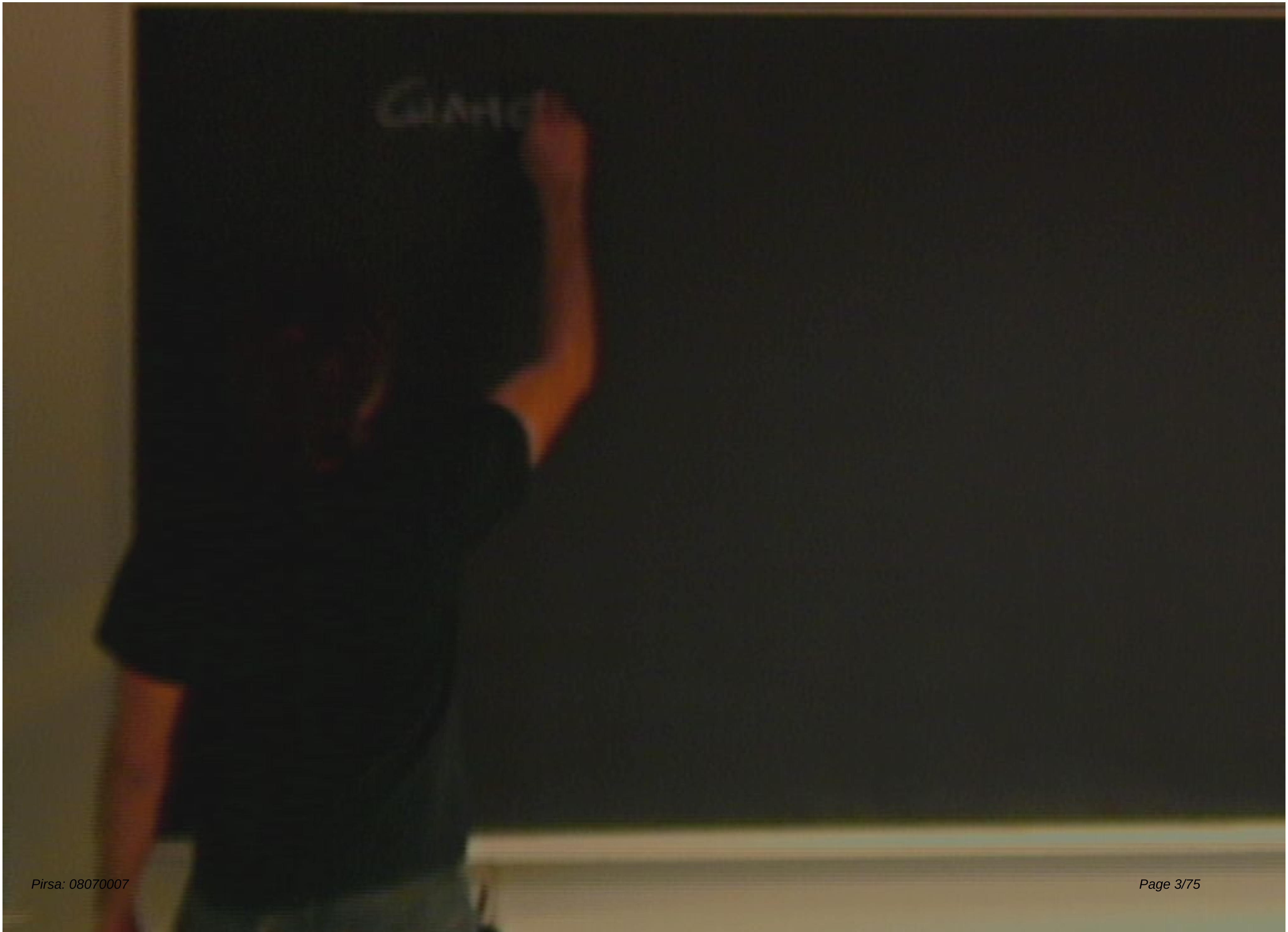
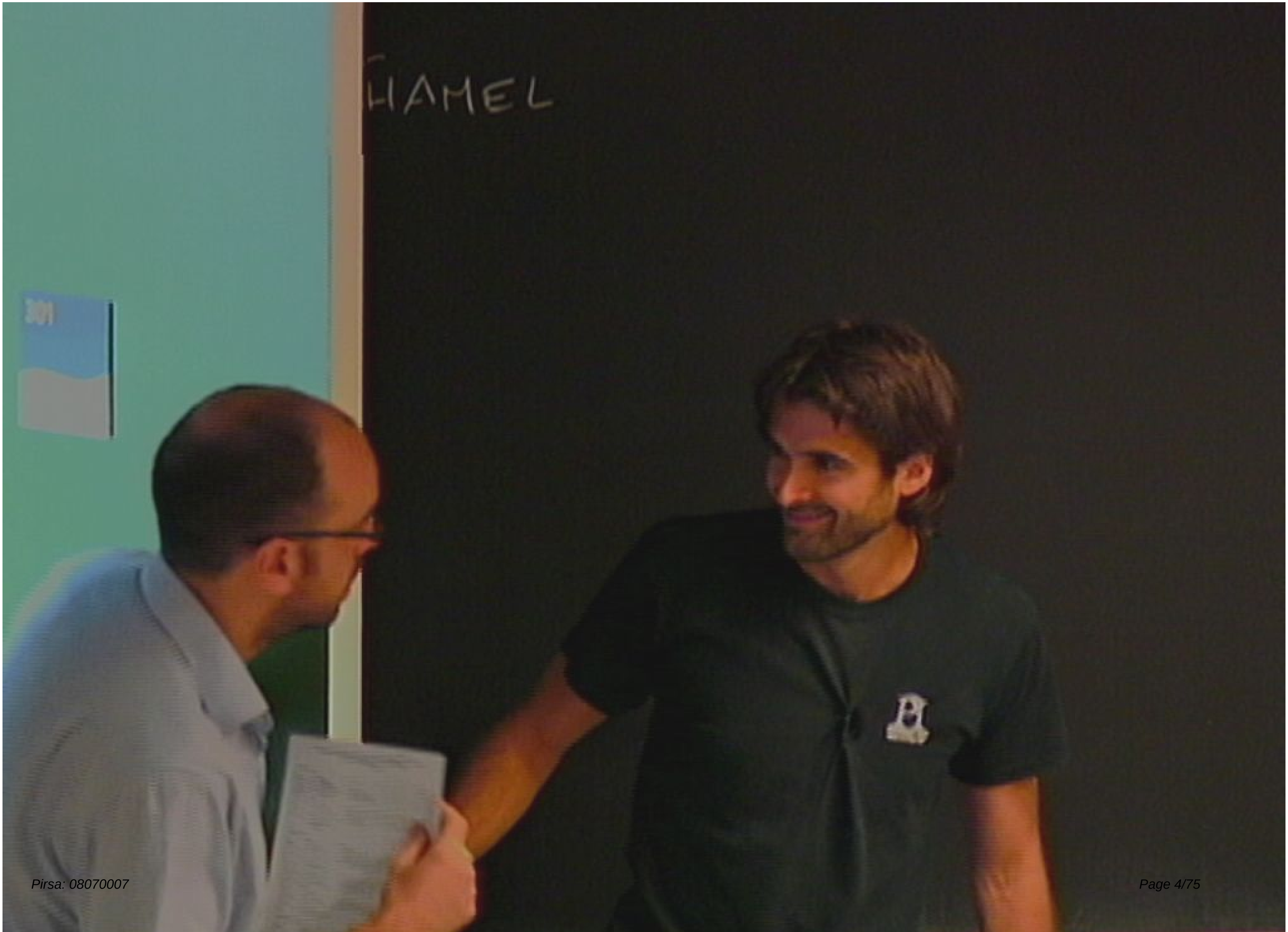
Title: Chameleon Theories

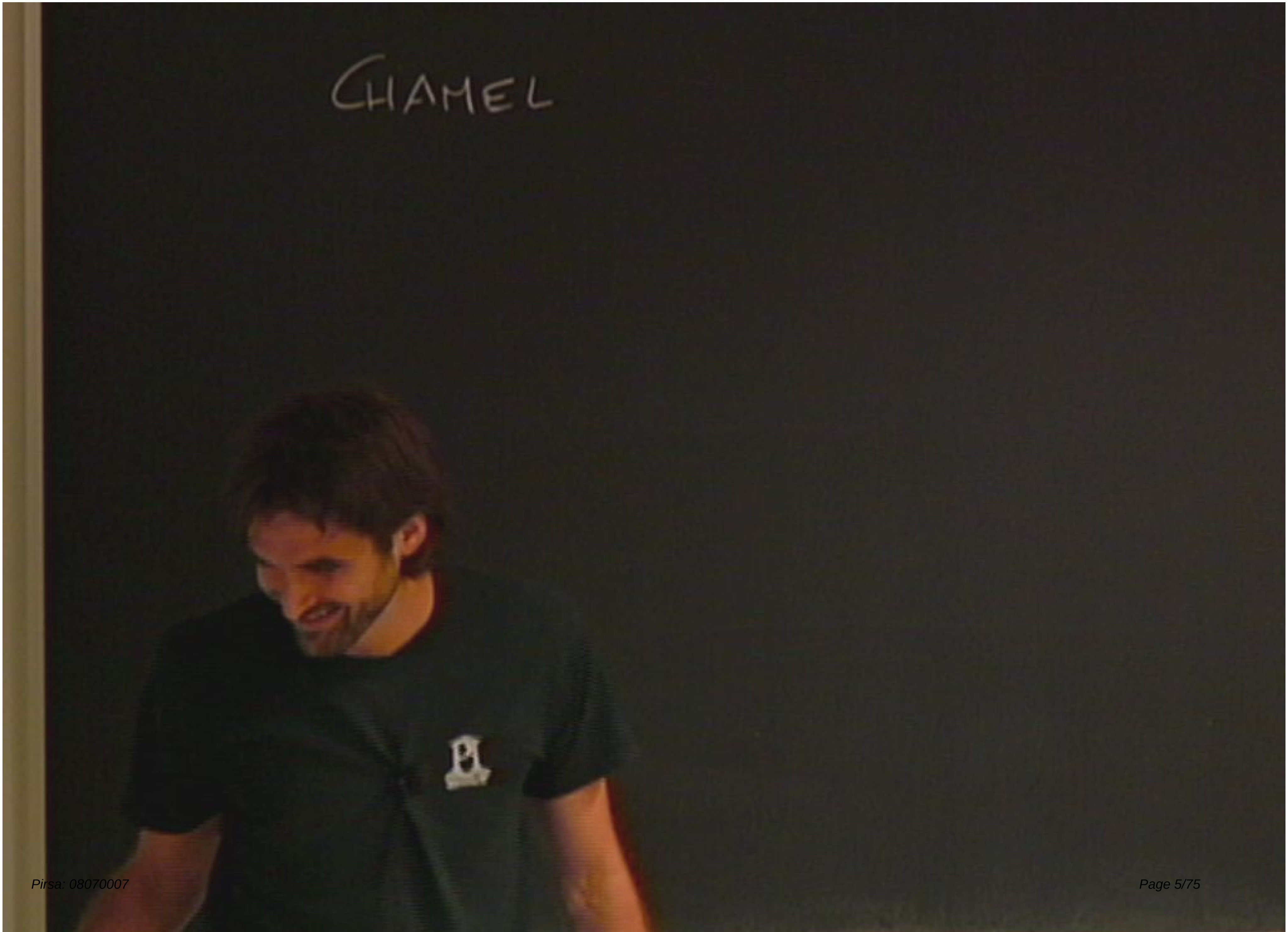
Date: Jul 14, 2008 12:00 PM

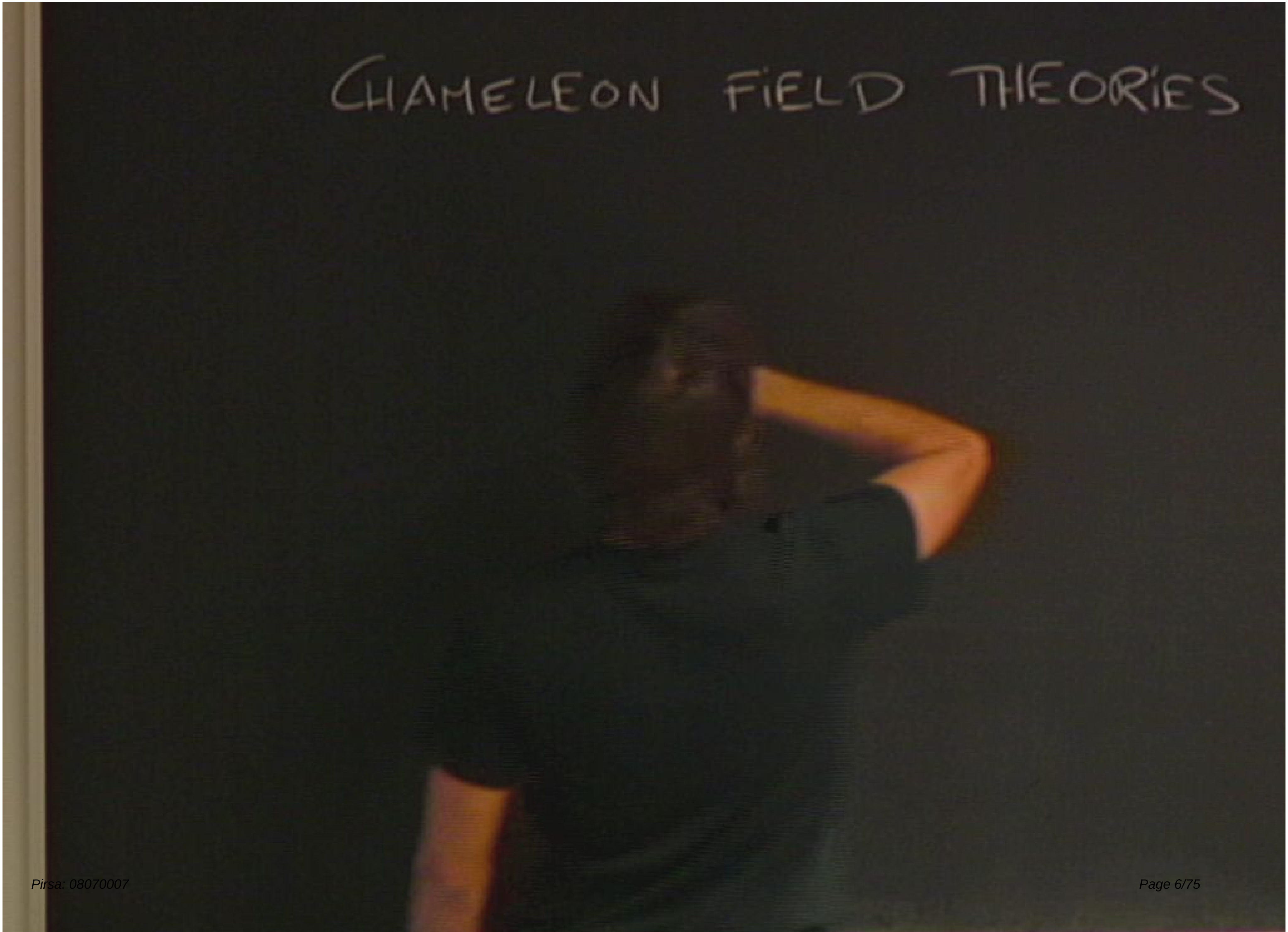
URL: http://pirsa.org/08070007

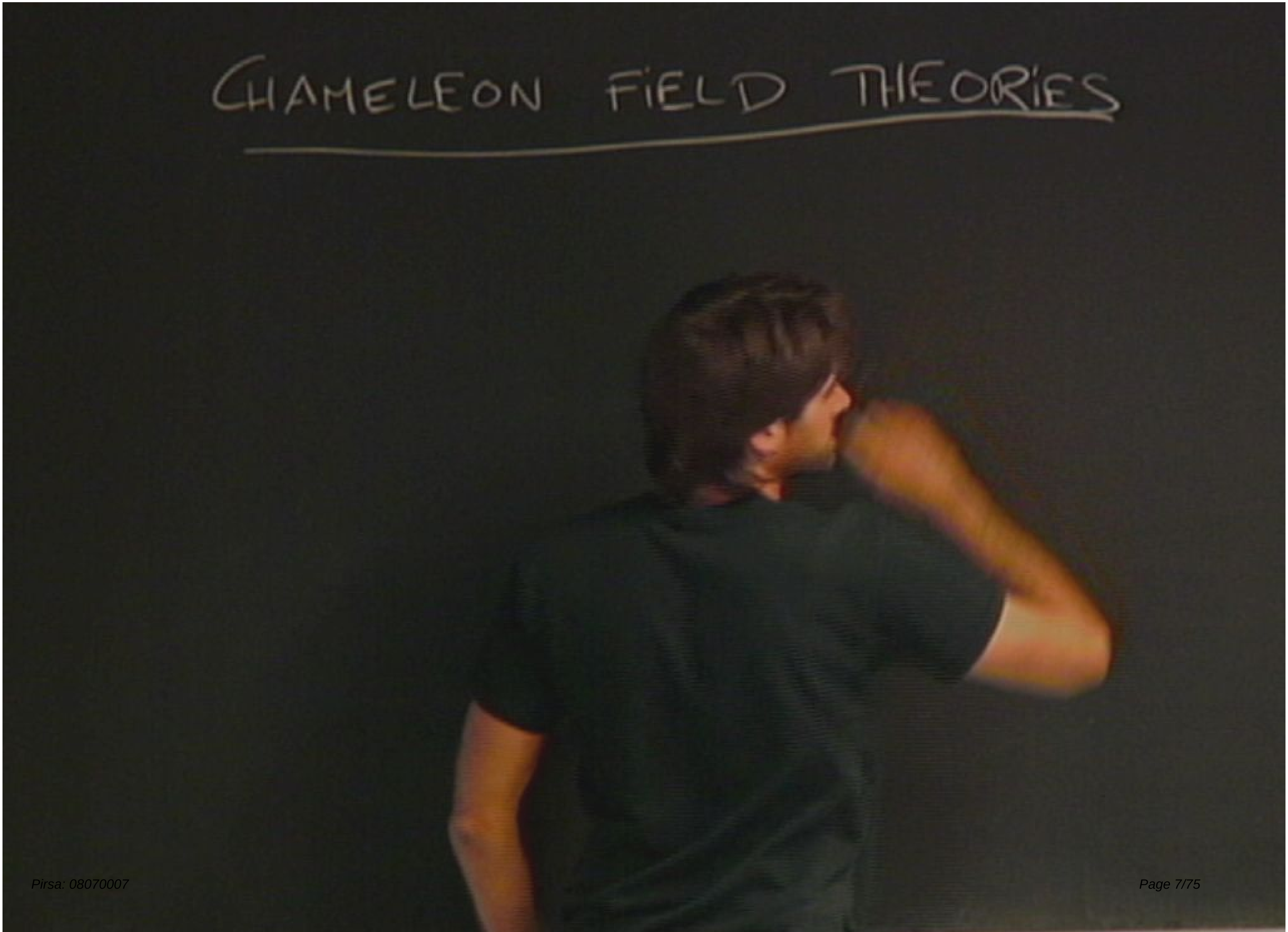
Abstract:

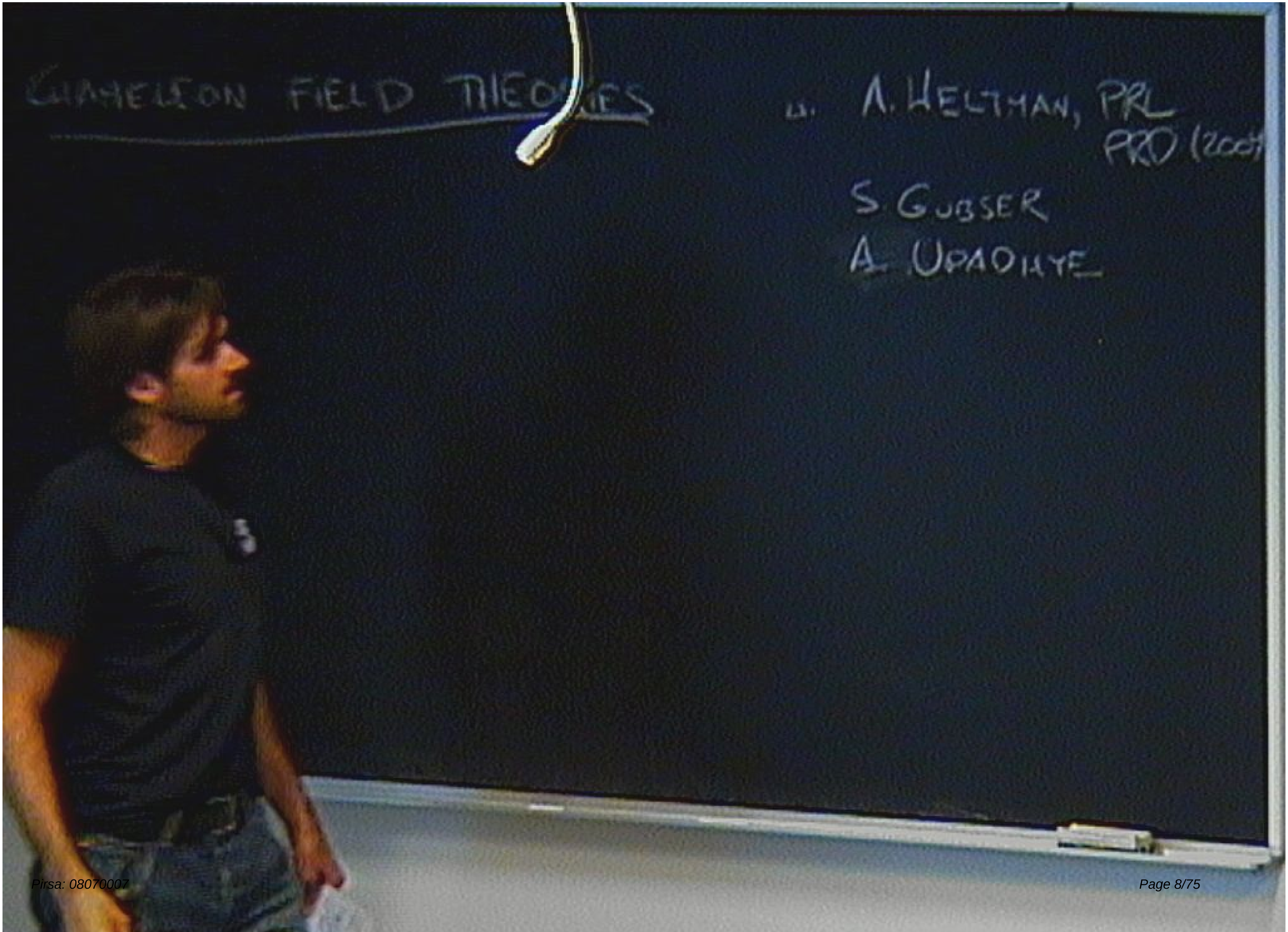


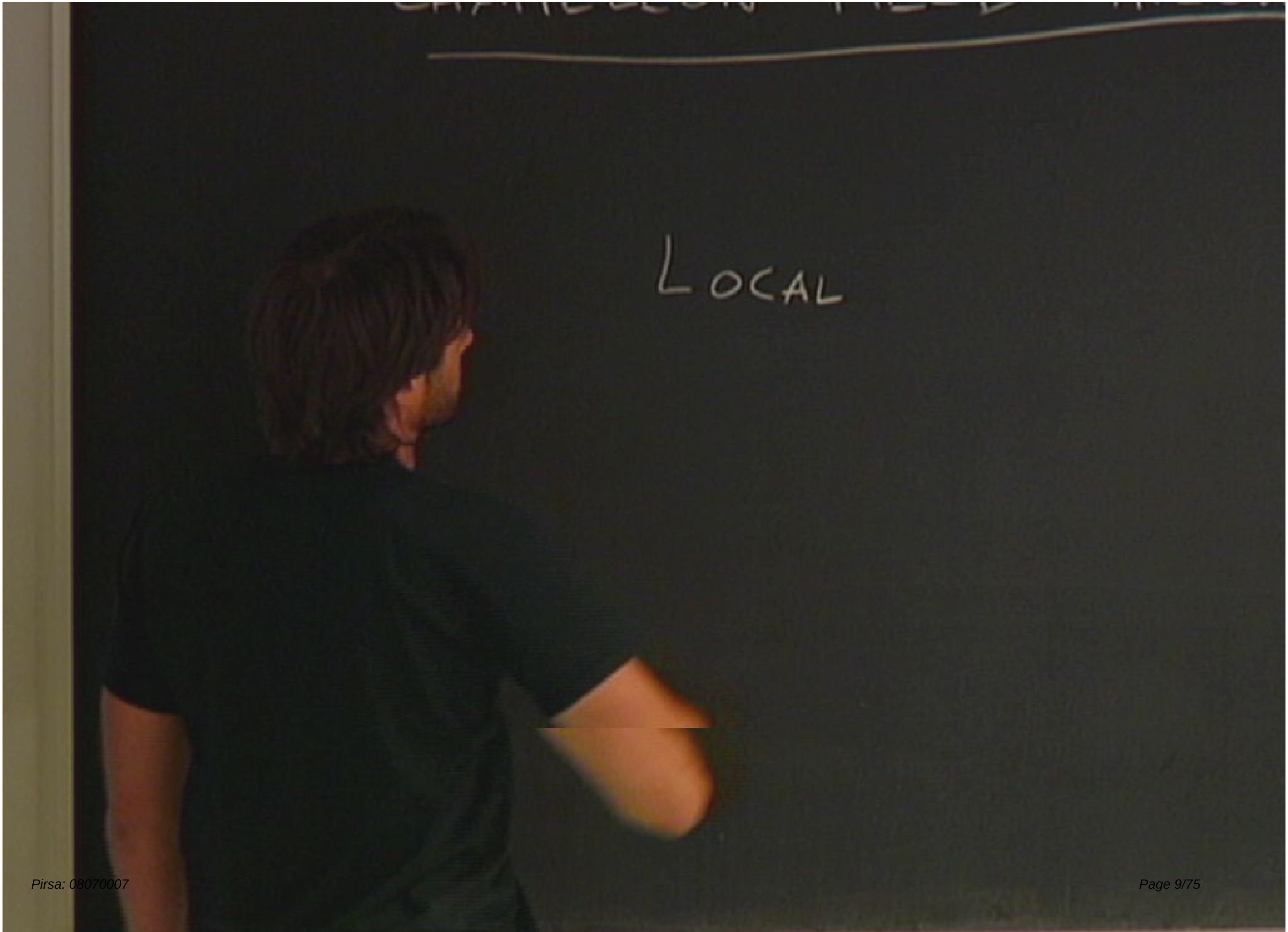

HAMEL

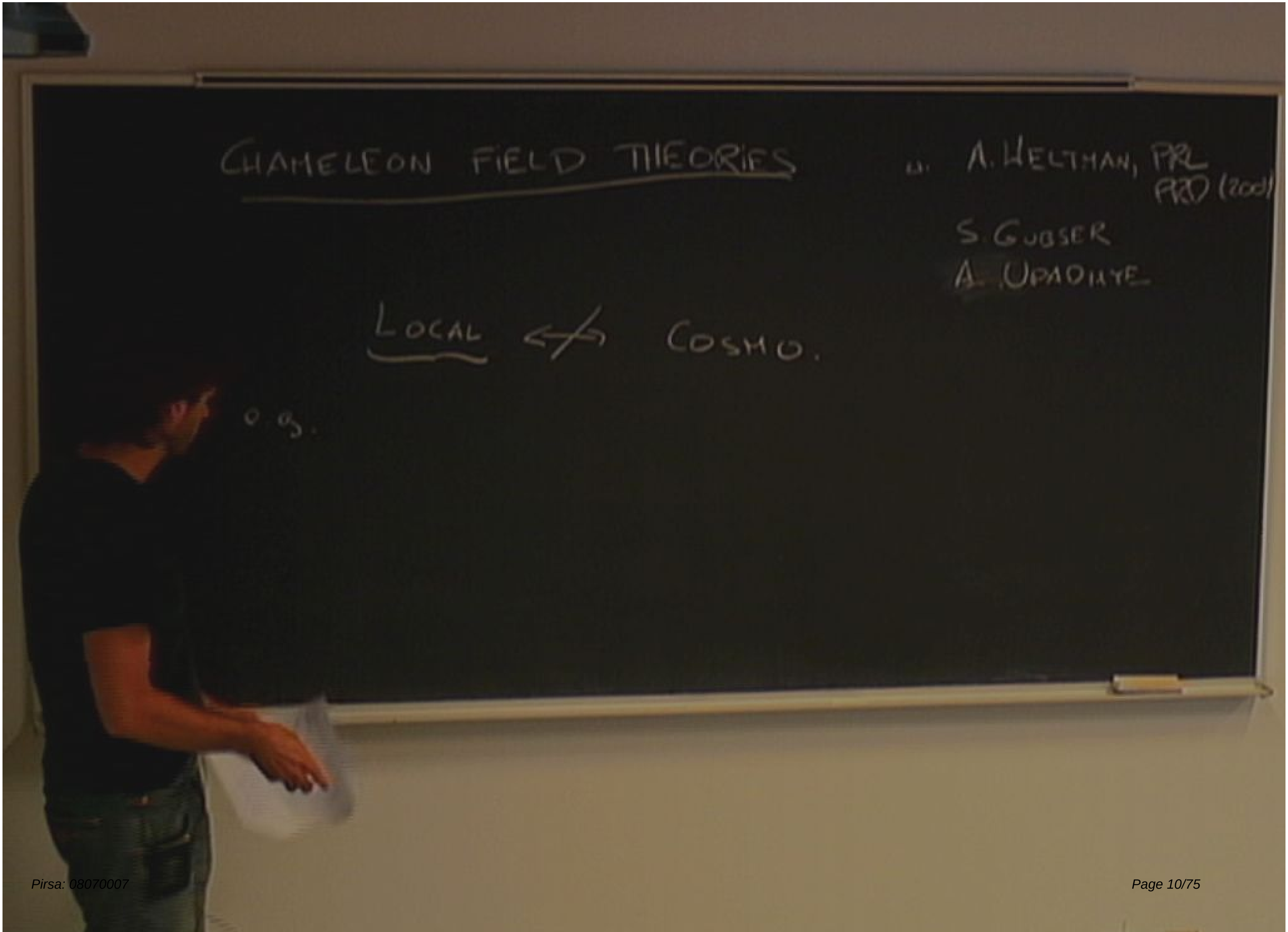

CHAMEL

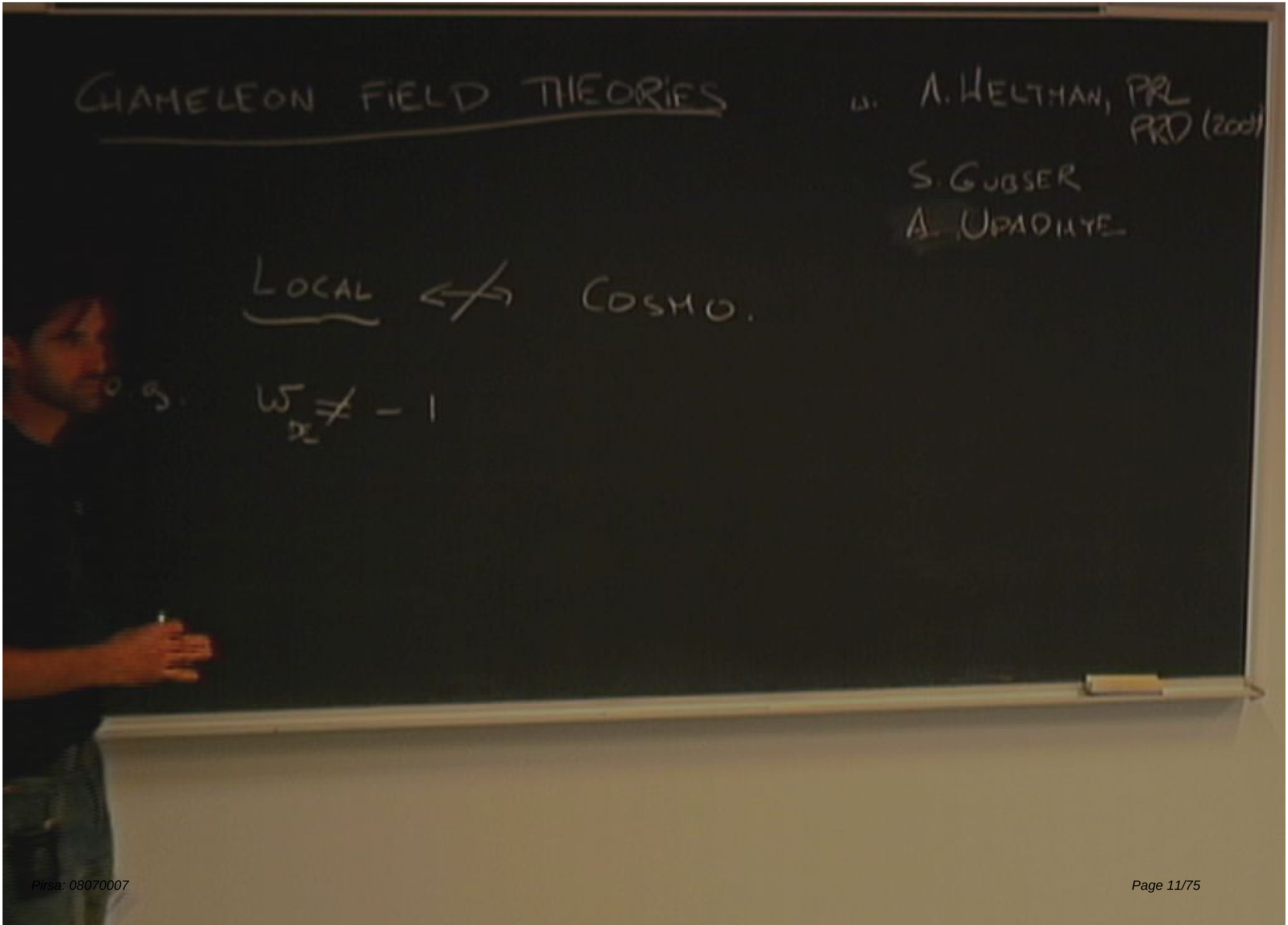

CHAMELEON FIELD THEORIES


CHAMELEON FIELD THEORIES


CHAMELEON FIELD THEORIES
A. WELTMAN, PRL
PRD (200
S. GUBSER
A. UPADHYE


LOCAL


CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (200
S. GUBSER
A. UPADHYE
LOCAL </> COSMO.
e.g.


CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (2004)
S. GUBSER
A. UPADHYE
LOCAL ⇎ COSMO.
e.g. $w_{DE} \neq -1$

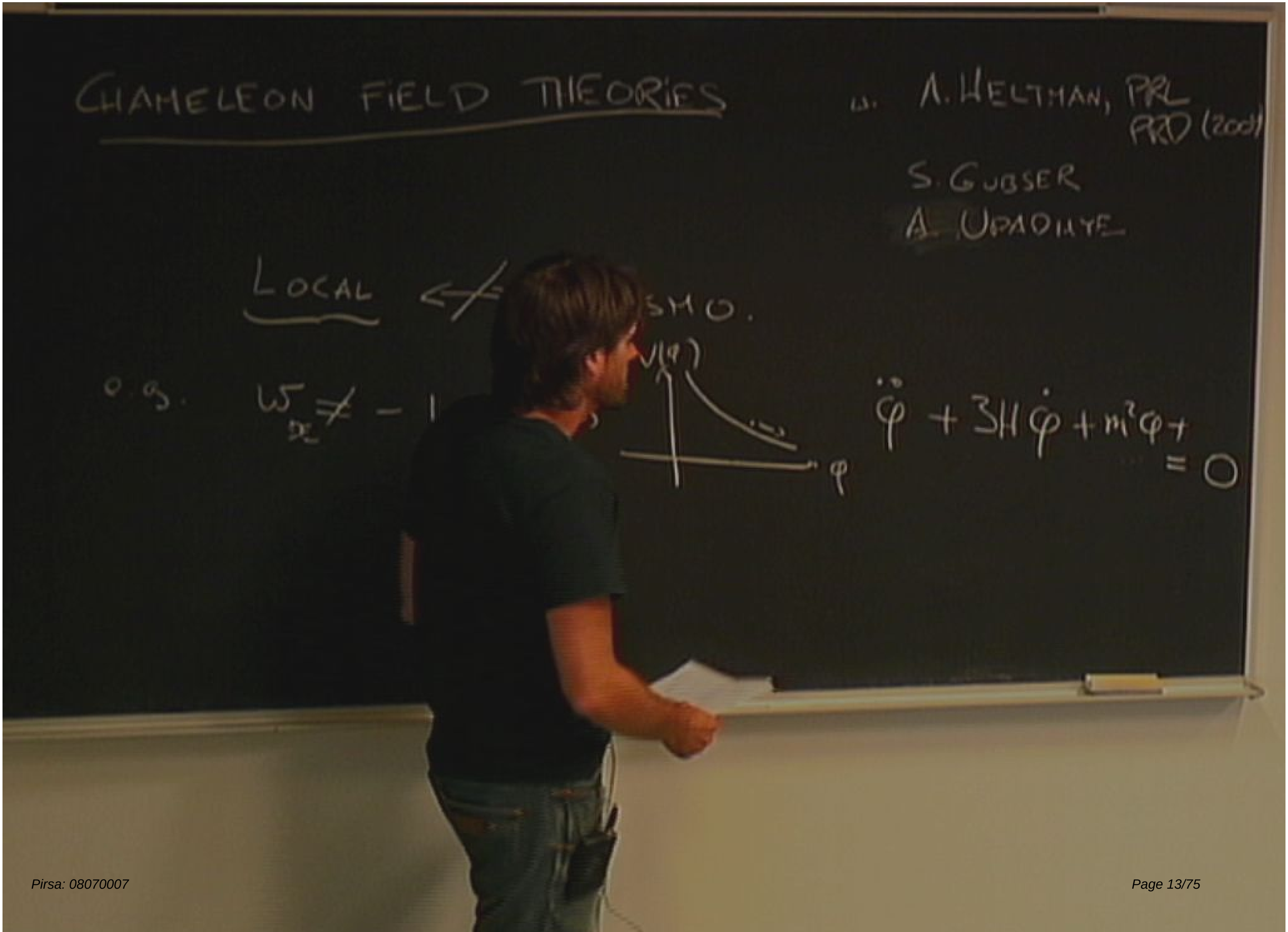
CHAMELEON FIELD THEORIES

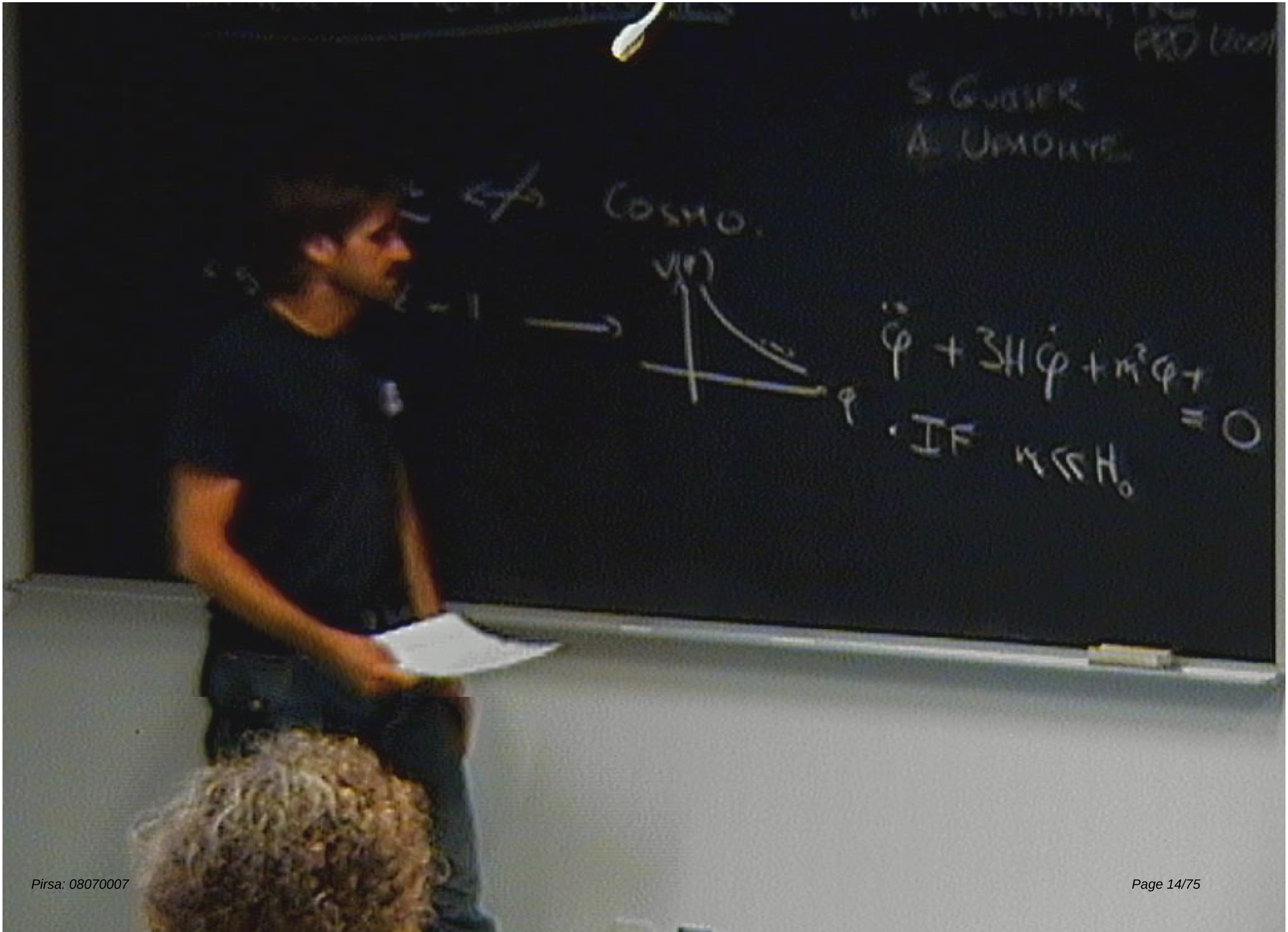
w. A. WELTMAN, PRL
PRD (200

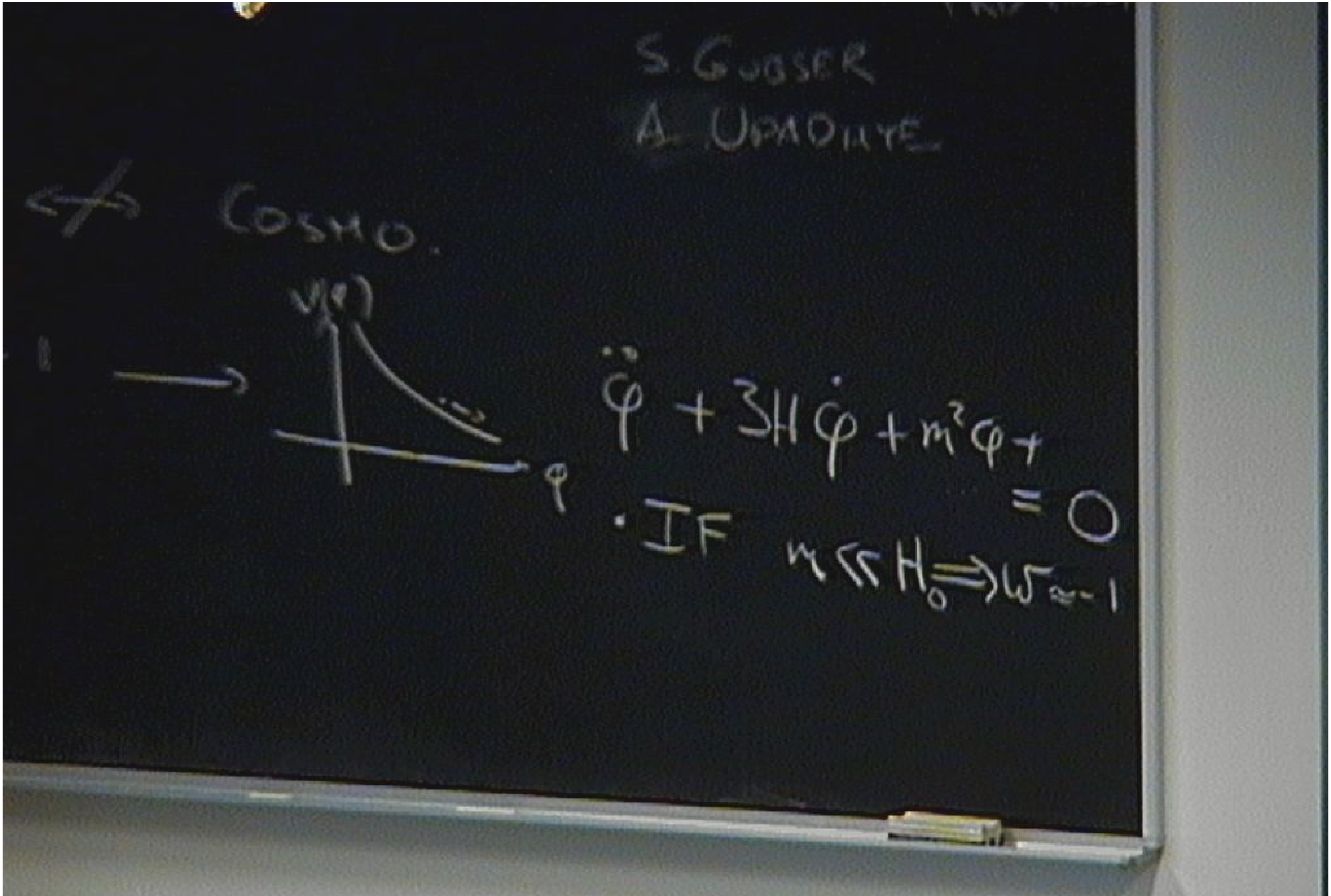
S. GUBSER
A. UPADHYE

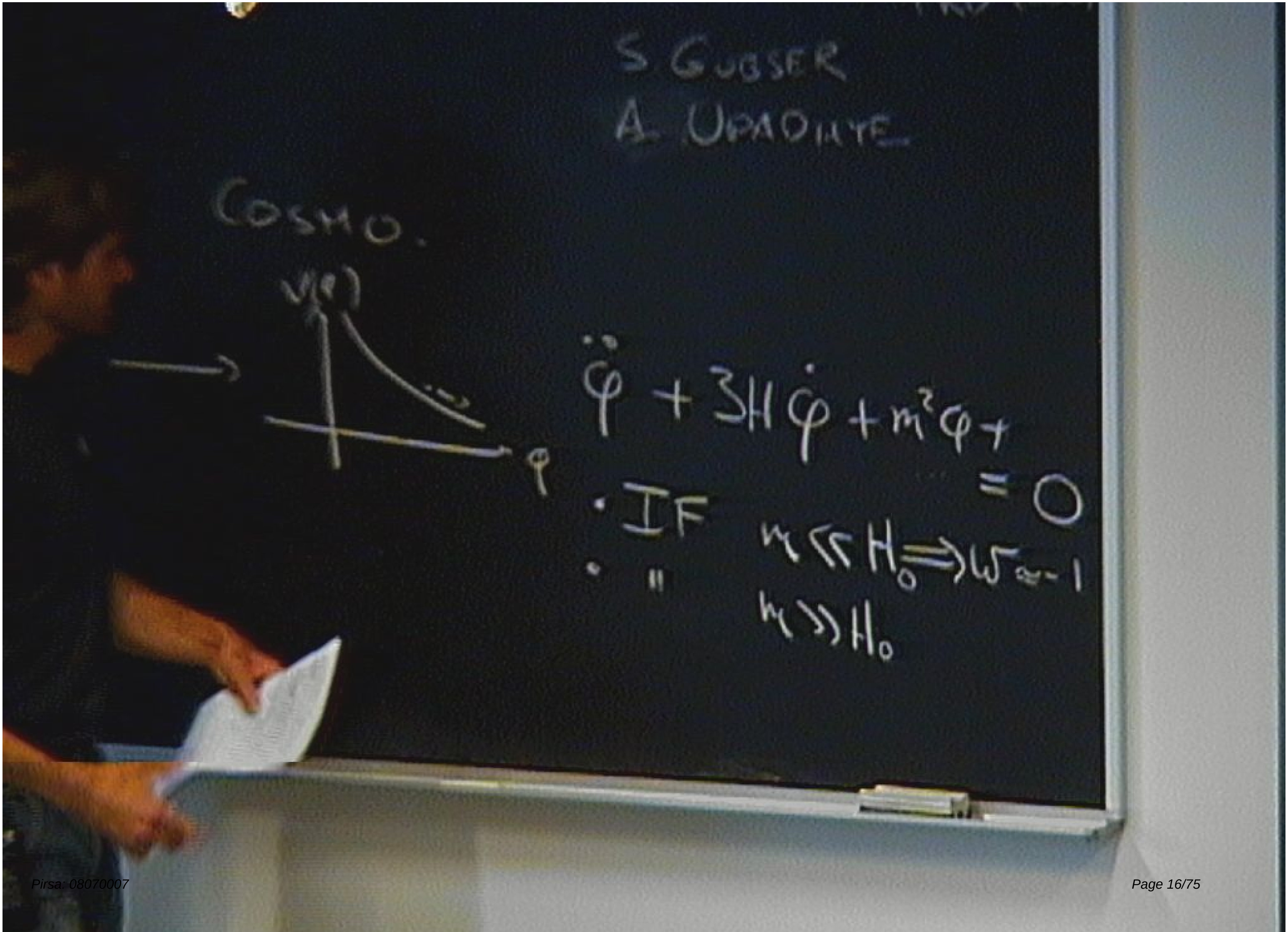
LOCAL $\not\leftrightarrow$ COSMO.

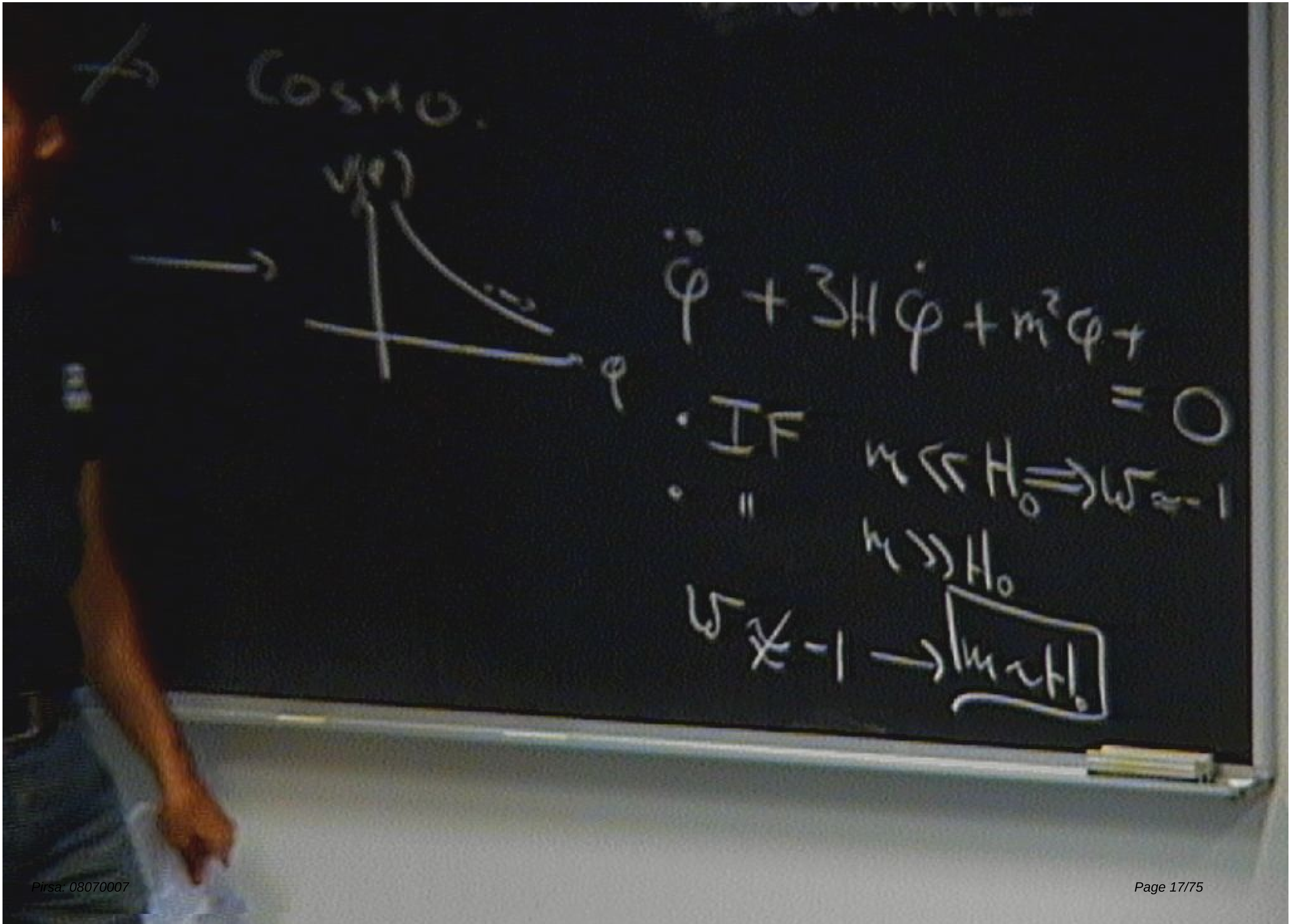
e.g. $w_{DE} \neq -1$

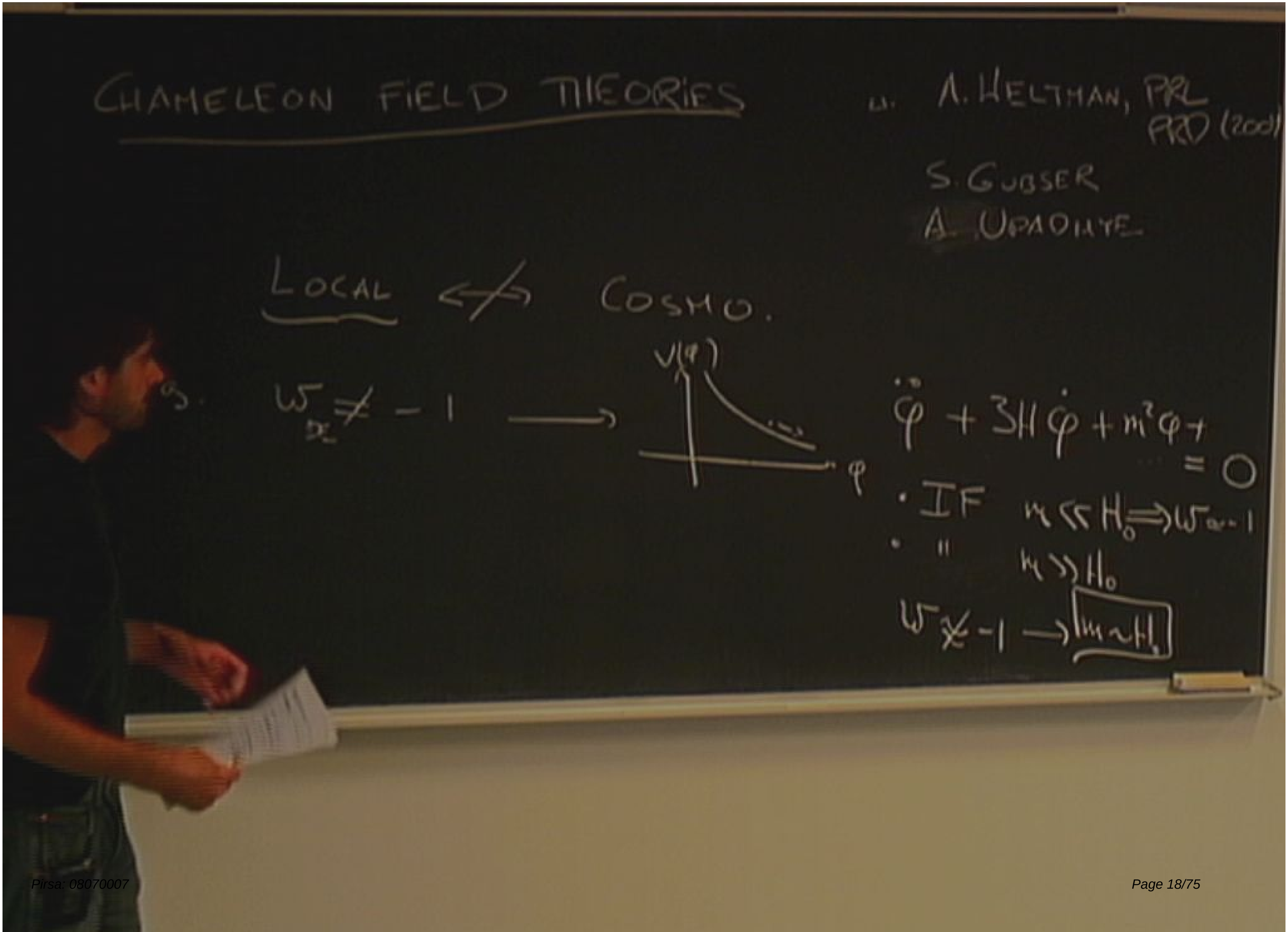

CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (200
S. GUBSER
A. UPADHYE
LOCAL
SMO.
V(φ)
e.g. $w_{DE} \neq -1$
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + \dots = 0$
φ


S. GUBSER
A. UPADHYE
COSMO.
$V(\varphi)$
φ
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + \ldots = 0$
• IF $m \lll H_0$


S. GUBSER
A. UPADHYE
COSMO.
V(φ)
φ
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + \ldots = 0$
• IF $m \ll H_0 \Rightarrow w \simeq -1$


S GUBSER
A. UPADHYE
COSMO.
V(φ)
φ
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + = 0$
• IF $m \ll H_0 \Longrightarrow w \approx -1$
• " $m \gg H_0$


Cosmo.
V(φ)
φ
φ̈ + 3Hφ̇ + m²φ + ... = 0
• IF m << H₀ ⟹ W ≈ -1
• " m >> H₀
W ≉ -1 → m ~ H₀


CHAMELEON FIELD THEORIES
A. WELTMAN, PRL
PRD (2004)
S. GUBSER
A. UPADHYE
LOCAL ⇎ COSMO.
w_DE ≠ −1 ⟶
V(φ)
φ
φ̈ + 3Hφ̇ + m²φ + ... = 0
• IF m ≪ H₀ ⟹ w_DE = −1
• " m ≫ H₀
w ≠ −1 ⟶ m ∼ H₀

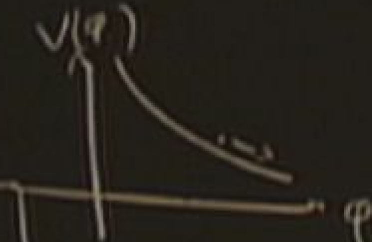
CHAMELEON FIELD THEORIES

w. A. WELTMAN, PRL
PRD (200

S. GUBSER
A. UPADHYE

LOCAL $\not\Leftrightarrow$ COSMO.

e.g. $w_{DE} \neq -1 \longrightarrow$

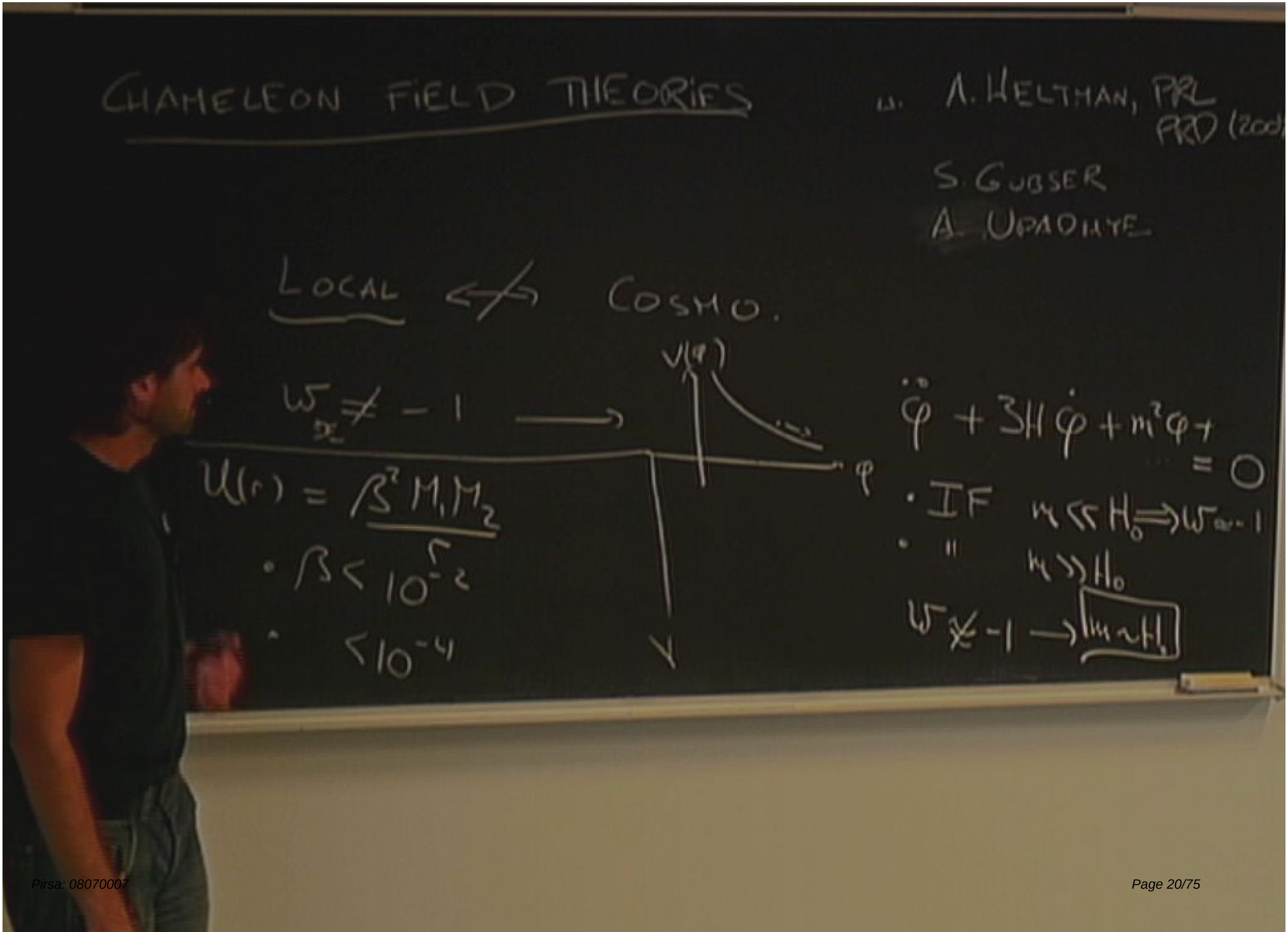


$U(r) = \frac{\beta^2 M_1 M_2}{r}$

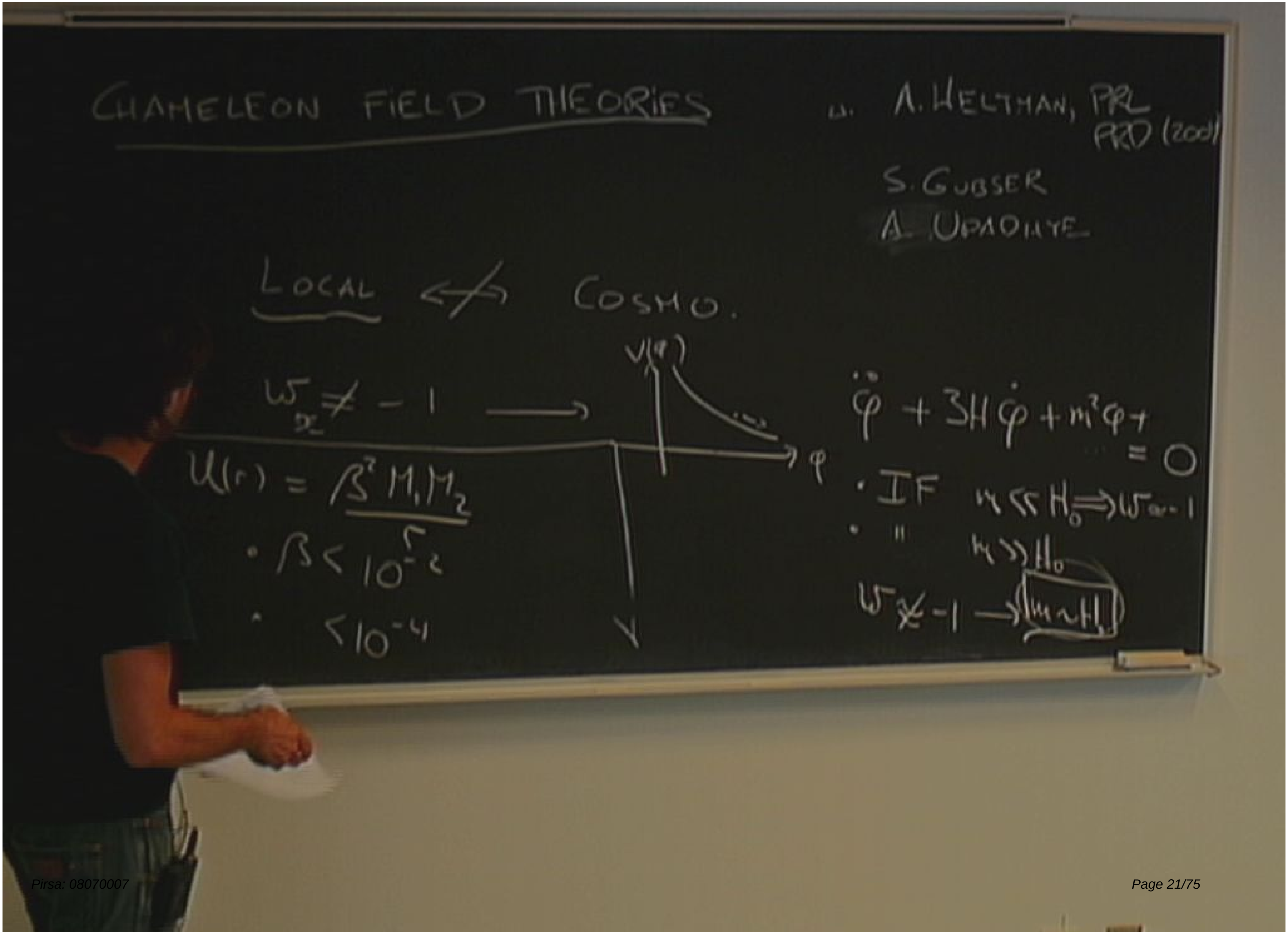
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + \ldots = 0$

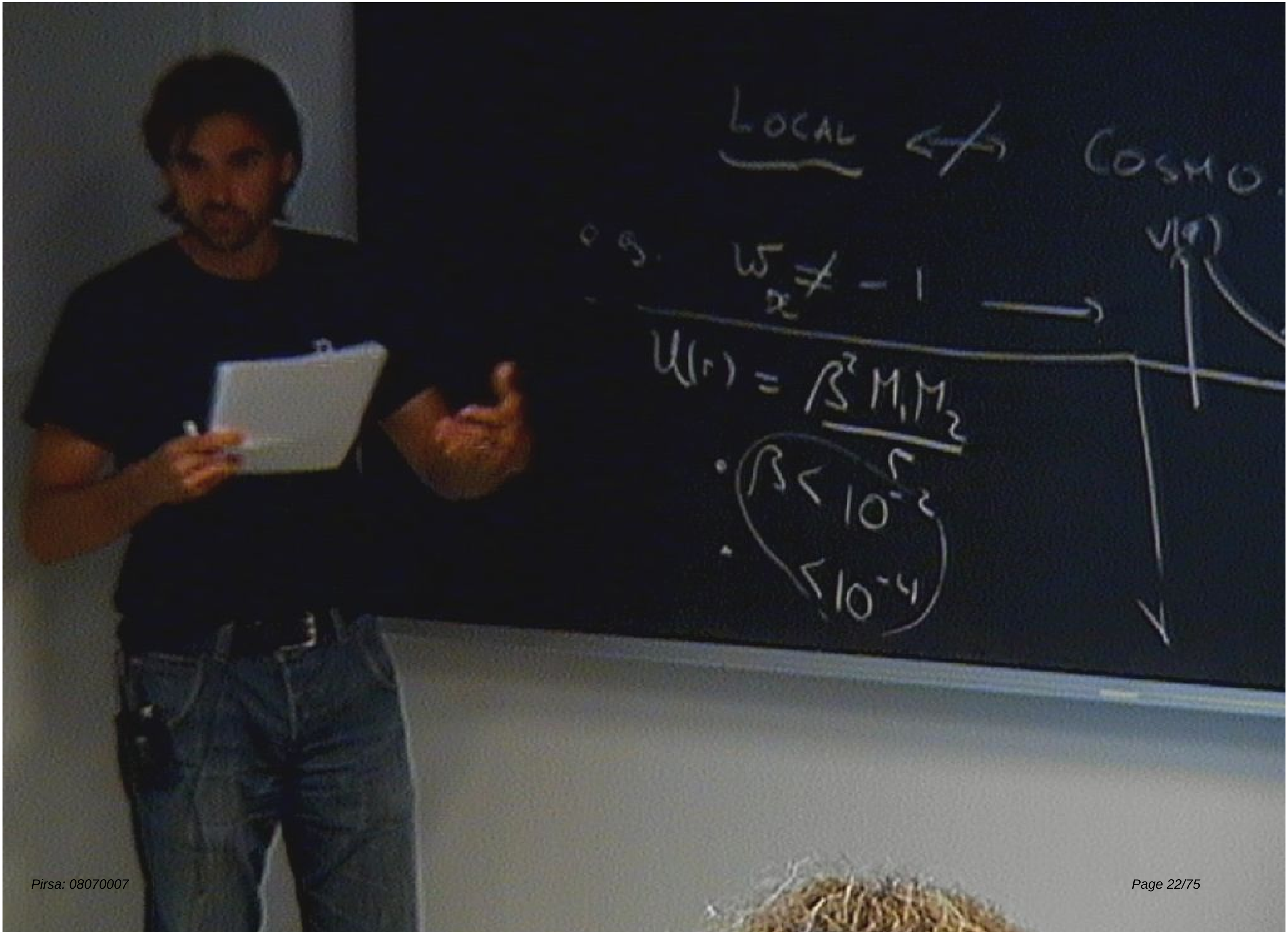
- IF $m \ll H_0 \Longrightarrow w_{DE} \sim -1$
- " $m \gg H_0$

$w \not\approx -1 \longrightarrow \boxed{m \sim H_0}$

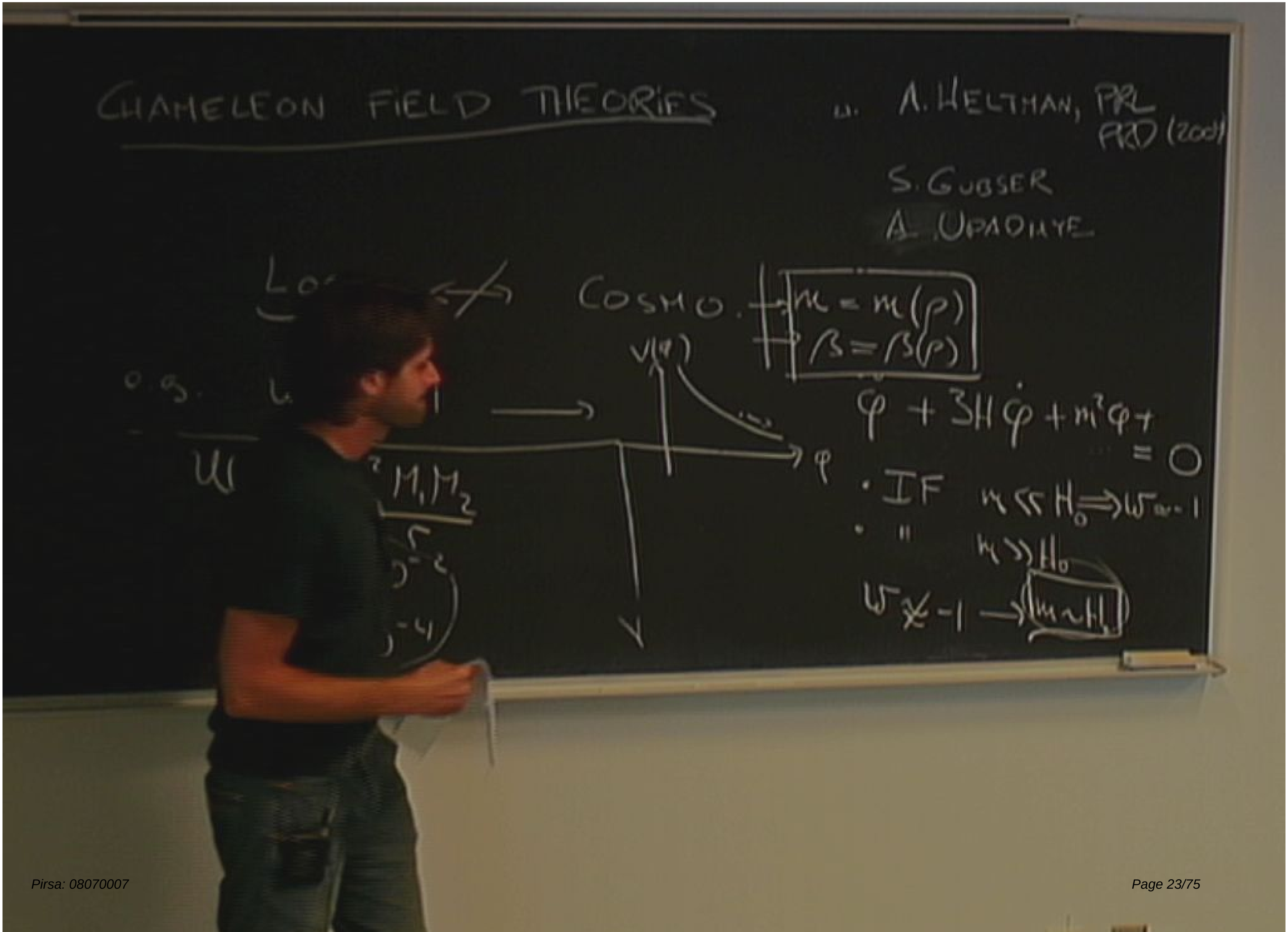


CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (200
S. GUBSER
A. UPADHYE
LOCAL
COSMO.
V(φ)
w ≠ -1
φ
U(r) = β² M₁M₂ / r
• β < 10⁻²
• < 10⁻⁴
φ̈ + 3H φ̇ + m²φ +
= 0
• IF m << H₀ ⟹ w ≈ -1
• " m >> H₀
w ≯ -1 ⟶ m ~ H₀


CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (2004)
S. GUBSER
A. UPADHYE
LOCAL $\not\leftrightarrow$ COSMO.
V(φ)
φ
$w_x \neq -1 \longrightarrow$
$U(r) = \frac{\beta^2 M_1 M_2}{r}$
• $\beta < 10^{-2}$
• $< 10^{-4}$
$\ddot{\varphi} + 3H\dot{\varphi} + m^2\varphi + \ldots = 0$
• IF $m \ll H_0 \Rightarrow w \approx -1$
• " $m \gg H_0$
$w \not\approx -1 \longrightarrow \boxed{m \sim H_0}$



LOCAL
COSMO.
V(φ)
e.g. $w_x \neq -1$
$U(r) = \frac{\beta^2 M_1 M_2}{r}$
$\beta < 10^{-2}$
$< 10^{-4}$


CHAMELEON FIELD THEORIES
w. A. WELTMAN, PRL
PRD (2004)
S. GUBSER
A. UPADHYE
COSMO.
m = m(ρ)
β = β(ρ)
V(φ)
φ
e.g.
M₁M₂
IF m ≪ H₀ ⟹ w ≈ -1
" m ≫ H₀
w ≠ -1 → m ~ H₀

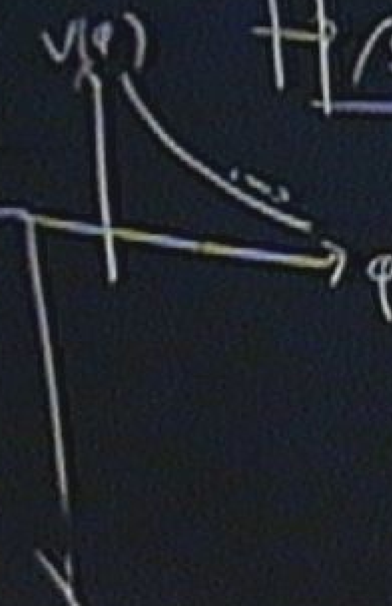
CHAMELEON FIELD THEORIES

J. KHOURY, A. WELTMAN, PRL
PRD (2004)

S. GUBSER
A. UPADHYE

LOCAL $\not\Longleftrightarrow$ COSMO. $\rightarrow$ $\boxed{\begin{array}{l} m = m(\rho) \\ \beta = \beta(\rho) \end{array}}$

e.g. $w_\varphi \neq -1 \longrightarrow$



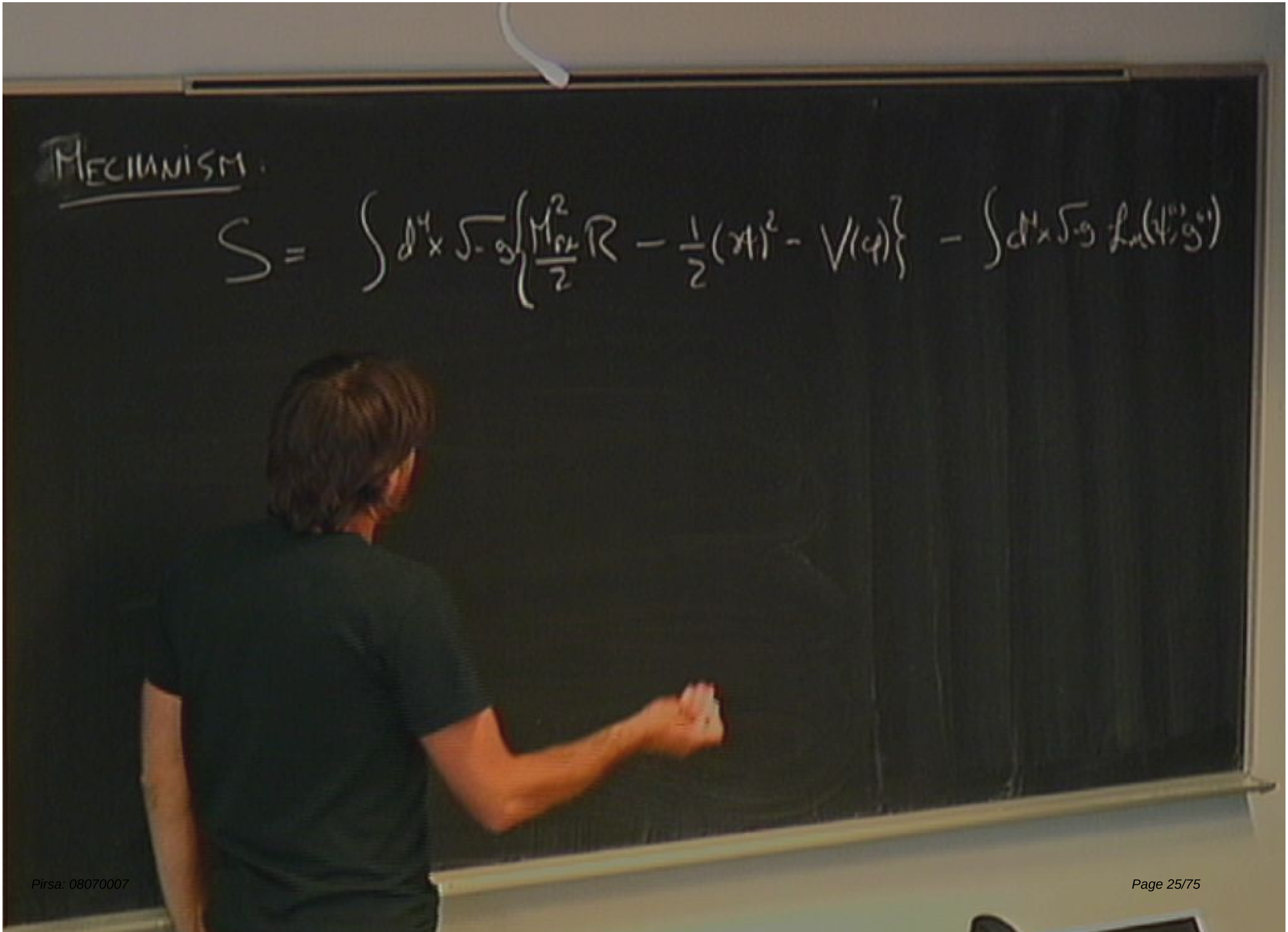
$U(r) = \dfrac{\beta^2 M_1 M_2}{r}$

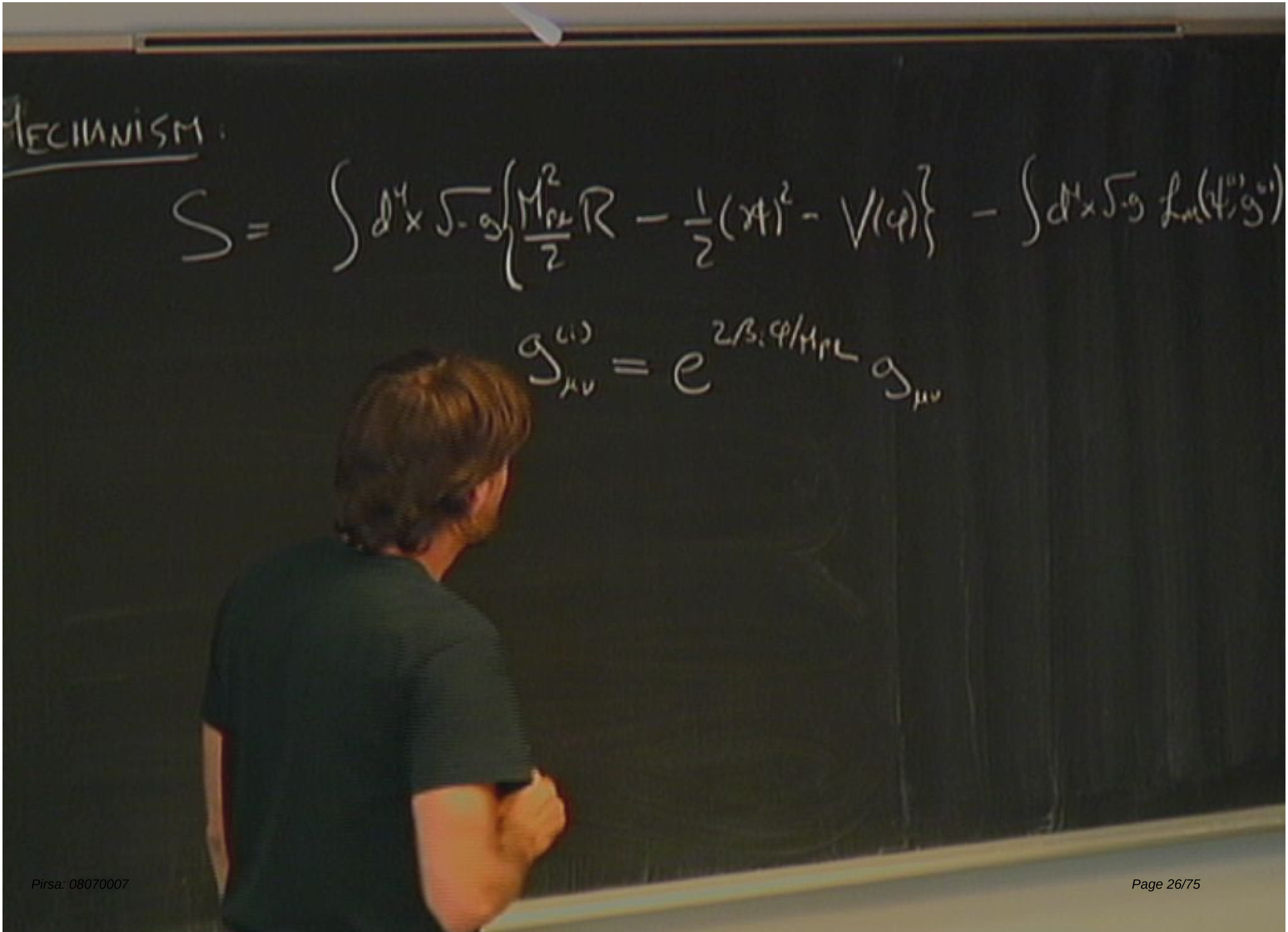
- $\beta < 10^{-2}$
- $< 10^{-4}$

$\ddot\varphi + 3H\dot\varphi + m^2\varphi + \dots = 0$

- IF $m \ll H_0 \Rightarrow w \simeq -1$
- " $m \gg H_0$

$w \not\simeq -1 \longrightarrow \boxed{m \sim H_0}$


MECHANISM:
$S = \int d^4x \sqrt{-g} \left\{ \frac{M_{Pl}^2}{2} R - \frac{1}{2}(\partial\phi)^2 - V(\phi) \right\} - \int d^4x \sqrt{-g}\, \mathcal{L}_m(\psi^{(i)}, g^{(i)})$


MECHANISM:
$S = \int d^4x \sqrt{-g} \left\{ \frac{M_{Pl}^2}{2} R - \frac{1}{2}(\partial\varphi)^2 - V(\varphi) \right\} - \int d^4x \sqrt{-g} \mathcal{L}_m(\psi^{(i)}, g^{(i)})$
$g^{(i)}_{\mu\nu} = e^{2\beta_i \varphi / M_{Pl}} g_{\mu\nu}$

MECHANISM:

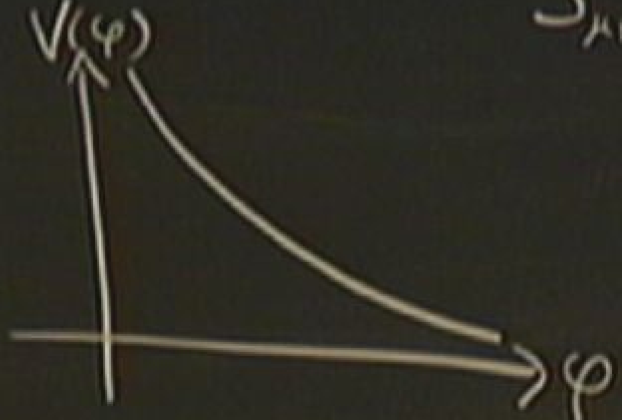
$$S = \int d^4x \sqrt{-g}\left\{\frac{M_{Pl}^2}{2}R - \frac{1}{2}(\partial\varphi)^2 - V(\varphi)\right\} - \int d^4x \sqrt{-g}\, \mathcal{L}_m(\psi^{(i)}, g^{(i)})$$

$$g^{(i)}_{\mu\nu} = e^{2\beta_i\varphi/M_{Pl}}\, g_{\mu\nu} \approx \left(1 + \frac{2\beta_i\varphi}{M_{Pl}}\right) g_{\mu\nu}$$

MECHANISM:

$$S = \int d^4x \sqrt{-g}\left\{\frac{M_{Pl}^2}{2}R - \frac{1}{2}(\partial\varphi)^2 - V(\varphi)\right\} - \int d^4x \sqrt{-g}\, \mathcal{L}_m(\psi^{(i)}; g^{(i)})$$

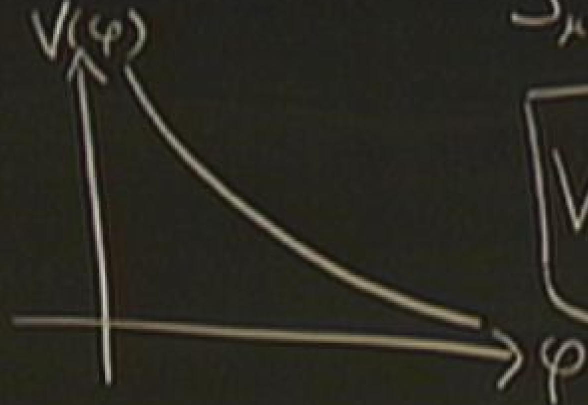
$$g^{(i)}_{\mu\nu} = e^{2\beta_i\varphi/M_{Pl}} g_{\mu\nu} \approx \left(1 + \frac{2\beta_i\varphi}{M_{Pl}}\right) g_{\mu\nu}$$



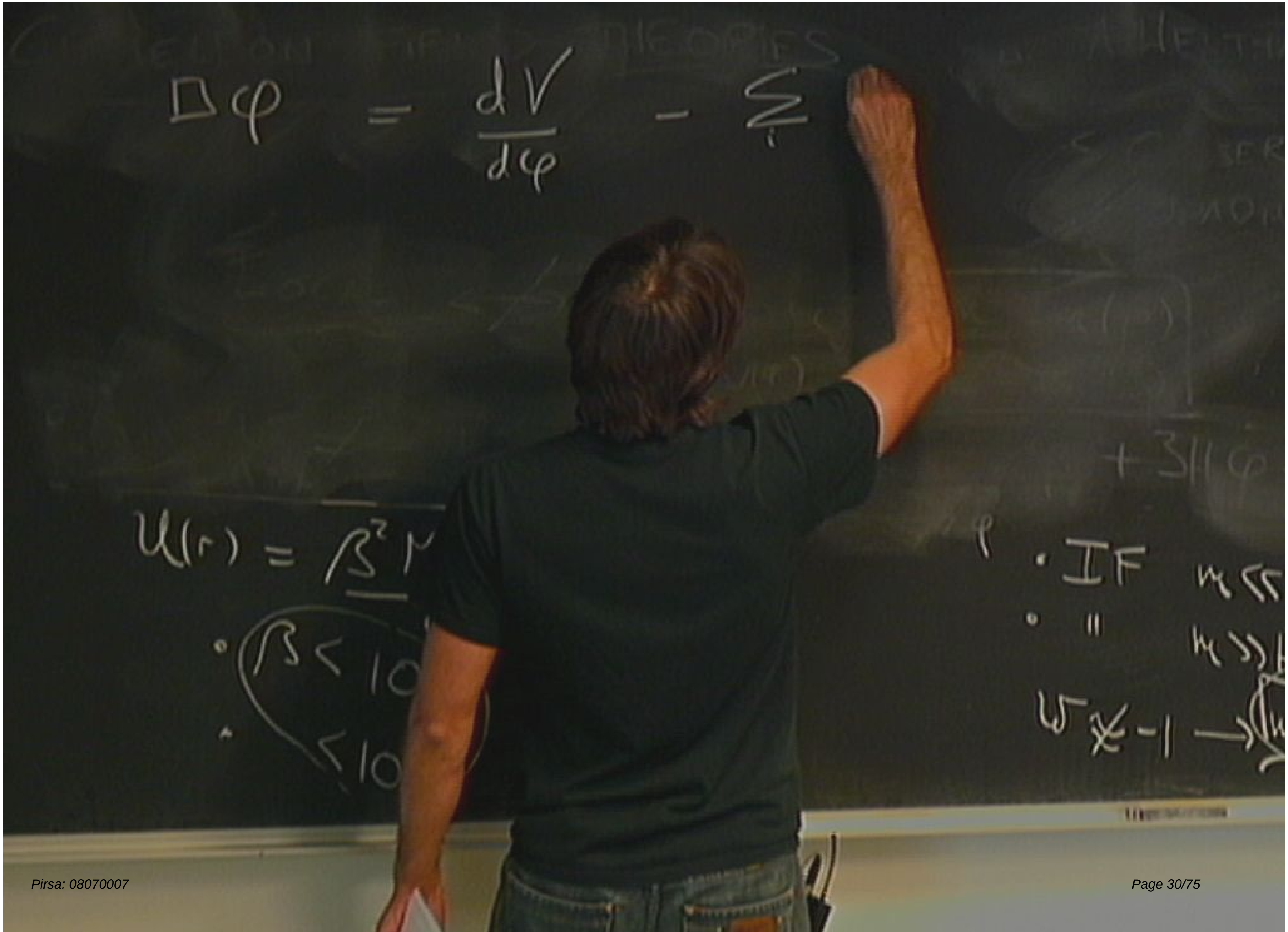
Mechanism:

$$S = \int d^4x \sqrt{-g} \left\{ \frac{M_{Pl}^2}{2} R - \frac{1}{2}(\partial\varphi)^2 - V(\varphi) \right\} - \int d^4x \sqrt{-g}\, \mathcal{L}_m(\psi^{(i)}, g^{(i)}_{\mu\nu})$$

$$g^{(i)}_{\mu\nu} = e^{2\beta_i \varphi / M_{Pl}} g_{\mu\nu} \approx \left(1 + \frac{2\beta_i \varphi}{M_{Pl}}\right) g_{\mu\nu}$$



$$\boxed{V(\varphi) = \frac{M^{4+n}}{\varphi^n}}$$



$\Box\varphi = \frac{dV}{d\varphi} - \sum_i$
$U(r) = \beta^2 \mu$
$\beta < 10$
< 10
• IF
• ''
$+3H\dot{\varphi}$

$$\Box \varphi = \frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{PL}} e^{4\beta_i \varphi / M_{PL}} T^{(i)}$$

$$U(r) = \frac{\beta^2 M_1 M_2}{r}$$

- $\beta < 10^{-2}$
- $< 10^{-4}$

- IF $m \ll H_0 =$
- " $m \gg H_0$

$w \neq -1 \longrightarrow m \sim H$

$$\Box\varphi = \underbrace{\frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{PL}} e^{4\beta_i\varphi/M_{PL}} T^{(i)}}$$

$$V(r) = \frac{\beta^2 M_1 M_2}{r}$$

- $\beta < 10^{-2}$
- $\beta < 10^{-4}$

- IF $m \ll H_0 \Rightarrow$
- " $m \gg H_0$

$w \neq -1 \longrightarrow \boxed{m \sim H_0}$

$$\Box\varphi = \underbrace{\frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{Pl}} e^{4\beta_i\varphi/M_{Pl}} T^{(i)}}_{\frac{dV_{eff}}{d\varphi}}$$

$$U(r) = \frac{\beta^2 M_1 M_2}{r}$$

- $\beta < 10^{-2}$
- $< 10^{-4}$

- IF $m \ll H_0$
- " $m \gg H_0$

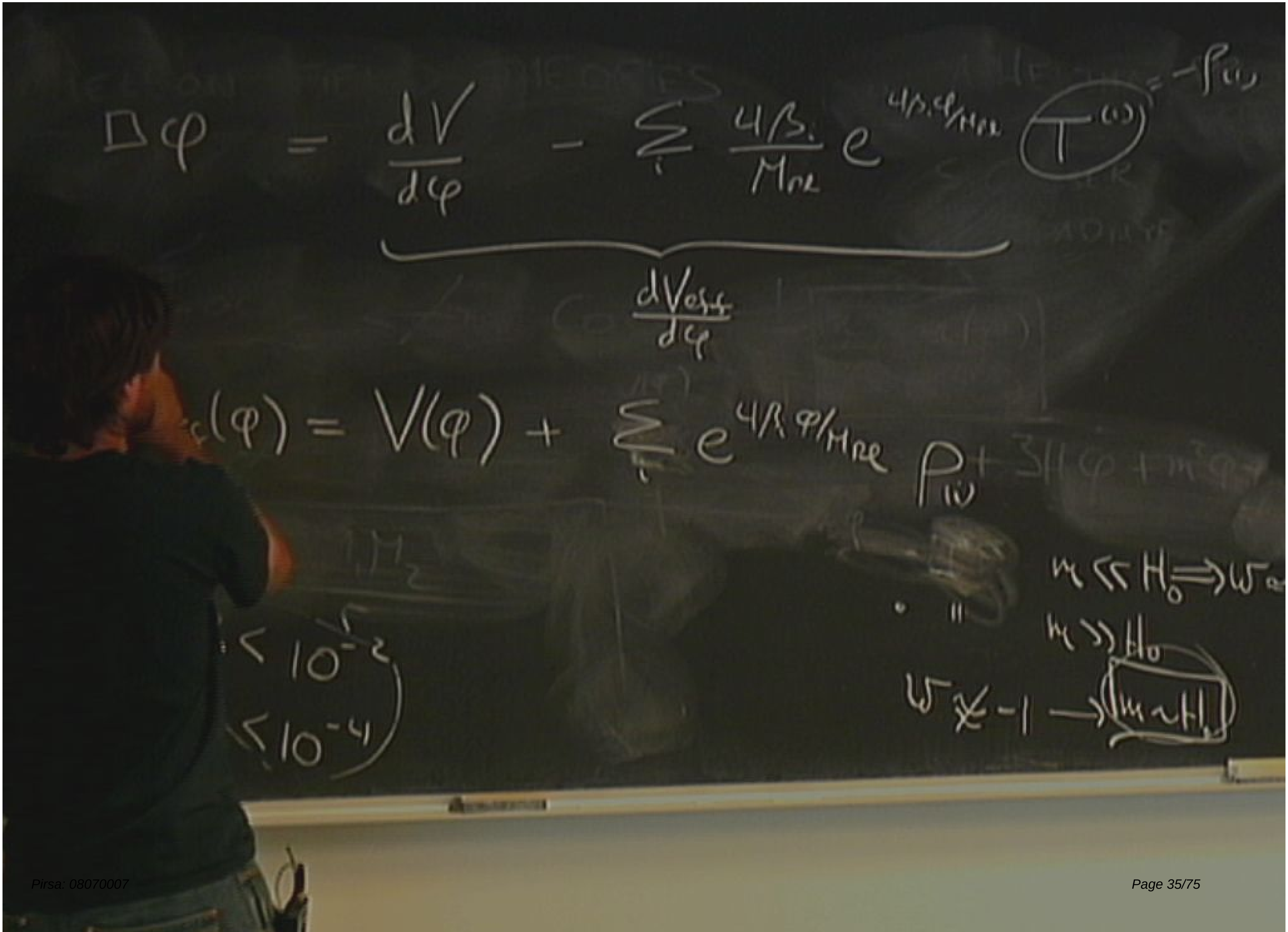
$w \neq -1 \rightarrow \boxed{m \sim}$

$$\Box\varphi = \underbrace{\frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{Pl}} e^{4\beta_i\varphi/M_{Pl}}\, T^{(i)}}_{\frac{dV_{eff}}{d\varphi}} \qquad T^{(i)} = -\rho_{(i)}$$

- $\beta < 10^{-2}$
- $\lesssim 10^{-4}$

- IF $m \ll H_0 \Rightarrow w \approx$
- " $m \gg H_0$

$w \not\approx -1 \longrightarrow \boxed{m \sim H_0}$


$\Box\varphi = \underbrace{\frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{Pl}} e^{4\beta_i\varphi/M_{Pl}}\, T^{(i)}}_{\frac{dV_{eff}}{d\varphi}}$
$T^{(i)} = -\rho_{(i)}$
$(\varphi) = V(\varphi) + \sum_i e^{4\beta_i\varphi/M_{Pl}}\, \rho_{(i)}$
$m \ll H_0 \Longrightarrow w$
$m \gg H_0$
$w \not\approx -1 \longrightarrow m \sim H_0$
$< 10^{-2}$
$< 10^{-4}$

$$\Box\varphi = \underbrace{\frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{Pl}} e^{4\beta_i \varphi/M_{Pl}}\, T^{(i)}}_{\frac{dV_{eff}}{d\varphi}} \qquad T^{(i)} = -\rho_{(i)}$$

$$\boxed{V_{eff}(\varphi) = V(\varphi) + \sum_i e^{4\beta_i \varphi/M_{Pl}}\, \rho_{(i)}}$$

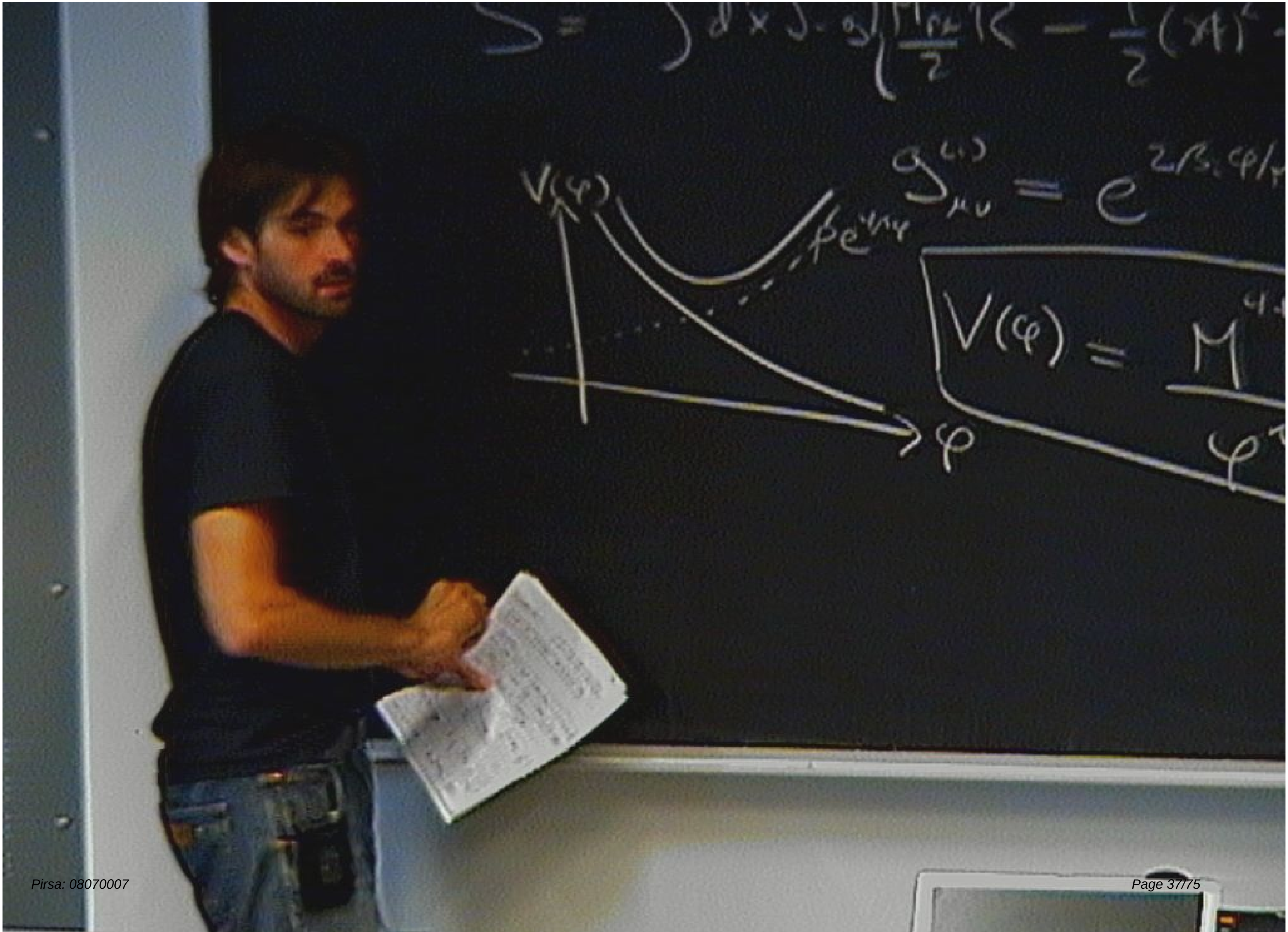
$$\beta < 10^{-5}$$

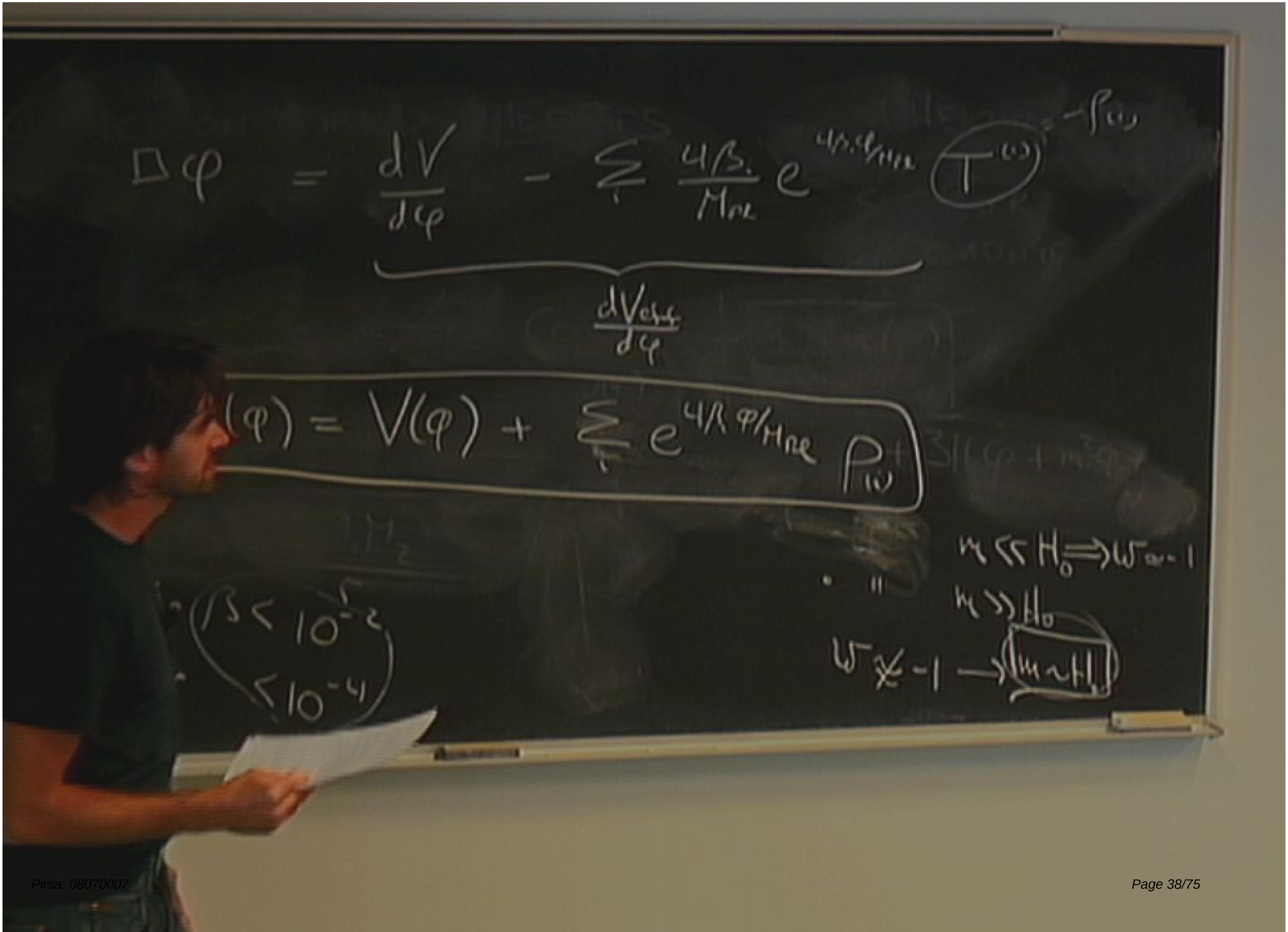
$$\lesssim 10^{-4}$$

$m \ll H_0 \Rightarrow w = \ldots$

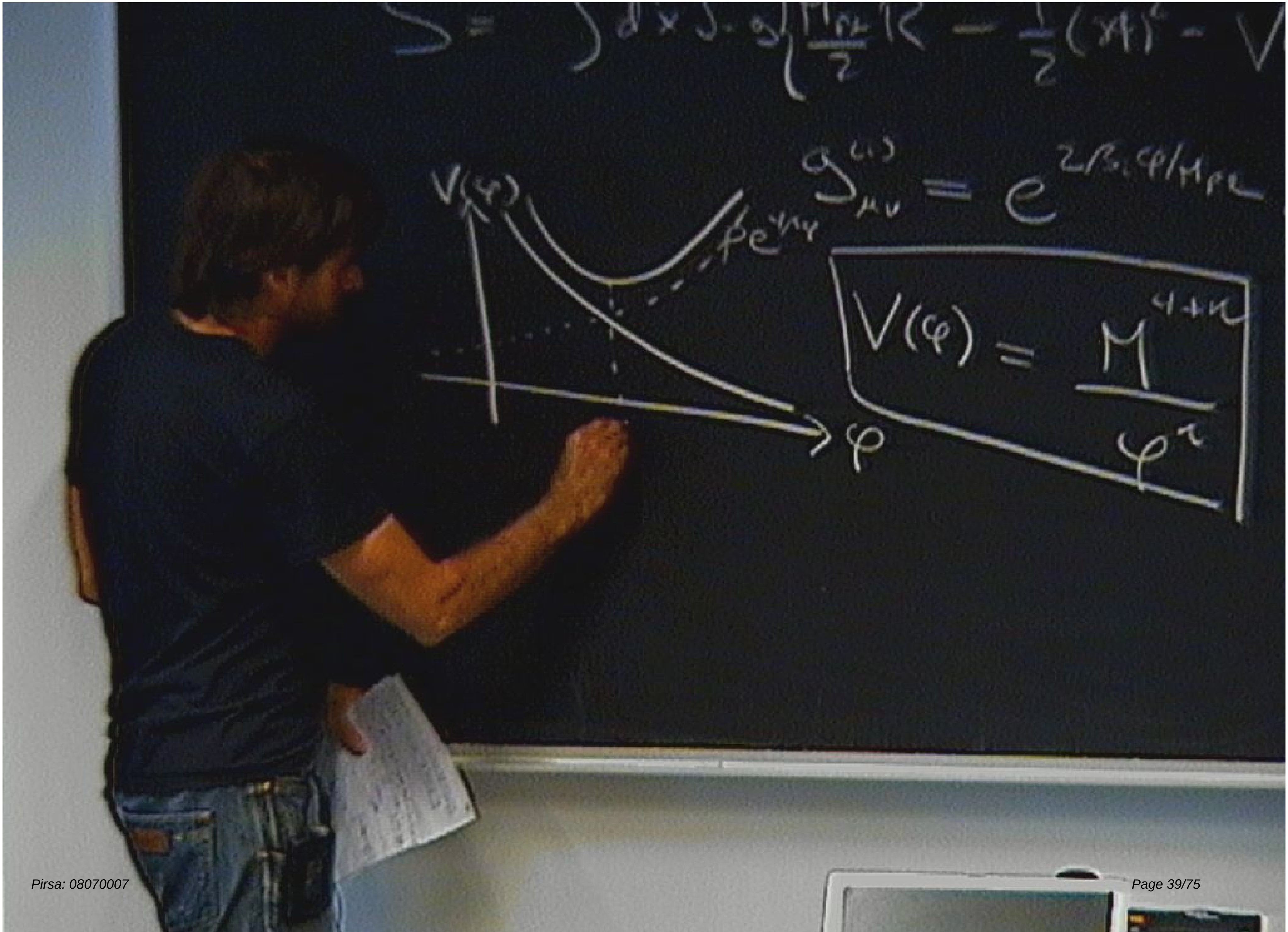
$m \gg H_0$

$w \not\approx -1 \longrightarrow \boxed{m \sim H_0}$

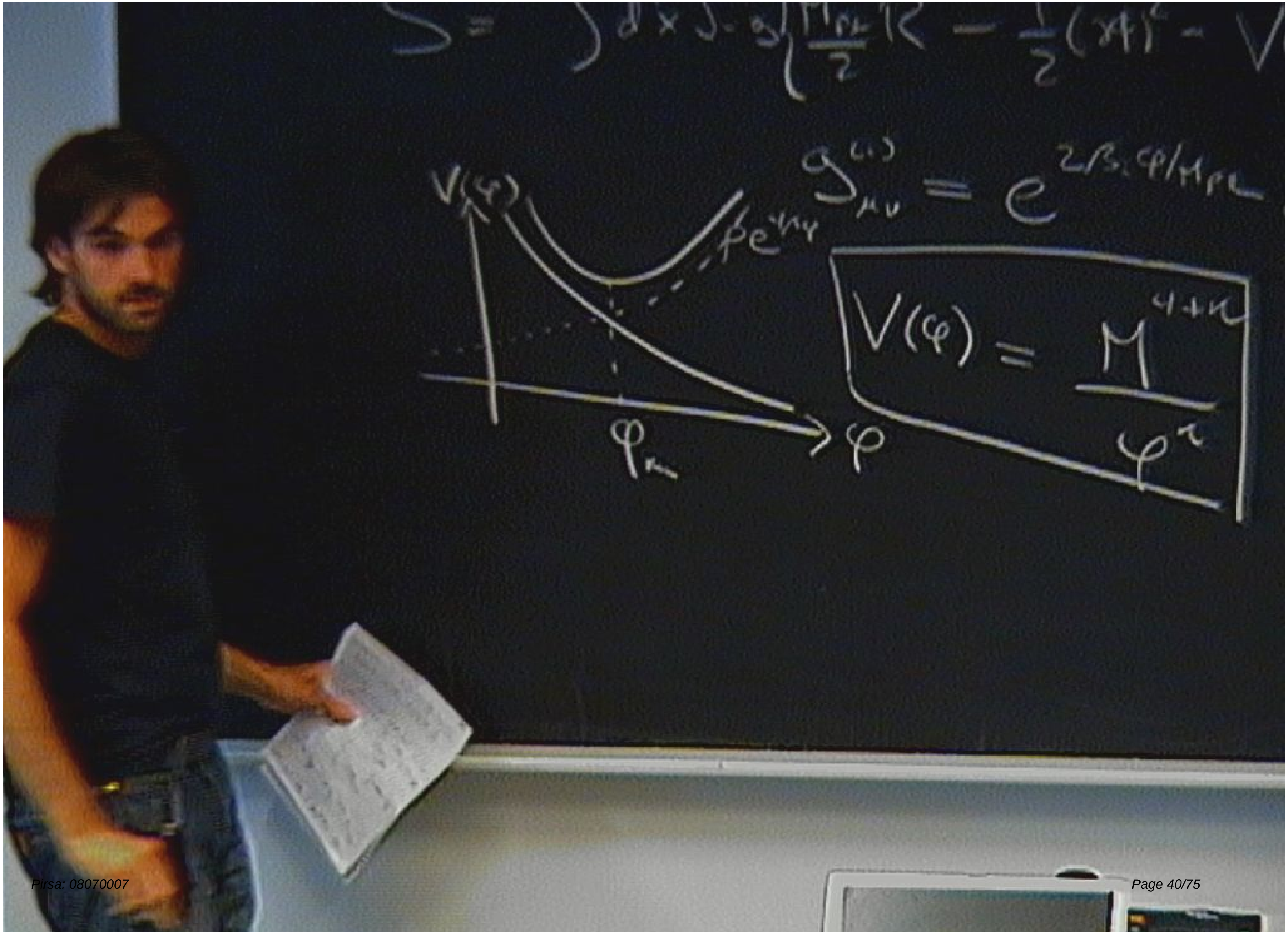

V(φ)
V(φ) =
φ

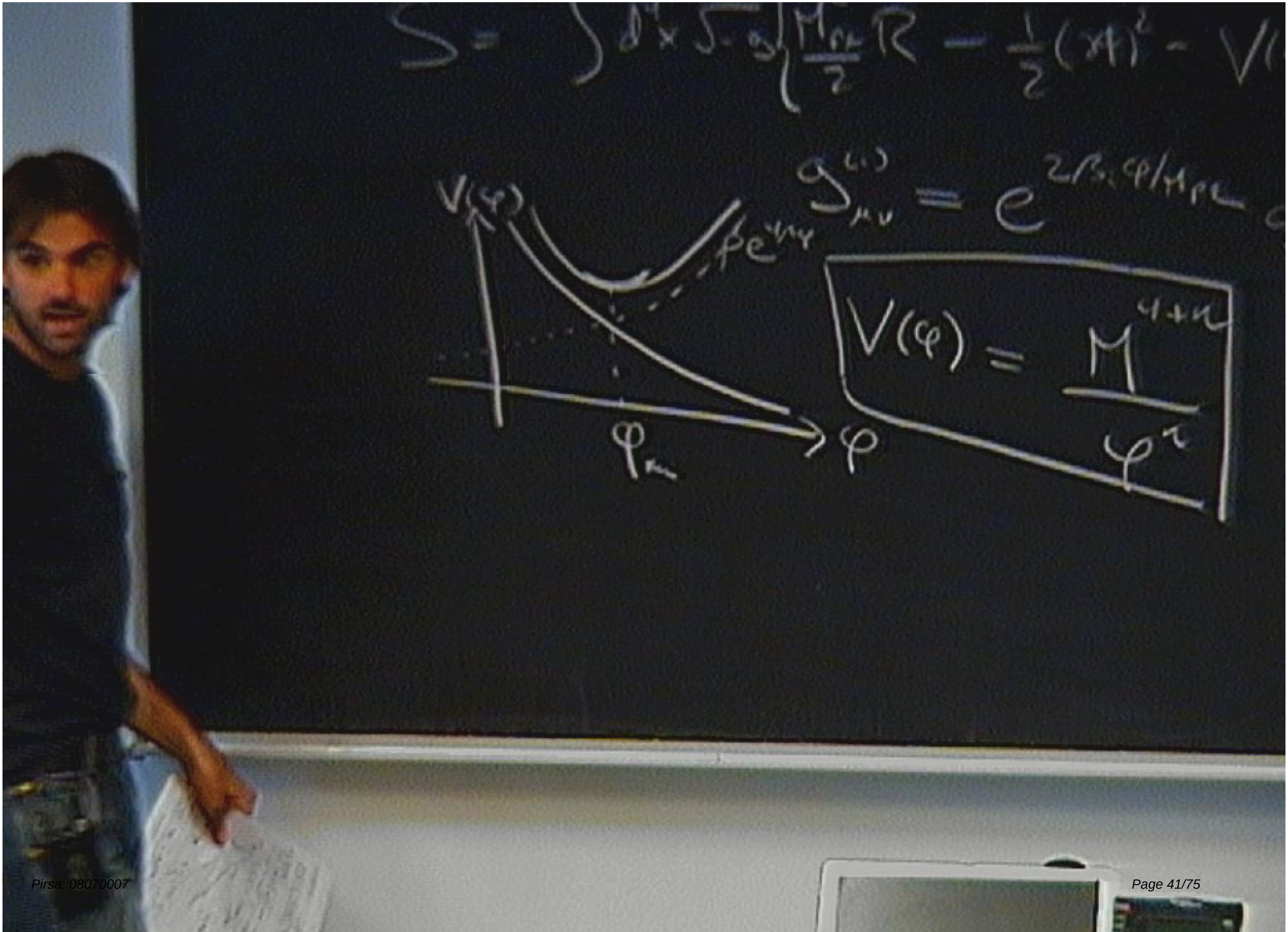


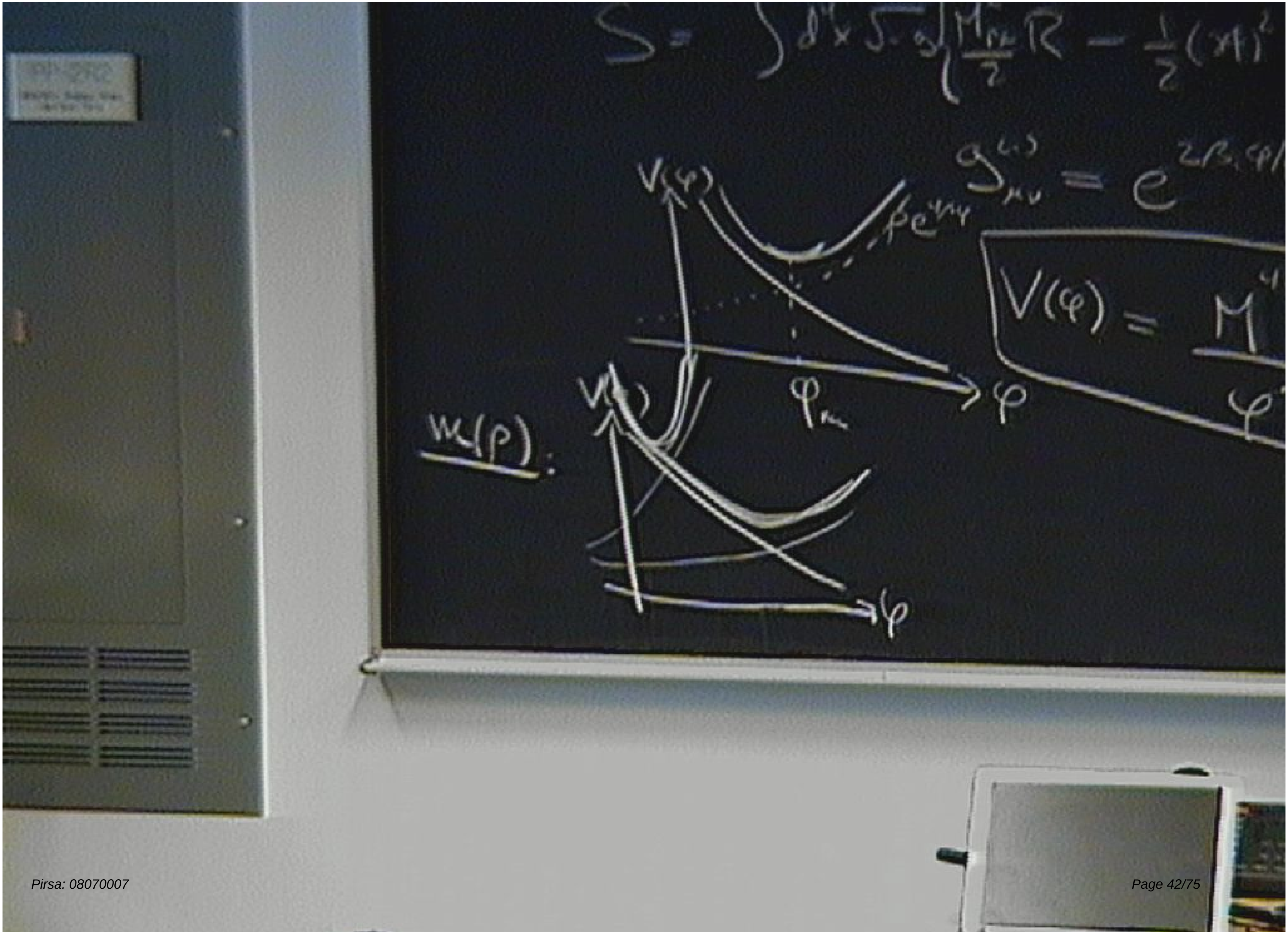
$\Box\varphi = \frac{dV}{d\varphi} - \sum_i \frac{4\beta_i}{M_{Pl}} e^{4\beta_i \varphi/M_{Pl}} T^{(i)}$
$= -\rho_{(i)}$
$\frac{dV_{eff}}{d\varphi}$
$(\varphi) = V(\varphi) + \sum_i e^{4\beta_i \varphi/M_{Pl}} \rho_{(i)}$
$m \ll H_0 \Longrightarrow w \approx -1$
$m \gg H_0$
$w \not\approx -1 \longrightarrow m \sim H_0$
$\beta < 10^{-2}$
$< 10^{-4}$

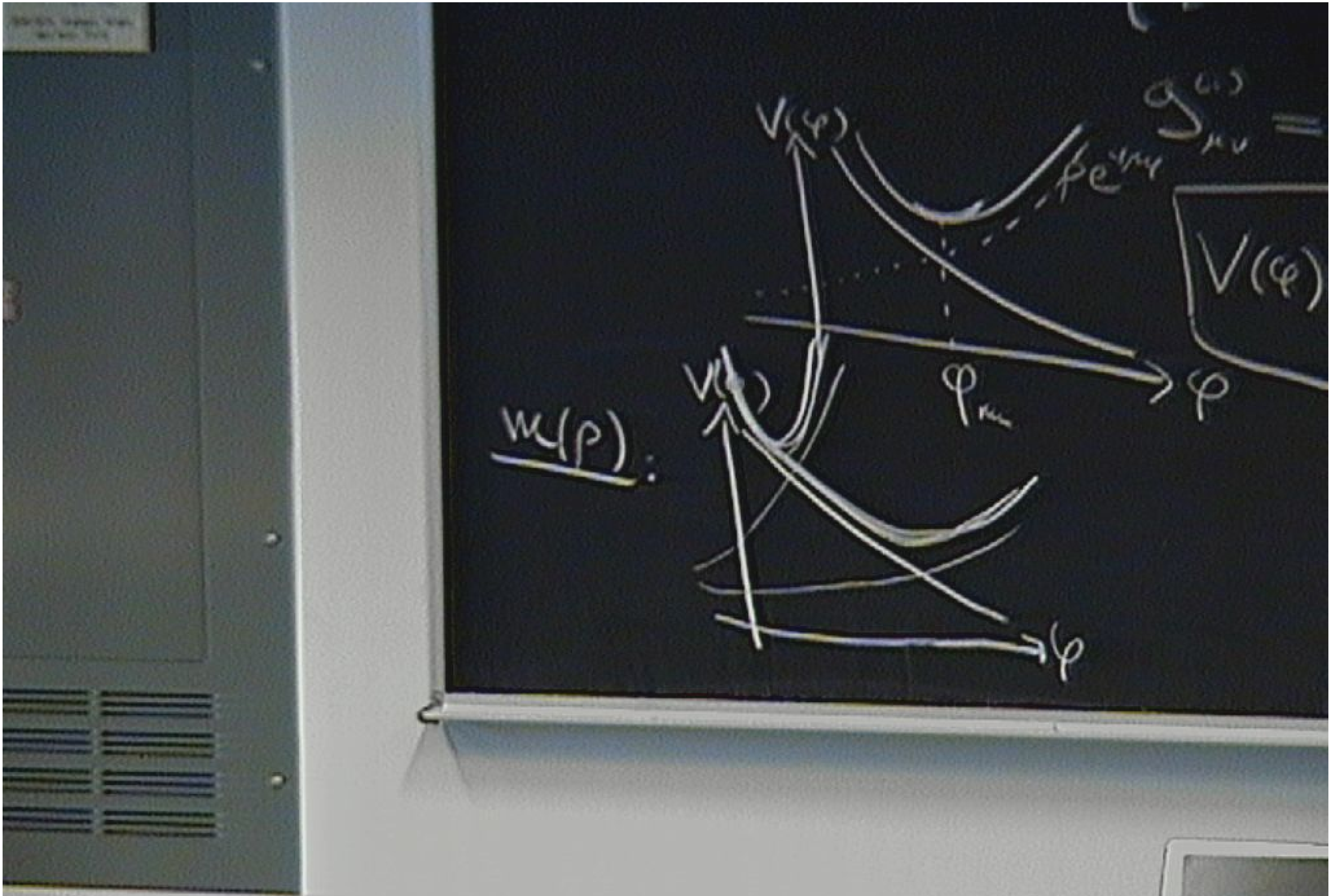


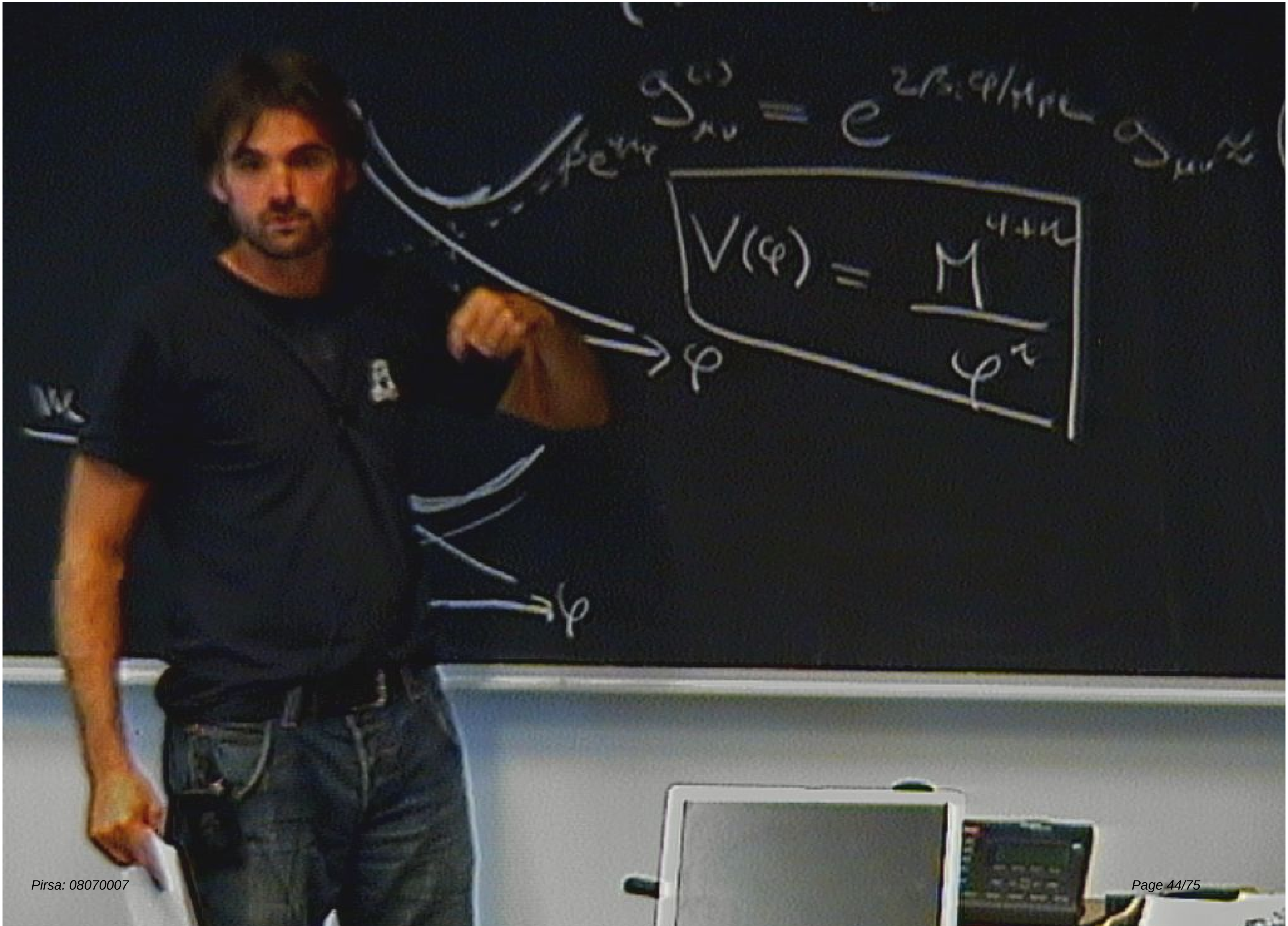
V(φ)
φ
V(φ) = M^{4+n} / φ^n

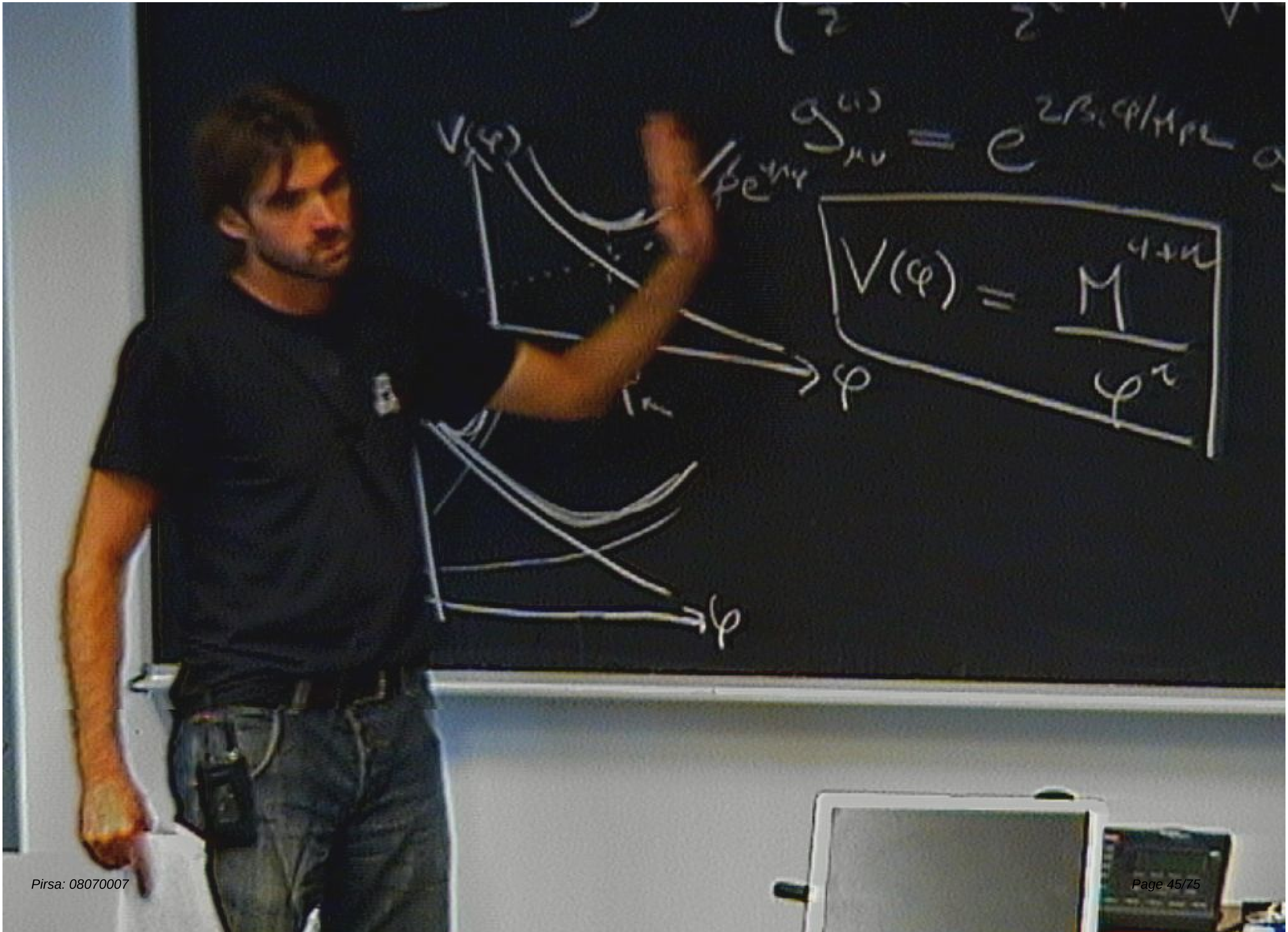

$g_{\mu\nu} = e^{2\beta\varphi/M_{Pl}}$
$V(\varphi)$
φ
$V(\varphi) = \frac{M^{4+n}}{\varphi^n}$

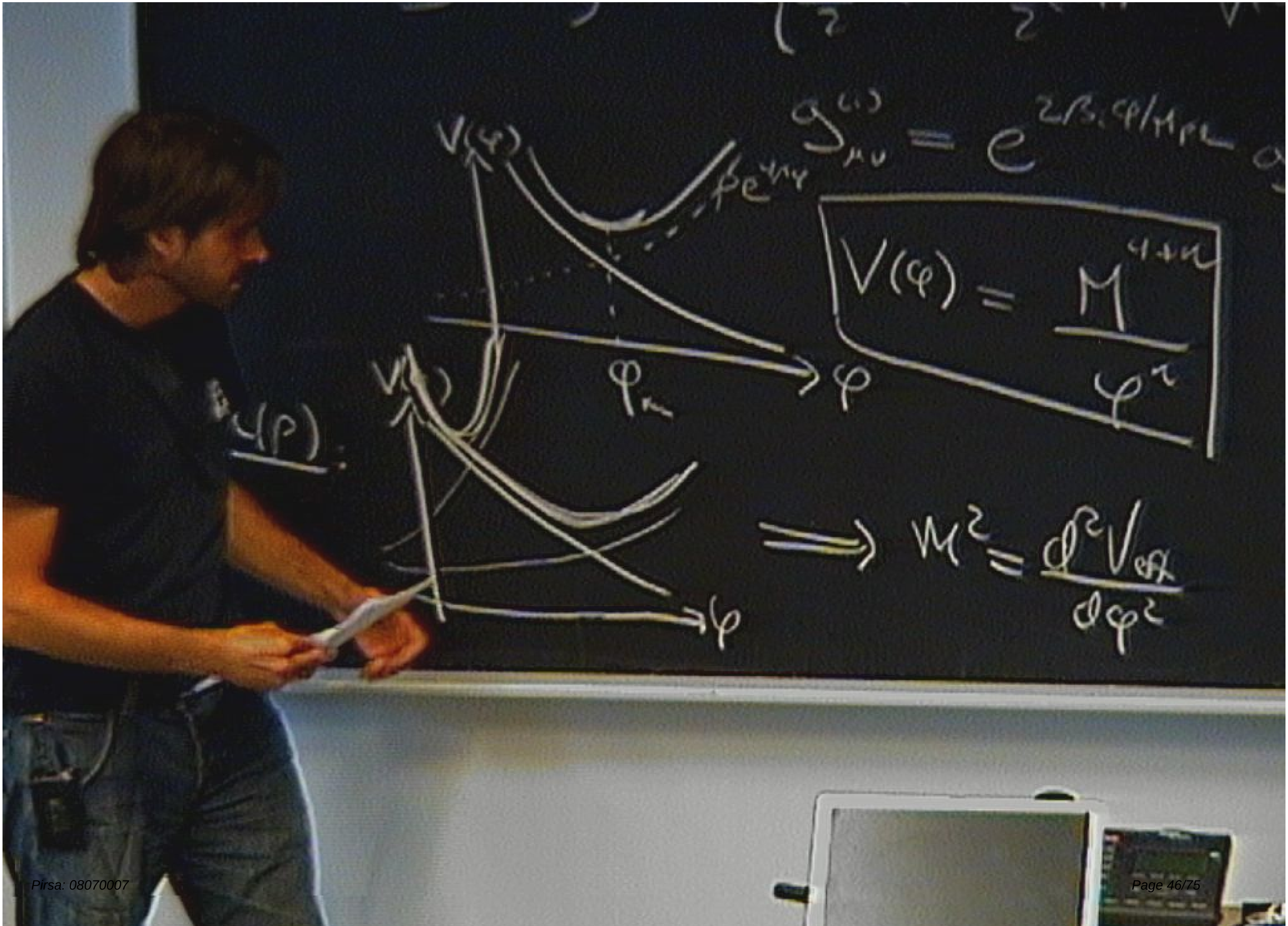

V(φ)
φ
V(φ) =

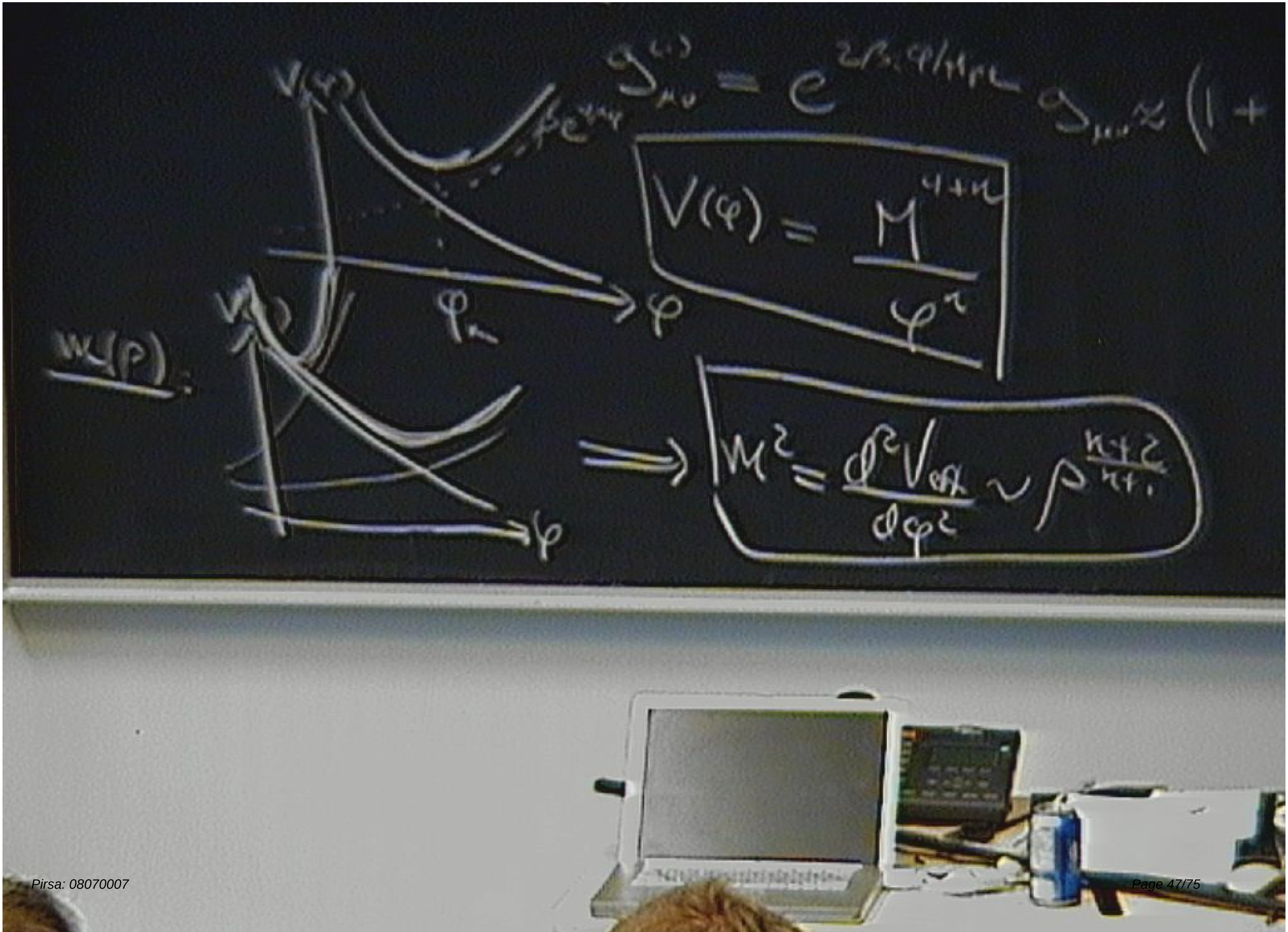

V(φ)
φ
V(φ) =

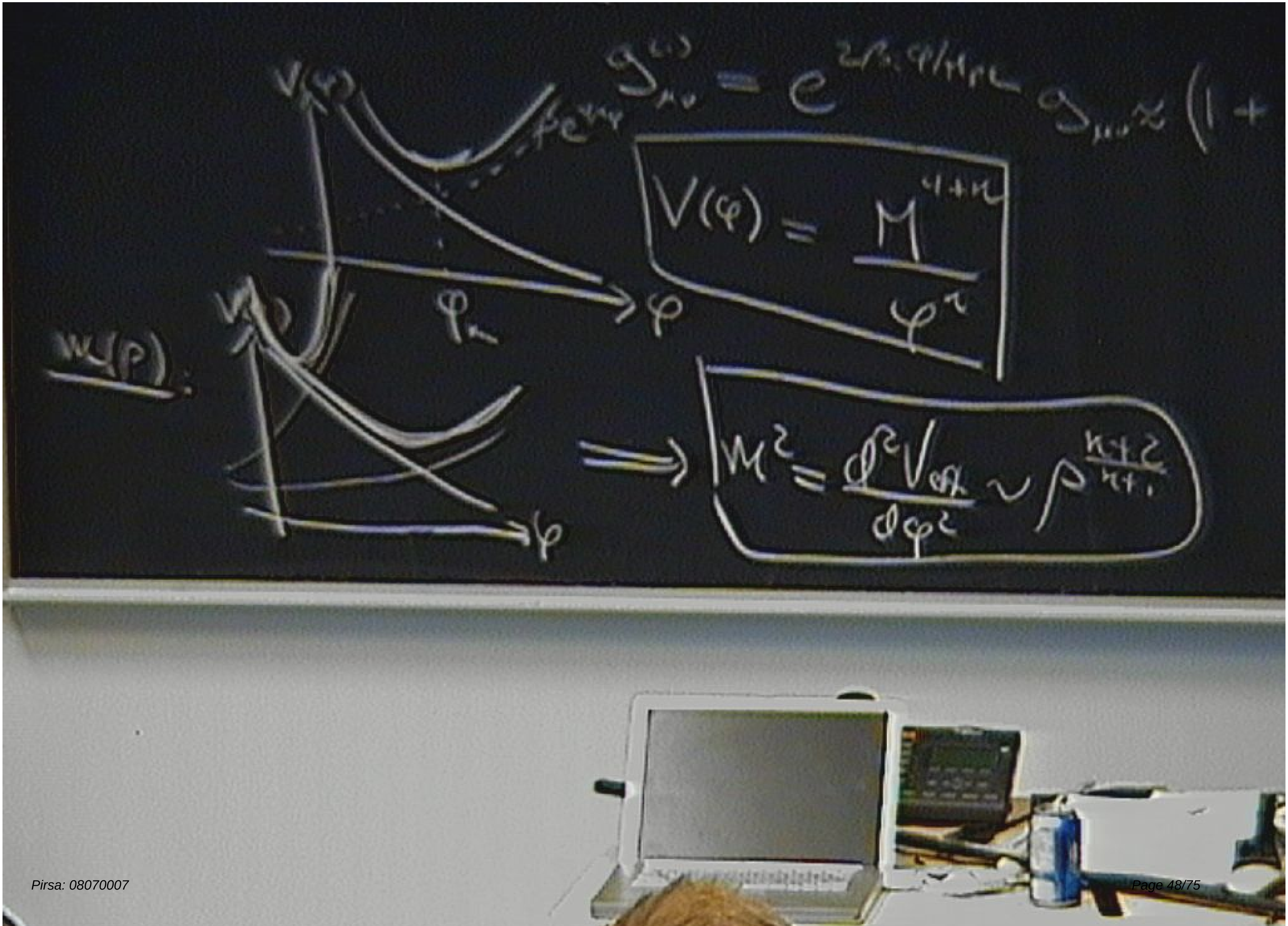

V(φ)
φ
φ_min
W(ρ):
V(φ)
φ
V(φ)

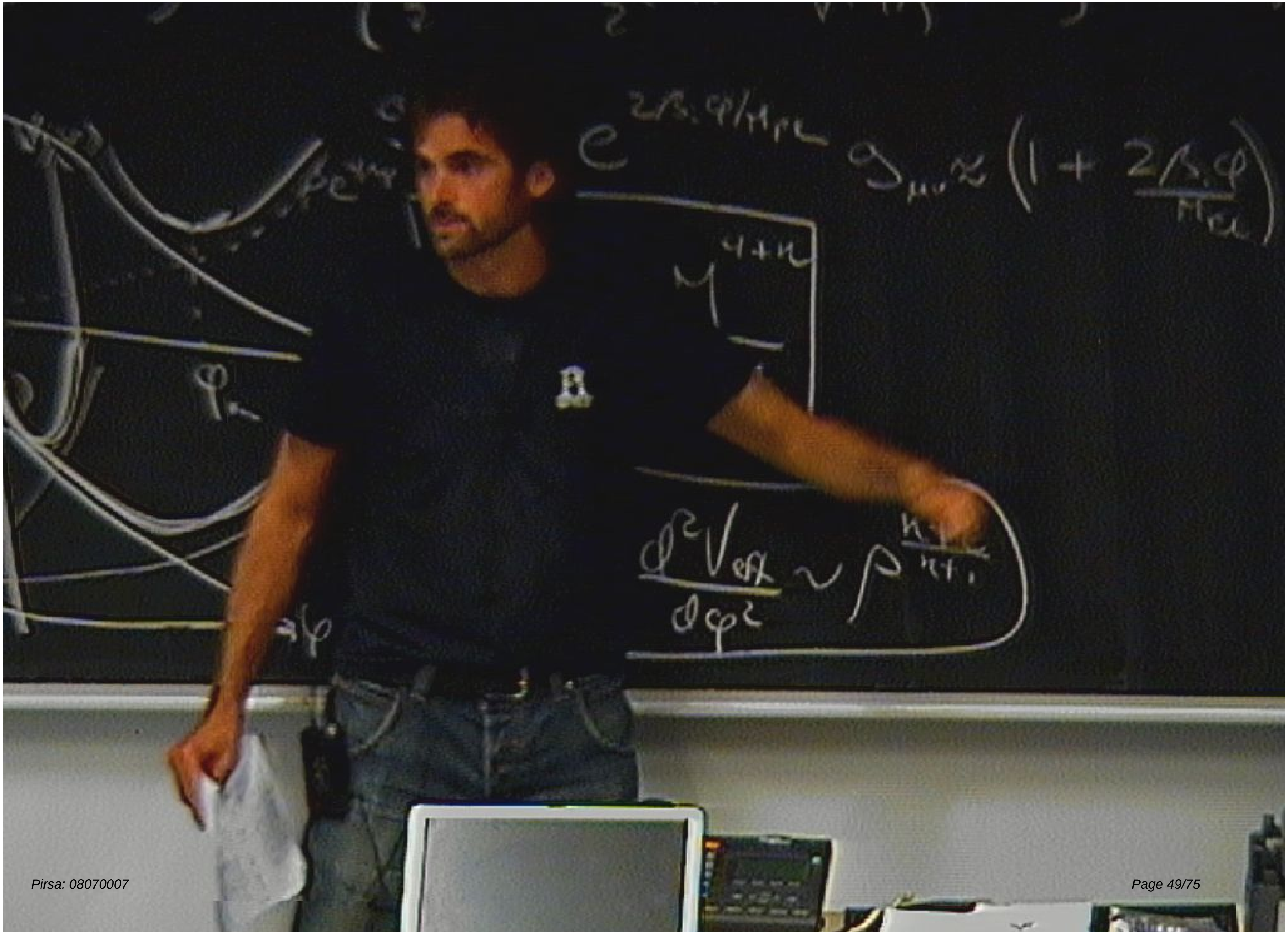

V(φ) = M^{4+n} / φ^n

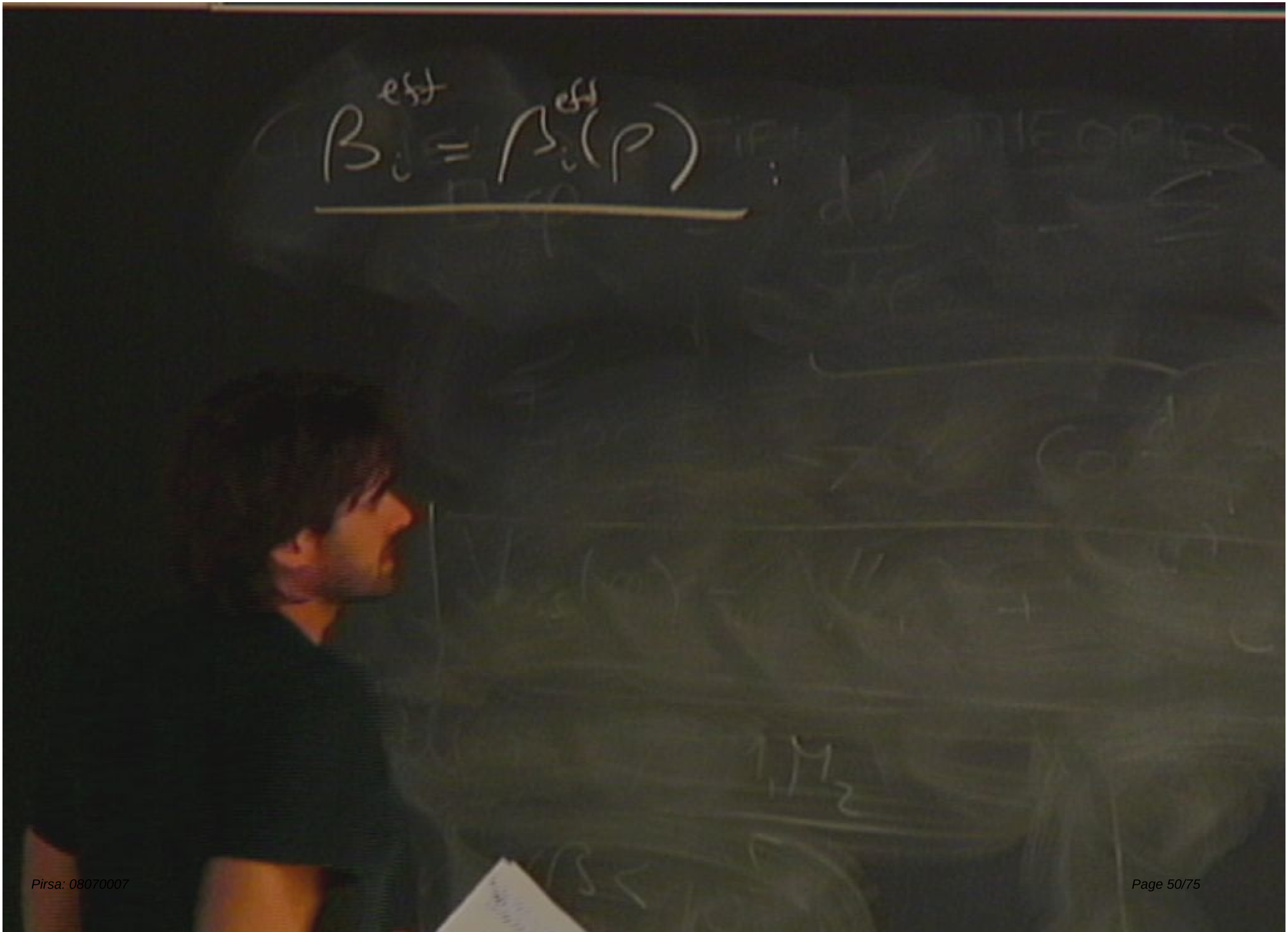

V(φ)
φ
φ
V(φ) = M^{4+n} / φ^n

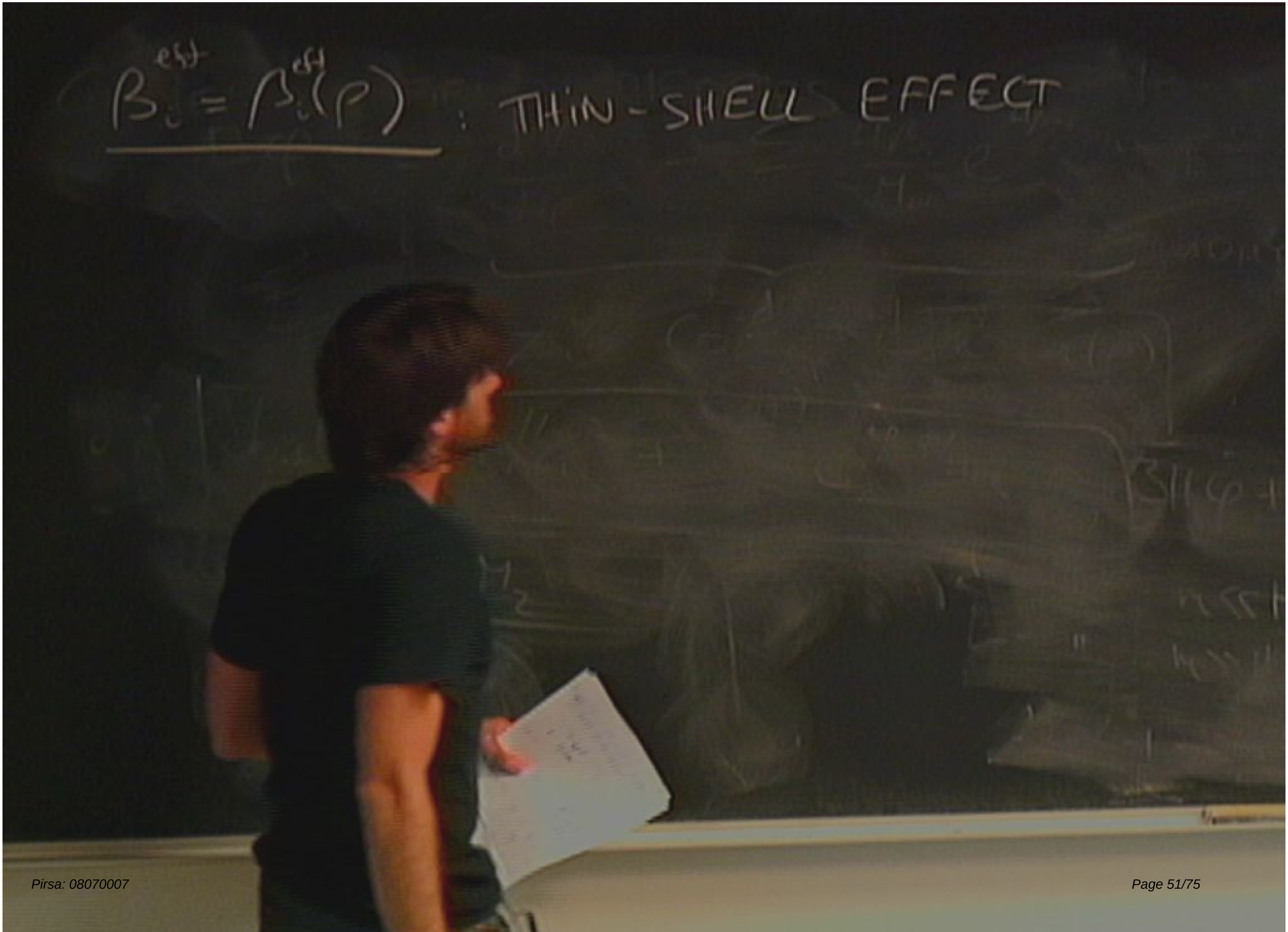

V(φ)
V(φ) = M^{4+n} / φ^n
φ_m
φ
⟹ m^2 = d^2V_eff / dφ^2

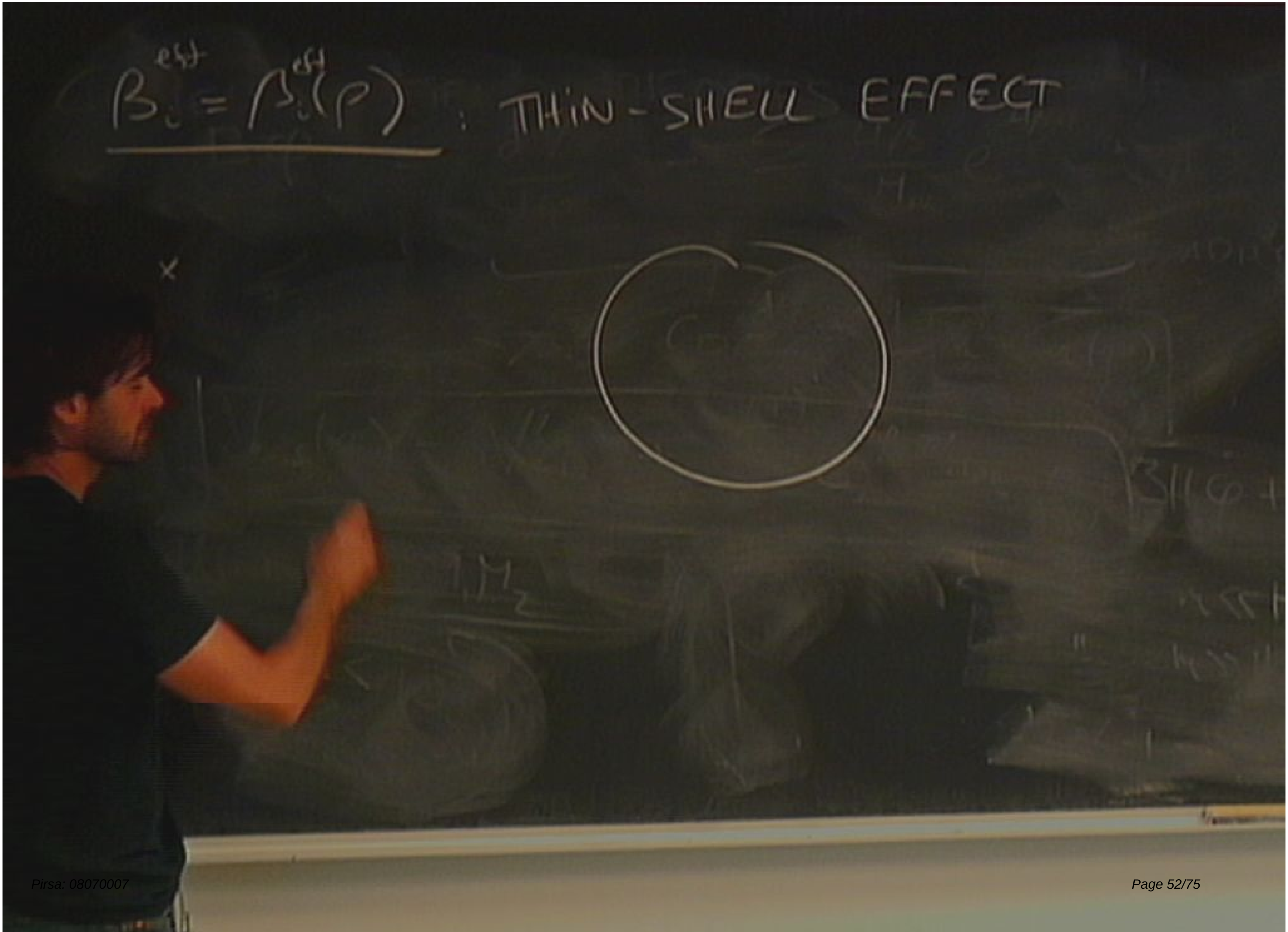

V(φ)
V(φ) = M^{4+n} / φ^n
V_eff(φ):
m² = d²V_eff / dφ² ∼ ρ^{(n+2)/(n+1)}
φ

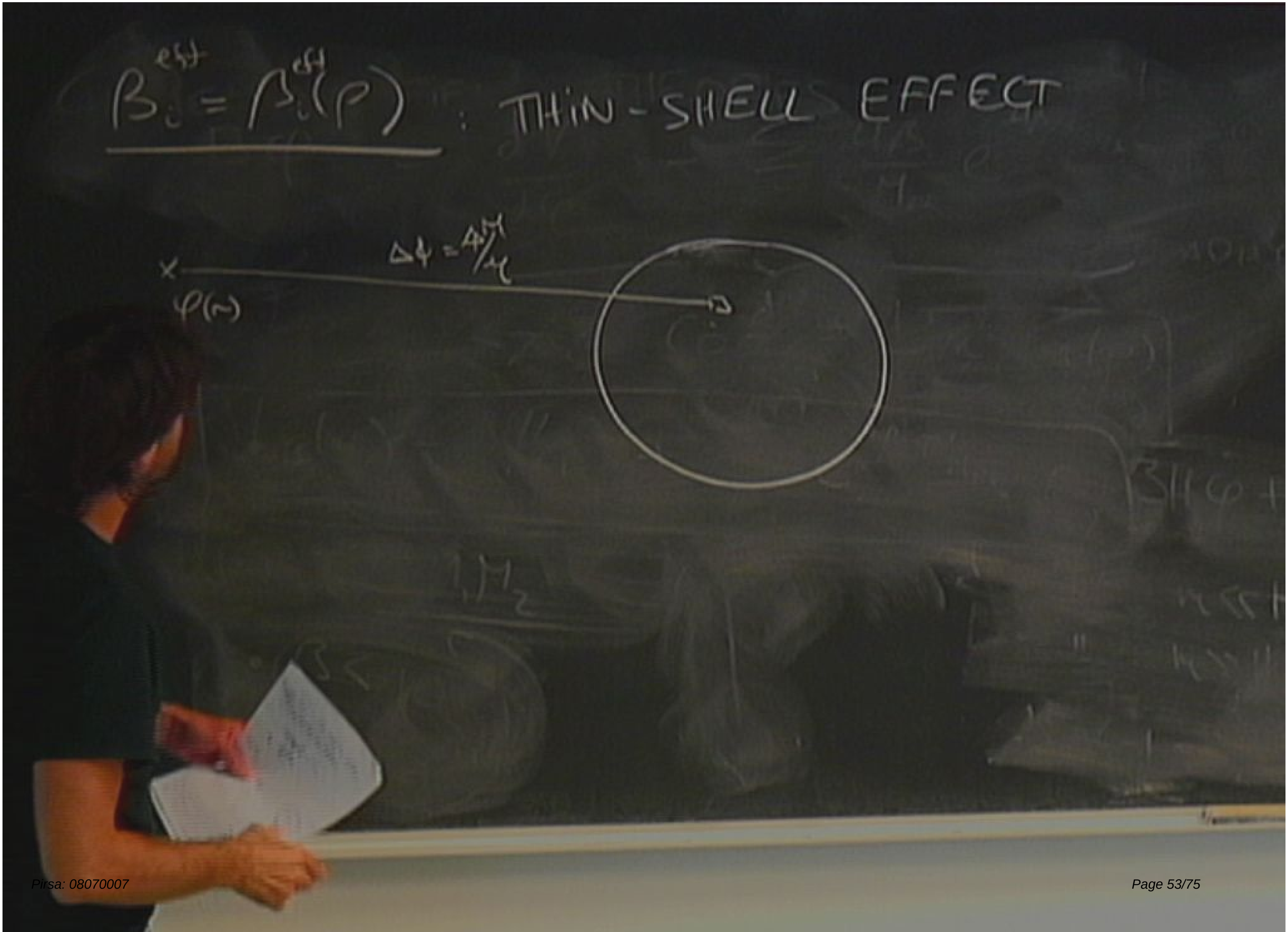

V(φ) = M^(4+n) / φ^n
m² = d²V_eff / dφ² ~ ρ^((n+2)/(n+1))

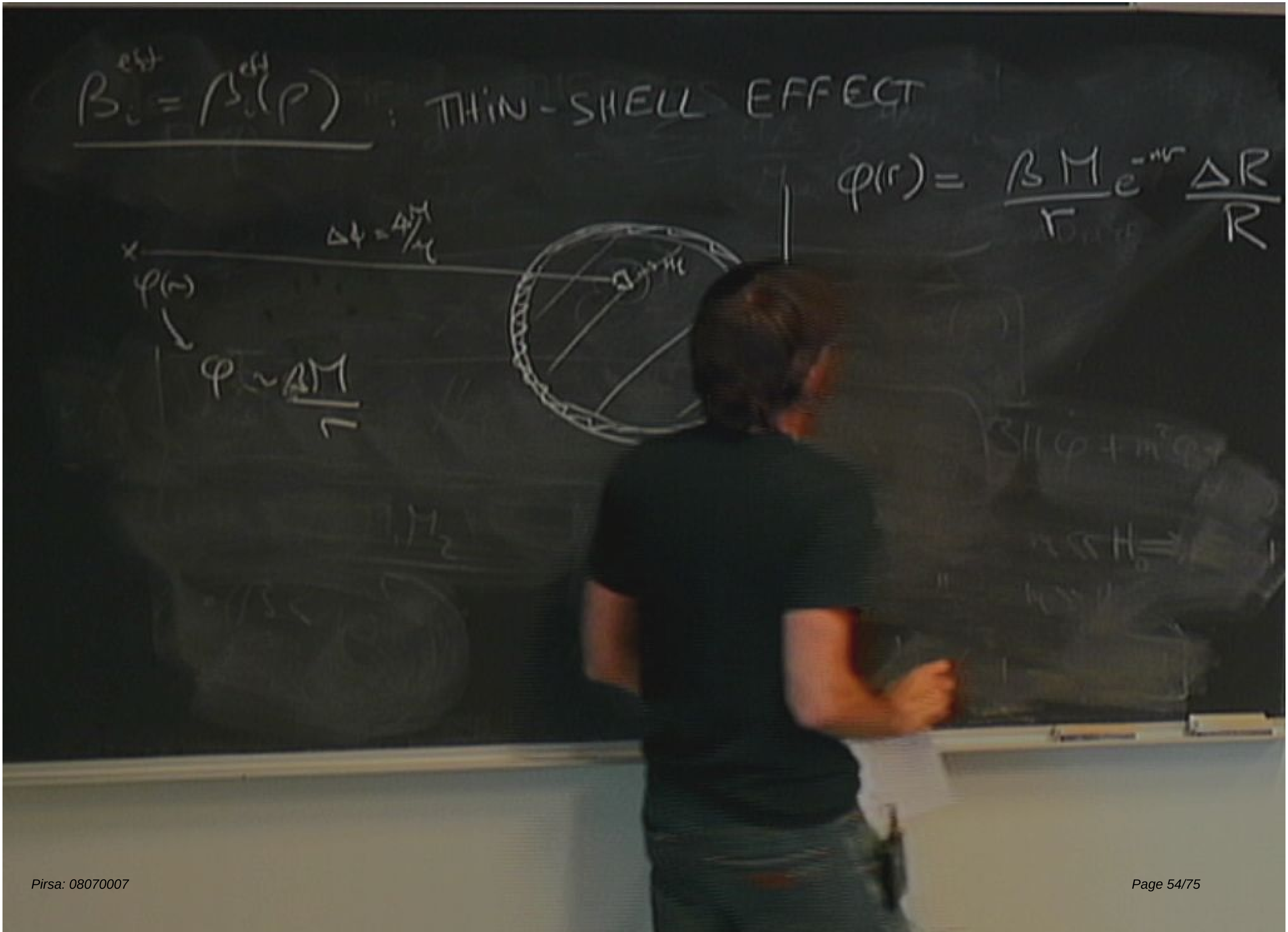


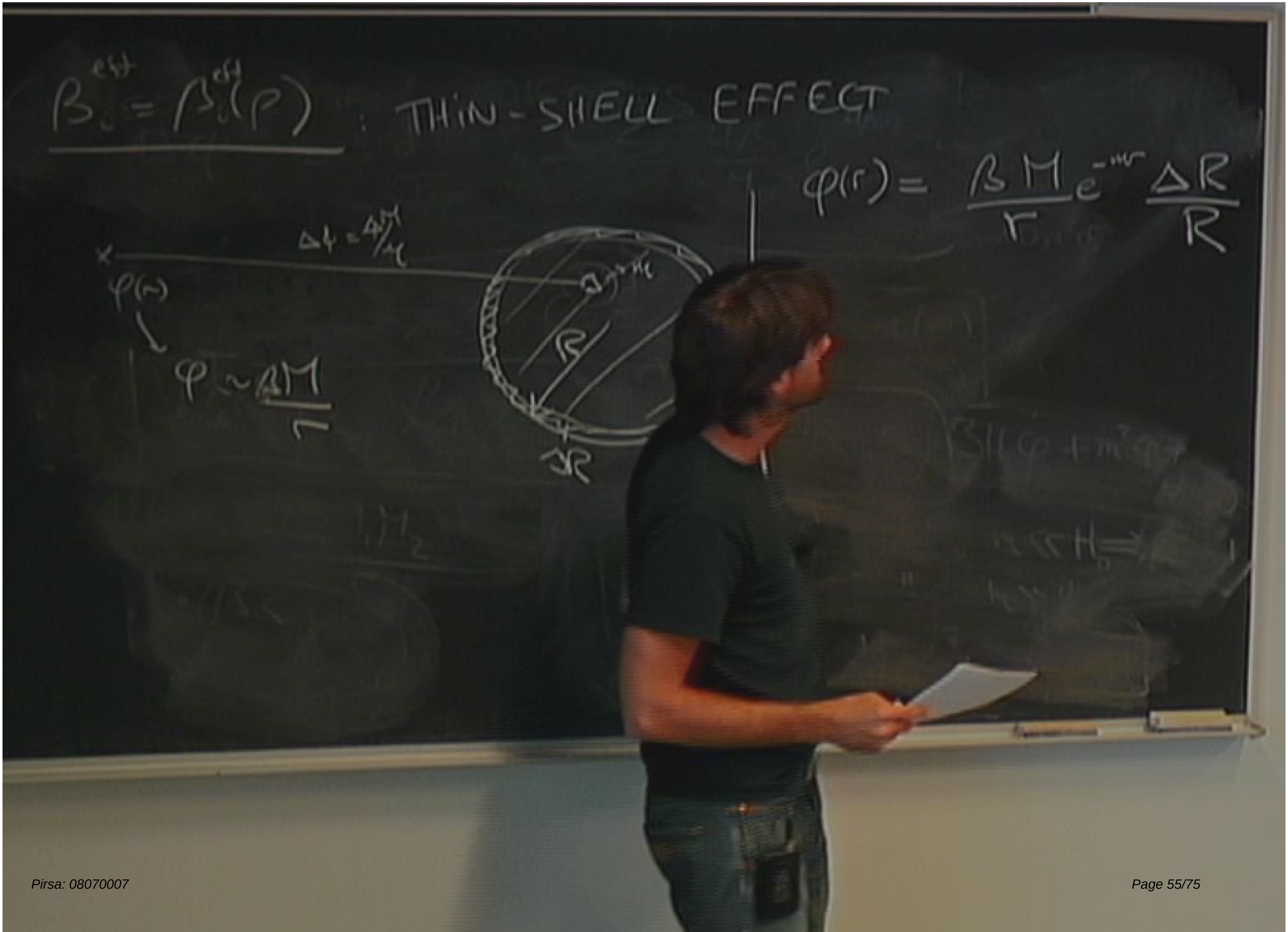

$\beta_i^{eff} = \beta_i^{eff}(\rho)$


$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT

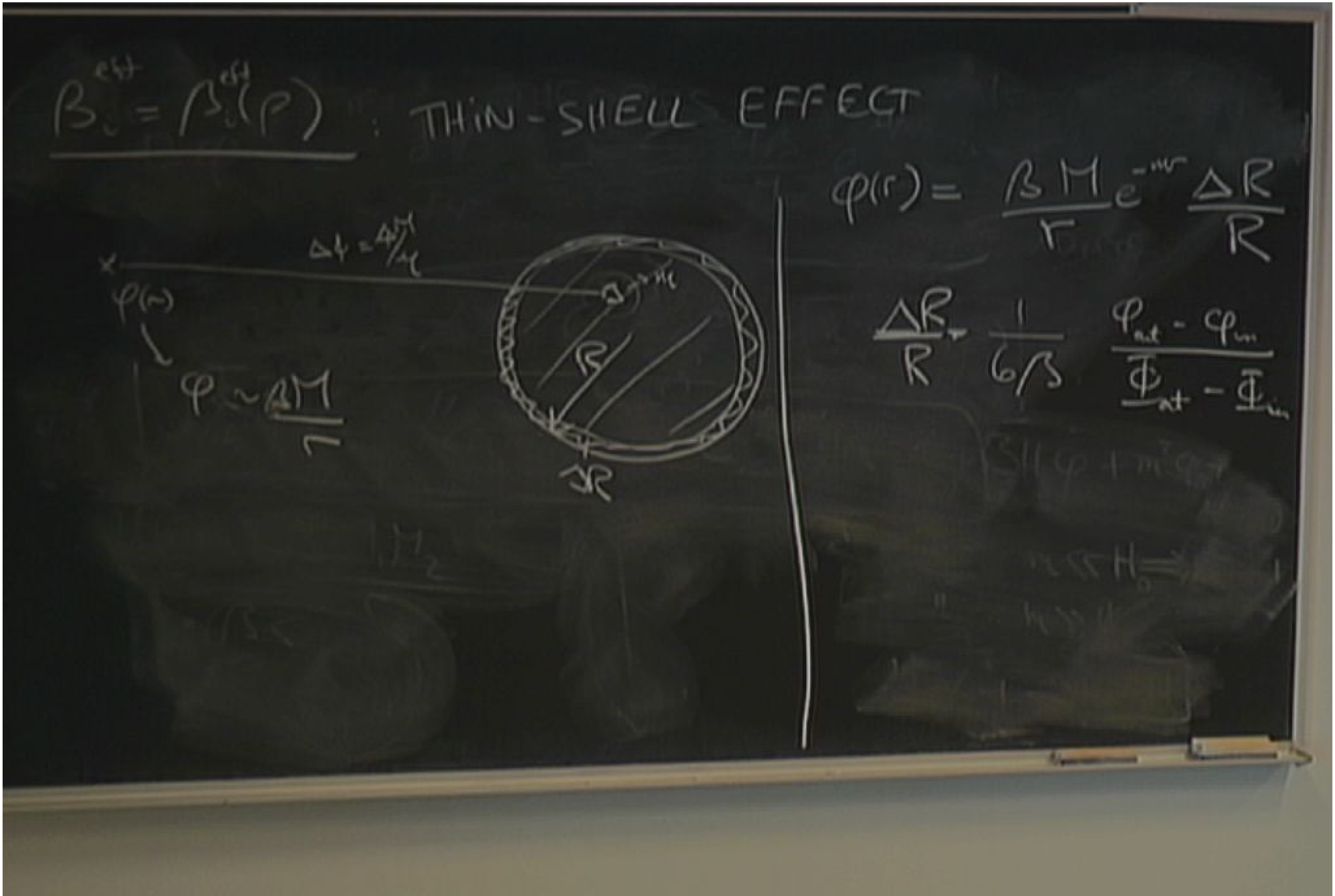

$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT

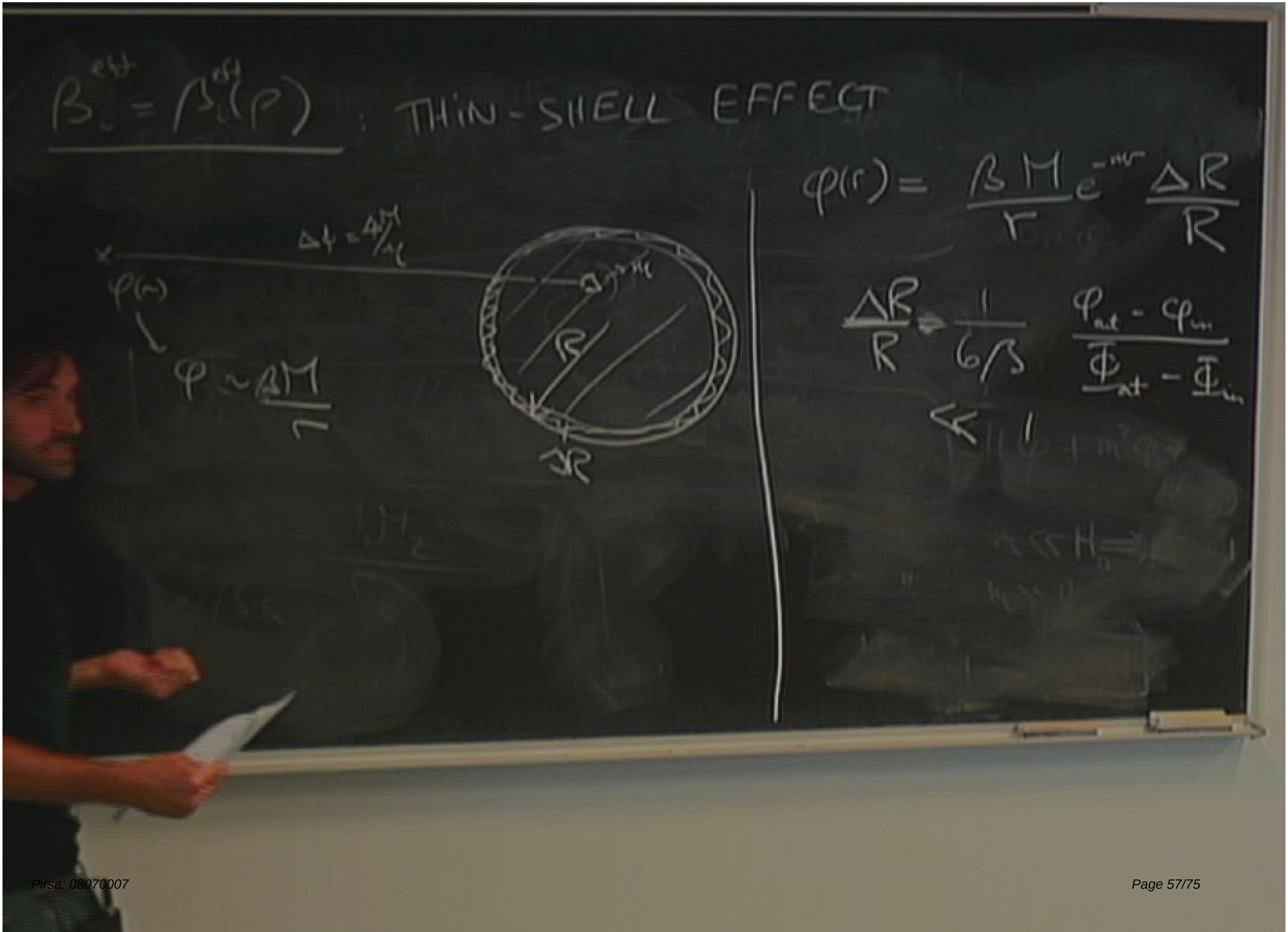

$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT
$\Delta\phi = 4\pi M / M$
$\varphi(r)$


$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT
$\varphi(r) = \frac{\beta M}{r} e^{-mr} \frac{\Delta R}{R}$
$\varphi(r)$
$\varphi \sim \frac{\beta M}{r}$



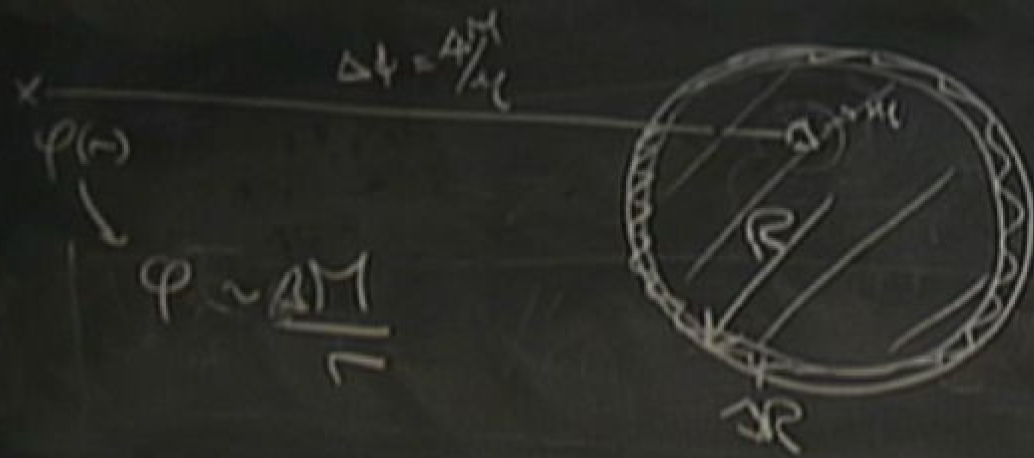
β_i^eff = β_i^eff(ρ) : THIN-SHELL EFFECT
φ(r) = βM/r e^-mr ΔR/R
φ(r)
φ ~ βM/r
R
ΔR


$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT
$\varphi(r)$
$\varphi \sim \frac{\beta M}{r}$
R
ΔR
$\varphi(r) = \frac{\beta M}{r} e^{-mr} \frac{\Delta R}{R}$
$\frac{\Delta R}{R} = \frac{1}{6\beta} \frac{\varphi_{out} - \varphi_{in}}{\Phi_{out} - \Phi_{in}}$



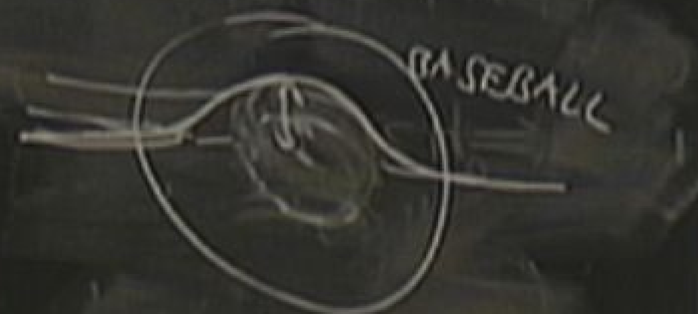
$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT
$\varphi(r) = \frac{\beta M}{r} e^{-mr} \frac{\Delta R}{R}$
$\frac{\Delta R}{R} = \frac{1}{6\beta} \frac{\varphi_{out} - \varphi_{in}}{\Phi_{out} - \Phi_{in}}$
$\ll 1$
$\varphi(r)$
$\varphi \sim \frac{\beta M}{r}$
R
ΔR

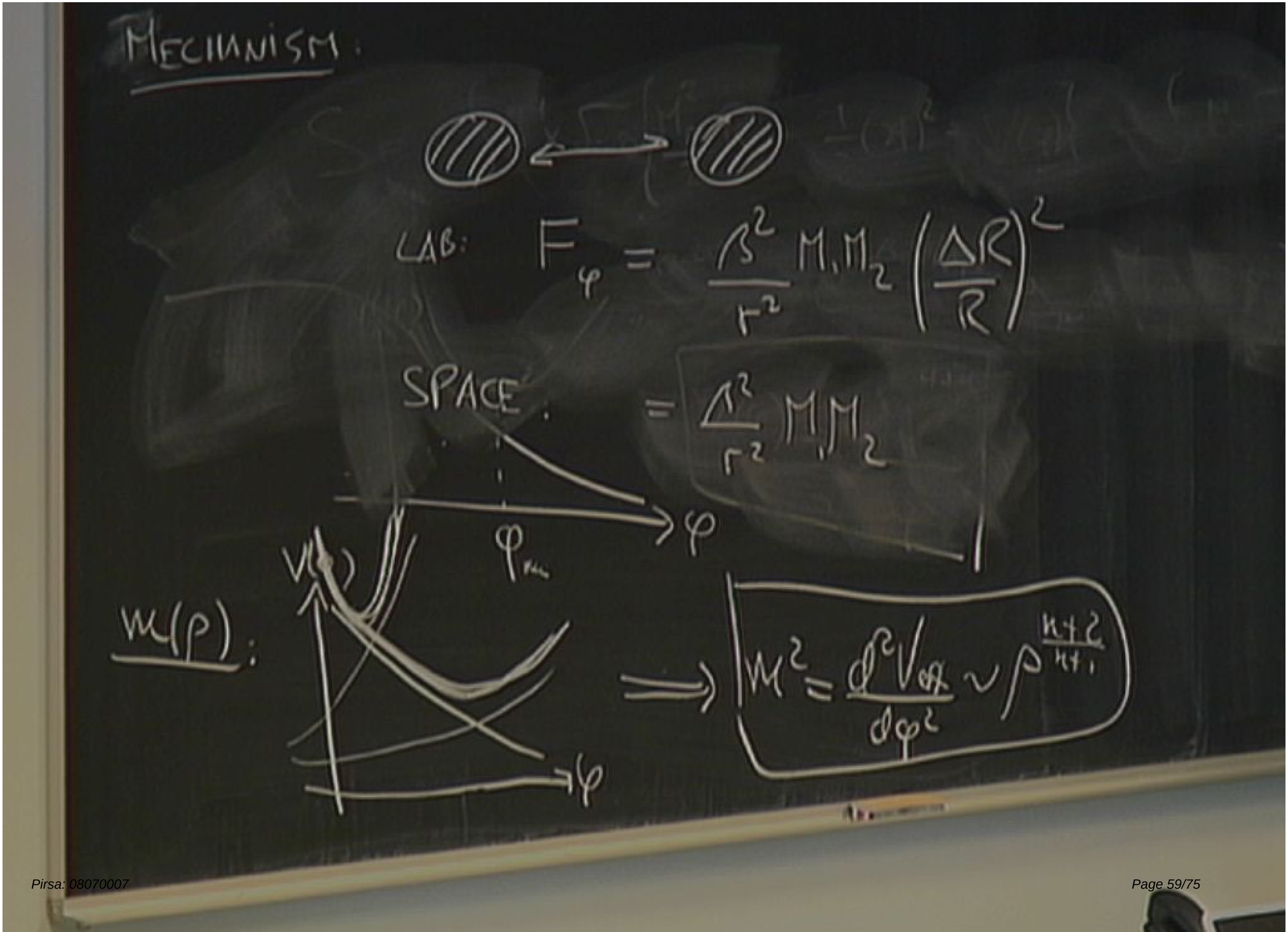
$\beta_i^{eff} = \beta_i^{eff}(\rho)$: THIN-SHELL EFFECT

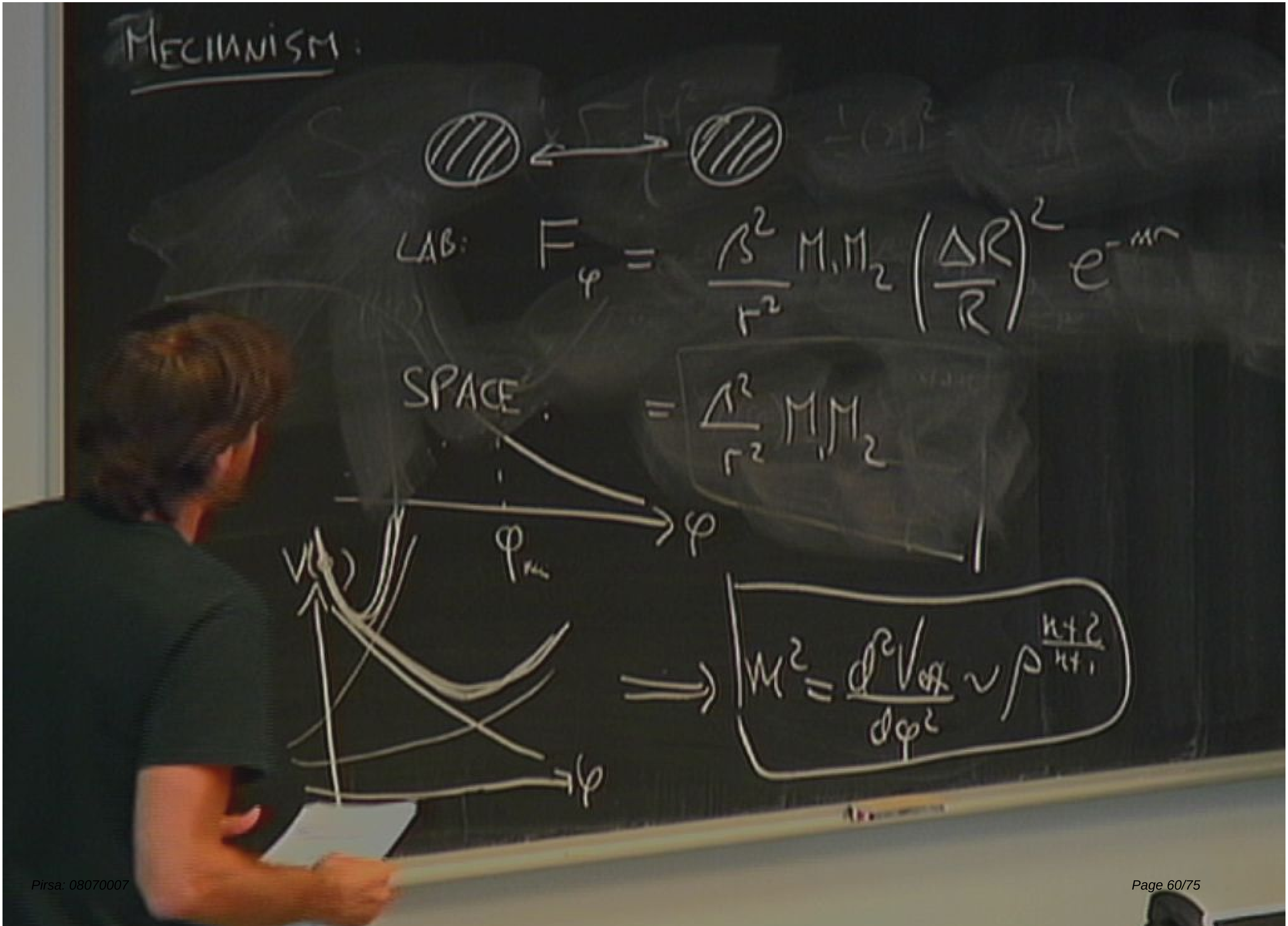


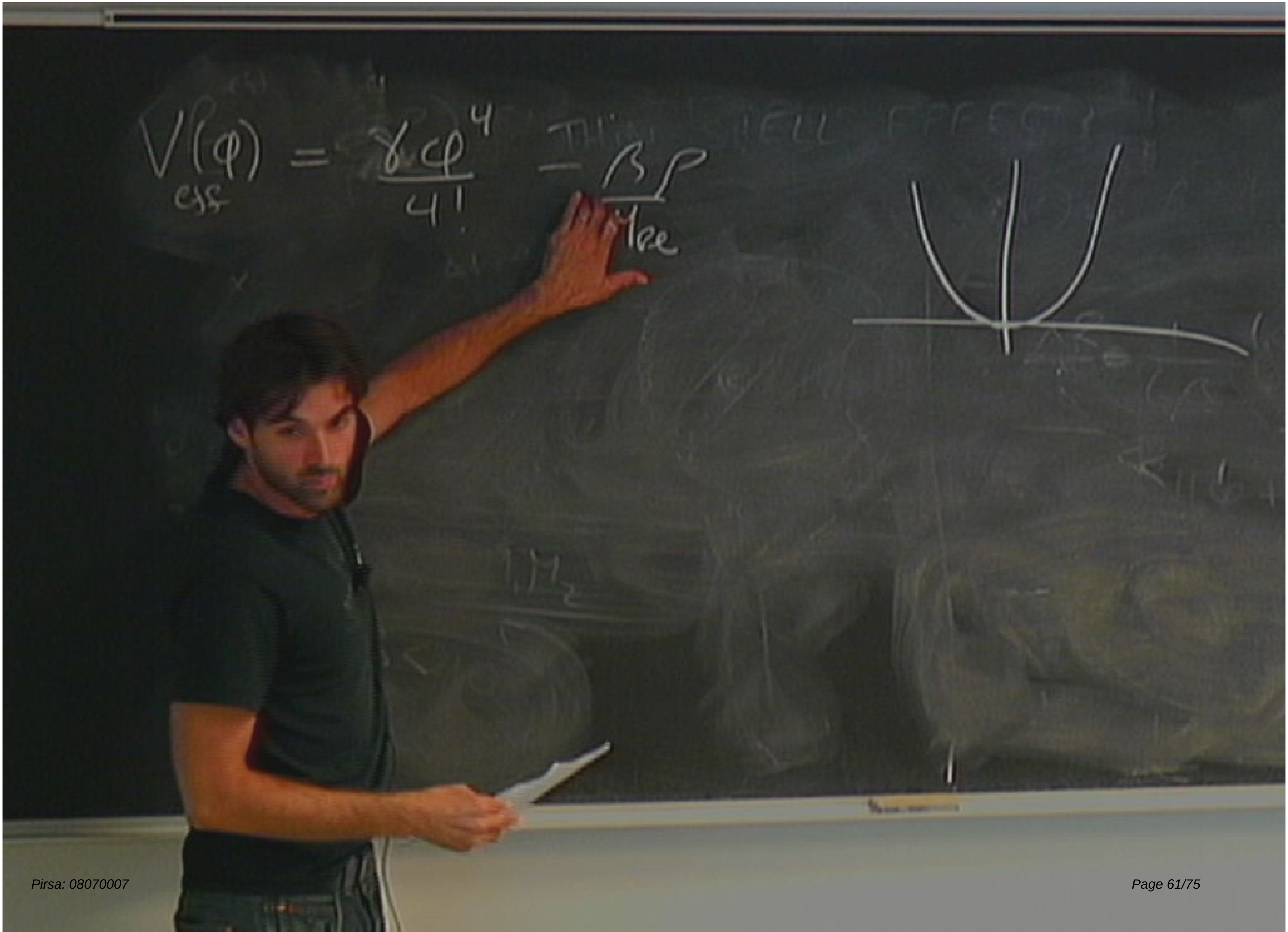
$$\varphi(r) = \frac{\beta M}{r} e^{-mr} \frac{\Delta R}{R}$$

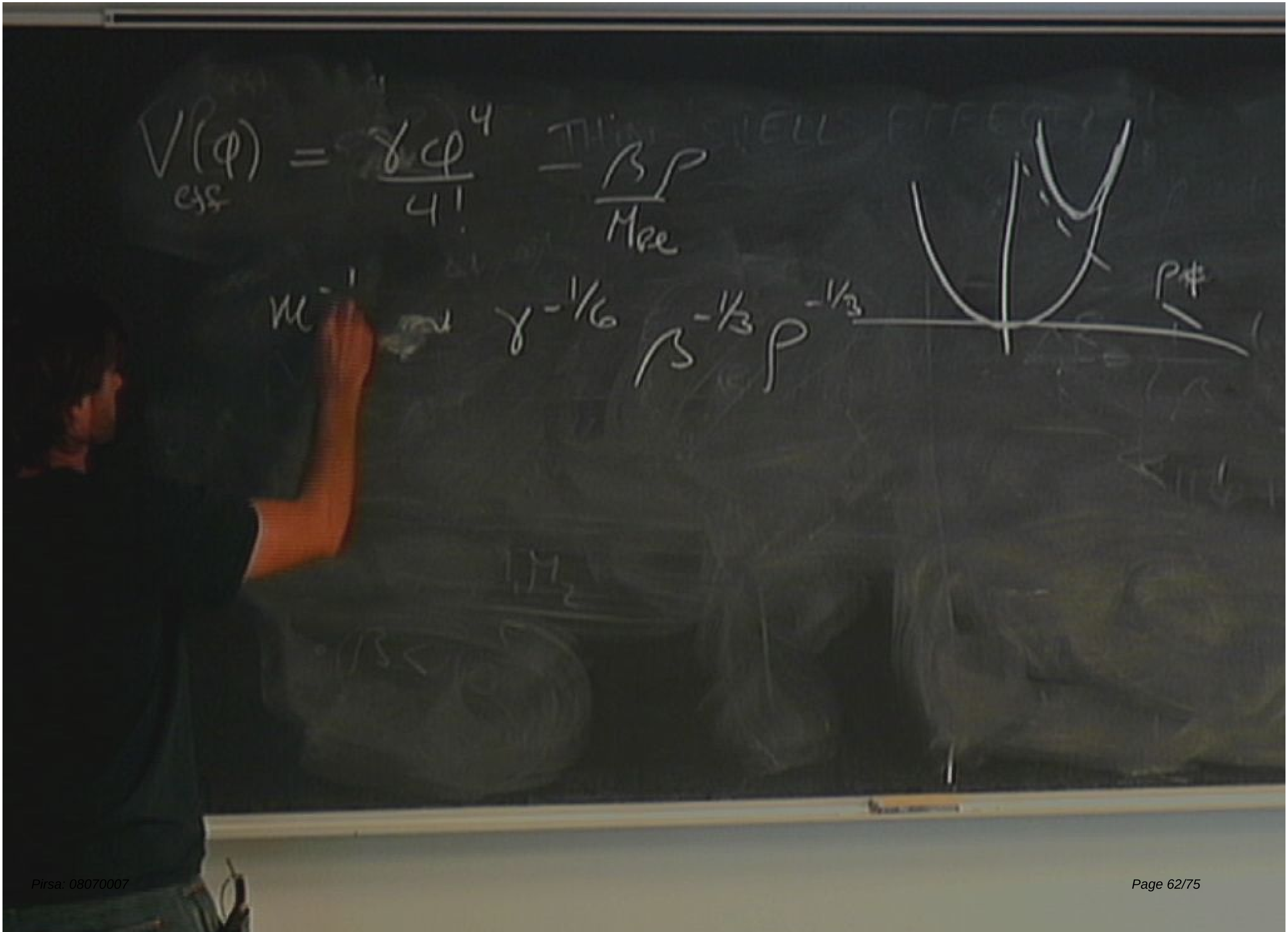
$$\frac{\Delta R}{R} = \frac{1}{6\beta} \frac{(\varphi_{out} - \varphi_{in})}{\Phi_{out} - \Phi_{in}} \ll 1$$

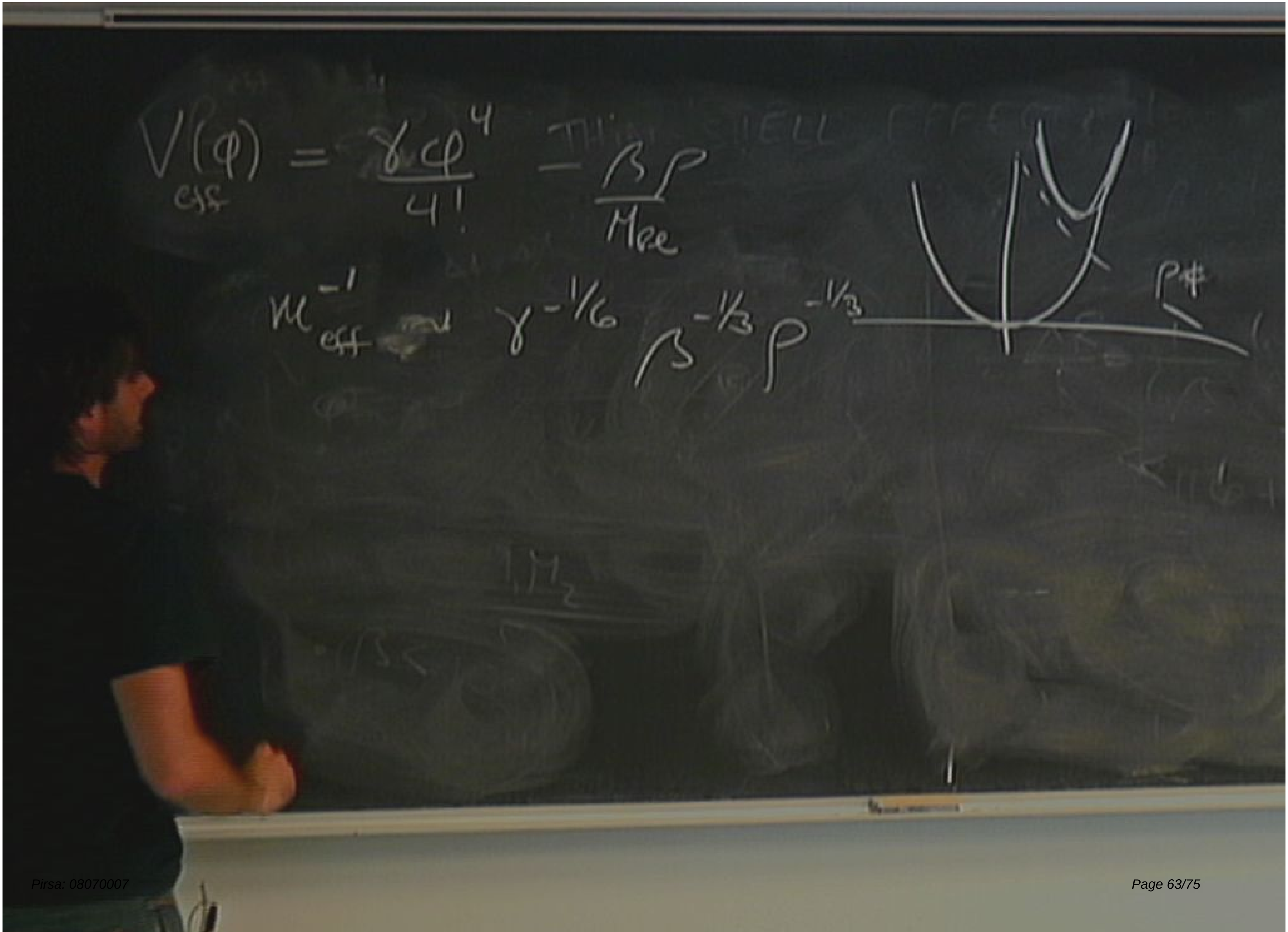


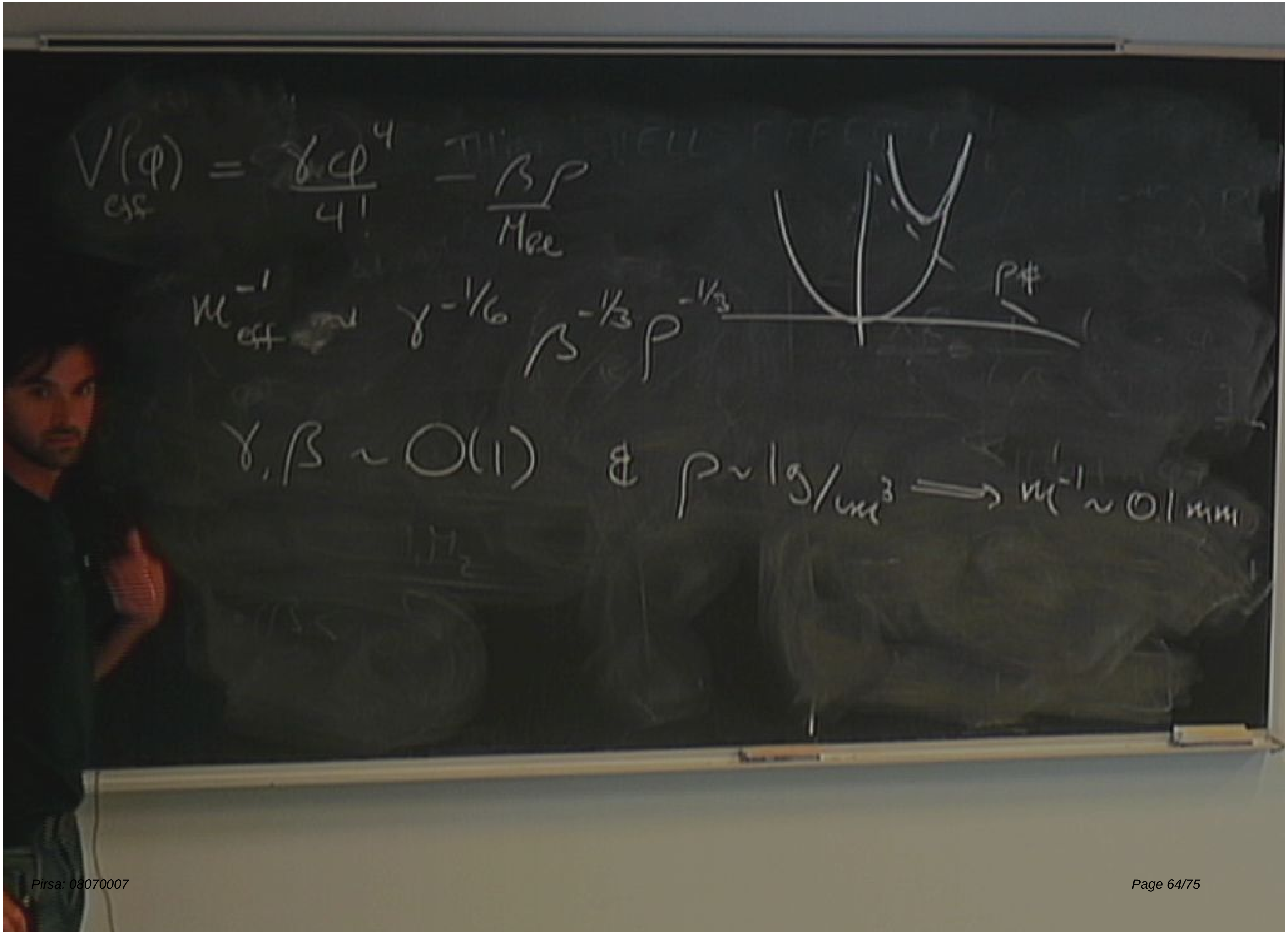

MECHANISM:
LAB: $F_\varphi = \frac{\beta^2}{r^2} M_1 M_2 \left(\frac{\Delta R}{R}\right)^2$
SPACE: $= \frac{\beta^2}{r^2} M_1 M_2$
φ
$V(\varphi)$
$m(\rho)$:
$\Longrightarrow m^2 = \frac{d^2 V_{eff}}{d\varphi^2} \sim \rho^{\frac{n+2}{n+1}}$


MECHANISM:
LAB: $F_\varphi = \frac{\beta^2}{r^2} M_1 M_2 \left(\frac{\Delta R}{R}\right)^2 e^{-mr}$
SPACE: $= \frac{\beta^2}{r^2} M_1 M_2$
$V(\varphi)$
φ
φ_{min}
$\Longrightarrow \boxed{m^2 = \frac{d^2 V_{eff}}{d\varphi^2} \sim \rho^{\frac{n+2}{n+1}}}$


$V_{eff}(\varphi) = \frac{\gamma\varphi^4}{4!} - \frac{\beta\rho}{M_{Pl}}$

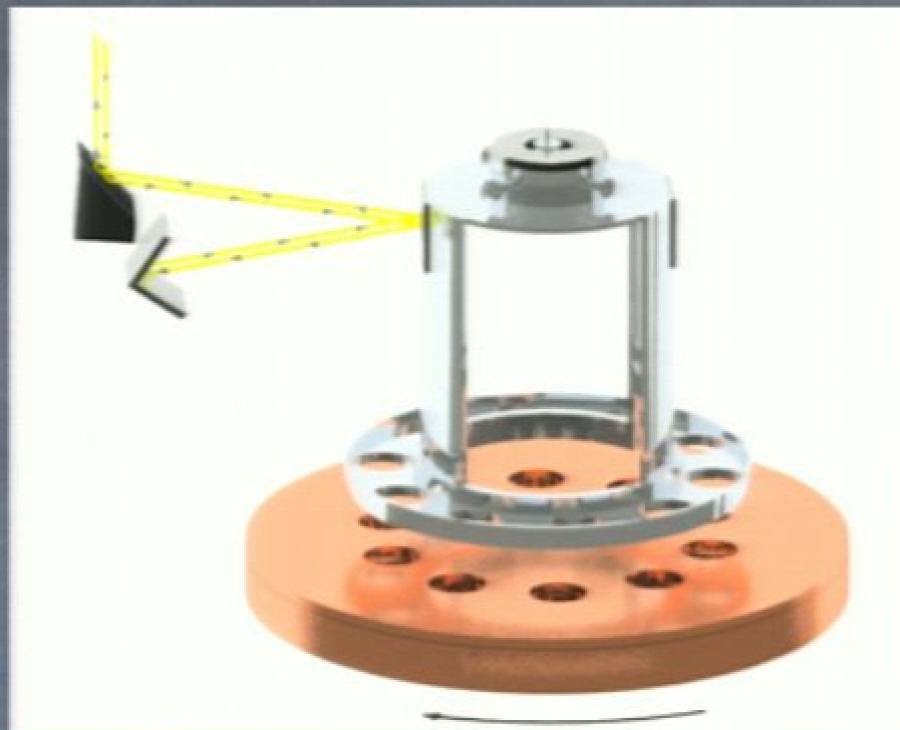

V(φ)eff = γφ⁴/4! ± βρ/MPl
m⁻¹ ~ γ^(-1/6) β^(-1/3) ρ^(-1/3)
ρφ


$V_{eff}(\varphi) = \frac{\gamma \varphi^4}{4!} - \frac{\beta \rho}{M_{Pl}}$
$m_{eff}^{-1} \sim \gamma^{-1/6} \beta^{-1/3} \rho^{-1/3}$
ρ^*

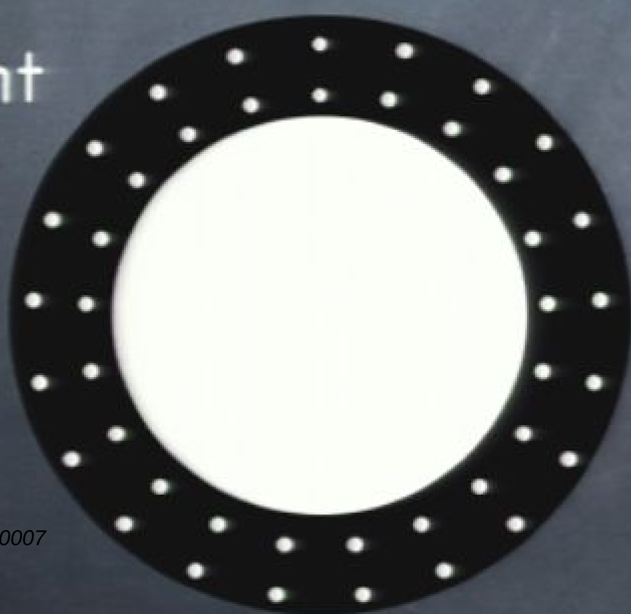


$V_{eff}(\varphi) = \frac{\gamma \varphi^4}{4!} - \frac{\beta \rho}{M_{Pl}}$
$m_{eff}^{-1} \sim \gamma^{-1/6} \beta^{-1/3} \rho^{-1/3}$
$\rho\uparrow$
$\gamma, \beta \sim O(1)$ & $\rho \sim 1 g/cm^3 \Longrightarrow m^{-1} \sim 0.1 mm$

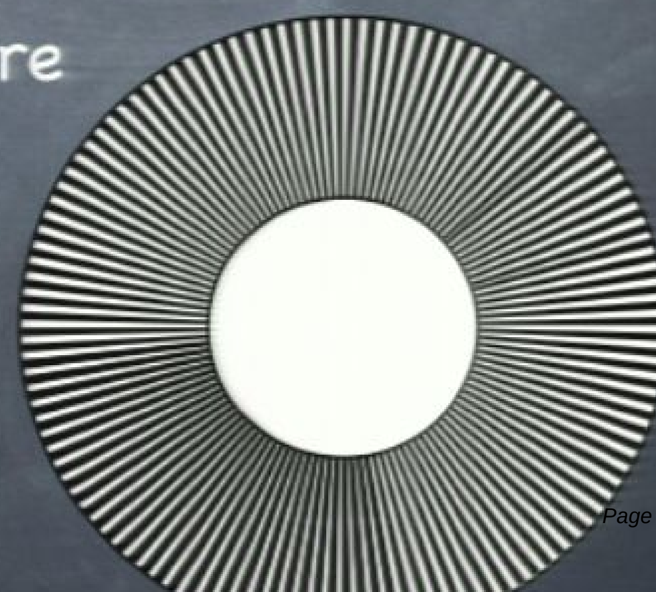
ot-Wash



urrent

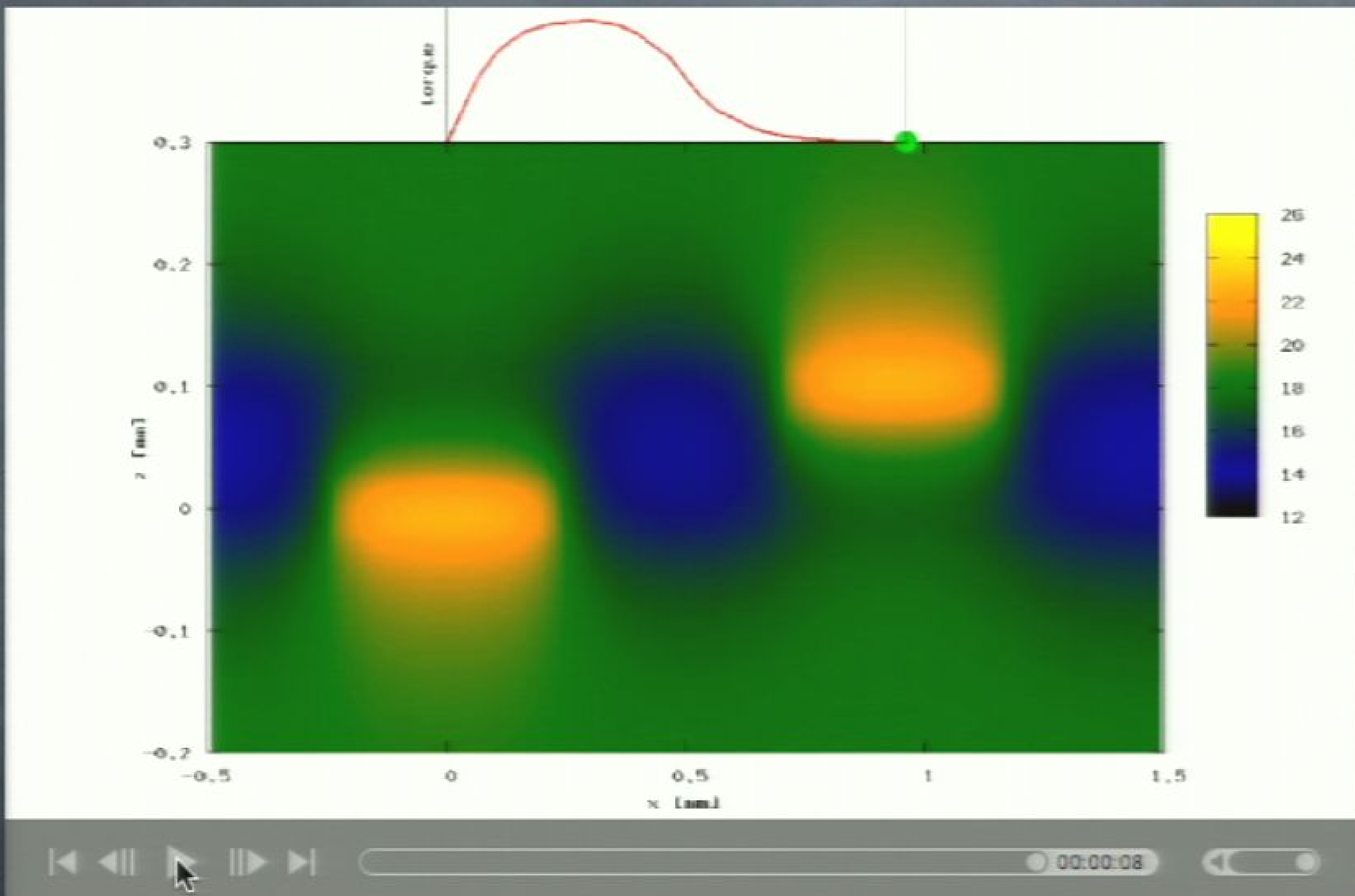


Future



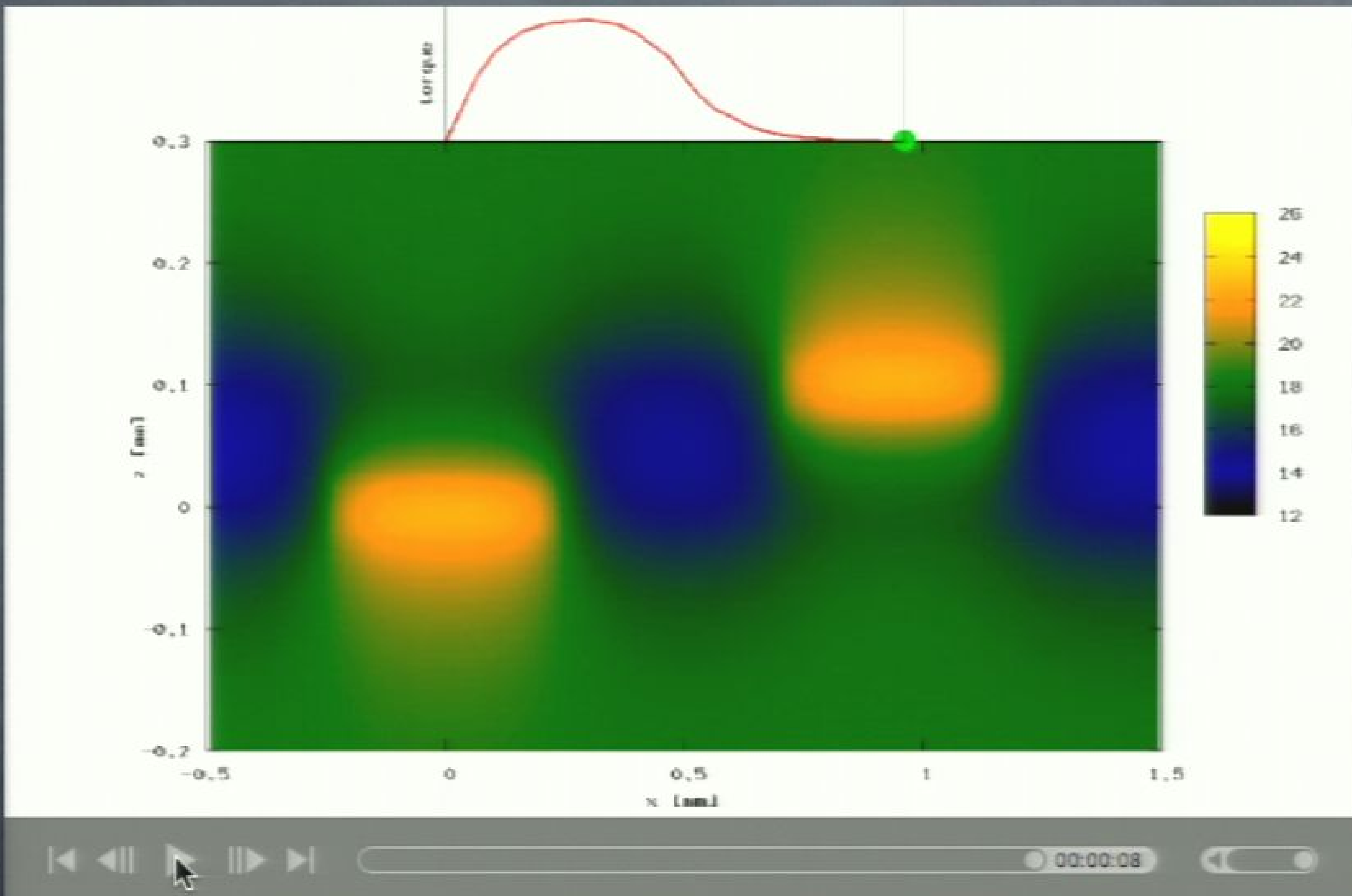
hameleon torque

Upadhye, Gubser & JK, hep-ph/0608186



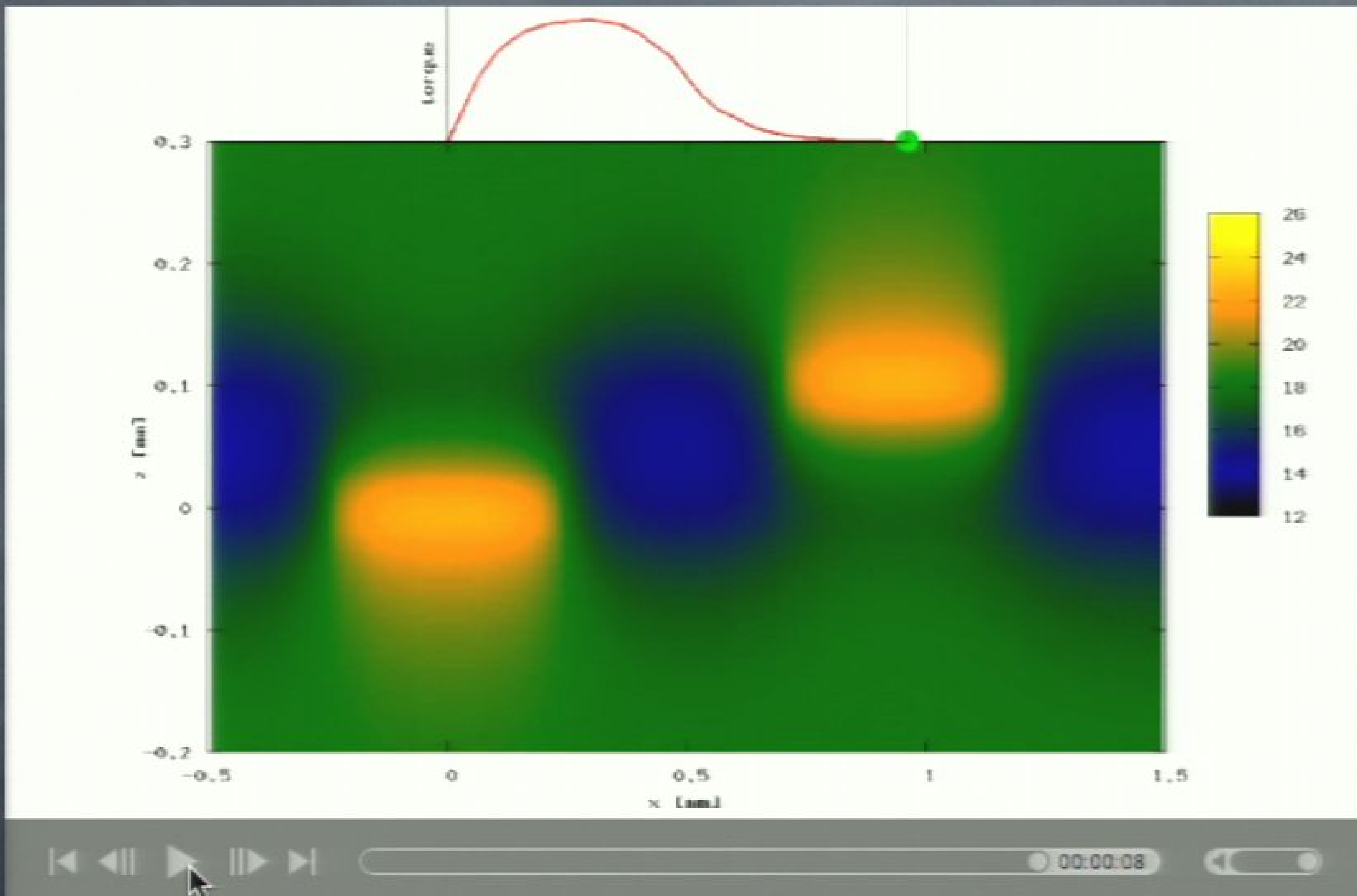
hameleon torque

Upadhye, Gubser & JK, hep-ph/0608186



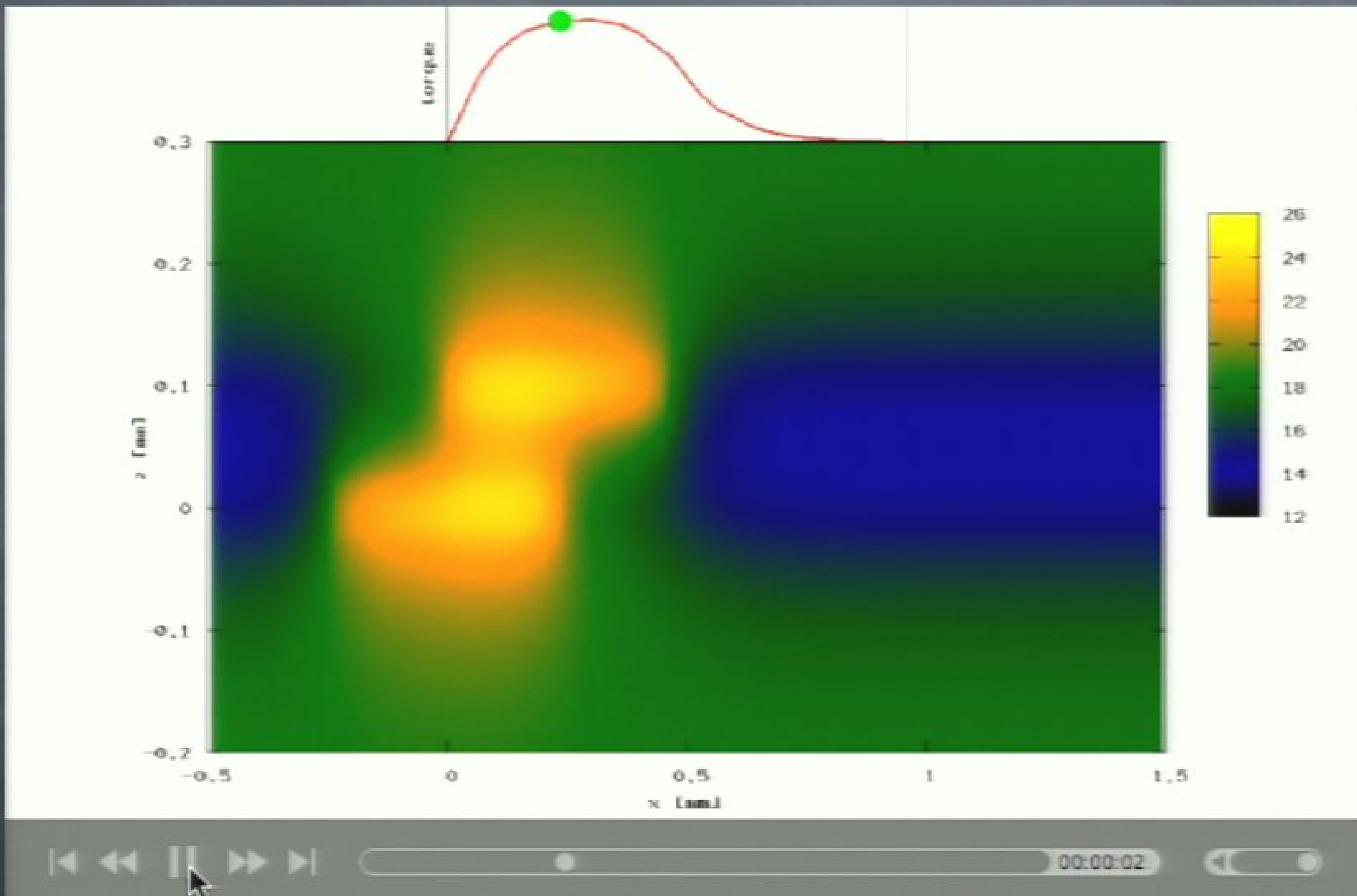
ameleon torque

Upadhye, Gubser & JK, hep-ph/0608186



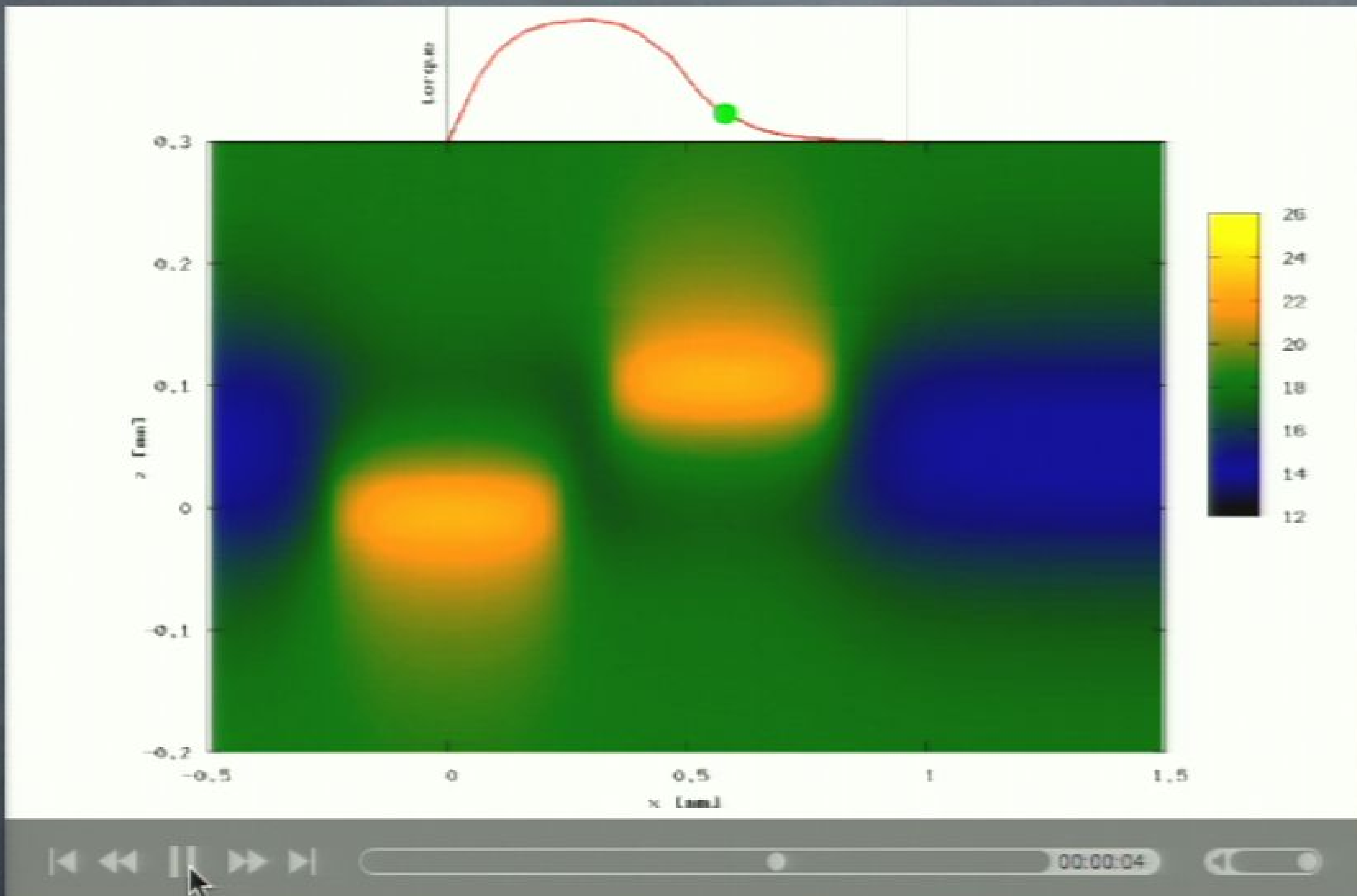
hameleon torque

Upadhye, Gubser & JK, hep-ph/0608186



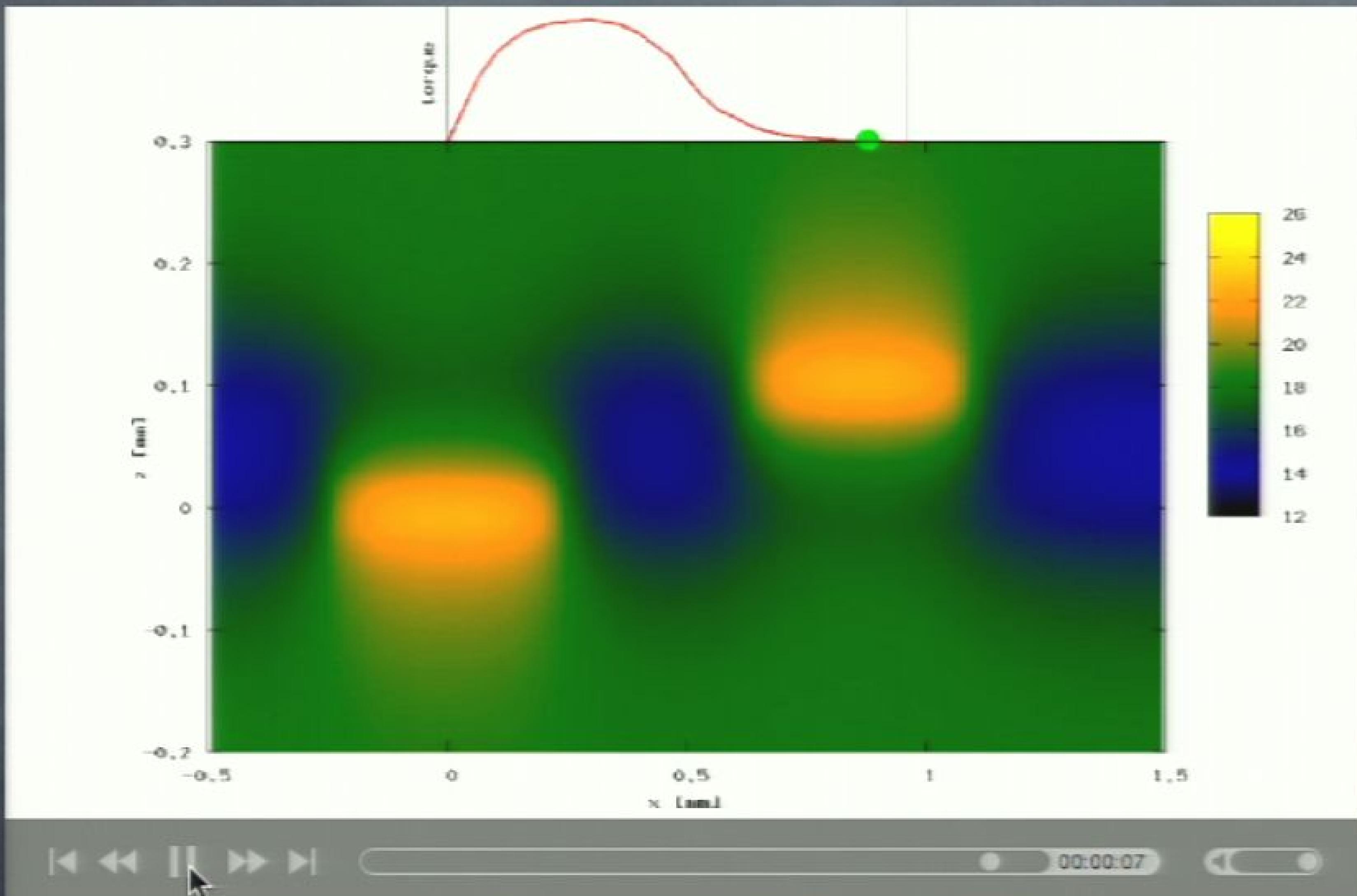
hameleon torque

Upadhye, Gubser & JK, hep-ph/0608186



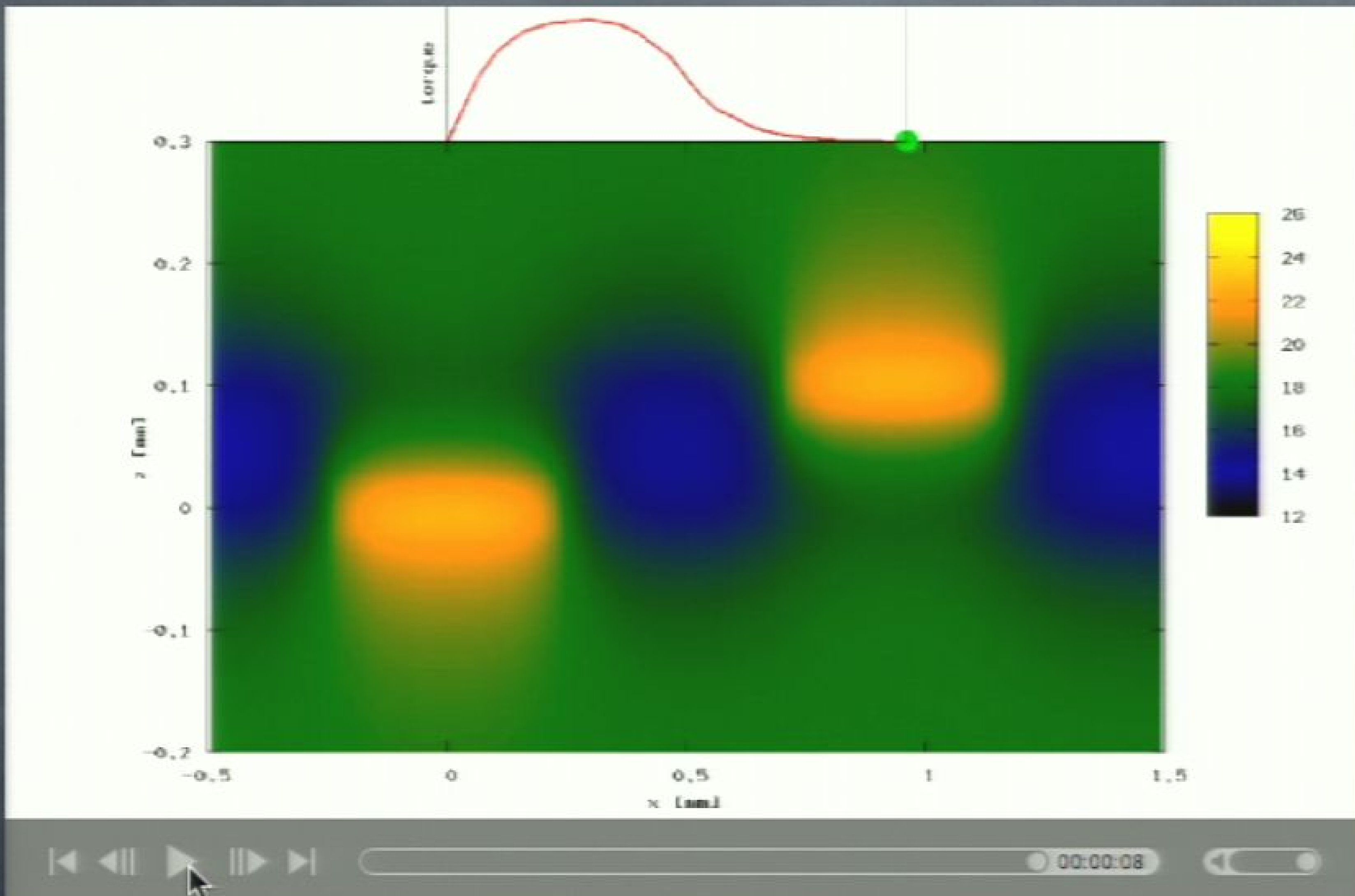
hameleon torque

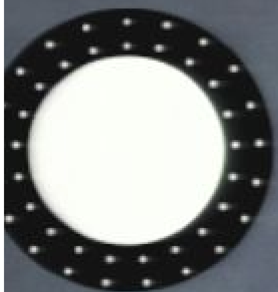
Upadhye, Gubser & JK, hep-ph/0608186

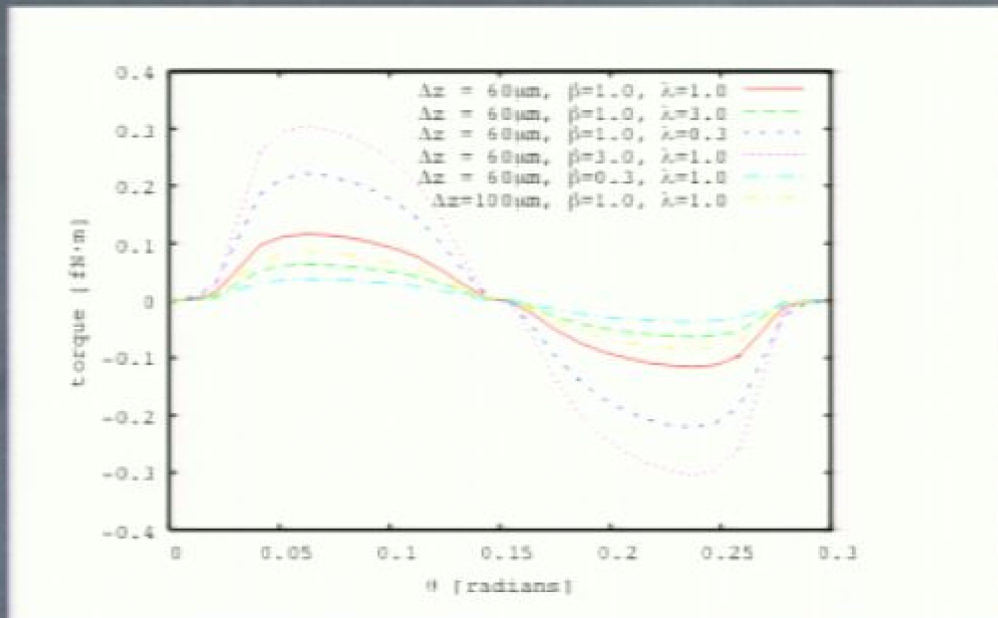


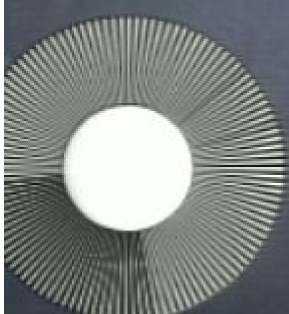
hameleon torque

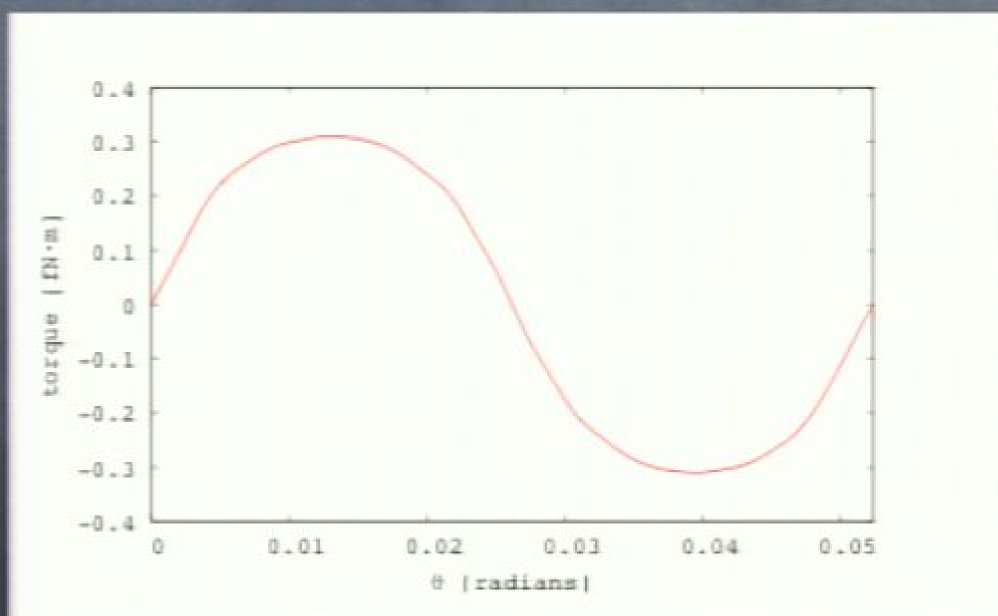
Upadhye, Gubser & JK, hep-ph/0608186






Δz = 60μm, β=1.0, λ=1.0
Δz = 60μm, β=1.0, λ=3.0
Δz = 60μm, β=1.0, λ=0.3
Δz = 60μm, β=3.0, λ=1.0
Δz = 60μm, β=0.3, λ=1.0
Δz=100μm, β=1.0, λ=1.0
torque [fN·m]
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
0.05
0.1
0.15
0.2
0.25
0.3
θ [radians]

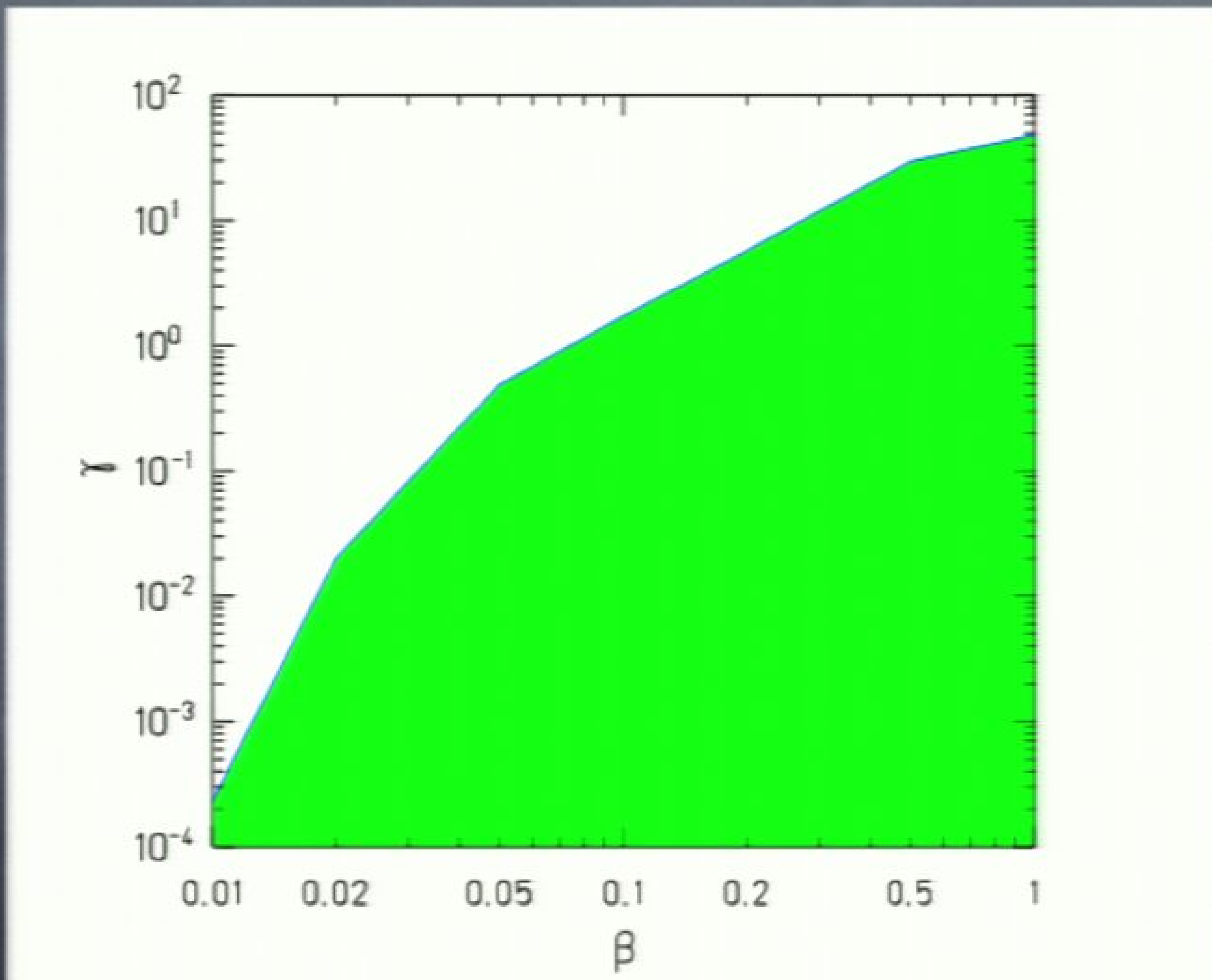



torque [fN·m]
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
0.01
0.02
0.03
0.04
0.05
θ [radians]

Chameleon Constraints

Adelberger et al., PRL (2007)

$$V_{\rm eff}(\phi, \vec{x}) = \frac{\gamma}{4!}\phi^4 - \frac{\beta}{M_{\rm Pl}}\rho(\vec{x})\phi$$



ammeV expt (FNAL)

Brax et al. (2007)
GammeV collaboration, to appear

$$e^{\beta\phi/M_{\mathrm{Pl}}} F_{\mu\nu} F^{\mu\nu}$$

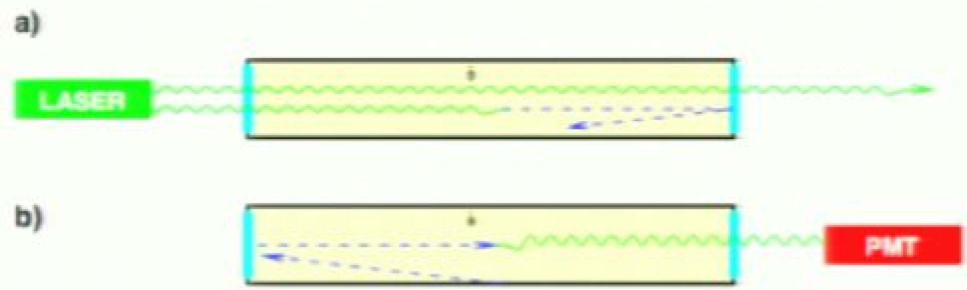


Figure 2: Schematic of the GammeV apparatus. a) Chameleon production phase: photons propagating through a region of magnetic field oscillate into chameleons. Photons travel through the glass endcaps whereas chameleons see the glass as a wall and are trapped. b) Afterglow phase: chameleons in the chamber gradually decay back into photons and are detected by a photomultiplier tube.

from A. Weltman (2008)