Title: A Microscopic Limit on Gravitational Waves from D-brane Inflation

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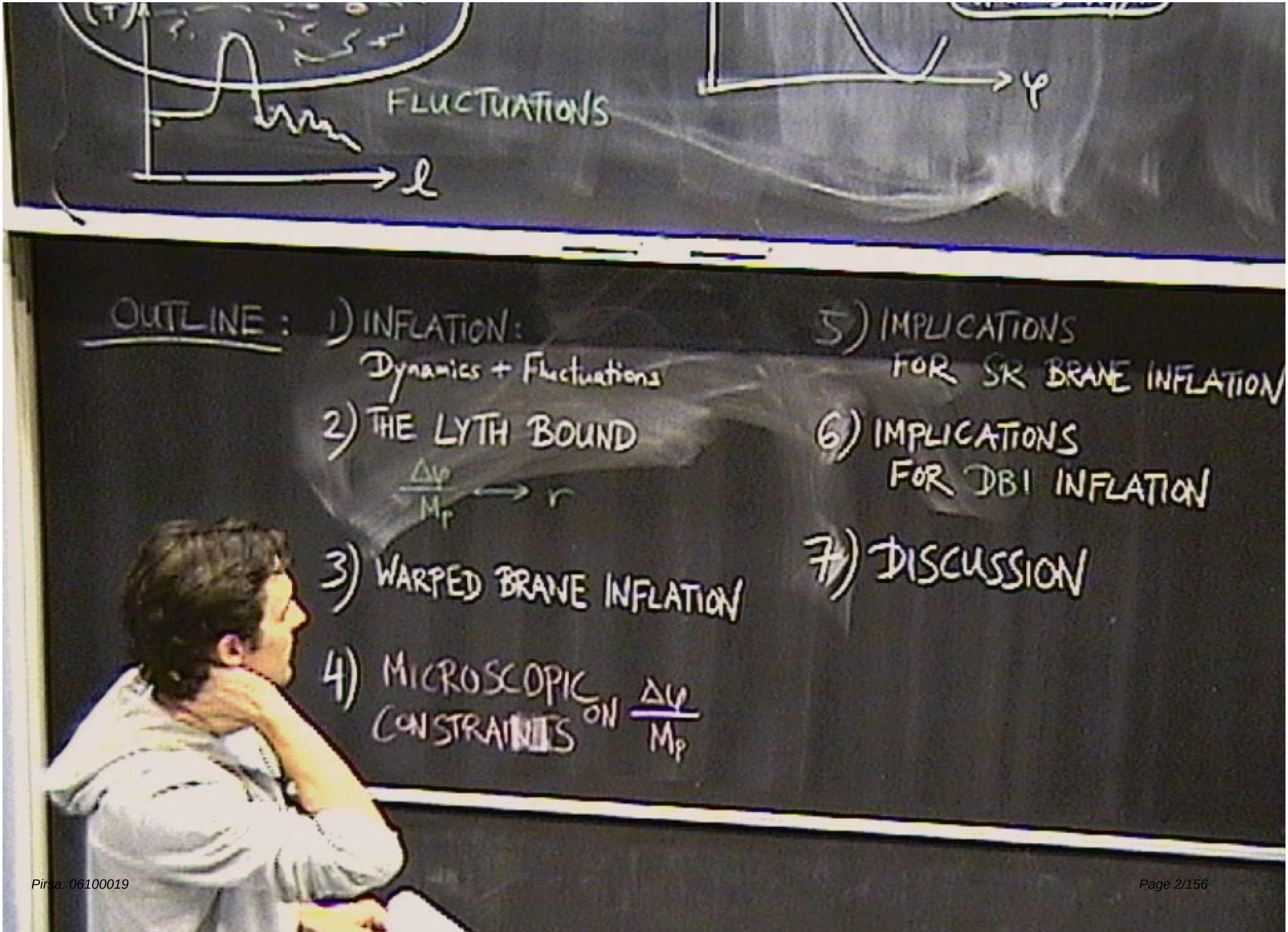
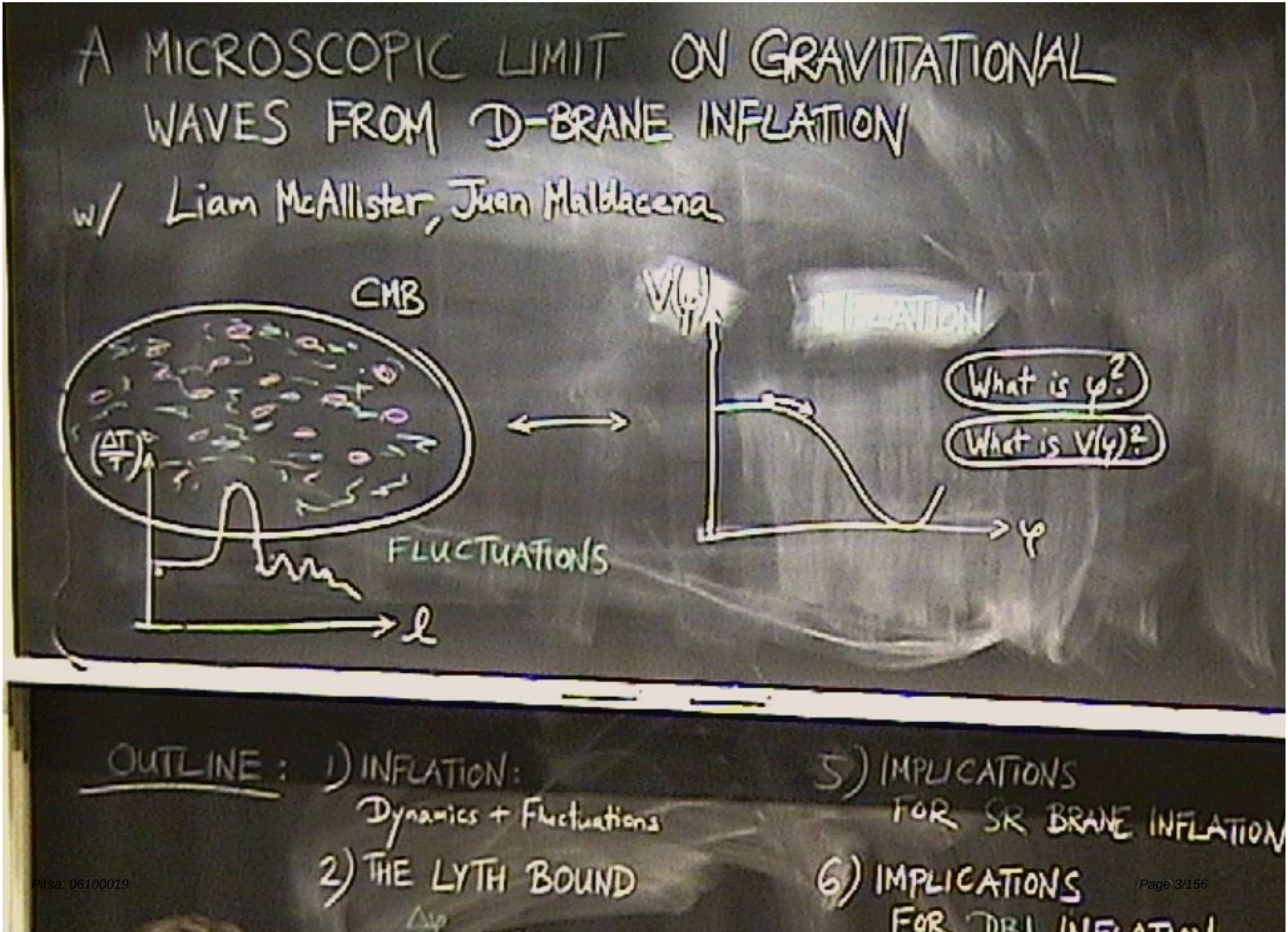
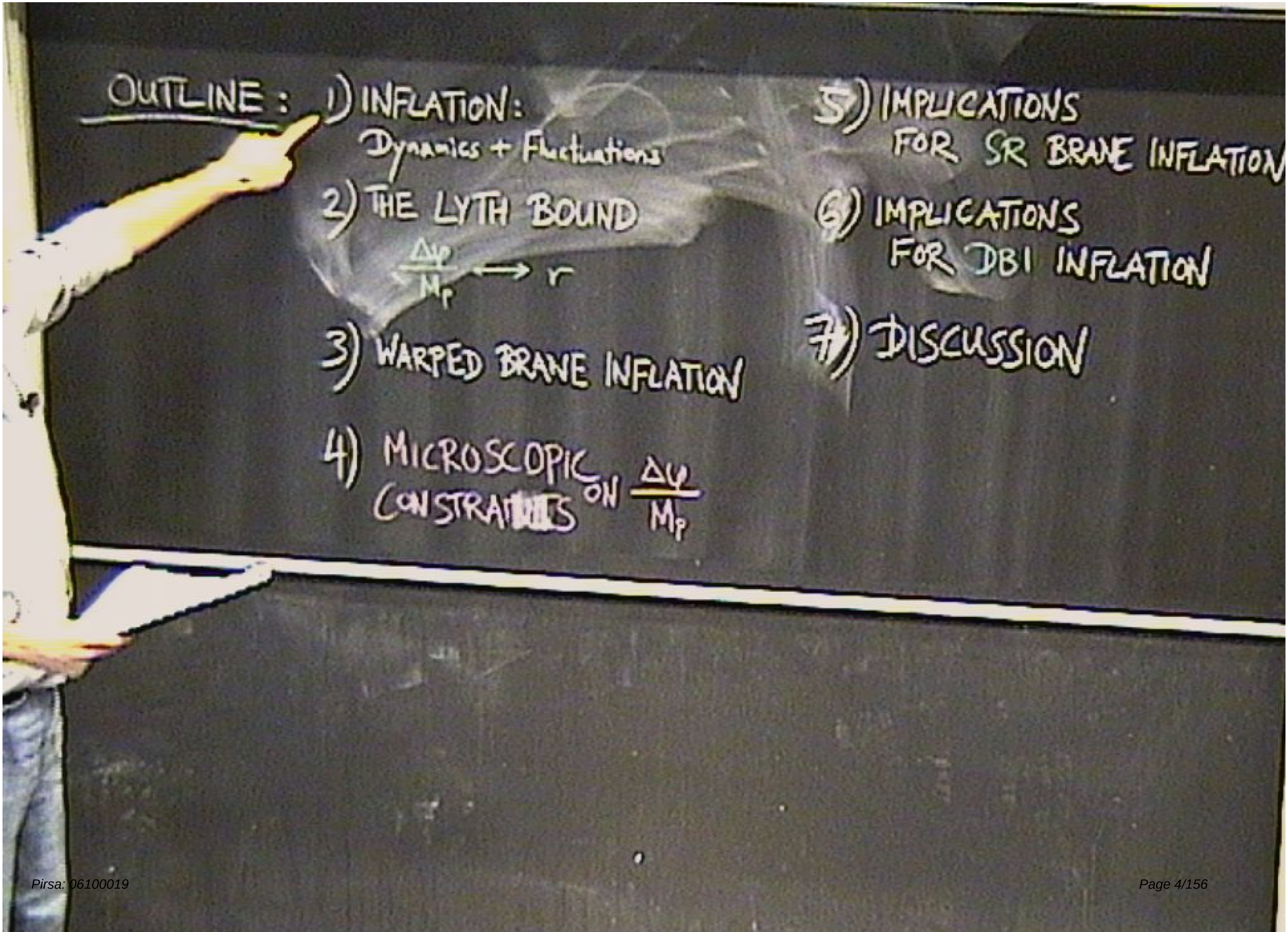
Abstract: TBA


FLUCTUATIONS
OUTLINE :
1) INFLATION:
Dynamics + Fluctuations
2) THE LYTH BOUND
$\frac{\Delta\varphi}{M_p} \longleftrightarrow r$
3) WARPED BRANE INFLATION
4) MICROSCOPIC CONSTRAINTS ON $\frac{\Delta\varphi}{M_p}$
5) IMPLICATIONS FOR SR BRANE INFLATION
6) IMPLICATIONS FOR DBI INFLATION
7) DISCUSSION


A MICROSCOPIC LIMIT ON GRAVITATIONAL WAVES FROM D-BRANE INFLATION
w/ Liam McAllister, Juan Maldacena
CMB
FLUCTUATIONS
ℓ
V(φ)
INFLATION
What is φ?
What is V(φ)?
φ
OUTLINE:
1) INFLATION: Dynamics + Fluctuations
2) THE LYTH BOUND
5) IMPLICATIONS FOR SR BRANE INFLATION
6) IMPLICATIONS FOR DBI INFLATION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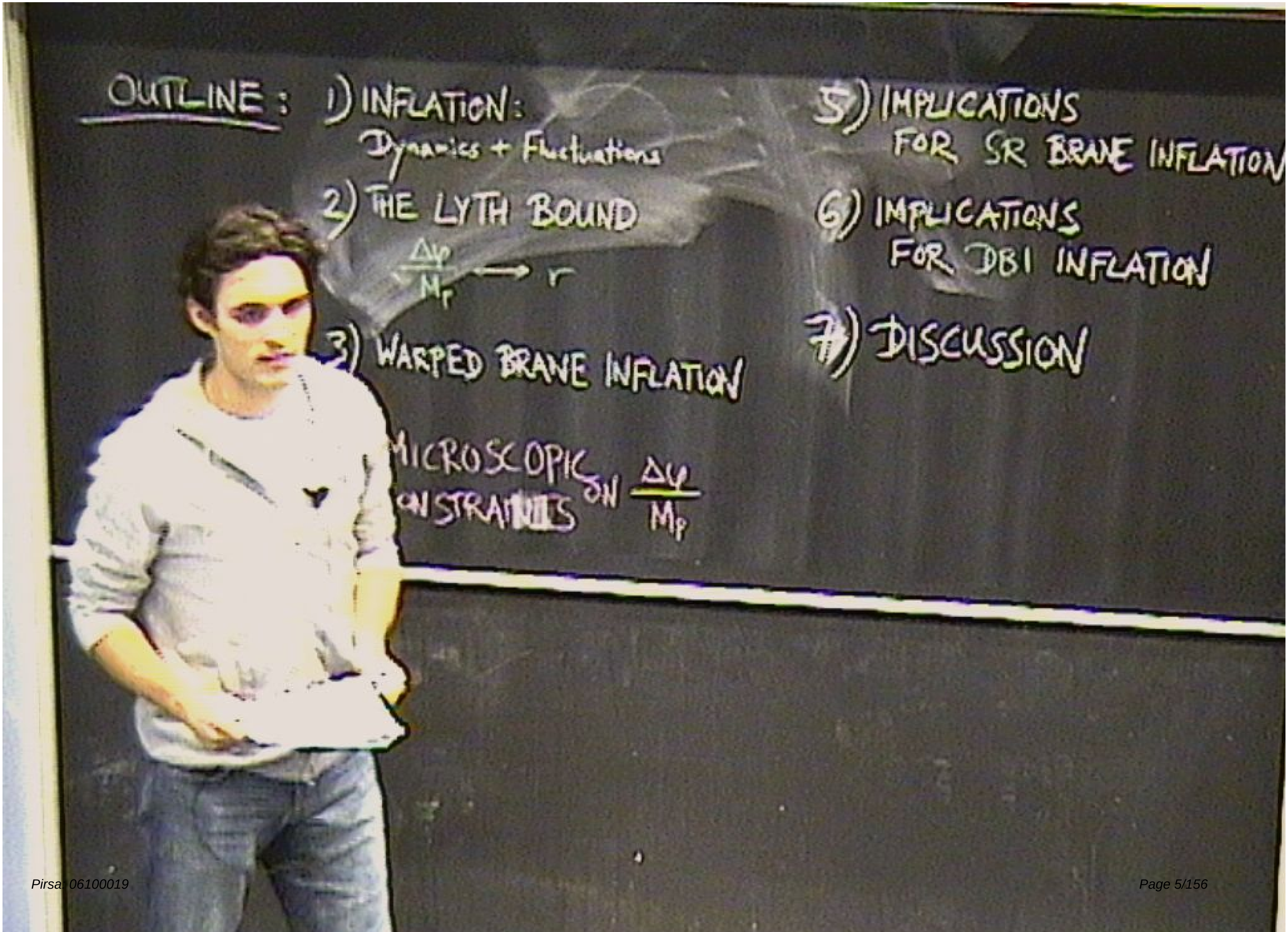
OUTLINE:
1) INFLATION:
Dynamics + Fluctuations
2) THE LYTH BOUND
Δφ/Mp ⟷ r
3) WARPED BRANE INFLATION
MICROSCOPIC CONSTRAINTS ON Δφ/Mp
5) IMPLICATIONS FOR SR BRANE INFLATION
6) IMPLICATIONS FOR DBI INFLATION
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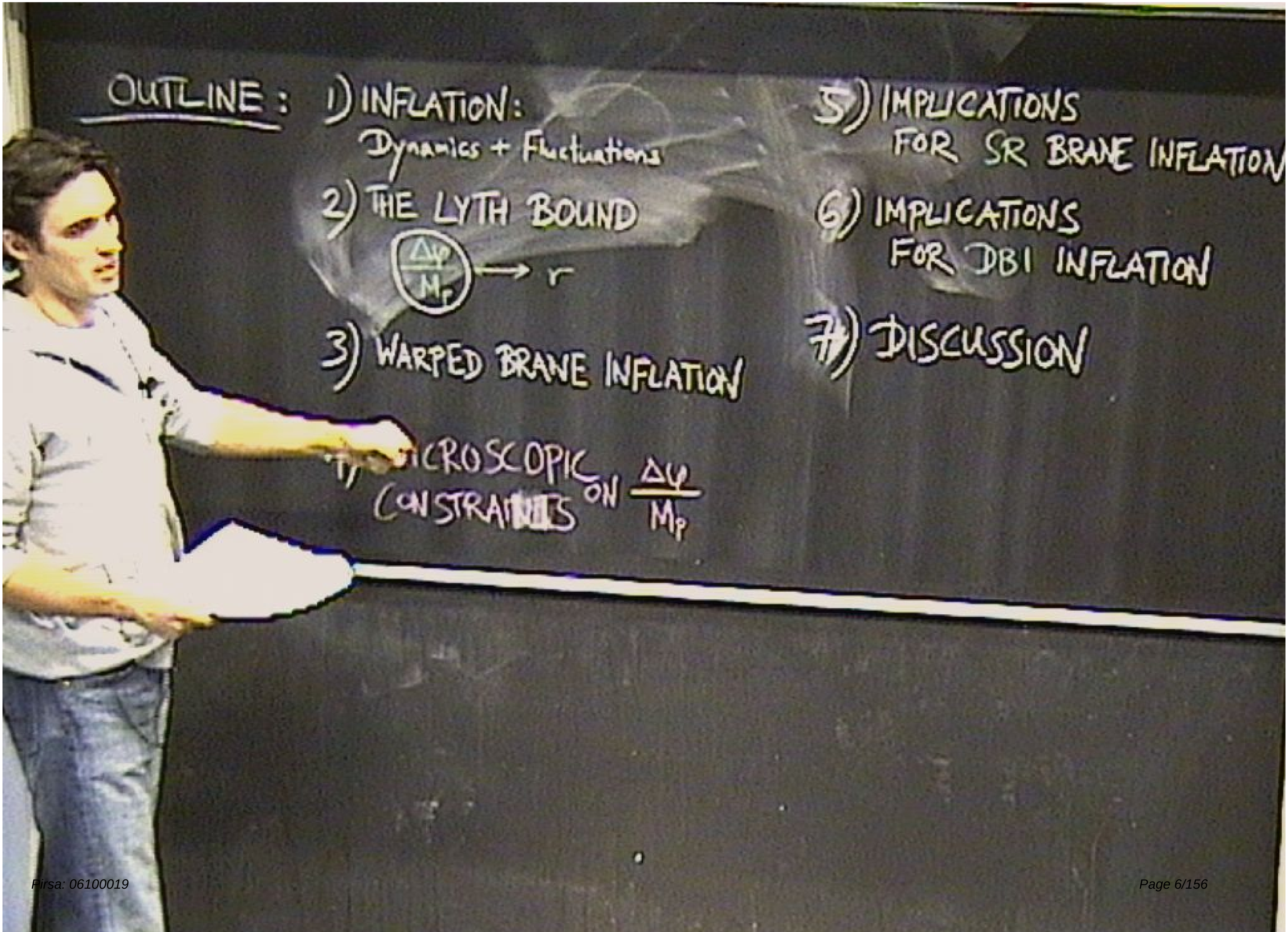
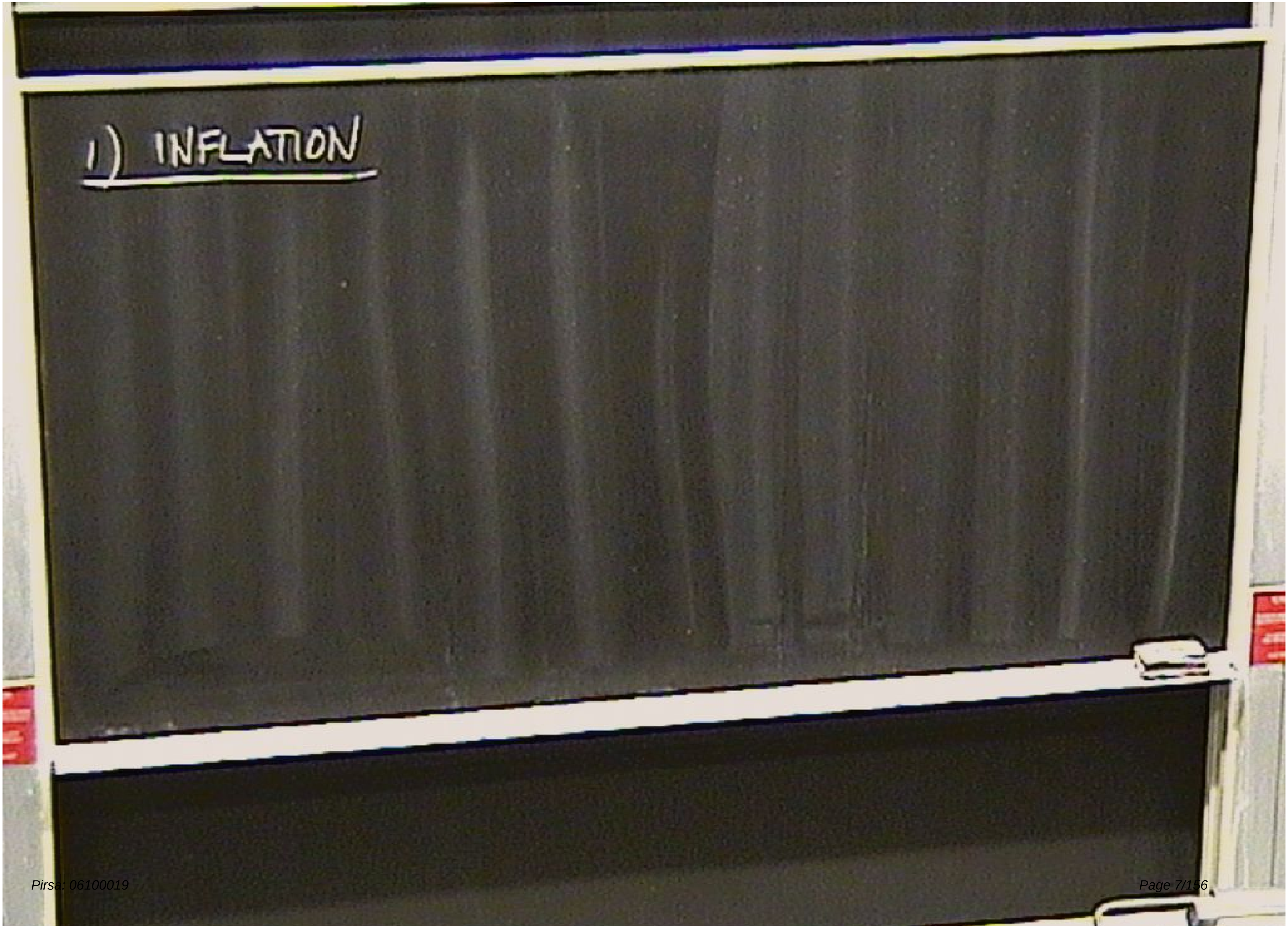
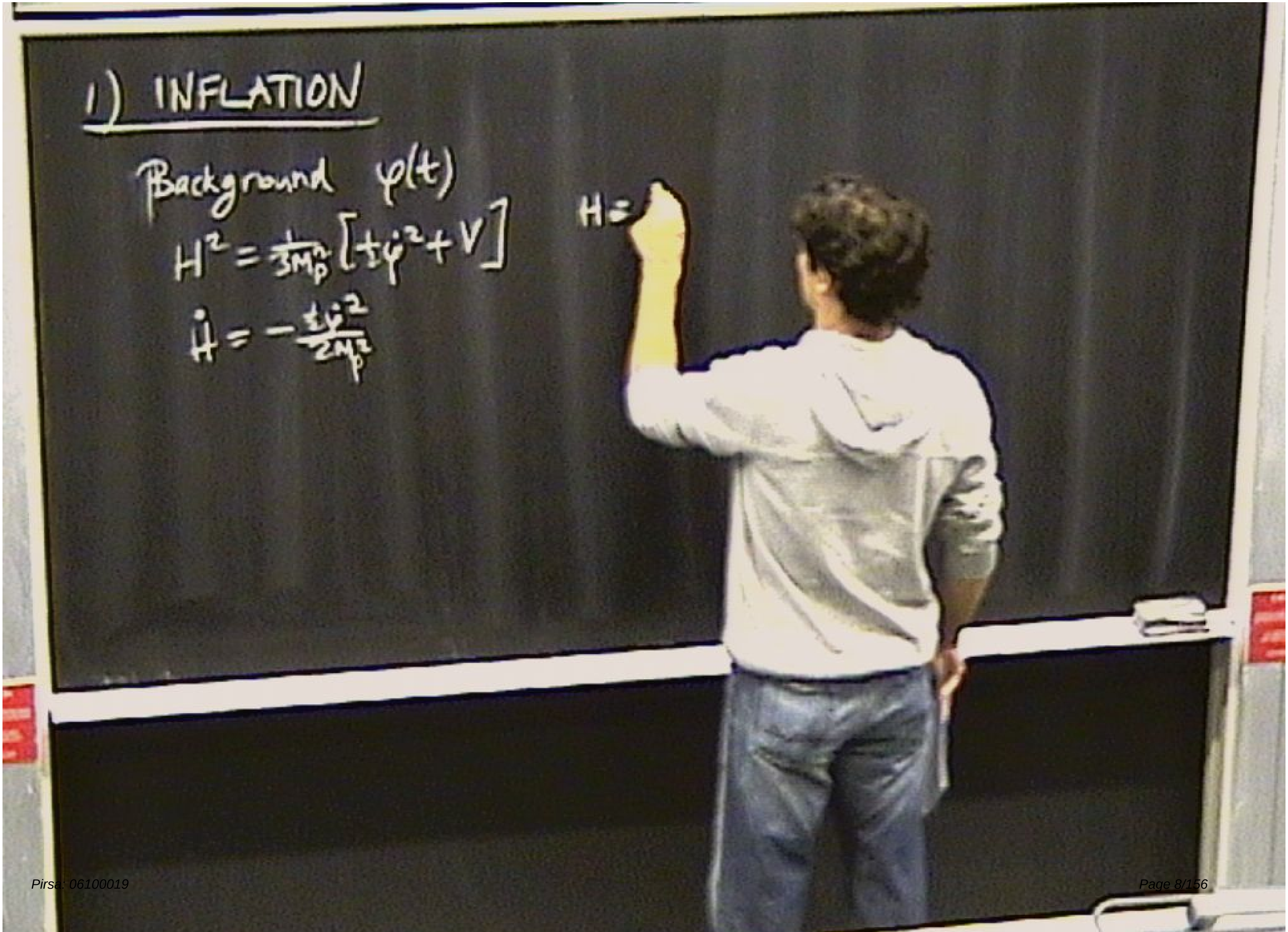
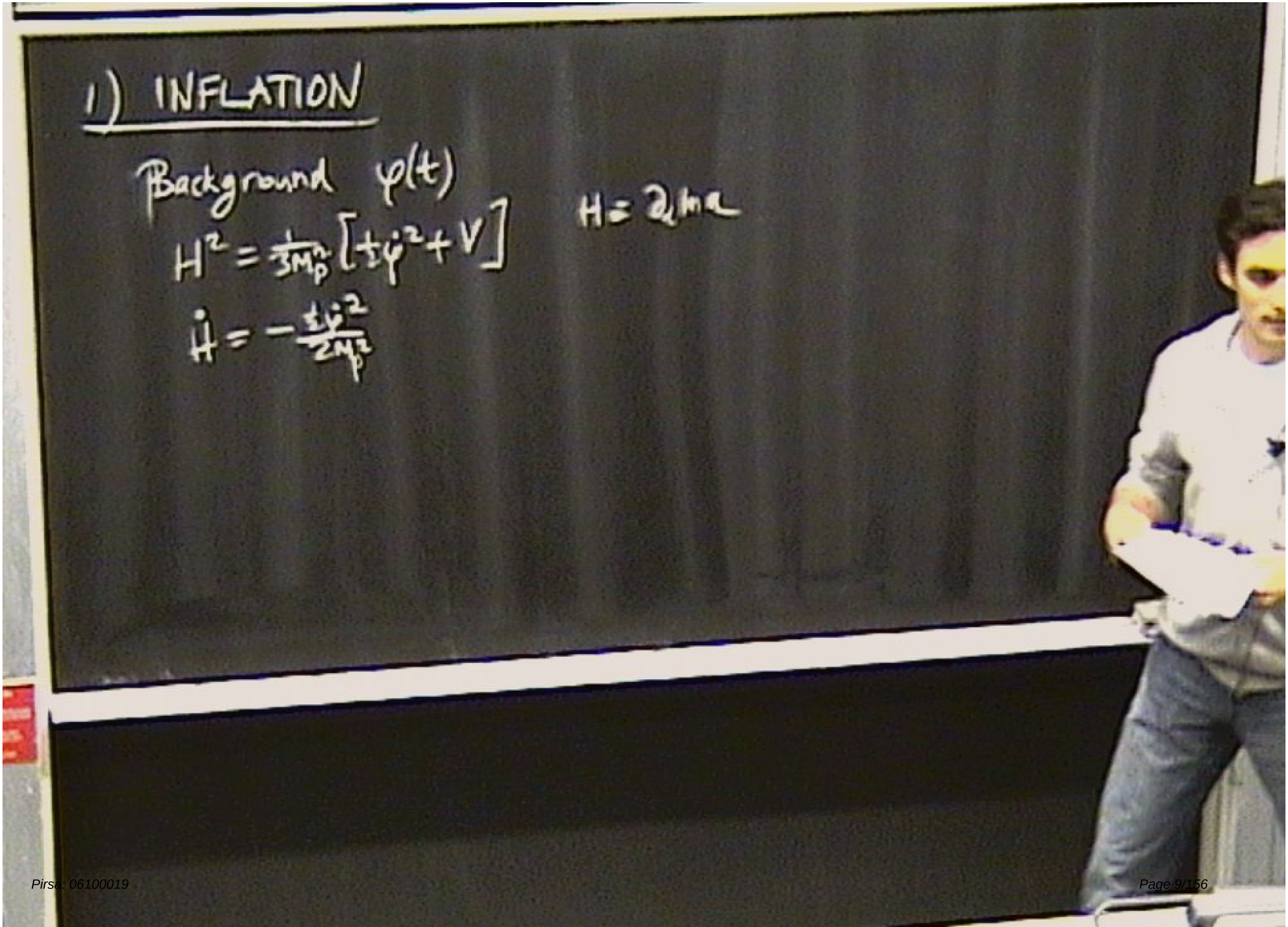

OUTLINE:
1) INFLATION:
Dynamics + Fluctuations
2) THE LYTH BOUND
Δφ / Mp → r
3) WARPED BRANE INFLATION
ICROSCOPIC
CONSTRAINTS ON Δφ / Mp
5) IMPLICATIONS
FOR SR BRANE INFLATION
6) IMPLICATIONS
FOR DBI INFLATION
7) DISCUSSION


1) INFLATION


1) INFLATION
Background φ(t)
H² = 1/3Mp² [½φ̇² + V]
Ḣ = −½φ̇²/2Mp²
H =


1) INFLATION
Background $\varphi(t)$
$H^2 = \frac{1}{3M_p^2}\left[\frac{1}{2}\dot{\varphi}^2 + V\right]$
$H = \partial_t \ln a$
$\dot{H} = -\frac{\frac{1}{2}\dot{\varphi}^2}{2M_p^2}$

1) INFLATION

Background $\varphi(t)$

$$H^2 = \frac{1}{3M_p^2}\left[\frac{1}{2}\dot\varphi^2 + V\right] \qquad H = \partial_t \ln a$$

$$\dot H = -\frac{\frac{1}{2}\dot\varphi^2}{2M_p^2}$$

$$\frac{\ddot a}{a} = H^2(1-\varepsilon)$$

$$\varepsilon \equiv -\frac{\dot H}{H^2} = \frac{1}{2M_p^2}\left(\frac{d\varphi}{dN_e}\right)^2 \qquad dN_e = H\,dt$$

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$$\eta \equiv \frac{\dot{\varepsilon}}{\varepsilon H} \equiv \frac{d\ln\varepsilon}{dN_e}$$

1) INFLATION

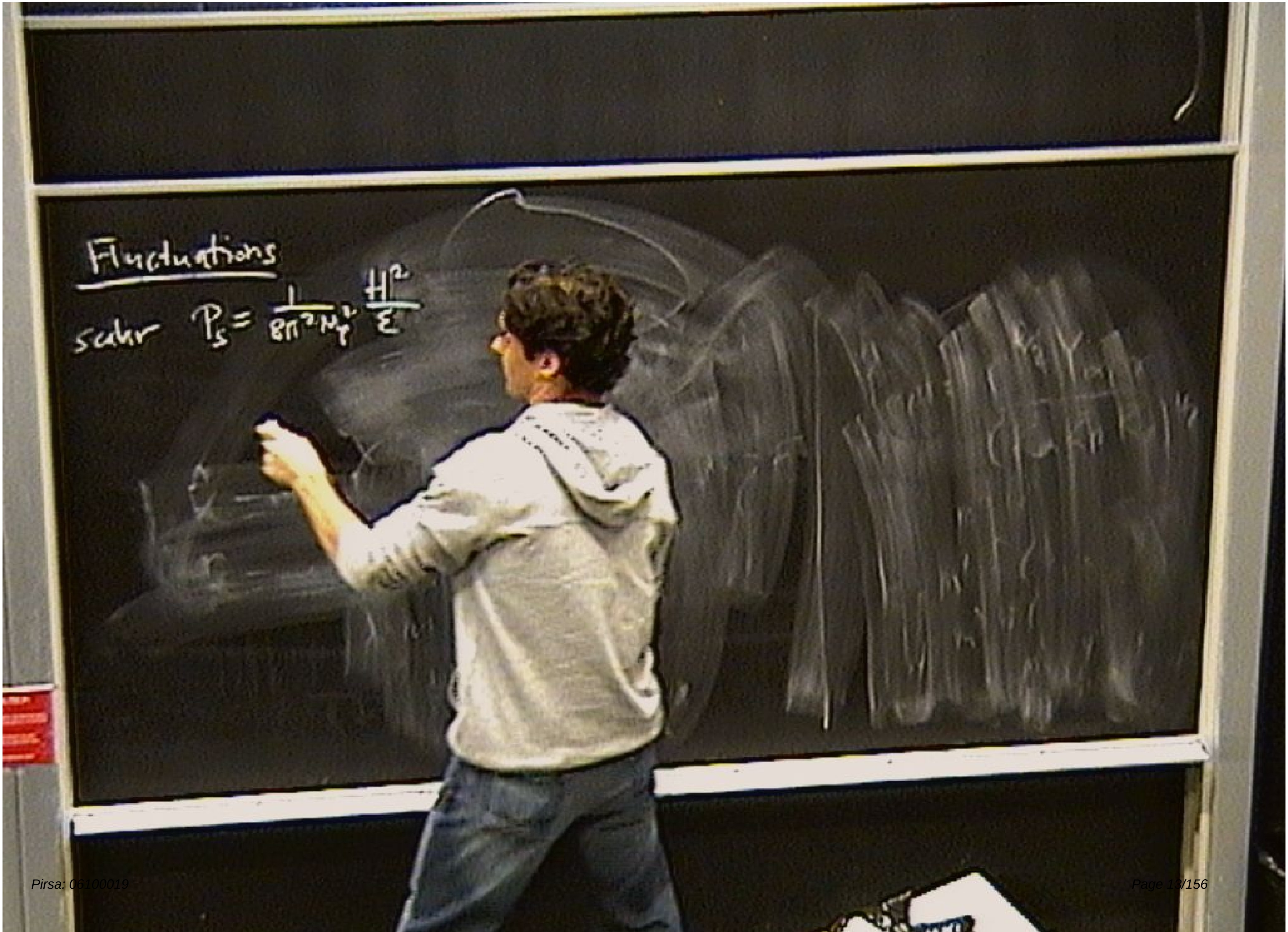
Background $\varphi(t)$

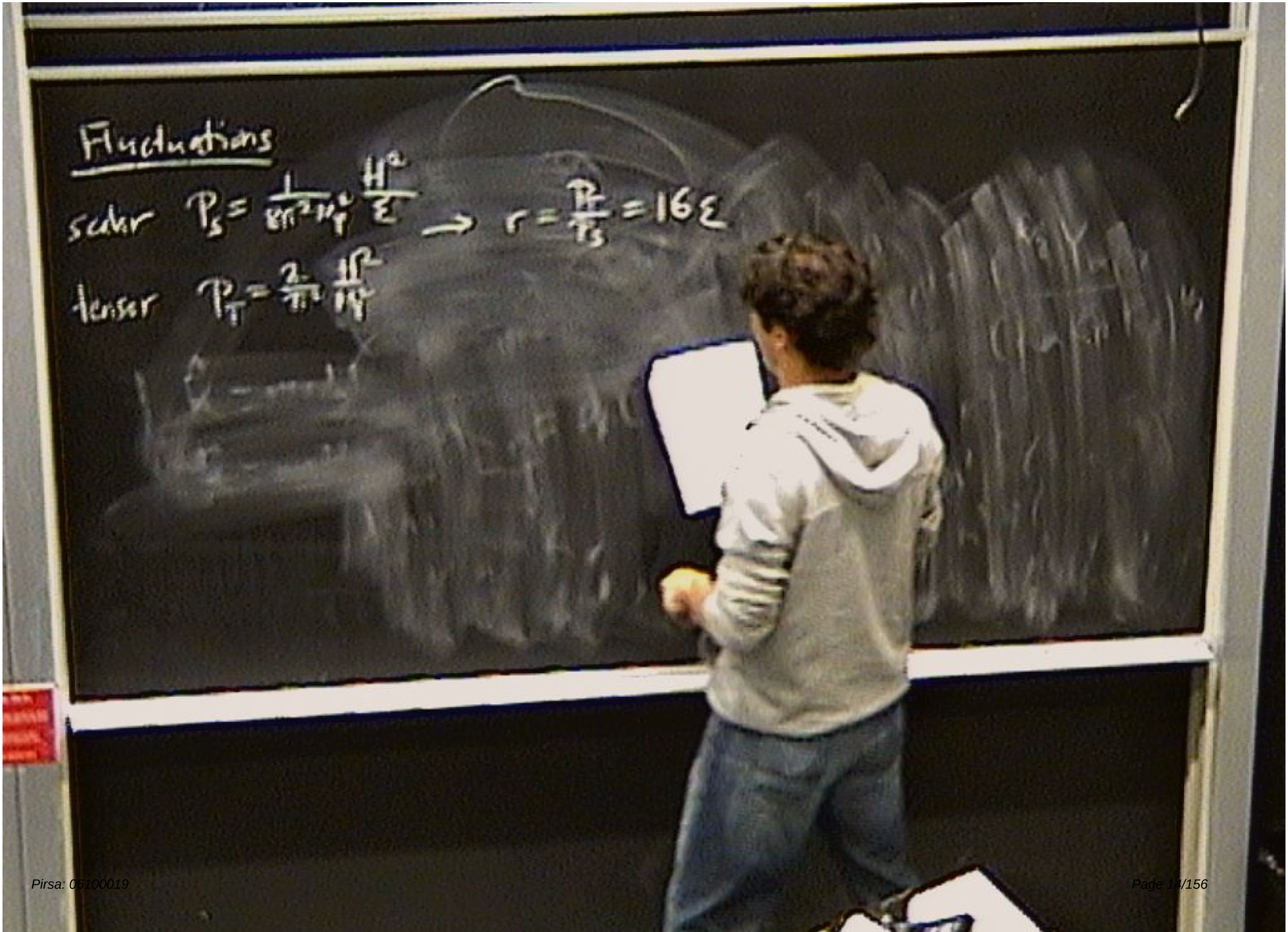
$$H^2 = \frac{1}{3M_p^2}\left[\frac{1}{2}\dot\varphi^2 + V\right] \qquad H = \partial_t \ln a$$

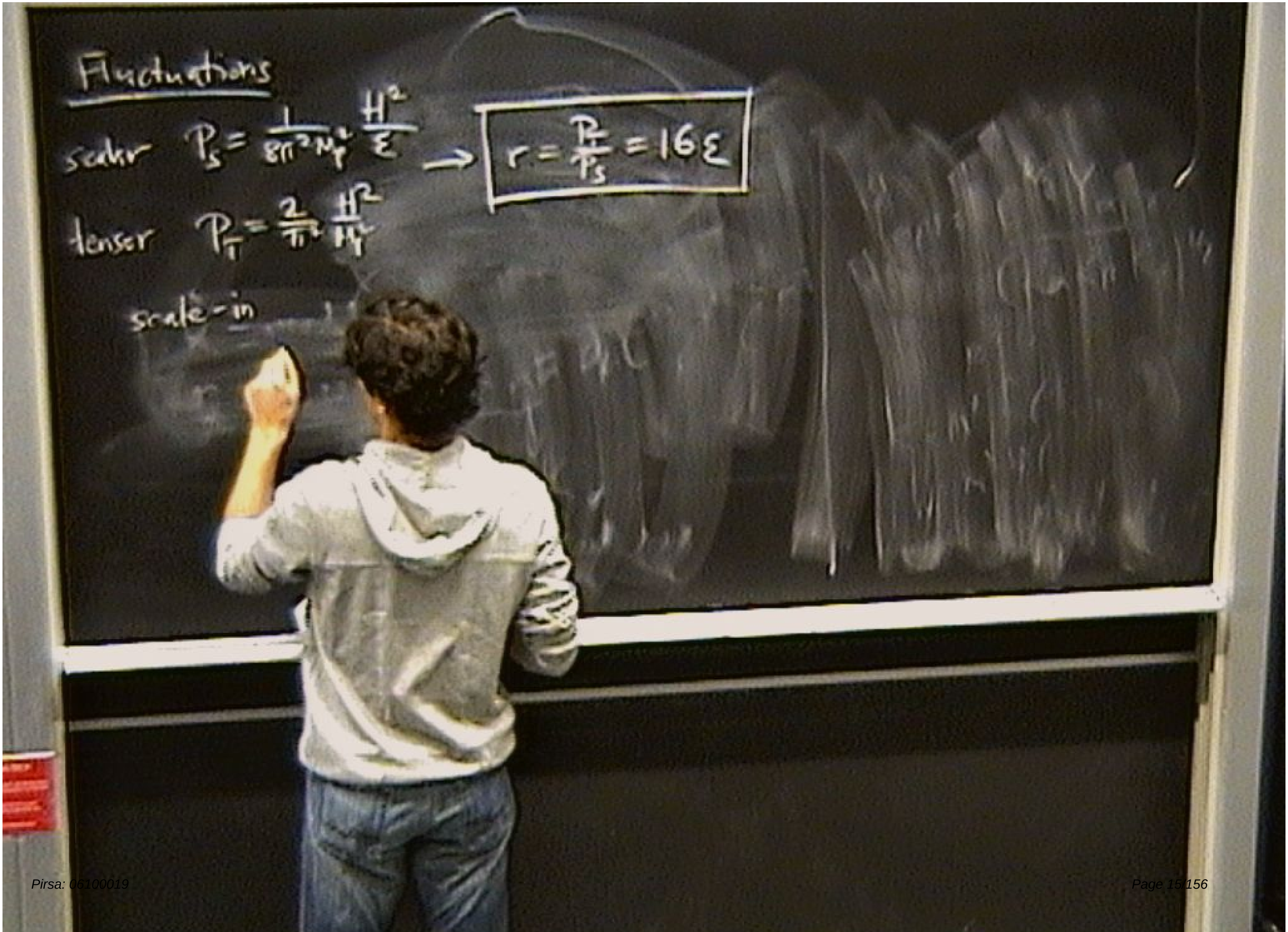
$$\dot H = -\frac{\frac{1}{2}\dot\varphi^2}{2M_p^2} \qquad \frac{\ddot a}{a} = H^2(1-\varepsilon)$$

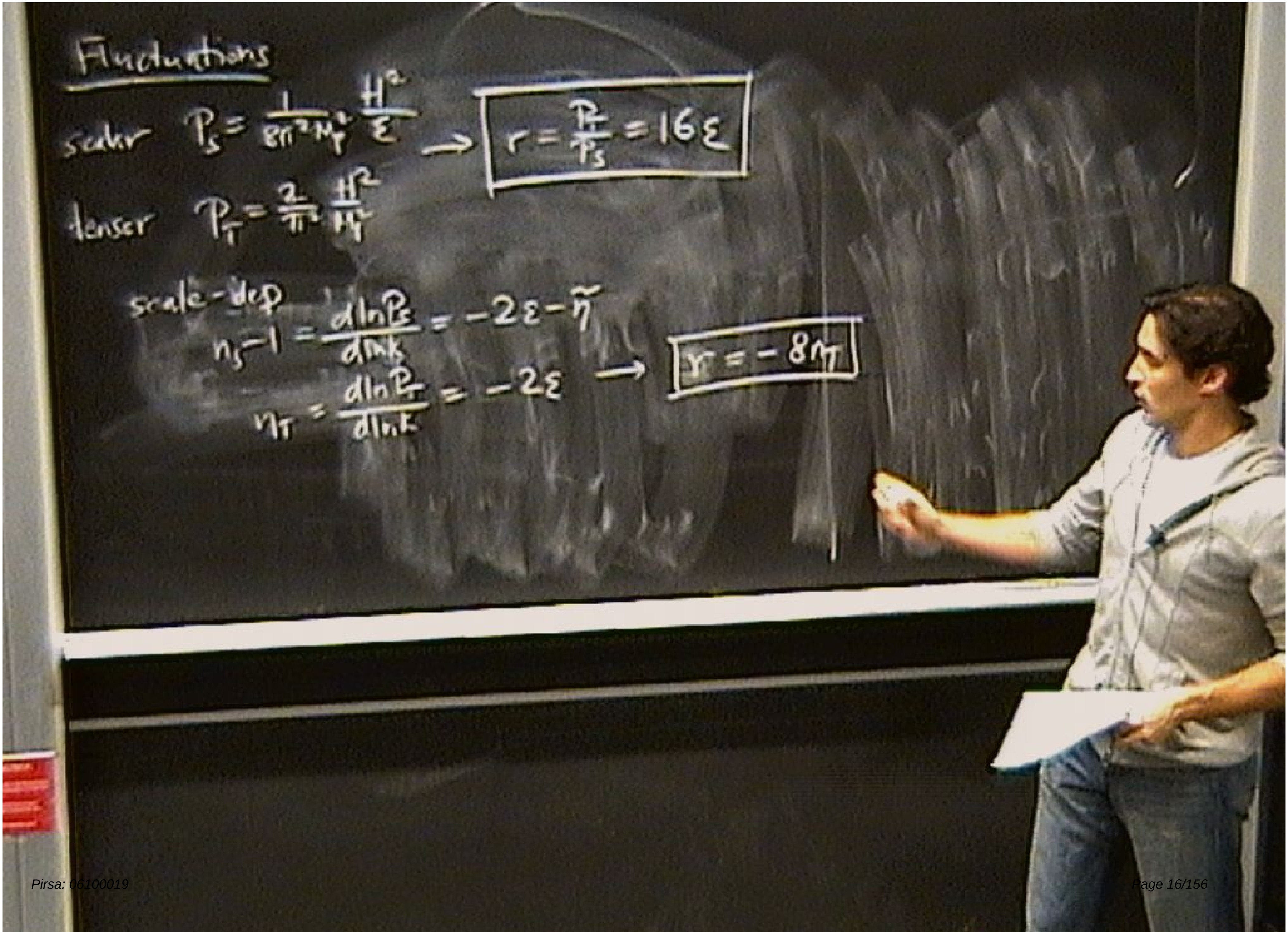
$$\varepsilon \equiv -\frac{\dot H}{H^2} = \frac{1}{2M_p^2}\left(\frac{d\varphi}{dN_e}\right)^2 \qquad dN_e = H\,dt$$

$$\eta \equiv \frac{\dot\varepsilon}{\varepsilon H} \equiv \frac{d\ln\varepsilon}{dN_e} = 2(\varepsilon - \eta_H)$$


Fluctuations
scalar $P_s = \frac{1}{8\pi^2 M_p^2} \frac{H^2}{\epsilon}$


Fluctuations
scalar $P_s = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\epsilon} \rightarrow r = \frac{P_T}{P_S} = 16\epsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$


Fluctuations
scalar $P_s = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\epsilon}$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
$r = \frac{P_T}{P_s} = 16\epsilon$
scale-in


Fluctuations
scalar $P_S = \frac{1}{8\pi^2 M_P^2}\frac{H^2}{\varepsilon}$ → $r = \frac{P_T}{P_S} = 16\varepsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_P^2}$
scale-dep
$n_S - 1 = \frac{d\ln P_S}{d\ln k} = -2\varepsilon - \tilde{\eta}$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon$ → $r = -8n_T$

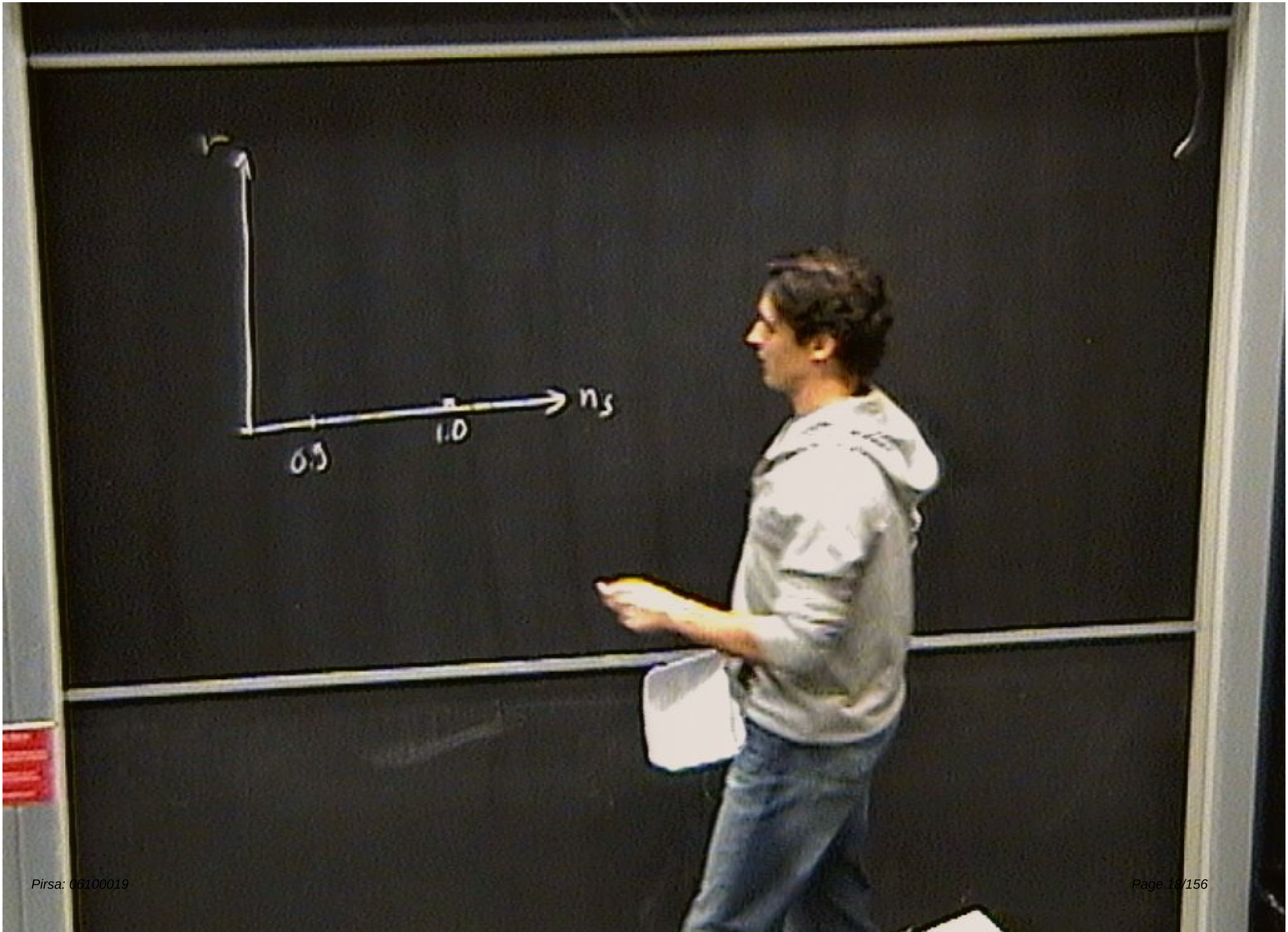
scalar $P_s = \frac{1}{8\pi^2 M_P^2}\frac{H^2}{\varepsilon}$ $\longrightarrow$ $r =$

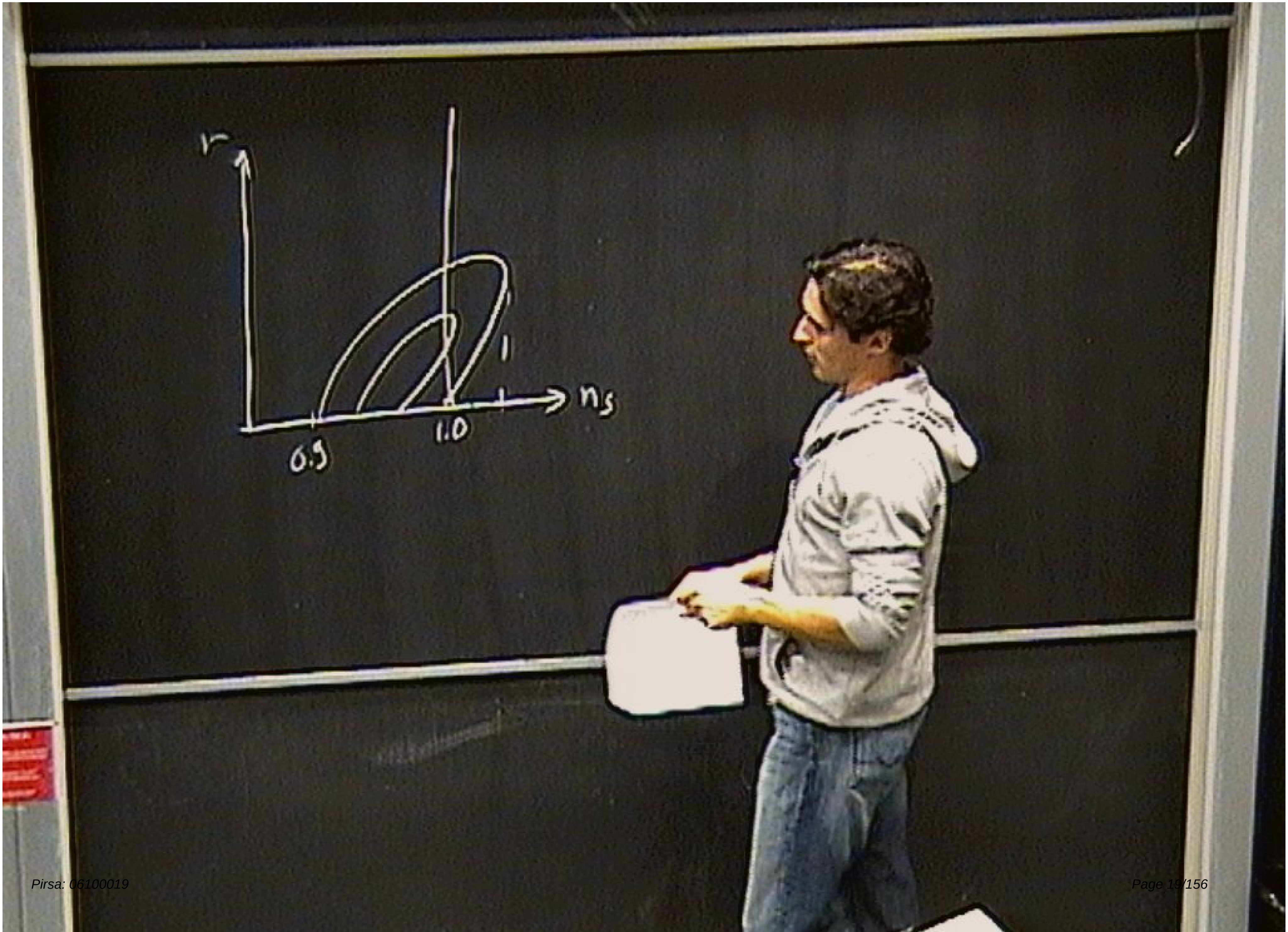
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_P^2}$

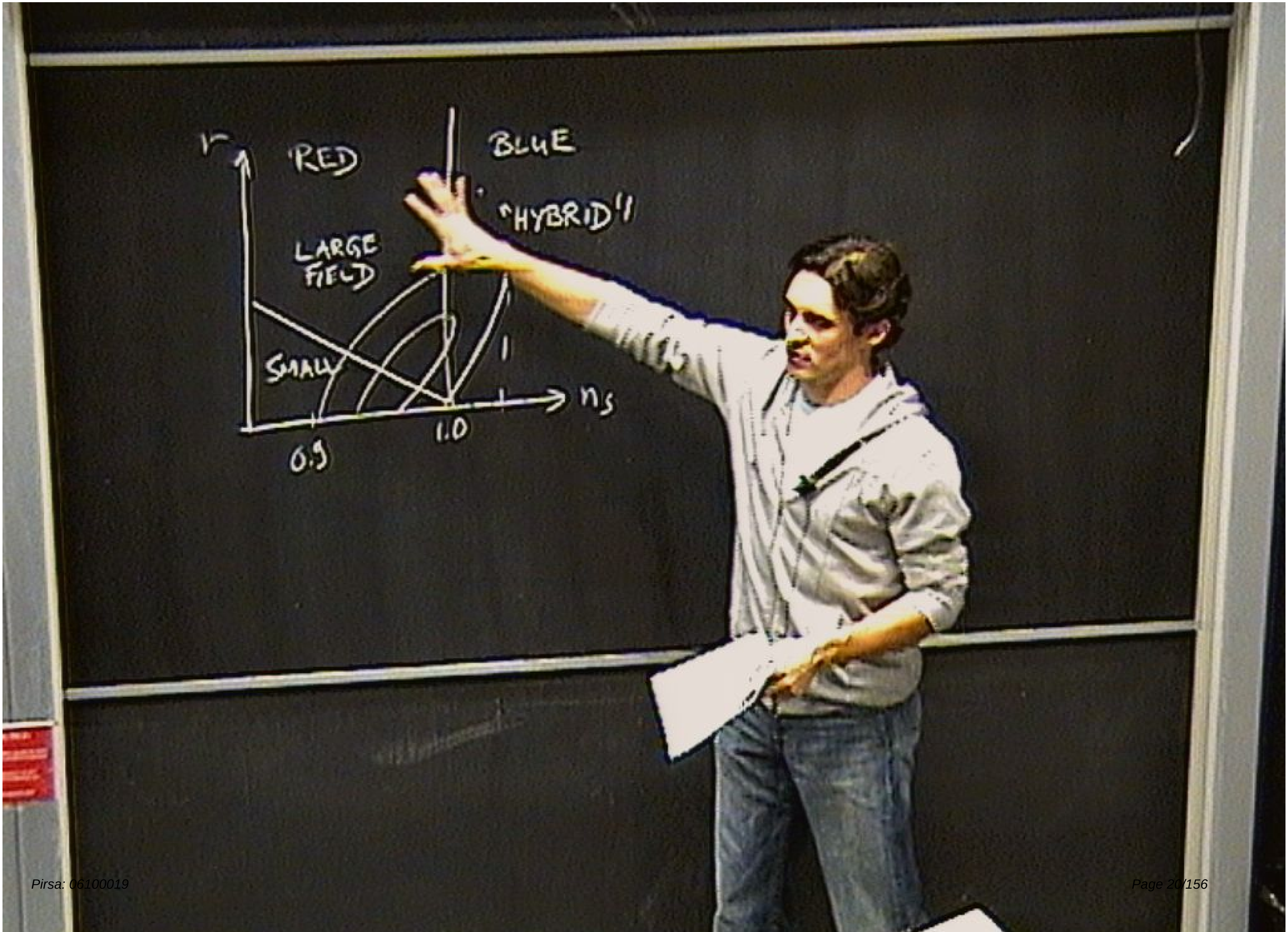
scale-dep

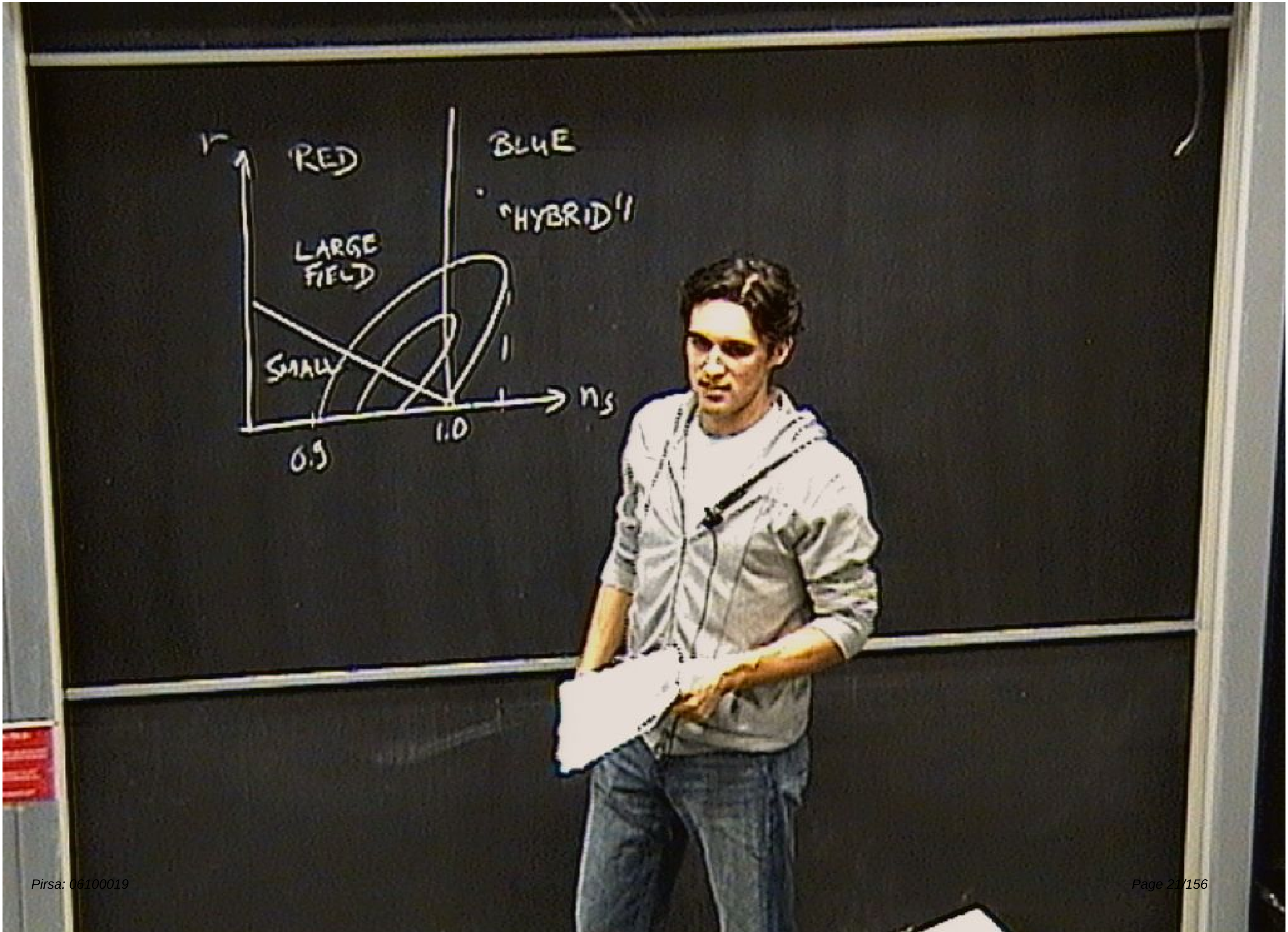
$$n_s - 1 = \frac{d\ln P_s}{d\ln k} = -2\varepsilon - \tilde{\eta}$$

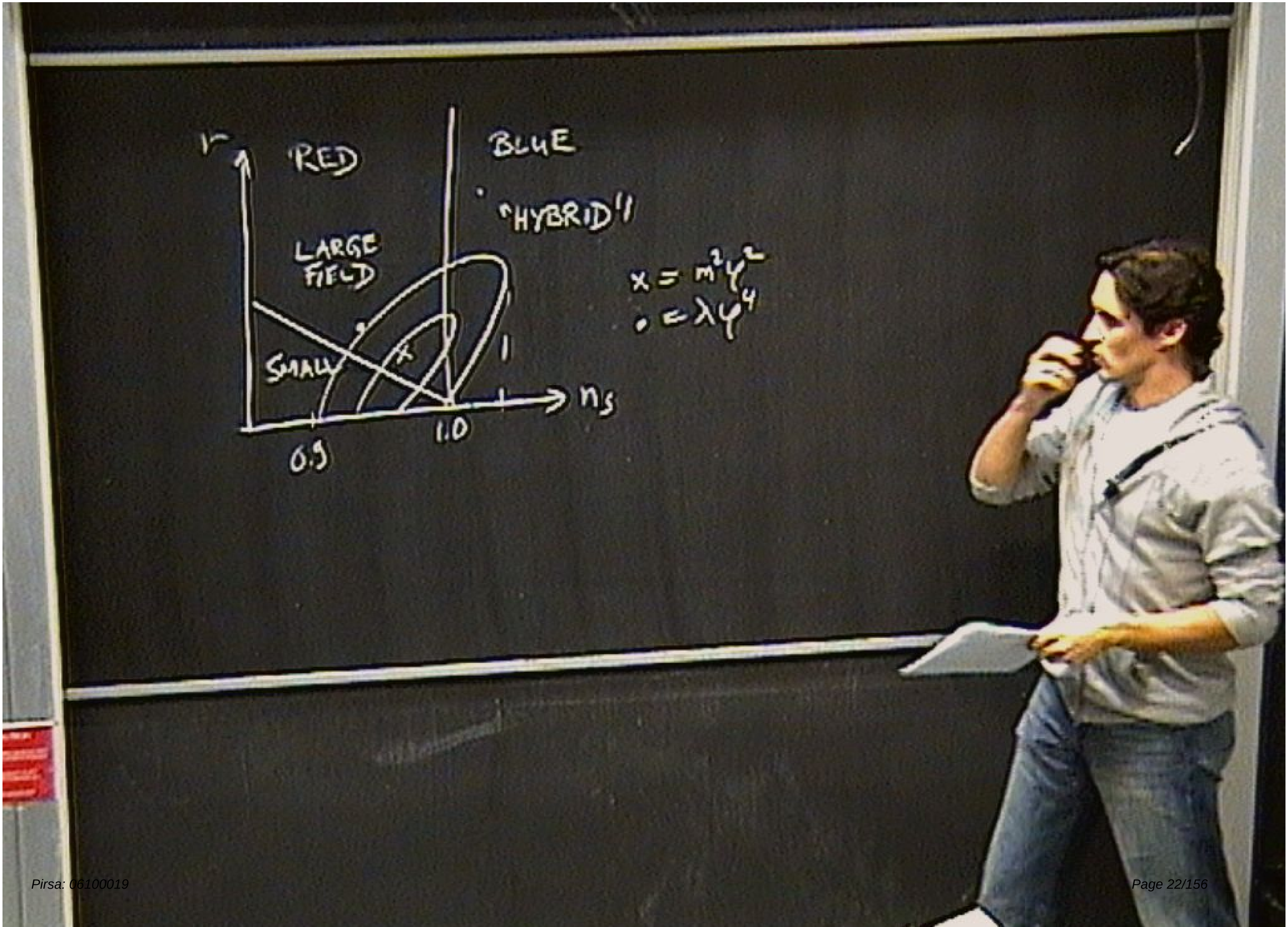
$$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon \longrightarrow \boxed{\;= -8n_T}$$

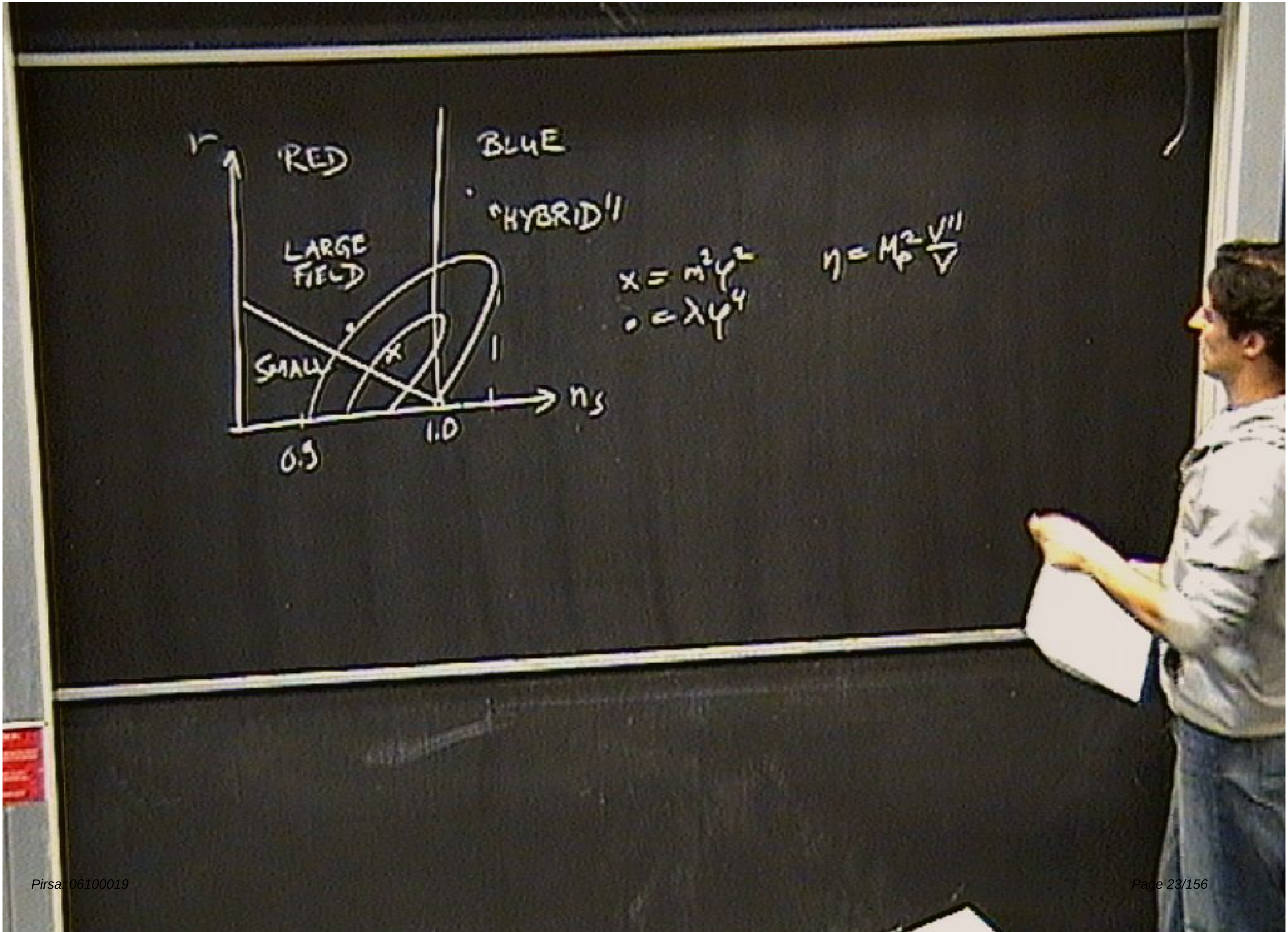

r
n_s
0.9
1.0


r
n_s
1
0.9
1.0

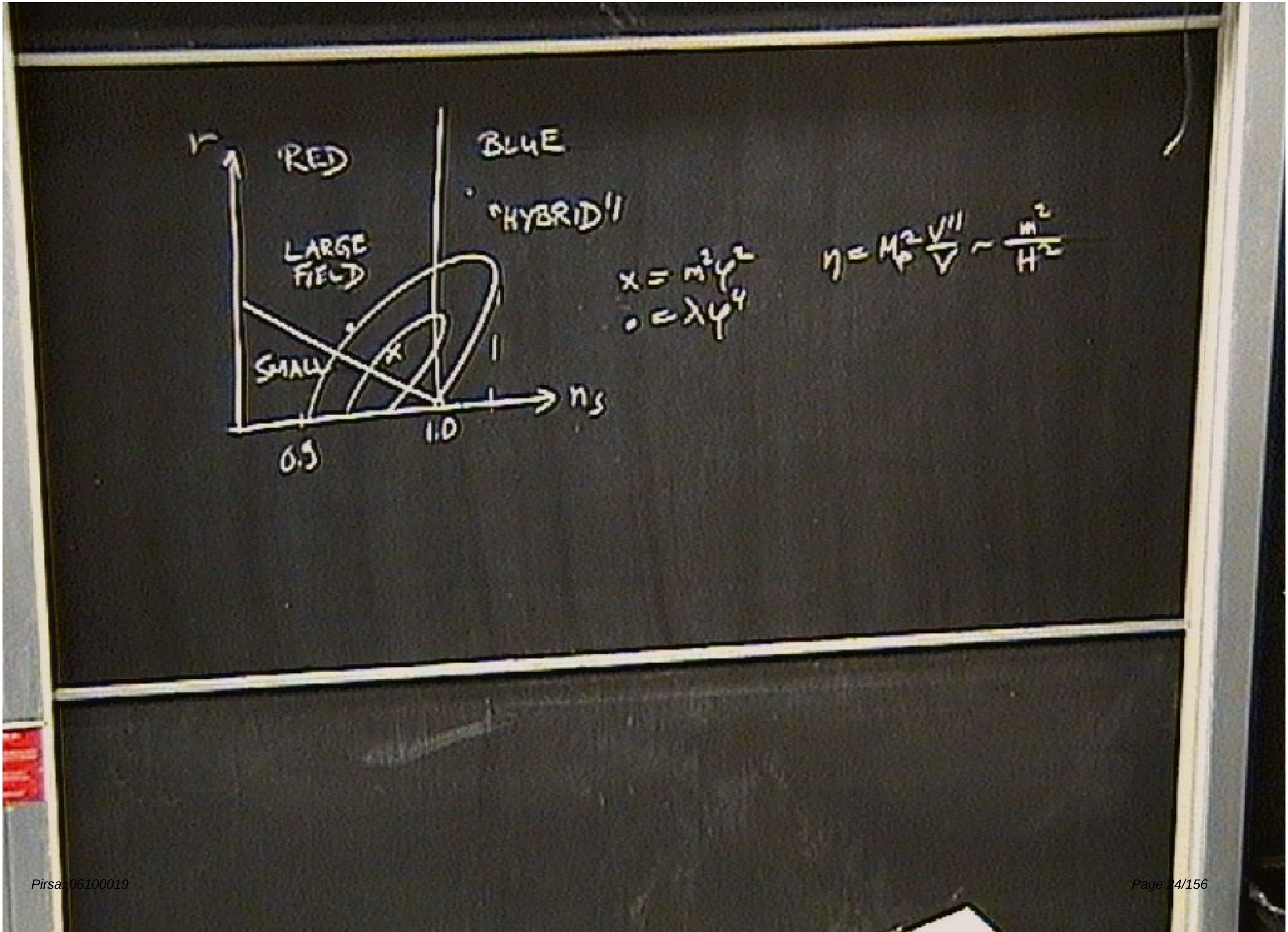

r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
1
n_s
0.9
1.0


r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
n_s
0.9
1.0

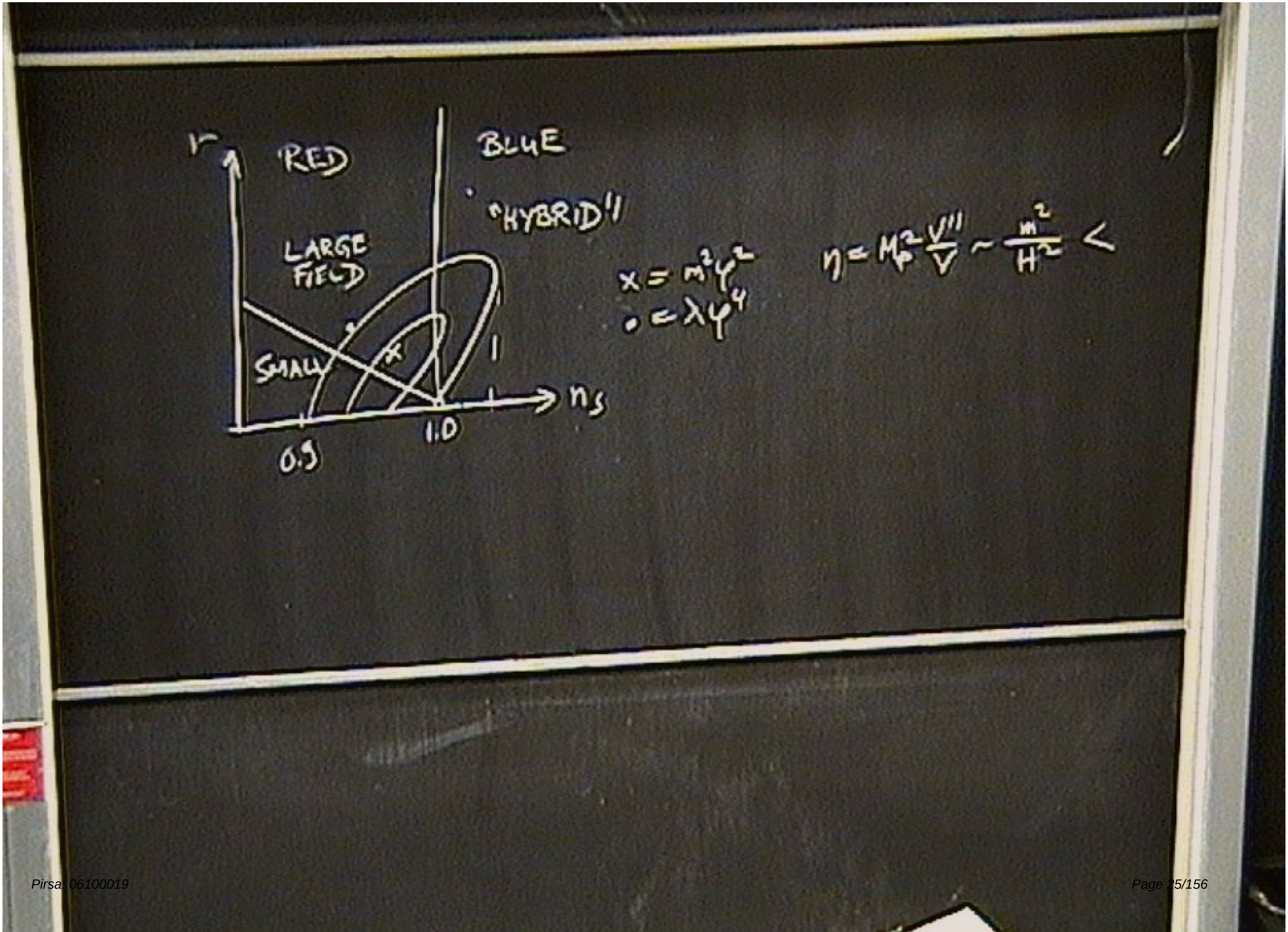

r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
x = m²φ²
• = λφ⁴
nₛ
0.9
1.0

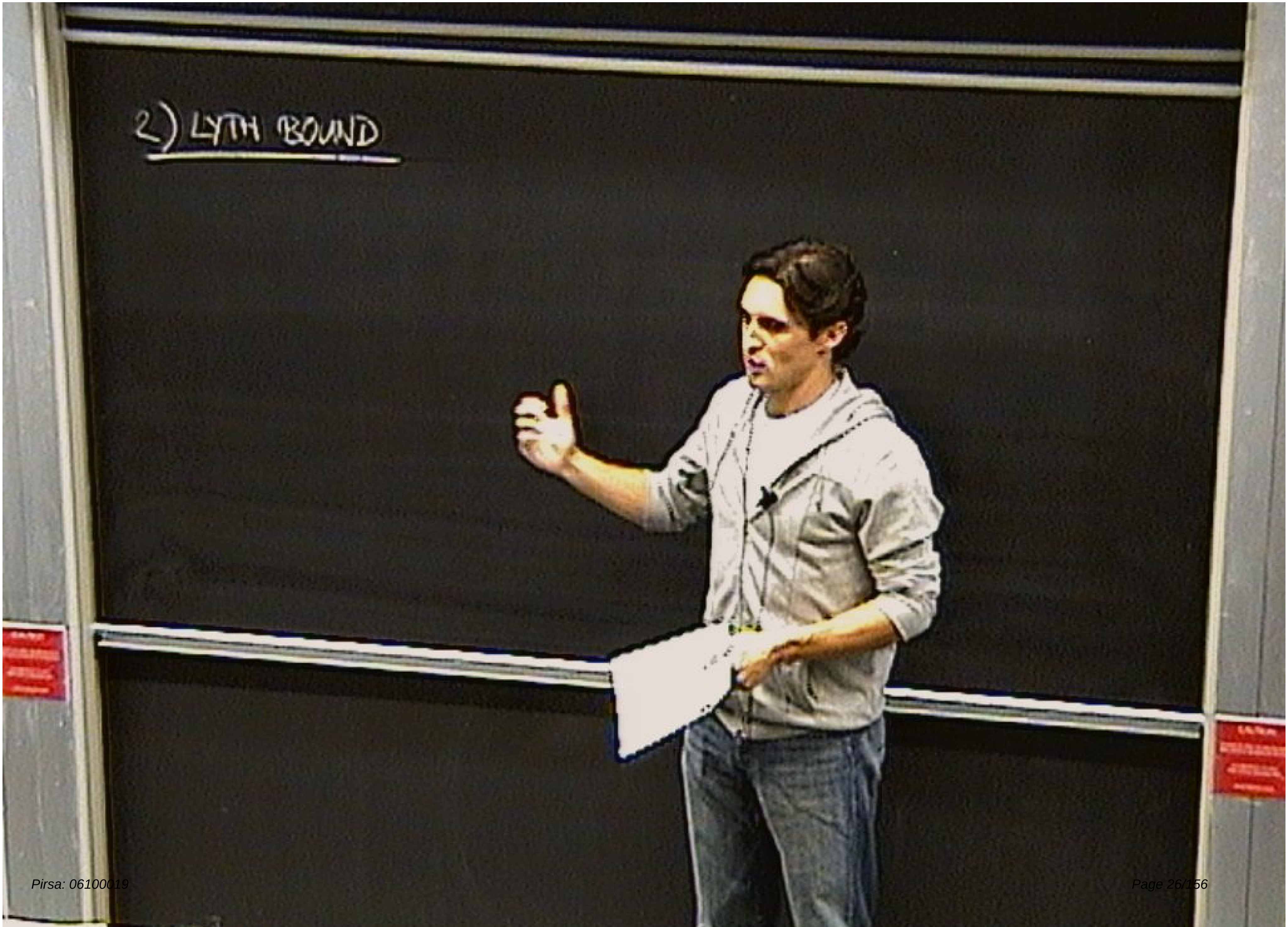


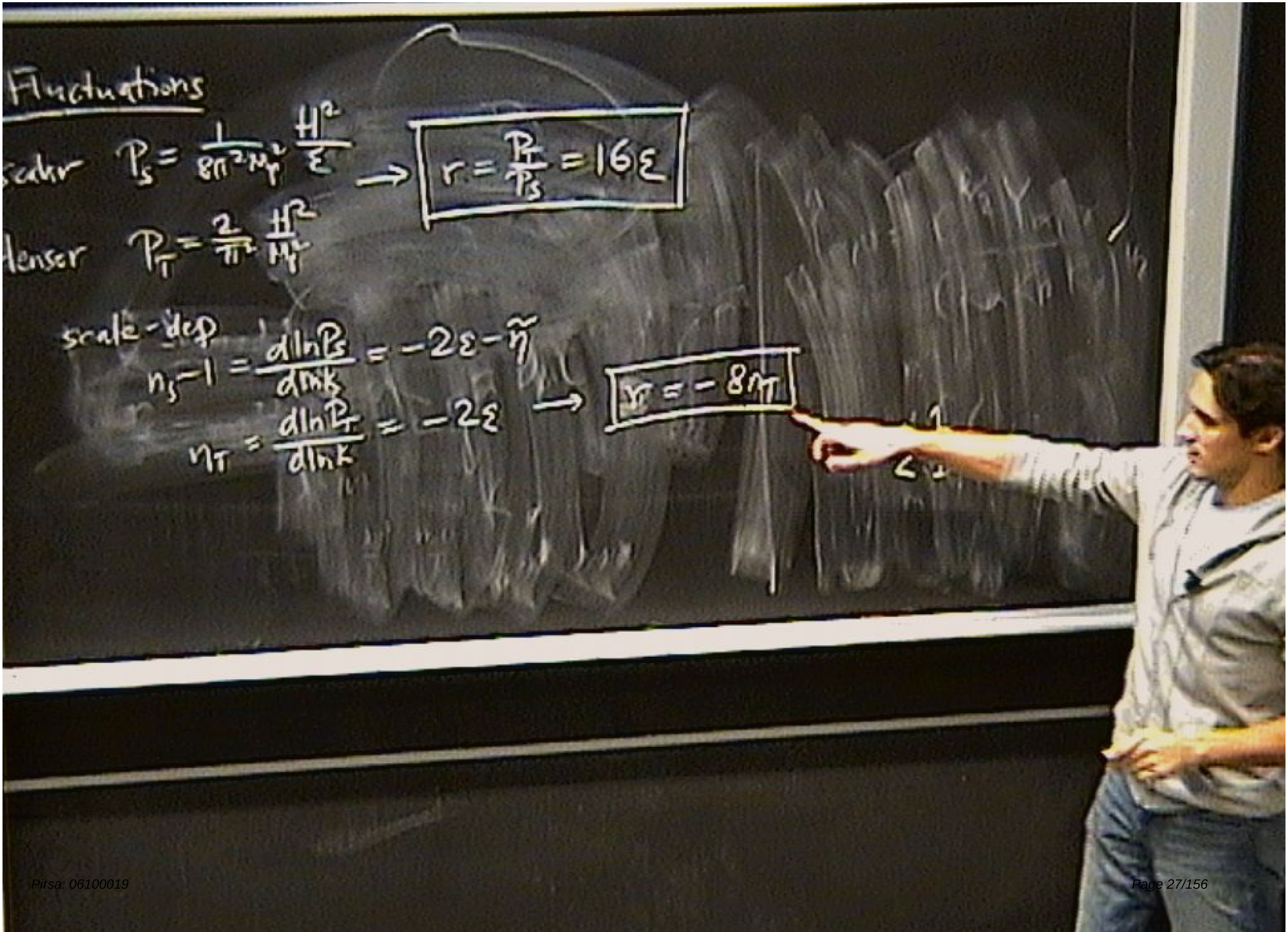
r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
1.0
0.9
n_s
$\times = m^2 \varphi^2$
$\bullet = \lambda \varphi^4$
$\eta = M_p^2 \frac{V''}{V}$



r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
n_s
0.9
1.0
1
$x = m^2\varphi^2$
$\bullet = \lambda\varphi^4$
$\eta = M_p^2 \frac{V''}{V} \sim \frac{m^2}{H^2}$


r
RED
BLUE
"HYBRID"
LARGE FIELD
SMALL
n_s
0.9
1.0
x = m²φ²
• = λφ⁴
η = M_p² V''/V ~ m²/H² <


2) LYTH BOUND


Fluctuations
$P_s = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\varepsilon}$
$r = \frac{P_T}{P_s} = 16\varepsilon$
$P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
scale-dep
$n_s - 1 = \frac{d\ln P_s}{d\ln k} = -2\varepsilon - \tilde{\eta}$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon$
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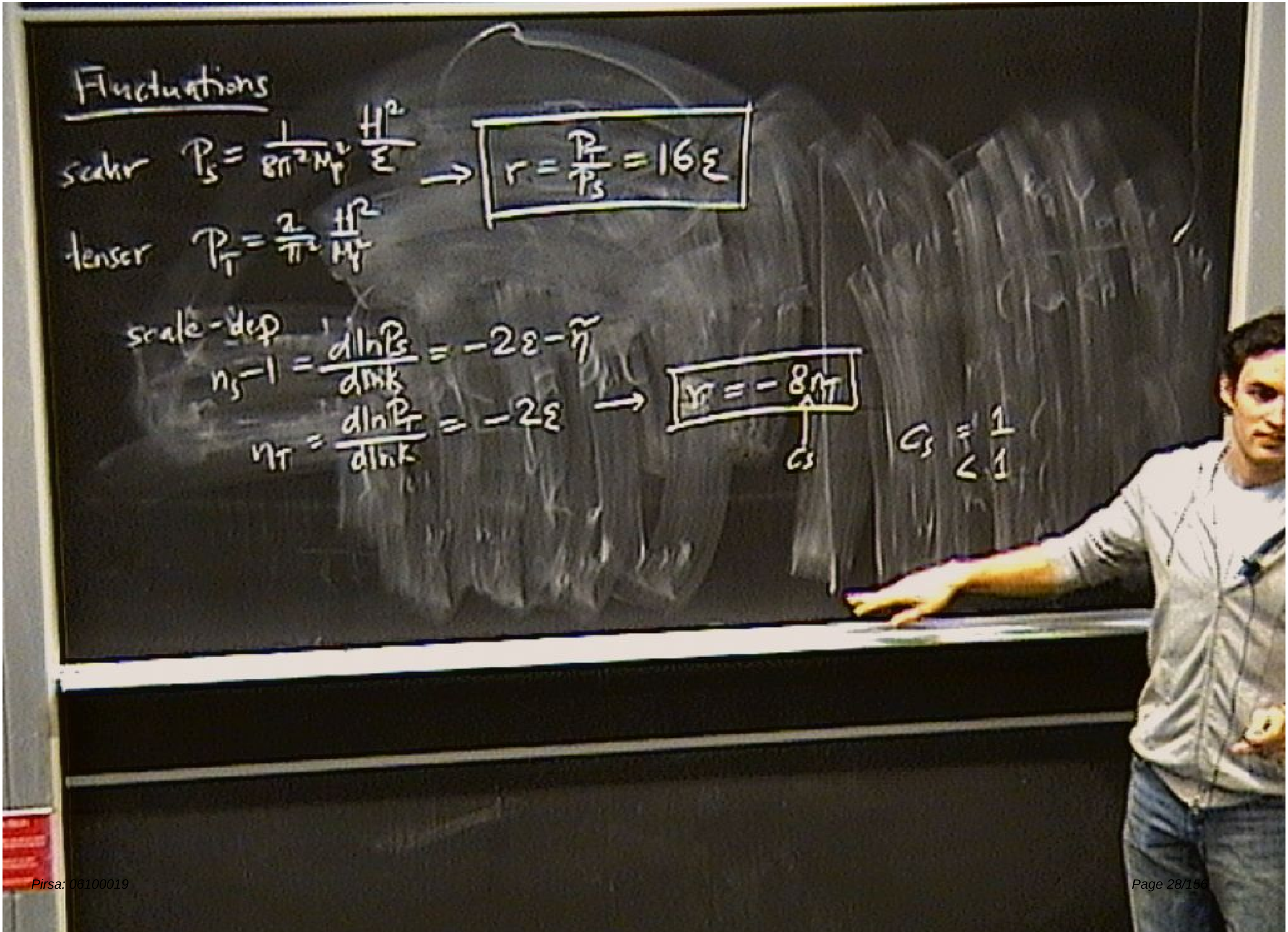
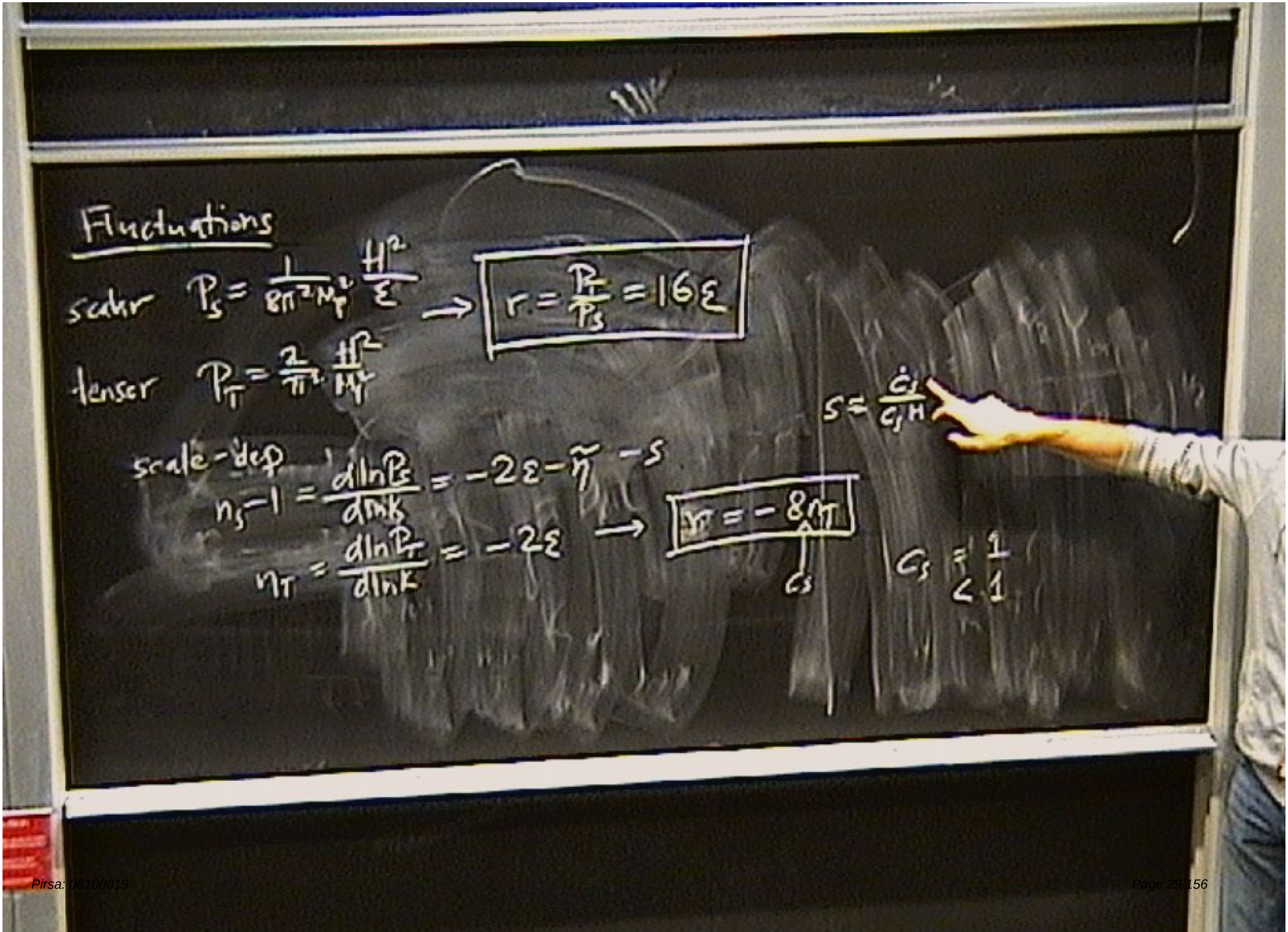
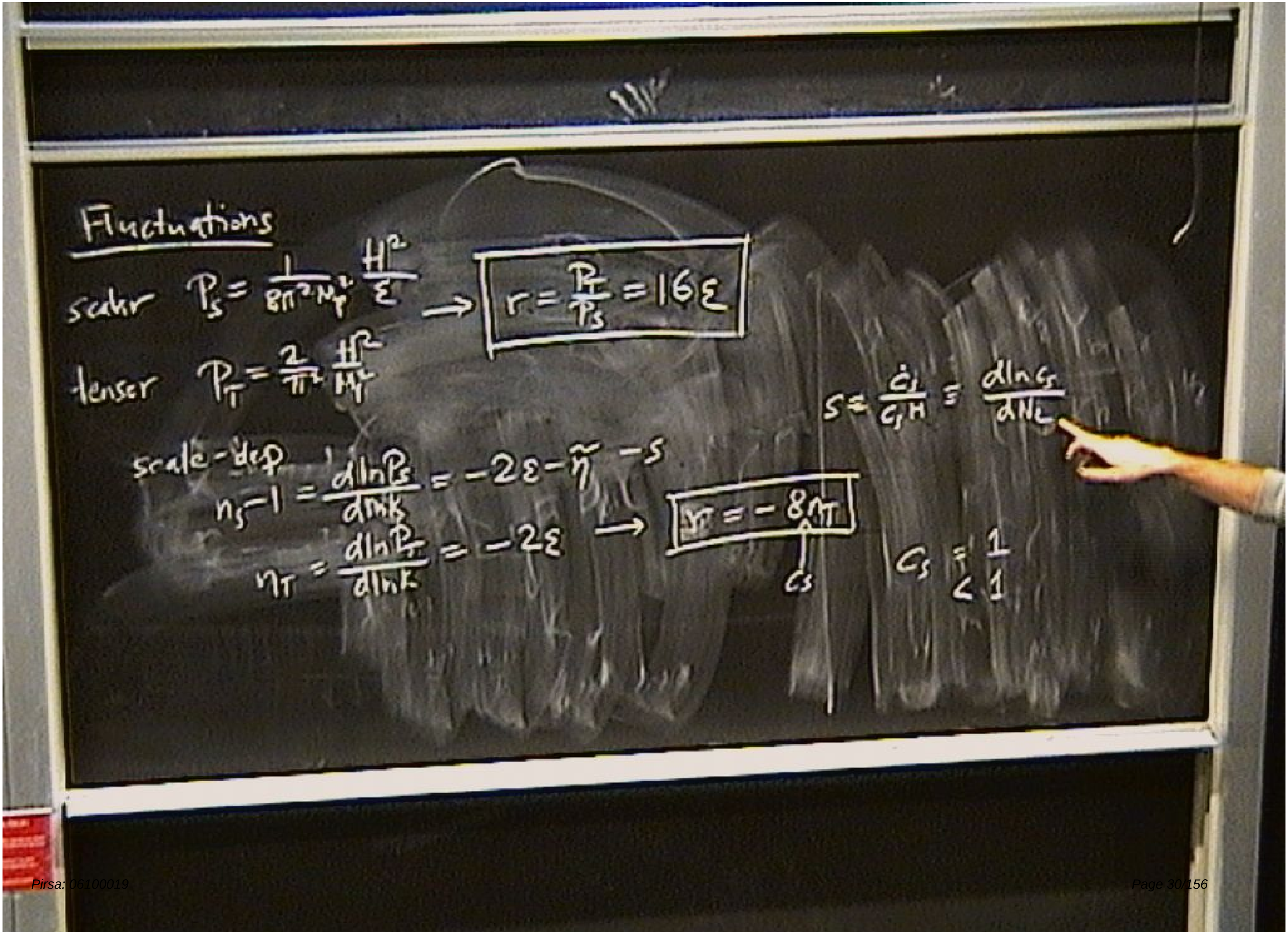
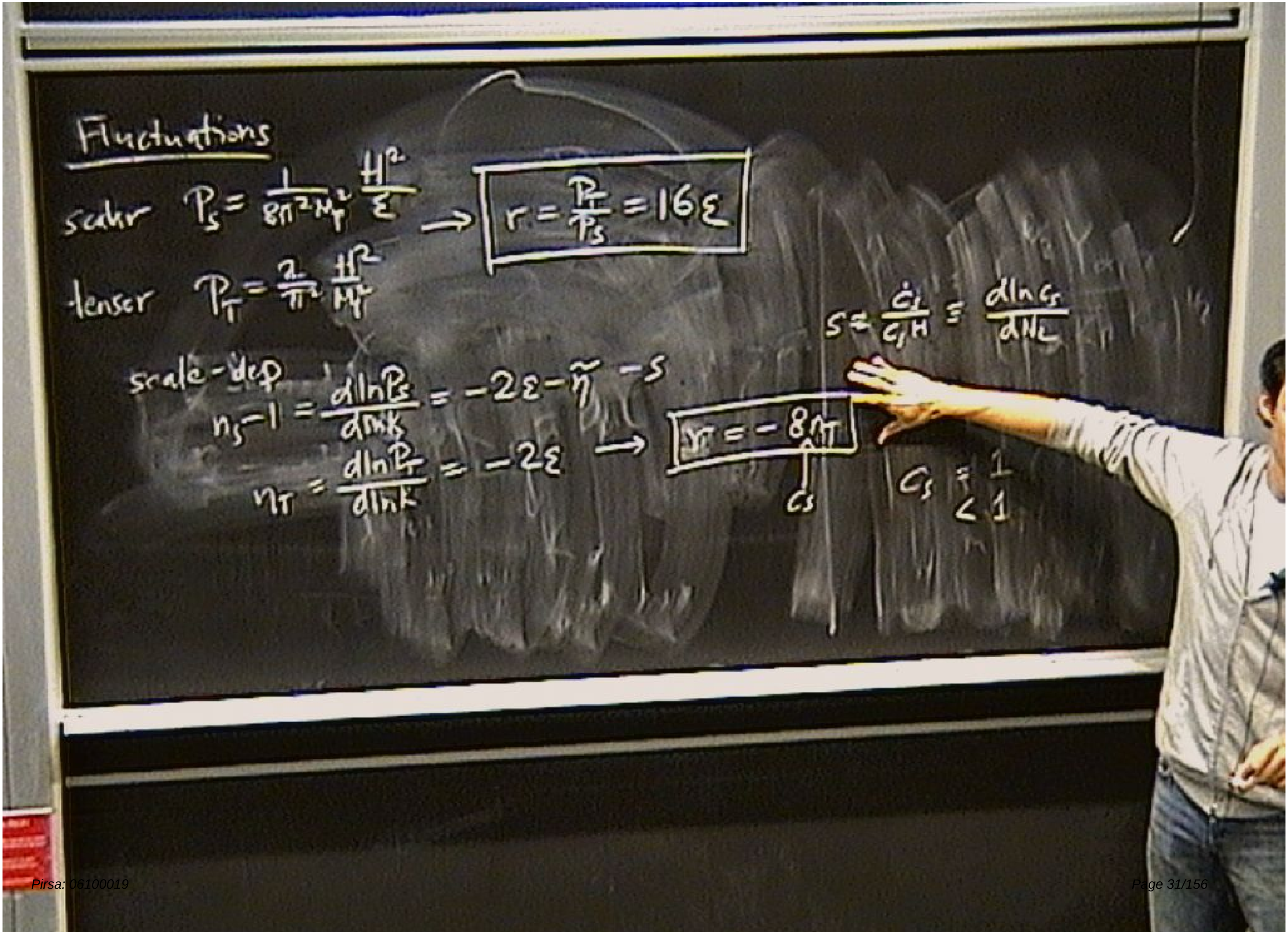
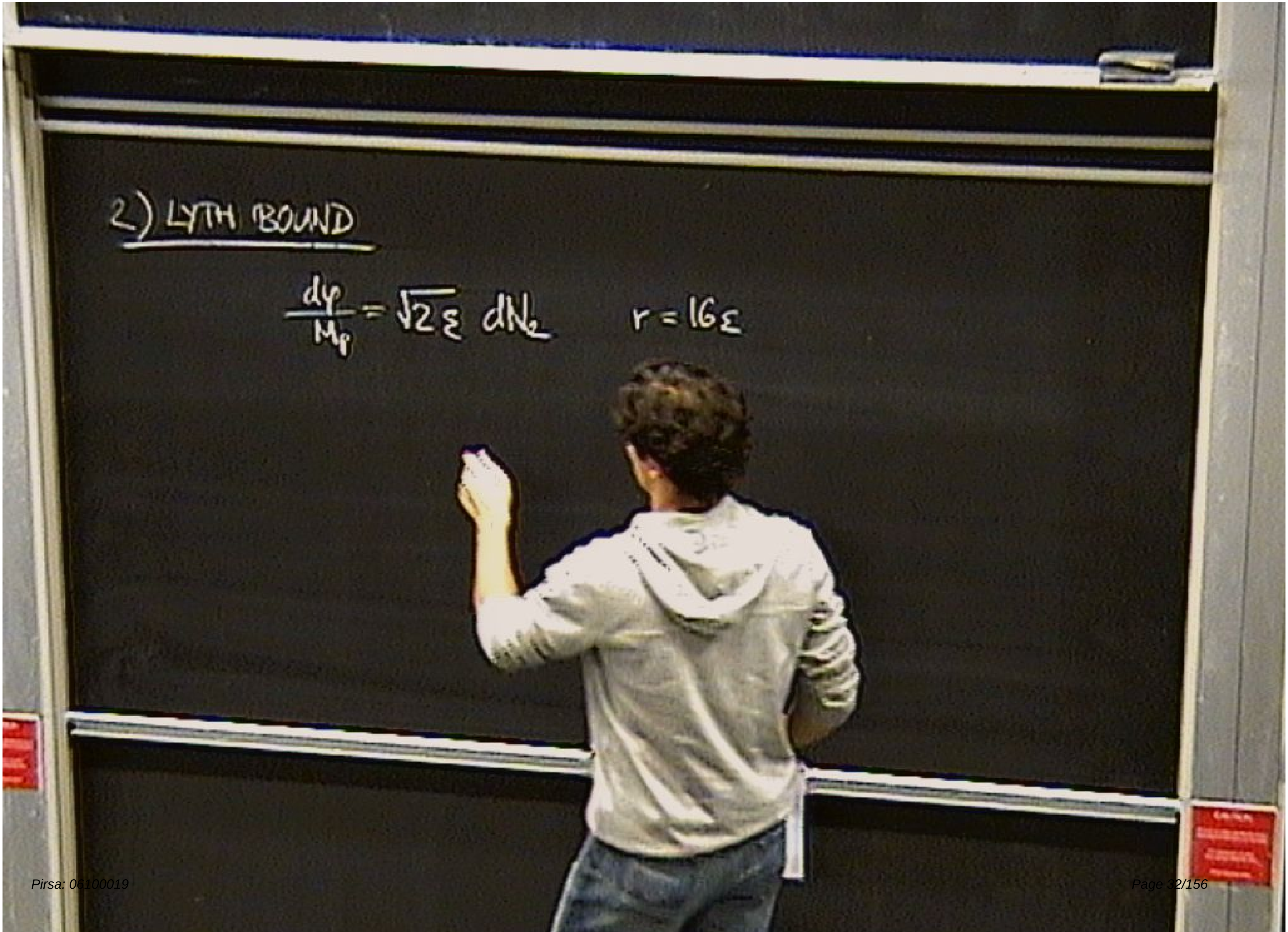
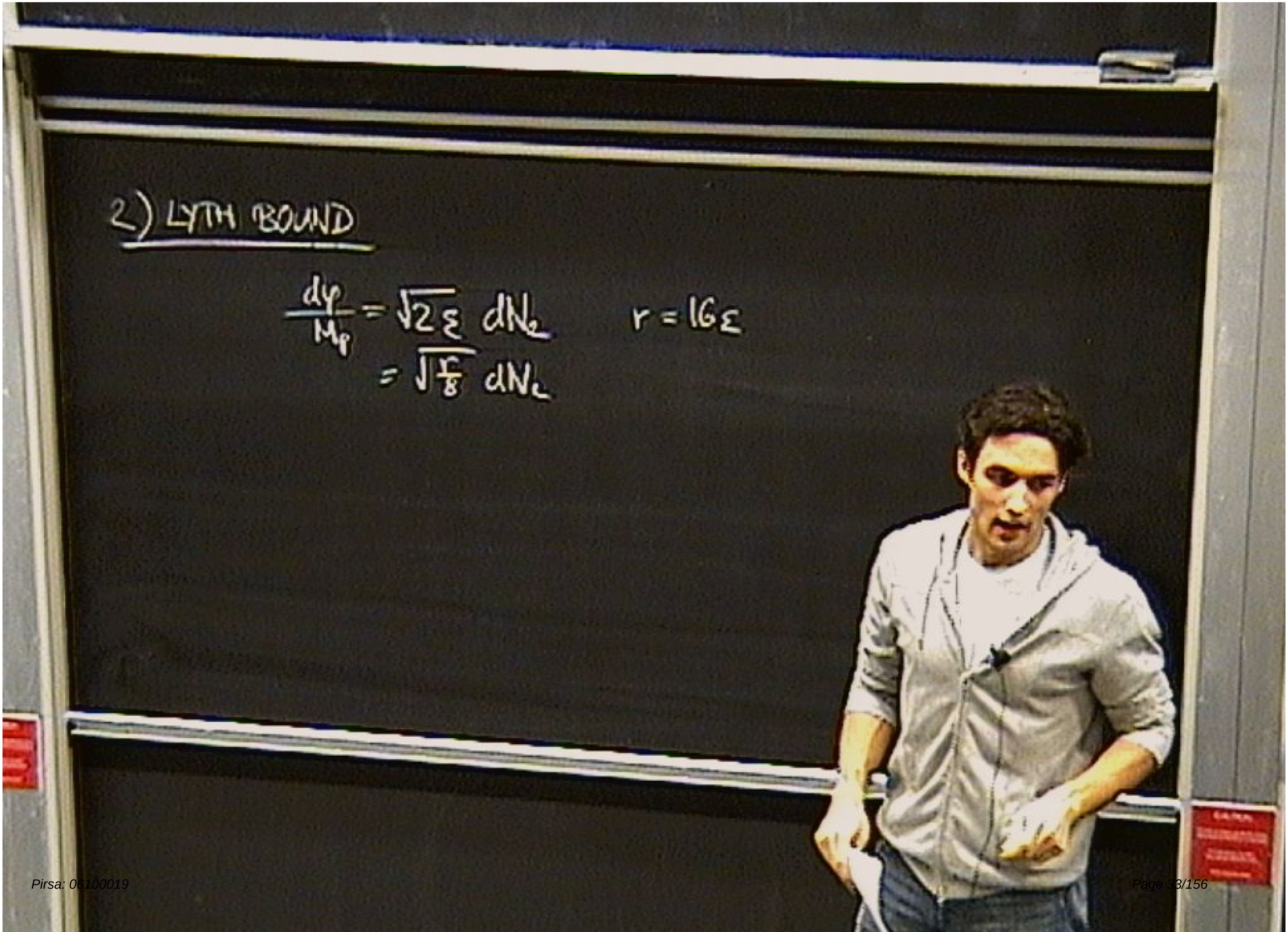

Fluctuations
scalar $P_S = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\varepsilon}$ → $r = \frac{P_T}{P_S} = 16\varepsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
scale-dep
$n_s - 1 = \frac{d\ln P_S}{d\ln k} = -2\varepsilon - \tilde{\eta}$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon$ → $r = -8n_T$
c_s
$c_s = 1$
< 1

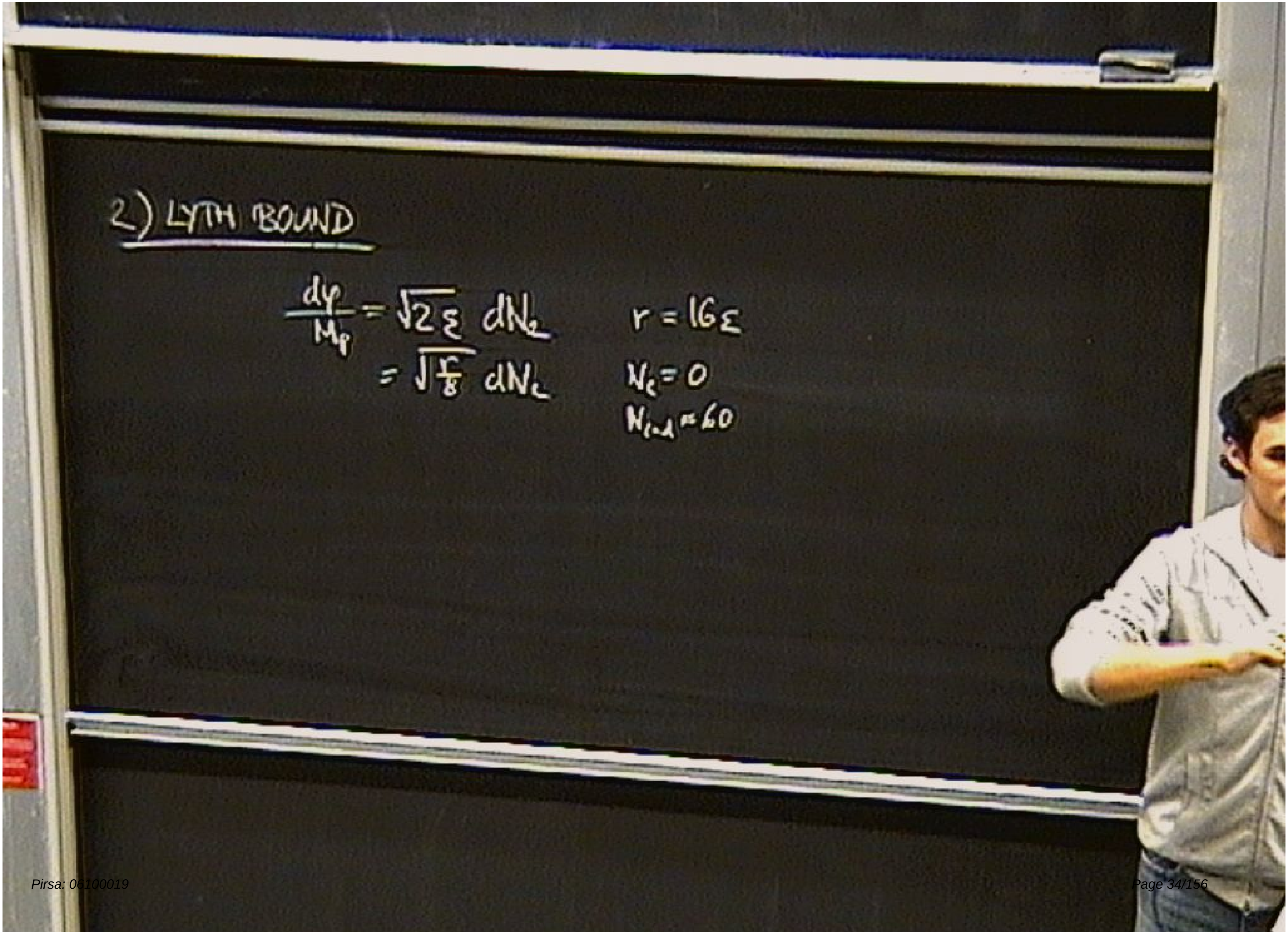

Fluctuations
scalr $P_s = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\varepsilon}$ → $r = \frac{P_T}{P_s} = 16\varepsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
$s = \frac{\dot{c}_s}{c_s H}$
scale-dep
$n_s - 1 = \frac{d\ln P_s}{d\ln k} = -2\varepsilon - \tilde{\eta} - s$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon$ → $r = -8 c_s n_T$
c_s
$c_s = 1$
< 1

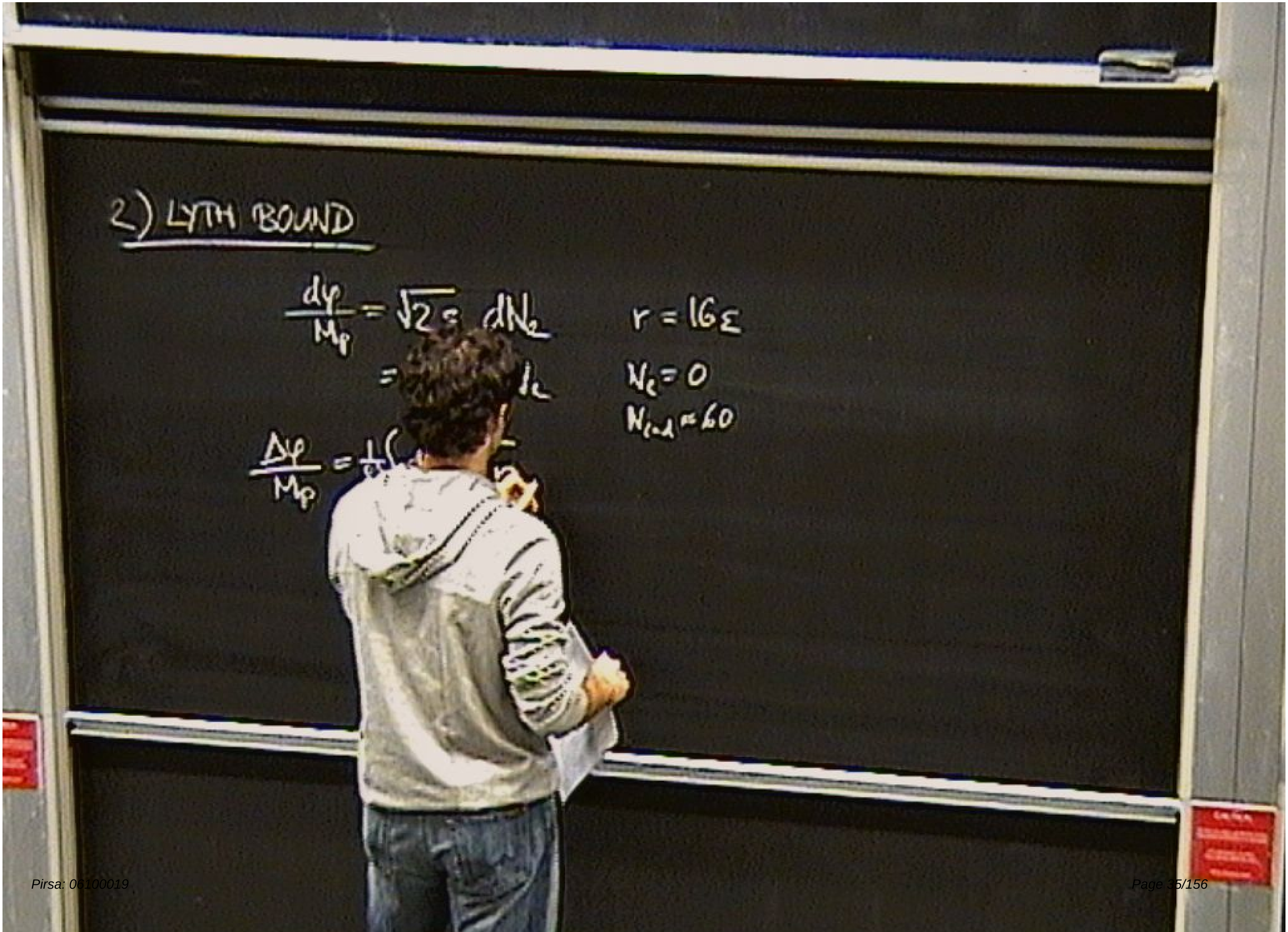

Fluctuations
scalar $P_S = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\varepsilon}$ → $r = \frac{P_T}{P_S} = 16\varepsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
$s = \frac{\dot{c}_s}{c_s H} = \frac{d\ln c_s}{dN_e}$
scale-dep
$n_s - 1 = \frac{d\ln P_s}{d\ln k} = -2\varepsilon - \tilde{\eta} - s$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\varepsilon$ → $r = -8 n_T$
c_s
$c_s = 1$
< 1


Fluctuations
scalar $P_s = \frac{1}{8\pi^2 M_p^2}\frac{H^2}{\epsilon}$ → $r = \frac{P_T}{P_S} = 16\epsilon$
tensor $P_T = \frac{2}{\pi^2}\frac{H^2}{M_p^2}$
scale-dep
$n_s - 1 = \frac{d\ln P_s}{d\ln k} = -2\epsilon - \tilde{\eta} - s$
$n_T = \frac{d\ln P_T}{d\ln k} = -2\epsilon$ → $r = -8 n_T$
c_s
$s = \frac{\dot{c}_s}{c_s H} = \frac{d\ln c_s}{dN_e}$
$c_s = 1$
< 1


2) LYTH BOUND
$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e$
$r = 16\varepsilon$


2) LYTH BOUND
$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e$
$r = 16\varepsilon$
$= \sqrt{\frac{r}{8}}\, dN_e$


2) LYTH BOUND
$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e$
$= \sqrt{\frac{r}{8}}\, dN_e$
$r = 16\varepsilon$
$N_e = 0$
$N_{e,1} \approx 60$


2) LYTH BOUND
dφ/Mp = √2ε dNe
r = 16ε
Ne = 0
Ne-1 ≈ 60
Δφ/Mp

2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

$$N_{end} \approx 60$$

$$\frac{\Delta\varphi}{M_p} = \frac{1}{8^{1/2}} \int_0^{N_{end}} dN_e \sqrt{r}$$

2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

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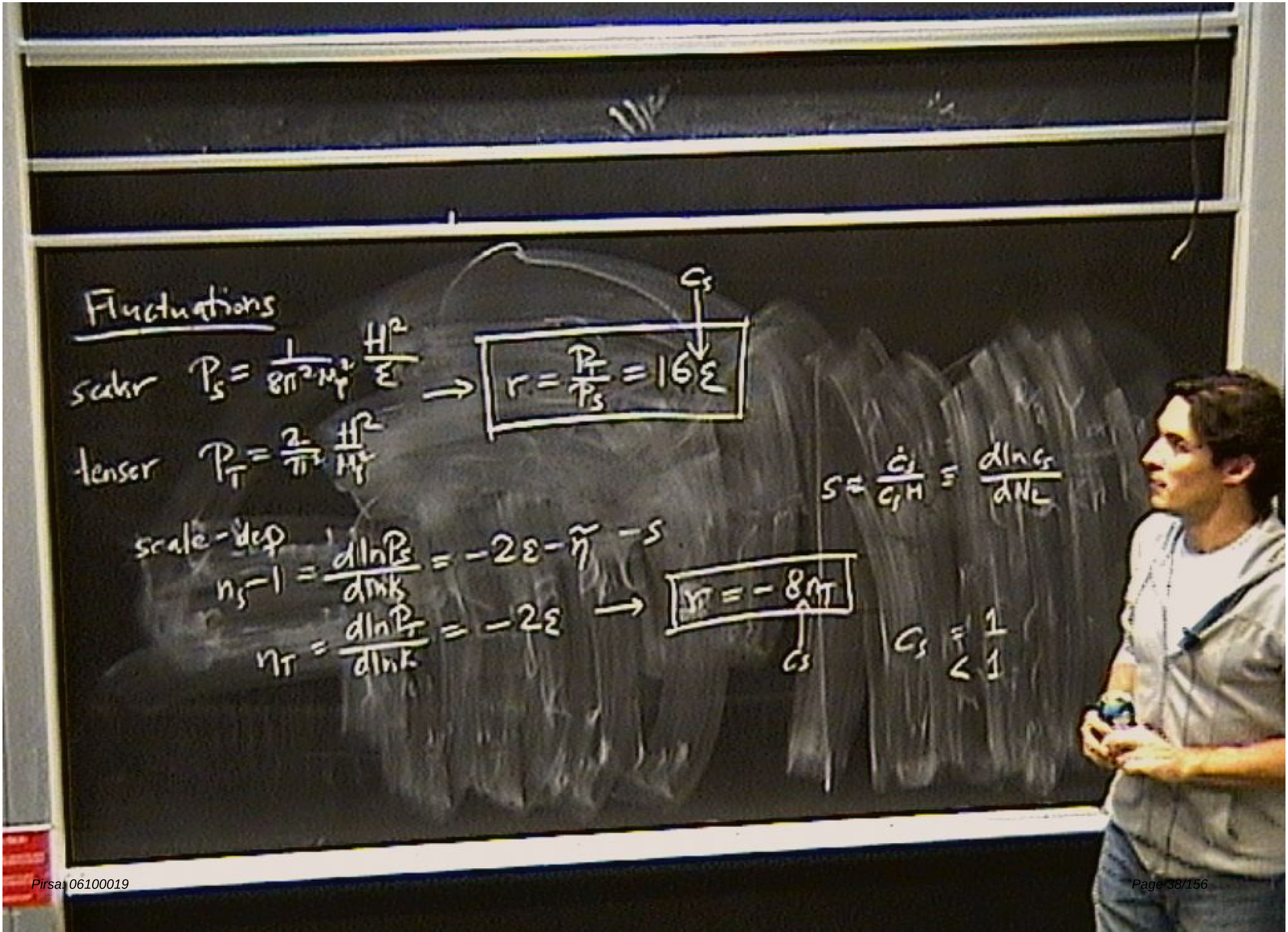
$$\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}} \int_0^{N_{end}} dN_e \sqrt{r}$$


Fluctuations
scalar Ps = 1/(8π² Mp²) H²/ε
r = PT/Ps = 16ε
cs
tenser PT = 2/π² H²/Mp²
s = ċs/(cs H) = d ln cs / dNe
scale-dep
ns − 1 = d ln Ps / d ln k = −2ε − η̃ − s
nT = d ln PT / d ln k = −2ε
r = −8nT
cs
cs = 1
< 1

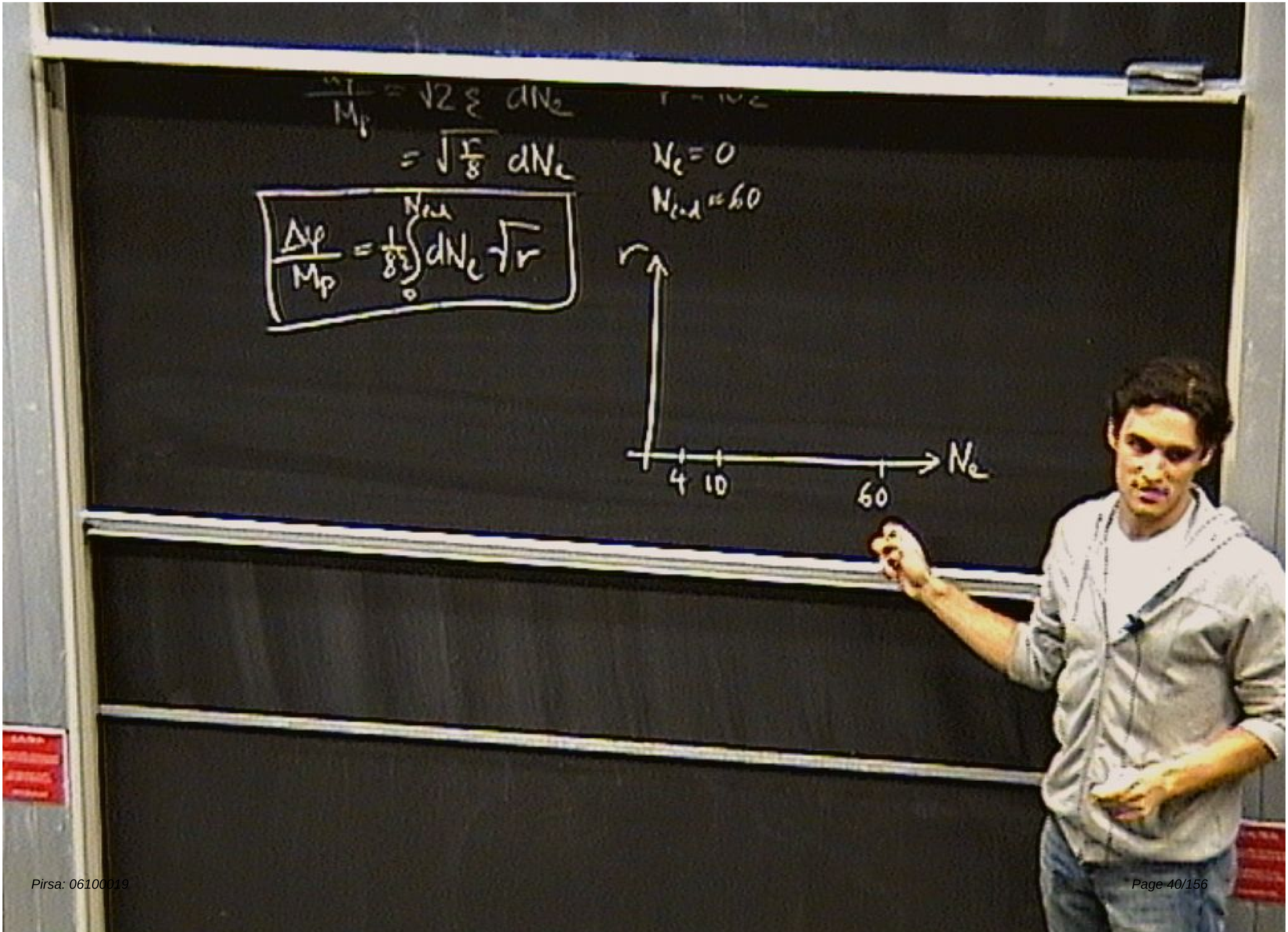
2) LYTH BOUND

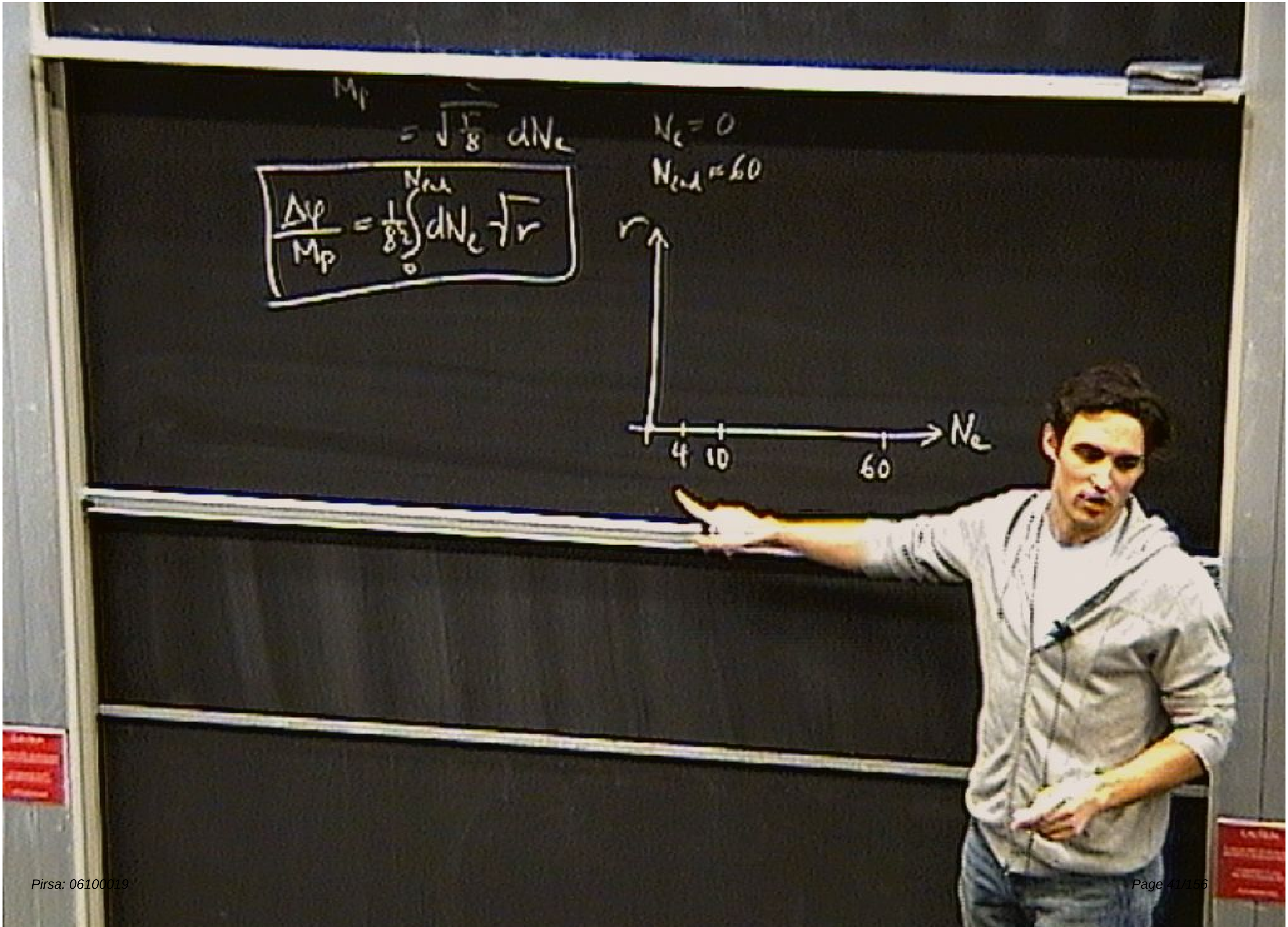
$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

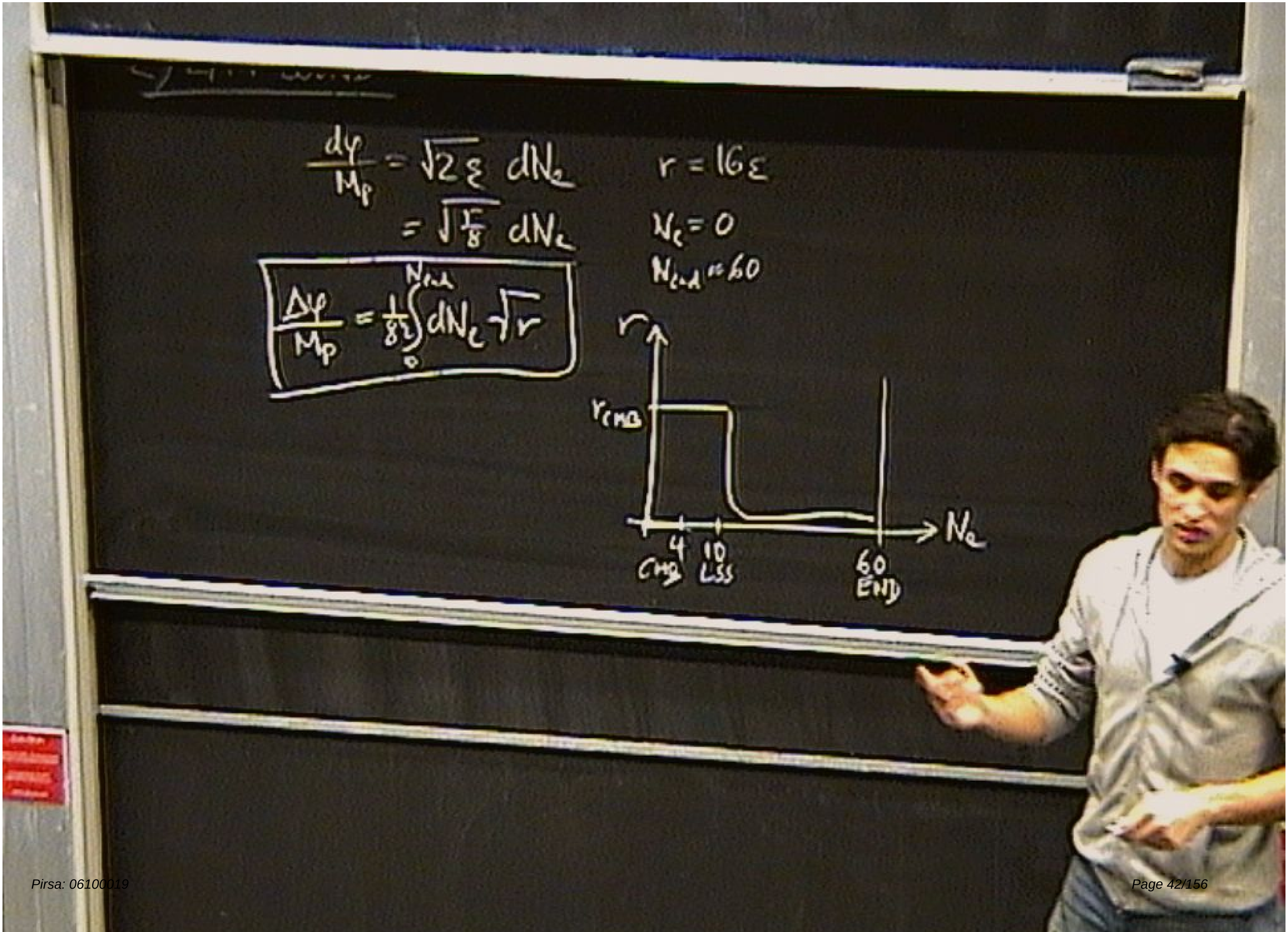
$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

$$N_{end} \approx 60$$

$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{8^{1/2}} \int_0^{N_{end}} dN_e \sqrt{r}}$$


= √(r/8) dNe
Ne = 0
Ne,end ≈ 60
Δφ/Mp = (1/√8) ∫ dNe √r
r
Ne
4
10
60


M_p
$= \sqrt{\frac{r}{8}}\, dN_e$
$N_e = 0$
$N_{end} \approx 60$
$\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}} \int_0^{N_{end}} dN_e \sqrt{r}$
r
N_e
4
10
60



dφ/M_p = √(2ε) dN_e = √(r/8) dN_e
r = 16ε
N_e = 0
N_end = 60
Δφ/M_p = (1/√8) ∫_0^{N_end} dN_e √r
r
r_CMB
N_e
4 CMB
10 LSS
60 END

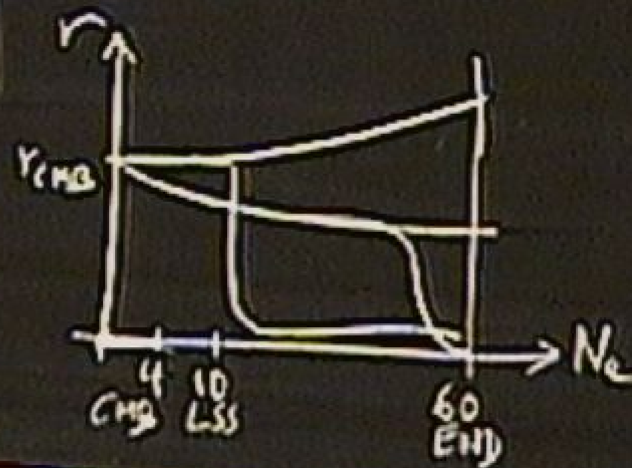
2) LYTH BOUND

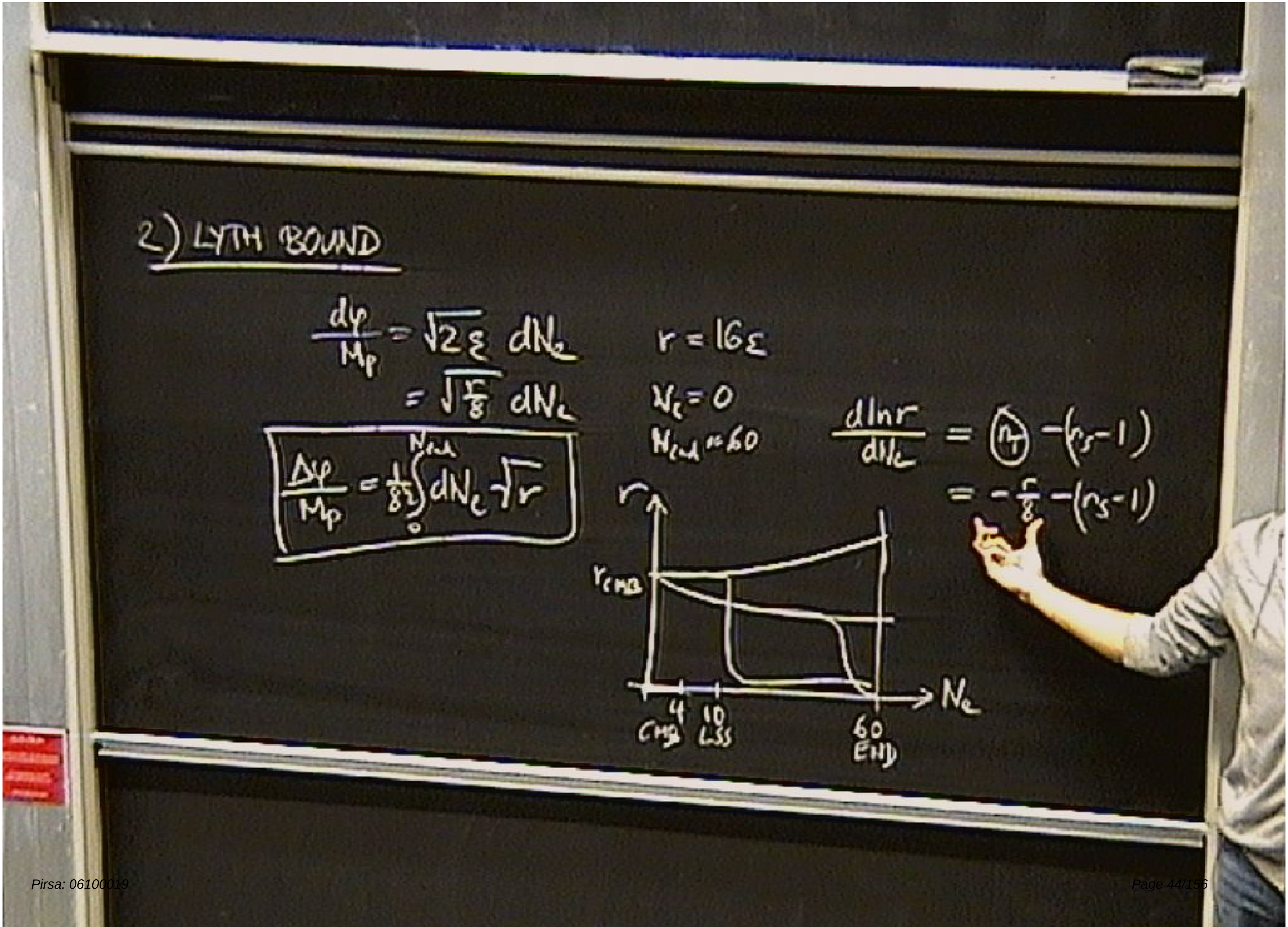
$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

$$N_{end} \approx 60 \qquad \frac{d\ln r}{dN_e}$$

$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}}\int_0^{N_{end}} dN_e \sqrt{r}}$$




2) LYTH BOUND
dφ/M_p = √(2ε) dN_e
= √(r/8) dN_e
Δφ/M_p = 1/(8^{1/2}) ∫_0^{N_end} dN_e √r
r = 16ε
N_e = 0
N_end ≈ 60
d ln r / dN_e = (n_T) − (n_S − 1)
= − r/8 − (n_S − 1)
r
r_CMB
N_e
4 CMB
10 LSS
60 END

$$\frac{d\varphi}{M_p} = \sqrt{2\epsilon}\, dN_e \qquad r = 16\epsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e$$

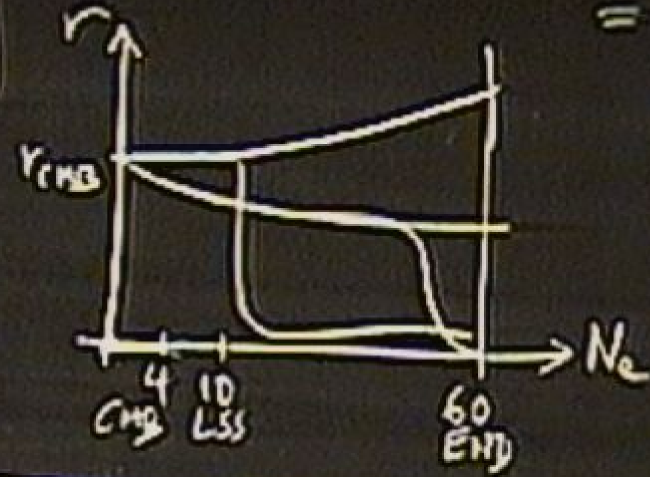
$$N_e = 0$$

$$N_{end} \approx 60$$

$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}}\int_0^{N_{end}} dN_e \sqrt{r}}$$

$$\frac{d\ln r}{dN_e} = \textcircled{n_T} - (n_s - 1)$$

$$= -\frac{r}{8} - (n_s - 1)$$



$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

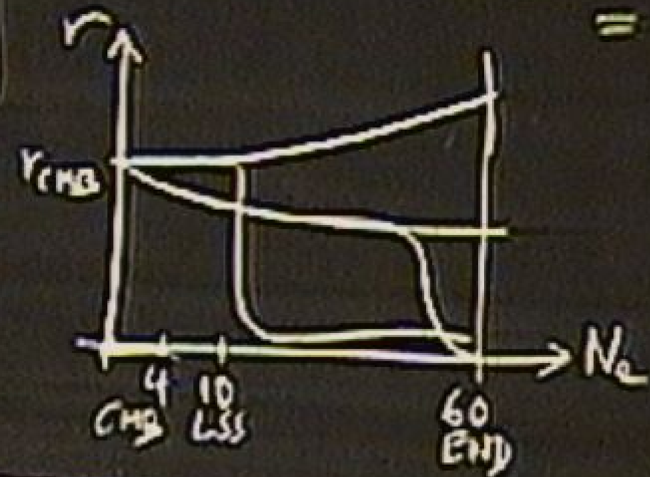
$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0 \qquad N_{end} = 60$$

$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}} \int_0^{N_{end}} dN_e \sqrt{r}}$$

$$\frac{d\ln r}{dN_e} = \textcircled{\eta} - (n_s - 1)$$

$$= -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$



$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

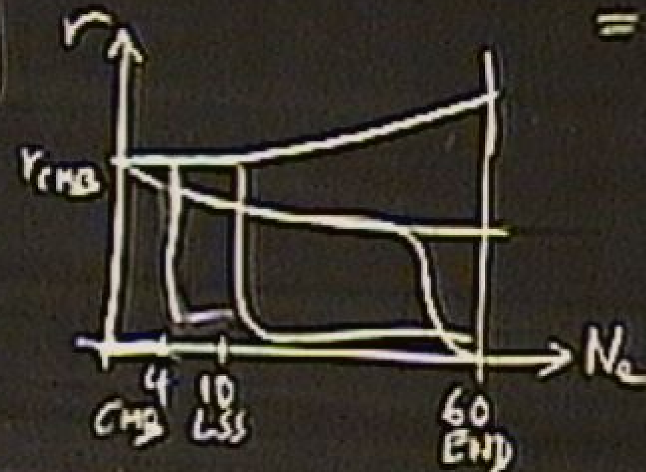
$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0, \quad N_{end} = 60$$

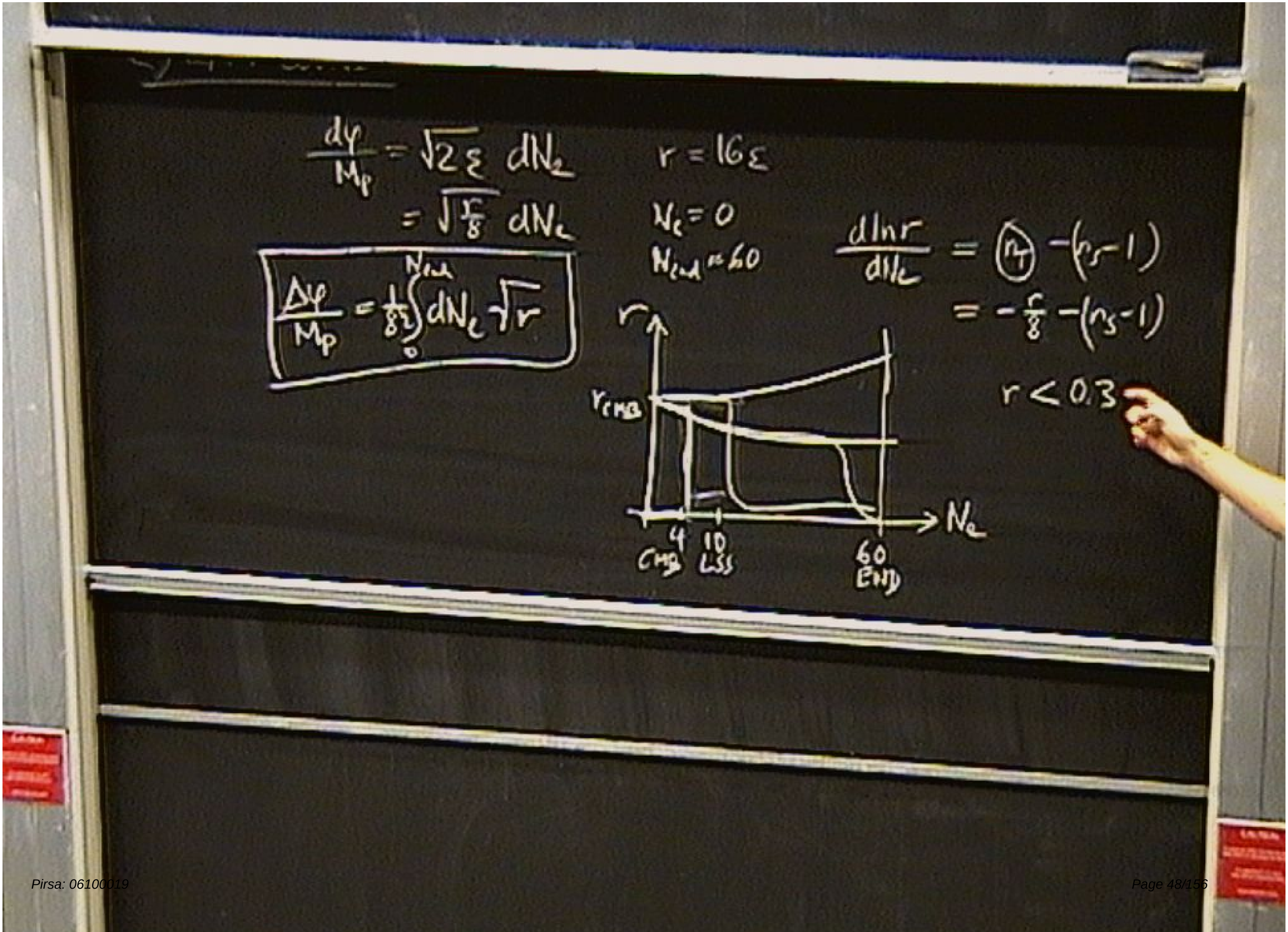
$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}} \int_0^{N_{end}} dN_e \sqrt{r}}$$

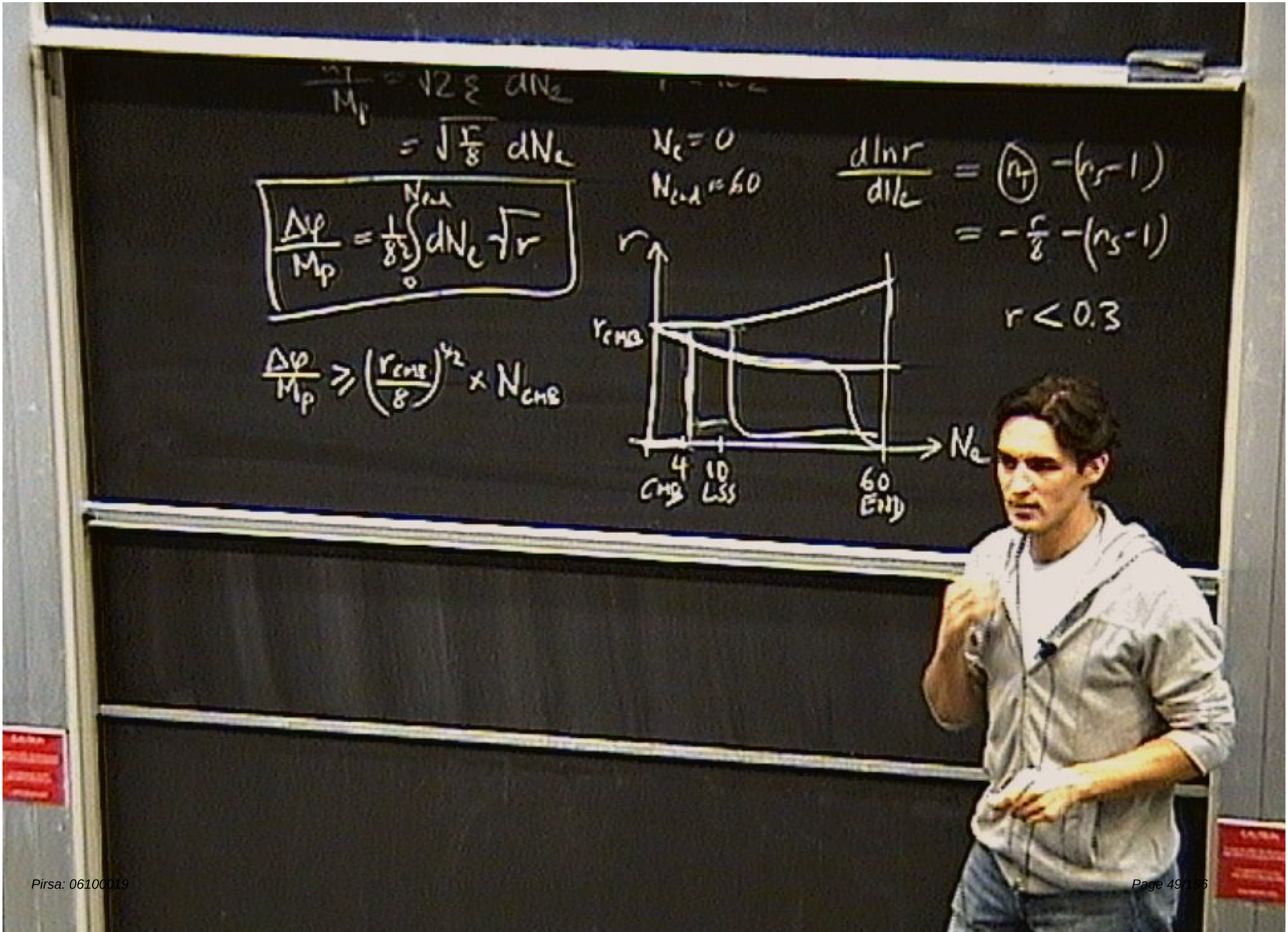
$$\frac{d\ln r}{dN_e} = (n_T) - (n_s - 1)$$

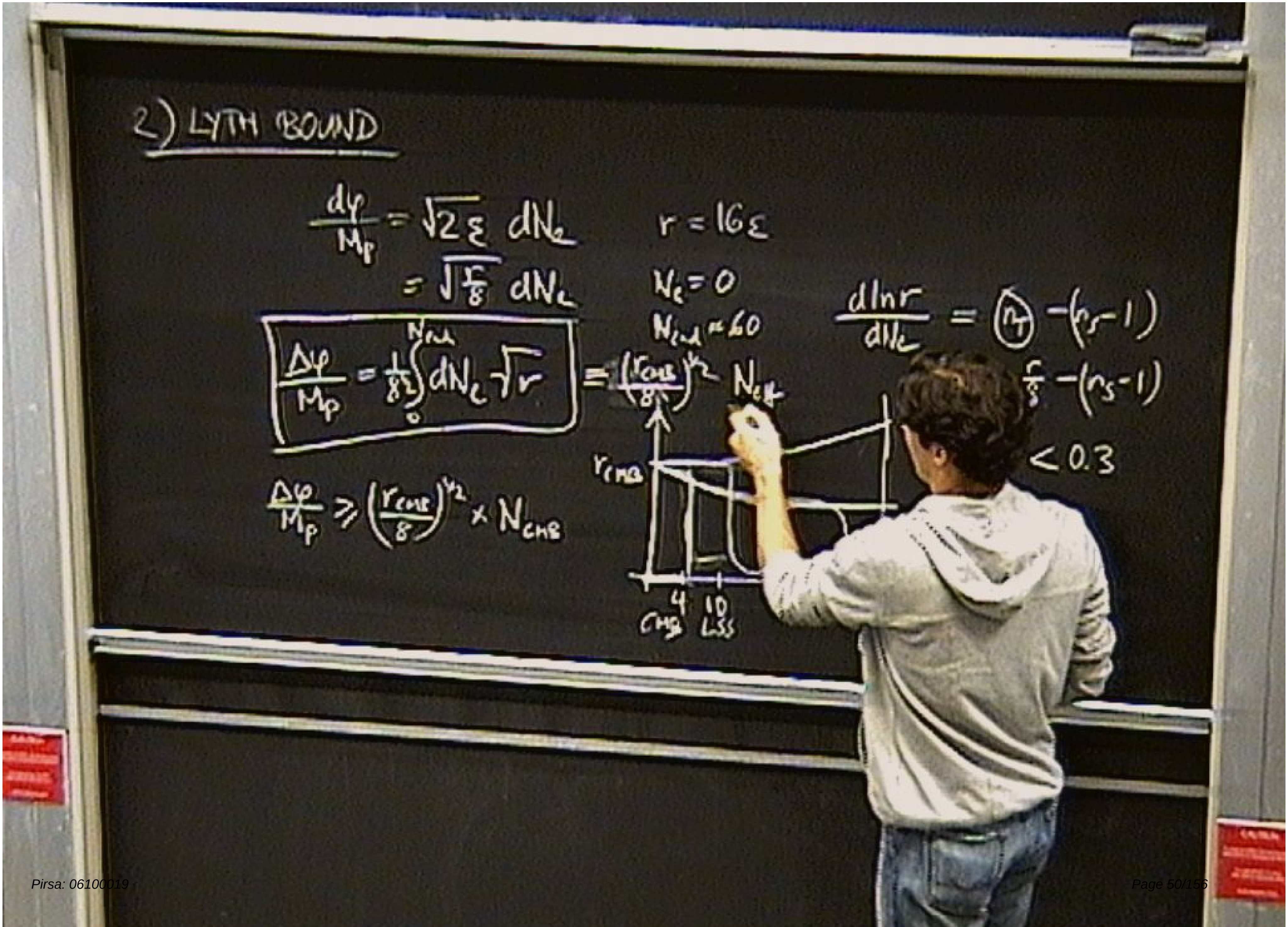
$$= -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$




dφ/Mp = √(2ε) dNe
= √(r/8) dNe
r = 16ε
Ne = 0
Nend = 60
Δφ/Mp = (1/√8) ∫_0^Nend dNe √r
d ln r / d Ne = (r) − (ns − 1)
= − r/8 − (ns − 1)
r < 0.3
r
rCMB
Ne
4
CMB
10
LSS
60
END


N_e = 0
N_end = 60
r < 0.3
r_CMB
N_e
4
CMB
10
LSS
60
END


2) LYTH BOUND
dφ/M_p = √2ε dN_e
r = 16ε
= √(r/8) dN_e
N_e = 0
N_end ≈ 60
dln r/dN_e = (r) − (n_s − 1)
Δφ/M_p = (1/√8) ∫_0^{N_end} dN_e √r = (r_CMB/8)^{1/2} N_eff
r/8 − (n_s − 1)
< 0.3
r_CMB
Δφ/M_p ≳ (r_CMB/8)^{1/2} × N_CMB
4 CMB
10 LSS

2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

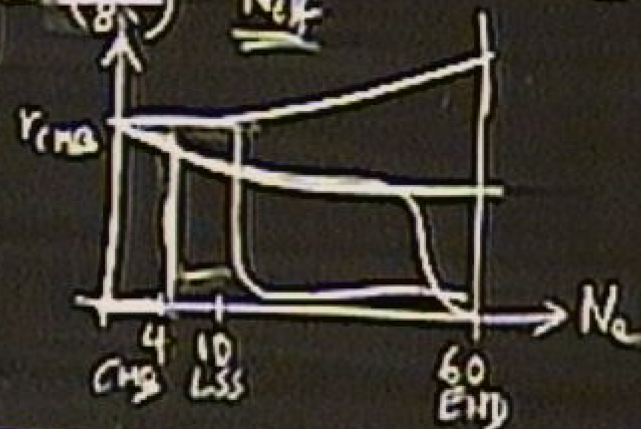
$$N_{end} \approx 60$$

$$\boxed{\frac{\Delta\varphi}{M_p} = \frac{1}{\sqrt{8}}\int_0^{N_{end}} dN_e \sqrt{r}} = \left(\frac{r_{CMB}}{8}\right)^{1/2} \underline{N_{eff}}$$

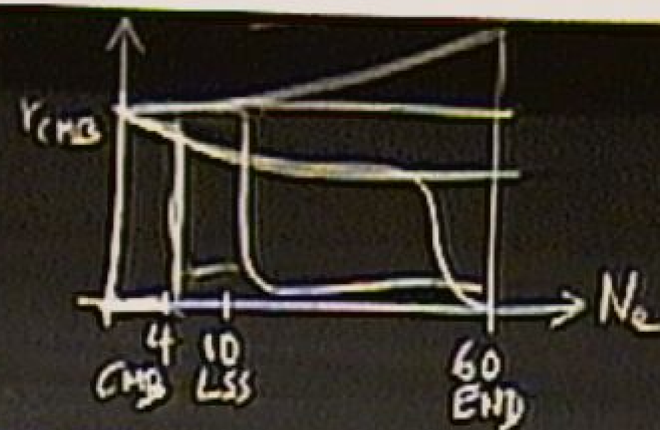
$$\frac{d\ln r}{dN_e} = n_T - (n_s - 1)$$
$$= -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$

$$\frac{\Delta\varphi}{M_p} \gtrsim \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$$

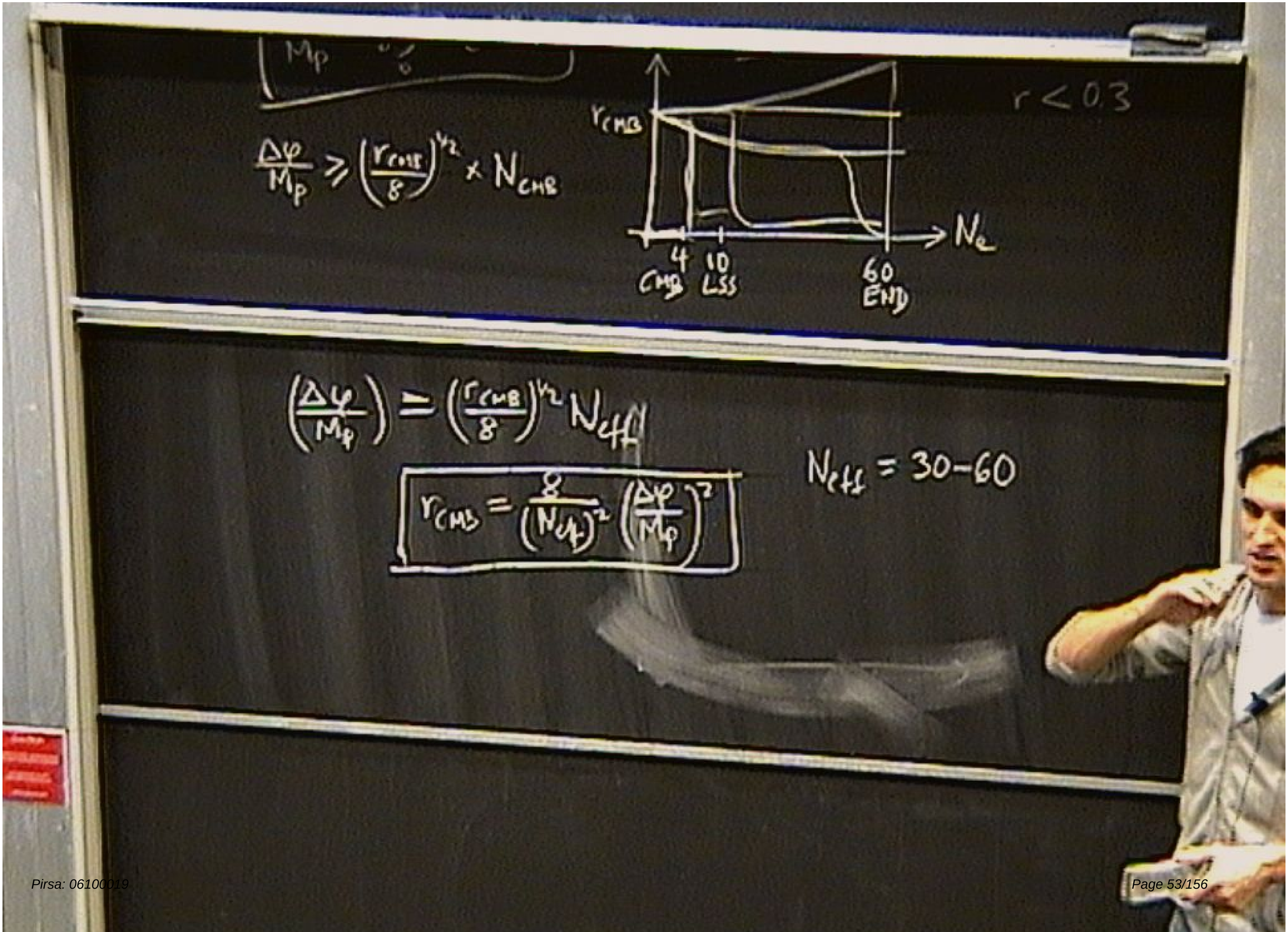


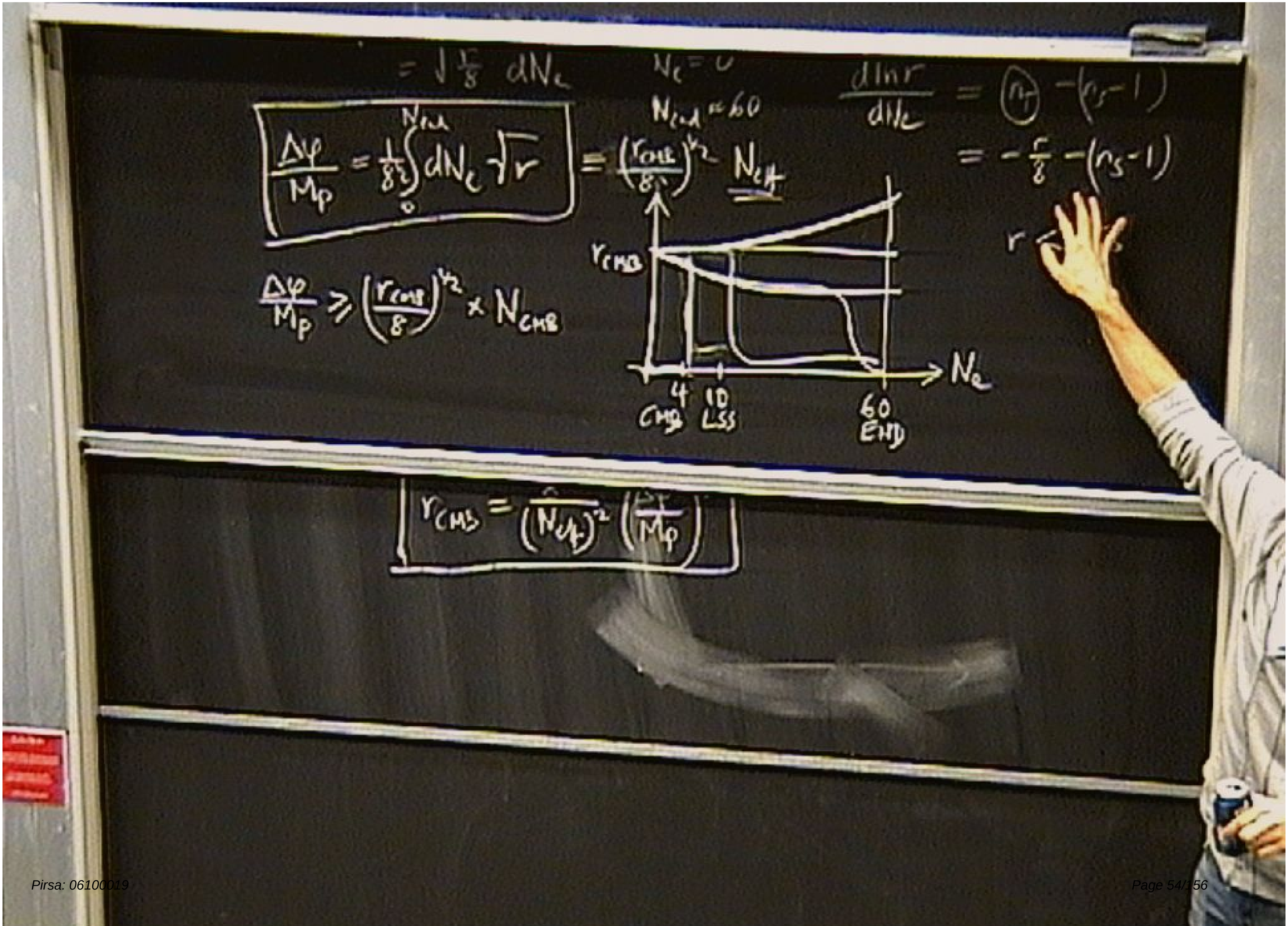
$$\frac{\Delta\varphi}{M_p} \gtrsim \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$$



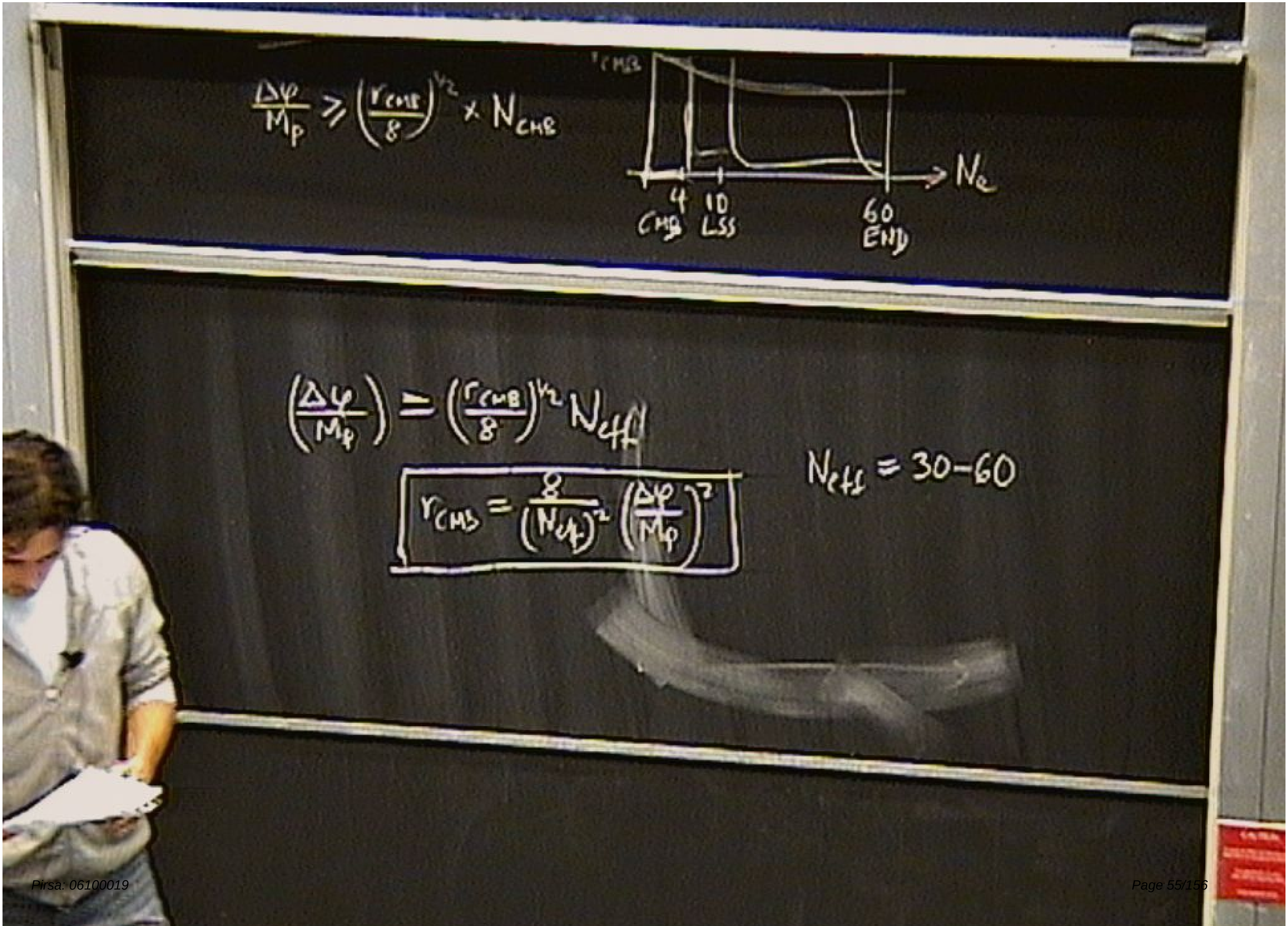
$r < 0.3$

$$\left(\frac{\Delta\varphi}{M_p}\right) \simeq \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

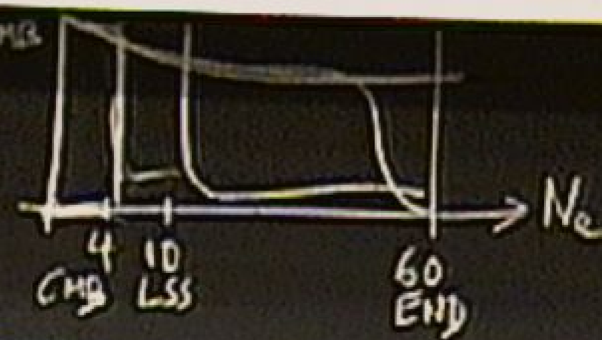

Δφ/Mp ≥ (r_CMB/8)^1/2 × N_CMB
r_CMB
N_e
4 CMB
10 LSS
60 END
r < 0.3
(Δφ/Mp) ≃ (r_CMB/8)^1/2 N_eff
r_CMB = 8/(N_eff)^2 (Δφ/Mp)^2
N_eff = 30–60



N_end ≈ 60
dln r / dN_e
r_CMB
Δφ/M_P ≳ (r_CMB/8)^½ × N_CMB
N_e
4 CMB
10 LSS
60 END


$\frac{\Delta\varphi}{M_P} \geq \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$
r_{CMB}
N_e
4 CMB
10 LSS
60 END
$\left(\frac{\Delta\varphi}{M_P}\right) \simeq \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$
$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_P}\right)^2$
$N_{eff} = 30-60$

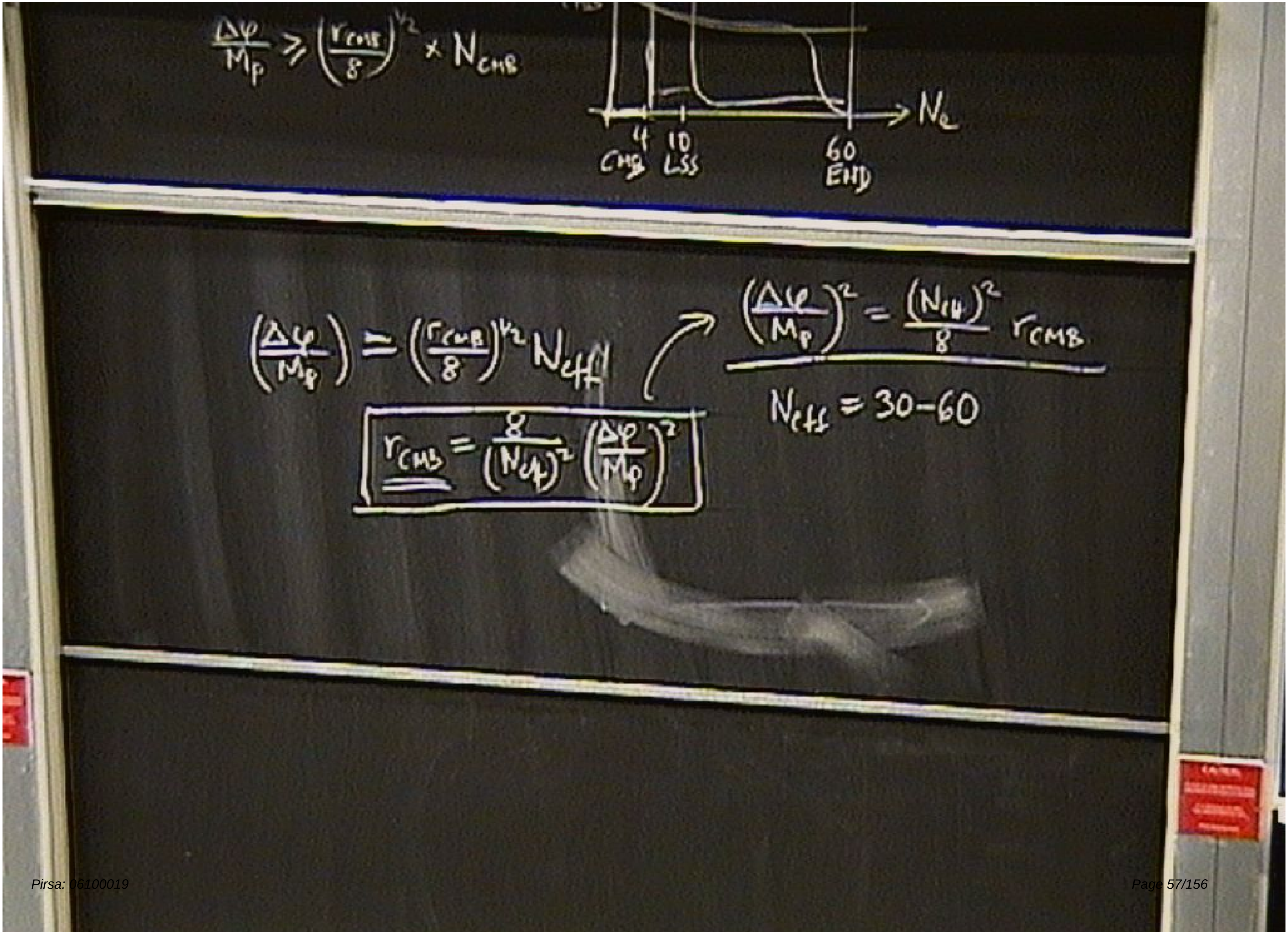
$$\frac{\Delta\varphi}{M_p} \gtrsim \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$$

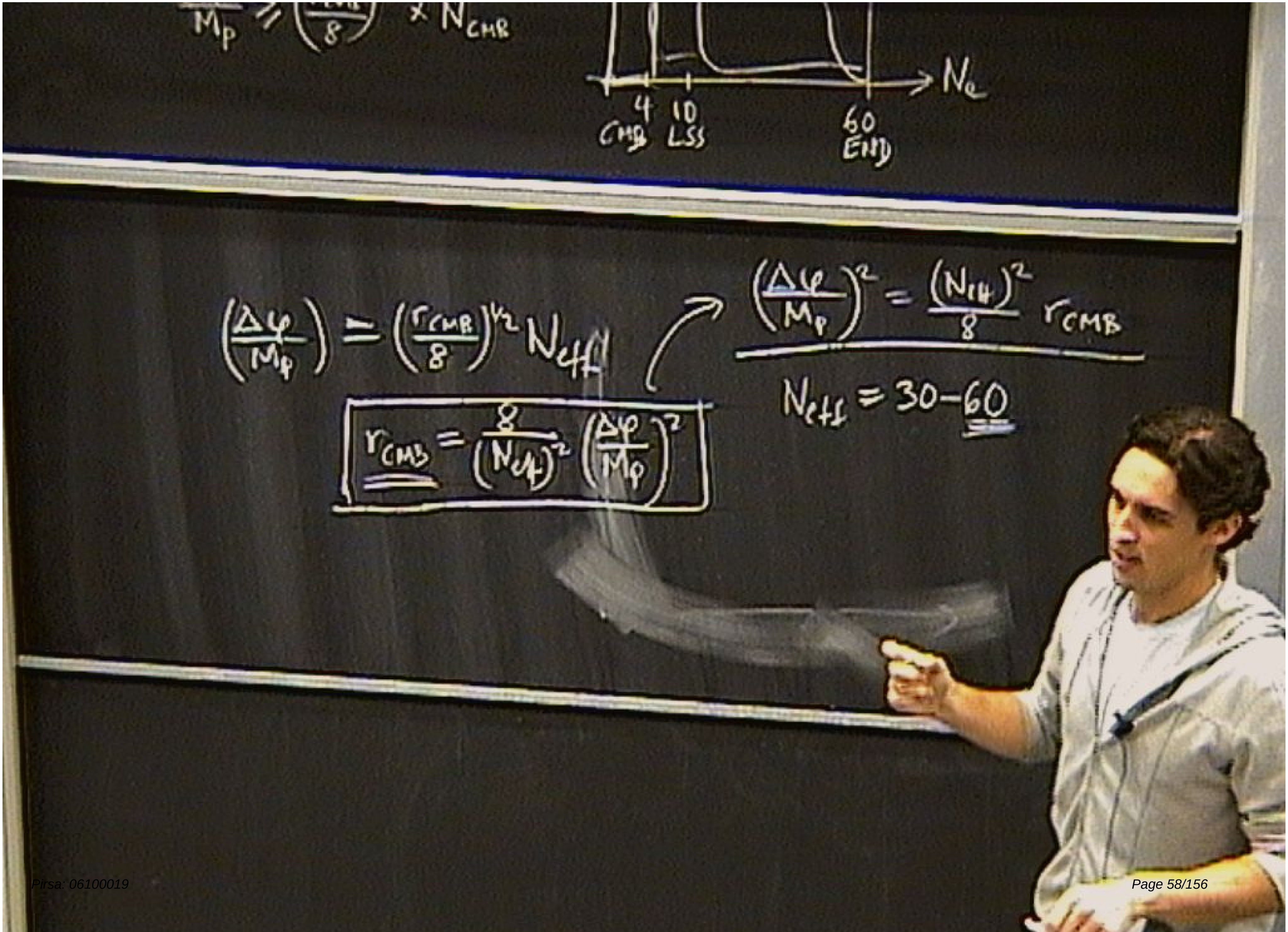


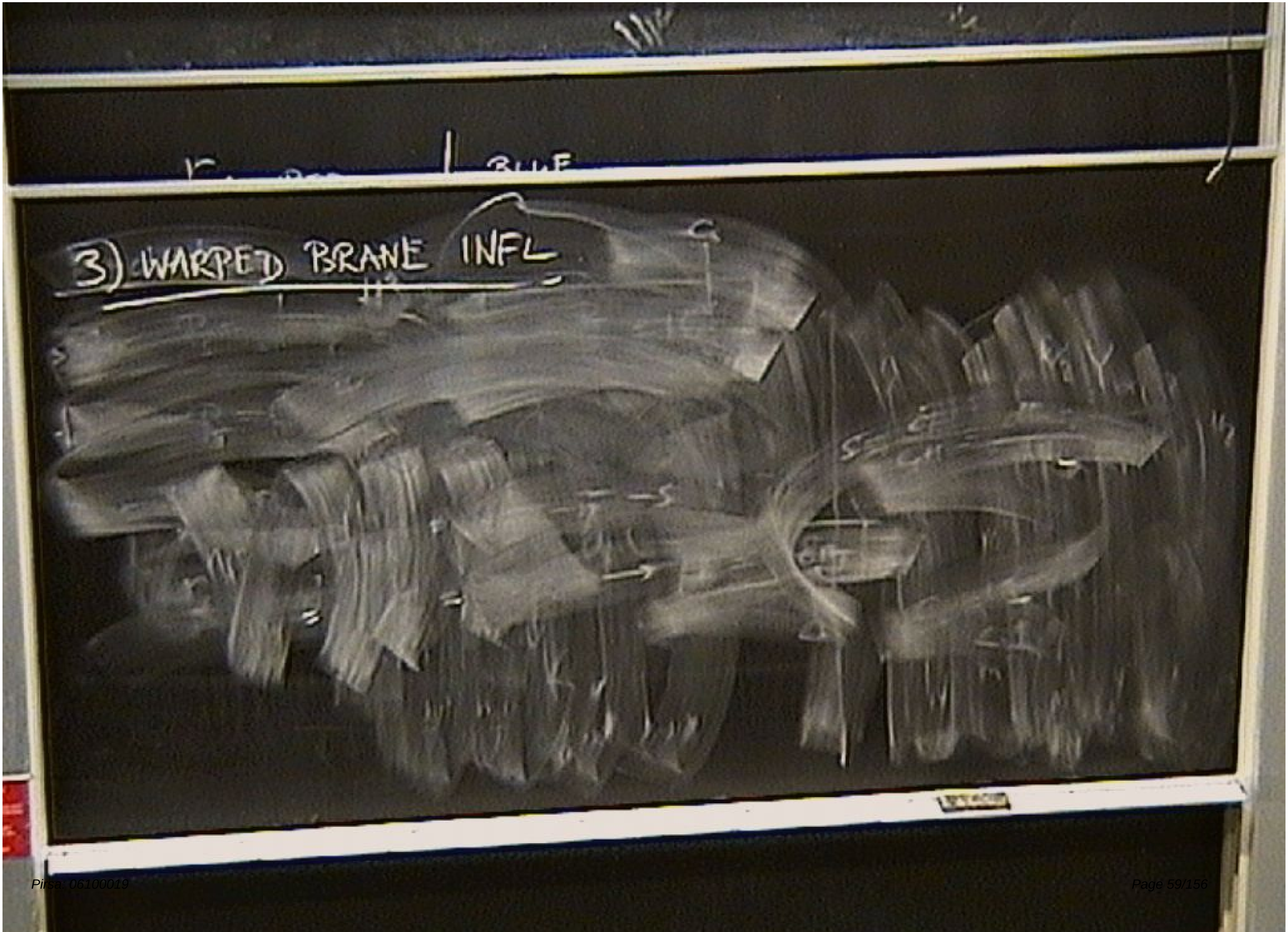
$$\left(\frac{\Delta\varphi}{M_p}\right) \simeq \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

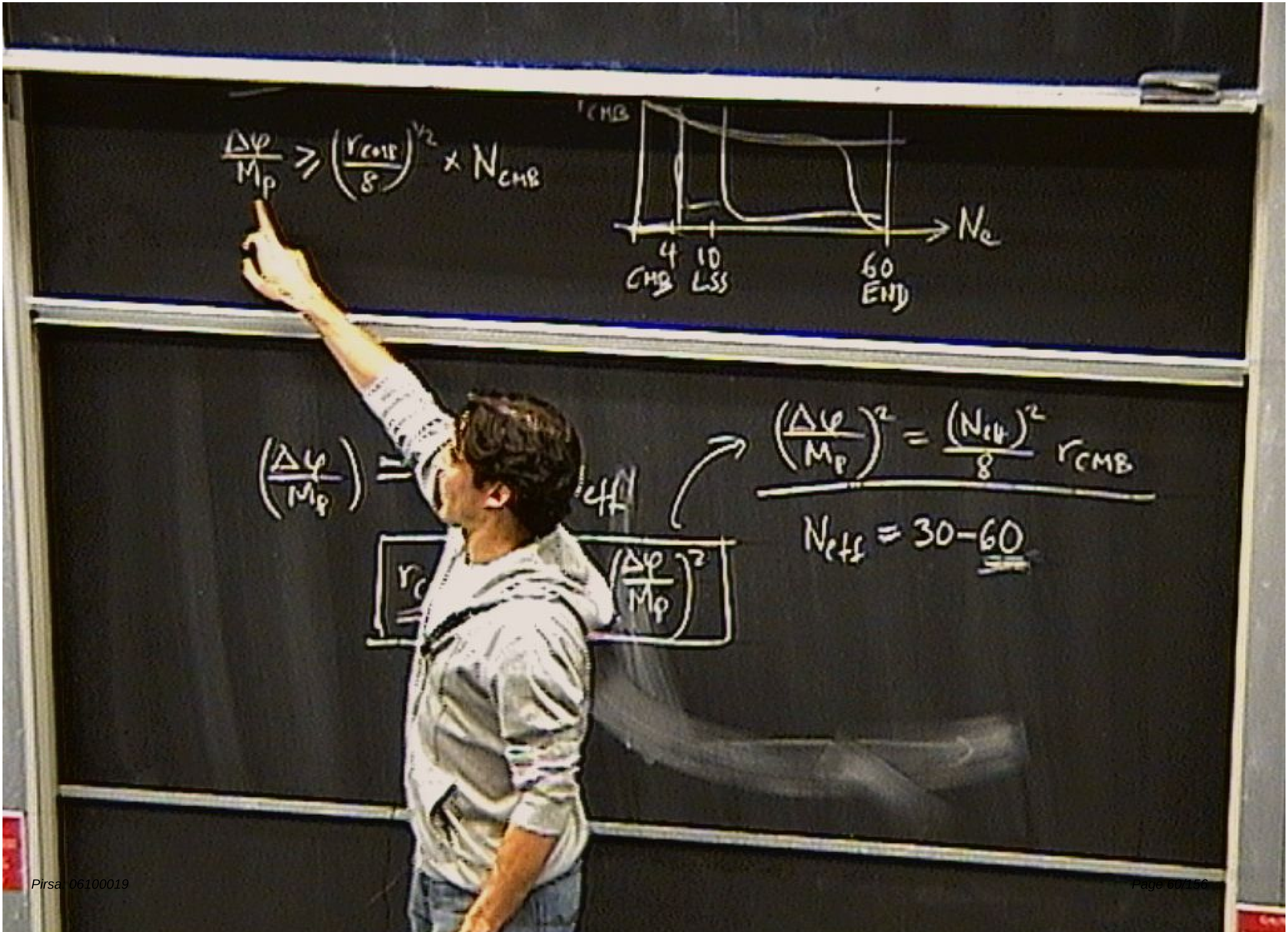
$$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_p}\right)^2$$

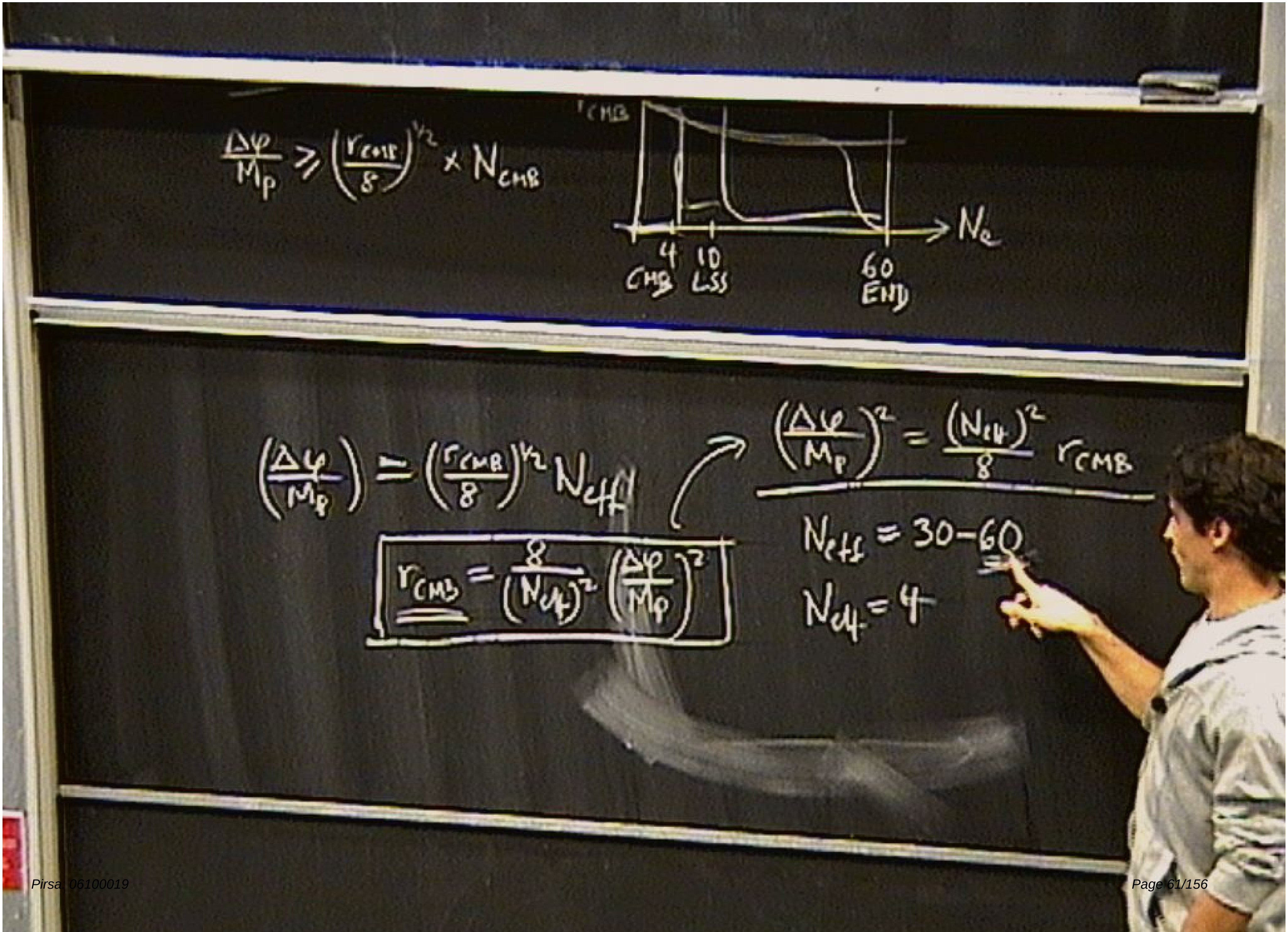
$N_{eff} = 30-60$


$\frac{\Delta\varphi}{M_p} \geq \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$
N_e
4 CMB
10 LSS
60 END
$\left(\frac{\Delta\varphi}{M_p}\right) = \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$
$\left(\frac{\Delta\varphi}{M_p}\right)^2 = \frac{(N_{eff})^2}{8} r_{CMB}$
$N_{eff} = 30-60$
$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_p}\right)^2$


× N_CMB
N_e
4 10 60
CMB LSS END
(Δφ/M_p) ≃ (r_CMB/8)^1/2 N_eff
(Δφ/M_p)^2 = (N_eff)^2/8 r_CMB
N_eff = 30-60
r_CMB = 8/(N_eff)^2 (Δφ/M_p)^2

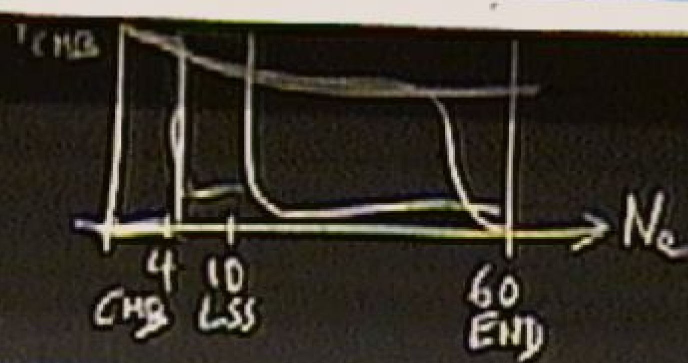

3) WARPED BRANE INFL


Δφ/Mp ≥ (rCMB/8)^1/2 × NCMB
rCMB
Ne
4
CMB
10
LSS
60
END
(Δφ/Mp)^2 = (Neff/8)^2 rCMB
Neff = 30-60



$\frac{\Delta\varphi}{M_p} \geq \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$
r_{CMB}
N_e
4
CMB
10
LSS
60
END
$\left(\frac{\Delta\varphi}{M_p}\right) = \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$
$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_p}\right)^2$
$\left(\frac{\Delta\varphi}{M_p}\right)^2 = \frac{(N_{eff})^2}{8} r_{CMB}$
$N_{eff} = 30-60$
$N_{eff} = 4$

$$\frac{\Delta\varphi}{M_p} \gtrsim \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$$



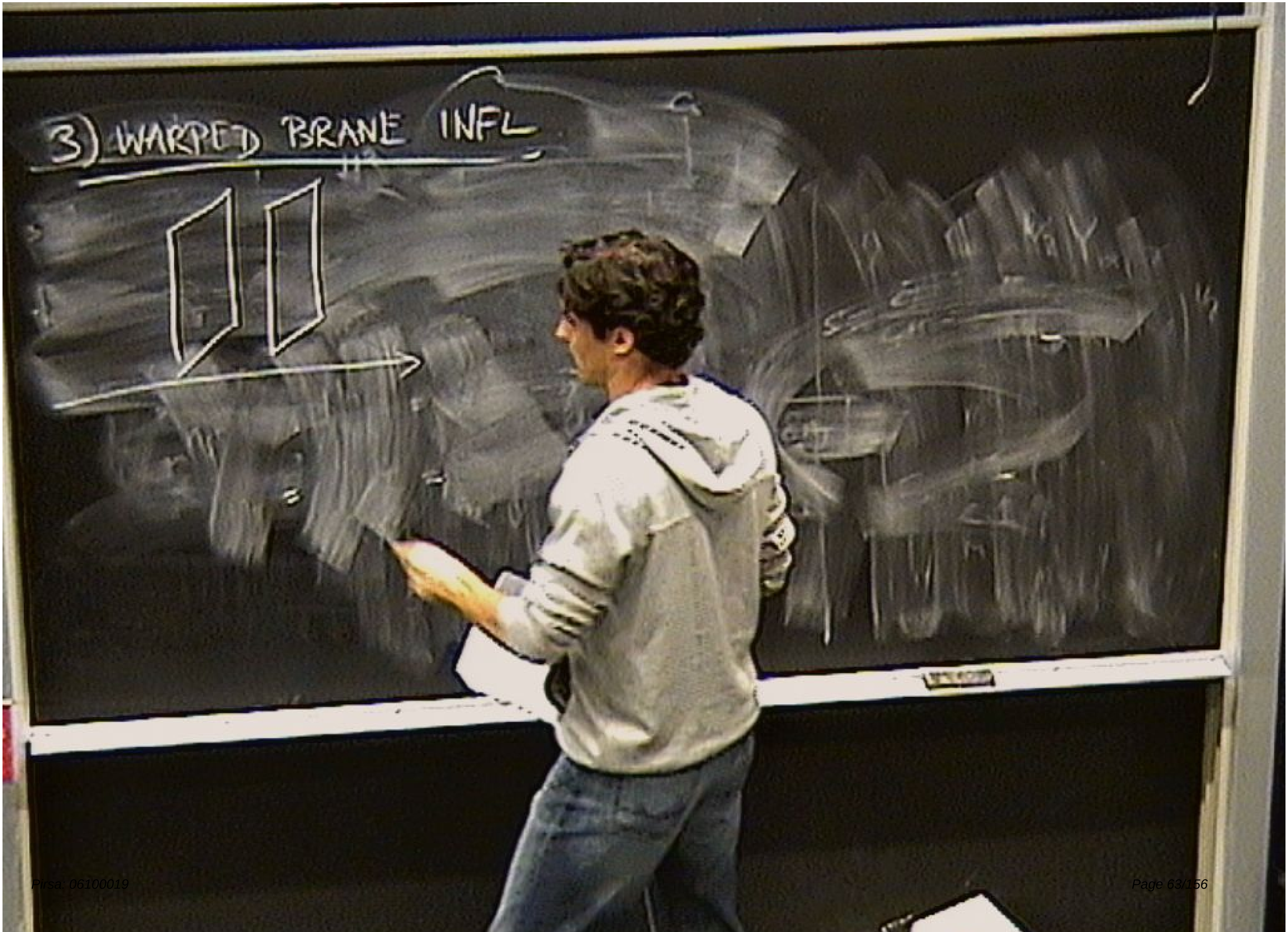
$$\left(\frac{\Delta\varphi}{M_p}\right) = \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

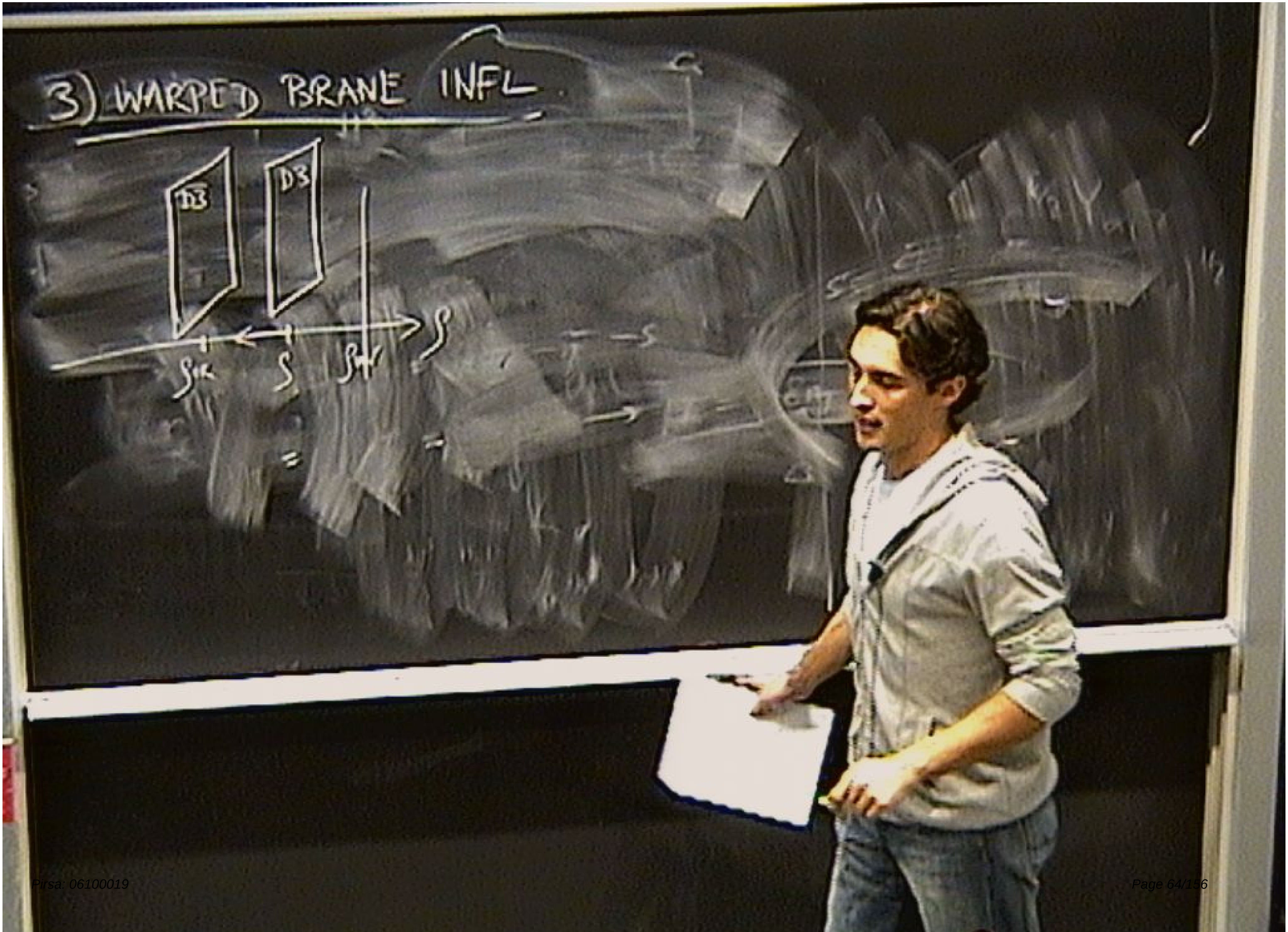
$$\left(\frac{\Delta\varphi}{M_p}\right)^2 = \frac{(N_{eff})^2}{8}\, r_{CMB}$$

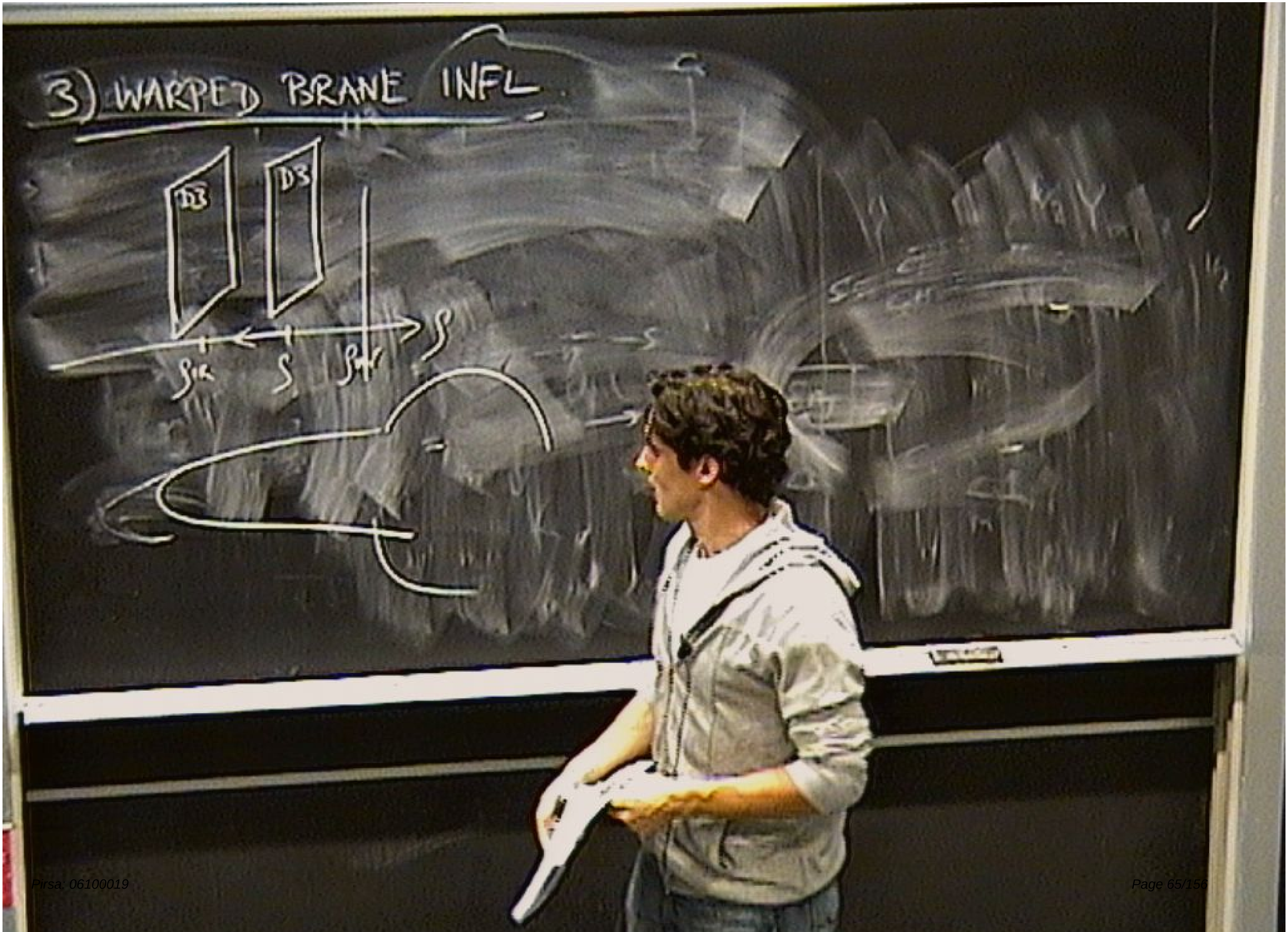
$$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_p}\right)^2$$

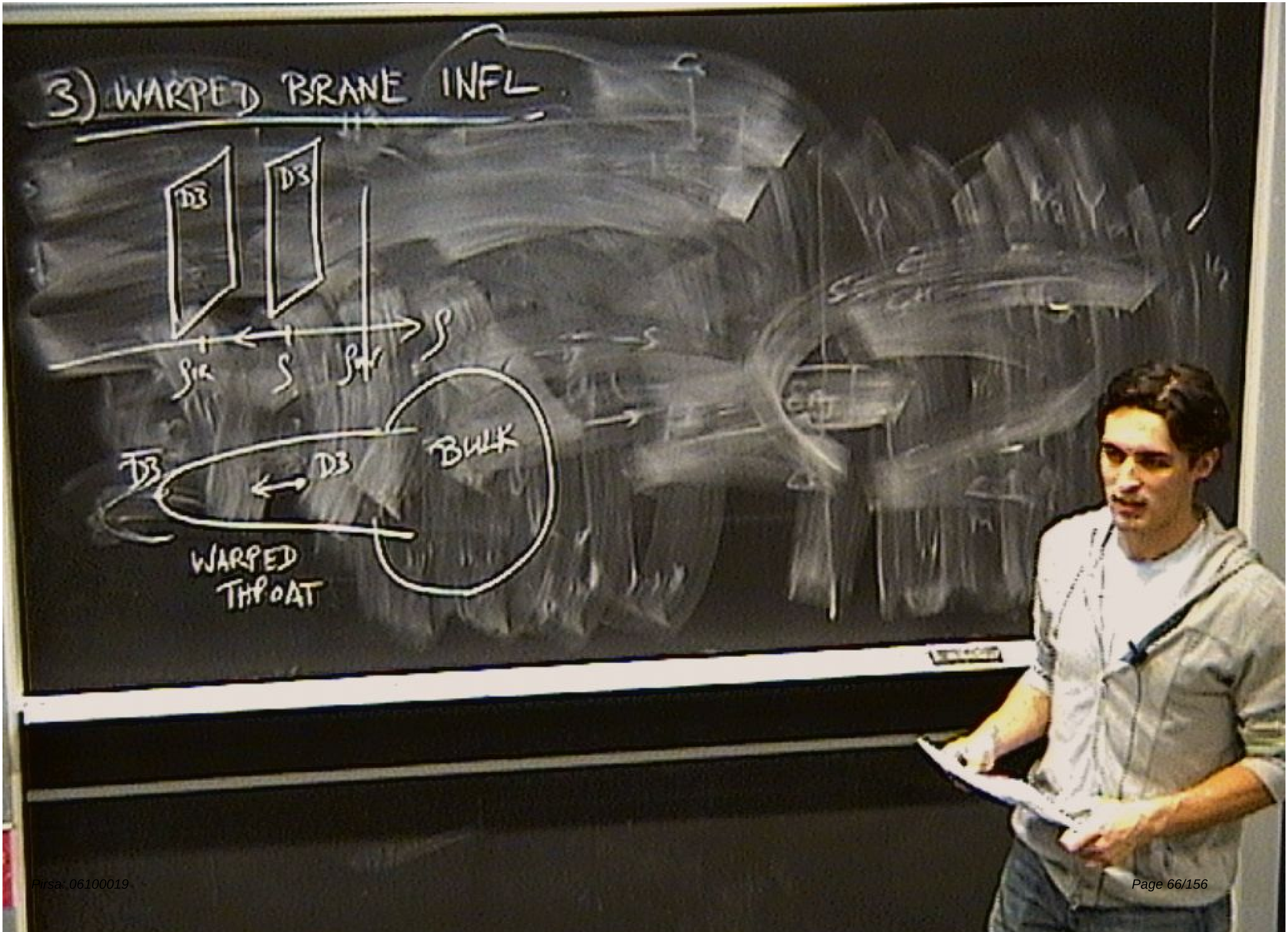
$N_{eff} = 30-60$

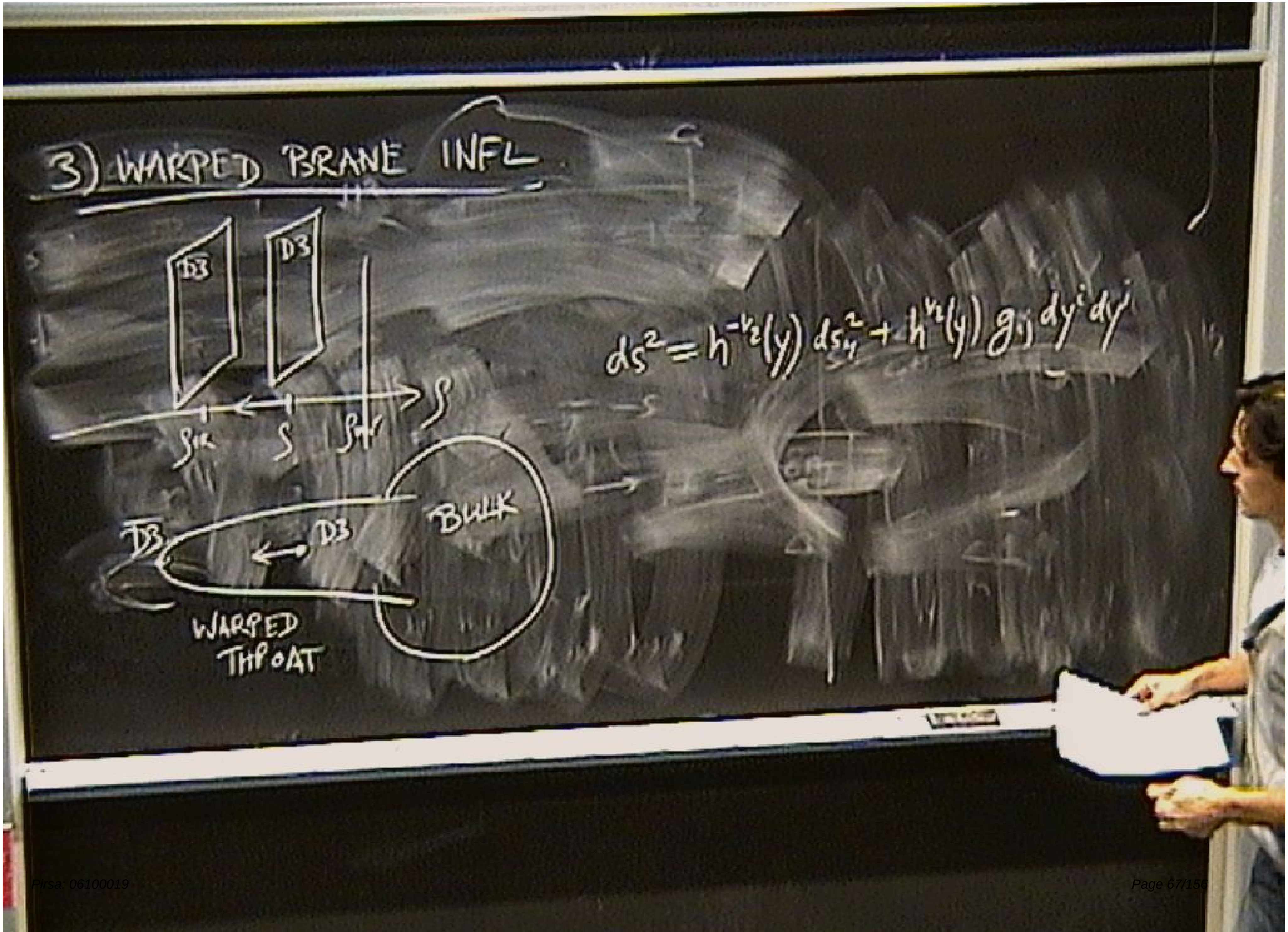
$N_{eff} = 4$

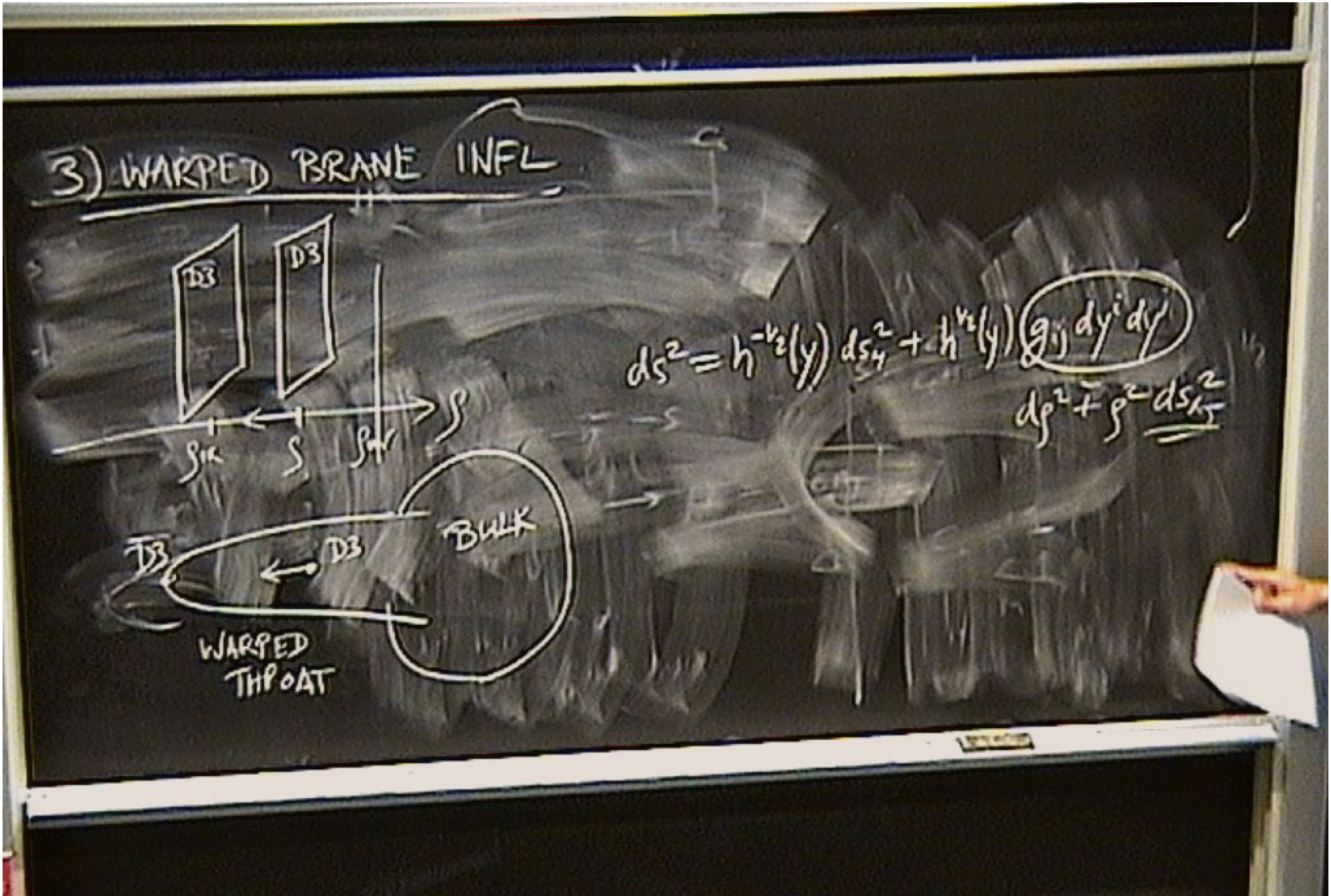

3) WARPED BRANE INFL


3) WARPED BRANE INFL
D3
D3

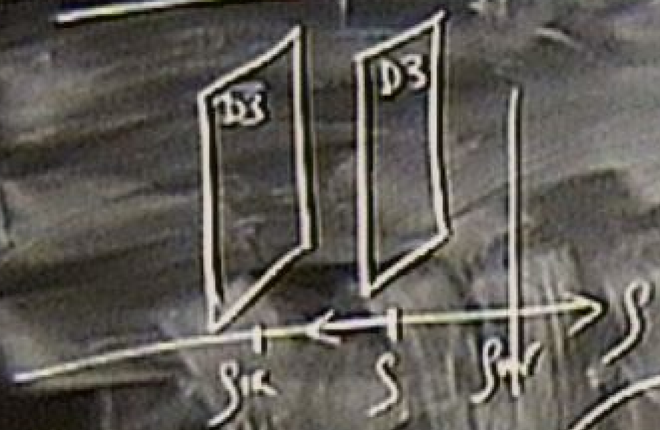

3) WARPED BRANE INFL
D3
D3


3) WARPED BRANE INFL
D3
D3
BULK
D3
D3
WARPED
THROAT


3) WARPED BRANE INFL
D3
D3
ρ_{IR}
ρ
ρ_{UV}
ρ
$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)\, g_{ij}\, dy^i dy^j$
BULK
D3
D3
WARPED
THROAT

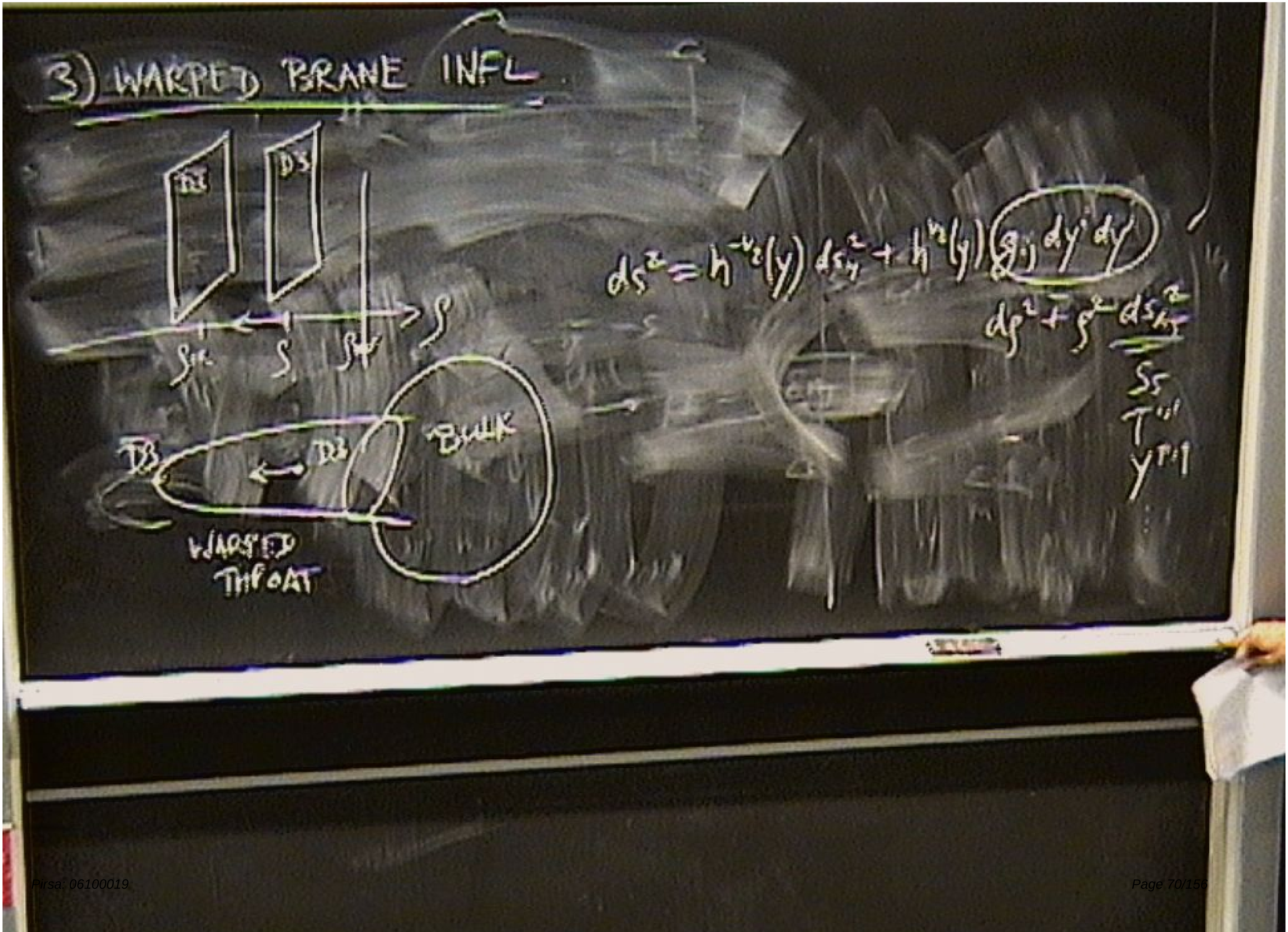

3) WARPED BRANE INFL
D3
D3
ρIR
ρ
ρUV
ρ
ds² = h^-1/2(y) ds4² + h^1/2(y) gij dy^i dy^j
dρ² + ρ² dsX5²
D3
D3
BULK
WARPED THROAT

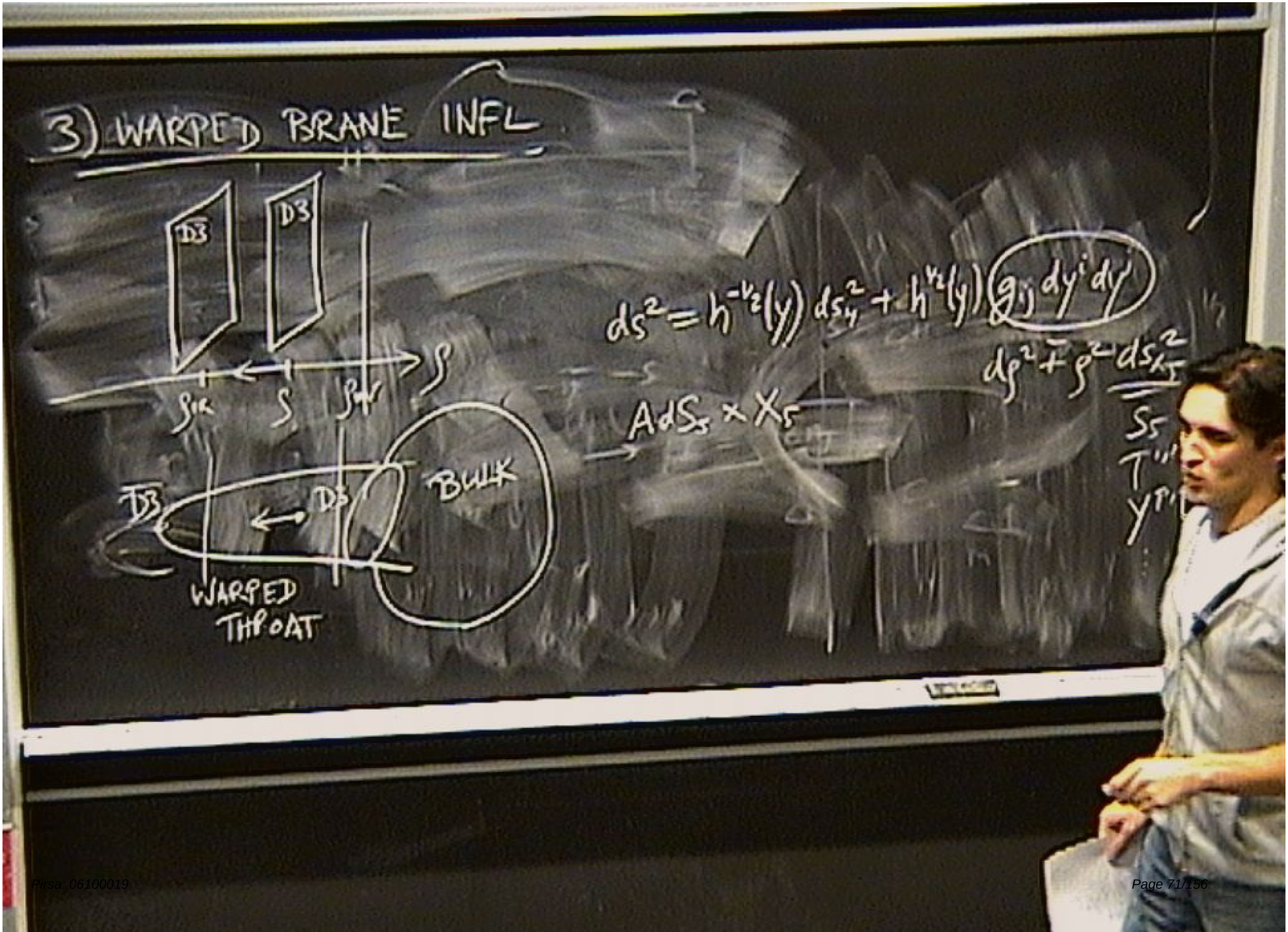
3) WARPED BRANE INFL



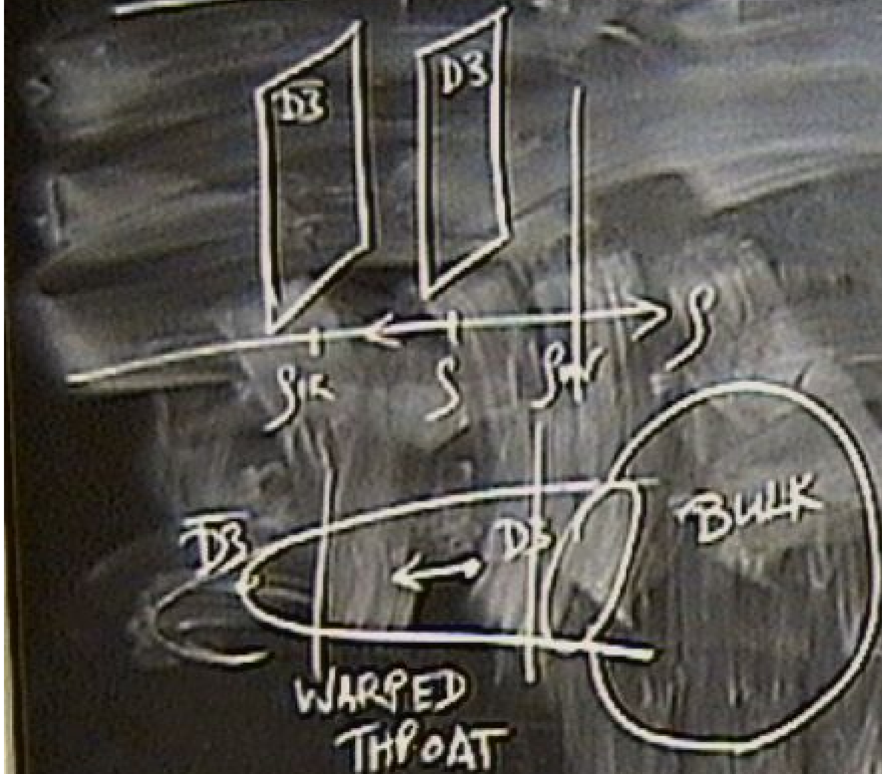
$$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)\, g_{ij}\, dy^i dy^j$$

$$d\rho^2 + \rho^2 ds_{X_5}^2$$


3) WARPED BRANE INFL
D3
D3
BULK
WARPED THROAT
ds² = h^{-1/2}(y) ds₄² + h^{1/2}(y) g_ij dy^i dy^j
dρ² + ρ² ds_{M5}²
S5
T^{1,1}
Y^{p,q}


3) WARPED BRANE INFL
D3
D3
ρ
ρIR
S
ρUV
D3
D3
BULK
WARPED THROAT
ds² = h^-1/2(y) ds4² + h^1/2(y) gij dy^i dy^j
dρ² + ρ² dsX5²
AdS5 × X5
S5

3) WARPED BRANE INFL



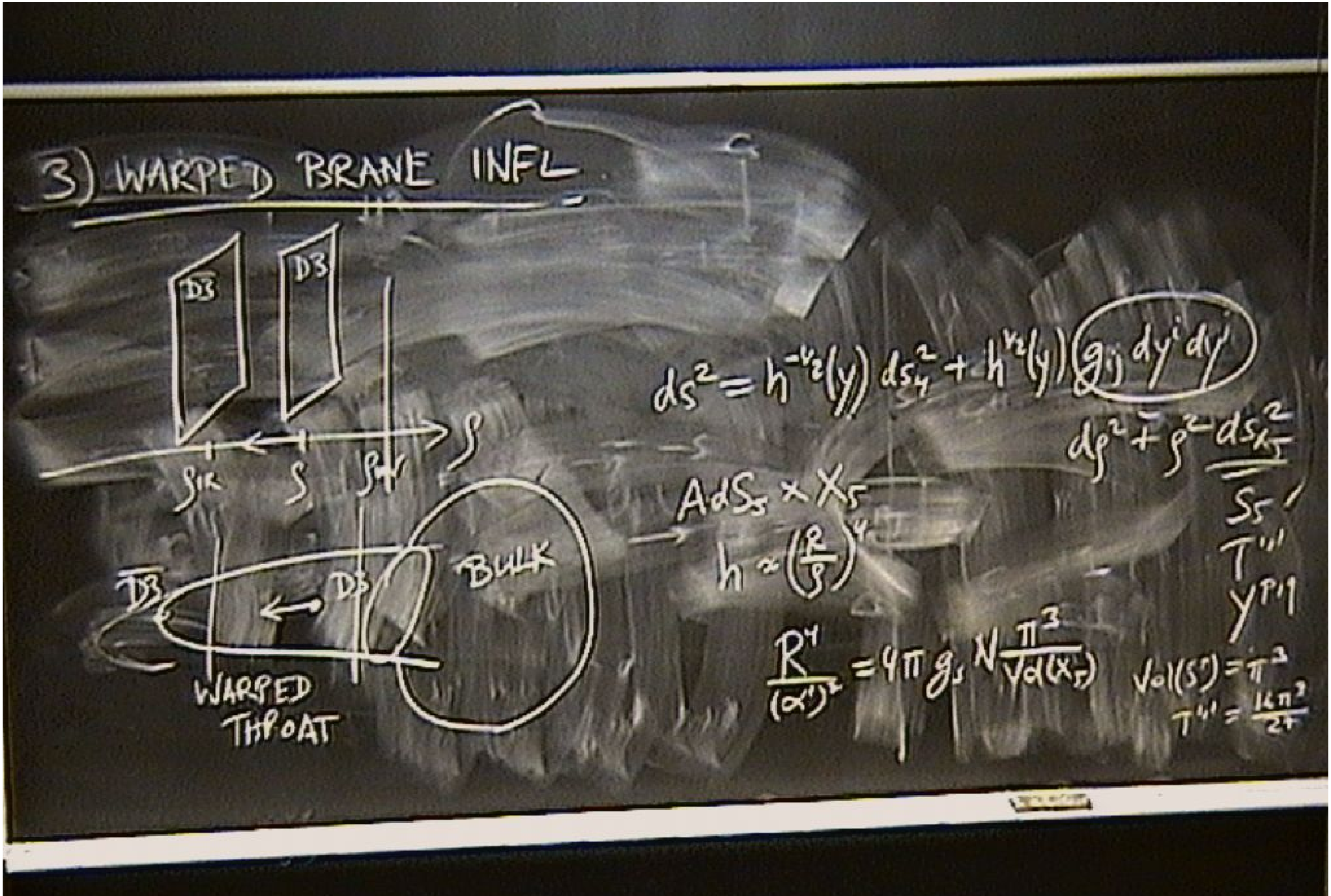
$$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)\, g_{ij}\, dy^i dy^j$$

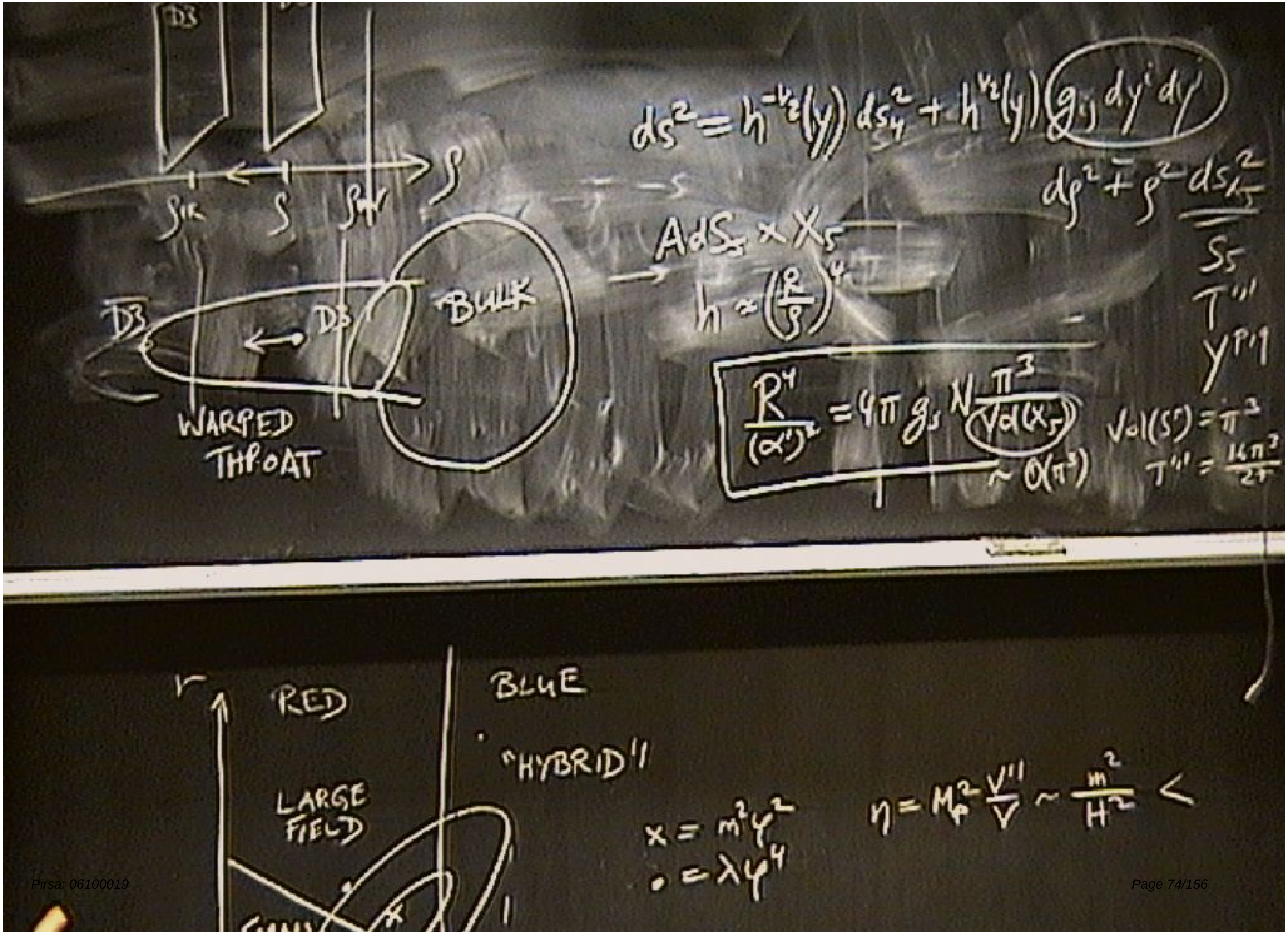
$$d\rho^2 + \rho^2 ds_{X_5}^2$$

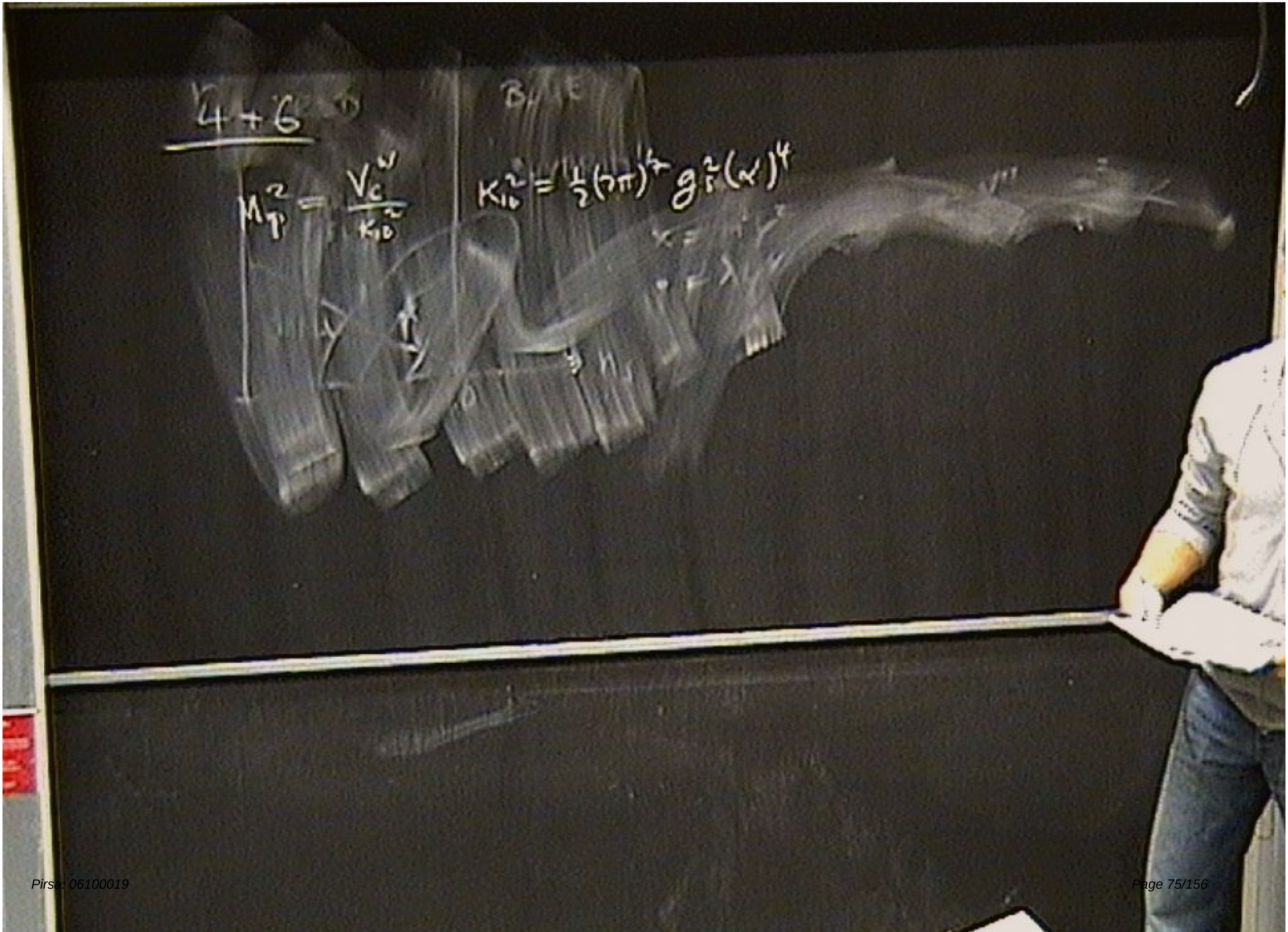
$$AdS_5 \times X_5 \rightarrow h \propto \left(\frac{R}{\rho}\right)^4$$

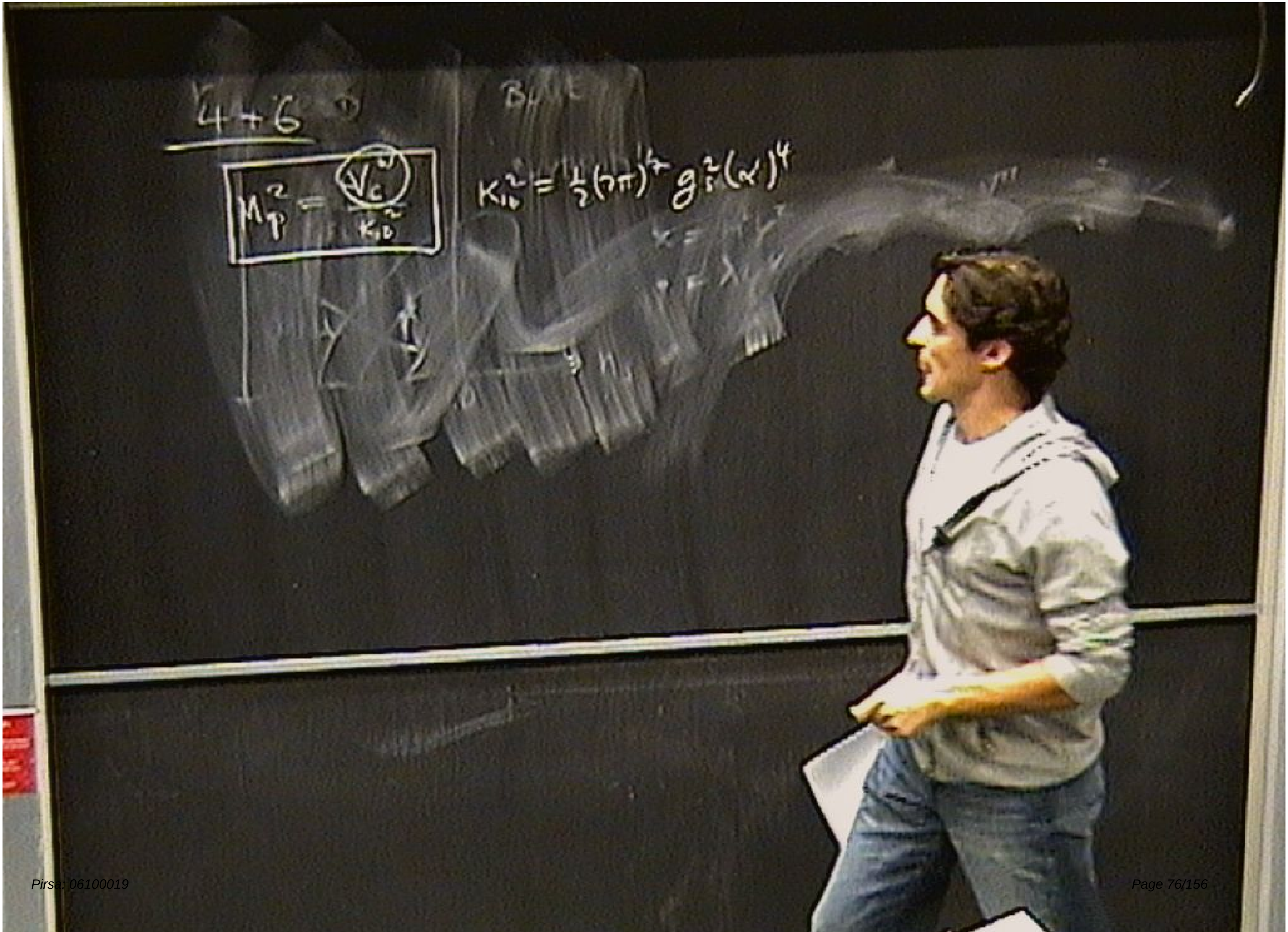
$$\frac{R^4}{(\alpha')^2} = 4\pi g_s N \frac{\pi^3}{\mathrm{Vol}(X_5)}$$

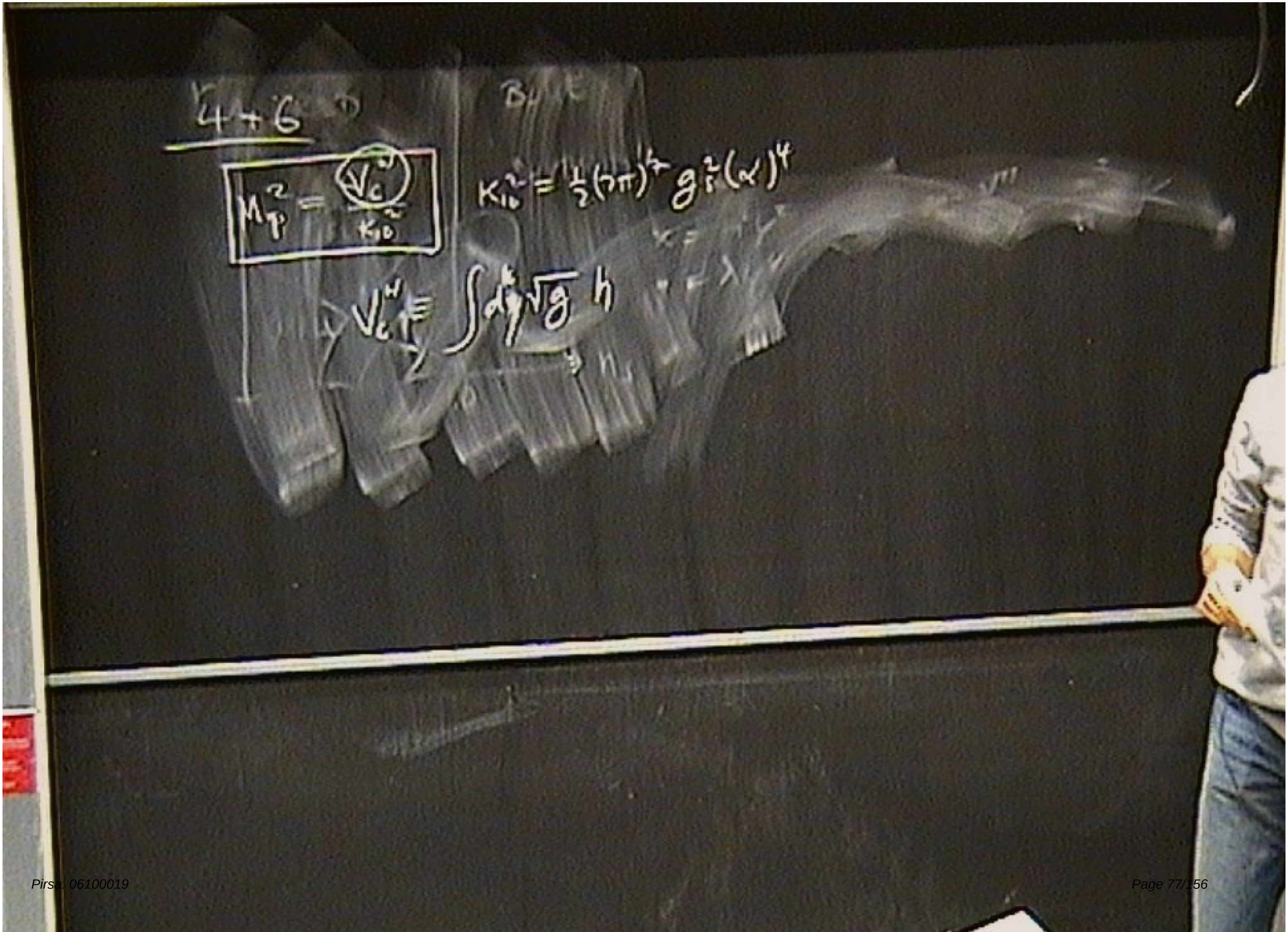
S^5
$T^{1,1}$
$Y^{p,q}$

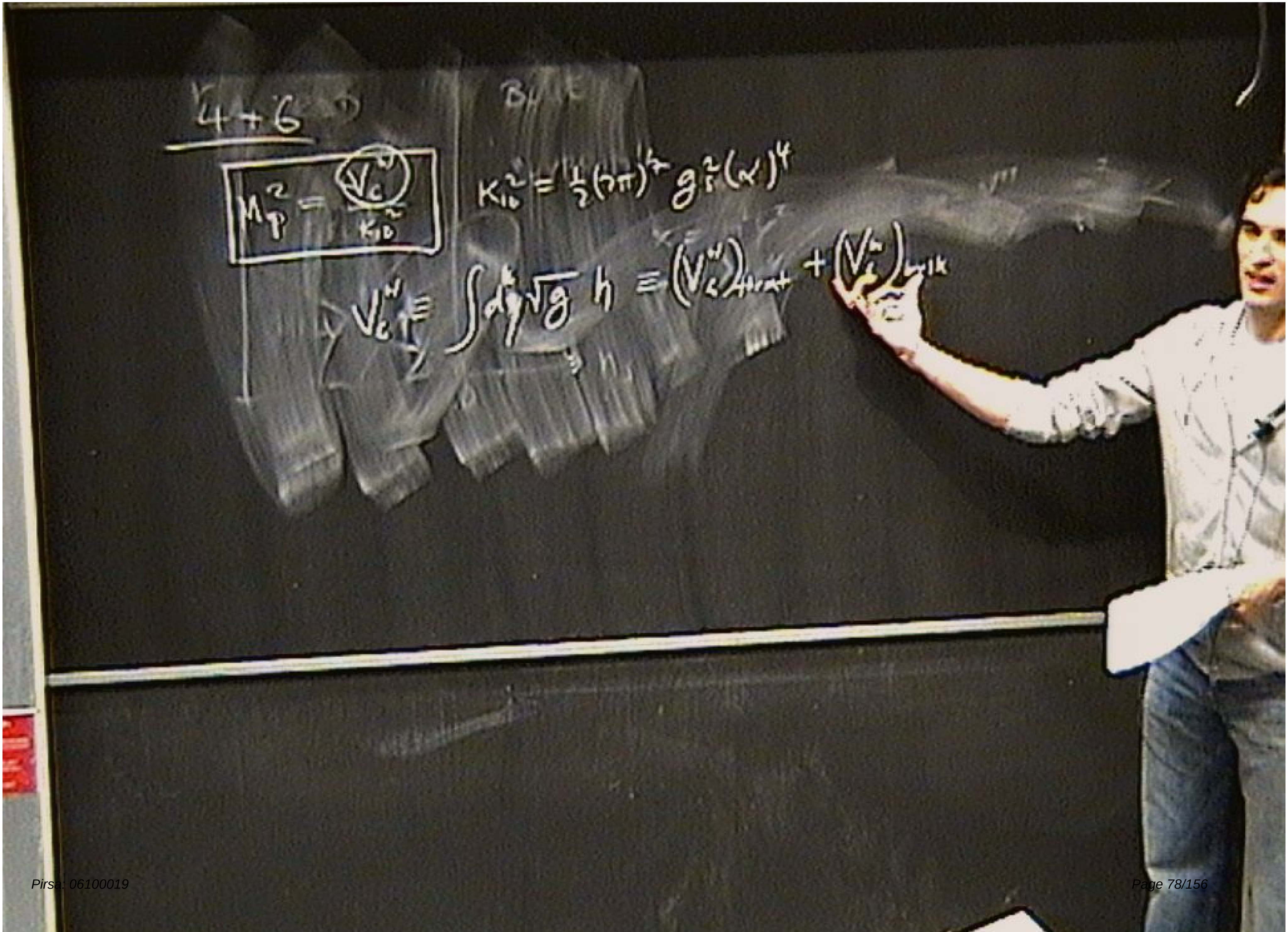

3) WARPED BRANE INFL
D3
D3
ρ_{IR}
ρ
ρ_{UV}
$\overline{D3}$
D3
BULK
WARPED THROAT
$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)\, g_{ij}\, dy^i dy^j$
$d\rho^2 + \rho^2 ds_{X_5}^2$
$AdS_5 \times X_5$
$h \approx \left(\frac{R}{\rho}\right)^4$
S_5
$T^{1,1}$
$Y^{p,q}$
$\frac{R^4}{(\alpha')^2} = 4\pi g_s N \frac{\pi^3}{Vol(X_5)}$
$Vol(S^5) = \pi^3$
$T^{1,1} = \frac{16\pi^3}{27}$


D3
ds² = h^{-1/2}(y) ds₄² + h^{1/2}(y) g_ij dy^i dy^j
dρ² + ρ² ds²
AdS₅ × X₅
h ∝ (R/ρ)⁴
S₅
T¹¹
Y^{p,q}
D3
D3
BULK
WARPED
THROAT
R⁴/(α')² = 4π g_s N π³/Vol(X₅)
~ O(π³)
Vol(S⁵) = π³
T¹¹ = 16π³/27
r
RED
BLUE
"HYBRID"
LARGE
FIELD
x = m²φ²
= λφ⁴
η = M_p² V''/V ~ m²/H² <


4 + 6


4+6
B.A.
$M_p^2 = \frac{V_c}{K_{10}^2}$
$K_{10}^2 = \frac{1}{2}(7\pi)^{1/2} g_s^2 (\alpha')^4$


4 + 6
M_p² = V_6^w / K_10²
K_10² = ½(2π)^7 g_s²(α')^4
V_6^w = ∫d^6y √g h


4+6
M_p^2 = V_6^w / κ_10^2
κ_10^2 = 1/2 (7π)^7 g_s^2 (α')^4
V_6^w ≡ ∫ d^6y √g h = (V_6^w)_throat + (V_6^w)_bulk

4 + 6

$$\boxed{M_p^2 = \frac{V_6^w}{\kappa_{10}^2}}$$

$$\kappa_{10}^2 = \frac{1}{2}(2\pi)^7 g_s^2 (\alpha')^4$$

$$V_6^w \equiv \int d^6y \sqrt{g}\, h = (V_6^w)_{throat} + (V_6^w)_{bulk} > (V_6^w)_{throat}$$

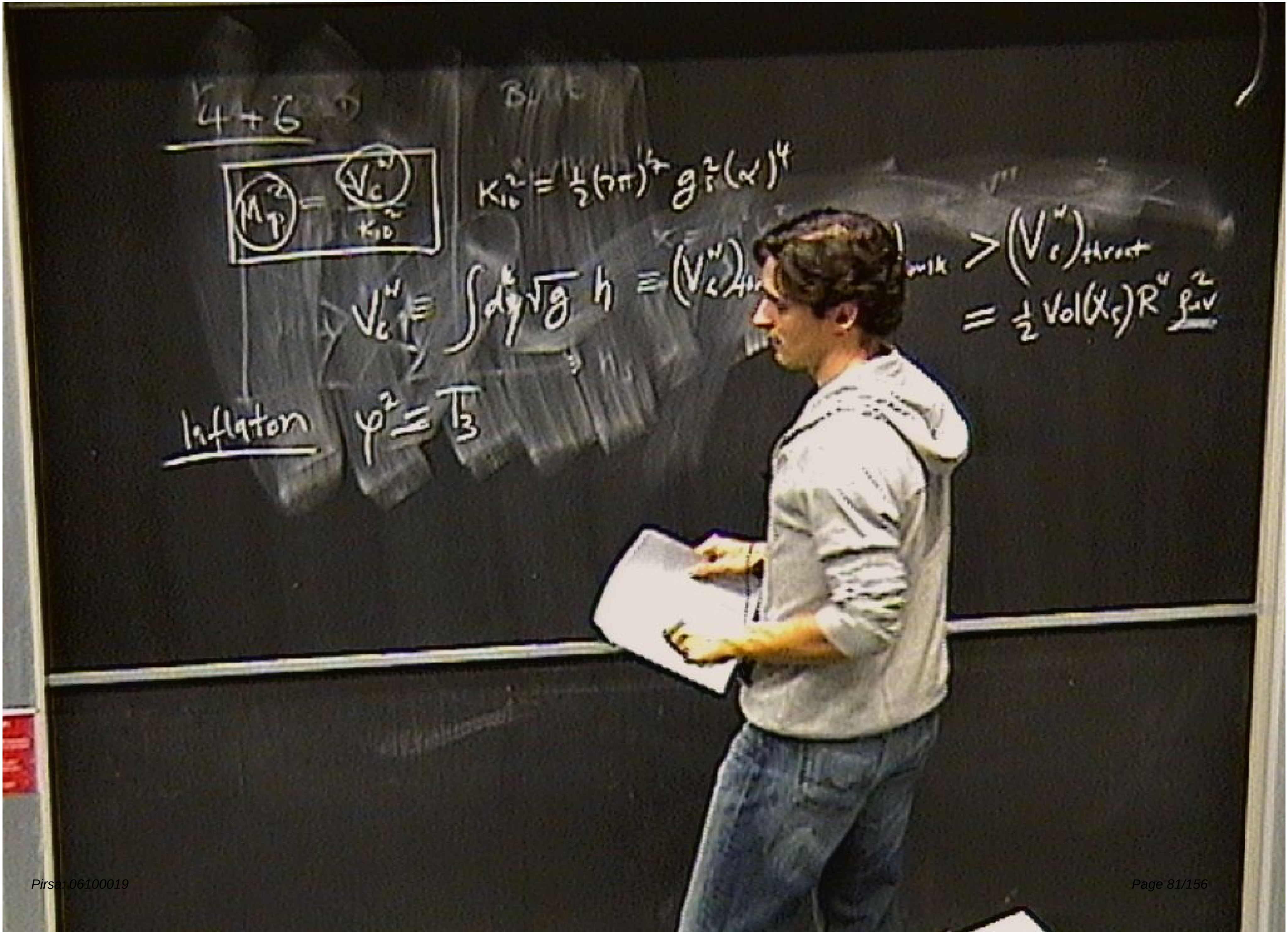
4 + 6

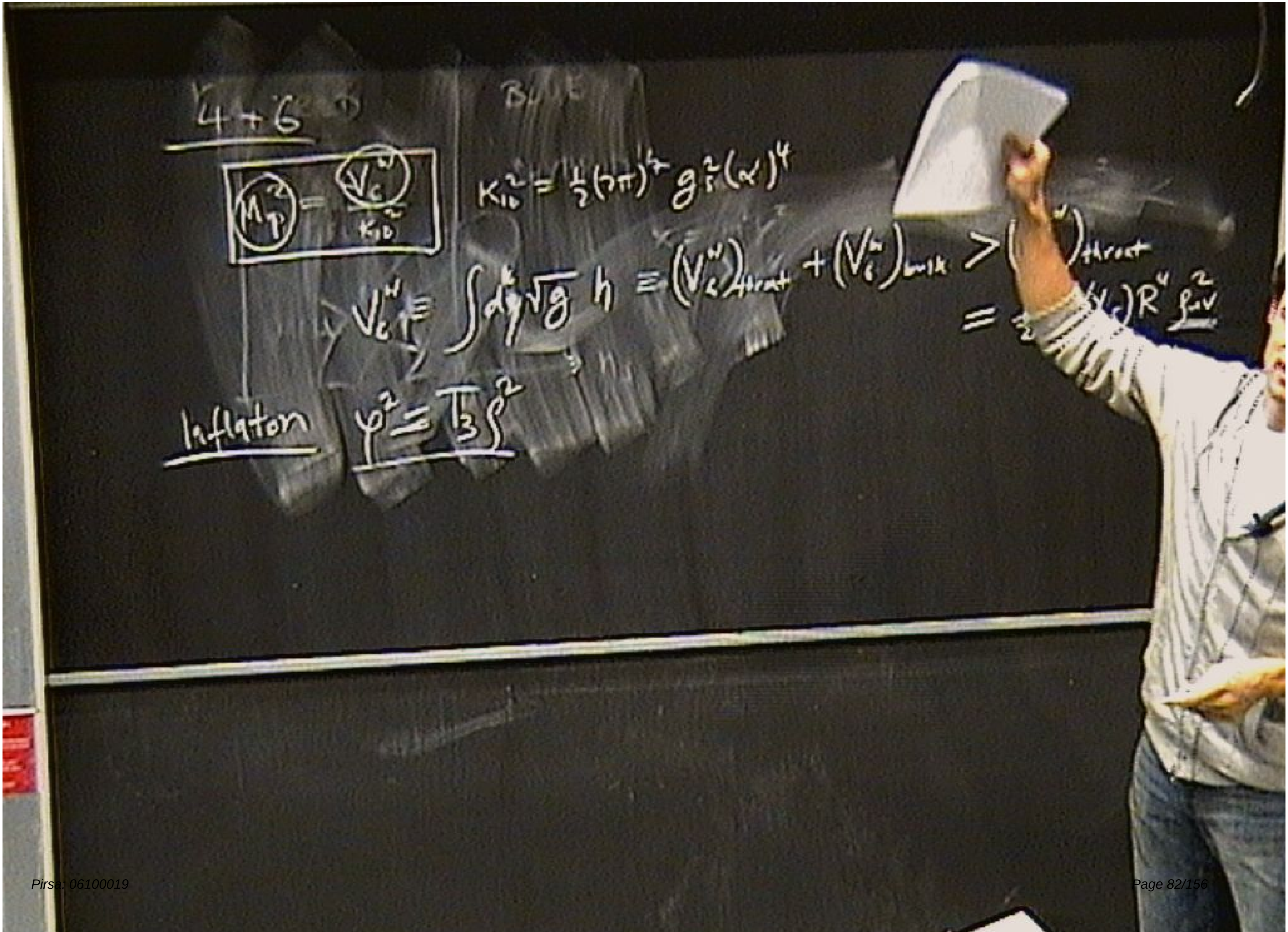
$$\boxed{M_p^2 = \frac{V_6^w}{\kappa_{10}^2}}$$

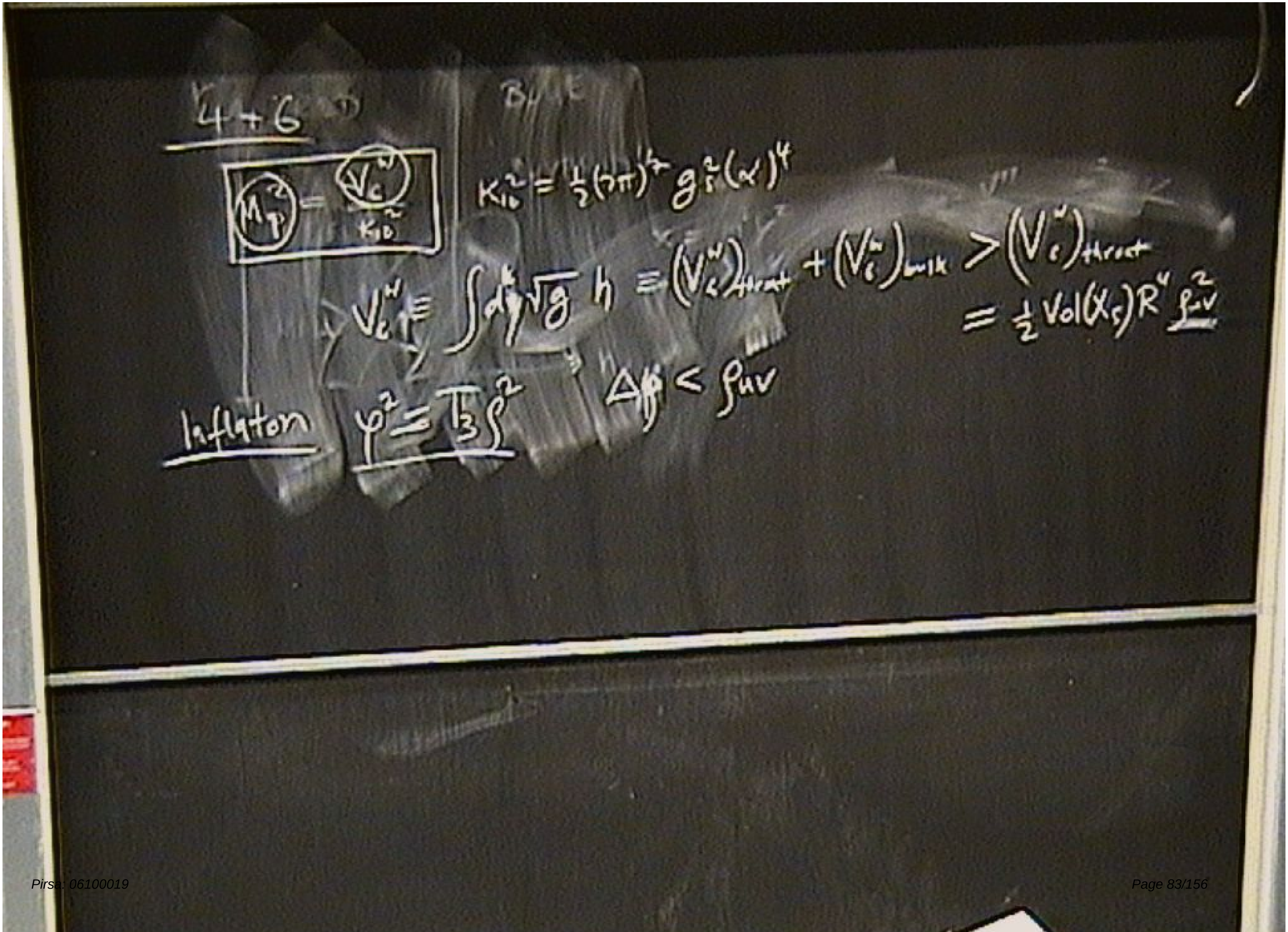
$$\kappa_{10}^2 = \frac{1}{2}(2\pi)^7 g_s^2 (\alpha')^4$$

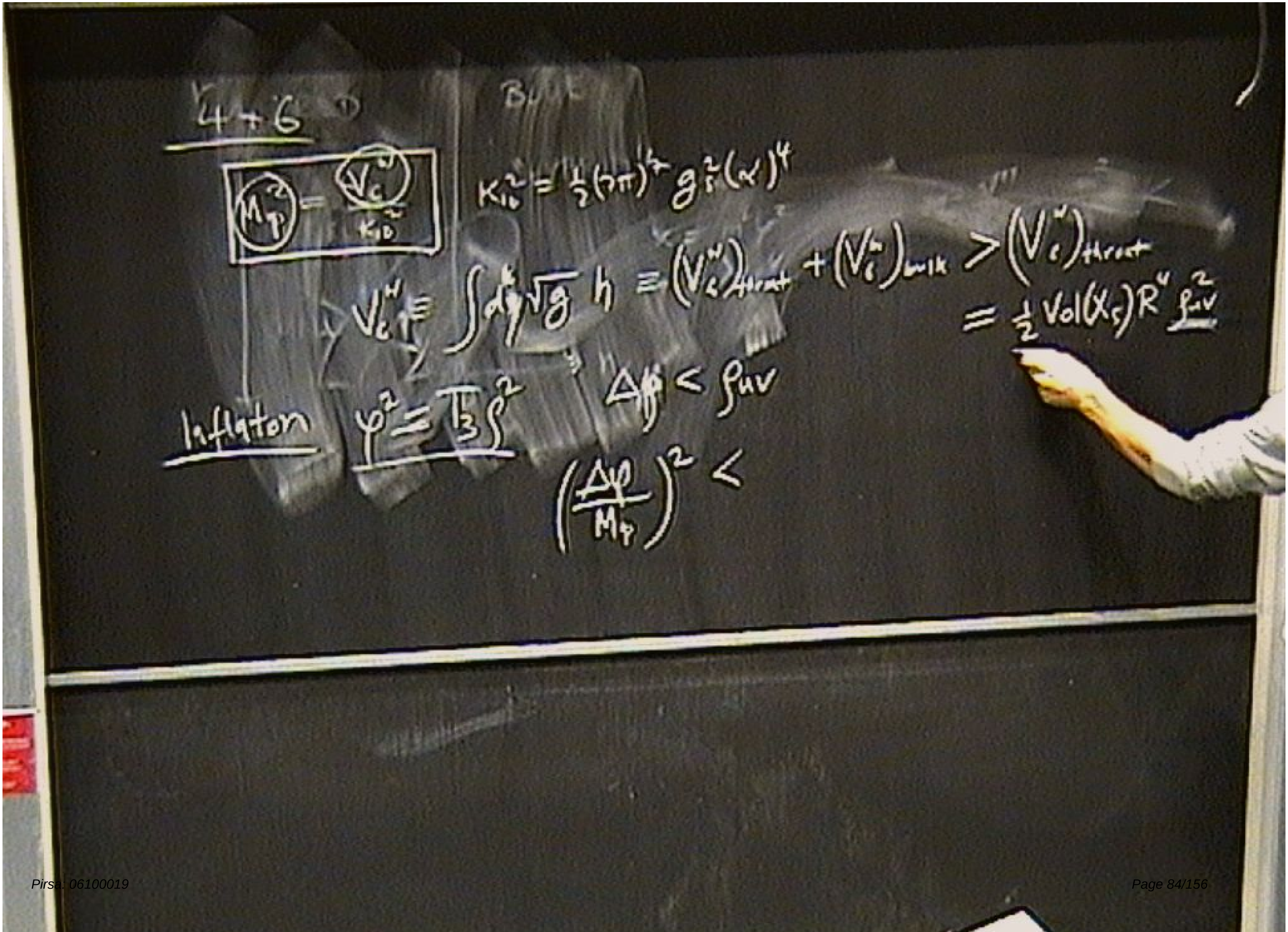
$$V_6^w \equiv \int d^6y \sqrt{g}\, h = (V_6^w)_{throat} + (V_6^w)_{bulk} > (V_6^w)_{throat}$$

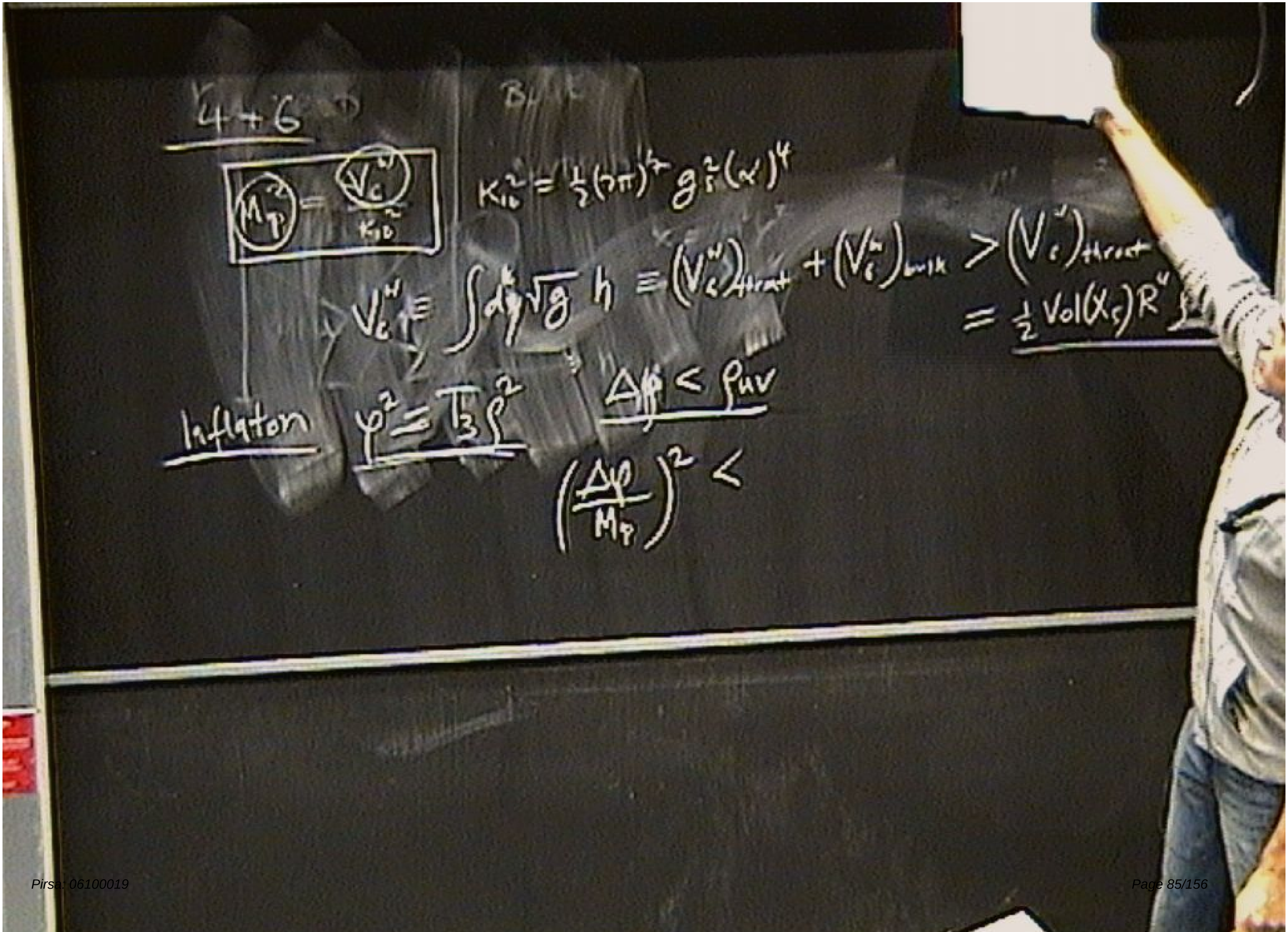
$$= \frac{1}{2} \mathrm{Vol}(X_5) R^4 \rho_{uv}^2$$

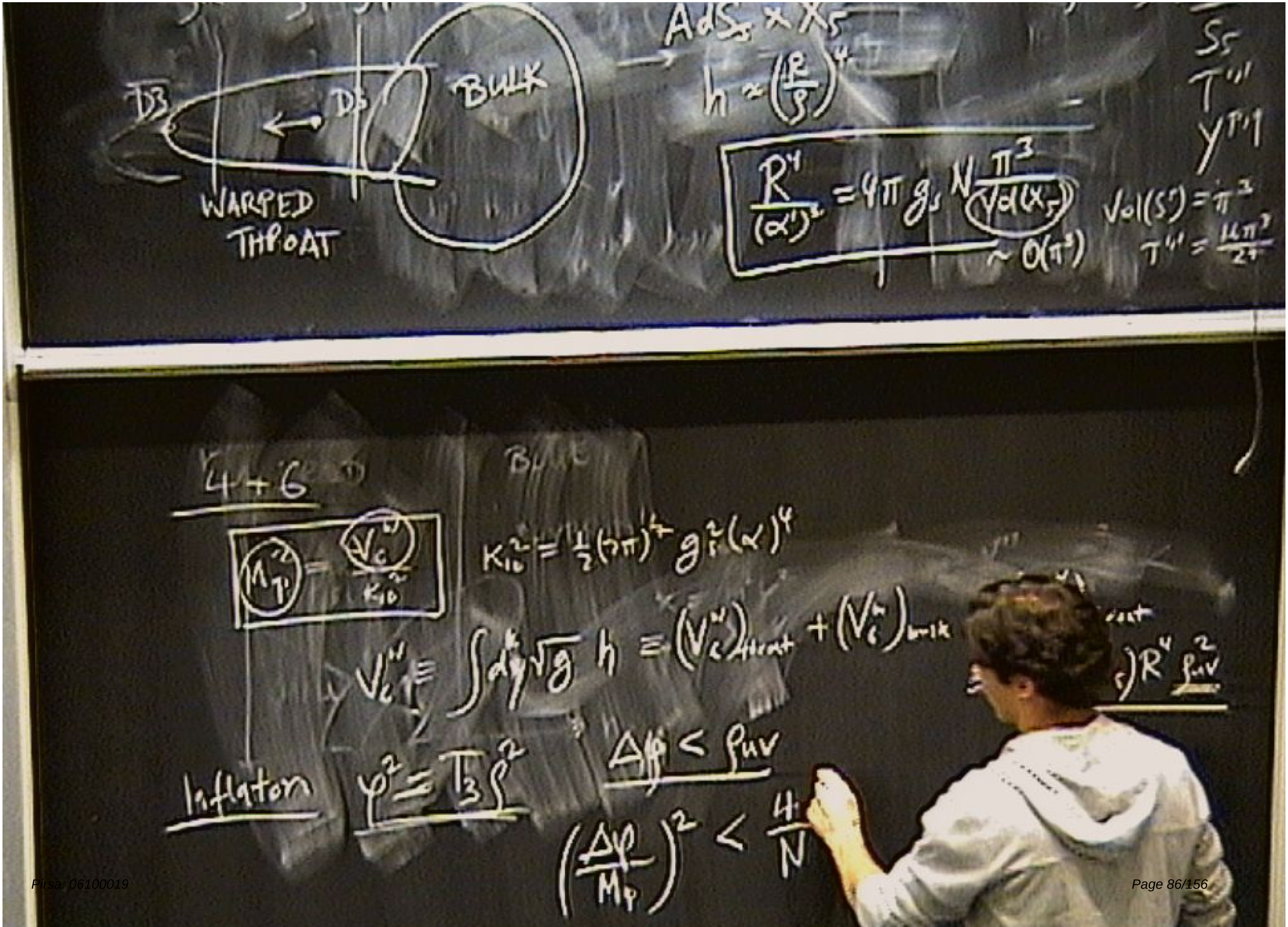

4+6
Inflaton


4 + 6
Inflaton

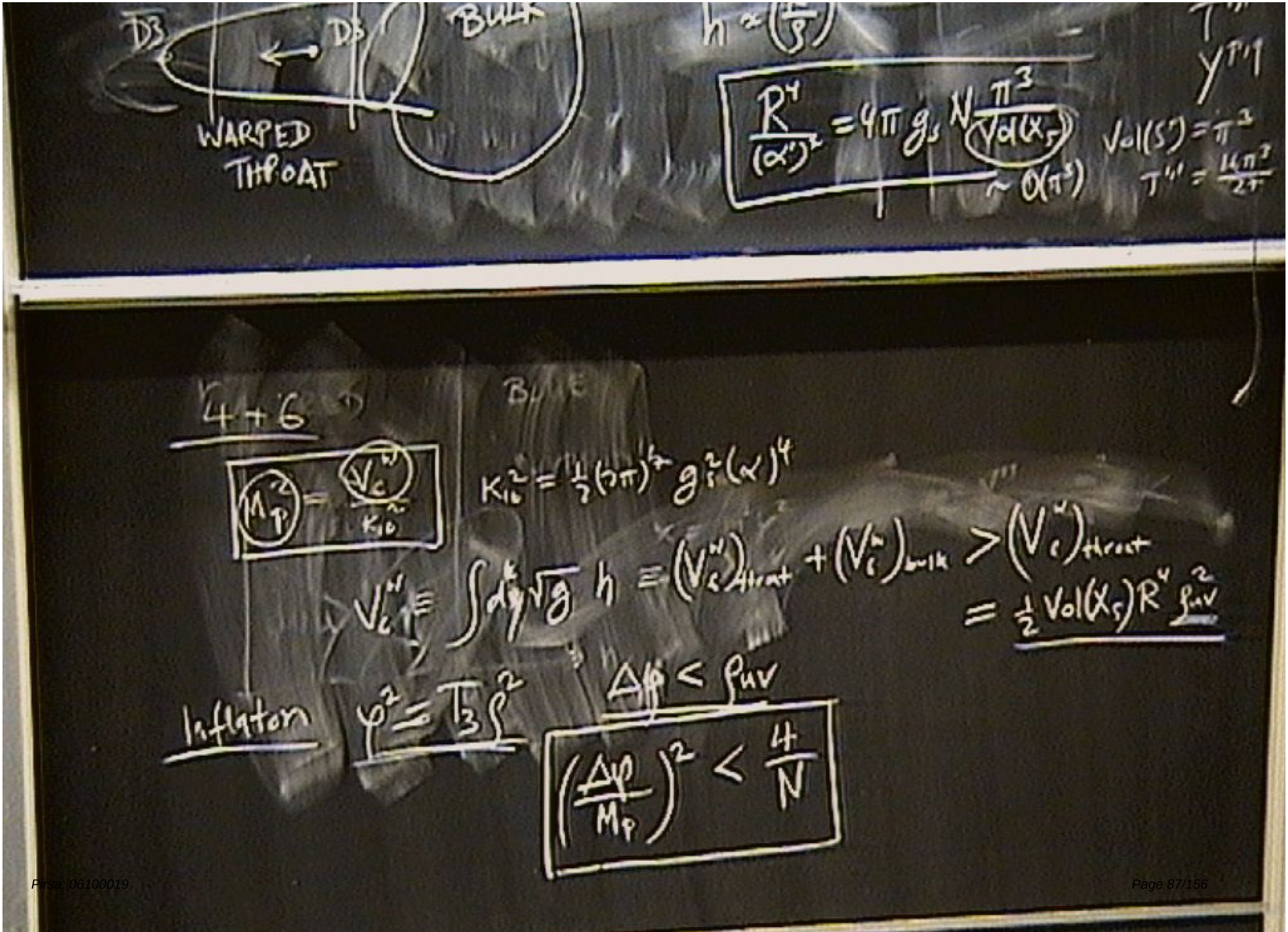

4+6
$M_p^2 = \frac{V_6^w}{\kappa_{10}^2}$
$\kappa_{10}^2 = \frac{1}{2}(2\pi)^7 g_s^2 (\alpha')^4$
$V_6^w \equiv \int d^6y \sqrt{g}\, h = (V_6^w)_{throat} + (V_6^w)_{bulk} > (V_6^w)_{throat}$
$= \frac{1}{2} \mathrm{Vol}(X_5) R^4 \rho_{UV}^2$
$\Delta\rho < \rho_{UV}$
Inflaton
$\varphi^2 = T_3 \rho^2$

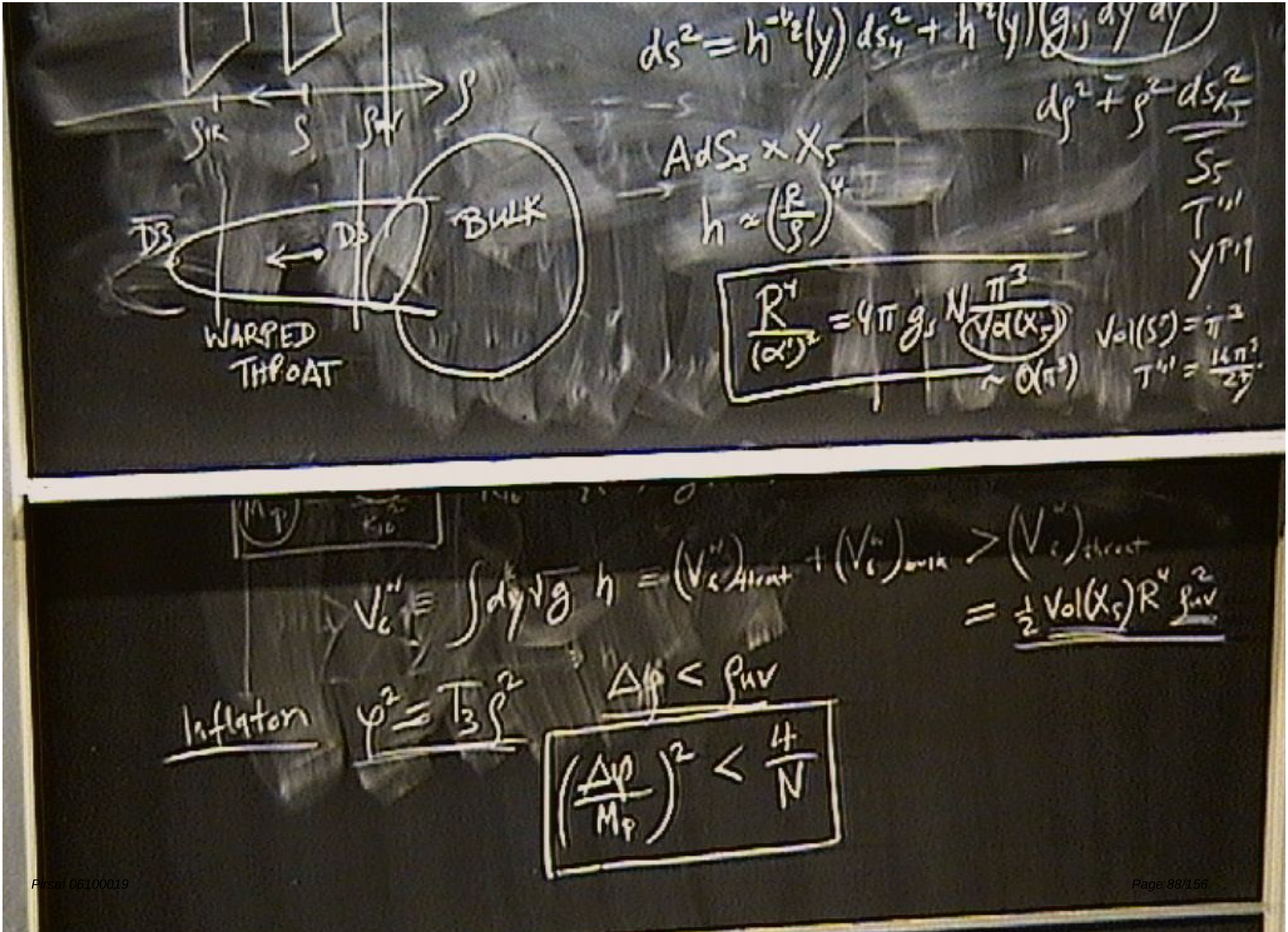

4+6
$M_p^2 = \frac{V_6^w}{\kappa_{10}^2}$
$\kappa_{10}^2 = \frac{1}{2}(7\pi)^{?} g_s^2 (\alpha')^4$
$V_6^w \equiv \int d^6y \sqrt{g}\, h = (V_6^w)_{throat} + (V_6^w)_{bulk} > (V_6^w)_{throat}$
$= \frac{1}{2} Vol(X_5) R^4 \rho_{uv}^2$
$\Delta\rho < \rho_{uv}$
Inflaton $\varphi^2 = T_3 \rho^2$
$\left(\frac{\Delta\varphi}{M_p}\right)^2 <$


4+6
Bulk
Inflaton
Δφ < φ_UV
= ½ Vol(X_5) R^4

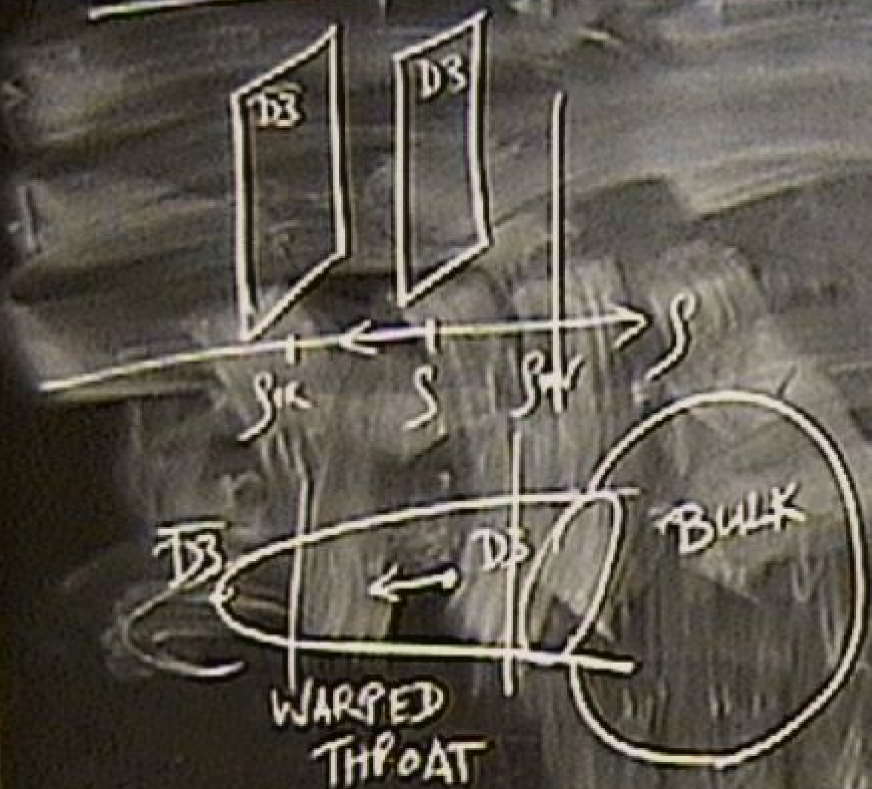


AdS5 x X5
BULK
D3
D3
WARPED THROAT
Vol(S5) = π3
4+6
Inflaton


D3
D3
BULK
WARPED
THROAT
R^4/(α')^2 = 4π g_s N π^3/Vol(X_5)
~ O(π^3)
Vol(S^5) = π^3
4+6
M_p^2 = V_6^w / κ_10^2
κ_10^2 = ½(2π)^7 g_s^2 (α')^4
V_6^w ≡ ∫ d^6y √g h = (V_6^w)_throat + (V_6^w)_bulk > (V_6^w)_throat
= ½ Vol(X_5) R^4 ρ_UV^2
Inflaton
φ^2 = T_3 ρ^2
Δρ < ρ_UV
(Δφ/M_p)^2 < 4/N


$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)(g_{ij}\, dy^i dy^j)$
$d\rho^2 + \rho^2 ds_{X_5}^2$
S_5
$T^{1,1}$
$Y^{p,q}$
$AdS_5 \times X_5$
$h \propto \left(\frac{R}{\rho}\right)^4$
$\frac{R^4}{(\alpha')^2} = 4\pi g_s N \frac{\pi^3}{Vol(X_5)}$
$\sim O(\pi^3)$
$Vol(S^5) = \pi^3$
$T^{1,1} = \frac{16\pi^3}{27}$
BULK
$\overline{D3}$
D3
WARPED THROAT
$V_6^{\text{''}} \equiv \int d^6y \sqrt{g}\, h = (V_6^{\text{''}})_{throat} + (V_6^{\text{''}})_{bulk} > (V_6^{\text{''}})_{throat}$
$= \frac{1}{2} Vol(X_5) R^4 \rho_{UV}^2$
Inflaton
$\varphi^2 = T_3 \rho^2$
$\Delta\varphi < \rho_{UV}$
$\left(\frac{\Delta\varphi}{M_P}\right)^2 < \frac{4}{N}$

3) WARPED BRANE INFL



$$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)\, g_{ij}\, dy^i dy^j$$

$$d\rho^2 + \rho^2 ds_{X_5}^2$$

$AdS_5 \times X_5$

S_5

$T^{1,1}$

$Y^{p,q}$

$h \approx \left(\frac{R}{\rho}\right)^4$ $\quad N = MK$

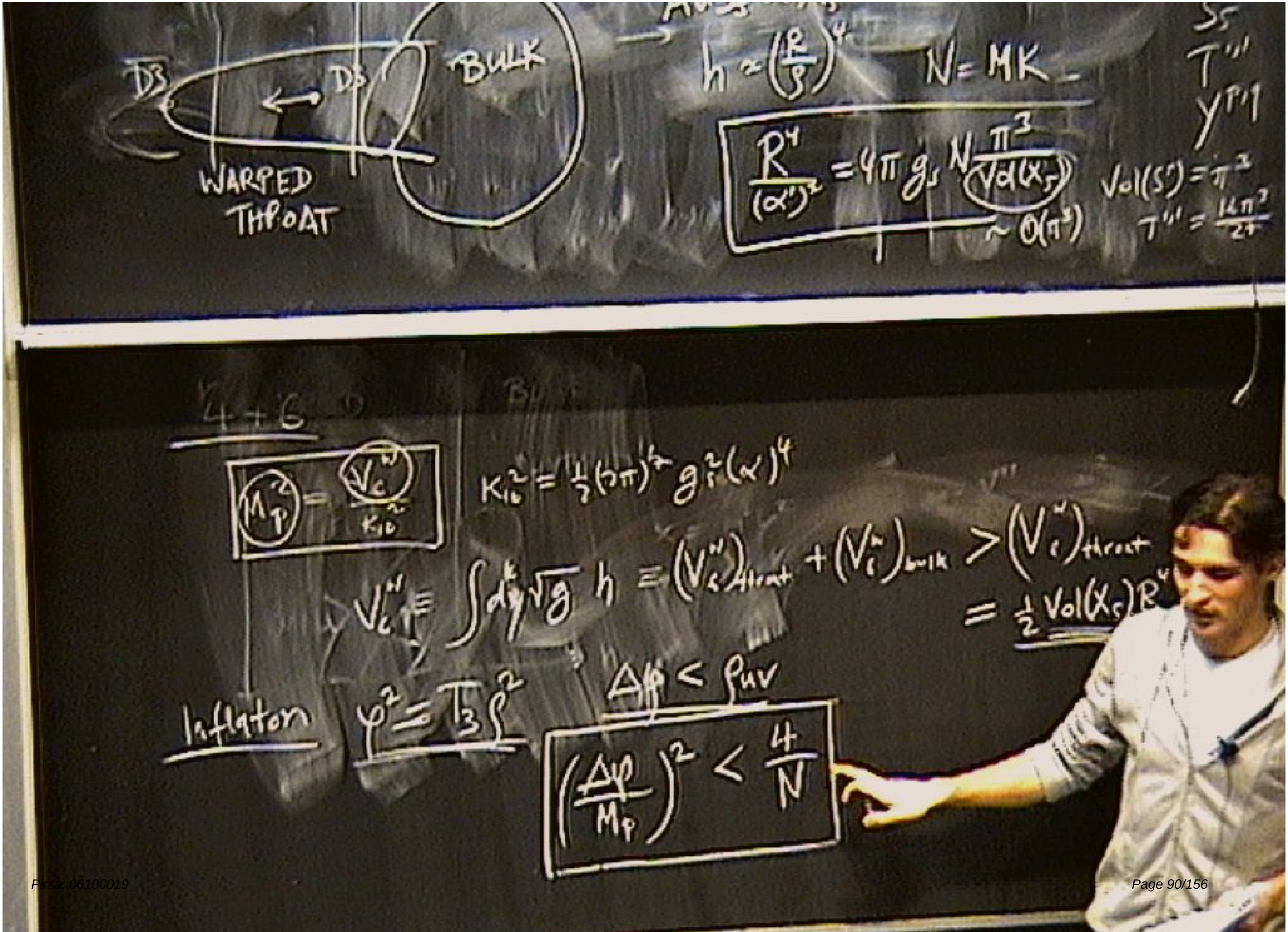
$$\boxed{\frac{R^4}{(\alpha')^2} = 4\pi g_s N \frac{\pi^3}{\mathrm{Vol}(X_5)}}$$

$\sim O(\pi^3)$

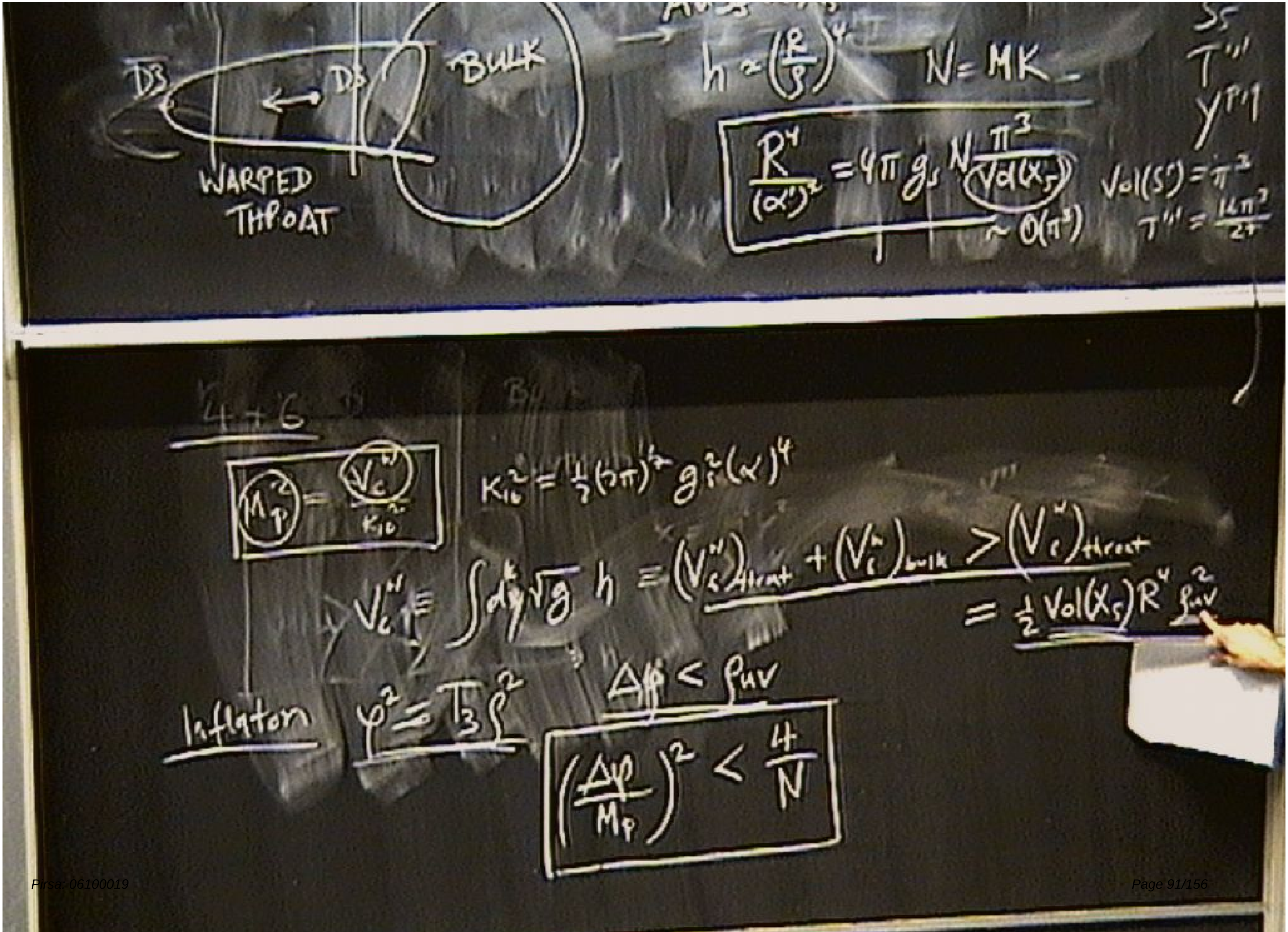
$\mathrm{Vol}(S^5) = \pi^3$

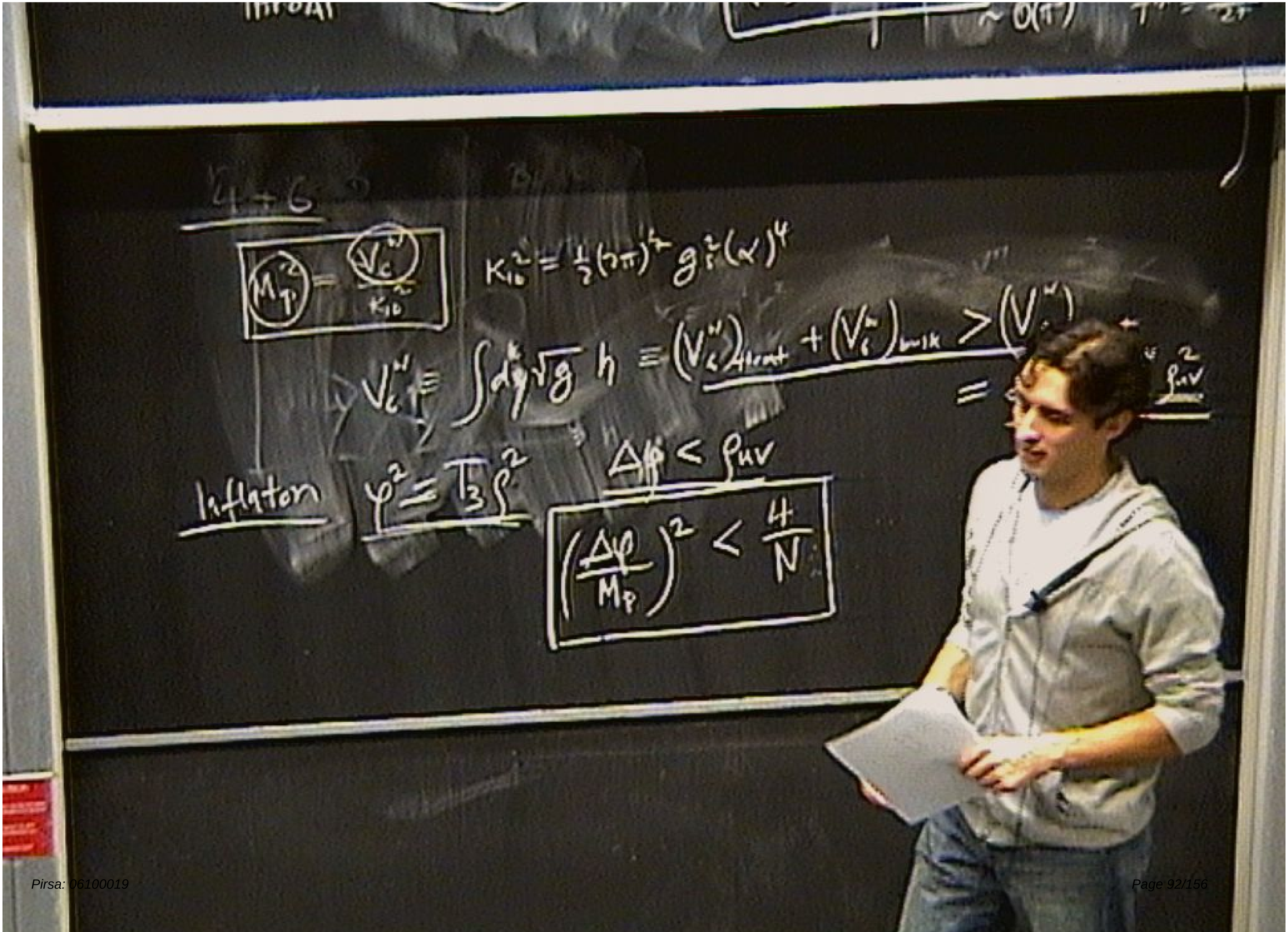
$T^{1,1} = \frac{16\pi^3}{27}$

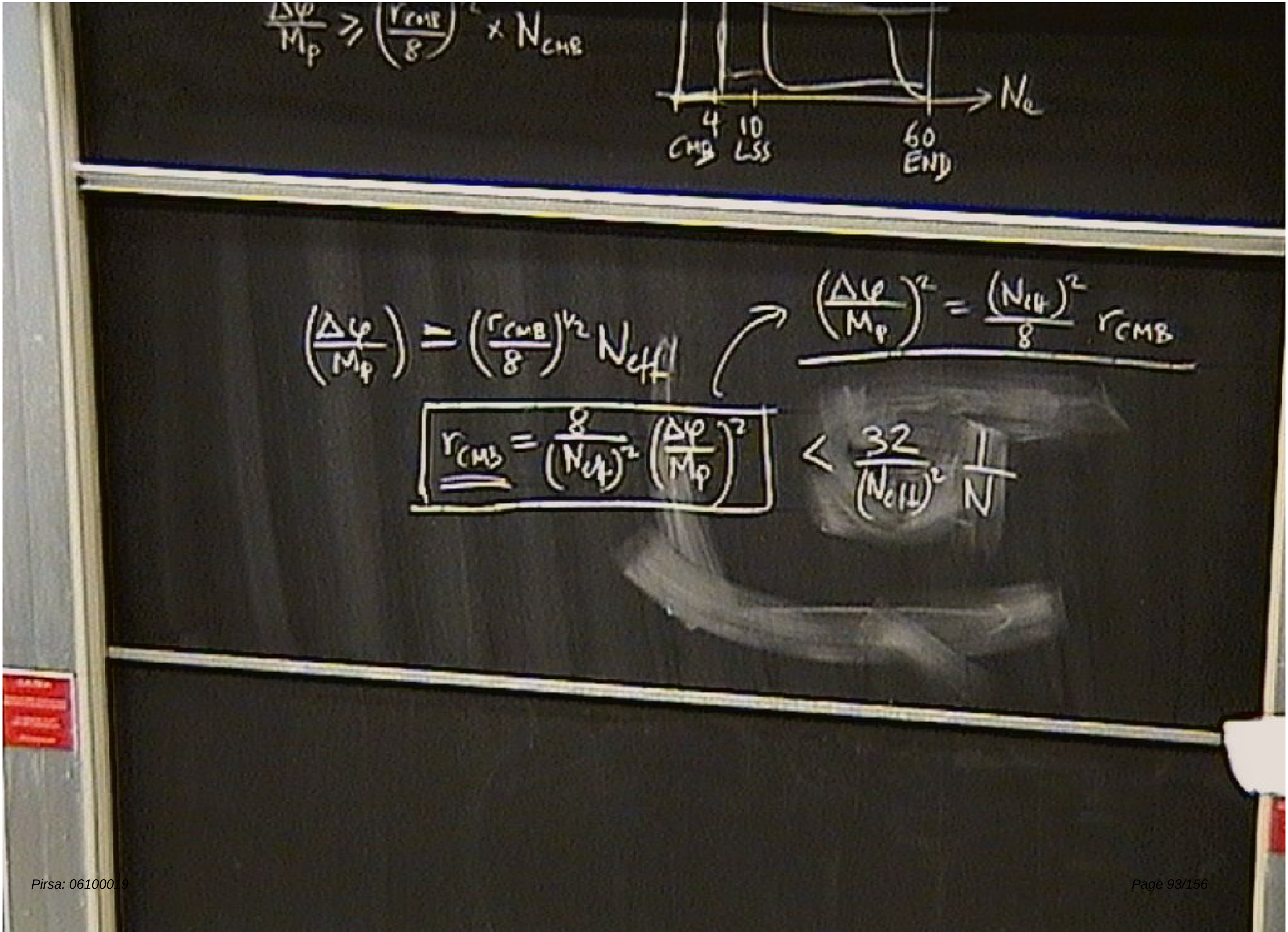
$\left(\frac{\Delta\phi}{M_p}\right) < N$

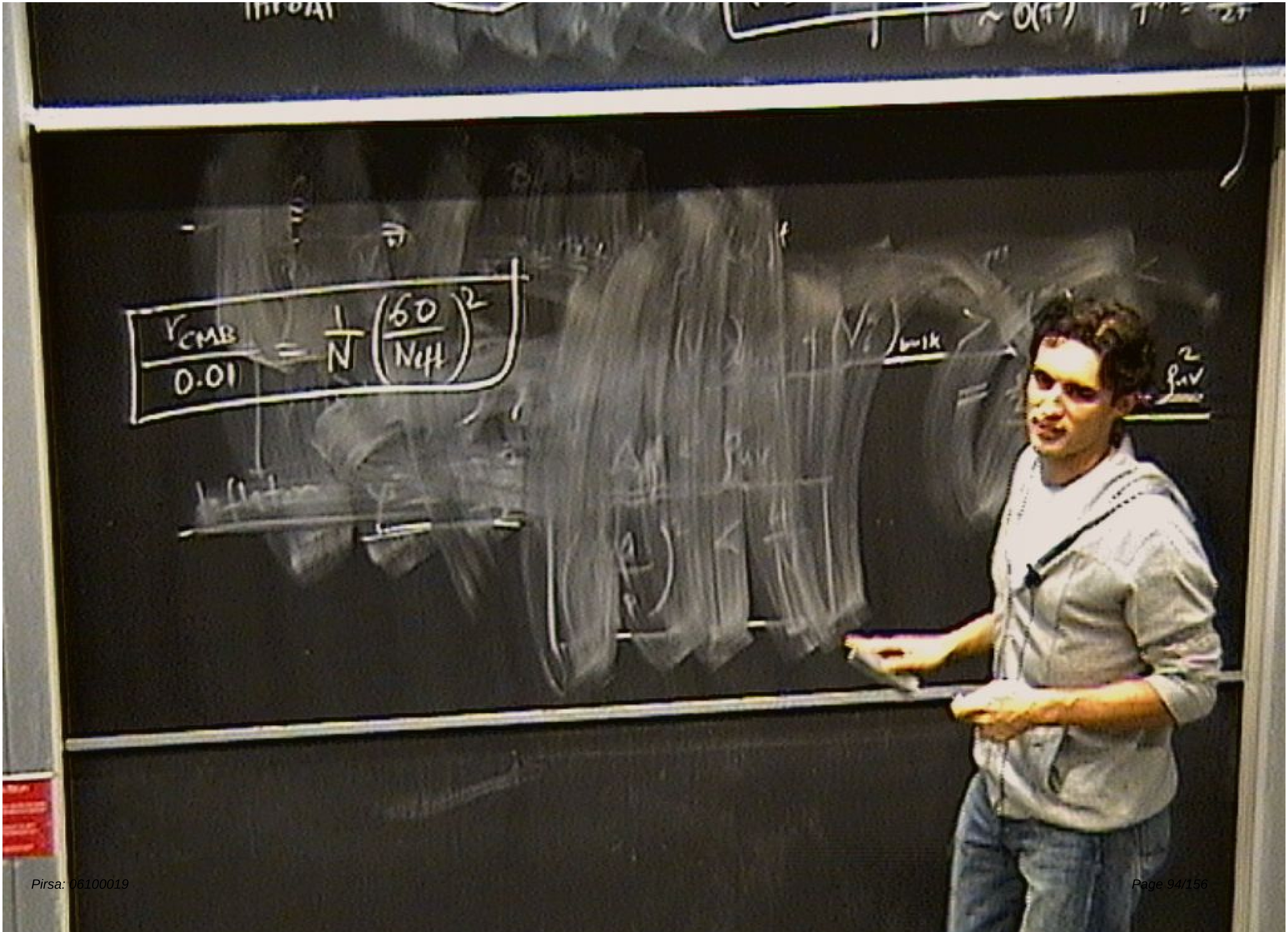


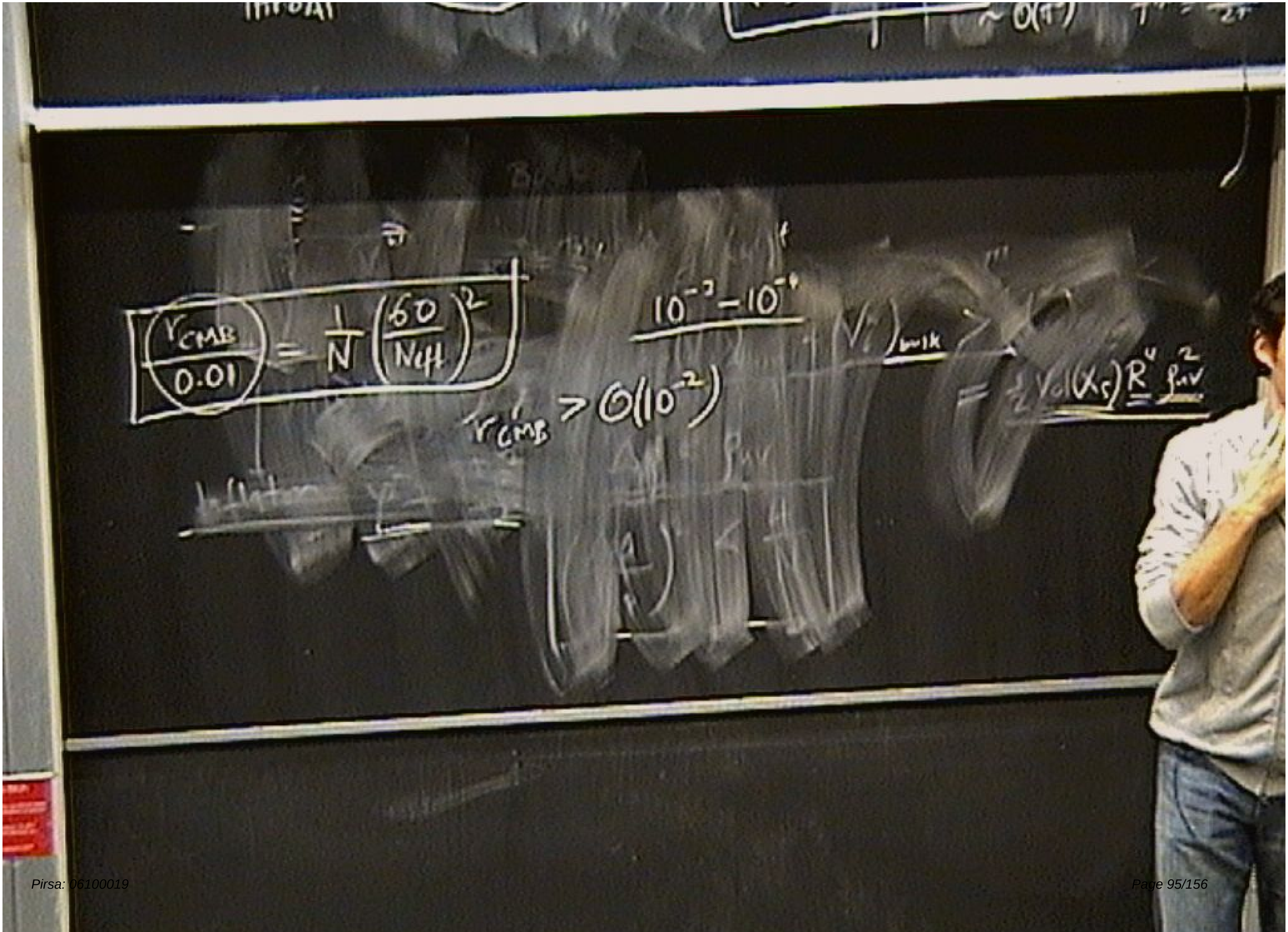
D3
D3
BULK
WARPED THROAT
N = MK
Vol(S⁵) = π³
~ O(π³)
Inflaton
Δφ < ρ_UV

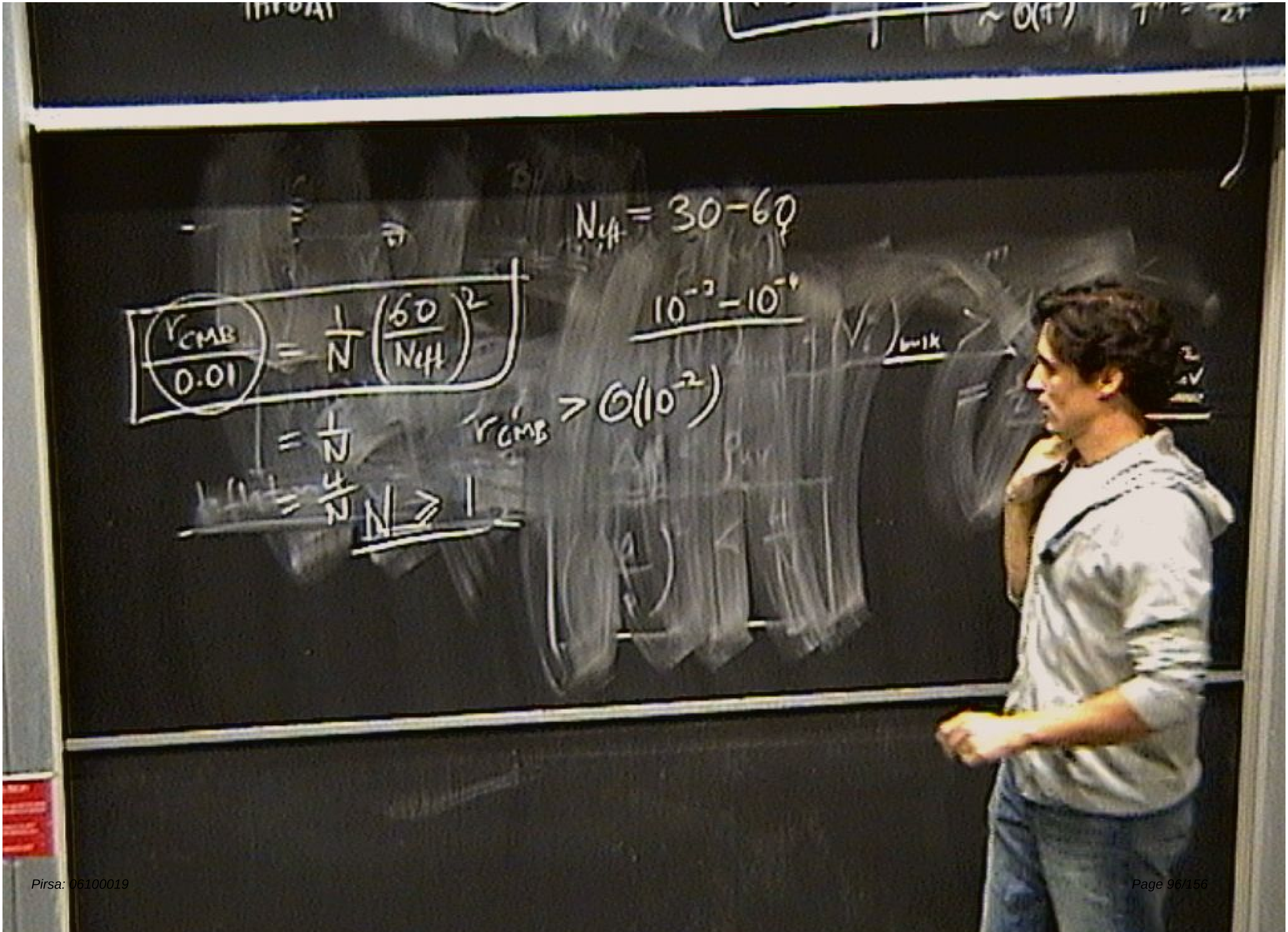

D3
D3
BULK
WARPED
THROAT
N = MK
Vol(S^5) = π^3
4+6
Inflation
Δφ < φ_UV
(Δφ/M_p)^2 < 4/N


Inflaton


$\frac{\Delta\varphi}{M_p} \geq \left(\frac{r_{CMB}}{8}\right)^{1/2} \times N_{CMB}$
N_e
4 CMB
10 LSS
60 END
$\left(\frac{\Delta\varphi}{M_p}\right) \simeq \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$
$\left(\frac{\Delta\varphi}{M_p}\right)^2 = \frac{(N_{eff})^2}{8} r_{CMB}$
$r_{CMB} = \frac{8}{(N_{eff})^2}\left(\frac{\Delta\varphi}{M_p}\right)^2 < \frac{32}{(N_{eff})^2}\frac{1}{N}$


r_CMB / 0.01 = 1/N (60/Neff)^2


rCMB / 0.01 = 1/N (60/Neff)^2
r'CMB > O(10^-2)
10^-3 – 10^-4


N_eff = 30-60
10^-3 - 10^-4
r_CMB / 0.01 = 1/N (60/N_eff)^2
= 1/N
r'_CMB > O(10^-2)
N ≥ 1

$$N_{eff} = 30-60?$$

$$\frac{r_{CMB}}{0.01} = \frac{1}{N}\left(\frac{60}{N_{eff}}\right)^2$$

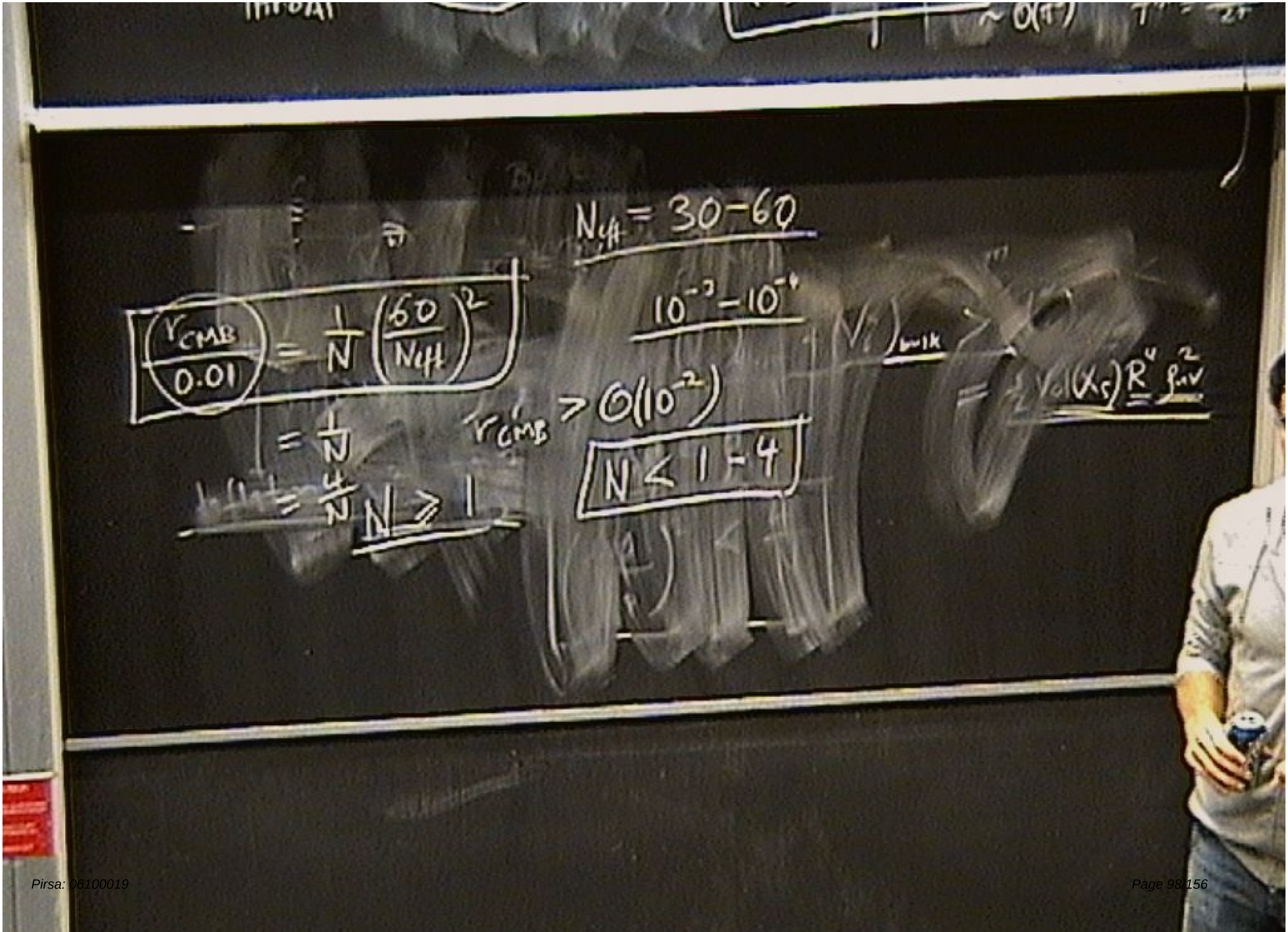
$$= \frac{1}{N}$$

$$= \frac{4}{N} \quad N \geq 1$$

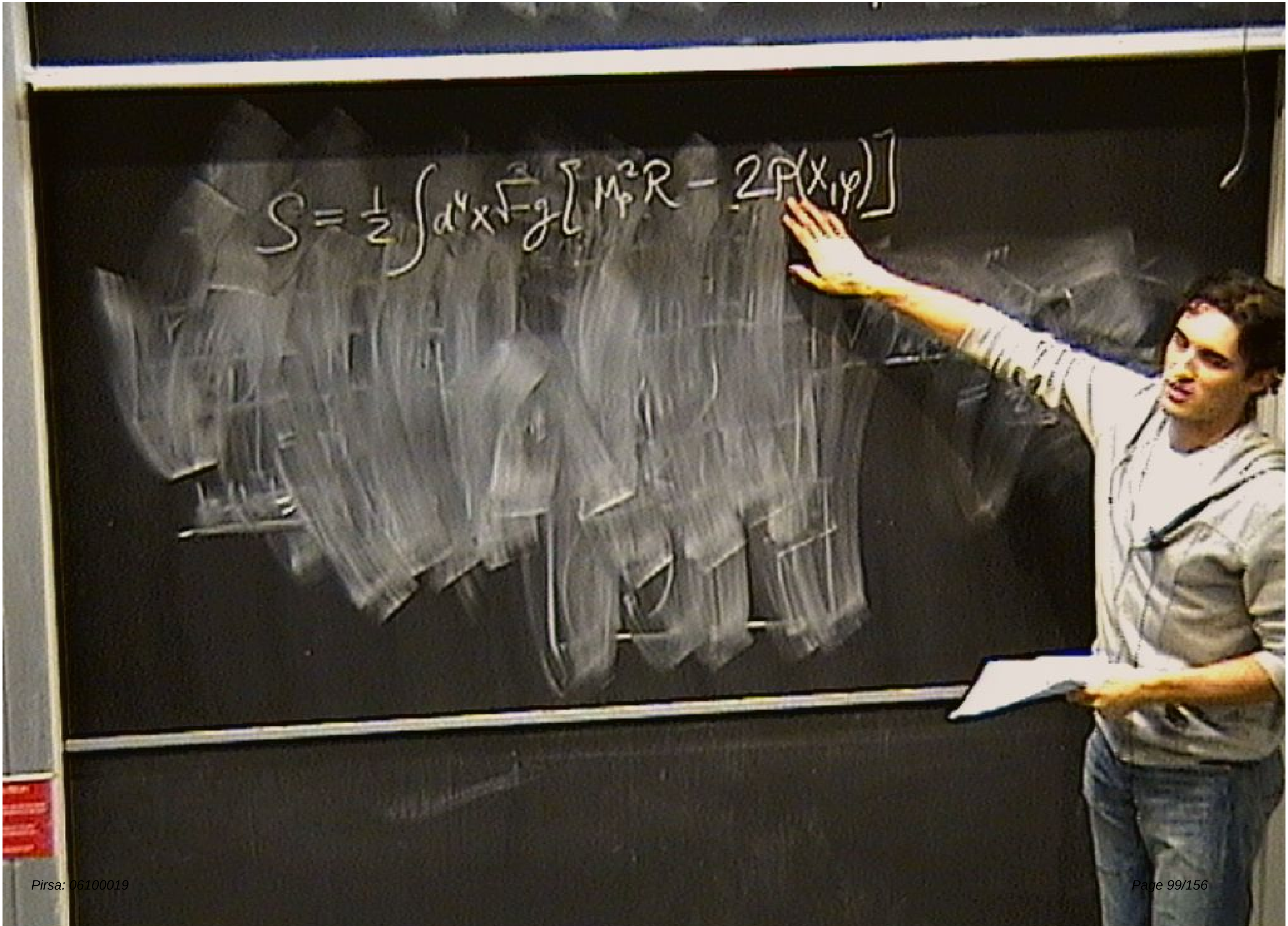
$$r'_{CMB} > O(10^{-2})$$

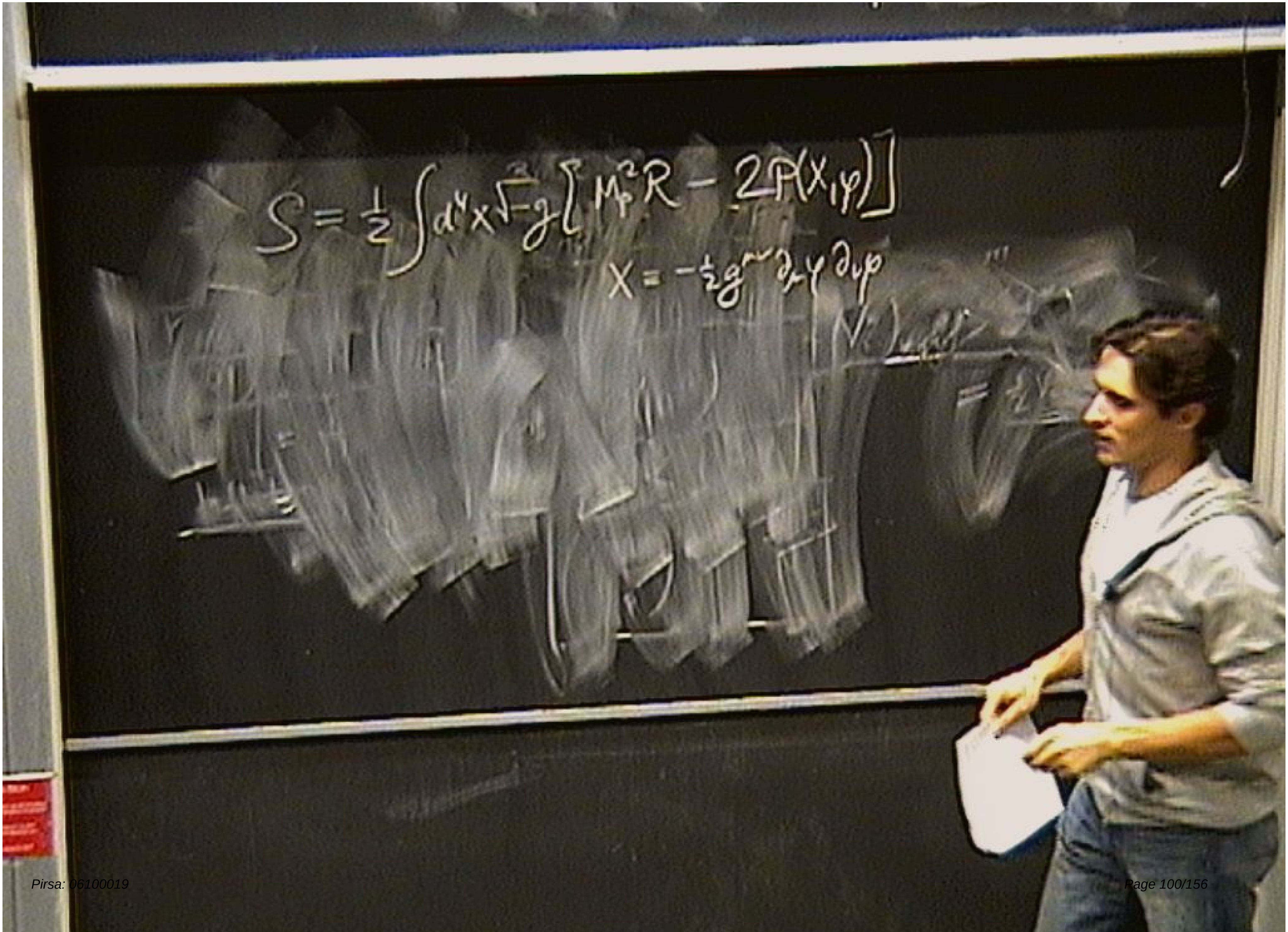
$$N < 1-4$$

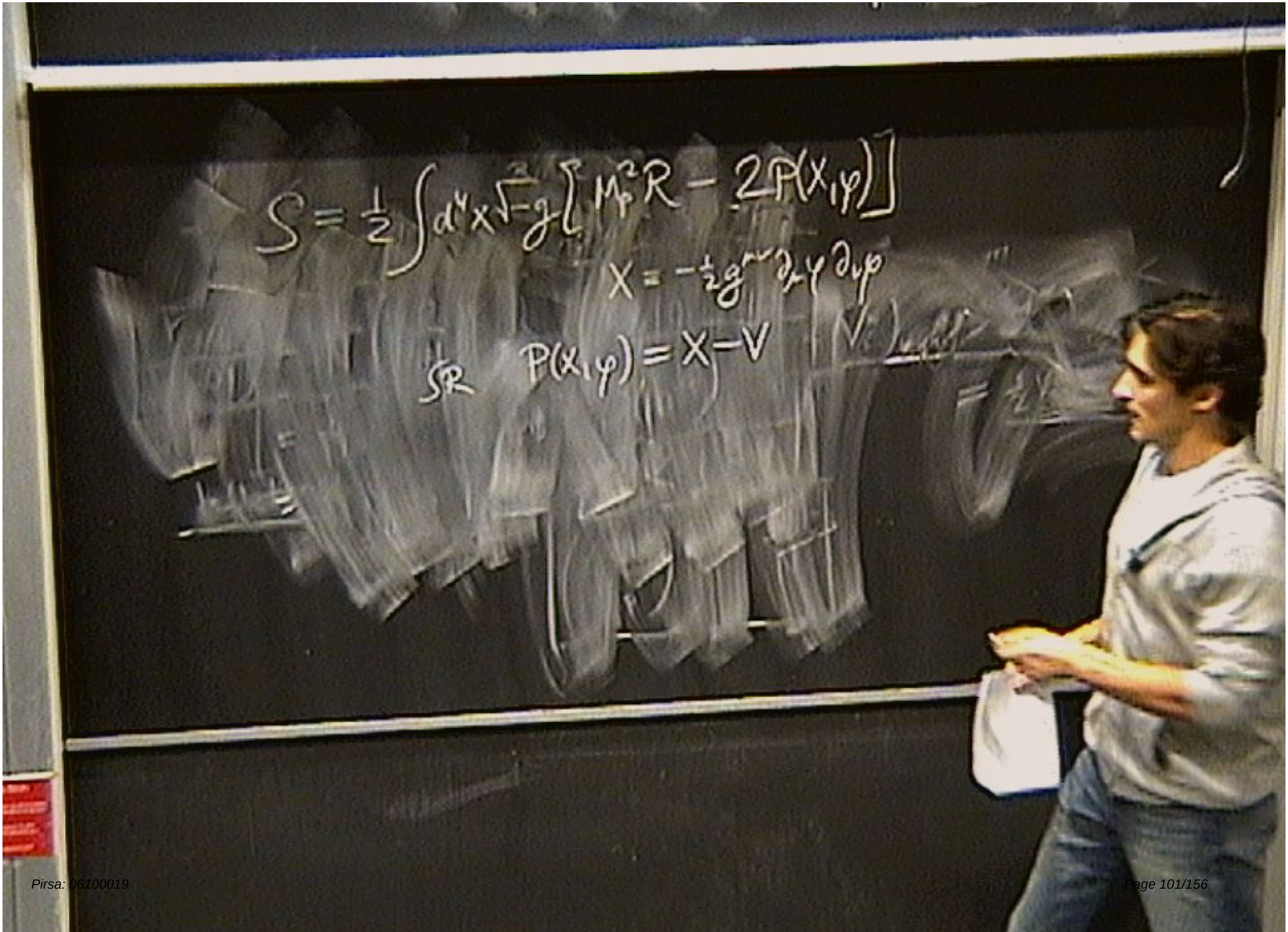
$$10^{-3} - 10^{-4}$$

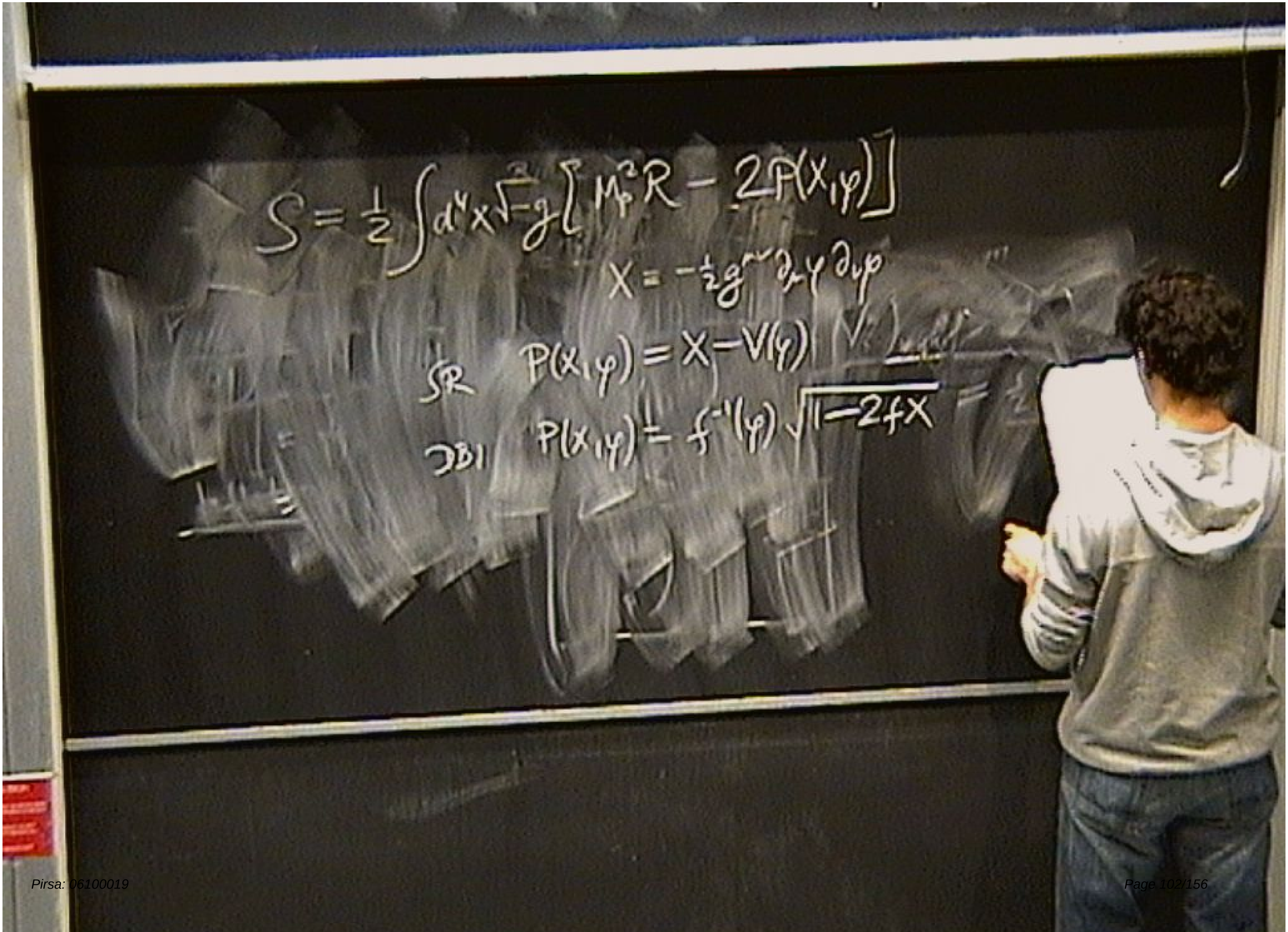


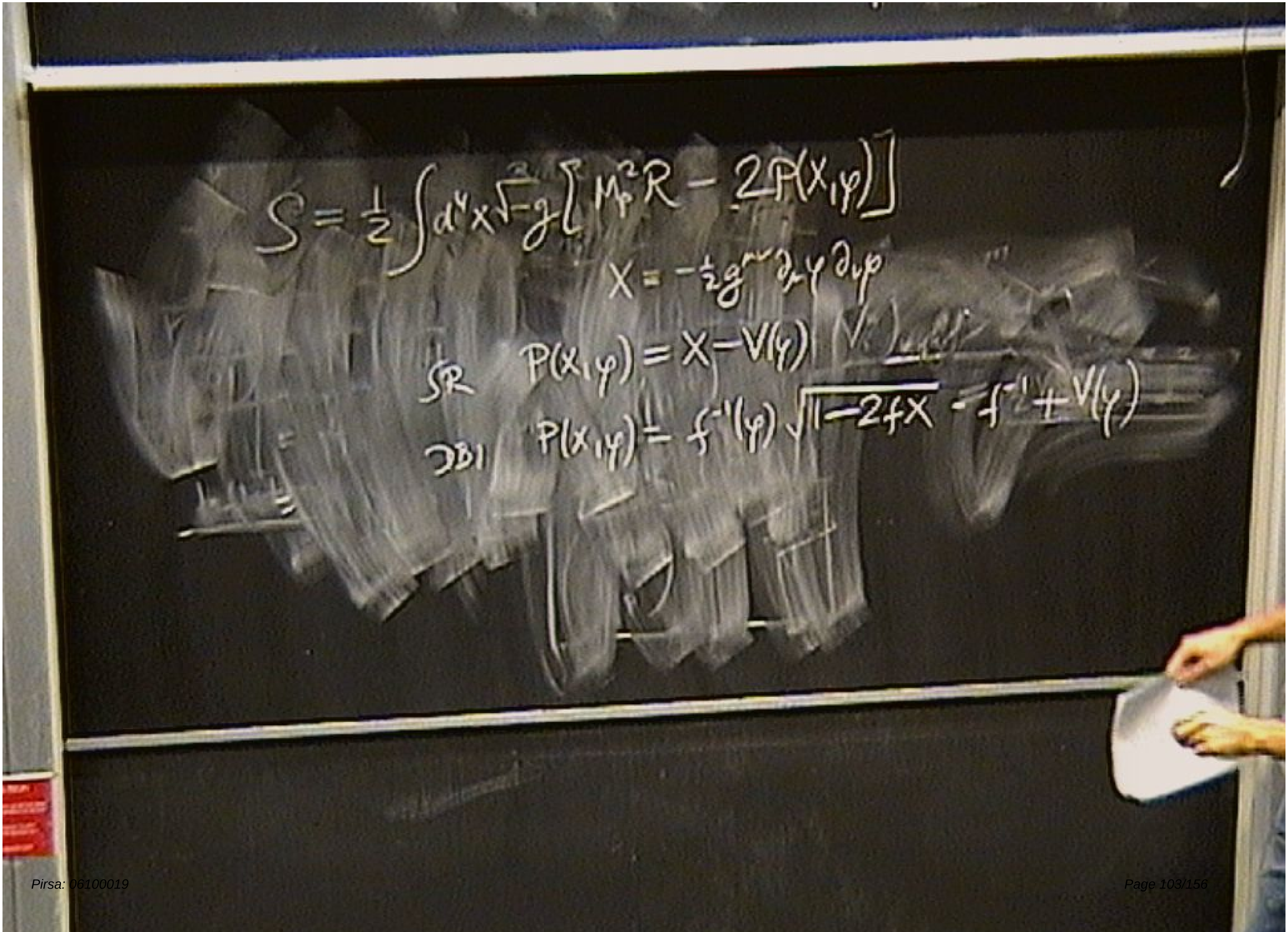
N_eff = 30-60
10^-3 - 10^-4
r_CMB / 0.01 = 1/N (60/N_eff)^2
= 1/N
= 4/N N ≥ 1
r'_CMB > O(10^-2)
N ≤ 1-4

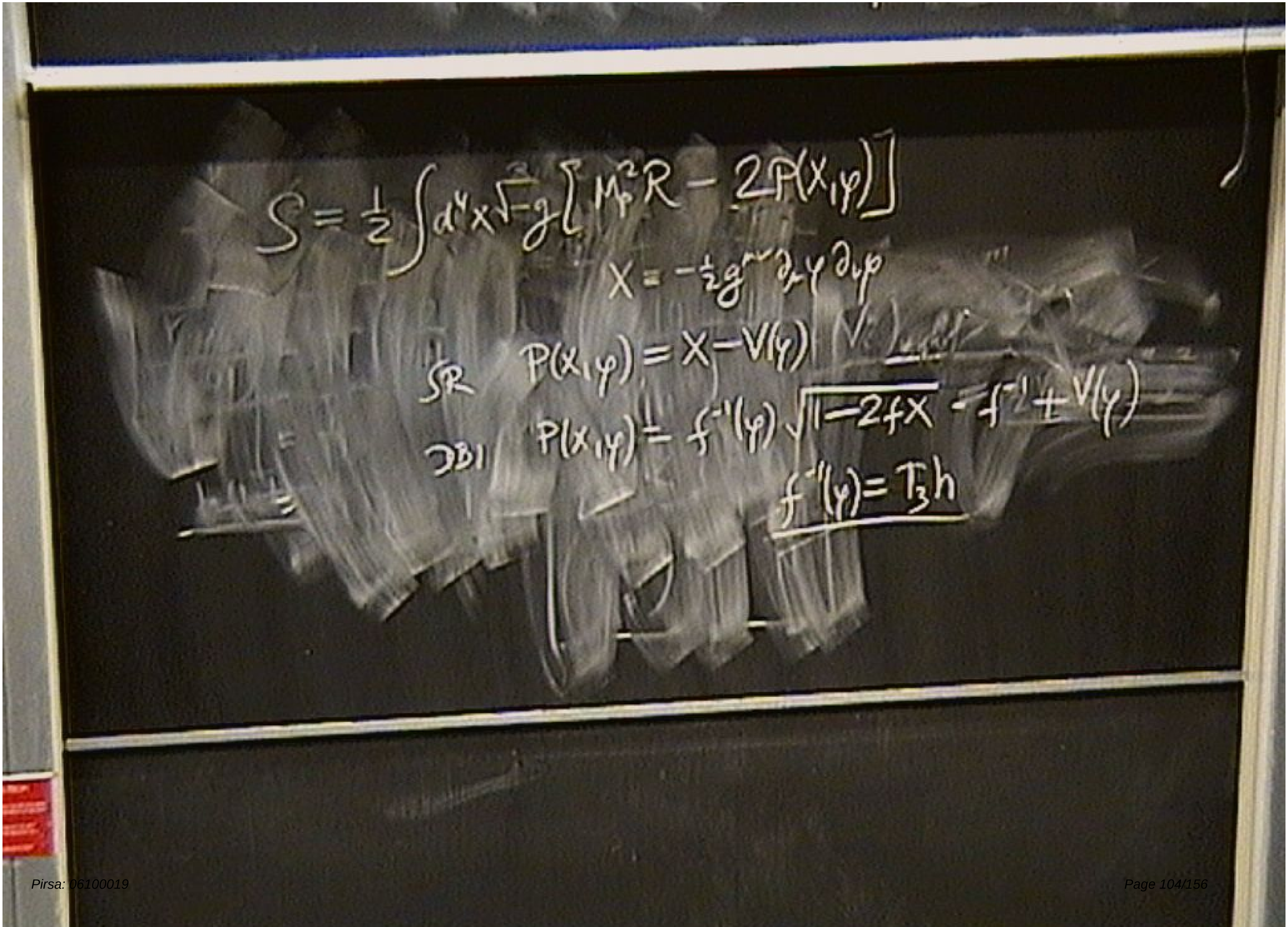

$S = \frac{1}{2}\int d^4x\sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$


$S = \frac{1}{2}\int d^4x\sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$
$X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\varphi\,\partial_\nu\varphi$


$S = \frac{1}{2}\int d^4x \sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$
$X = -\frac{1}{2} g^{\mu\nu} \partial_\mu \varphi \partial_\nu \varphi$
δR
$P(X,\varphi) = X - V$


$S = \frac{1}{2}\int d^4x \sqrt{-g}\,[M_p^2 R - 2P(X,\varphi)]$
$X = -\frac{1}{2} g^{\mu\nu}\partial_\mu\varphi\,\partial_\nu\varphi$
SR $P(X,\varphi) = X - V(\varphi)$
DBI $P(X,\varphi) = -f^{-1}(\varphi)\sqrt{1-2fX}$


$S = \frac{1}{2}\int d^4x\sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$
$X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\varphi\,\partial_\nu\varphi$
SR $P(X,\varphi) = X - V(\varphi)$
DBI $P(X,\varphi) = -f^{-1}(\varphi)\sqrt{1-2fX} - f^{-1} \pm V(\varphi)$


$S = \frac{1}{2}\int d^4x\sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$
$X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\varphi\,\partial_\nu\varphi$
SR $P(X,\varphi) = X - V(\varphi)$
DBI $P(X,\varphi) = -f^{-1}(\varphi)\sqrt{1-2fX} - f^{-1} + V(\varphi)$
$f^{-1}(\varphi) = T_3 h$

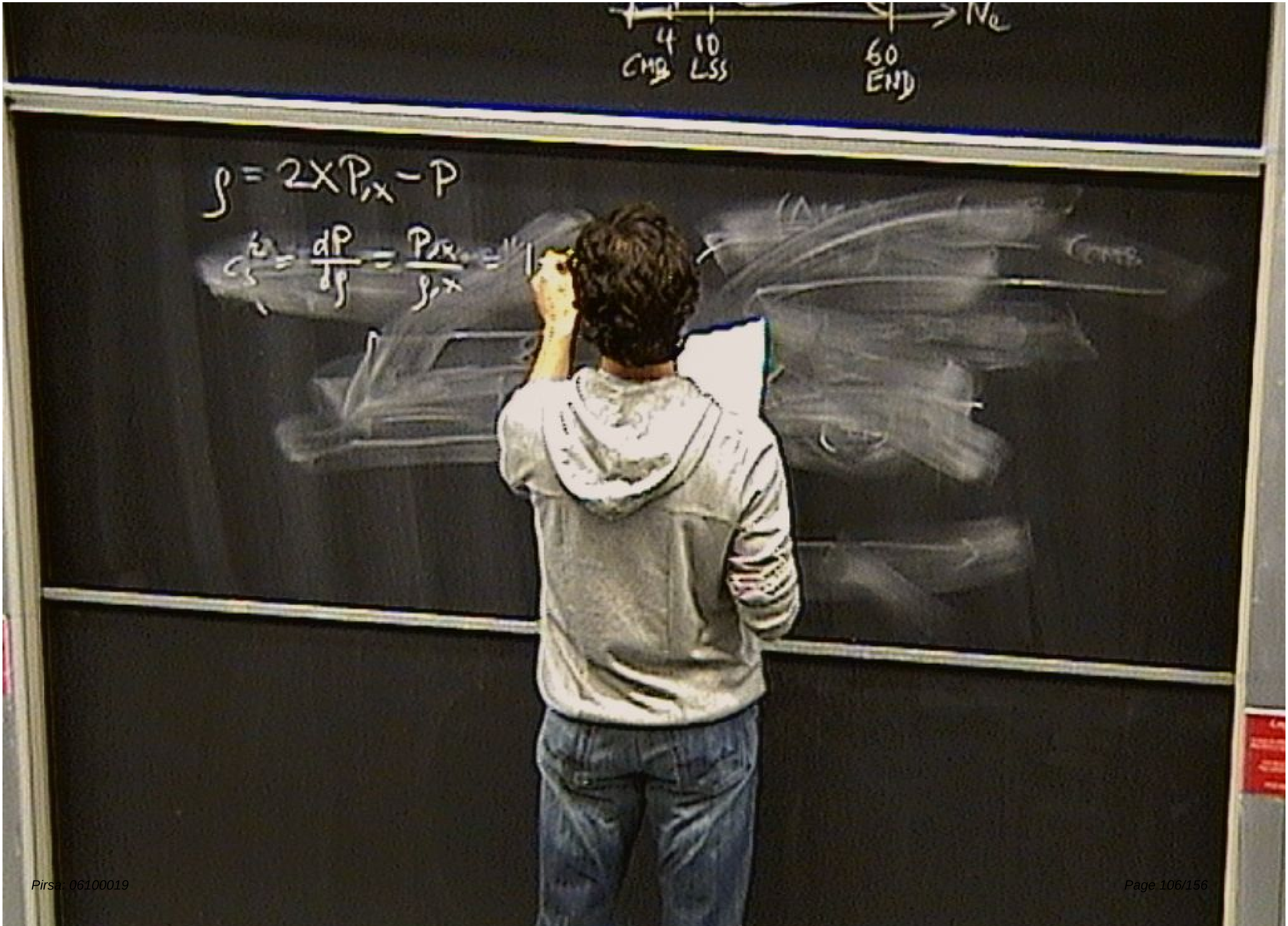
$$S = \frac{1}{2}\int d^4x\sqrt{-g}\left[M_p^2 R - 2P(X,\varphi)\right]$$

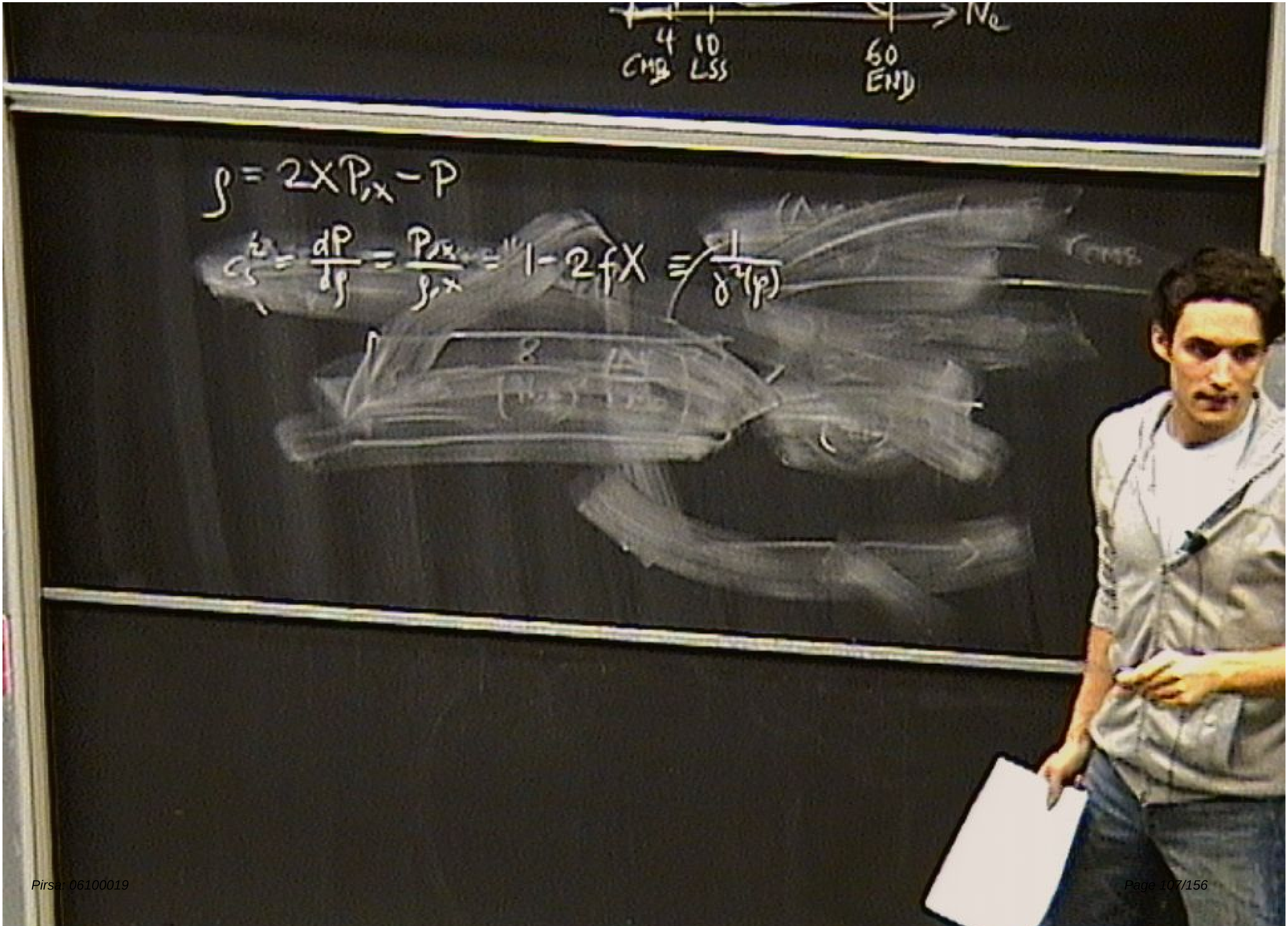
$$X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\varphi\,\partial_\nu\varphi$$

SR $\quad P(X,\varphi) = X - V(\varphi)$

DBI $\quad P(X,\varphi) = -f^{-1}(\varphi)\sqrt{1-2fX} - f^{-1} + V(\varphi)$

$$f^{-1}(\varphi) = T_3 h$$


Ne
4 10 60
CMB LSS END
ρ = 2XP,x − P


N_e
4 CMB
10 LSS
60 END
ρ = 2XP,X − P
c_s^2 = dP/dρ = P,X/ρ,X = 1 − 2fX = 1/γ^2(p)

N_e

4 CMB, 10 LSS, 60 END

$$\rho = 2XP_{,X} - P$$

$$c_s^2 = \frac{dP}{d\rho} = \frac{P_{,X}}{\rho_{,X}} = 1 - 2fX = \frac{1}{\gamma^2(p)}$$

Speed of Sound (c_s)

Lorentz (γ)

4 CMB, 10 LSS, 60 END → N_e

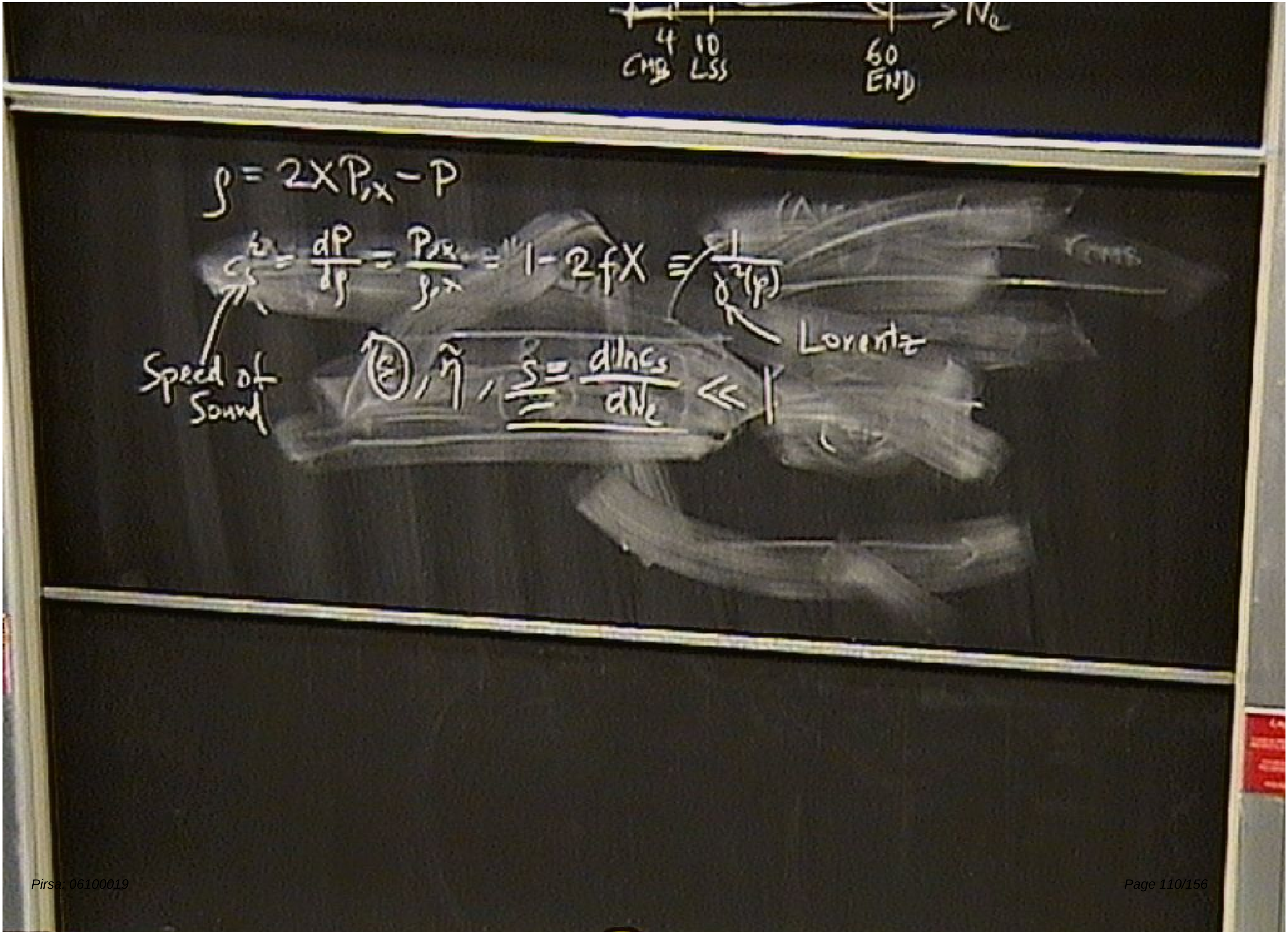
$$\rho = 2X P_{,X} - P$$

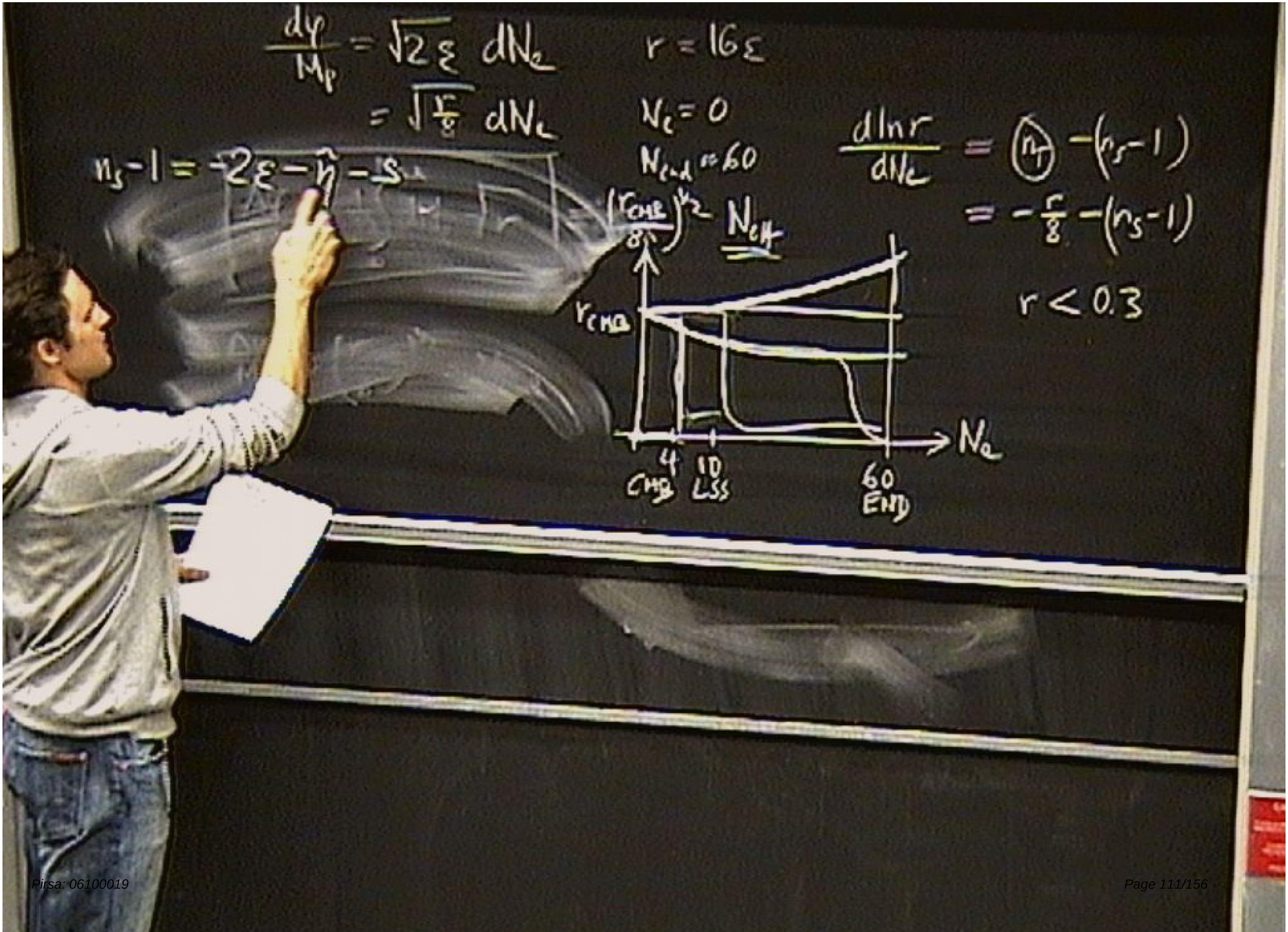
$$c_s^2 = \frac{dP}{d\rho} = \frac{P_{,X}}{\rho_{,X}} = \text{"}1 - 2fX\text{"} \equiv \frac{1}{\gamma^2(\rho)}$$

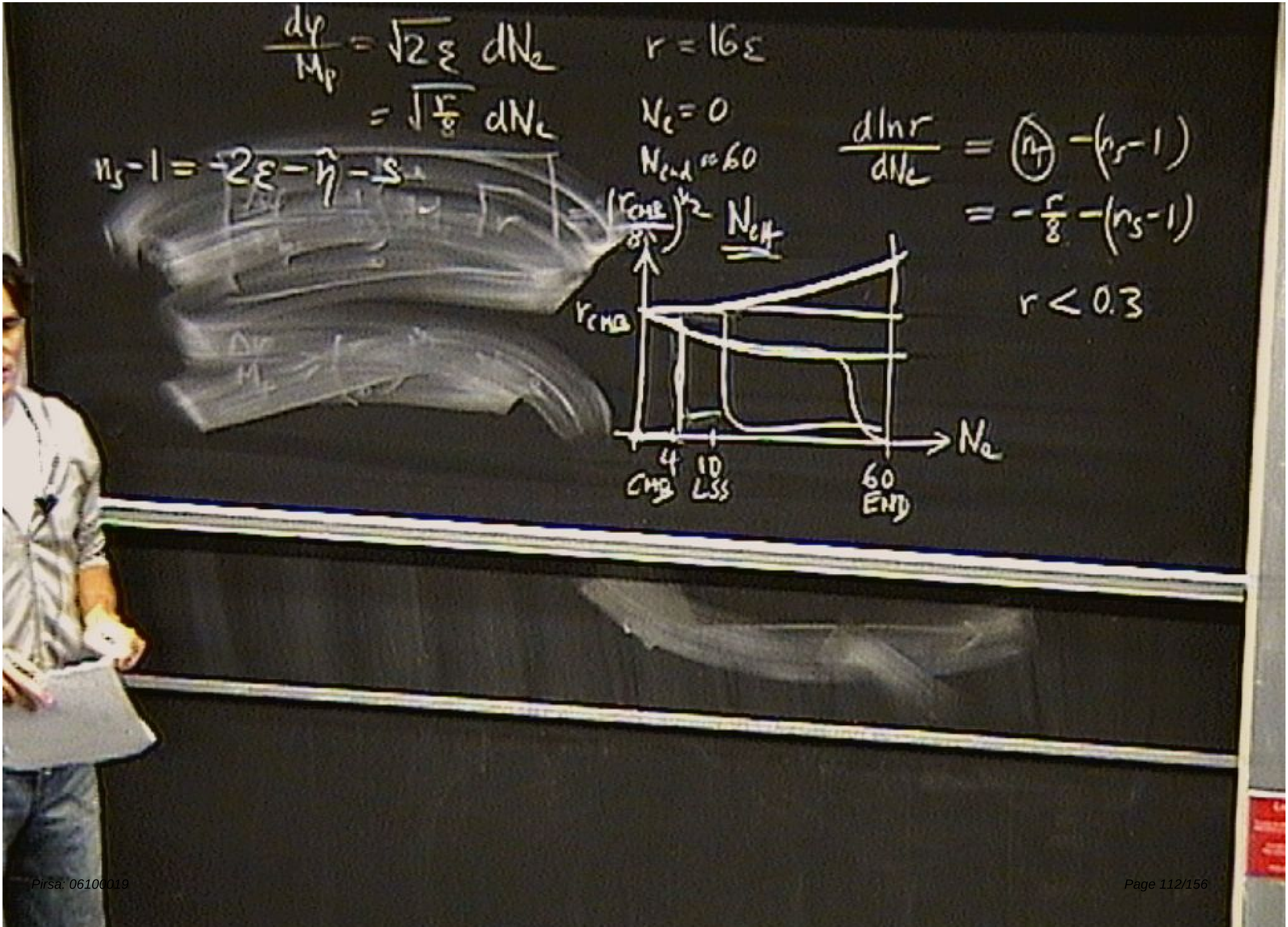
c_s ← Speed of Sound

γ ← Lorentz

$$\epsilon, \tilde{\eta}, s = \frac{d\ln c_s}{dN_e} \ll 1$$


N_e
4 CMB
10 LSS
60 END
ρ = 2XP,x − P
c_s^2 = dP/dρ = P,x/ρ,x = 1 − 2fX ≡ 1/γ^2(φ)
Lorentz
Speed of Sound
ε, η, s = dln c_s/dN_e ≪ 1


dφ/M_P = √(2ε) dN_e
= √(r/8) dN_e
r = 16ε
N_e = 0
N_end ≈ 60
n_s − 1 = −2ε − η̂ − s
(r_CMB/8)^{1/2} N_eff
dln r/dN_e = (n_T) − (n_s − 1)
= −r/8 − (n_s − 1)
r < 0.3
r_CMB
N_e
4 CMB
10 LSS
60 END


dφ/Mp = √2ε dNe
= √(r/8) dNe
r = 16ε
Ne = 0
Nend ≈ 60
ns − 1 = −2ε − η̂ − S
(rCMB/8)^½ Neff
d ln r / dNe = (η) − (ns − 1)
= − r/8 − (ns − 1)
r < 0.3
rCMB
Ne
4 CMB
10 LSS
60 END

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0$$

$$N_{end} \approx 60$$

$$n_s - 1 = -2\varepsilon - \hat{\eta} - S$$

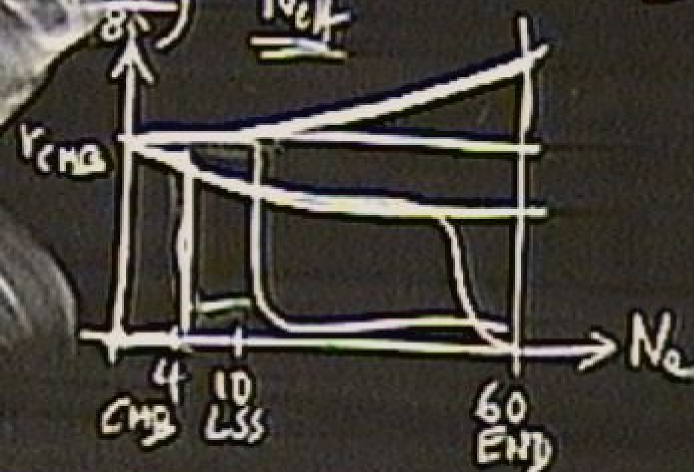
$$n_T = -2\varepsilon$$

$$\frac{\Delta\varphi}{M_p} = \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

$$\frac{d\ln r}{dN_e} = (n_T) - (n_s - 1)$$

$$= -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$



$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e = \sqrt{\frac{r}{8}}\, dN_e$$

$r = 16\varepsilon$

$N_e = 0$

$N_{end} \approx 60$

$$n_s - 1 = -2\varepsilon - \tilde{\eta} - s$$

$$n_T = -2\varepsilon$$

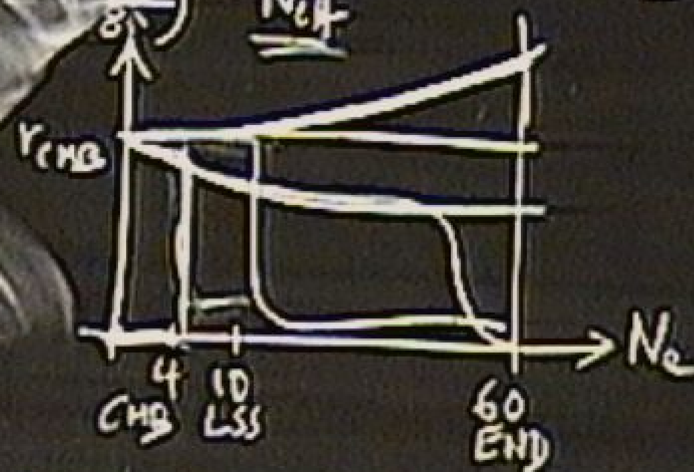
$$\boxed{r = 16 c_s \varepsilon}$$

$$\frac{d\ln r}{dN_e} = \frac{d\ln \varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$$

$$\left(\frac{r_{CMB}}{8}\right)^{1/2} \underline{N_{eff}}$$

$$\frac{d\ln r}{dN_e} = n_T - (n_s - 1) = -\frac{r}{8} - (n_s - 1)$$

$r < 0.3$



2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \sqrt{\frac{r}{8}}\, dN_e$$

$N_e = 0$

$N_{end} \approx 60$

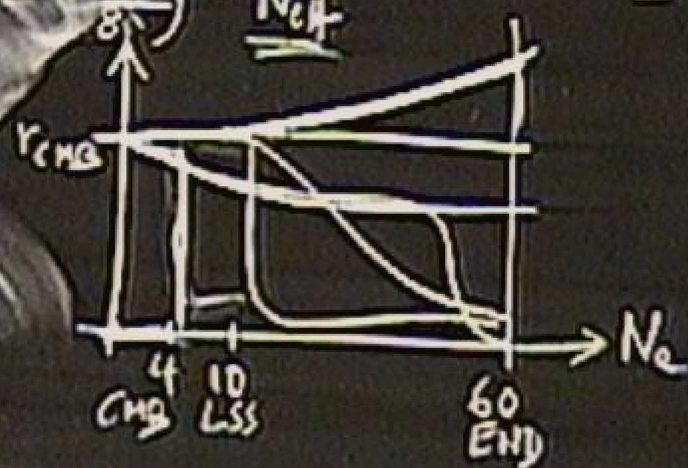
$$n_s - 1 = -2\varepsilon - \hat{\eta} - (s)$$

$$n_T = -2\varepsilon$$

$$r = 16 c_s \varepsilon$$

$$\left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

$$\frac{d\ln r}{dN_e} = \frac{d\ln \varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$$



$$\frac{d\ln r}{dN_e} = (n_T) - (n_s - 1)$$

$$= -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$

2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e = \sqrt{\frac{r}{8}}\, dN_e \qquad r = 16\varepsilon$$

$N_e = 0$

$N_{end} \approx 60$

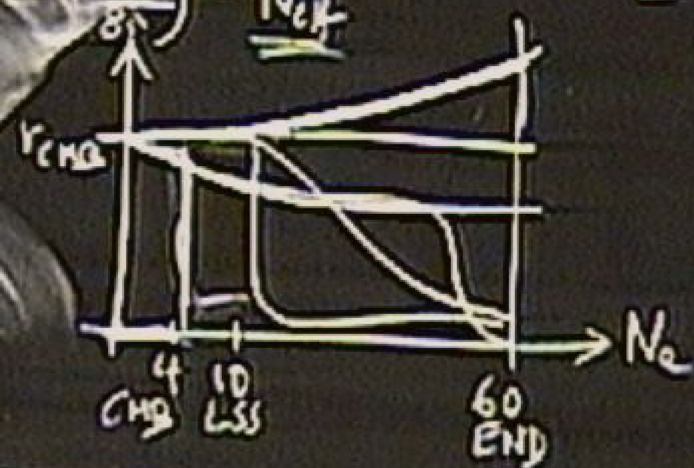
$$\left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

$$n_s - 1 = -2\varepsilon - \tilde{\eta} - (s)$$

$$n_t = -2\varepsilon$$

$$\boxed{r = 16 c_s \varepsilon}$$

$$\frac{d\ln r}{dN_e} = \frac{d\ln \varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$$



$$\frac{d\ln r}{dN_e} = n_t - (n_s - 1) = -\frac{r}{8} - (n_s - 1)$$

$$r < 0.3$$

2) LYTH BOUND

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e \qquad r = 16\varepsilon$$

$$= \int \sqrt{\frac{r}{8}}\, dN_e \qquad N_e = 0 \qquad N_{end} \approx 60$$

$$= \left(\frac{r_{CMB}}{8}\right)^{1/2} N_{eff}$$

$$n_s - 1 = -2\varepsilon - \eta - s$$

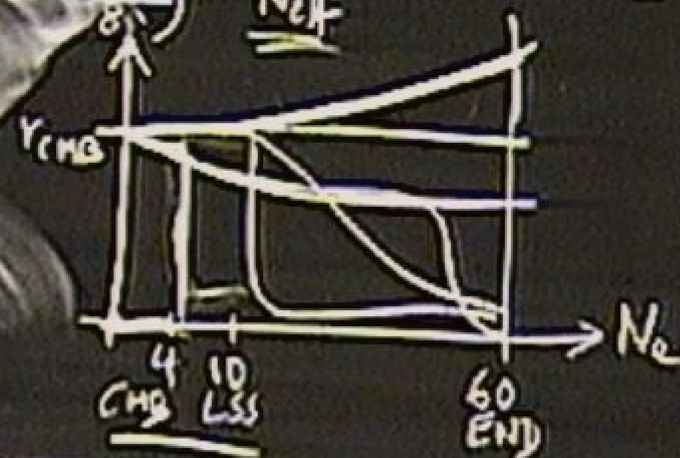
$$n_T = -2\varepsilon$$

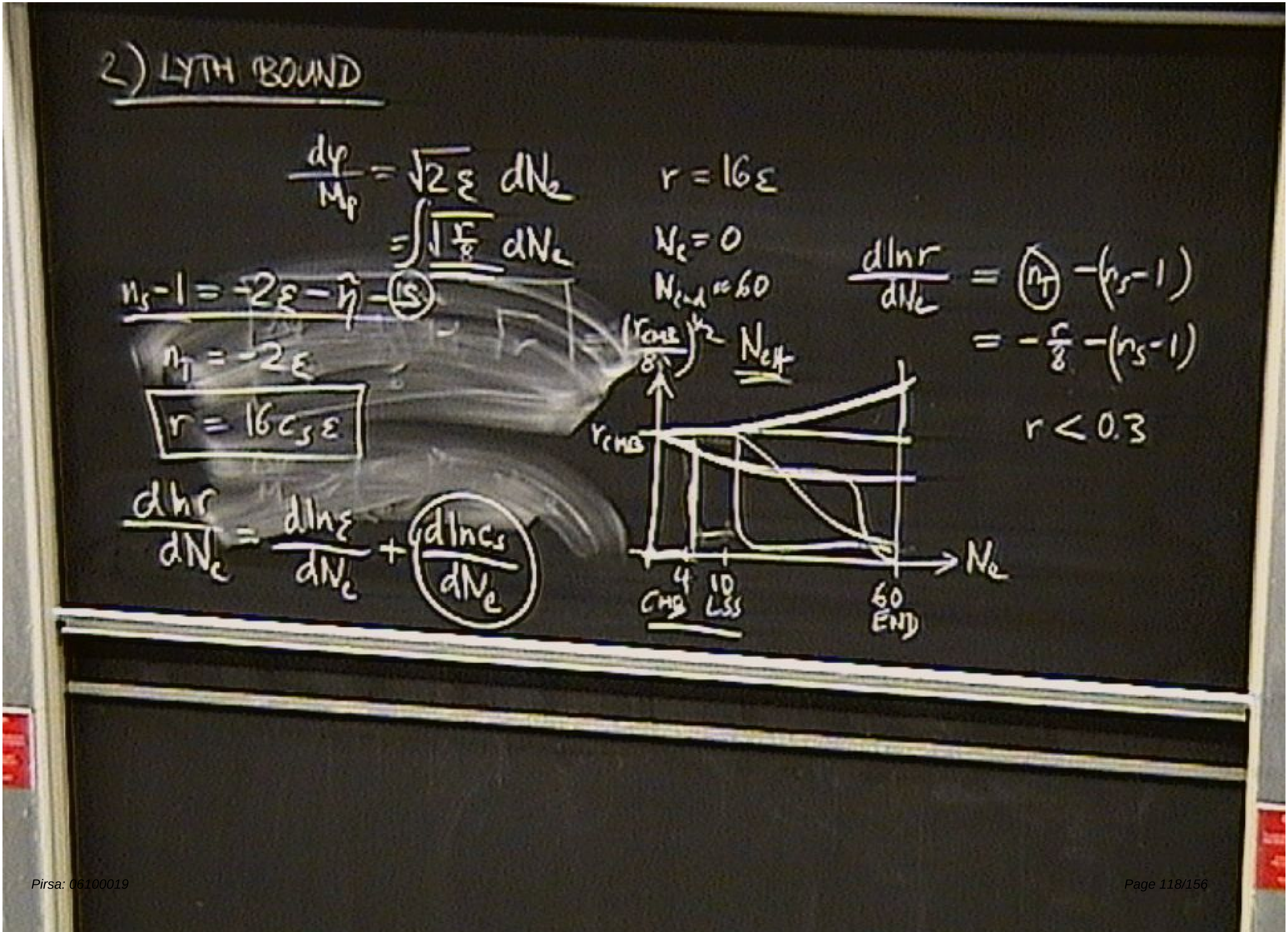
$$\boxed{r = 16 c_s \varepsilon}$$

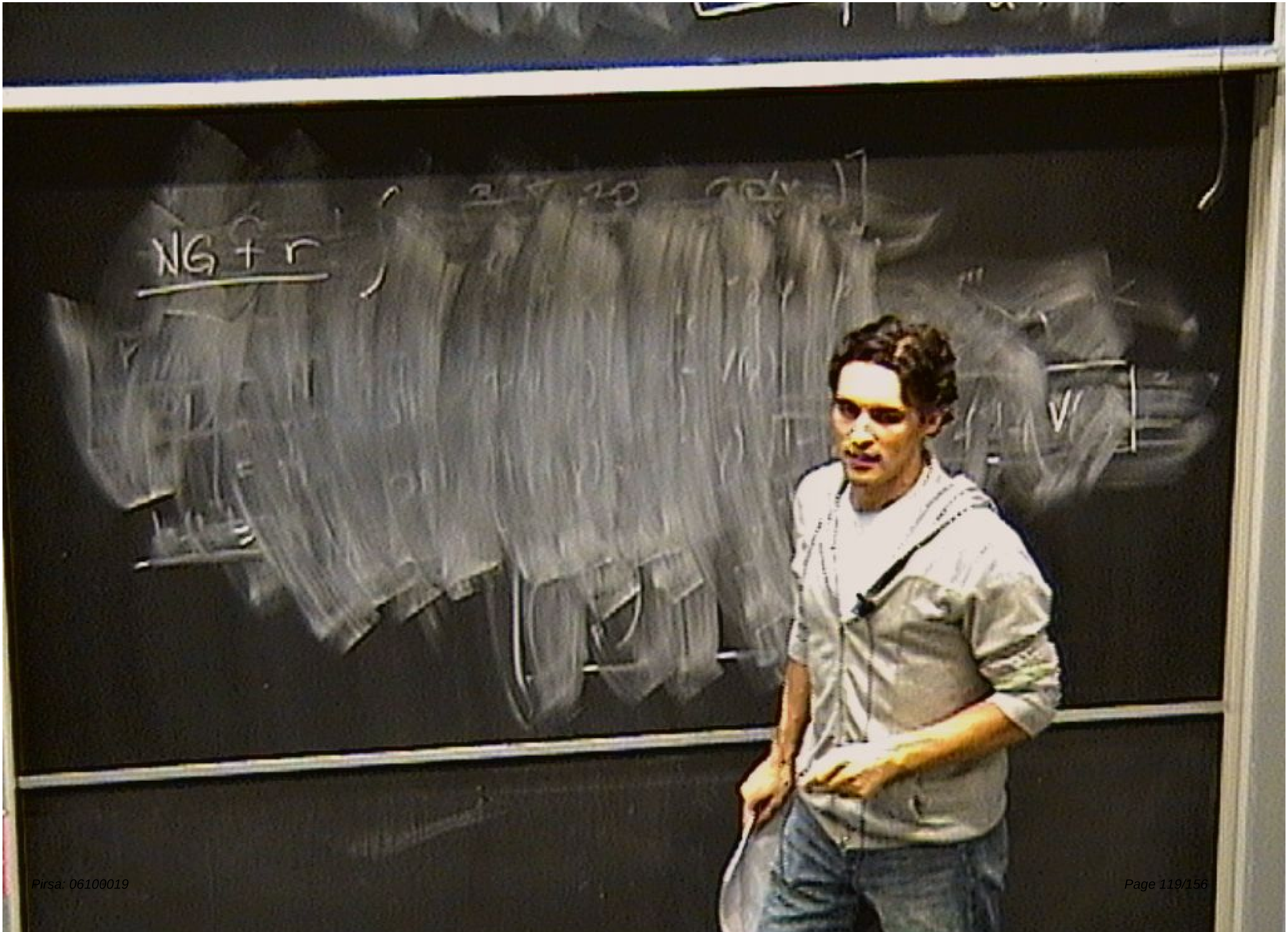
$$\frac{d\ln r}{dN_e} = \frac{d\ln \varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$$

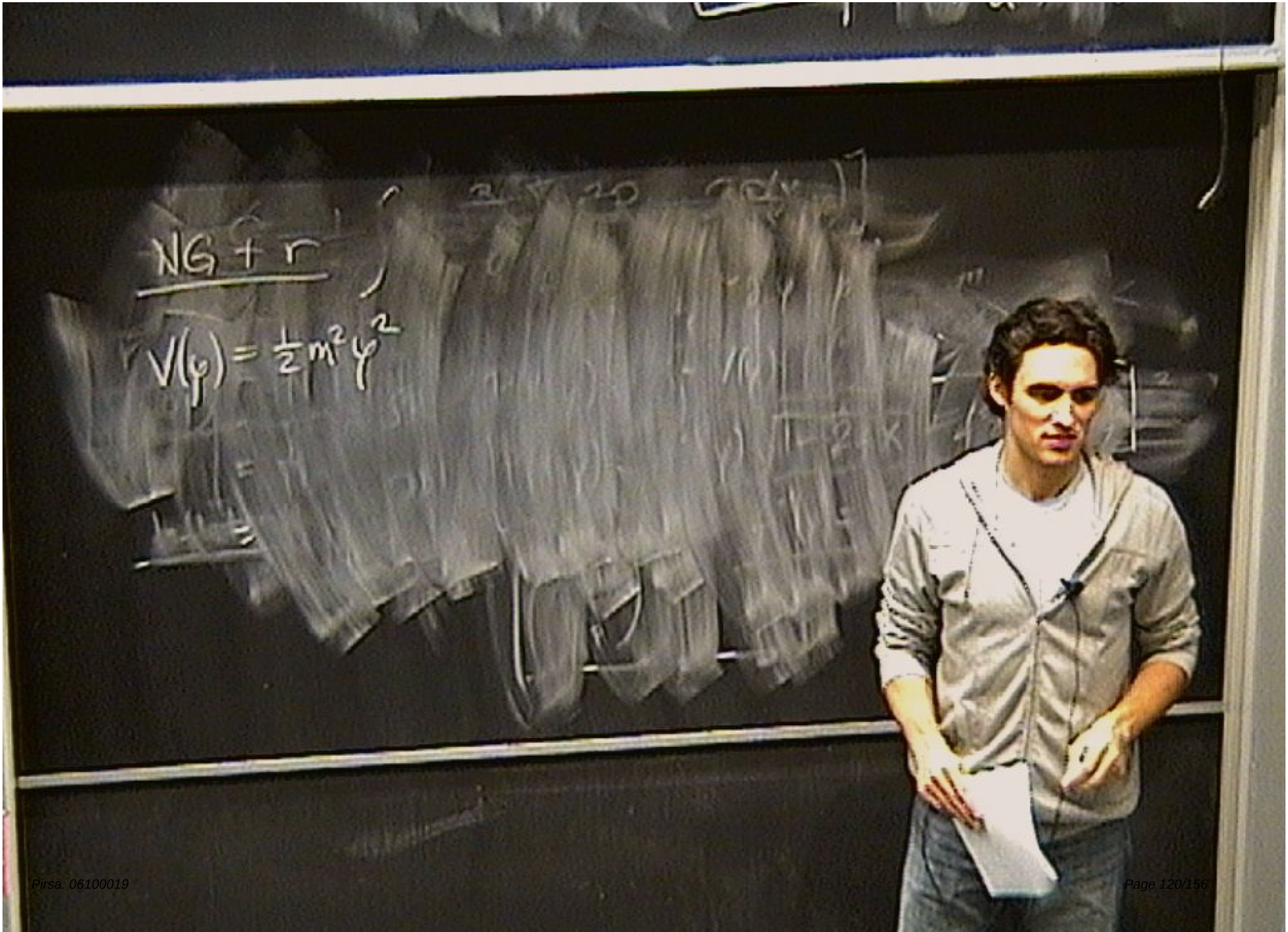
$$\frac{d\ln r}{dN_e} = n_T - (n_s - 1) = -\frac{r}{8} - (n_s - 1)$$

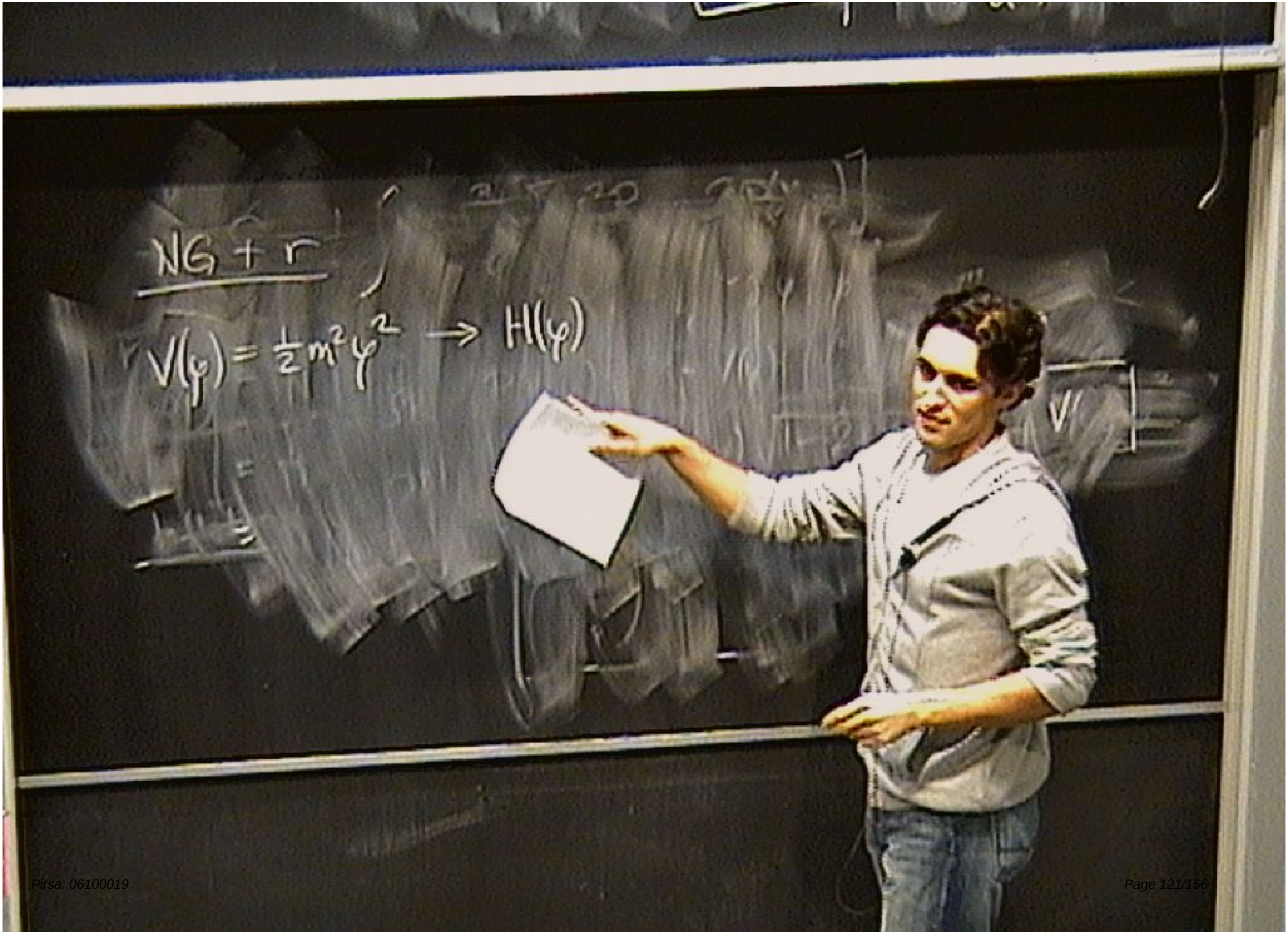
$$r < 0.3$$

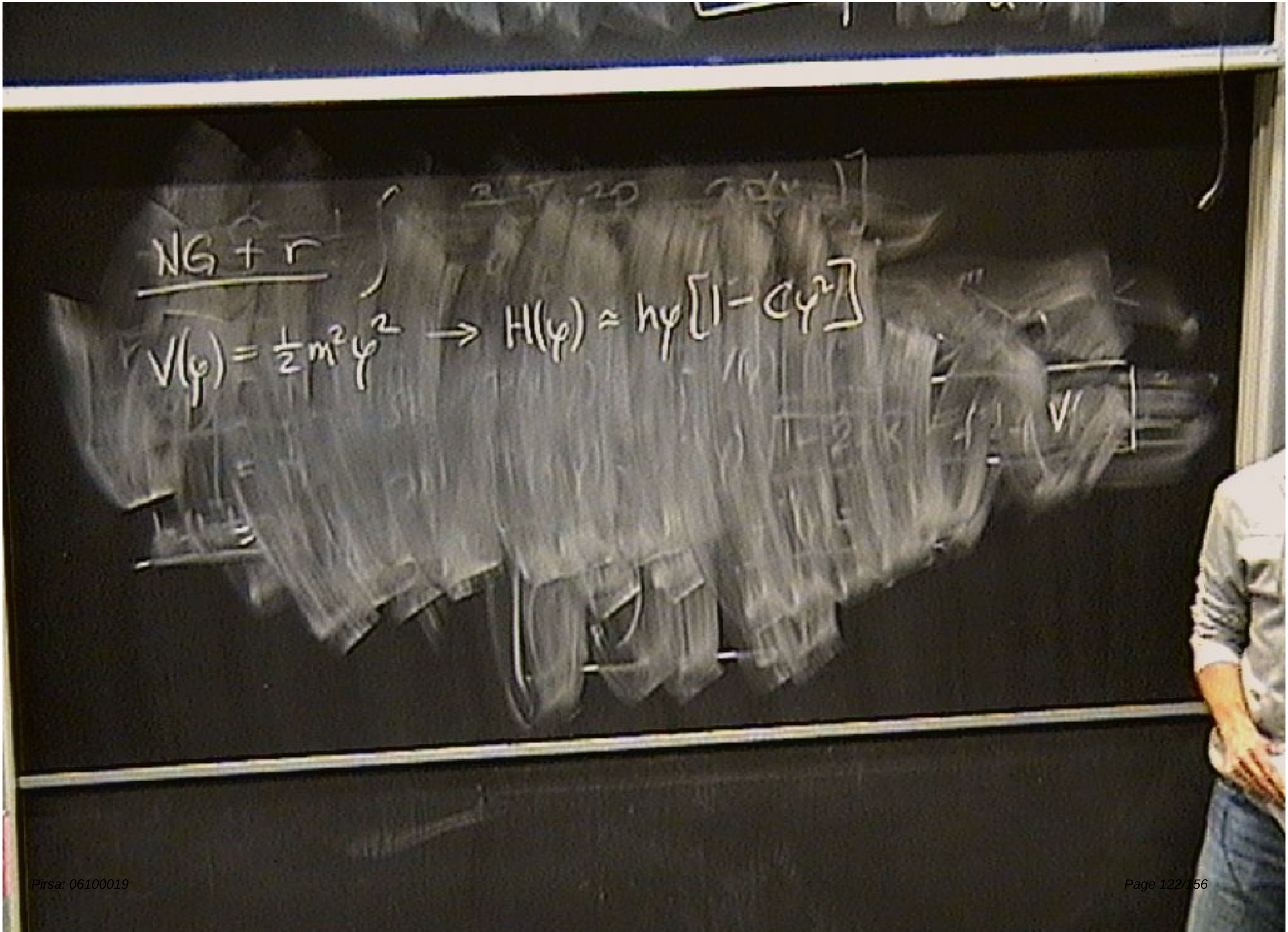


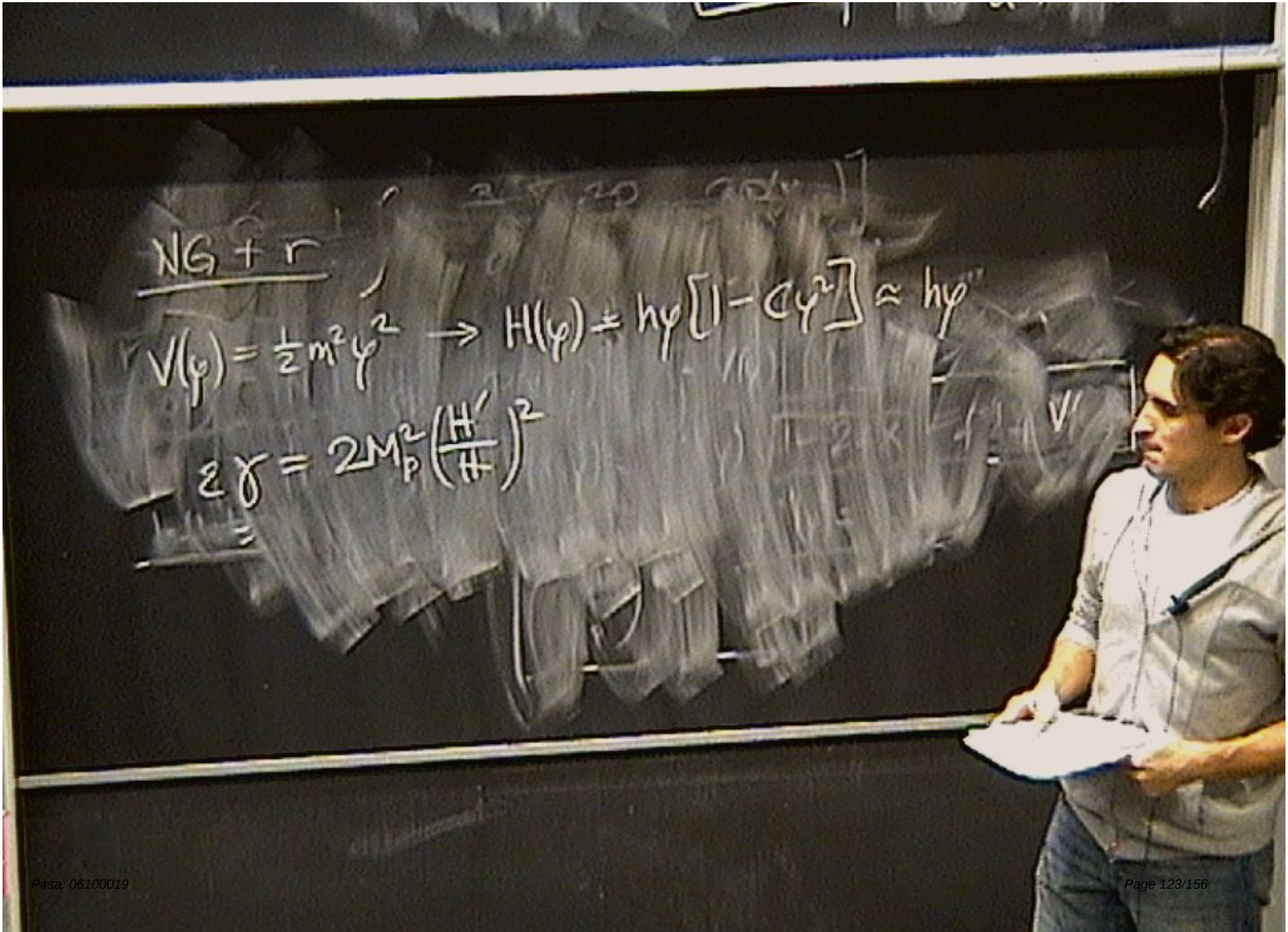

2) LYTH BOUND
dφ/M_P = √2ε dN_e
= ∫√(r/8) dN_e
r = 16ε
N_e = 0
N_end ≈ 60
n_s − 1 = −2ε − η̃ − (s)
n_T = −2ε
r = 16 c_s ε
dlnr/dN_e = dlnε/dN_e + dlnc_s/dN_e
(r_CMB/8)^1/2 N_eff
dlnr/dN_e = (n_T) − (n_s − 1)
= −r/8 − (n_s − 1)
r < 0.3
r_CMB
N_e
4 CMB
10 LSS
60 END

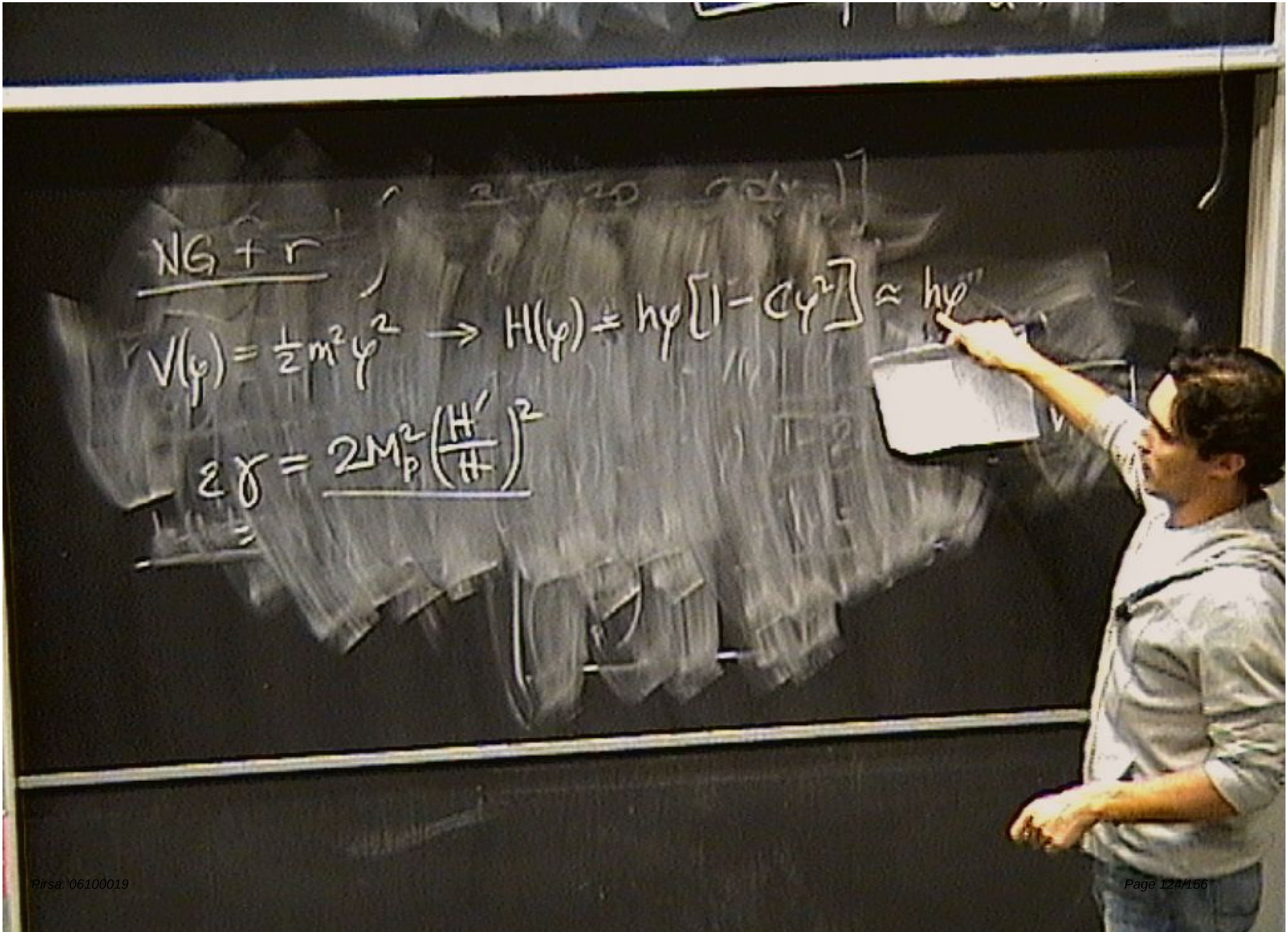


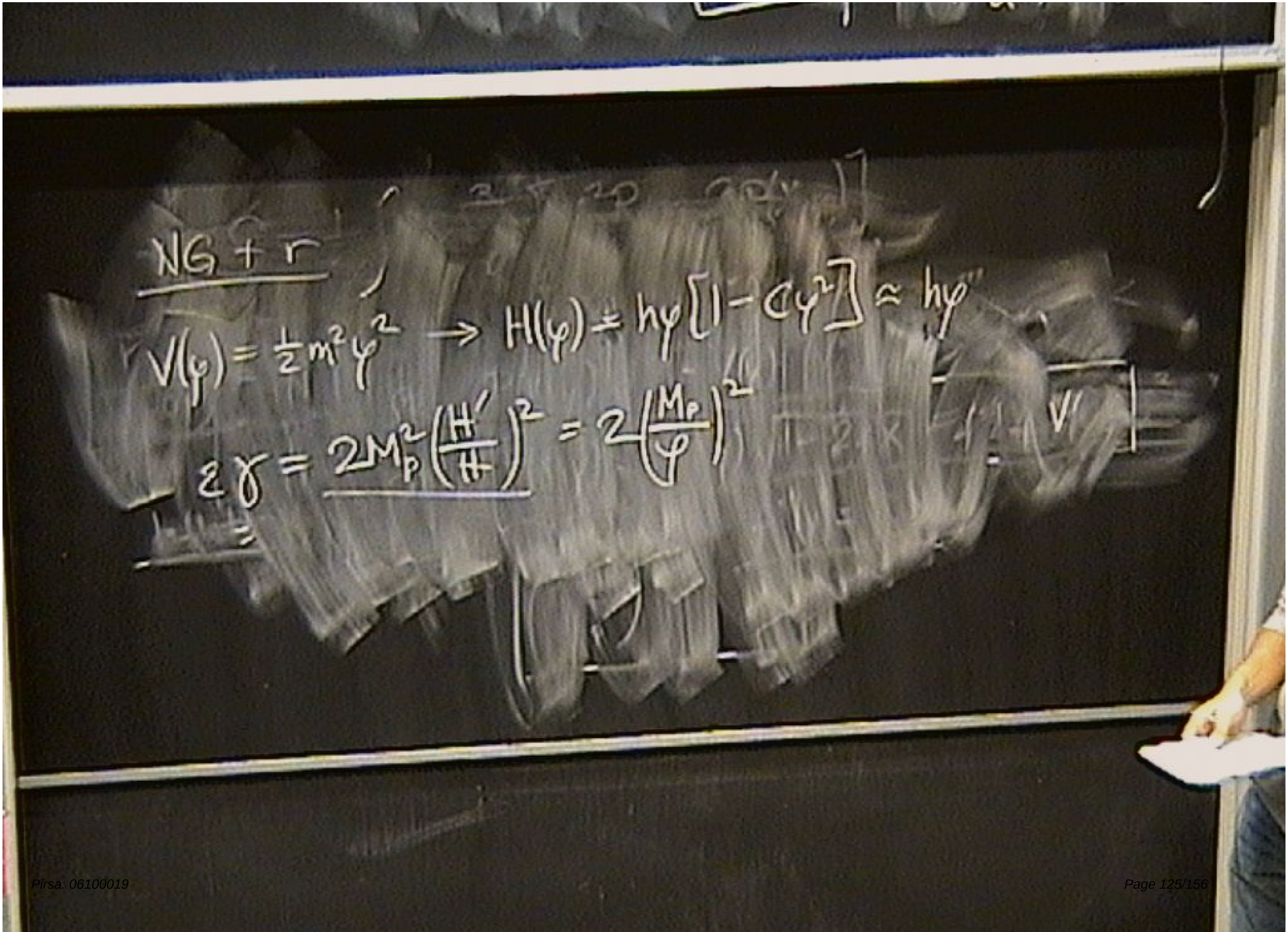

NG + r
V(φ) = ½ m² φ²


NG + r
V(φ) = ½ m² φ² → H(φ)


NG + r
V(φ) = ½m²φ² → H(φ) ≈ hφ[1 − Cφ²]


NG + r
V(φ) = ½m²φ² → H(φ) ≐ hφ[1 − Cφ²] ≈ hφ
εγ = 2M_p²(H′/H)²

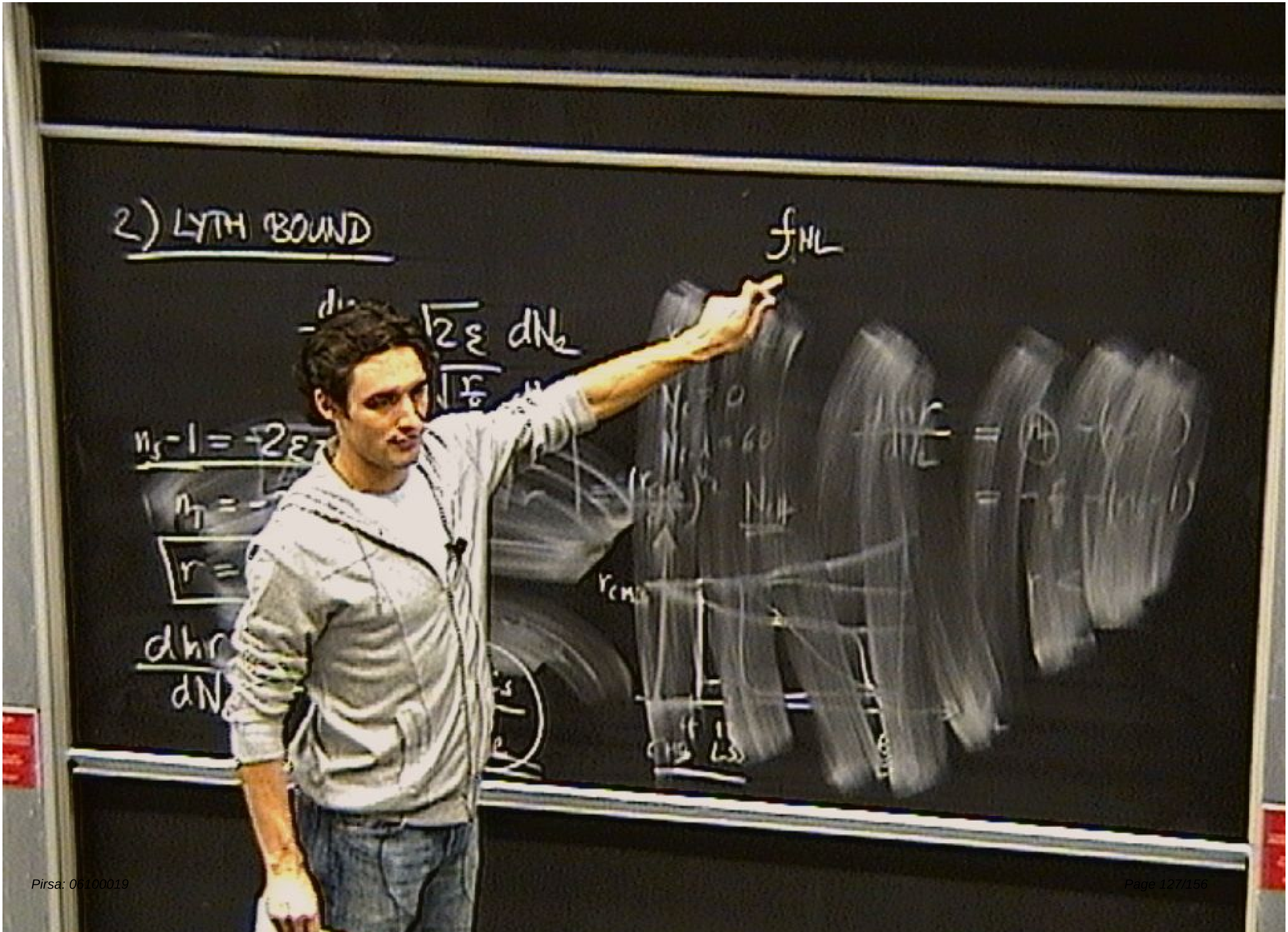

NG + r
V(φ) = ½ m² φ² → H(φ) ≈ hφ [1 − Cφ²] ≈ hφ
εγ = 2M_p² (H′/H)²


NG + r
$V(\varphi) = \frac{1}{2} m^2 \varphi^2 \rightarrow H(\varphi) \doteq h\varphi [1 - C\varphi^2] \approx h\varphi$
$\epsilon_\gamma = 2M_p^2 \left(\frac{H'}{H}\right)^2 = 2\left(\frac{M_p}{\varphi}\right)^2$

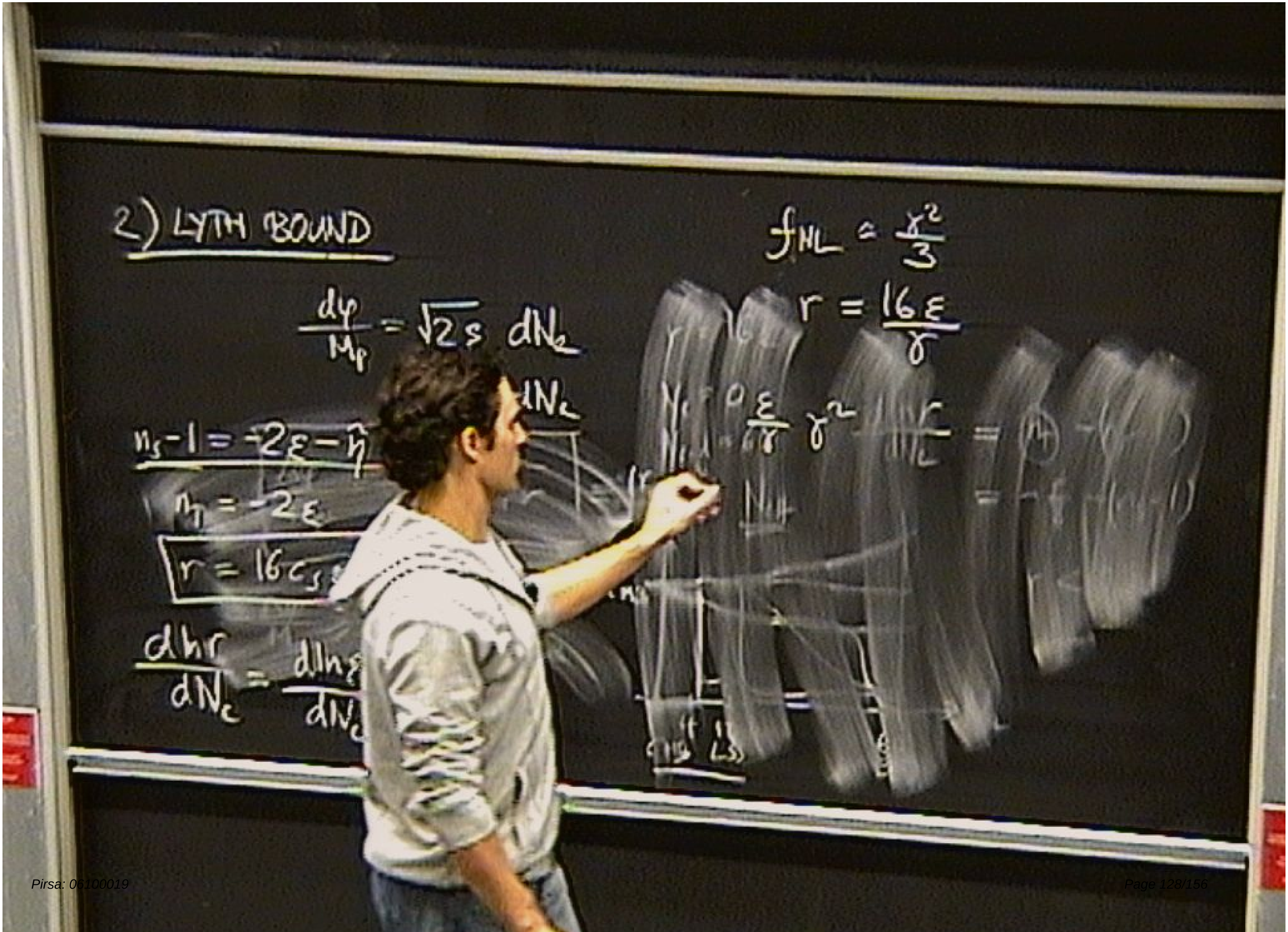
NG + r

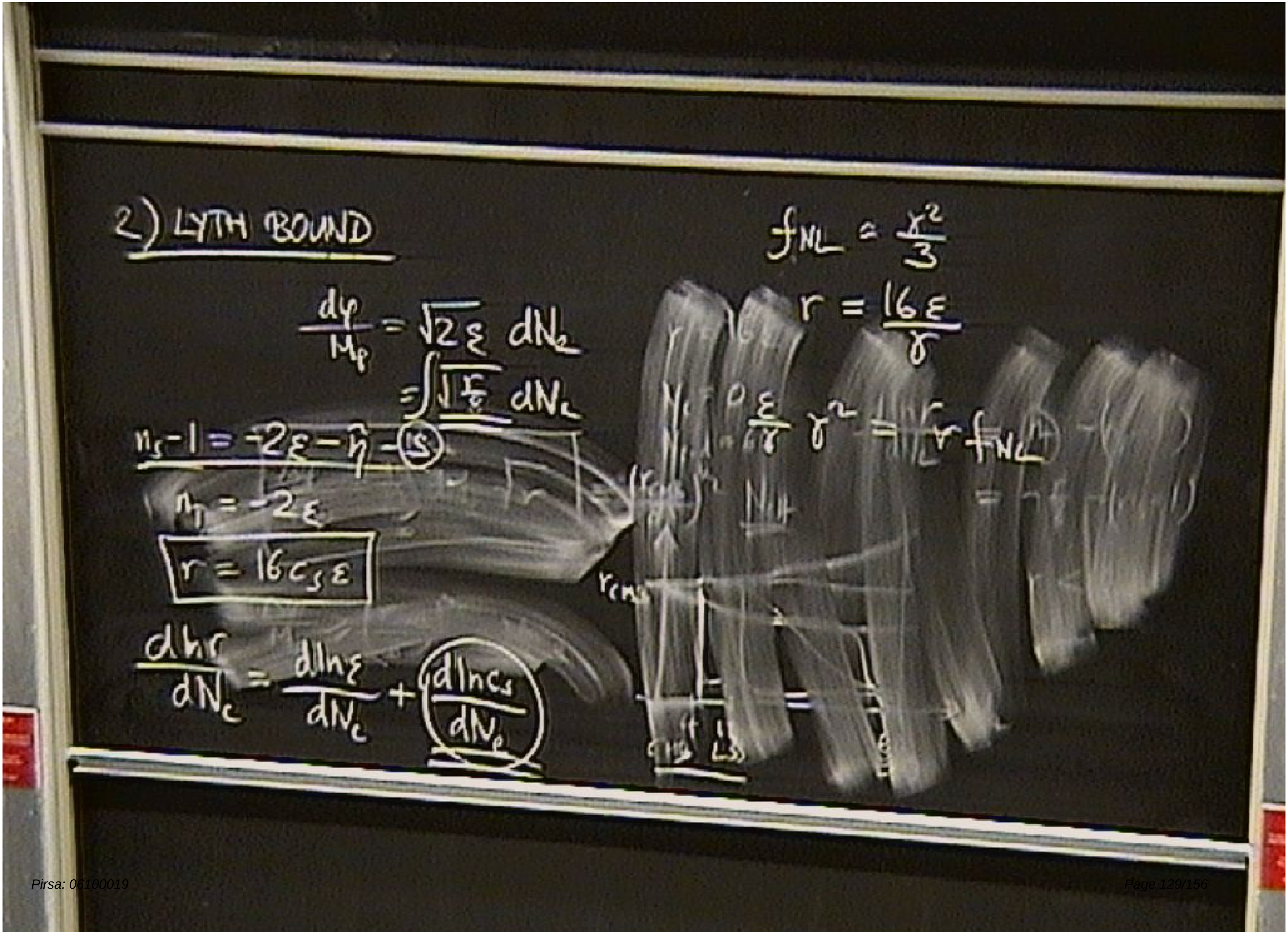
$$V(\varphi) = \frac{1}{2} m^2 \varphi^2 \longrightarrow H(\varphi) \simeq h\varphi\left[1 - C\varphi^2\right] \approx h\varphi$$

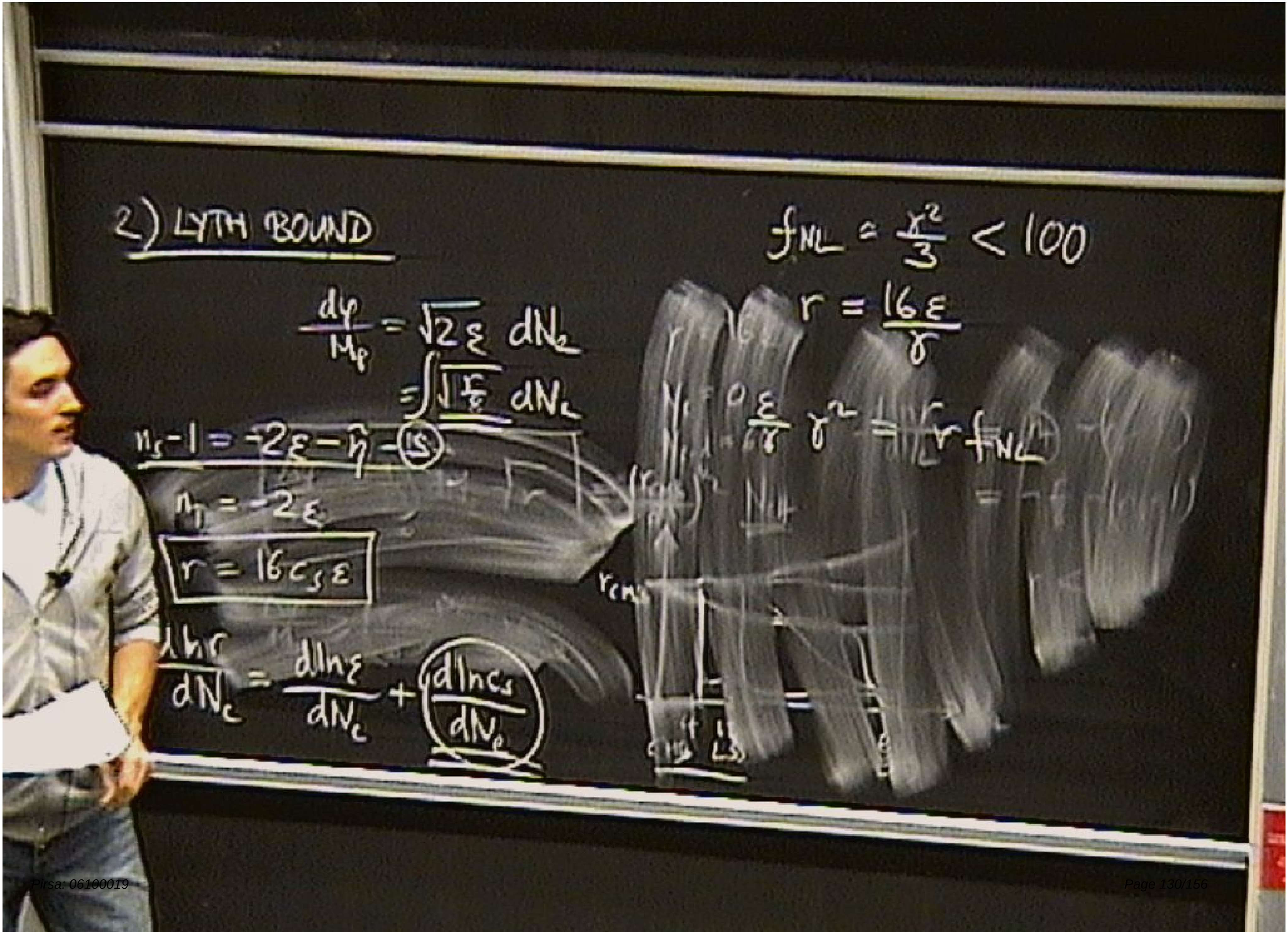
$$\varepsilon_\gamma = 2M_p^2 \left(\frac{H'}{H}\right)^2 = 2\left(\frac{M_p}{\varphi}\right)^2 \qquad \left(\frac{\Delta\varphi}{M_p}\right)^2 \gtrsim \frac{\gamma}{W}$$



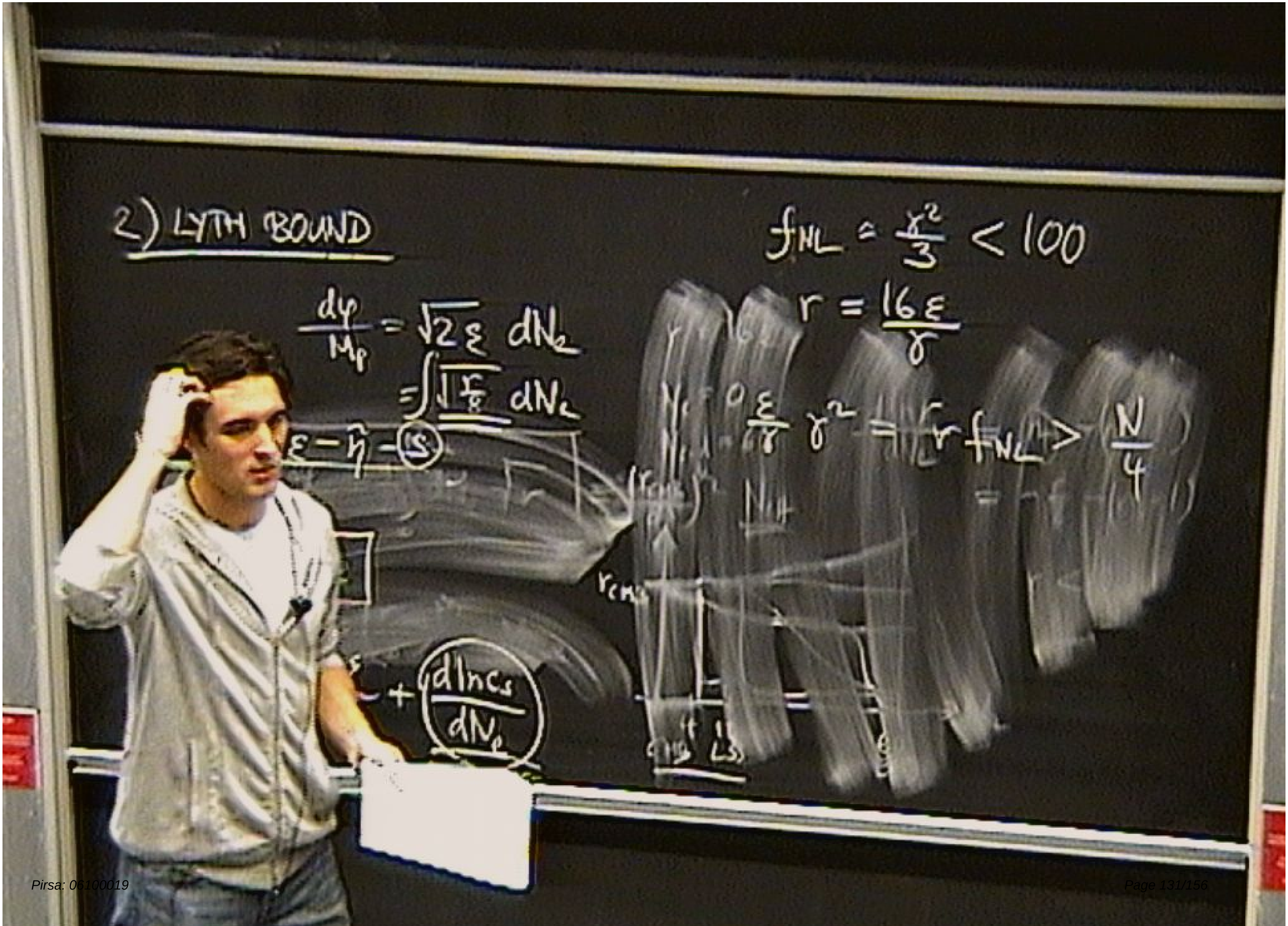
2) LYTH BOUND
fNL

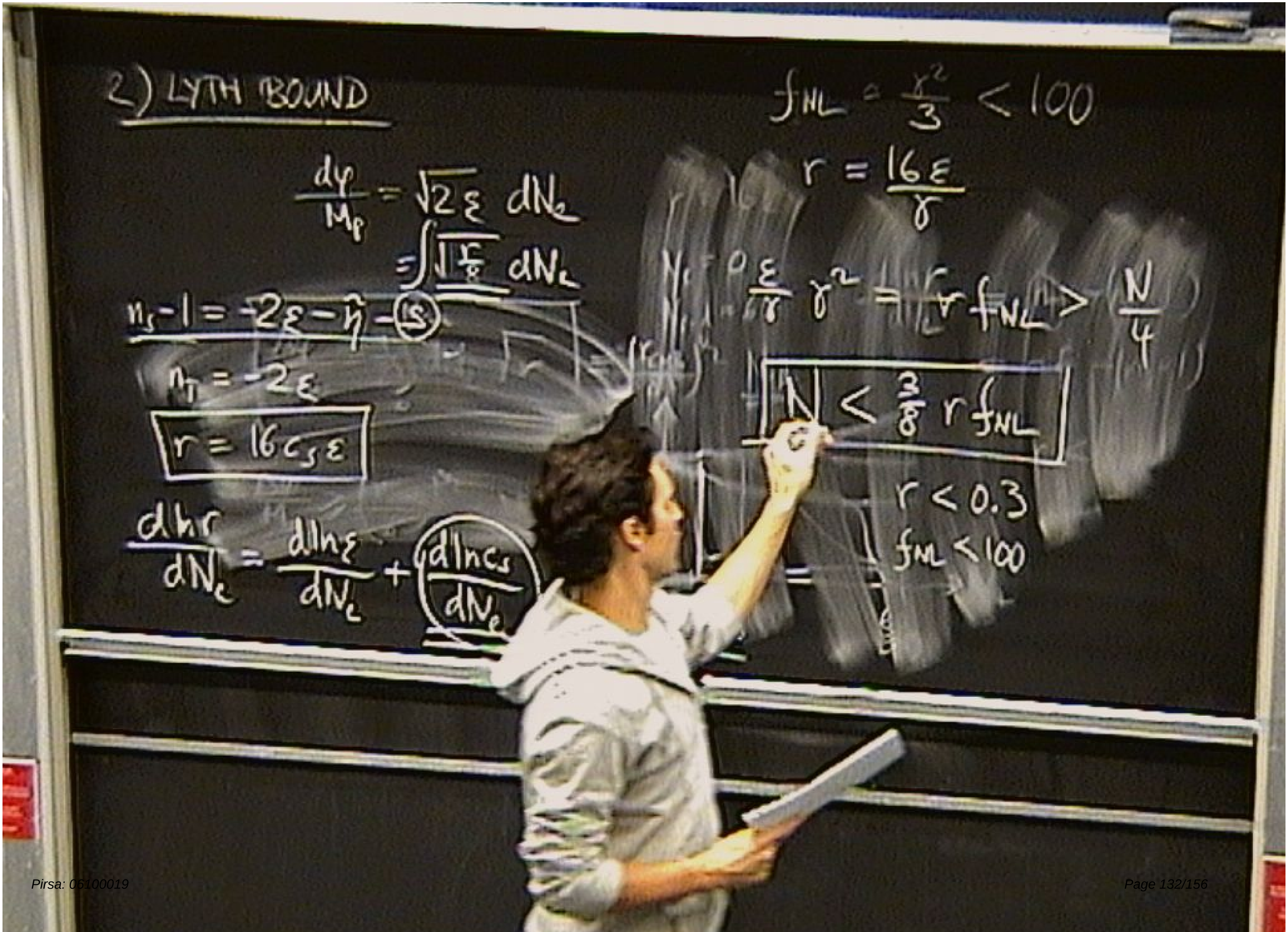

2) LYTH BOUND
fNL ≈ γ²/3
r = 16ε/γ
dφ/Mp = √2ε dNe
ns − 1 = −2ε − η
η = −2ε
r = 16cs
dlnr/dNe = dlnε/dNe


2) LYTH BOUND
$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e$
$= \int \sqrt{\frac{\varepsilon}{\gamma}}\, dN_e$
$n_s - 1 = -2\varepsilon - \tilde{\eta} - s$
$n_T = -2\varepsilon$
$r = 16 c_s \varepsilon$
$\frac{d\ln r}{dN_e} = \frac{d\ln\varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$
$f_{NL} \simeq \frac{\gamma^2}{3}$
$r = \frac{16\varepsilon}{\gamma}$



2) LYTH BOUND
dφ/M_P = √2ε dN_e
= ∫√ε/γ dN_e
n_s − 1 = −2ε − η̃ − (s)
n_t = −2ε
r = 16 c_s ε
d ln r / dN_e = d ln ε / dN_e + d ln c_s / dN_e
f_NL ≈ γ²/3 < 100
r = 16ε/γ


2) LYTH BOUND
fNL ≃ γ²/3 < 100
r = 16ε/γ
dφ/Mp = √2ε dNe
dlncs/dNe


2) LYTH BOUND
dφ/M_p = √(2ε) dN_e
= ∫√(r/8) dN_e
n_s − 1 = −2ε − η̃ − s
n_T = −2ε
r = 16 c_s ε
d ln r / dN_e = d ln ε / dN_e + d ln c_s / dN_e
f_NL = γ²/3 < 100
r = 16ε/γ
N < 3/8 r f_NL
r < 0.3
f_NL < 100

2) LYTH BOUND

$$f_{NL} = \frac{\gamma^2}{3} < 100$$

$$r = \frac{16\varepsilon}{\gamma}$$

$$\frac{d\varphi}{M_p} = \sqrt{2\varepsilon}\, dN_e$$

$$= \int \sqrt{\frac{r}{8}}\, dN_e$$

$$n_s - 1 = -2\varepsilon - \tilde{\eta} - s$$

$$n_T = -2\varepsilon$$

$$r = 16 c_s \varepsilon$$

$$\frac{N}{4}$$

$$N < \frac{3}{8} r f_{NL} \lesssim 10$$

$r < 0.3$

$f_{NL} < 100$

$$\frac{d\ln r}{dN_e} = \frac{d\ln\varepsilon}{dN_e} + \frac{d\ln c_s}{dN_e}$$

2) LYTH

$$\left(\frac{\delta\rho}{\rho}\right)^2 \sim \frac{\#\,\mathrm{Vol}(X)}{N}$$

$$f_{NL} = \frac{\gamma^2}{3} < 100$$

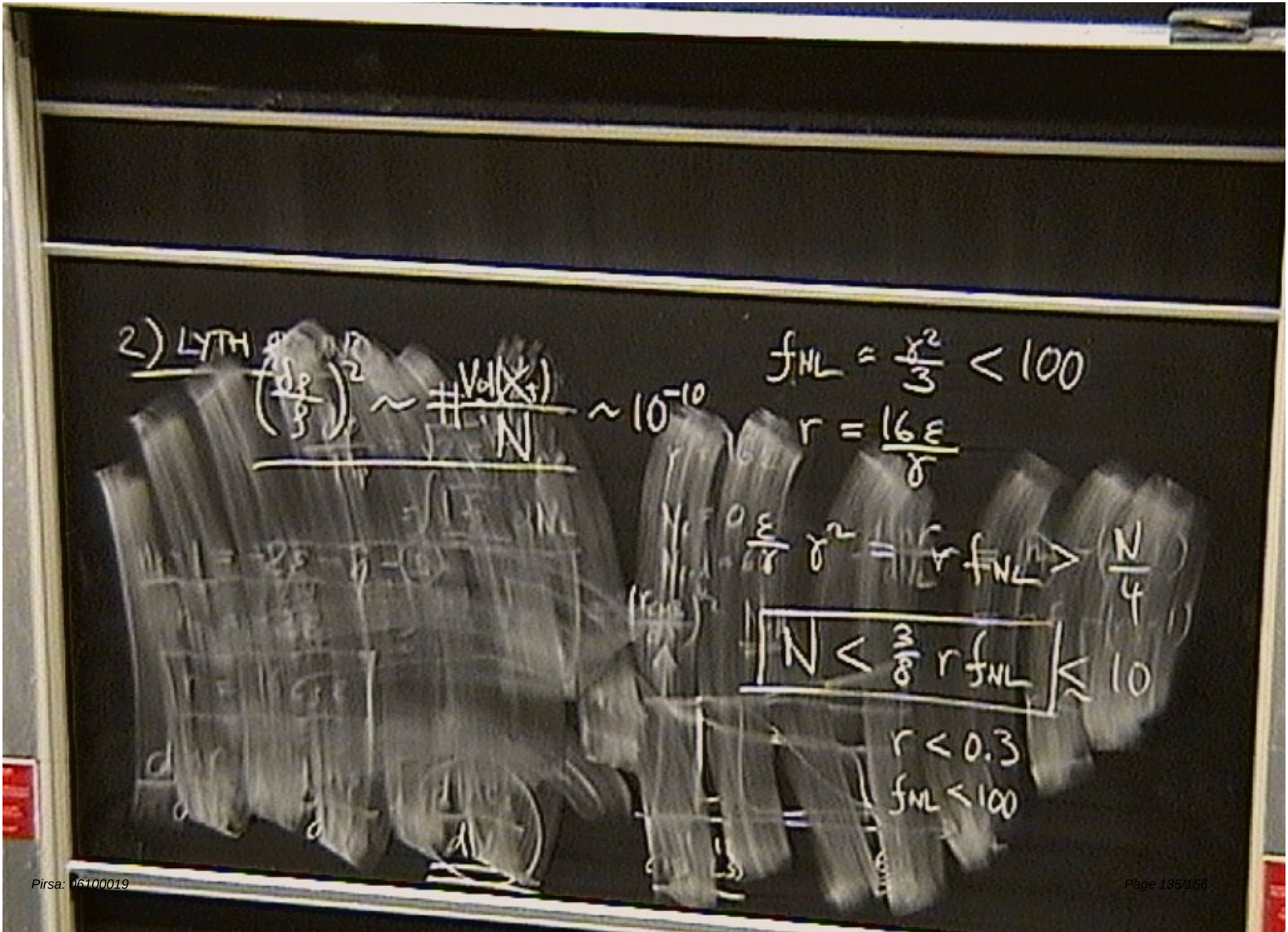
$$r = \frac{16\epsilon}{\gamma}$$

$$\frac{\epsilon}{\gamma}\gamma^2 = r f_{NL} > \frac{N}{4}$$

$$\boxed{N < \frac{3}{8} r f_{NL}} \lesssim 10$$

$r < 0.3$

$f_{NL} < 100$


2) LYTH
fNL = γ²/3 < 100
~ 10⁻¹⁰
r = 16ε/γ
N < 3/8 r fNL ≲ 10
r < 0.3
fNL < 100

2) LYTH BOUND

$$\left(\frac{\delta\rho}{\rho}\right)^2 \sim \# \frac{\mathrm{Vol}(X_5)}{N} \sim 10^{-10}$$

$$\boxed{N > 10^9\, \mathrm{Vol}(X_5)}$$

$$f_{NL} = \frac{\gamma^2}{3} < 100$$

$$r = \frac{16\varepsilon}{\gamma}$$

$$\frac{\varepsilon}{\gamma}\,\gamma^2 = r f_{NL} > \frac{N}{4}$$

$$\boxed{N < \frac{3}{8}\, r f_{NL}} \lesssim 10$$

$r < 0.3$

$f_{NL} < 100$

2) LYTH [illegible]

$$\left(\frac{\delta\rho}{\rho}\right)^2 \sim \# \frac{Vol(X_?)}{N} \sim 10^{-10}$$

$$f_{NL} = \frac{\gamma^2}{3} < 100$$

$$r = \frac{16\epsilon}{\gamma}$$

$$\boxed{N > 10^9\, Vol(X_5)}$$

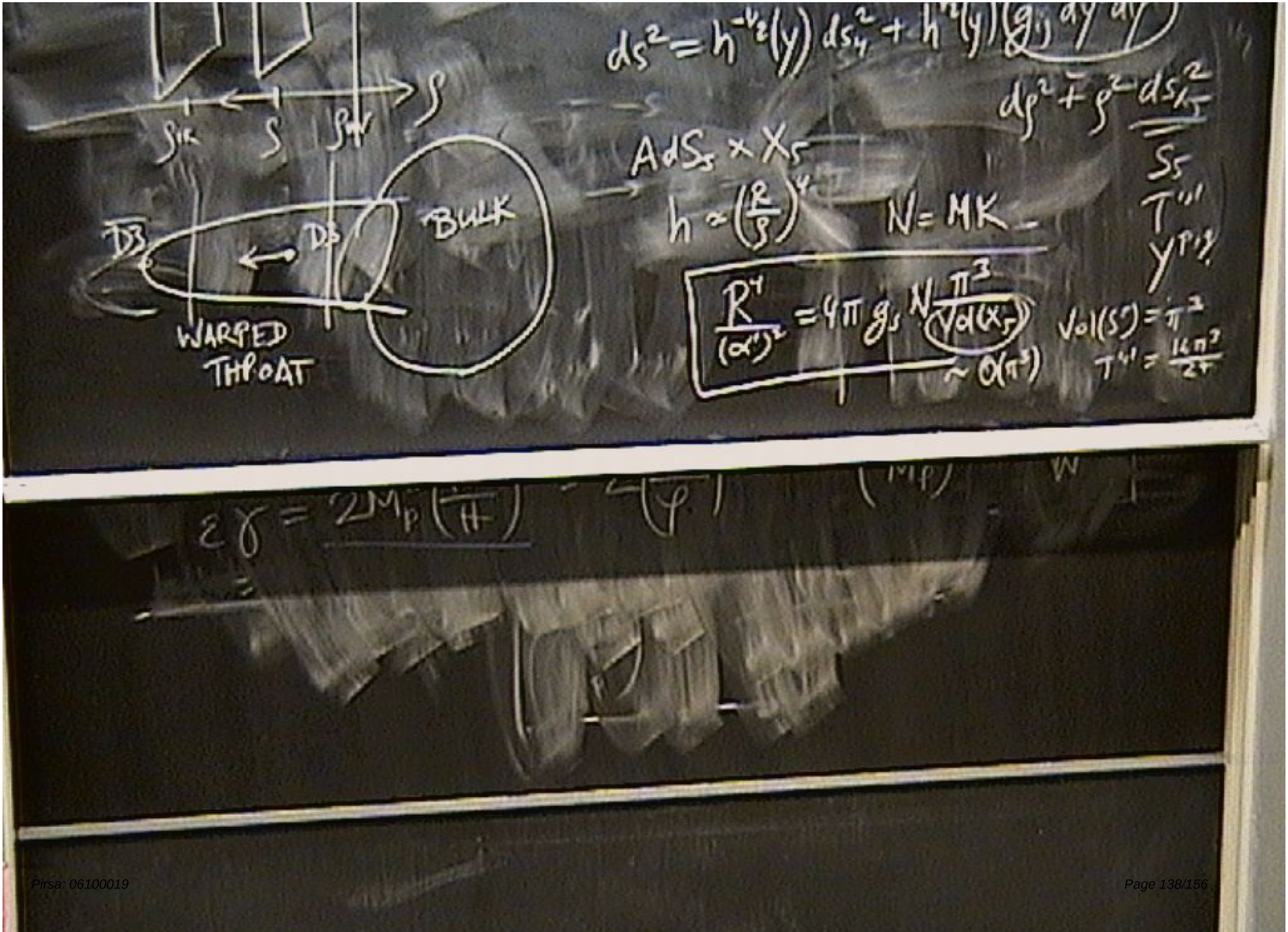
$$\boxed{Vol(X_5) < 10^{-9}}$$

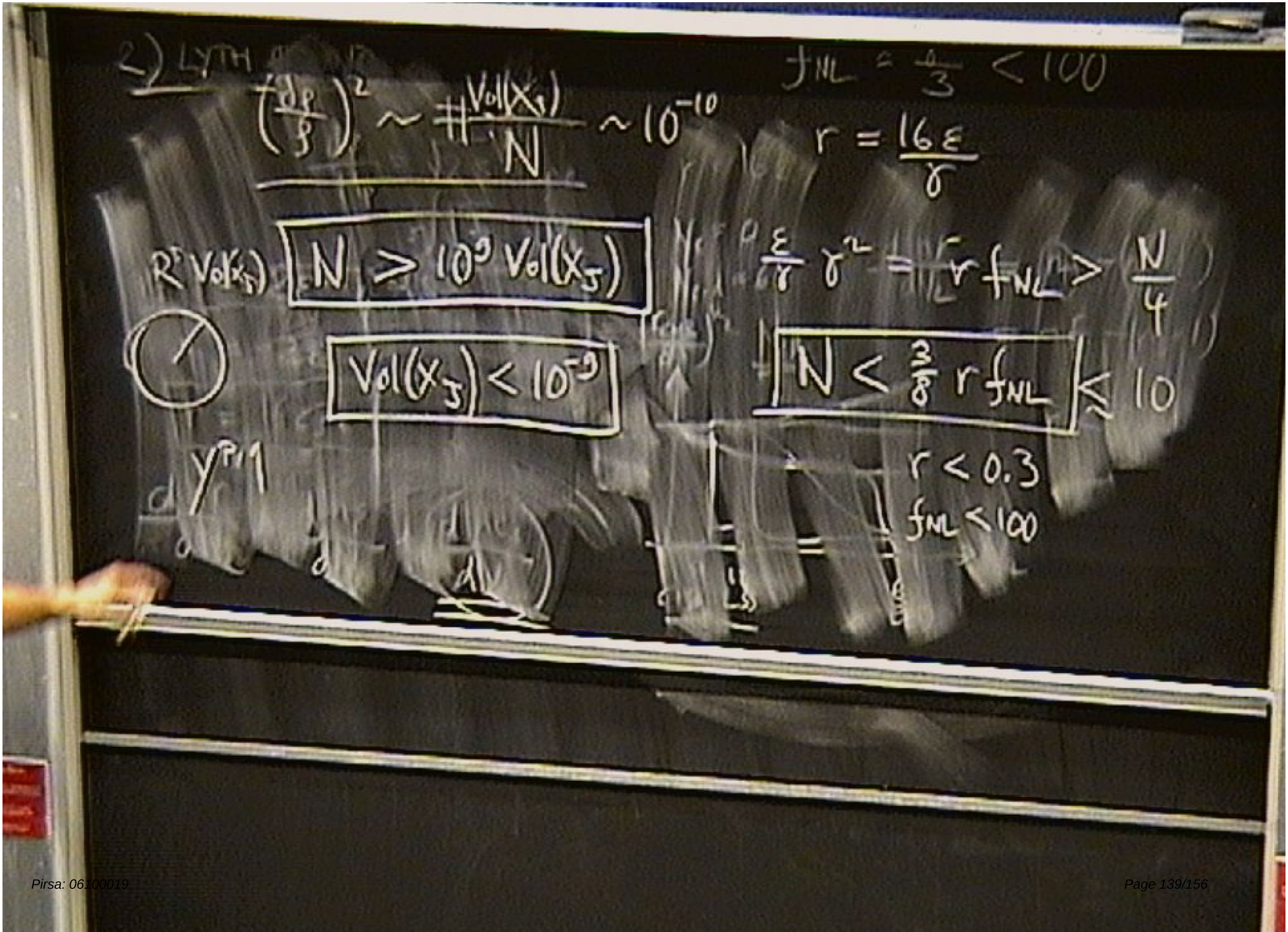
$$\frac{\epsilon}{\gamma}\gamma^2 = \ldots r f_{NL} > \frac{N}{4}$$

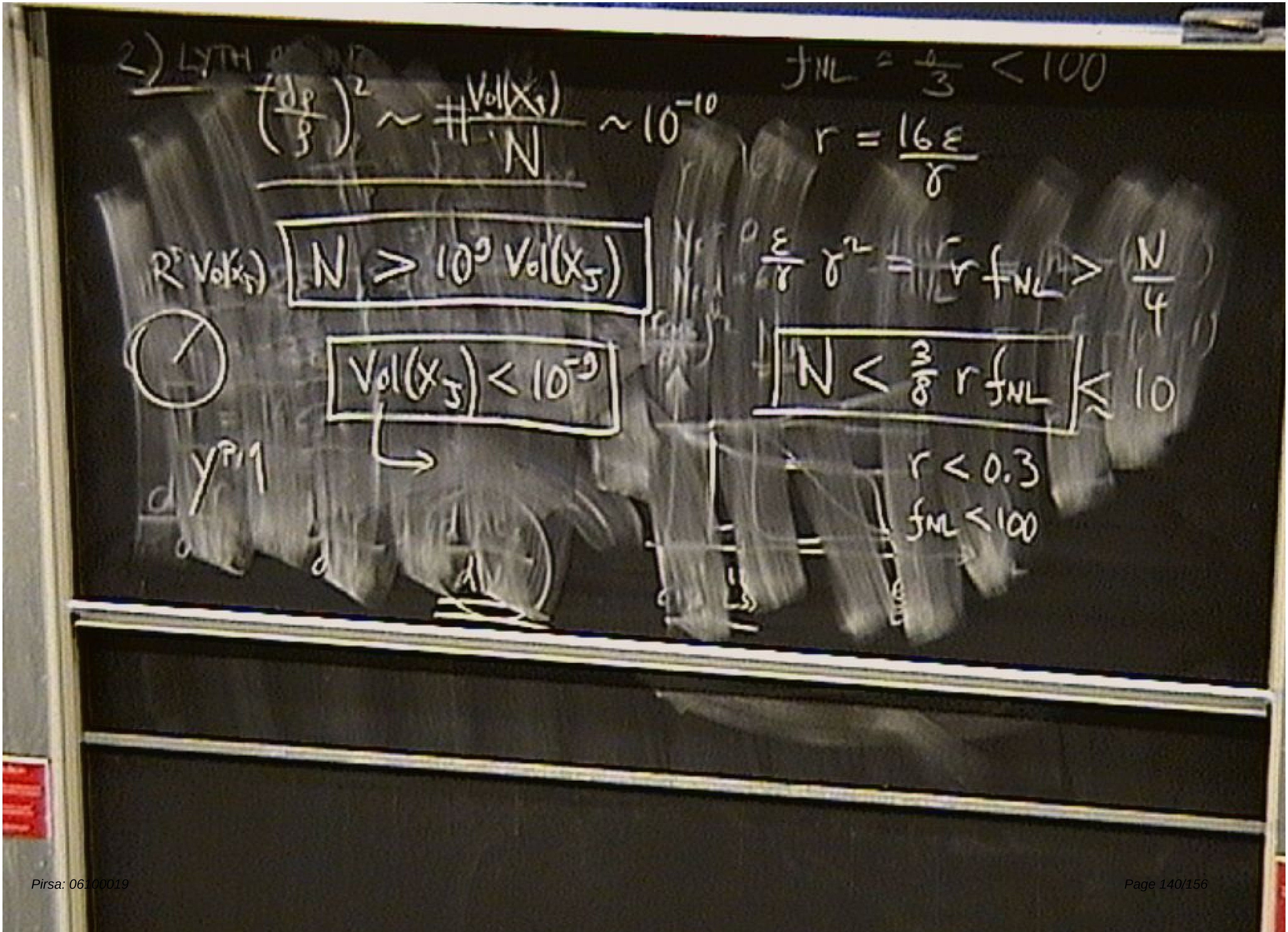
$$\boxed{N < \frac{3}{8} r f_{NL}} \lesssim 10$$

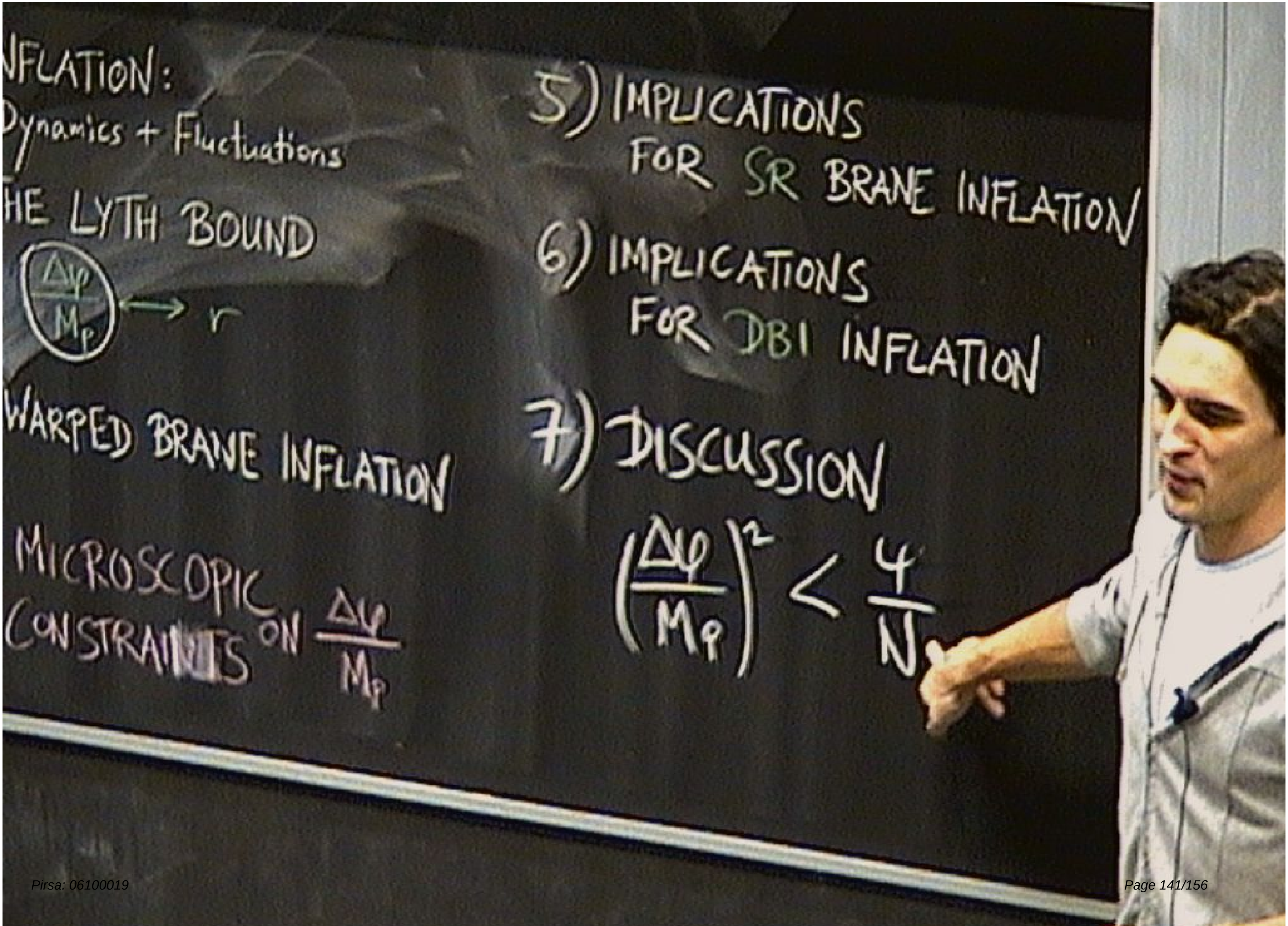
$r < 0.3$

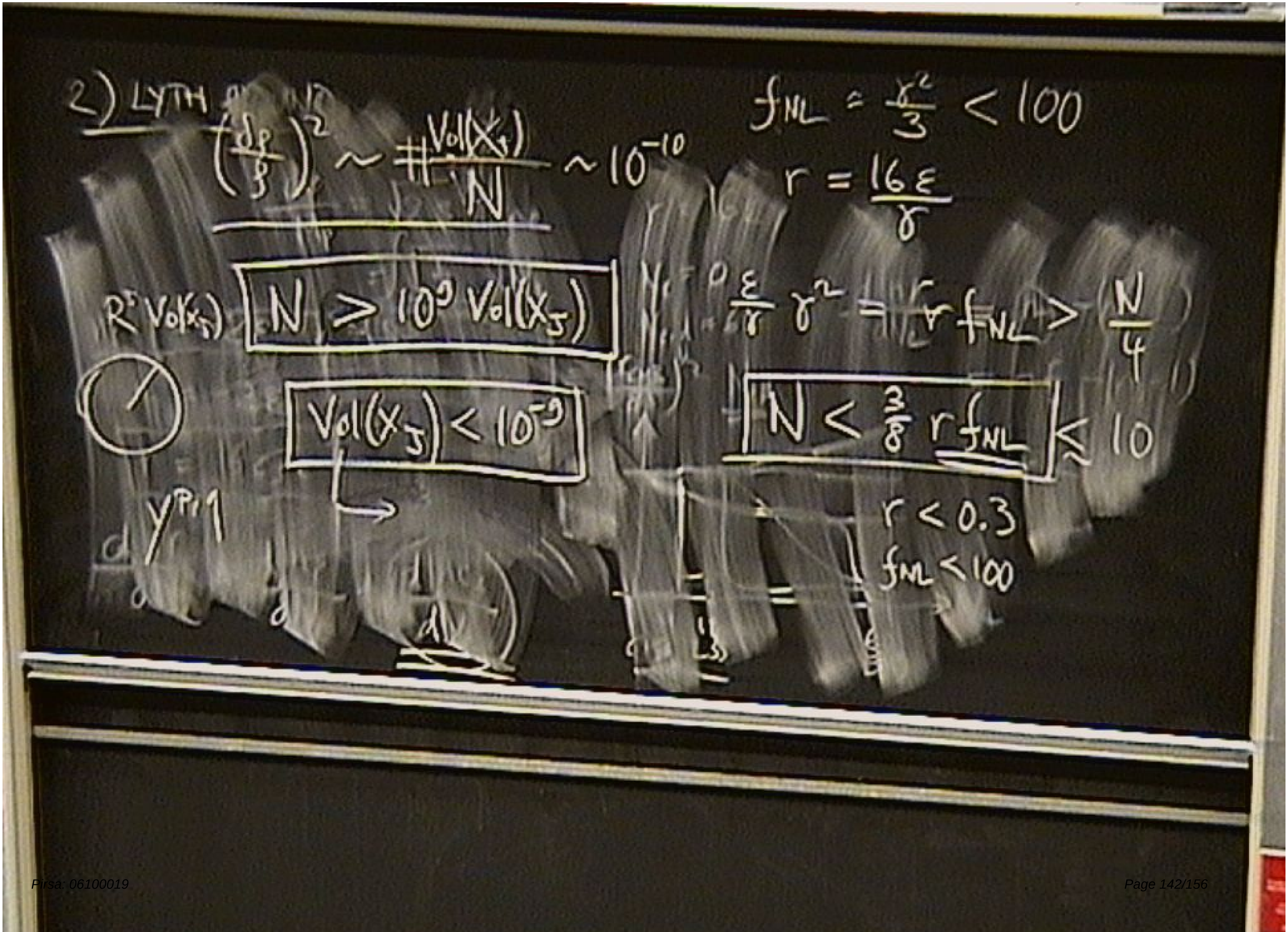
$f_{NL} < 100$

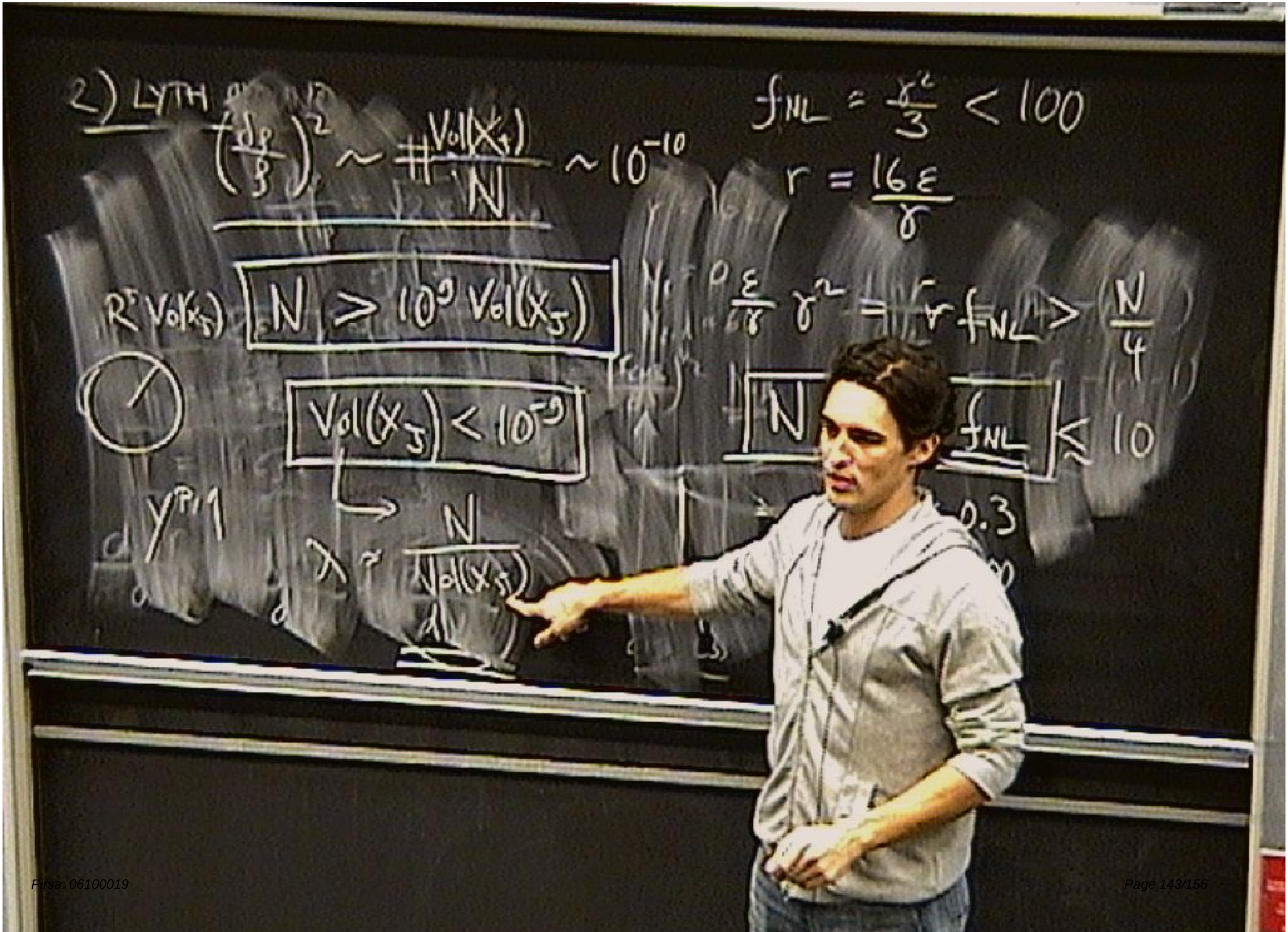

$ds^2 = h^{-1/2}(y)\, ds_4^2 + h^{1/2}(y)(g_{ij}\, dy^i dy^j)$
$d\rho^2 + \rho^2 ds_{X_5}^2$
$AdS_5 \times X_5$
$h \propto \left(\frac{R}{\rho}\right)^4$
$N = MK$
$\frac{R^4}{(\alpha')^2} = 4\pi g_s N \frac{\pi^3}{\mathrm{Vol}(X_5)}$
$\sim O(\pi^3)$
S_5
$T^{1,1}$
$Y^{p,q}$
$\mathrm{Vol}(S^5) = \pi^3$
$T^{1,1} = \frac{16\pi^3}{27}$
BULK
D3
WARPED
THROAT

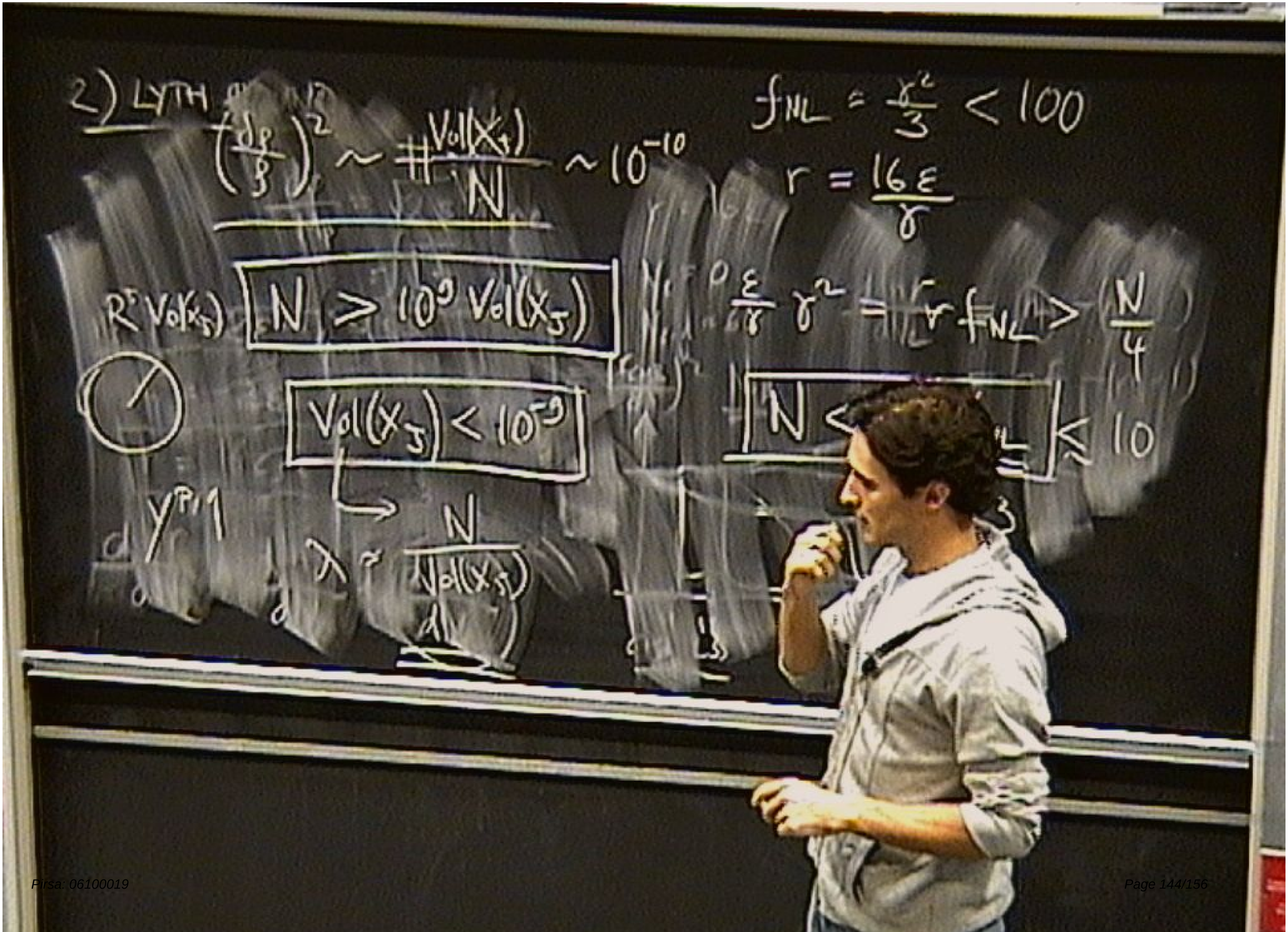

2) LYTH
fNL ≈ ε/3 < 100
(δρ/ρ)² ~ # Vol(X₅)/N ~ 10⁻¹⁰
r = 16ε/γ
N > 10⁹ Vol(X₅)
Vol(X₅) < 10⁻⁹
N < 3/8 r fNL ≲ 10
r < 0.3
fNL < 100

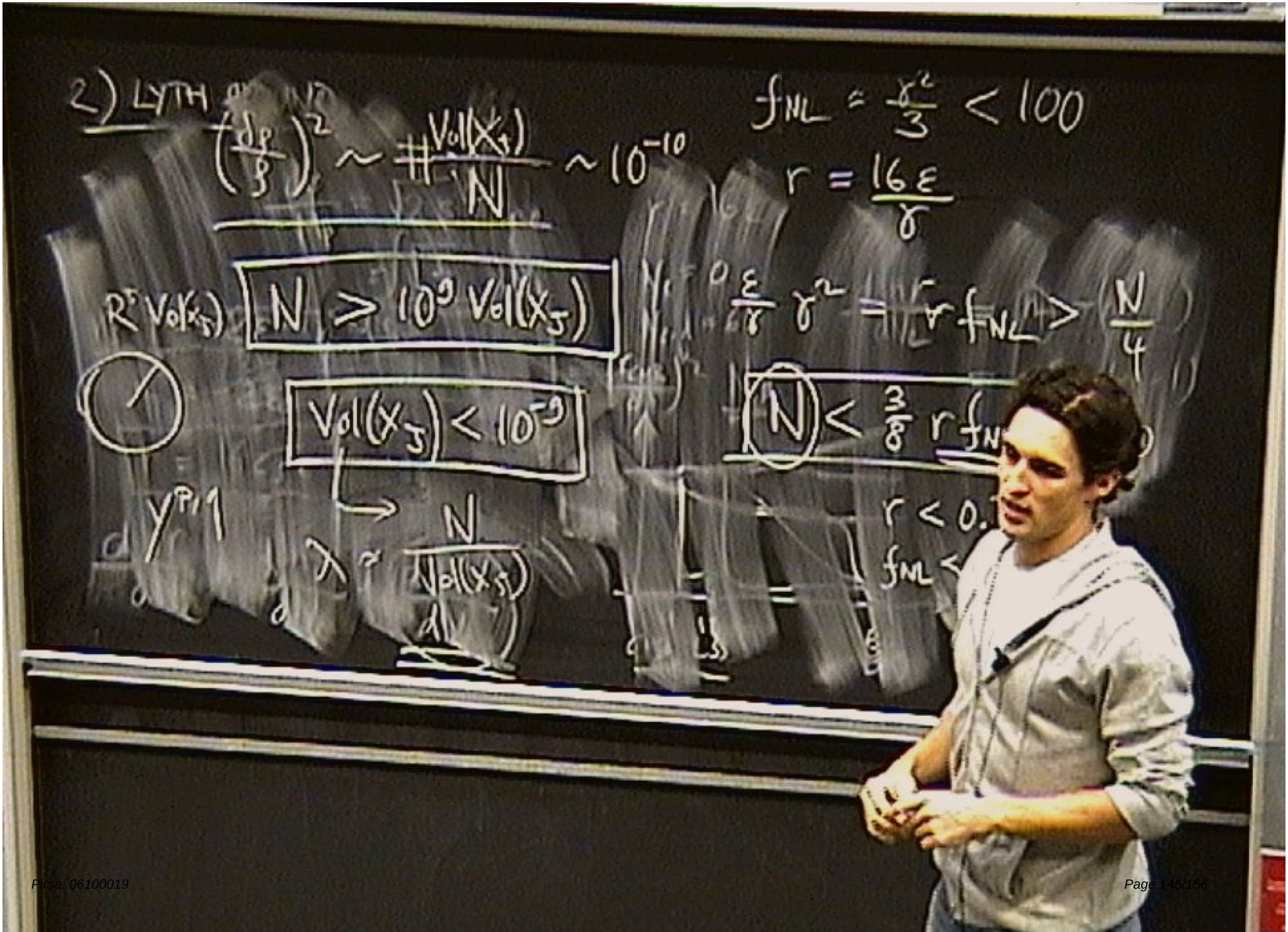

2) LYTH
fNL ≃ r/3 < 100
(dρ/ρ)² ~ # Vol(X5)/N ~ 10^-10
r = 16ε/γ
N > 10^9 Vol(X5)
Vol(X5) < 10^-9
N < 3/8 r fNL ≲ 10
r < 0.3
fNL < 100

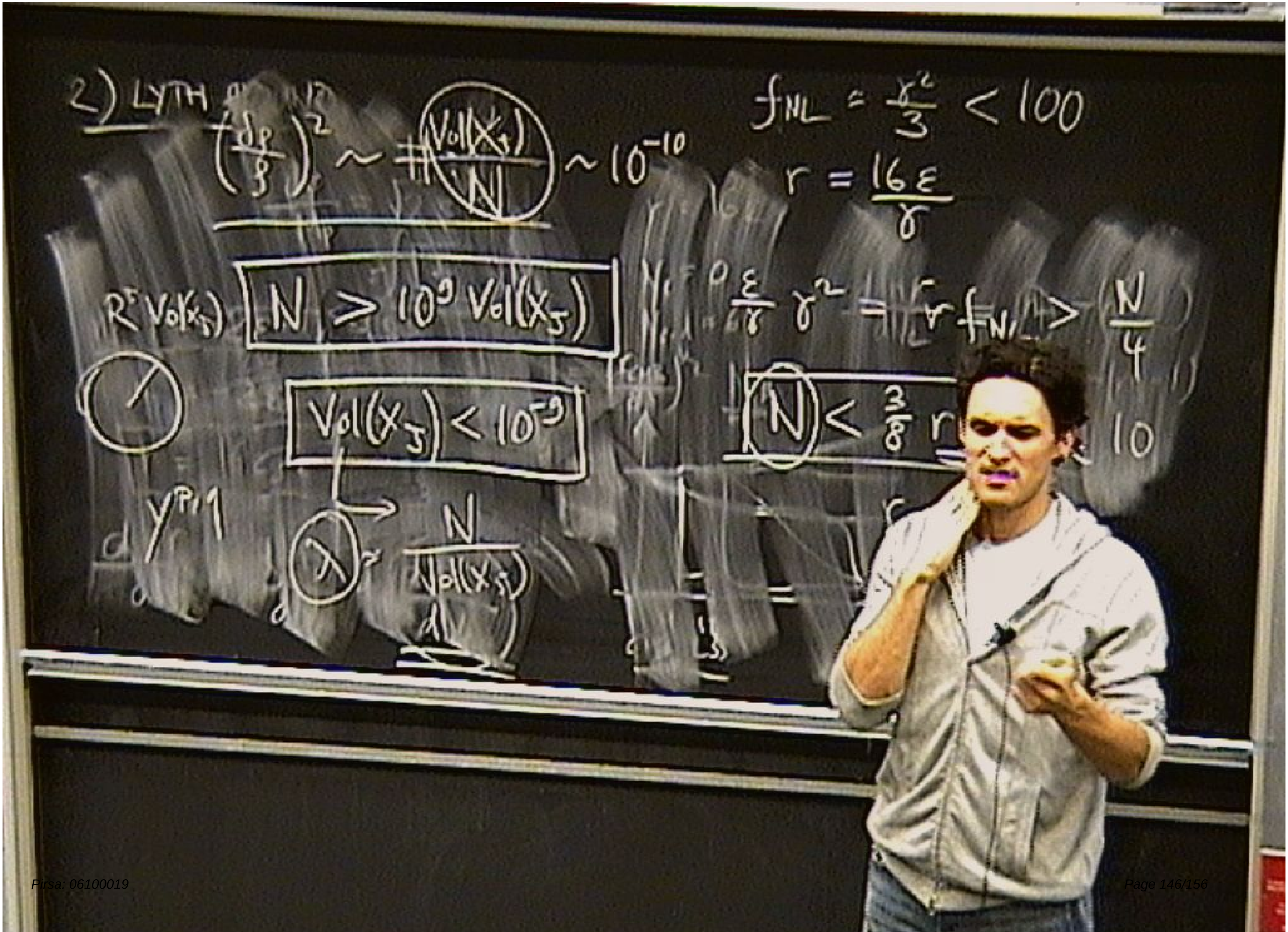

NFLATION:
ynamics + Fluctuations
HE LYTH BOUND
$\frac{\Delta\varphi}{M_p} \longleftrightarrow r$
WARPED BRANE INFLATION
MICROSCOPIC CONSTRAINTS ON $\frac{\Delta\varphi}{M_p}$
5) IMPLICATIONS FOR SR BRANE INFLATION
6) IMPLICATIONS FOR DBI INFLATION
7) DISCUSSION
$\left(\frac{\Delta\varphi}{M_p}\right)^2 < \frac{4}{N}$

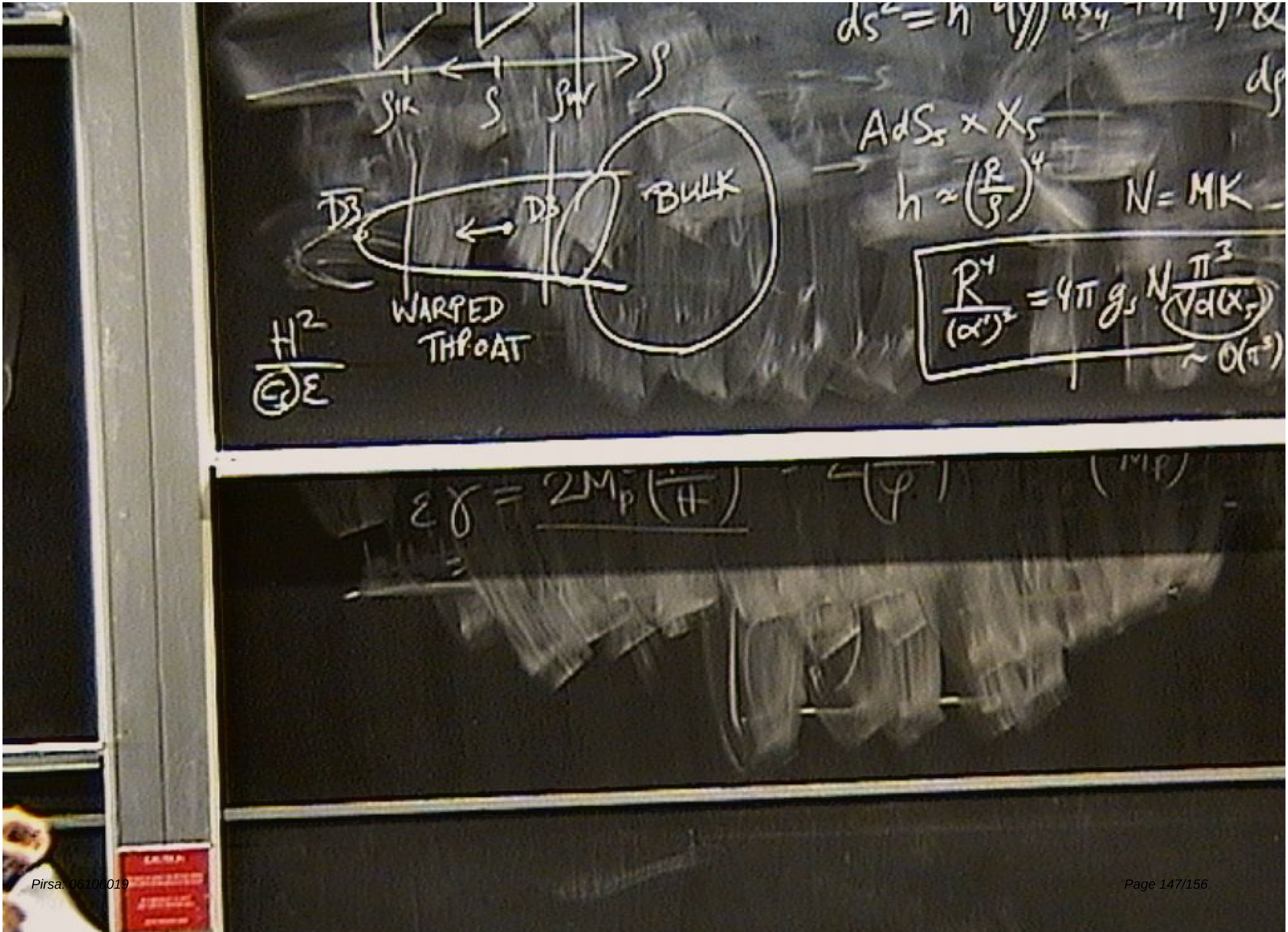

2) LYTH
(dρ/ρ)^2 ~ # Vol(X)/N ~ 10^-10
f_NL = γ^2/3 < 100
r = 16ε/γ
R^2 Vol(X_5)
N > 10^9 Vol(X_5)
Vol(X_5) < 10^-9
ε/γ γ^2 = r f_NL > N/4
N < 3/8 r f_NL < 10
r < 0.3
f_NL < 100

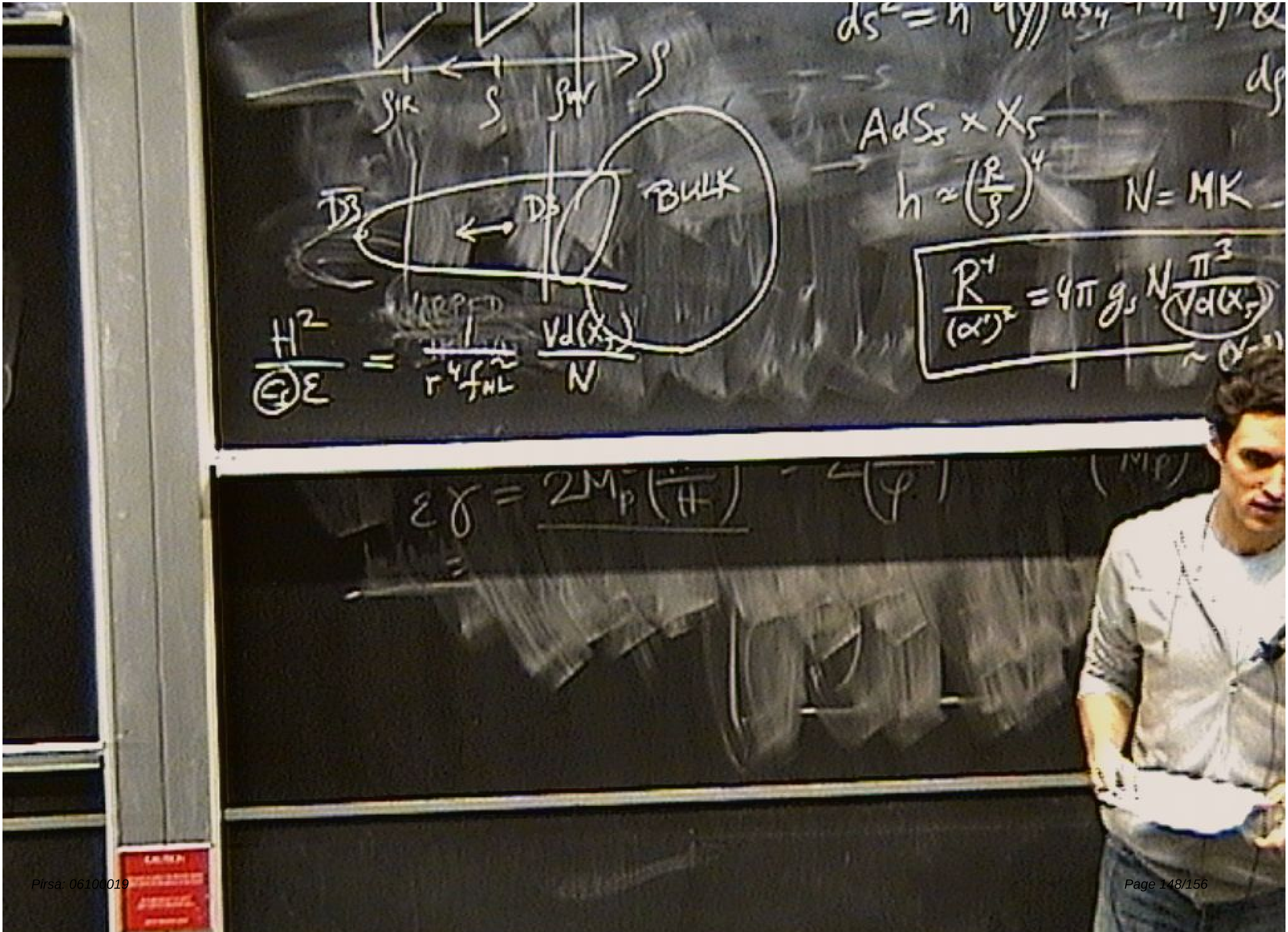

2) LYTH
fNL = γ²/3 < 100
r = 16ε/γ
~ 10^-10
N > 10^9 Vol(X5)
Vol(X5) < 10^-9
fNL < 10

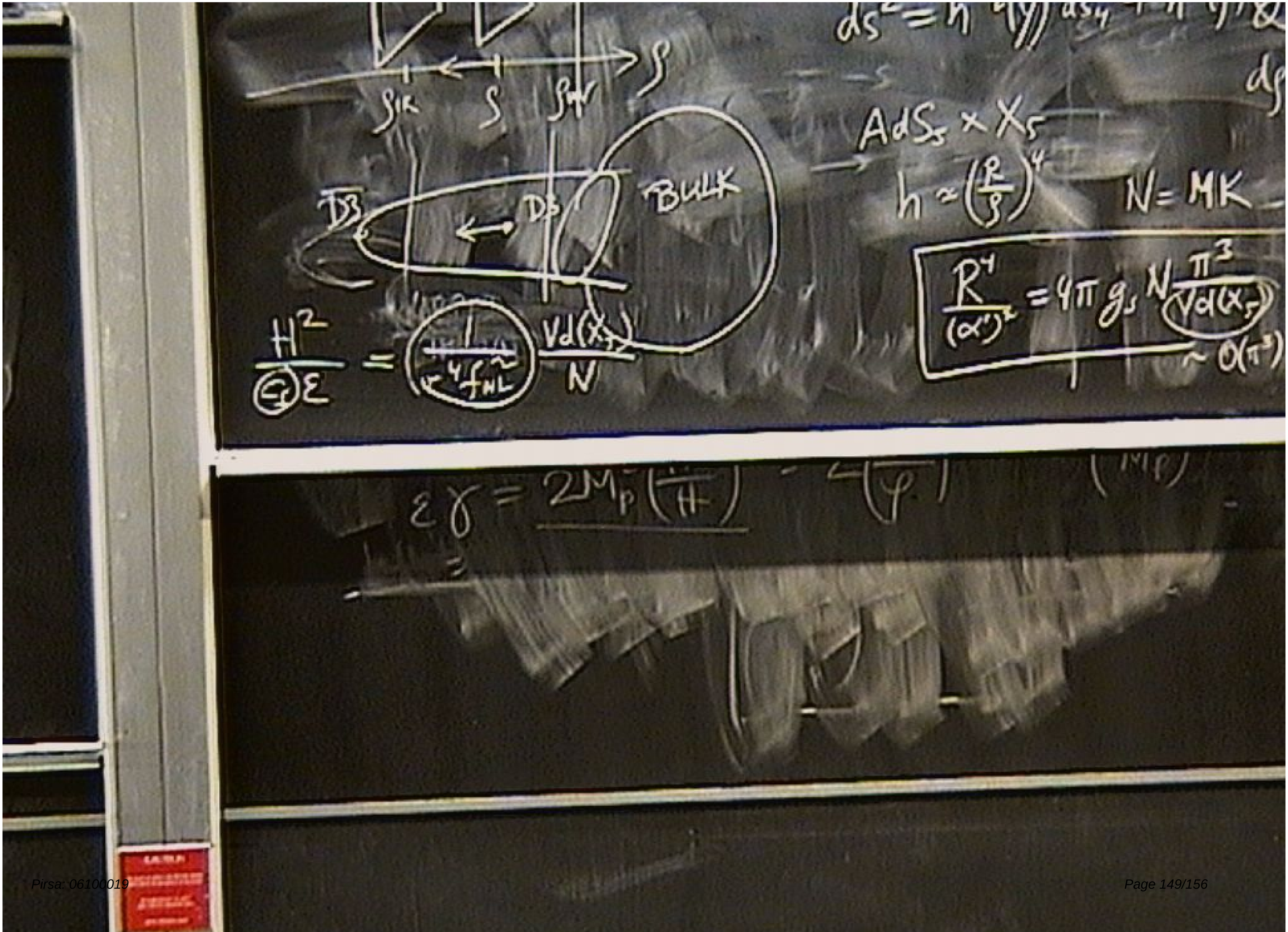

2) LYTH
fNL = γ²/3 < 100
r = 16ε/γ
~ 10^-10
N > 10^9 Vol(X5)
Vol(X5) < 10^-9
R² Vol(X5)
γ ~ N/Vol(X5)
r fNL > N/4
10

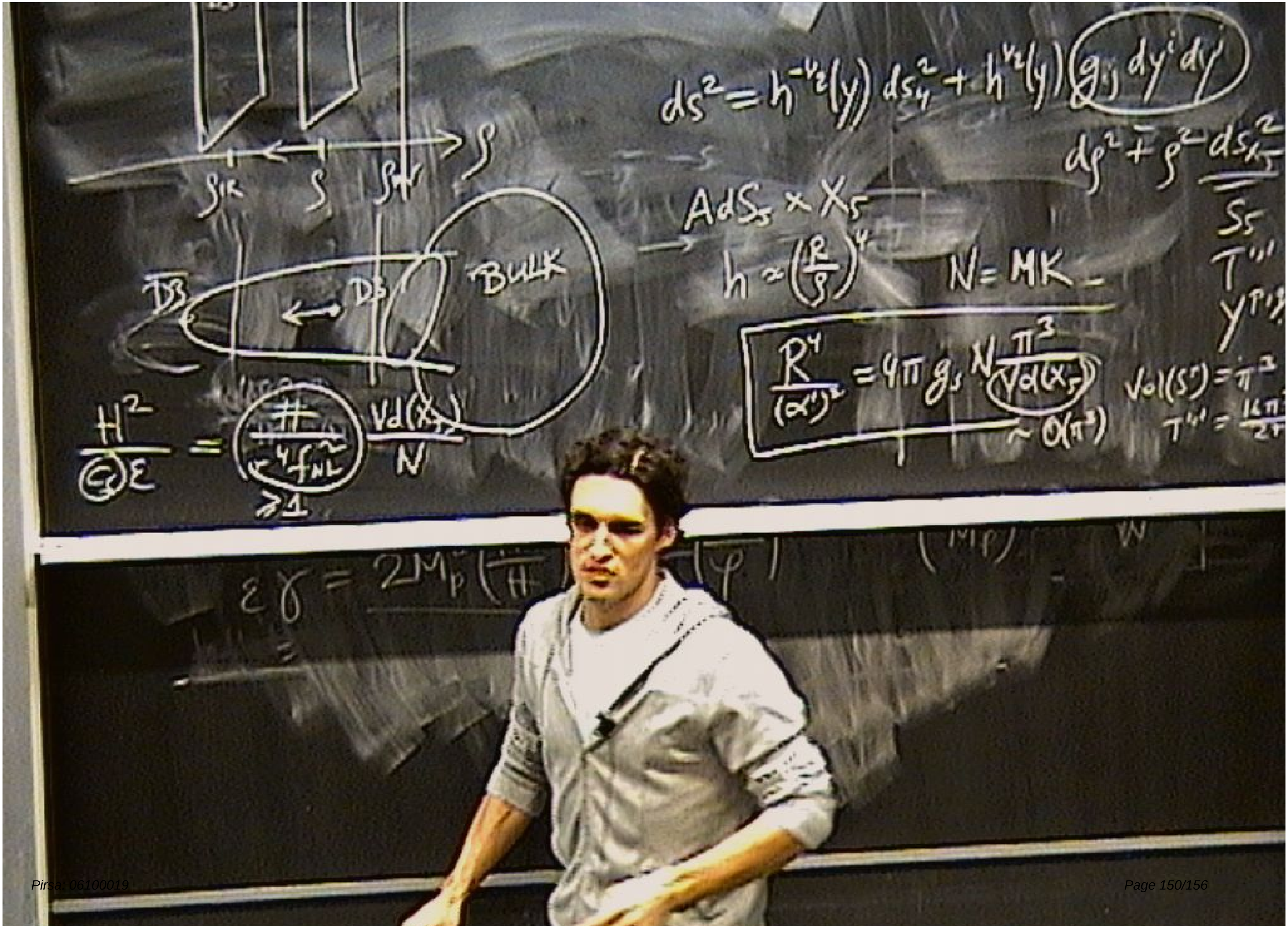

2) LYTH
fNL = γ²/3 < 100
r = 16ε/γ
~ 10^-10
N > 10^9 Vol(X5)
Vol(X5) < 10^-9
N < 3/8 r fNL
r < 0.
fNL <

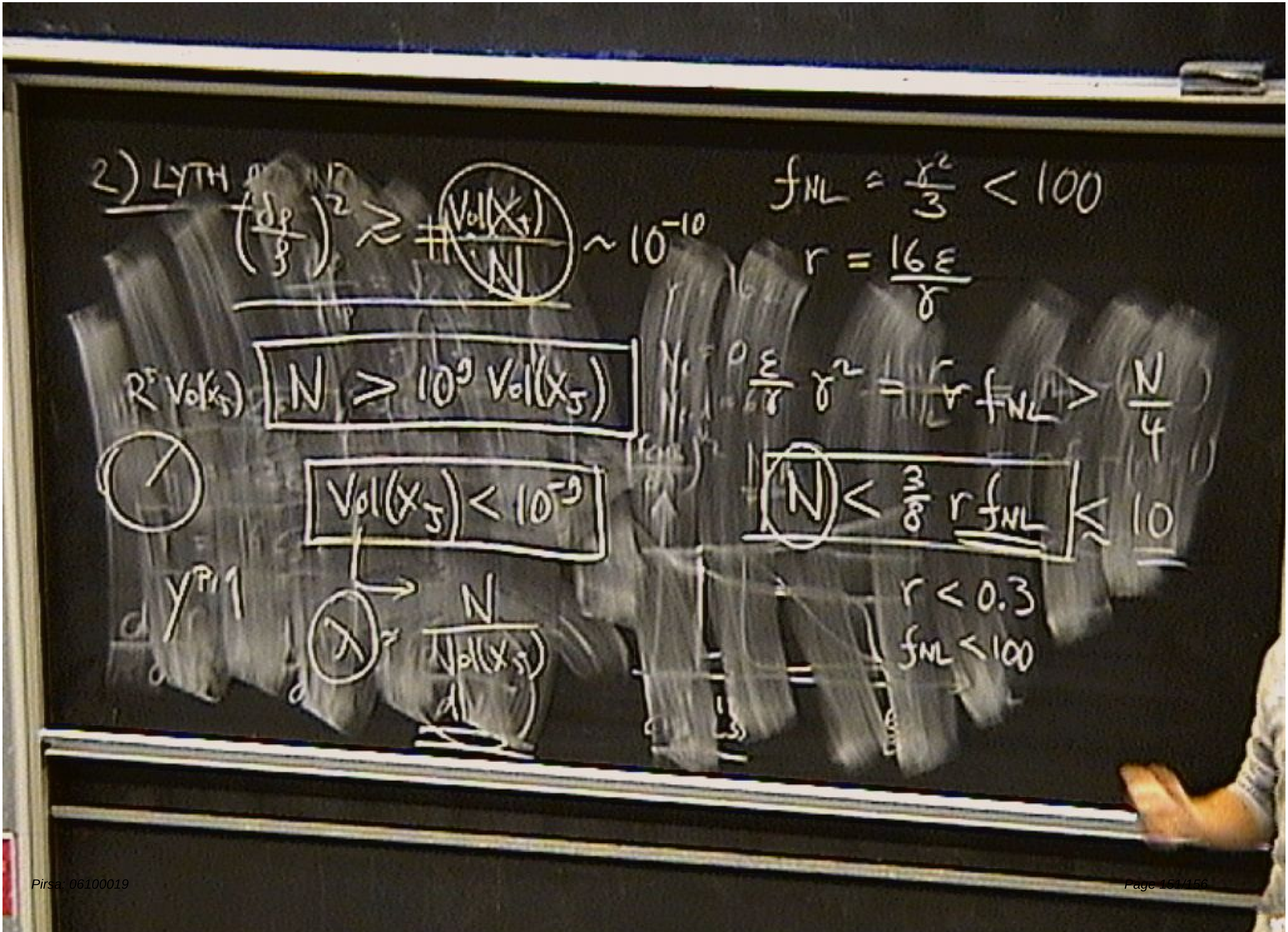

2) LYTH
$f_{NL} = \frac{r^2}{3} < 100$
$r = \frac{16\varepsilon}{\gamma}$
$\sim 10^{-10}$
$N > 10^9\, Vol(X_5)$
$Vol(X_5) < 10^{-9}$
$N < \frac{3}{8}\, r$
$\frac{N}{4}$
$\frac{N}{Vol(X_5)}$

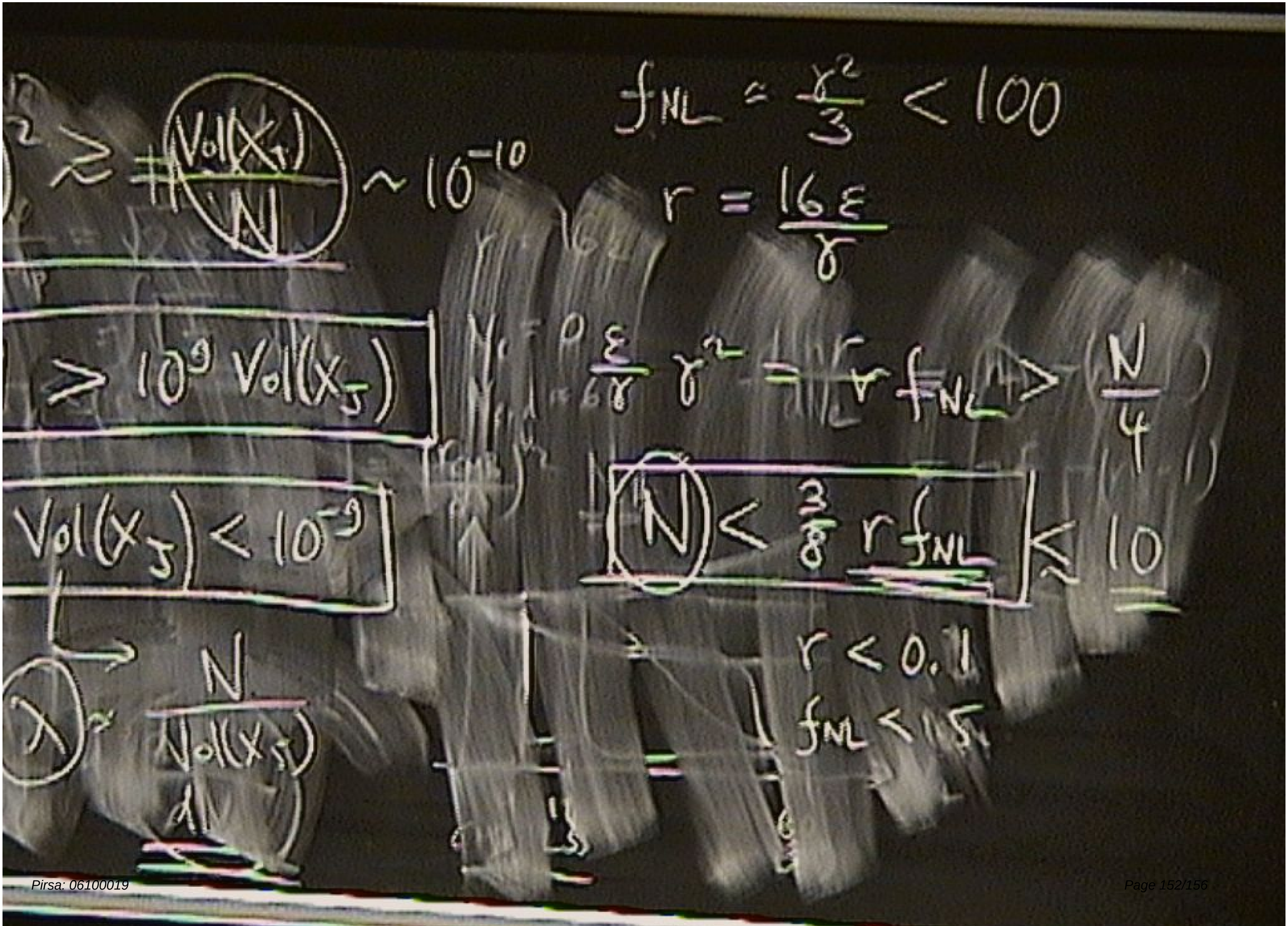

BULK
WARPED
THROAT
D3
AdS5 × X5
N = MK


BULK
D3
AdS5 × X5
N = MK

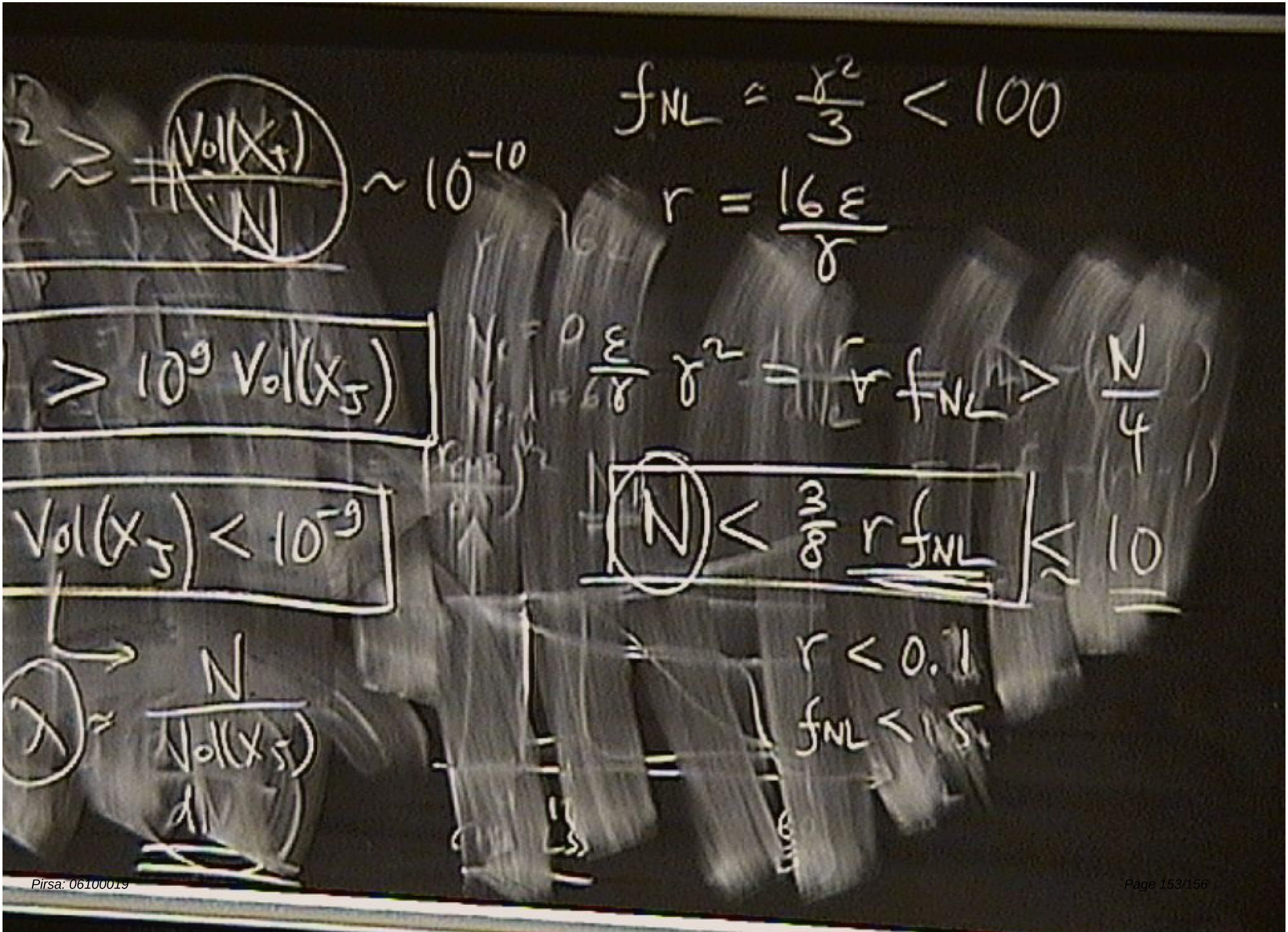

BULK
D3
AdS5 × X5
N = MK

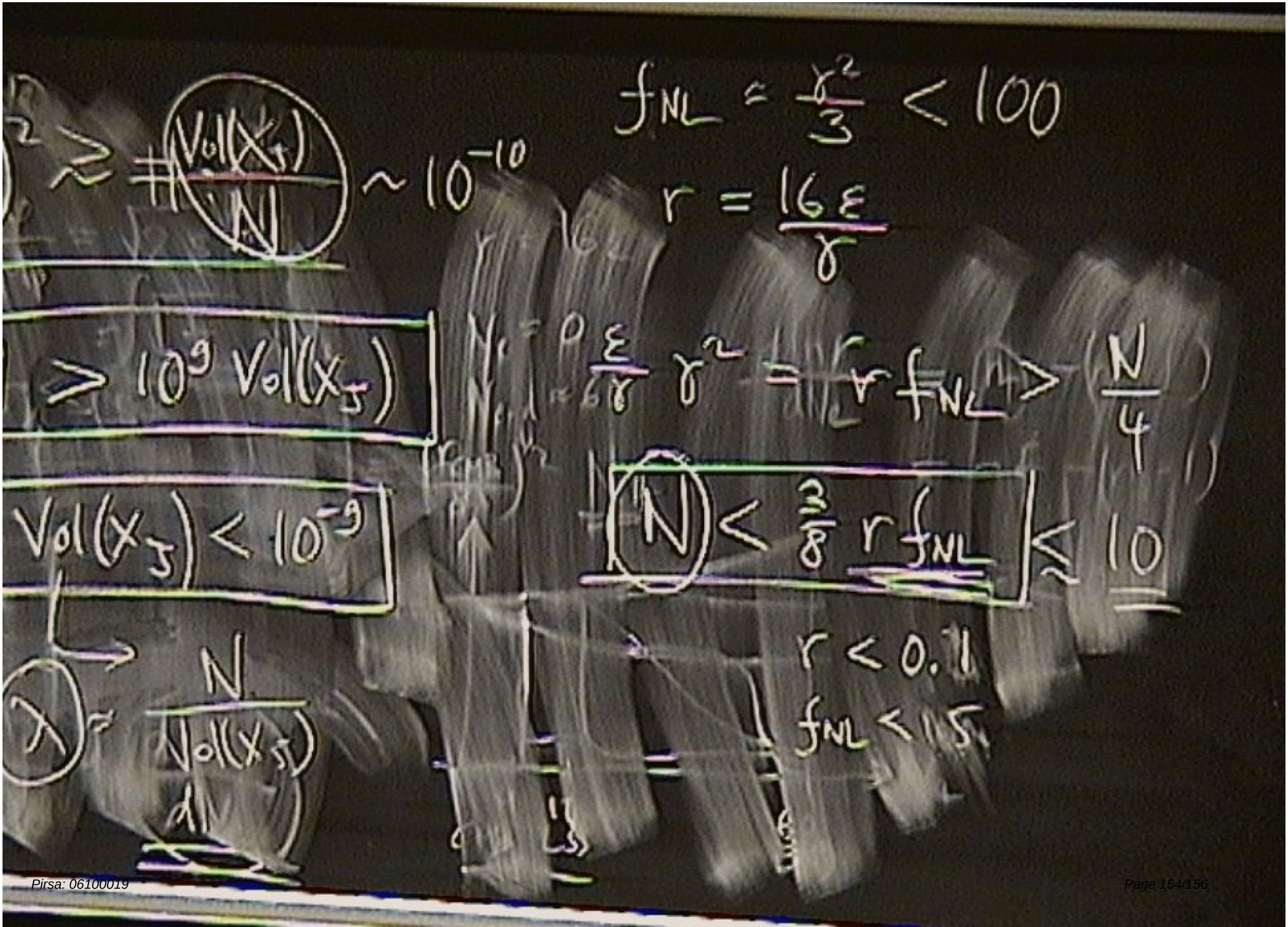

BULK
AdS5 × X5
N = MK
D3

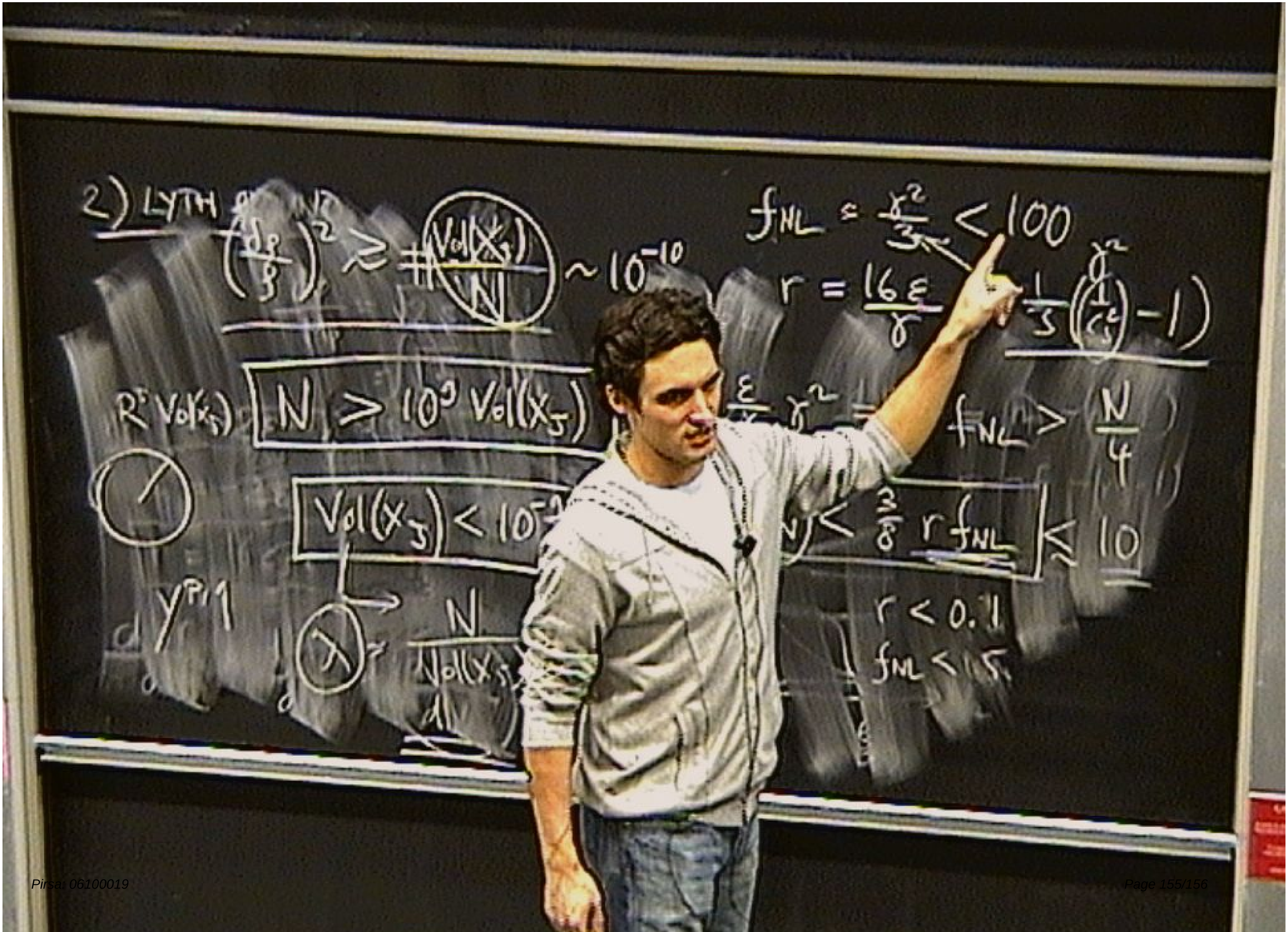

2) LYTH
fNL = r²/3 < 100
~10^-10
r = 16ε/γ
N > 10^9 Vol(X_5)
Vol(X_5) < 10^-9
N < 3/8 r fNL < 10
r < 0.3
fNL < 100



fNL ≈ γ²/3 < 100
r = 16ε/γ
~10⁻¹⁰
> 10⁹ Vol(X_J)
Vol(X_J) < 10⁻⁹
N < 3/8 r fNL < 10
r < 0.1


$f_{NL} \simeq \frac{\gamma^2}{3} < 100$
$\sim 10^{-10}$
$r = \frac{16\varepsilon}{\gamma}$
$> 10^9 \, Vol(X_J)$
$Vol(X_J) < 10^{-9}$
$N < \frac{3}{8} r f_{NL} < 10$
$r < 0.1$
$f_{NL} < 1.5$


fNL ≈ γ²/3 < 100
~ 10^-10
r = 16ε/γ
> 10^9 Vol(X_5)
r fNL > N/4
Vol(X_5) < 10^-9
N < 3/8 r fNL < 10
r < 0.1
N / Vol(X_5)


2) LYTH
~10^-10
N > 10^9 Vol(X_5)
r < 0.1

2) LYTH BOUND

$$\left(\frac{\delta\rho}{\rho}\right)^2 \gtrsim \# \frac{\mathrm{Vol}(X_5)}{N} \sim 10^{-10}$$

$R^4\,\mathrm{Vol}(X_5)$ $\boxed{N > 10^9\,\mathrm{Vol}(X_5)}$

$\boxed{\mathrm{Vol}(X_5) < 10^{-9}}$

$y^p \gg 1$ $\quad \lambda \sim \frac{N}{\mathrm{Vol}(X_5)}$

$$f_{NL} = \frac{\gamma^2}{3} < 100 \qquad \frac{\gamma^2}{3} \to \frac{1}{3}\left(\frac{1}{c_s^2} - 1\right)$$

$$r = \frac{16\epsilon}{\gamma}$$

$$\frac{\epsilon}{\gamma}\gamma^2 = r f_{NL} > \frac{N}{4}$$

$$\boxed{N < \frac{3}{8} r f_{NL}} < 10$$

$r < 0.1$

$f_{NL} < 15$