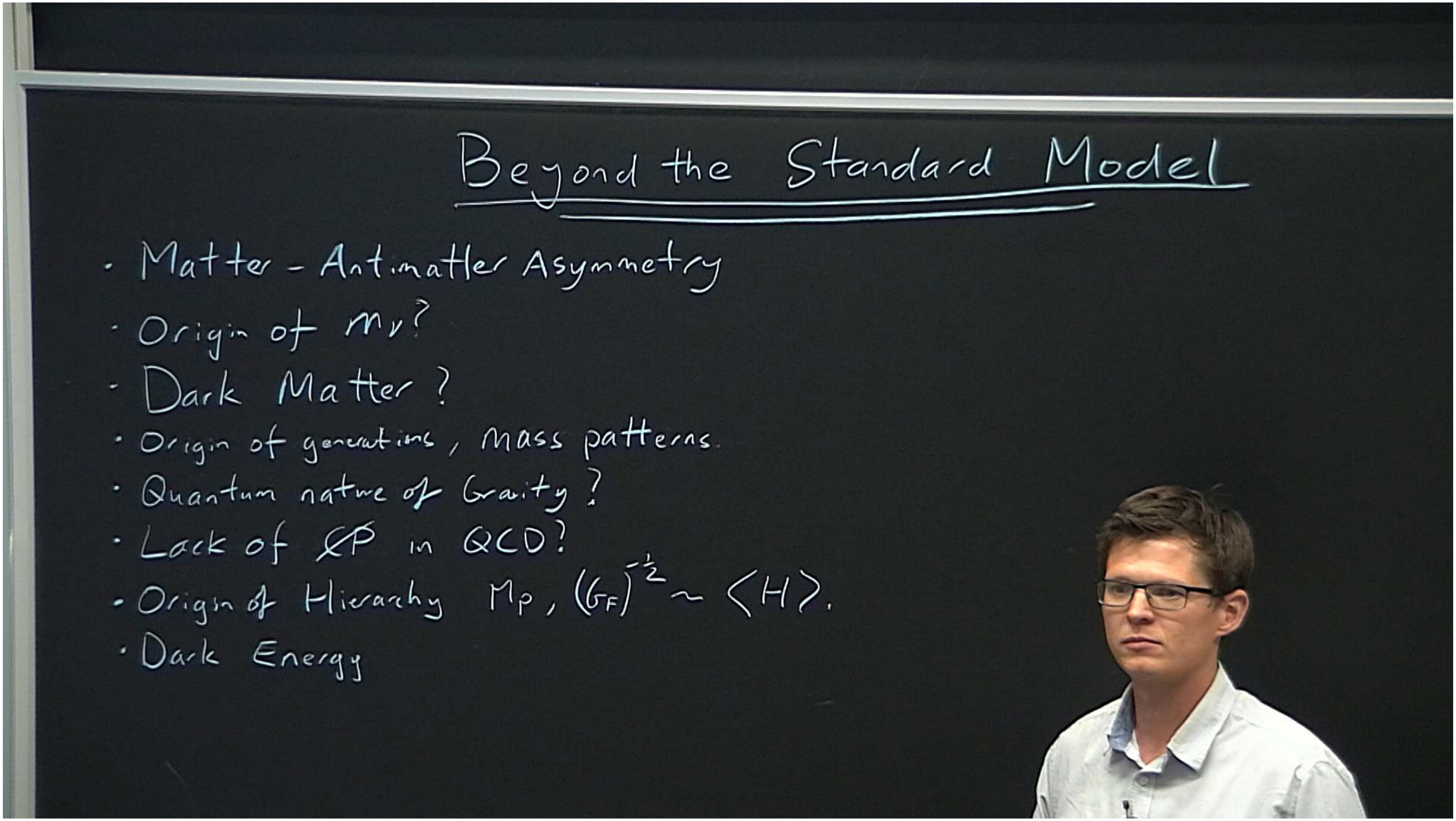
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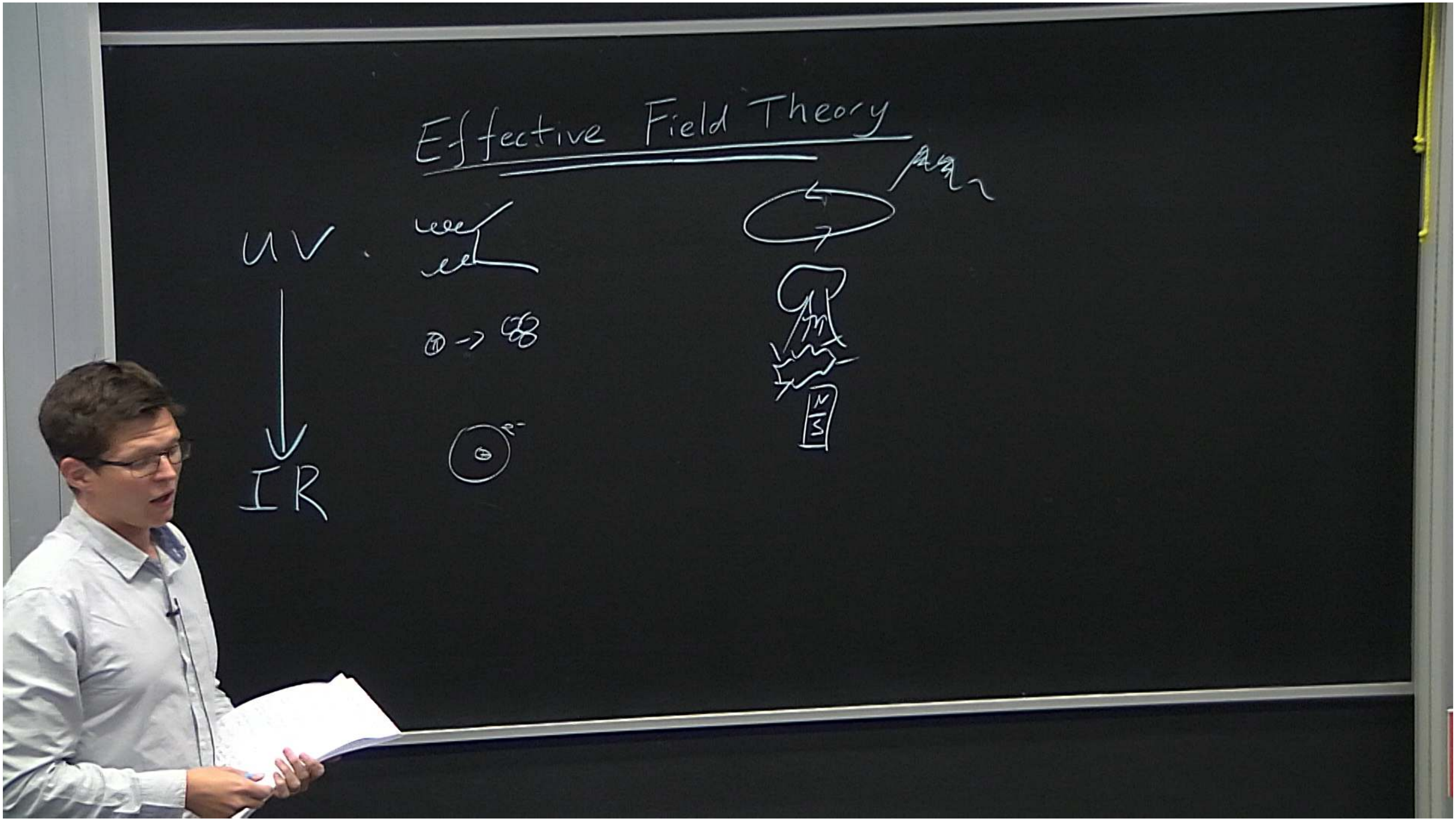
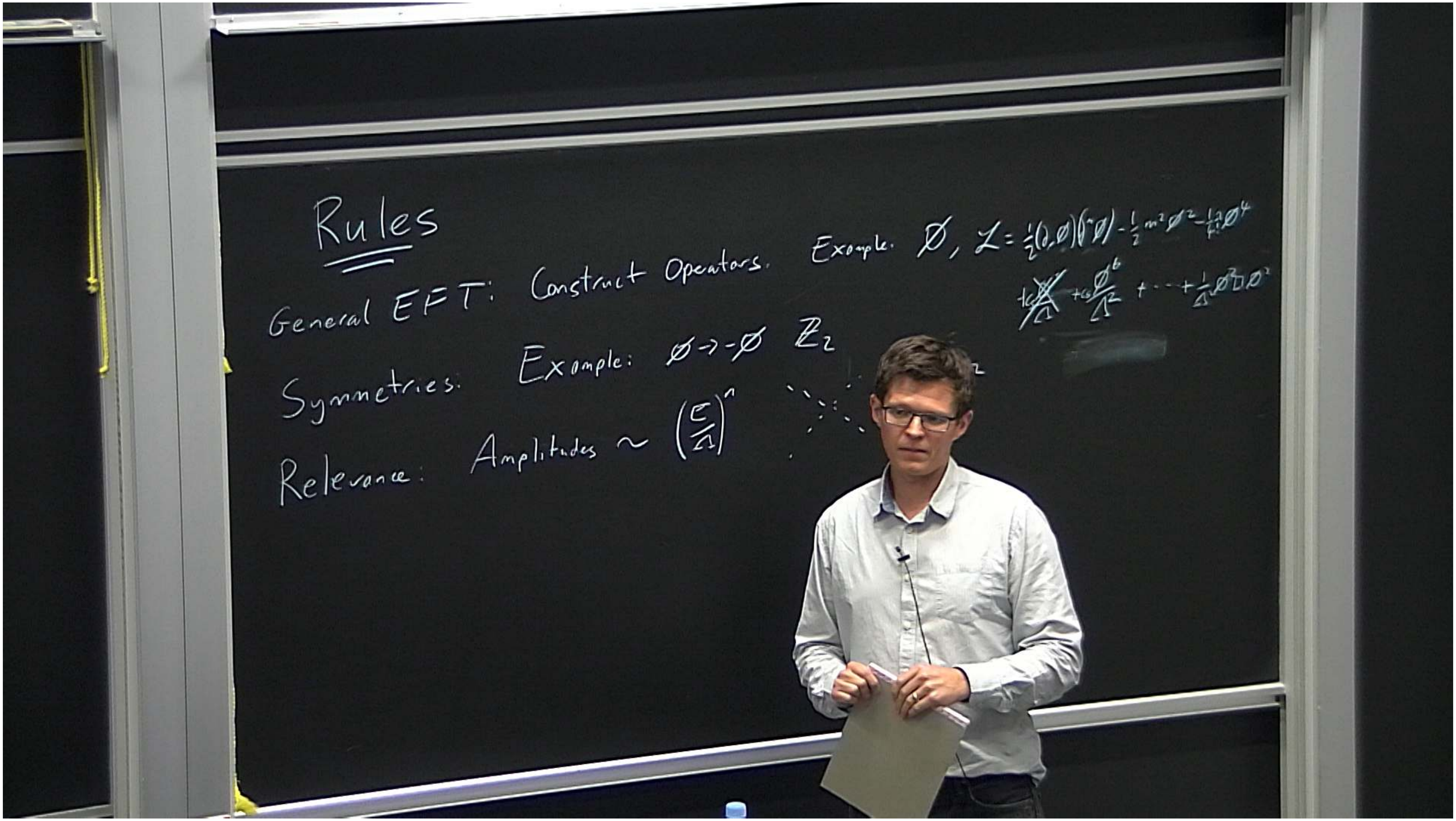
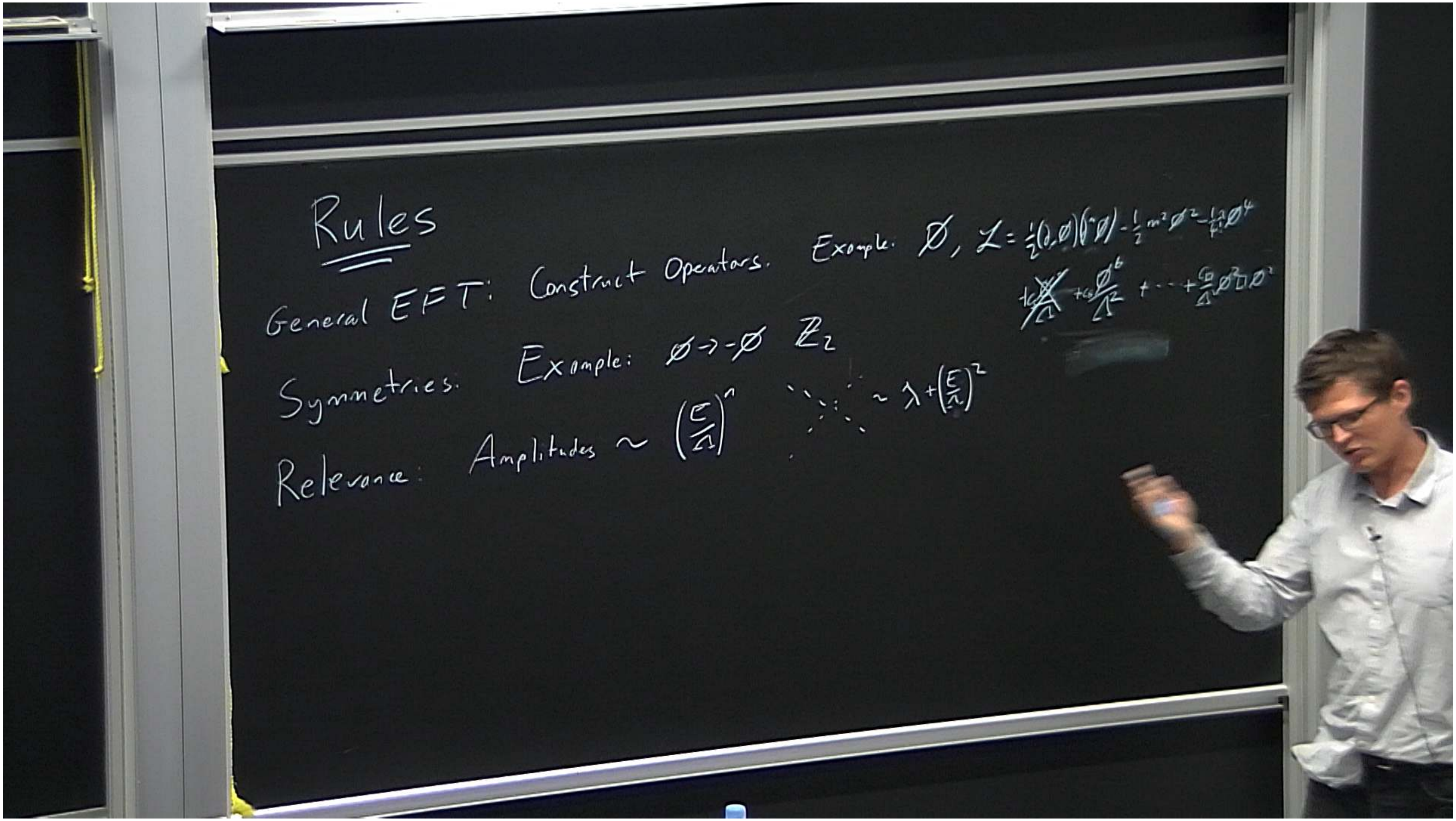
• Origin of Hierarchy $M_P, (G_F)^{-\frac{1}{2}} \sim \langle H \rangle$.
• Dark Energy


Effective Field Theory
UV
IR
N
S


Rules
General EFT: Construct Operators. Example. ∅, L = ½(∂μ∅)(∂^μ∅) − ½m²∅²
Symmetries: Example: ∅ → −∅ Z2
Relevance: Amplitudes ~ (E/Λ)^n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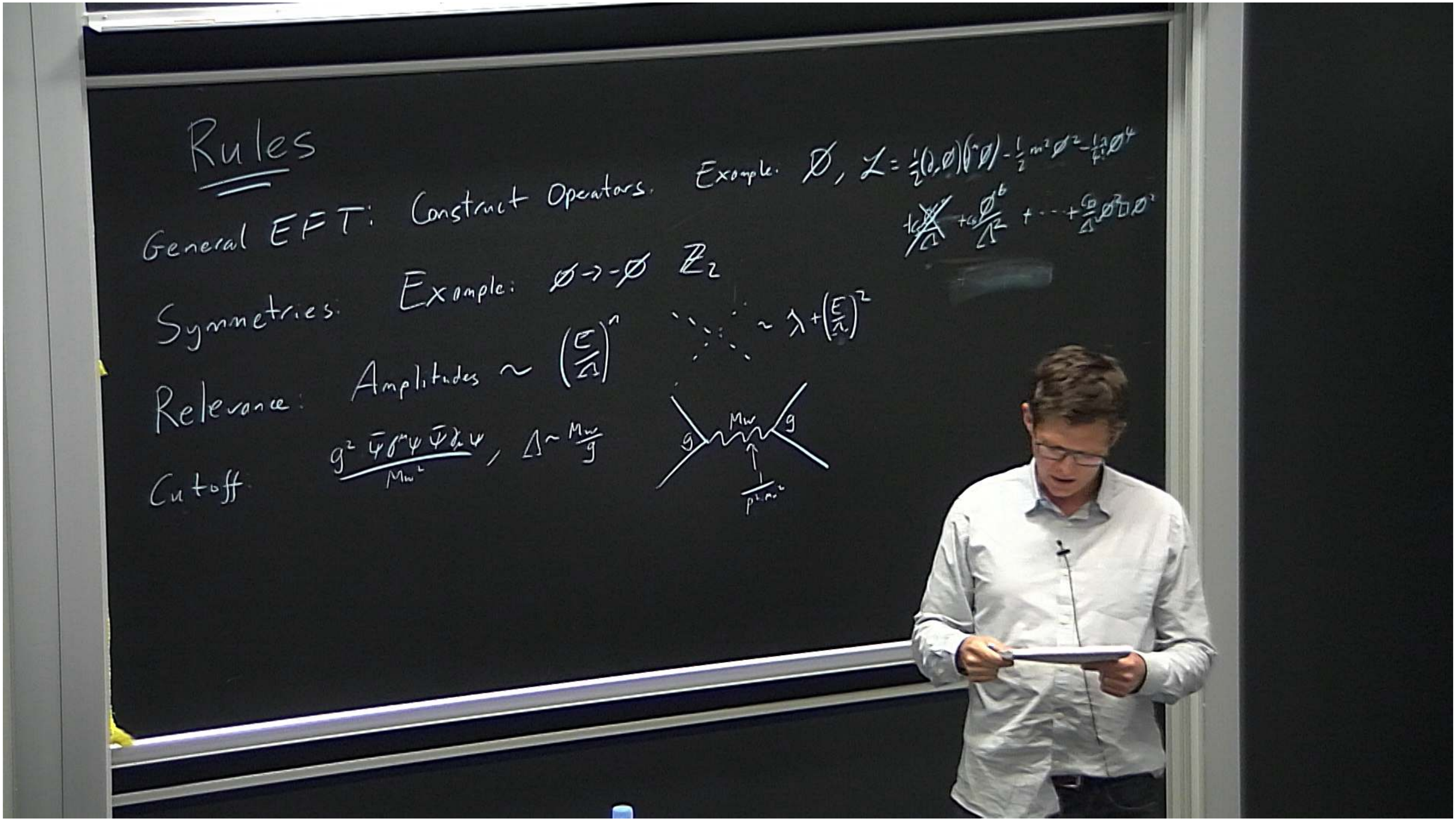
$\cancel{+c_5\frac{\phi^5}{\Lambda}} + c_6\frac{\phi^6}{\Lambda^2} + \cdots + \frac{c_8}{\Lambda^4}\phi^2\Box\phi^2$
Symmetries: Example: $\phi \to -\phi$ $\mathbb{Z}_2$
$\sim \lambda + \left(\frac{E}{\Lambda}\right)^2$
Relevance: Amplitudes $\sim \left(\frac{E}{\Lambda}\right)^n$


Rules
General EFT: Construct Operators. Example. Ø, L = ½(∂μØ)(∂μØ) - ½m²Ø² - λ/4! Ø⁴
+ c₆Ø⁶/Λ² + ... + c/Λ Ø²□Ø²
Symmetries: Example: Ø → -Ø Z₂
~ λ + (E/Λ)²
Relevance: Amplitudes ~ (E/Λ)ⁿ
Cutoff: g² Ψ̄γμΨ Ψ̄γμΨ / Mw², Λ ~ Mw/g
Mw
g
g
1/(p² - m²)

Rules

General EFT: Construct Operators. Example: ϕ, $\mathcal{L} = \frac{1}{2}(\partial_\mu\phi)(\partial^\mu\phi) - \frac{1}{2}m^2\phi^2 - \frac{\lambda}{4!}\phi^4$
$\cancel{+c_5\frac{\phi^5}{\Lambda}} + c_6\frac{\phi^6}{\Lambda^2} + \cdots + \frac{c_{\square}}{\Lambda^2}\phi^2\square\phi^2$

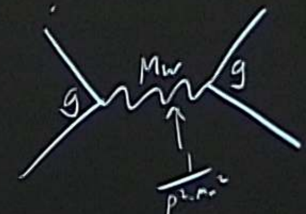
Symmetries: Example: $\phi \to -\phi$ $\mathbb{Z}_2$


$\sim \lambda + \left(\frac{E}{\Lambda}\right)^2$

Relevance: Amplitudes $\sim \left(\frac{E}{\Lambda}\right)^n$

Cutoff: $\frac{g^2\,\bar{\Psi}\gamma^\mu\Psi\,\bar{\Psi}\gamma_\mu\Psi}{M_W^2}$, $\Lambda \sim \frac{M_W}{g}$

$\frac{1}{\Lambda^2} = \frac{g^2}{M_W^2} + \frac{\tilde{g}^2}{M_W^2}$



Spurions

$$\mathcal{L} = |\partial_\mu \phi|^2 + i\psi^\dagger \sigma \psi - m_\phi^2 |\phi|^2 + \tfrac{1}{2} m_\psi \psi^2 + h.c. + \mathcal{L}_{INT}$$

$m_\phi \to 0$

$\phi \to \phi + c$; $(\partial_\mu \phi)\,\mathcal{O}^\mu$

$m_\psi \to 0$

$\psi \to e^{i\theta}\psi$

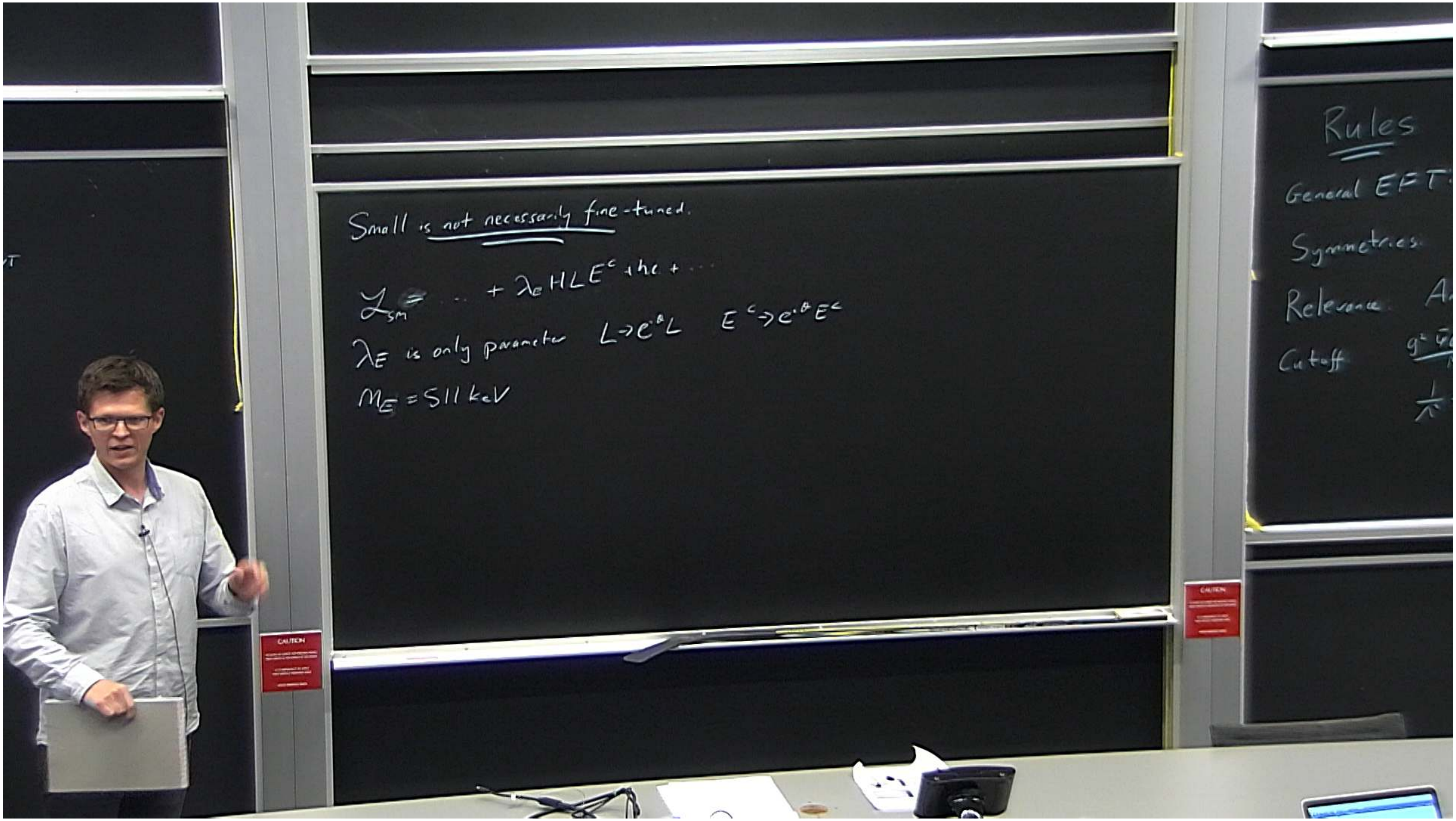
$m_\phi, m_\psi \to 0$

Scale Symmetry

$m_\phi = m_\psi$

Supersymmetry

$\delta^2 = m_\phi^2 - m_\psi^2$


Small is not necessarily fine-tuned.
$\mathcal{L}_{SM} = \ldots + \lambda_E H L E^c + h.c. + \ldots$
λ_E is only parameter $L \to e^{i\theta} L$ $E^c \to e^{-i\theta} E^c$
$m_E = 511$ keV
Rules
General EFT
Symmetries
Relevance
Cutoff

Spurions

$$\mathcal{L} = |\partial_\mu \phi|^2 + i\psi^\dagger \bar{\sigma} \psi - m_\phi^2 |\phi|^2 + \frac{1}{2} m_\psi \psi^2 + h.c. + \mathcal{L}_{INT}$$

$m_\phi \to 0$

$\phi \to \phi + c$; $(\partial_\mu \phi)\, \mathcal{O}^\mu$

$$\frac{(\partial_\mu \phi)^4}{\Lambda^4}$$

$m_\psi \to 0$

$\psi \to e^{i\theta} \psi$

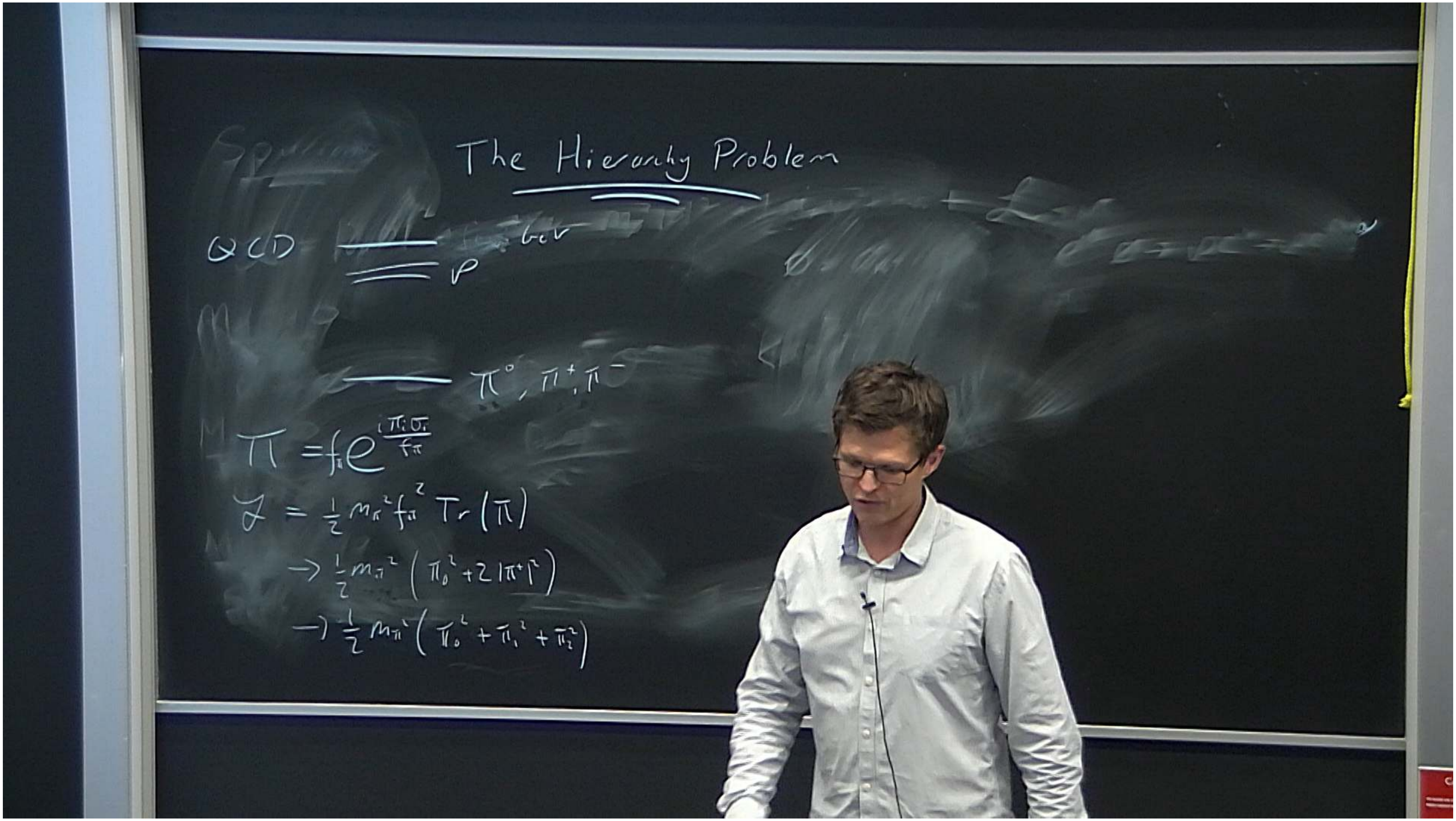
$m_\phi , m_\psi \to 0$

Scale Symmetry $\quad x^\mu \to \alpha x^\mu \quad \phi \to \alpha^{-1} \phi \quad \int d^4x\, \mathcal{L}$

$m_\phi = m_\psi$

Supersymmetry

$\delta^2 = m_\phi^2 - m_\psi^2$


The Hierarchy Problem
QCD
GeV
ρ
π^0, π^+, π^-
$\Pi = f_\pi e^{\frac{i \pi_i \sigma_i}{f_\pi}}$
$\mathcal{L} = \frac{1}{2} m_\pi^2 f_\pi^2 \, Tr(\Pi)$
$\rightarrow \frac{1}{2} m_\pi^2 (\pi_0^2 + 2|\pi^+|^2)$
$\rightarrow \frac{1}{2} m_\pi^2 (\pi_0^2 + \pi_1^2 + \pi_2^2)$

The Hierarchy Problem

QCD

—— GeV

—— ρ

—— π^0, π^+, π^-

$$\Pi = f_\pi e^{\frac{i \pi_i \sigma_i}{f_\pi}}$$

$$\mathcal{L} = \frac{1}{2} m_\pi^2 f_\pi^2 \, \mathrm{Tr}(\Pi)$$

$$\rightarrow \frac{1}{2} m_\pi^2 \left(\pi_0^2 + 2|\pi^+|^2 \right)$$

$$\rightarrow \frac{1}{2} m_\pi^2 \left(\pi_0^2 + \pi_1^2 + \pi_2^2 \right)$$

$$\mathcal{L}_{kin} = \frac{1}{2}(\partial_\mu \pi^0)^2 + \left|(\partial_\mu + ieA_\mu)\pi^+\right|^2$$

$$+ \frac{1}{2} \Lambda^2 e^2 |\pi^+|^2$$

$$m_{\pi^+}^2 - m_{\pi^0}^2 \simeq \frac{3e^2}{(4\pi)^2} \frac{m_\rho^2 m_{a_1}^2}{m_\rho^2 + m_{a_1}^2} \log\left(\frac{m_{a_1}^2}{m_\rho^2}\right)$$