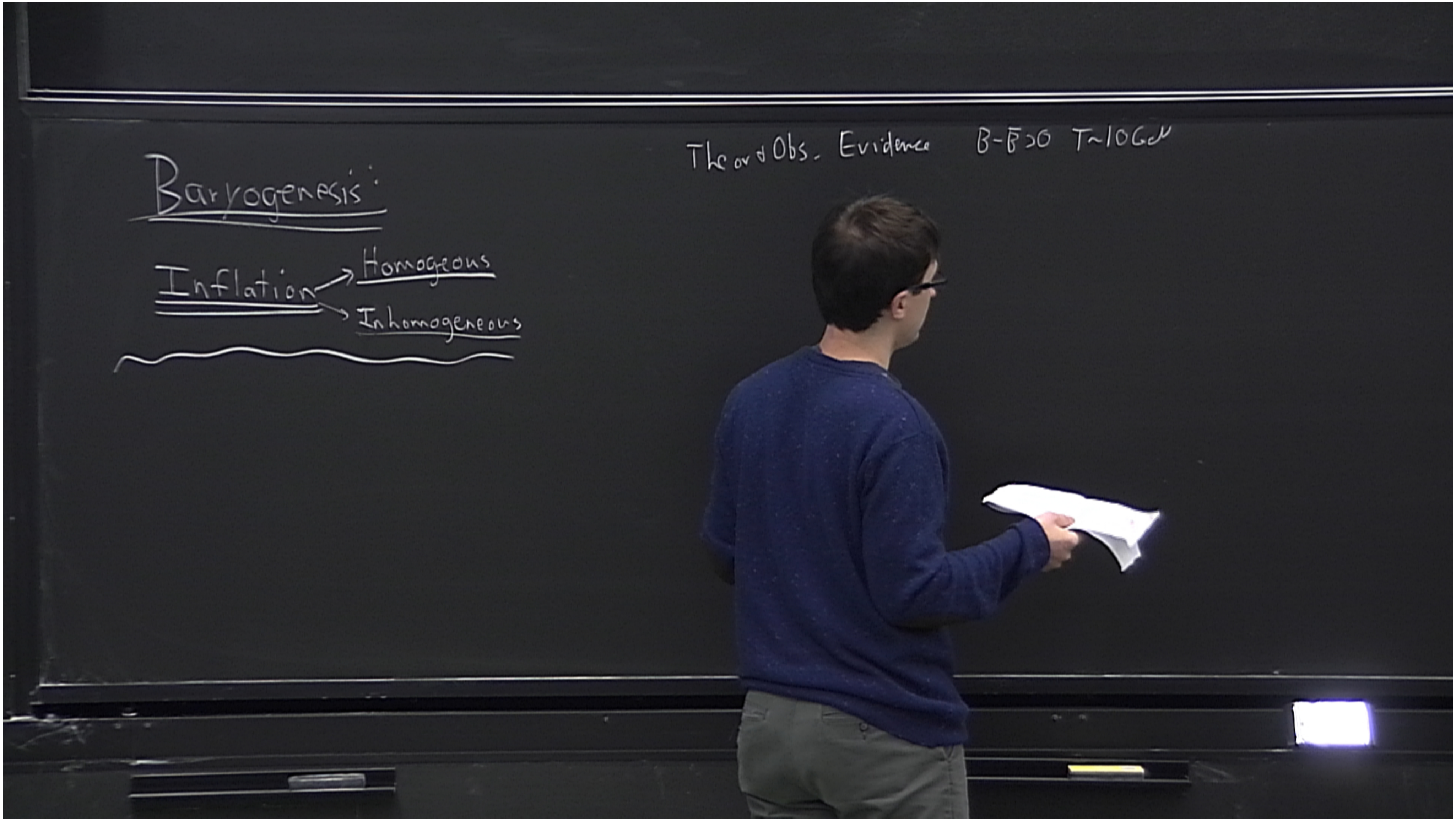
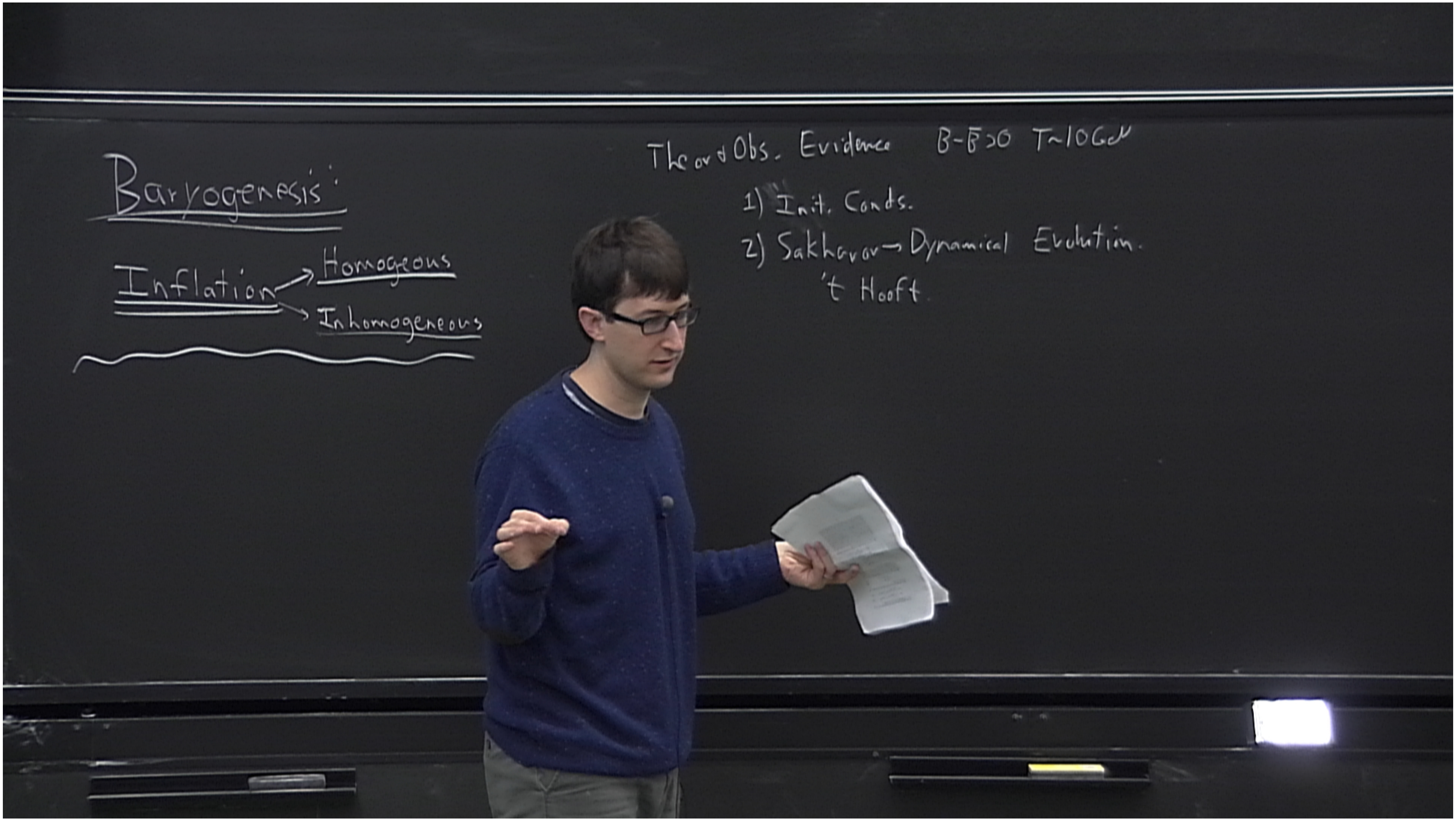
Title: Cosmology (Review) - Lecture 14

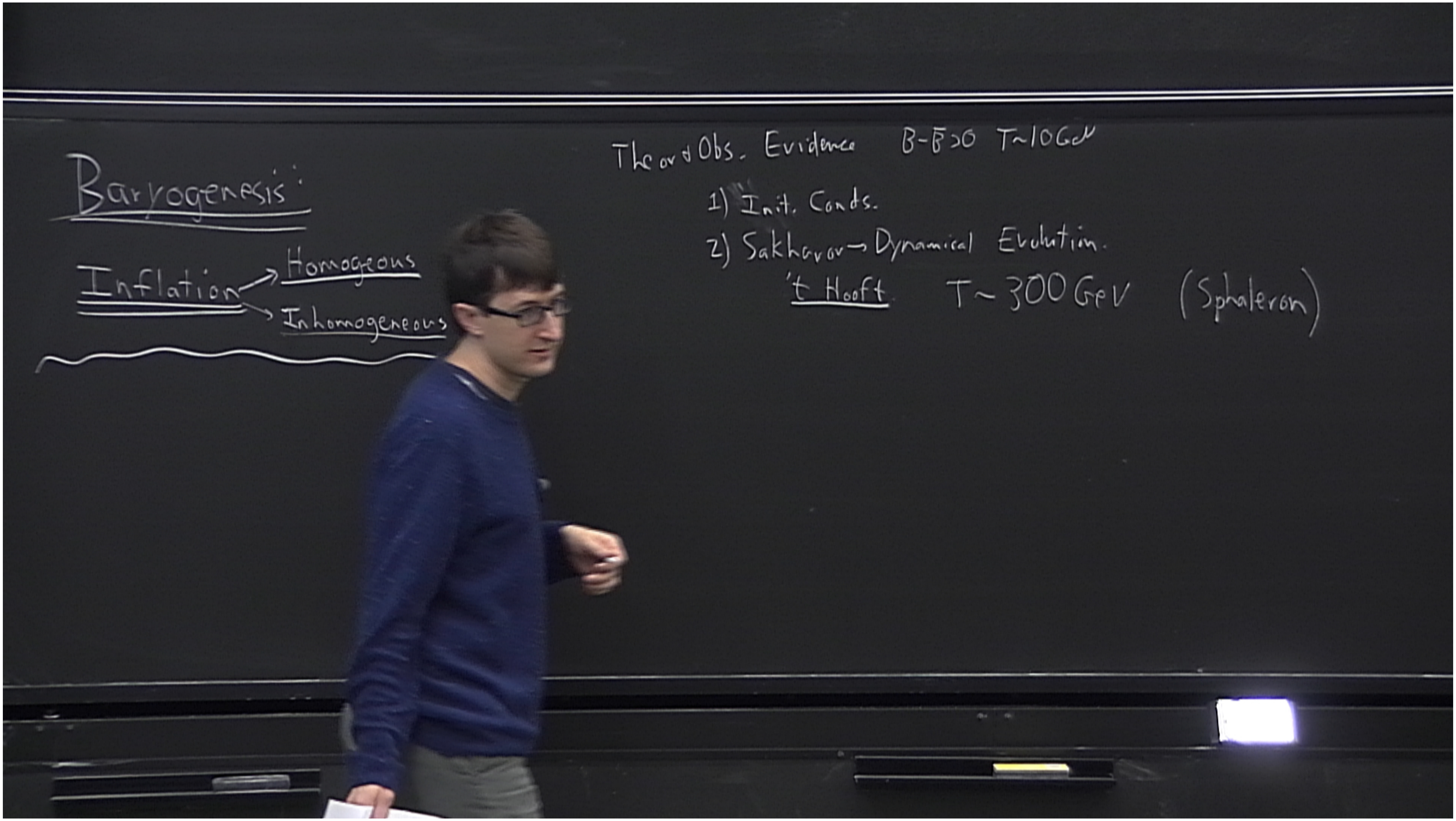
Date: Feb 10, 2012 09:00 AM

URL: http://pirsa.org/12010077

Abstract:


Theor & Obs. Evidence
$B-\bar{B}>0$
Baryogenesis:
Inflation
Homogeous
Inhomogeneous


Baryogenesis:
Inflation
Homogeous
Inhomogeneous
Theor & Obs. Evidence B-B̄>0 T~10GeV
1) Init. Conds.
2) Sakharov → Dynamical Evolution.
't Hooft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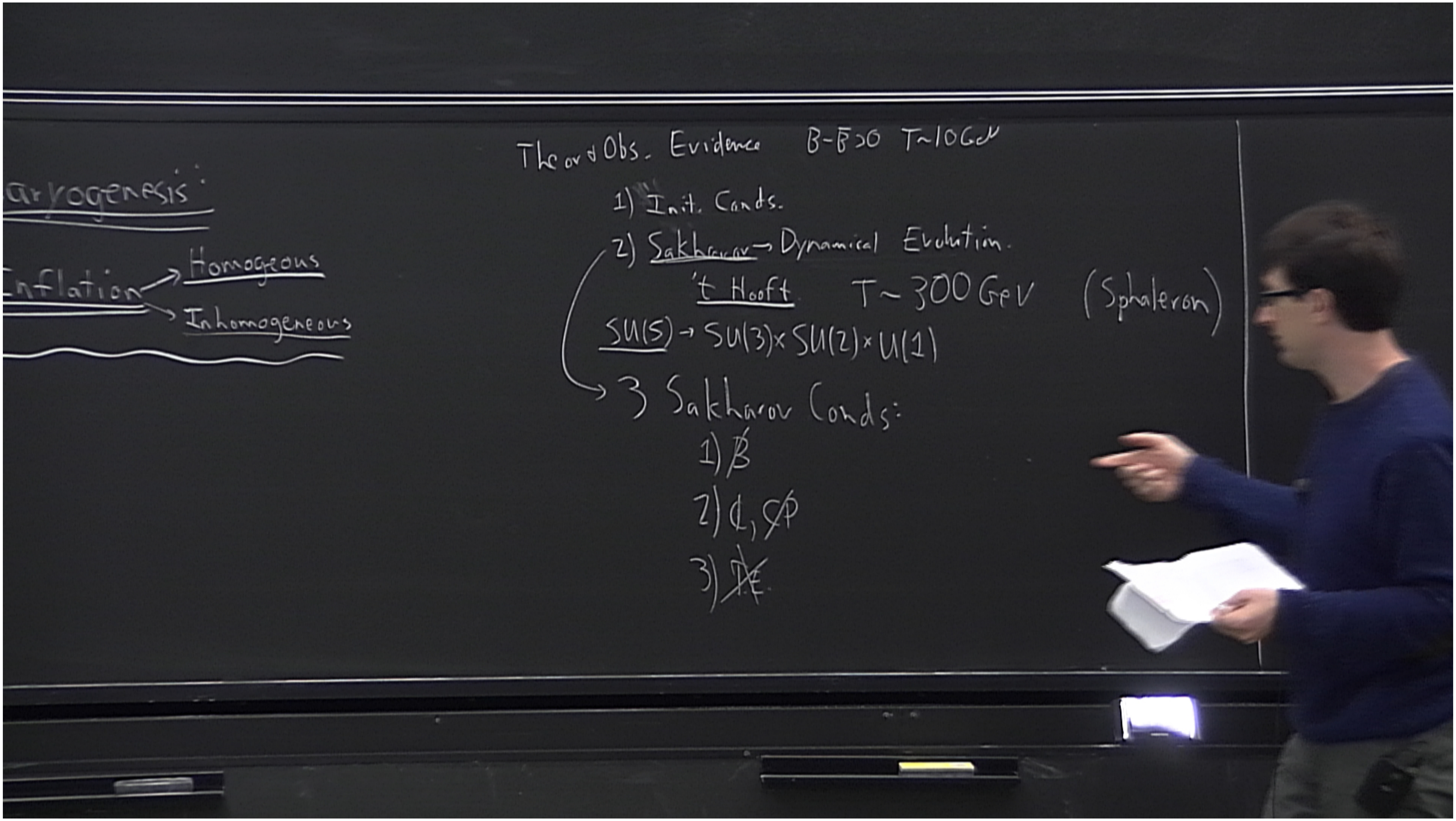
't Hooft T ~ 300 GeV (Sphaleron)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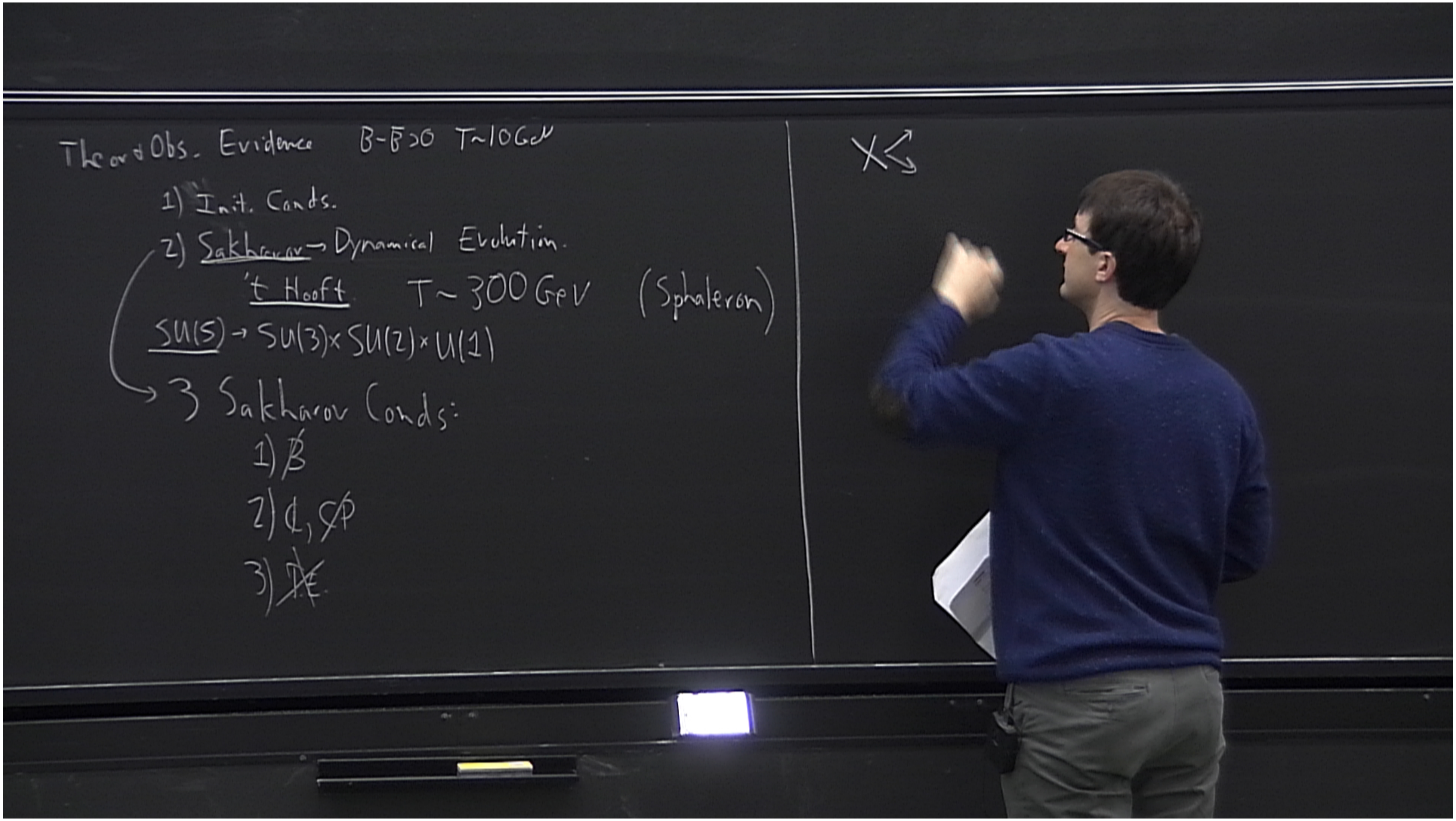
SU(5) → SU(3)×SU(2)×U(1)
3 Sakharov Conds:
1) B̸
2) C̸, CP̸
3) T.E.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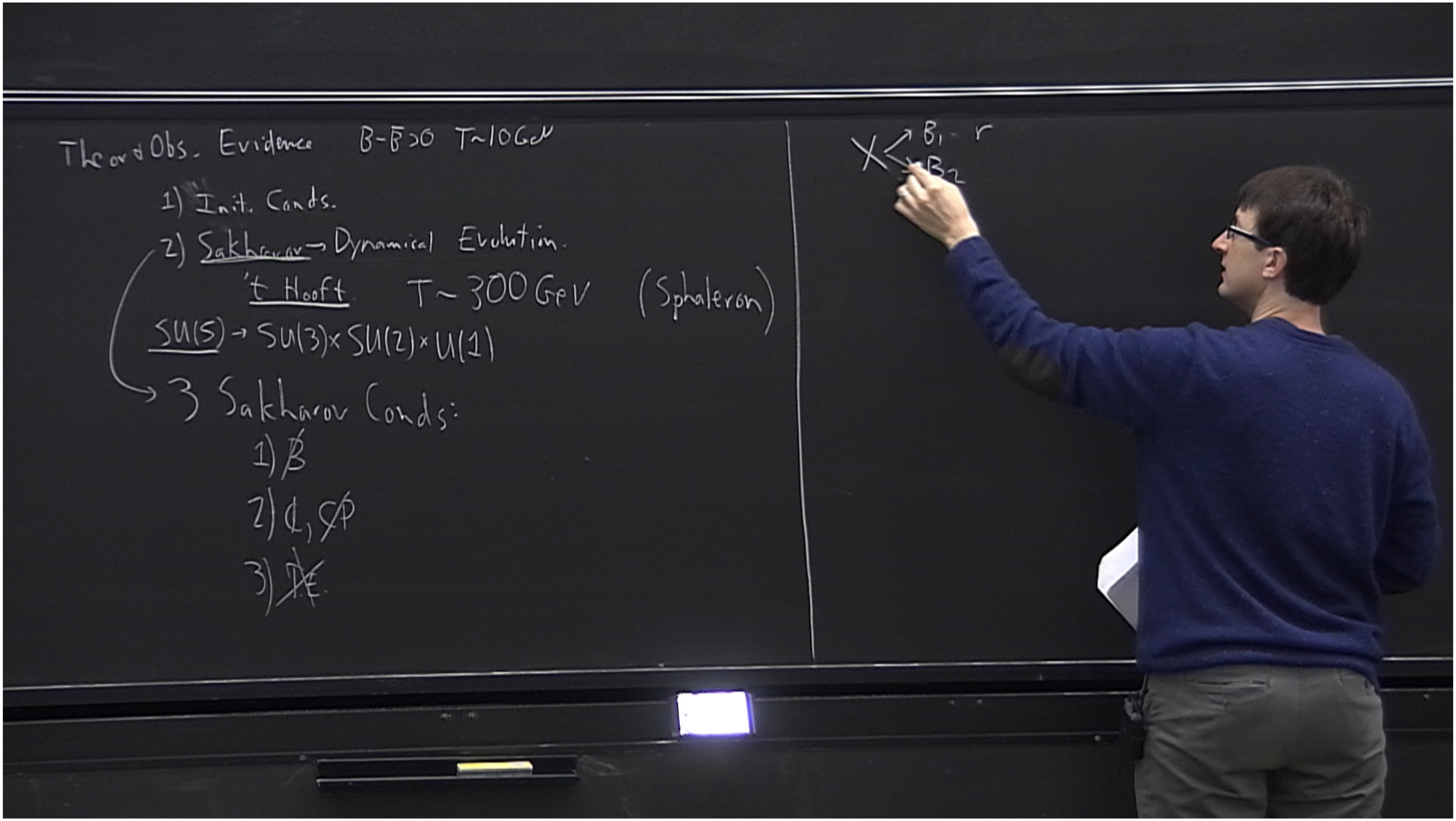
SU(5) → SU(3)×SU(2)×U(1)
3 Sakharov Conds:
1) B̸
2) C̸, CP̸
3)
X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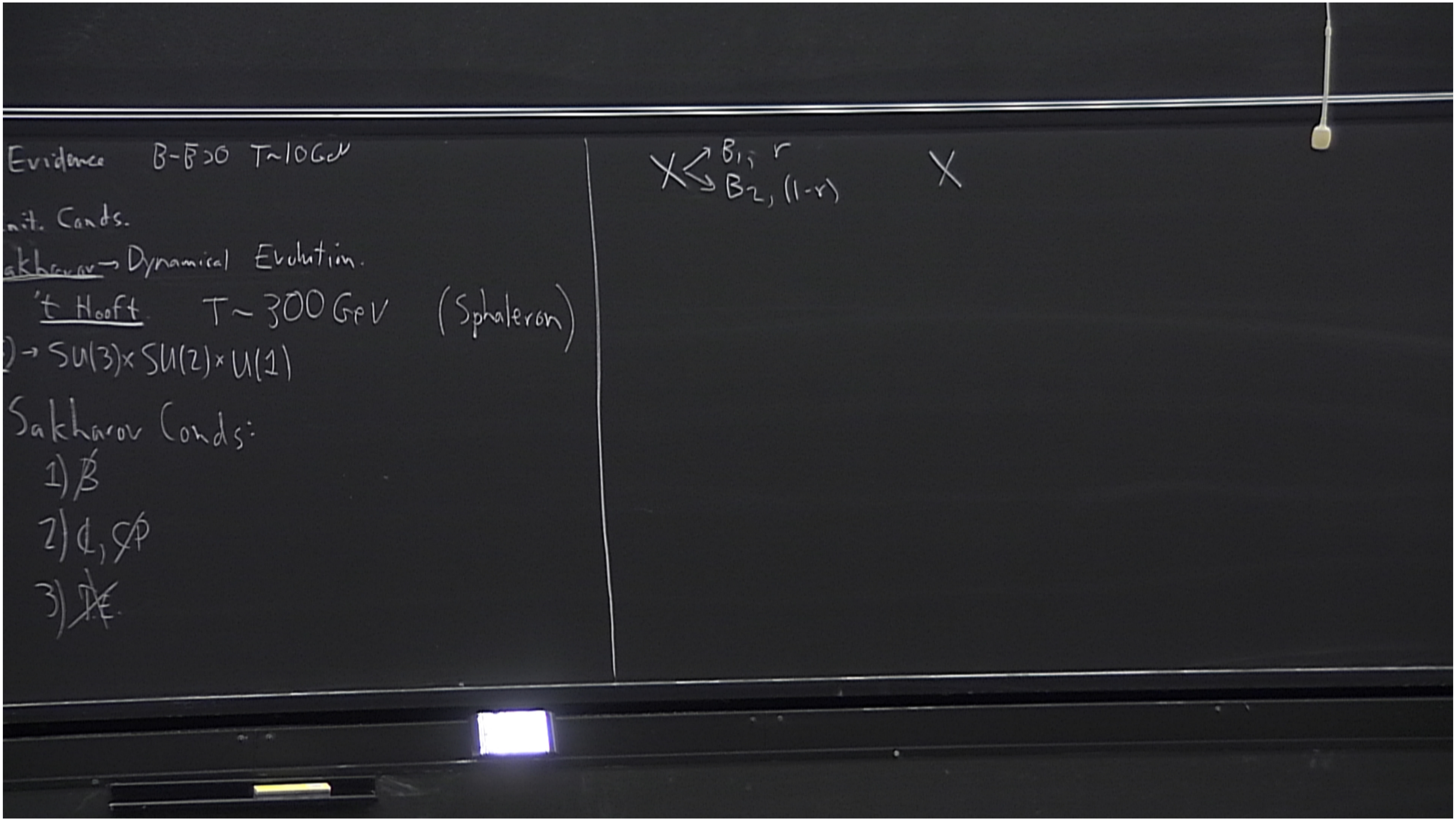
3 Sakharov Conds:
1) B̸
2) C̸, CP̸
3) TE̸
X B1 B2 r


Evidence B−B̄>0 T~10GeV
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't Hooft T ~ 300 GeV (Sphaleron)
) → SU(3)×SU(2)×U(1)
Sakharov Conds:
1) B̸
2) C̸, CP̸
3) TE̸
X → B1, r
X → B2, (1−r)
X̄

vidence $B-\bar{B}>0$ $T\sim 10\,GeV$

. Conds.

...arov → Dynamical Evolution.

't Hooft $T\sim 300\,GeV$ (Sphaleron)

$SU(3)\times SU(2)\times U(1)$

akharov Conds:

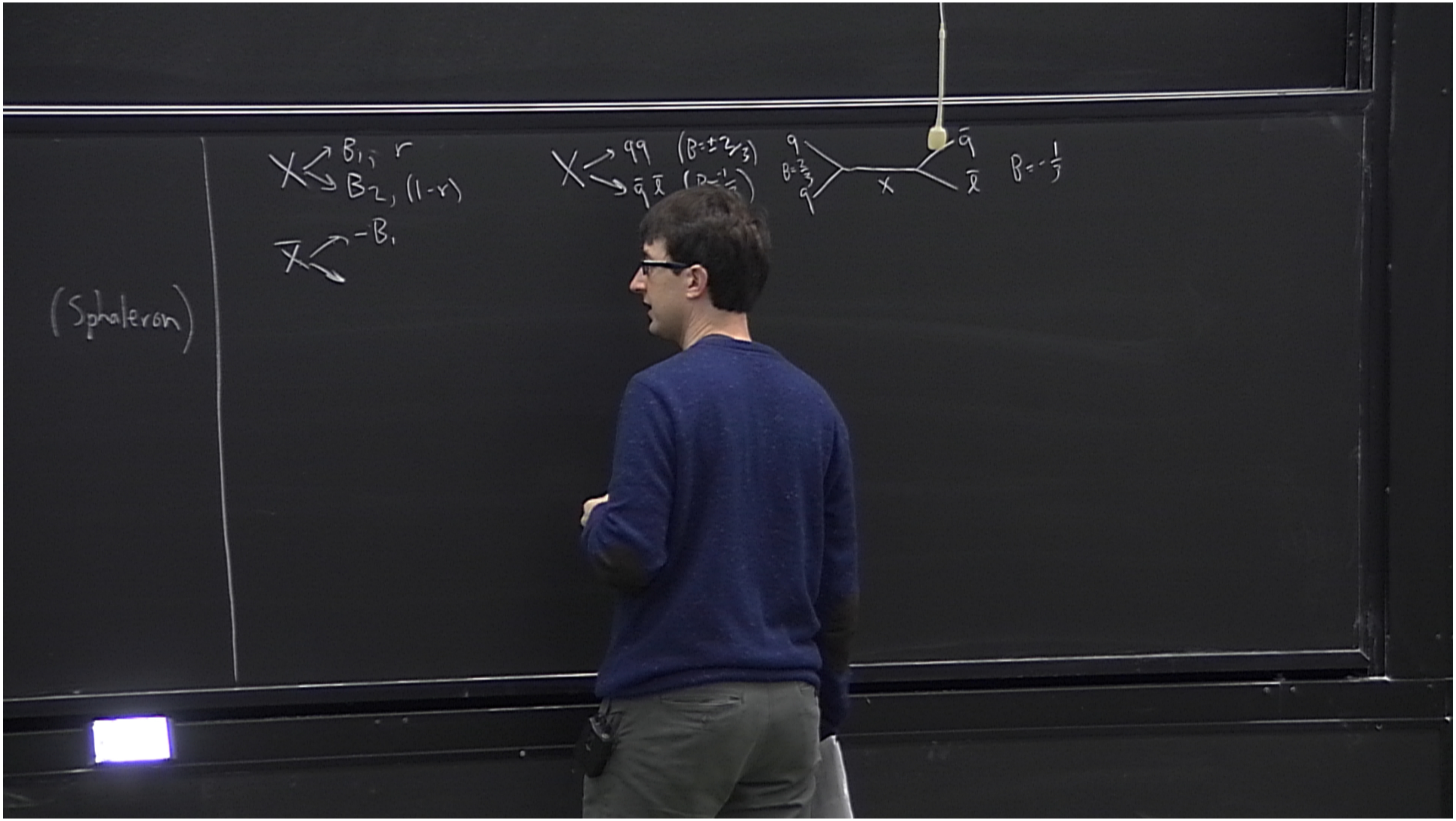
1) $\cancel{B}$

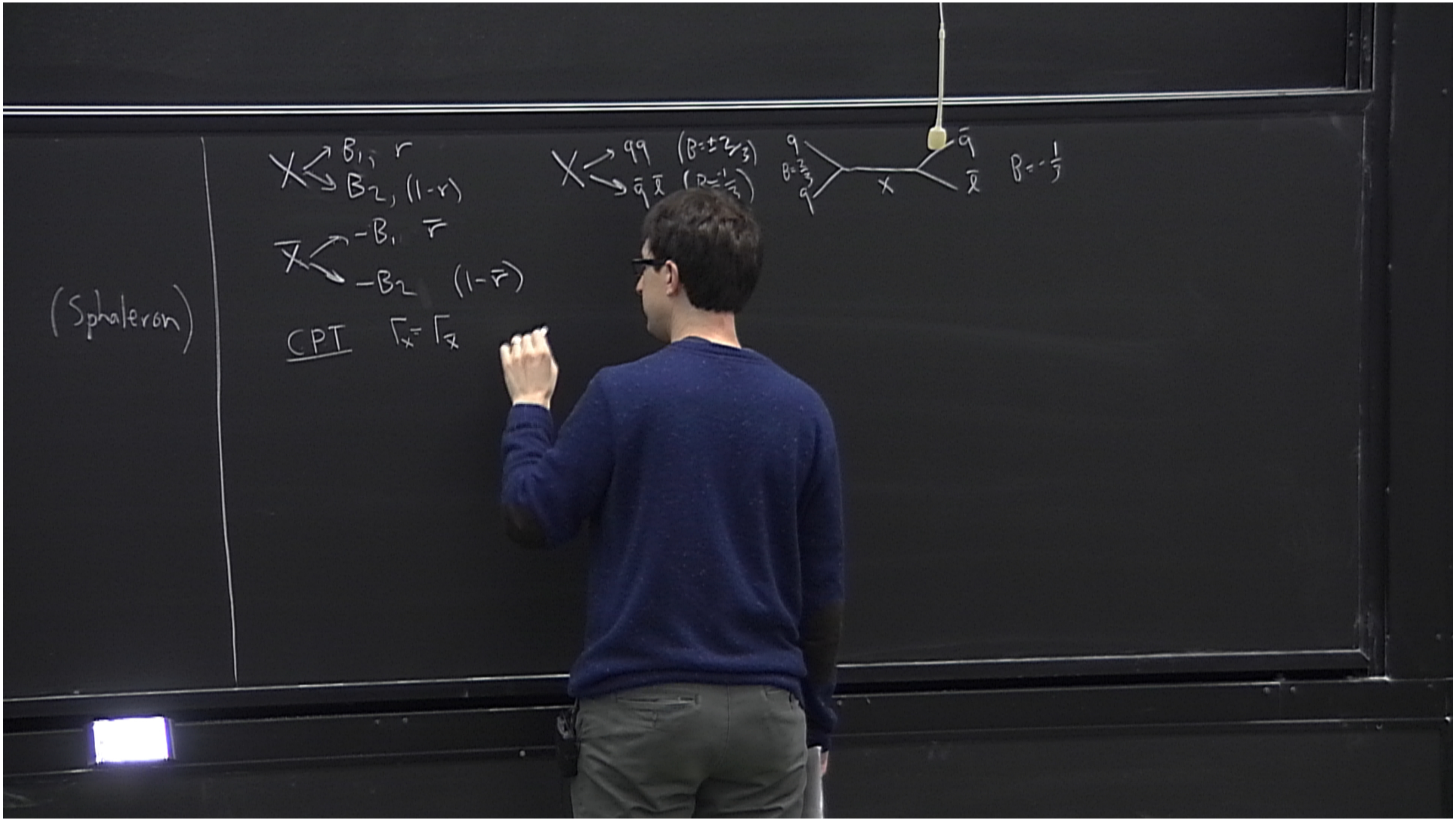
2) $\cancel{C}$, $\cancel{CP}$

3) $\cancel{TE}$.

$$X \begin{array}{l} \nearrow B_1;\ r \\ \searrow B_2,\ (1-r) \end{array}$$

$\bar{X}$


(Sphaleron)
X → B1; r
B2, (1-r)
X̄ → -B1
X → qq (B=±2/3)
q̄ ℓ̄
B = -1/3

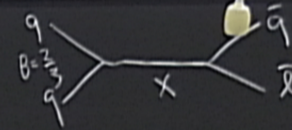

(Sphaleron)
X → B1, r
B2, (1-r)
X̄ → -B1 r̄
-B2 (1-r̄)
CPT Γx = Γx̄
X → qq (B=±2/3)
q̄ ℓ̄ (B=-1/3)
q
B=2/3
q
x
q̄
ℓ̄
B=-1/3

leron)

$$X \to B_1,\ r \qquad X \to B_2,\ (1-r)$$

$$\bar{X} \to -B_1,\ \bar{r} \qquad \bar{X} \to -B_2,\ (1-\bar{r})$$

$$X \to qq \quad (B = \pm 2/3) \qquad X \to \bar{q}\,\bar{\ell} \quad (B = -\tfrac{1}{3})$$



$B = -\frac{1}{3}$

<u>CPT</u> $\quad \Gamma_X = \Gamma_{\bar{X}}$ $\qquad r = \bar{r} \Longleftrightarrow \cancel{C}, \cancel{CP}$

$$T < m_X = m_{\bar{X}} \qquad \frac{1}{\Gamma_X} \qquad n_X = n_{\bar{X}}$$

$$\left(\frac{n_X + n_{\bar{X}}}{s}\right)_i = n_X \left(\frac{rB_1 + (1-r)B_2 - B_1\bar{r} - B_2(1-\bar{r})}{s}\right)$$

$$X \to B_1,\ r \qquad X \to B_2,\ (1-r)$$

$$\bar{X} \to -B_1,\ \bar{r} \qquad \bar{X} \to -B_2 \quad (1-\bar{r})$$

(...leron)

$\underline{CPT}$ $\quad \Gamma_X = \Gamma_{\bar{X}}$

$T < m_X = m_{\bar{X}}$

$$X \to qq \quad (B = \pm 2/3) \qquad X \to \bar{q}\bar{\ell} \quad (B = -\tfrac{1}{3})$$

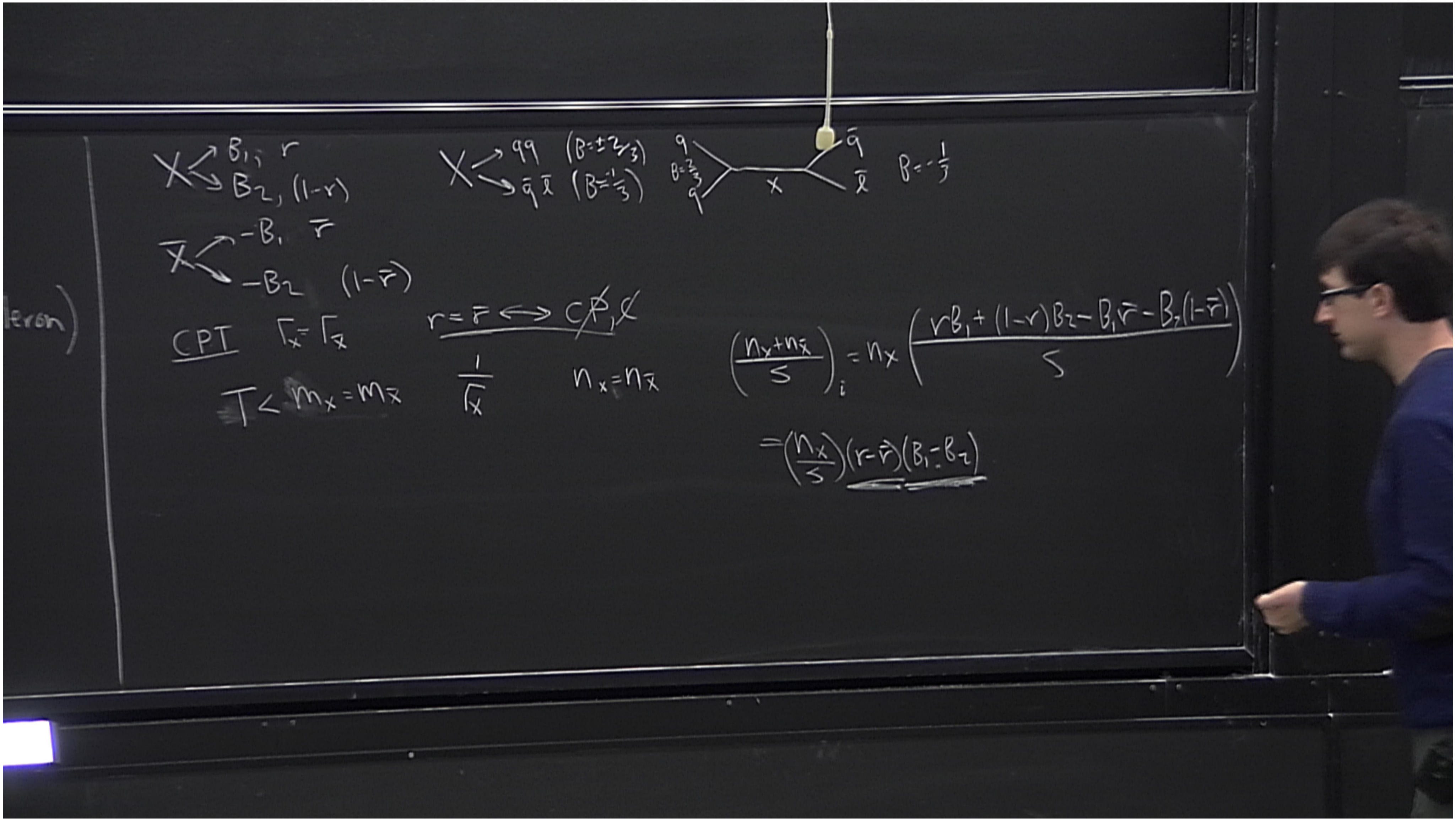
q, $B = \tfrac{2}{3}$, q — X — $\bar{q}$, $\bar{\ell}$ $\quad B = -\tfrac{1}{3}$

$\underline{r = \bar{r} \Longleftrightarrow \cancel{C}\cancel{P}, \cancel{C}}$

$\dfrac{1}{\Gamma_X}$ $\qquad n_X = n_{\bar{X}}$

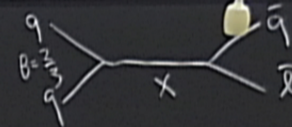
$$\left(\frac{n_X + n_{\bar{X}}}{s}\right)_i = n_X \left(\frac{rB_1 + (1-r)B_2 - B_1\bar{r} - B_2(1-\bar{r})}{s}\right)$$

$$= \left(\frac{n_X}{s}\right)\underline{(r-\bar{r})(B_1 - B_2)}$$


X → B1, r
X → B2, (1-r)
X̄ → -B1, r̄
X̄ → -B2, (1-r̄)
CPT Γx = Γx̄
T < mx = mx̄
r = r̄ ⟺ CP̸, C̸
1/Γx
nx = nx̄
X → qq (B = ±2/3)
X → q̄ l̄ (B = -1/3)
B = -1/3
(nx + nx̄)/s)i = nx ((rB1 + (1-r)B2 - B1r̄ - B2(1-r̄))/s)
= (nx/s)(r - r̄)(B1 - B2)

$X \to B_1,\ r$
$X \to B_2,\ (1-r)$

$X \to qq \quad (B = \pm 2/3)$
$X \to \bar{q}\,\bar{\ell} \quad (B = -\tfrac{1}{3})$



$B = -\tfrac{1}{3}$

$\bar{X} \to -B_1,\ \bar{r}$
$\bar{X} \to -B_2,\ (1-\bar{r})$

leron)

$\underline{\text{CPT}} \quad \Gamma_X = \Gamma_{\bar{X}}$

$\underline{r = \bar{r} \Longleftrightarrow \cancel{C}\cancel{P}, \cancel{C}}$

$T < m_X = m_{\bar{X}} \qquad \frac{1}{\Gamma_X} \qquad n_X = n_{\bar{X}}$

$$\left(\frac{n_X + n_{\bar{X}}}{s}\right)_i = n_X \left(\frac{rB_1 + (1-r)B_2 - B_1\bar{r} - B_2(1-\bar{r})}{s}\right)$$

$$= \left(\frac{n_X}{s}\right)\underline{(r-\bar{r})(B_1 - B_2)}$$

$\underline{m_X} > T$

$e^{-\frac{m_X}{T}}$

(Sphaleron)

$X \to B_1,\ r$

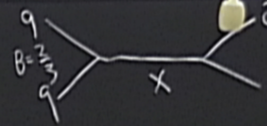
$X \to B_2,\ (1-r)$

$\bar{X} \to -B_1 \quad \bar{r}$

$\bar{X} \to -B_2 \quad (1-\bar{r})$

$X \to qq \quad (B = \pm 2/3)$

$X \to \bar{q}\,\bar{\ell} \quad (B = -\tfrac{1}{3})$



$B = -\frac{1}{3}$

$\underline{\text{CPT}}$ $\quad \Gamma_X = \Gamma_{\bar{X}}$ $\qquad \underline{r = \bar{r} \Longleftrightarrow \cancel{C}\cancel{P}, \cancel{C}}$

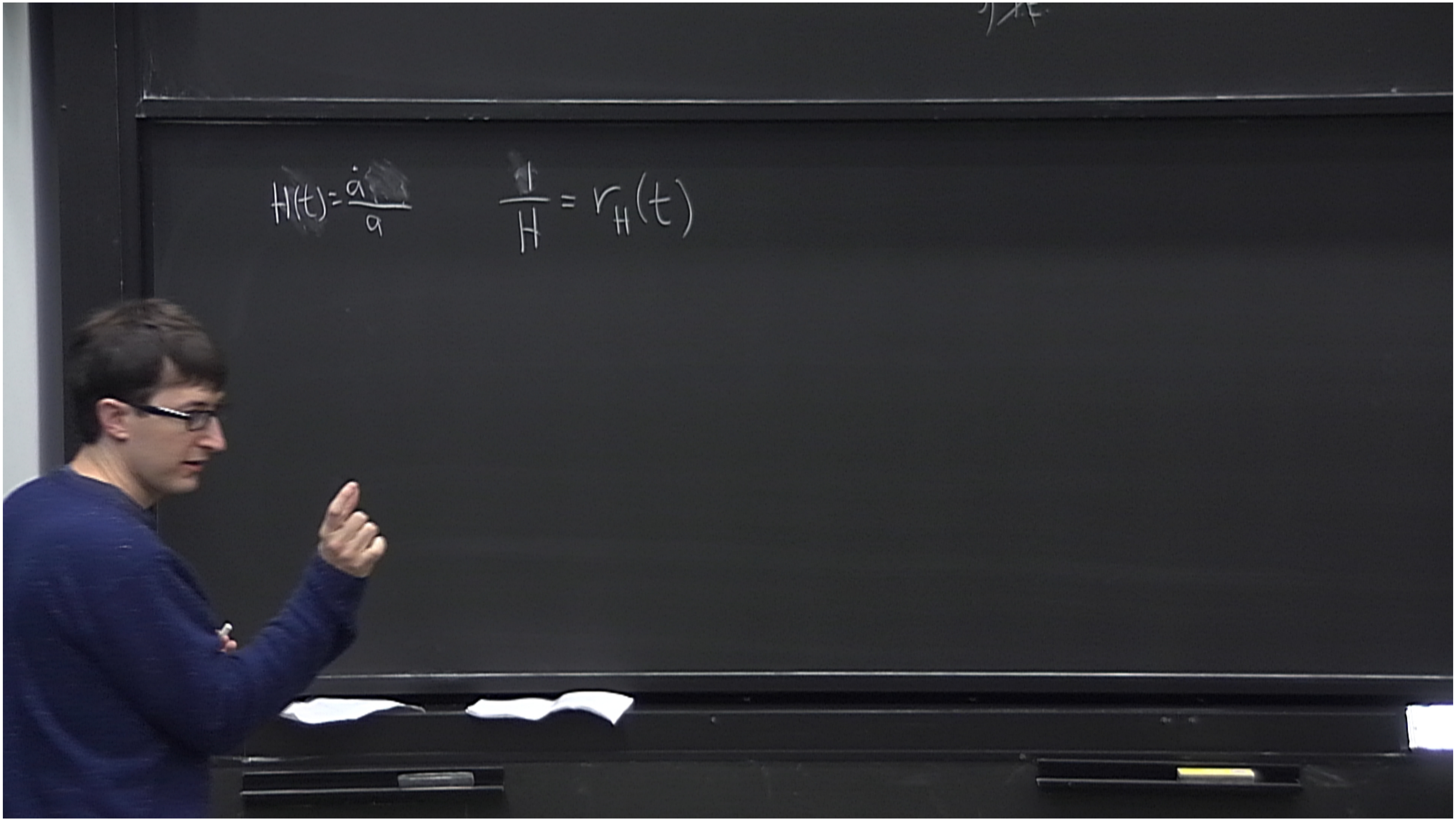
$T < m_X = m_{\bar{X}} \qquad \frac{1}{\Gamma_X} \qquad n_X = n_{\bar{X}}$

$$\left(\frac{n_X + n_{\bar{X}}}{s}\right)_i = n_X \left(\frac{rB_1 + (1-r)B_2 - B_1\bar{r} - B_2(1-\bar{r})}{s}\right)$$

$$10^{-9} = \left(\frac{n_X}{s}\right)\underline{(r-\bar{r})(B_1 - B_2)}$$

$\underline{m_X} > T$

$e^{-\frac{m_X}{T}}$

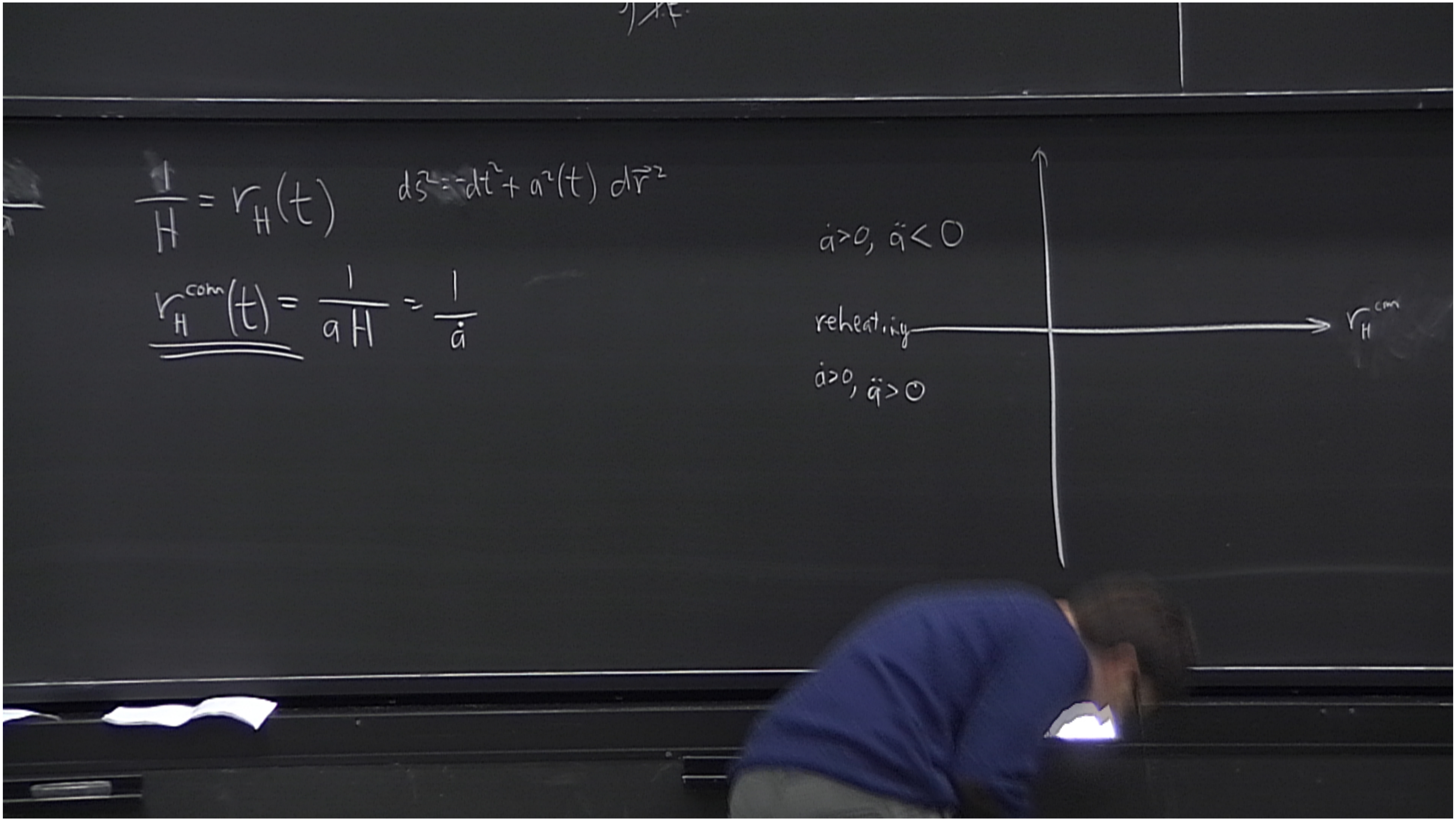

H(t) = ȧ/a
1/H = r_H(t)

$H(t) = \frac{\dot{a}}{a}$

$\frac{1}{H} = r_H(t)$

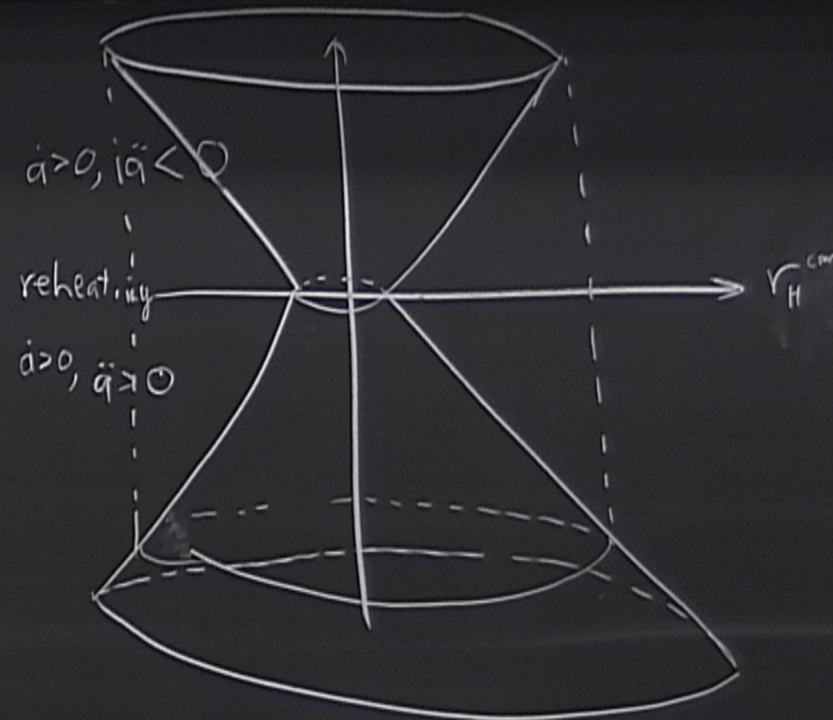
$ds^2 = -dt^2 + a^2(t)\, d\vec{r}^{\,2}$

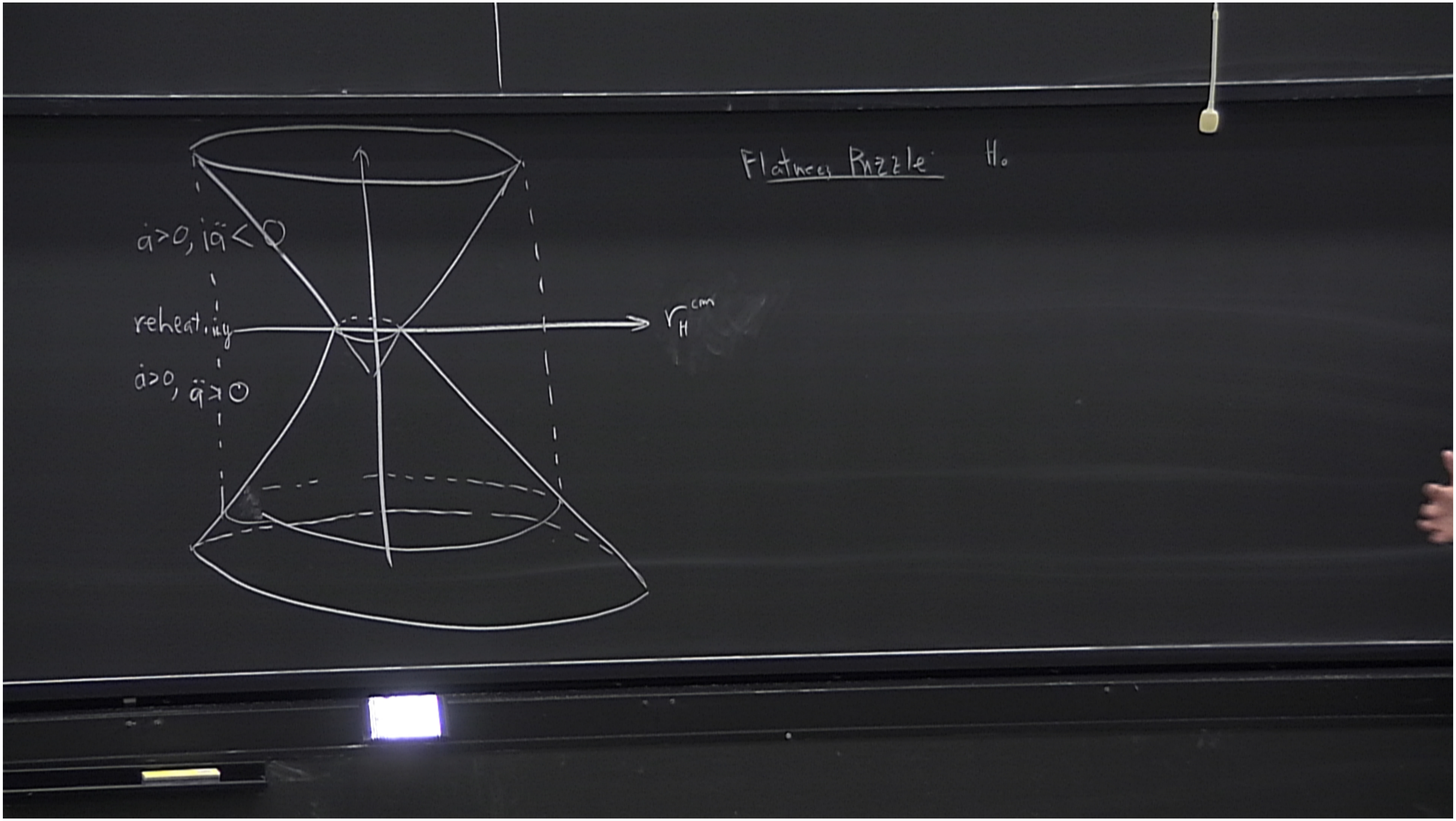
$r_H^{com}(t) = \frac{1}{aH} = \frac{1}{\dot{a}}$

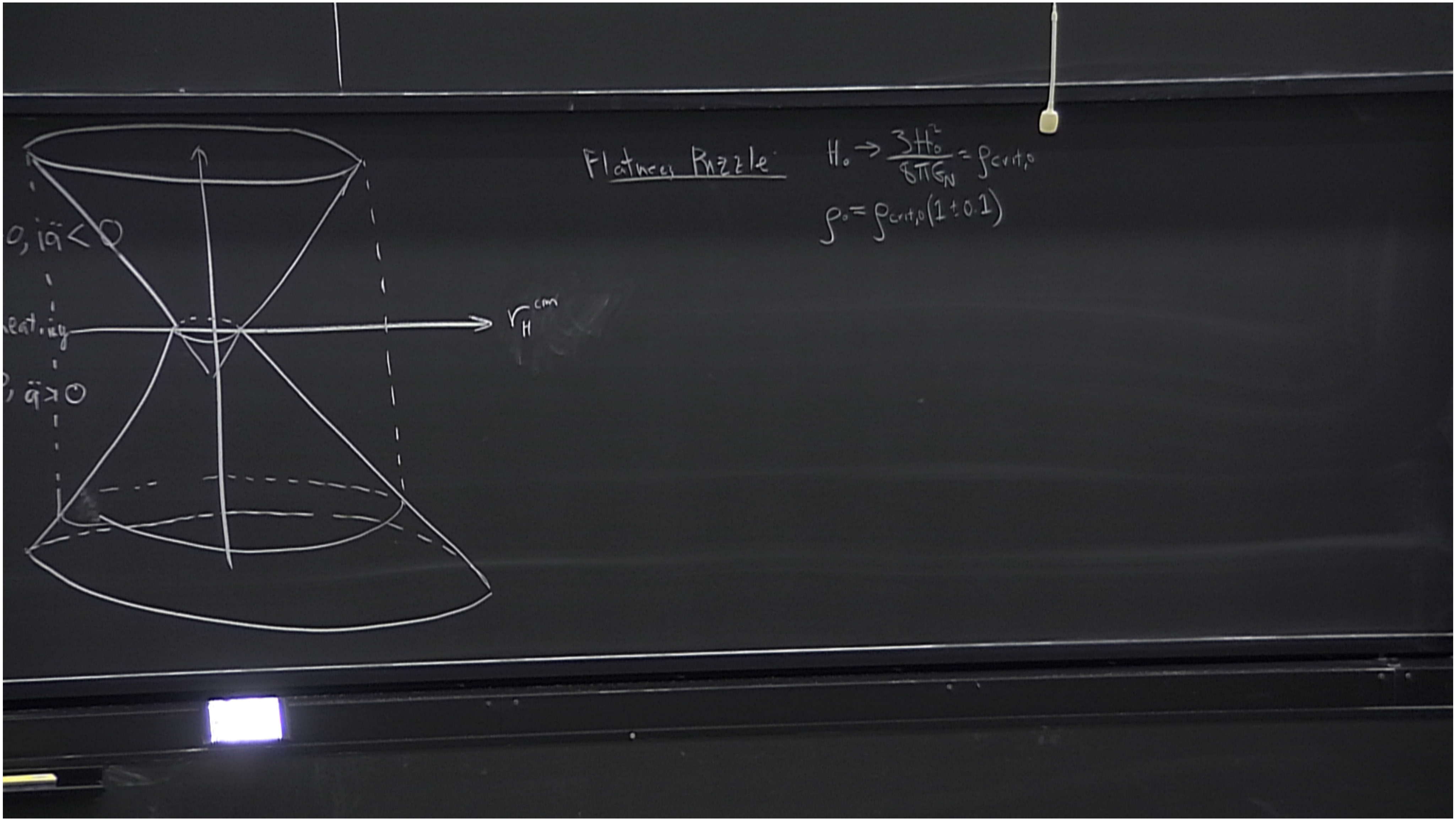

$\frac{1}{H} = r_H(t)$
$ds^2 = -dt^2 + a^2(t)\, d\vec{r}^{\,2}$
$r_H^{com}(t) = \frac{1}{aH} = \frac{1}{\dot{a}}$
$\dot{a}>0,\ \ddot{a}<0$
reheating
$\dot{a}>0,\ \ddot{a}>0$
r_H^{com}

$$\frac{1}{H} = r_H(t) \qquad ds^2 = -dt^2 + a^2(t)\, d\vec{r}^{\,2}$$

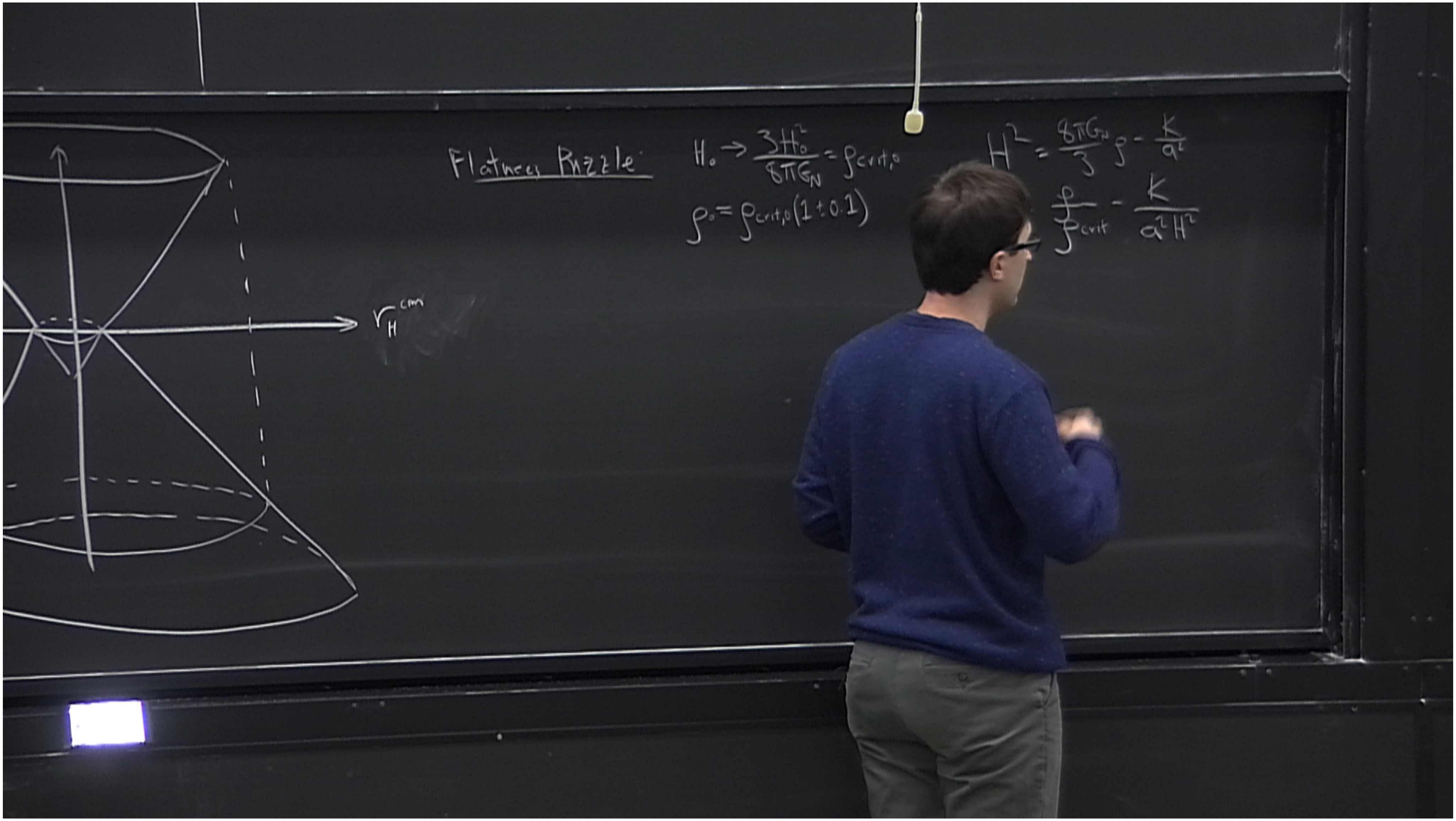
$$\underline{\underline{r_H^{com}(t)}} = \frac{1}{aH} = \frac{1}{\dot{a}}$$

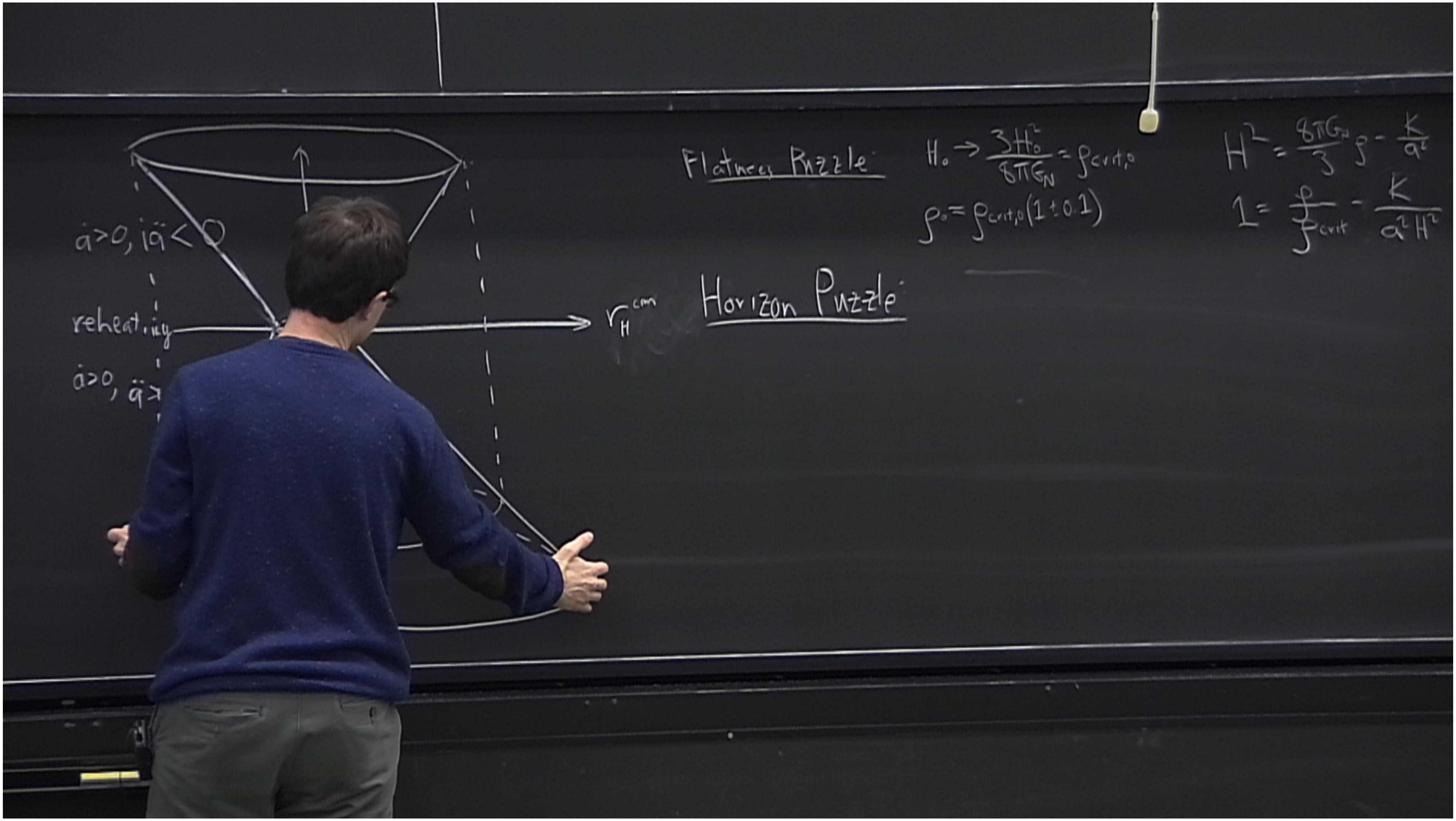


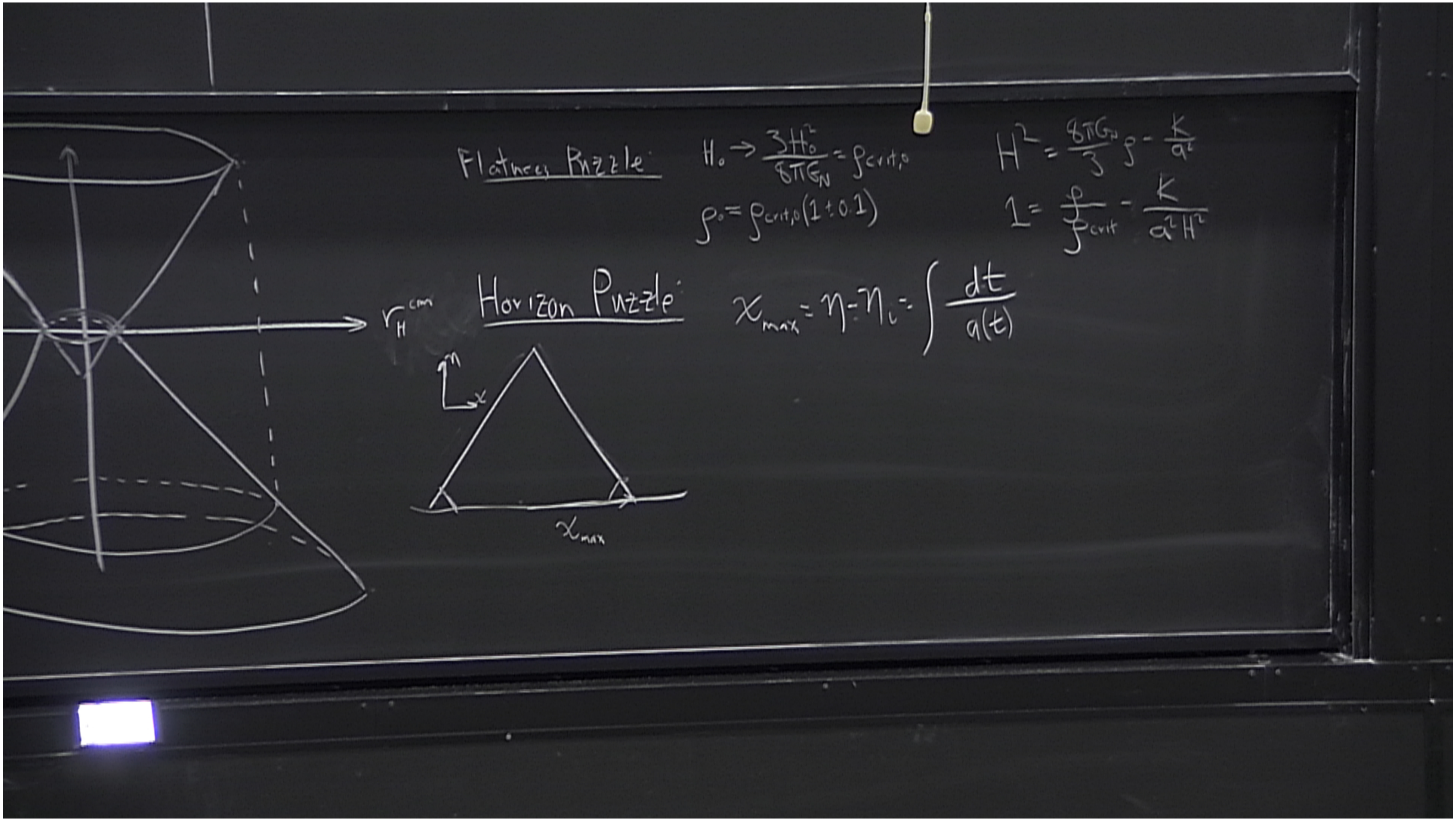

Flatness Puzzle
H₀
ȧ>0, ä<0
reheating
ȧ>0, ä>0
r_H^cm



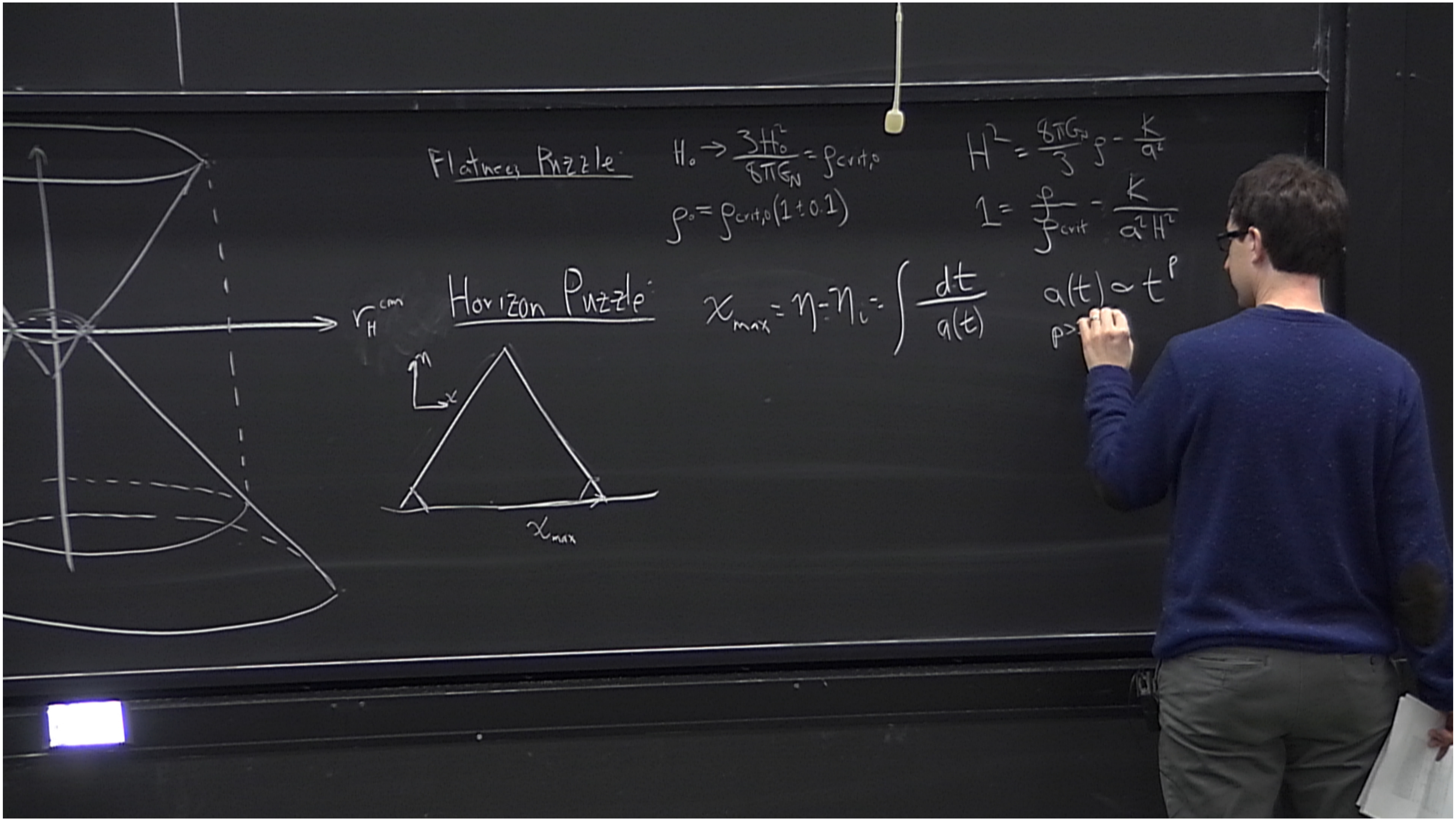
Flatness Puzzle:
$H_0 \to \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$
$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$
r_H^{cm}

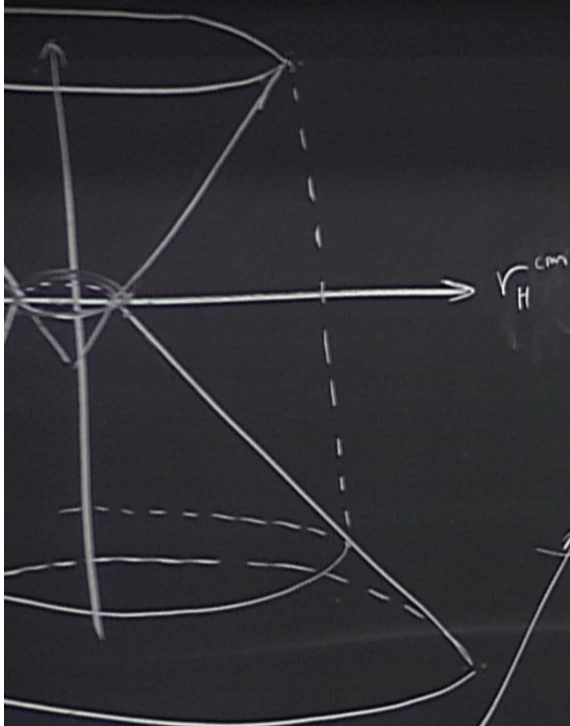

Flatness Puzzle
H₀ → 3H₀²/8πG_N = ρcrit,0
ρ₀ = ρcrit,0 (1 ± 0.1)
H² = 8πG_N/3 ρ - K/a²
ρ/ρcrit - K/a²H²
r_H^com


Flatness Puzzle
$H_0 \to \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$
$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$
$H^2 = \frac{8\pi G_N}{3}\rho - \frac{K}{a^2}$
$1 = \frac{\rho}{\rho_{crit}} - \frac{K}{a^2 H^2}$
Horizon Puzzle
$\dot{a}>0, \ddot{a}<0$
reheating
r_H^{com}



Flatness Puzzle:
$H_0 \to \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$
$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$
$H^2 = \frac{8\pi G_N}{3}\rho - \frac{K}{a^2}$
$1 = \frac{\rho}{\rho_{crit}} - \frac{K}{a^2 H^2}$
r_H^{com}
Horizon Puzzle:
$\chi_{max} = \eta - \eta_i = \int \frac{dt}{a(t)}$
η
x
χ_{max}


Flatness Puzzle
H₀ → 3H₀²/8πG_N = ρ_crit,0
ρ₀ = ρ_crit,0 (1 ± 0.1)
H² = (8πG_N/3) ρ − K/a²
1 = ρ/ρ_crit − K/(a²H²)
Horizon Puzzle
r_H^cm
χ_max = η − η_i = ∫ dt/a(t)
a(t) ∝ t^p
χ_max



Flatness Puzzle:

$$H_0 \to \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$$

$$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$$

$$H^2 = \frac{8\pi G_N}{3}\rho - \frac{K}{a^2}$$

$$1 = \frac{\rho}{\rho_{crit}} - \frac{K}{a^2H^2}$$

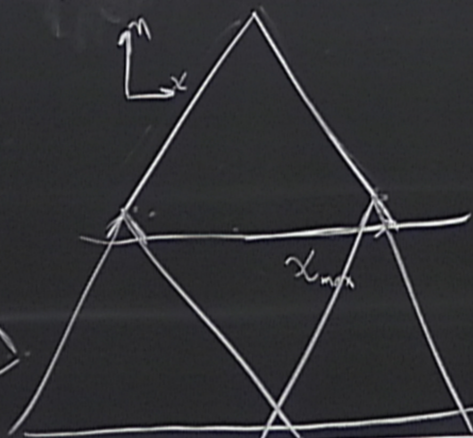
Horizon Puzzle:

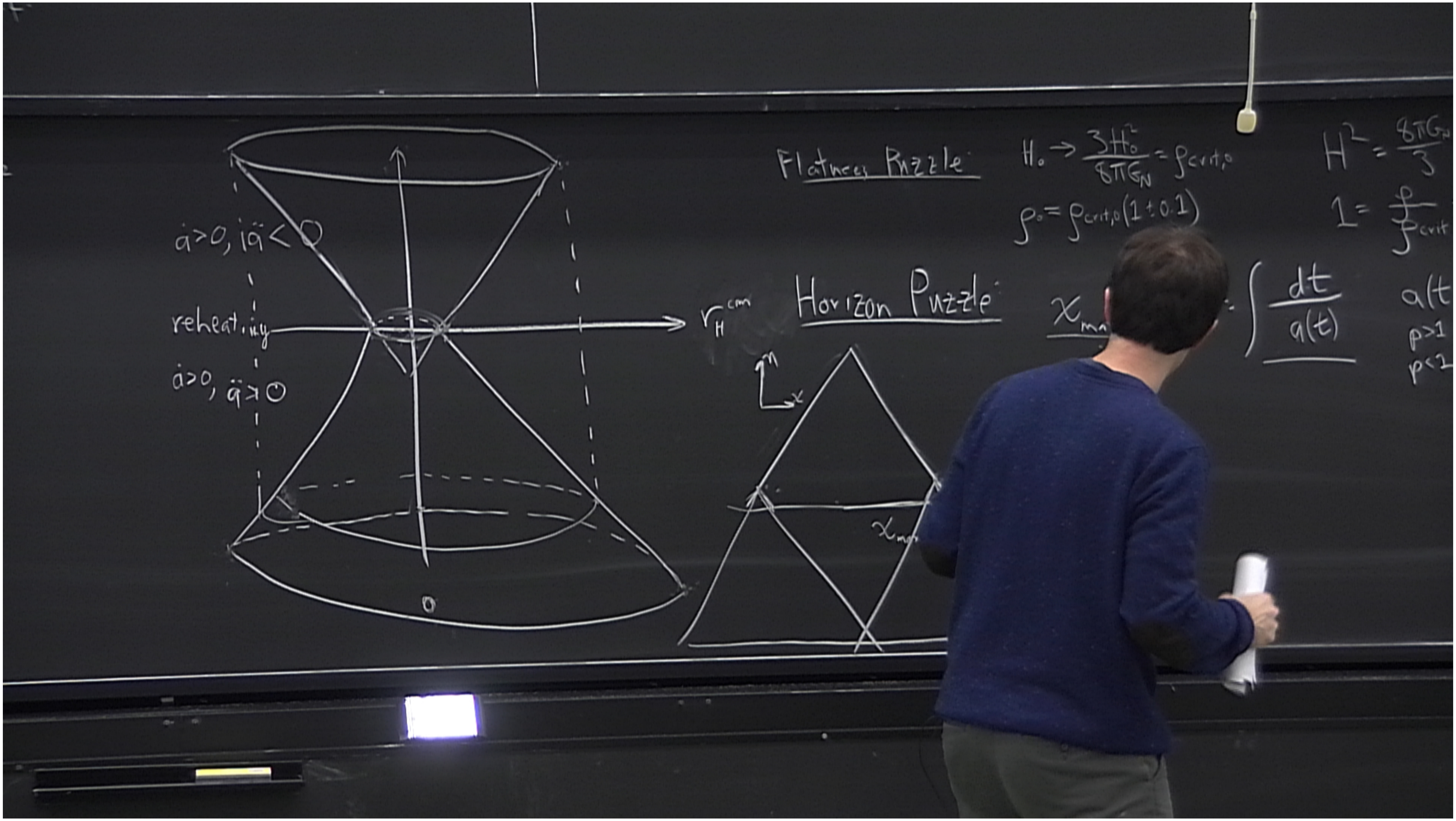
$$\chi_{max} = \eta - \eta_i = \int \frac{dt}{a(t)}$$

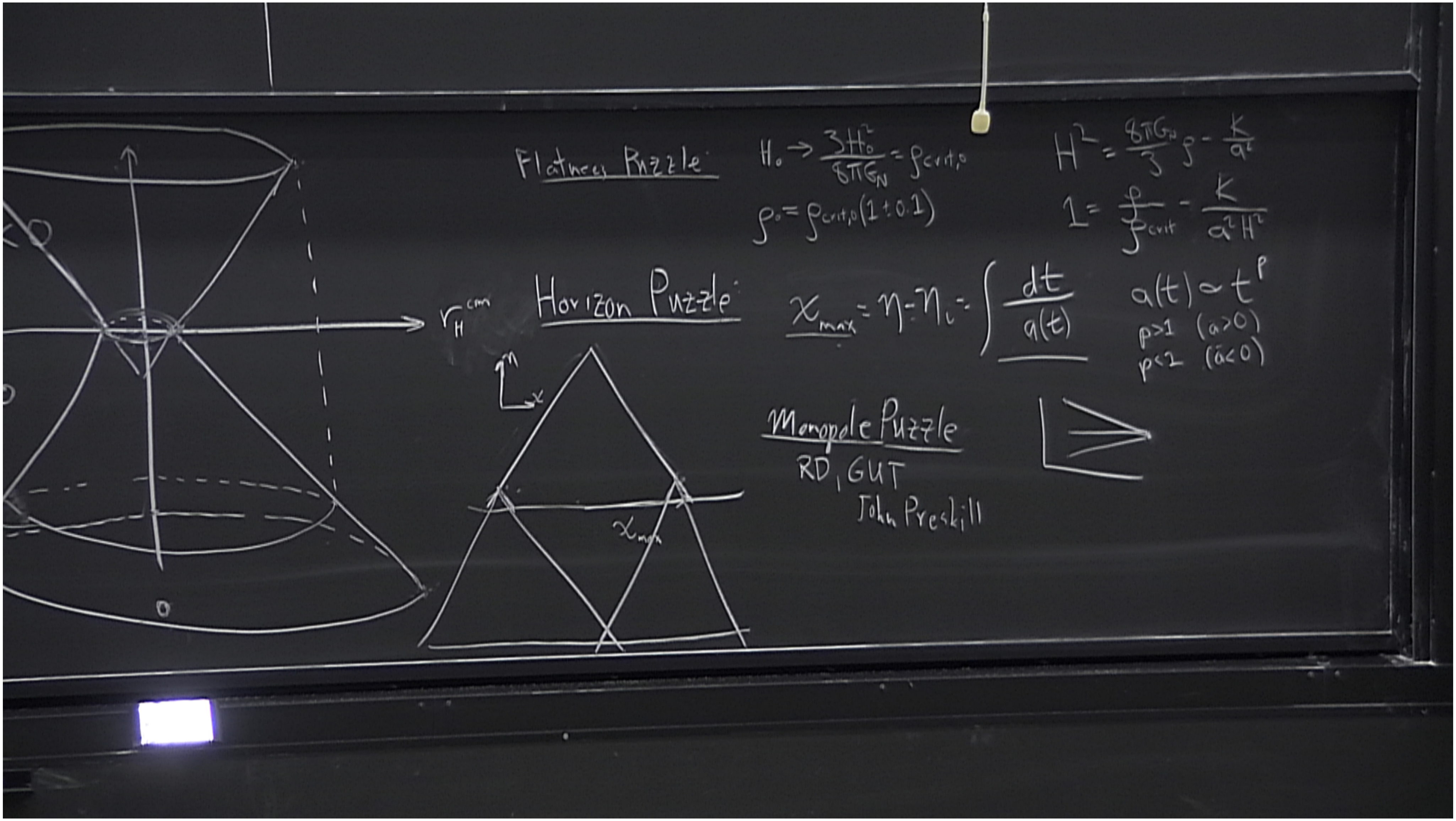
$$a(t) \propto t^p$$

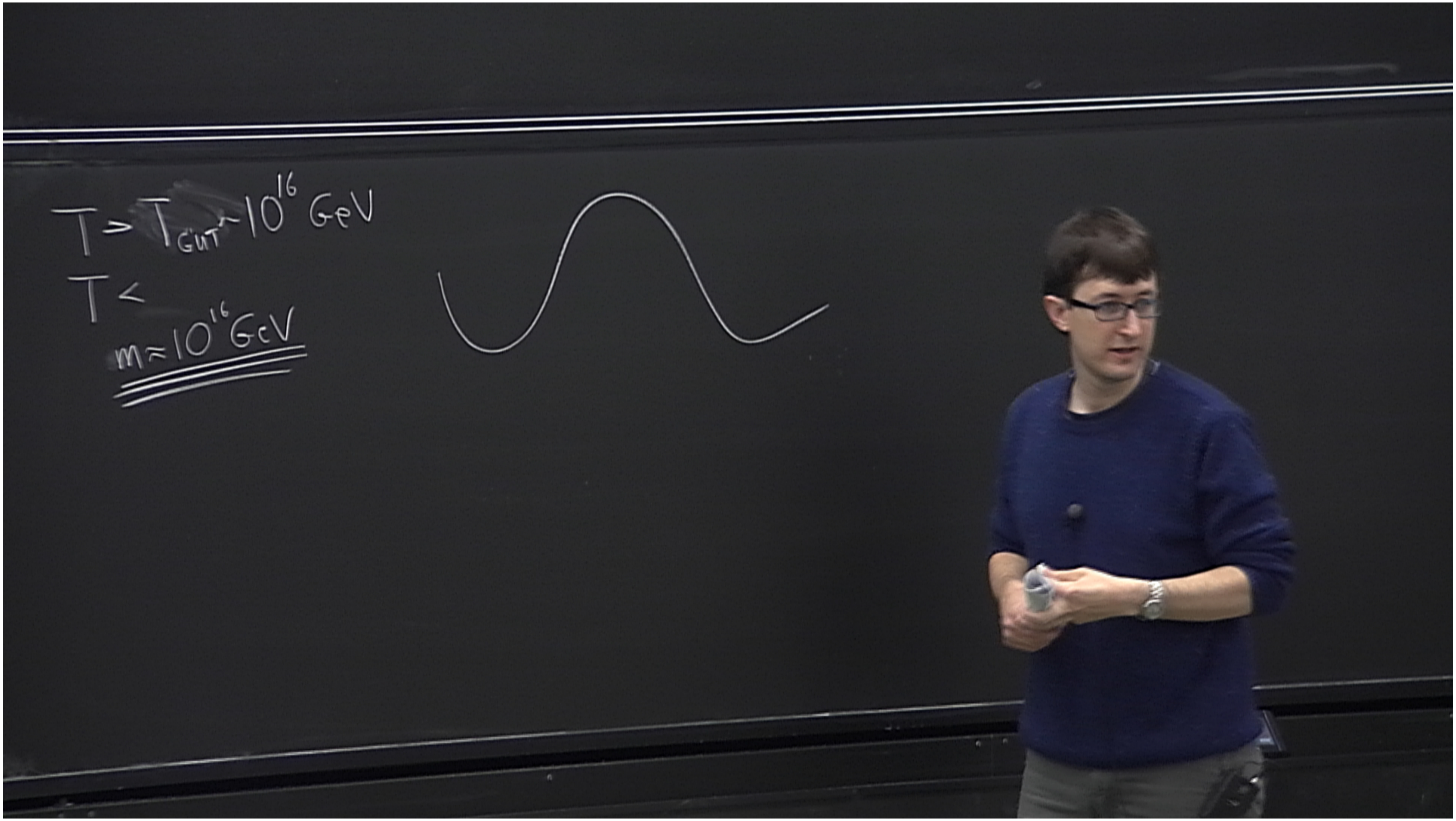
$p>1$ $(\ddot{a}>0)$

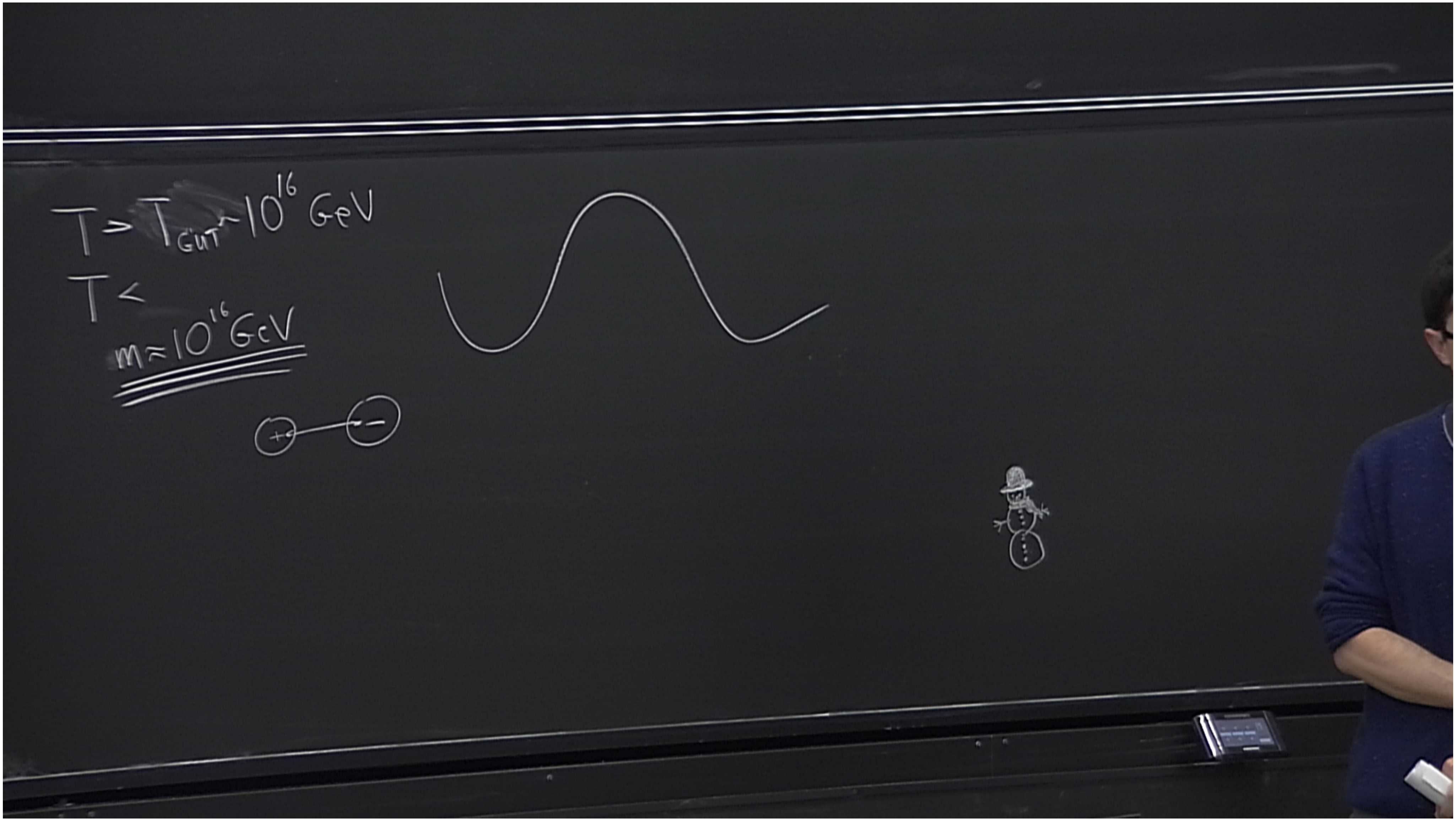
$p<1$ $(\ddot{a}<0)$

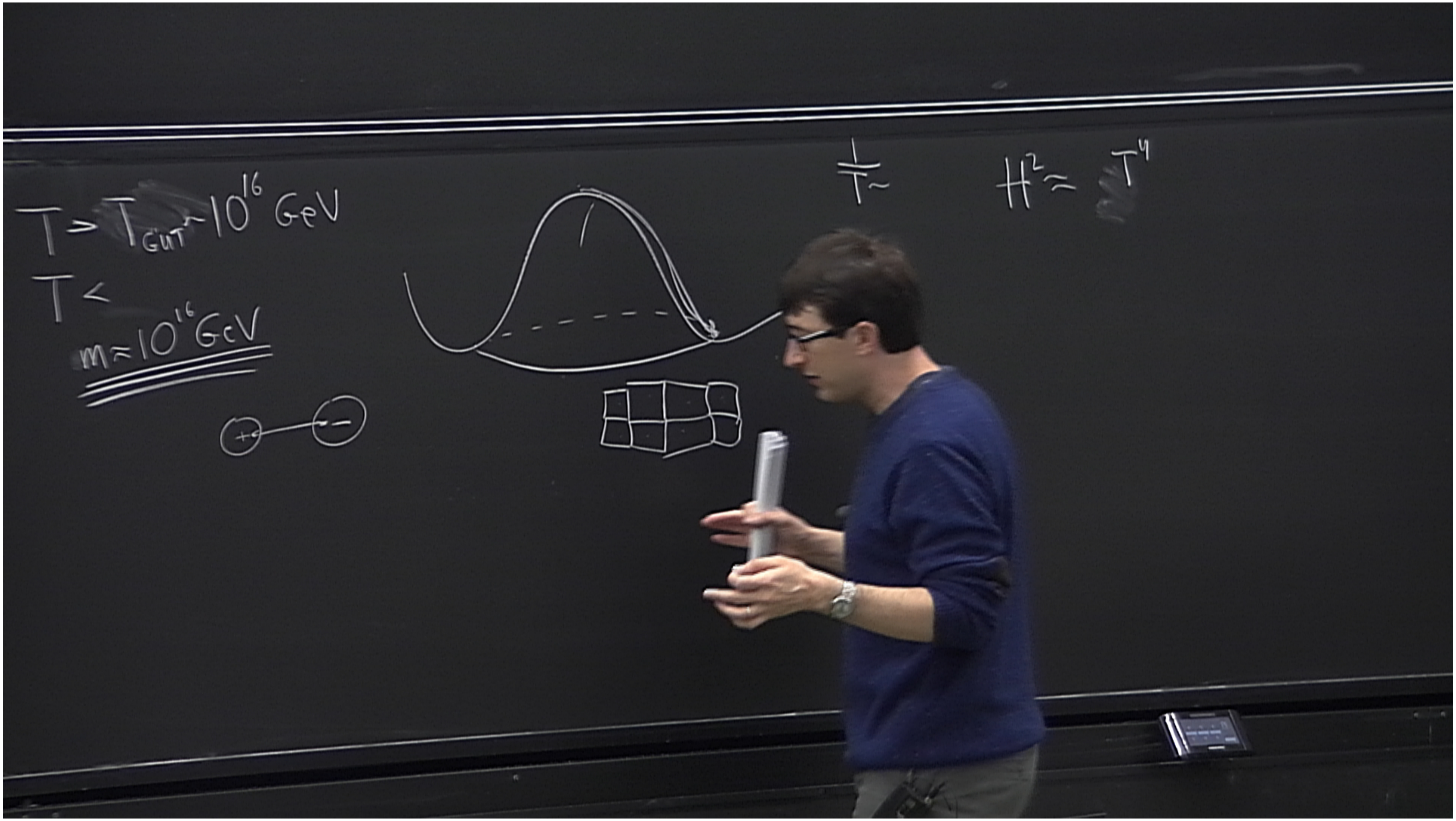



Flatness Puzzle
$H_0 \to \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$
$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$
$H^2 = \frac{8\pi G_N}{3}$
$1 = \frac{\rho}{\rho_{crit}}$
Horizon Puzzle
$\int \frac{dt}{a(t)}$
$\dot a > 0, \ddot a < 0$
reheating
$\dot a > 0, \ddot a > 0$
r_H^{cm}
x_{max}

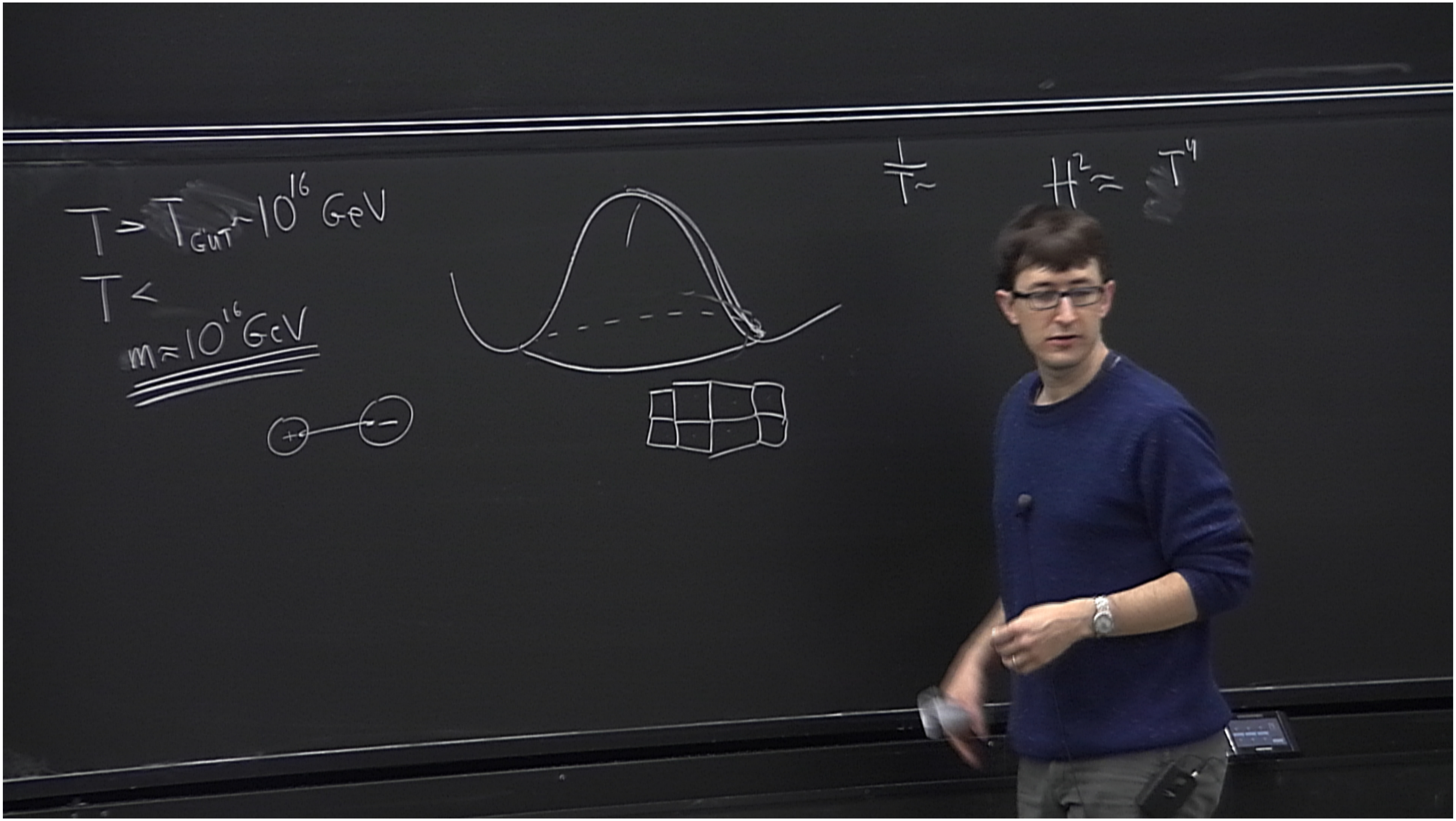

Flatness Puzzle
$H_0 \rightarrow \frac{3H_0^2}{8\pi G_N} = \rho_{crit,0}$
$\rho_0 = \rho_{crit,0}(1 \pm 0.1)$
$H^2 = \frac{8\pi G_N}{3}\rho - \frac{K}{a^2}$
$1 = \frac{\rho}{\rho_{crit}} - \frac{K}{a^2H^2}$
r_H^{cmv}
Horizon Puzzle
$\chi_{max} = \eta - \eta_i = \int \frac{dt}{a(t)}$
$a(t) \propto t^p$
$p>1$ $(\ddot{a}>0)$
$p<1$ $(\ddot{a}<0)$
η
x
χ_{max}
Monopole Puzzle
RD, GUT
John Preskill

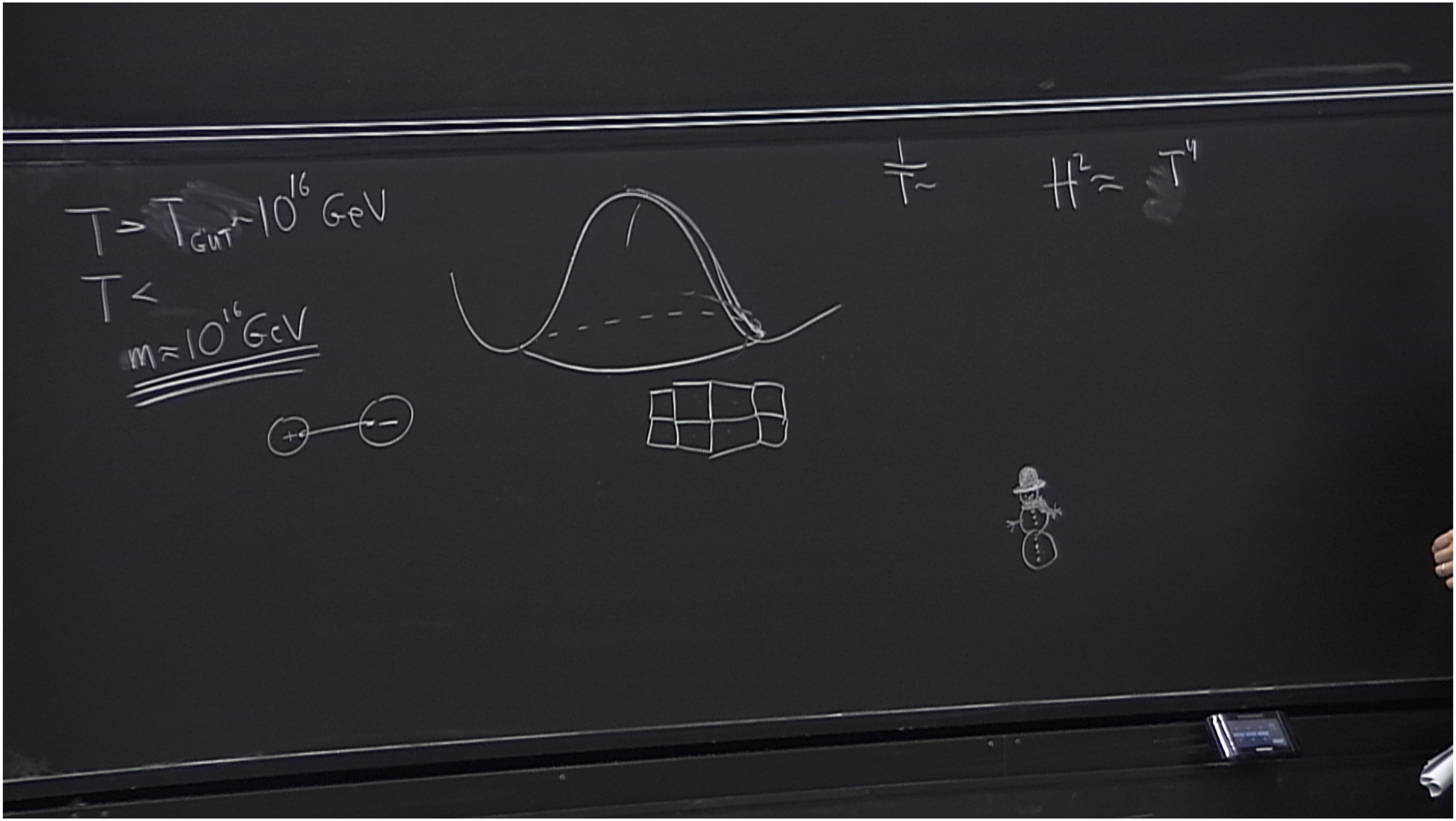

T > T_GUT ~ 10^16 GeV
T <
m ≈ 10^16 GeV


T > T_GUT ~ 10^16 GeV
T <
m ≈ 10^16 GeV
+
−



T > T_GUT ~ 10^16 GeV
T <
m ≈ 10^16 GeV
H^2 ≃ T^4


T > T_GUT ~ 10^16 GeV
T <
m ≈ 10^16 GeV
H^2 ≃ T^4


$T > T_{GUT} \sim 10^{16}$ GeV
$T <$
$m \approx 10^{16}$ GeV
$T \sim$
$H^2 \approx T^4$