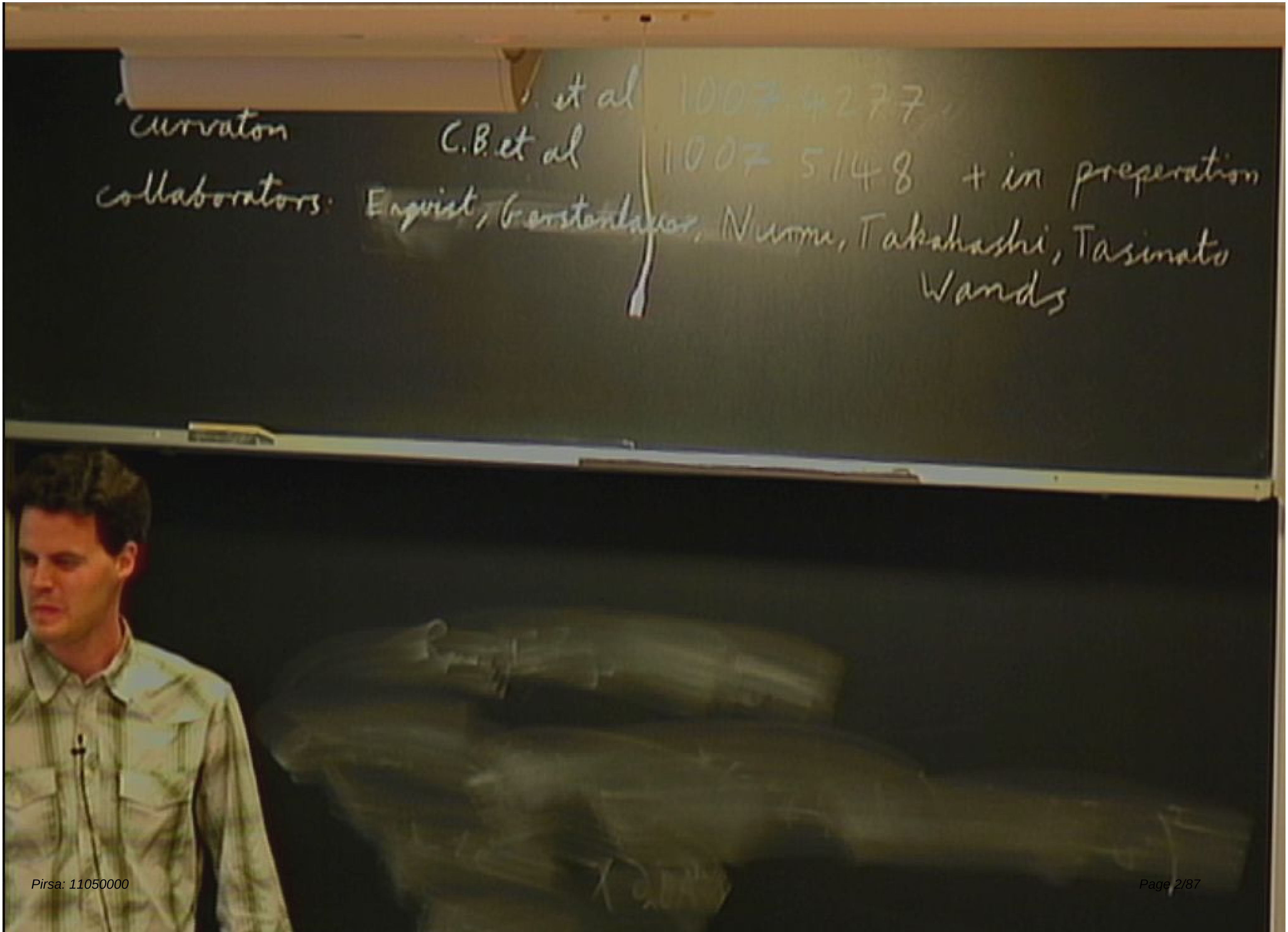
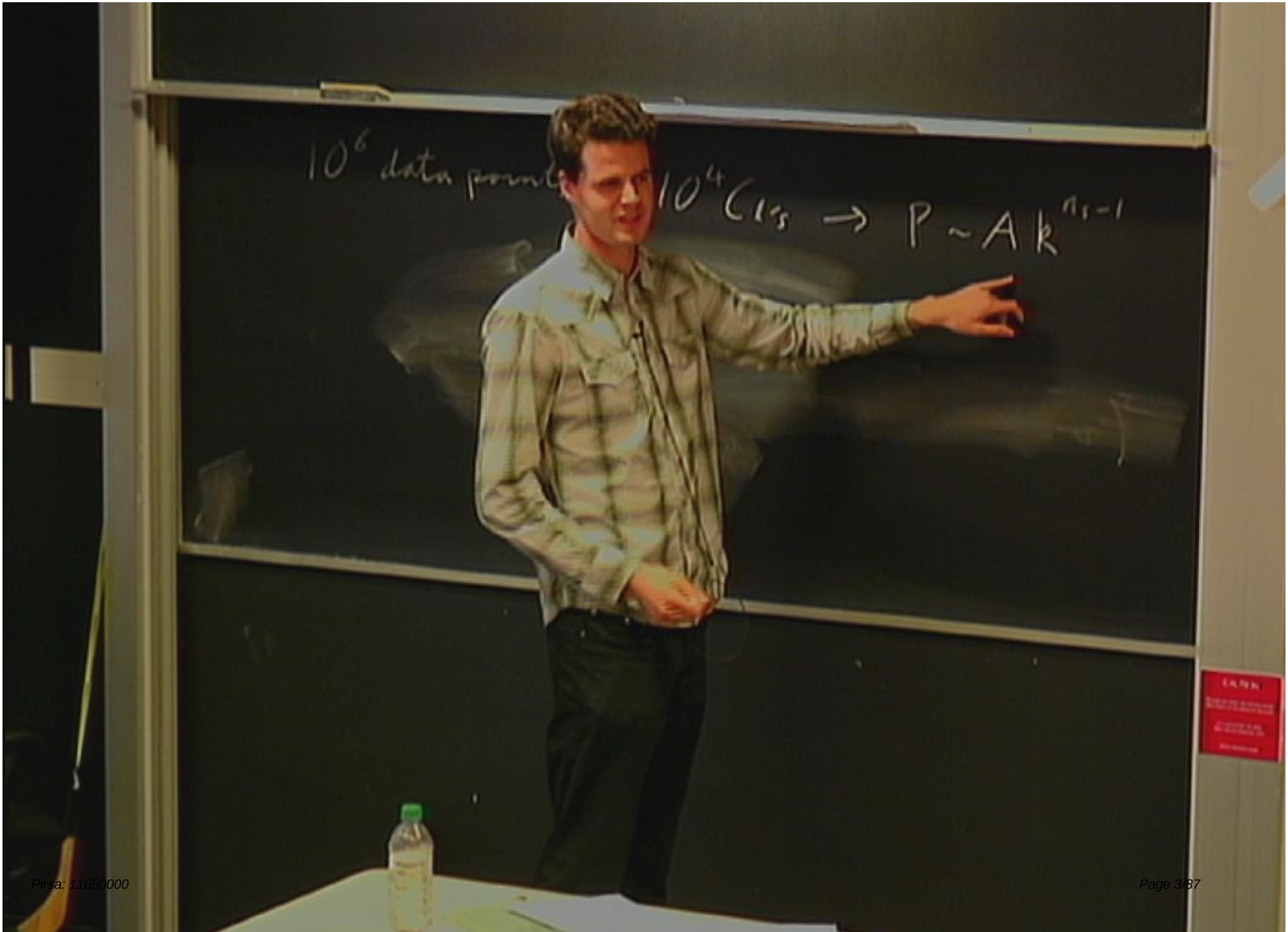
Title: Maximizing the scientific return from cosmic non-Gaussianity

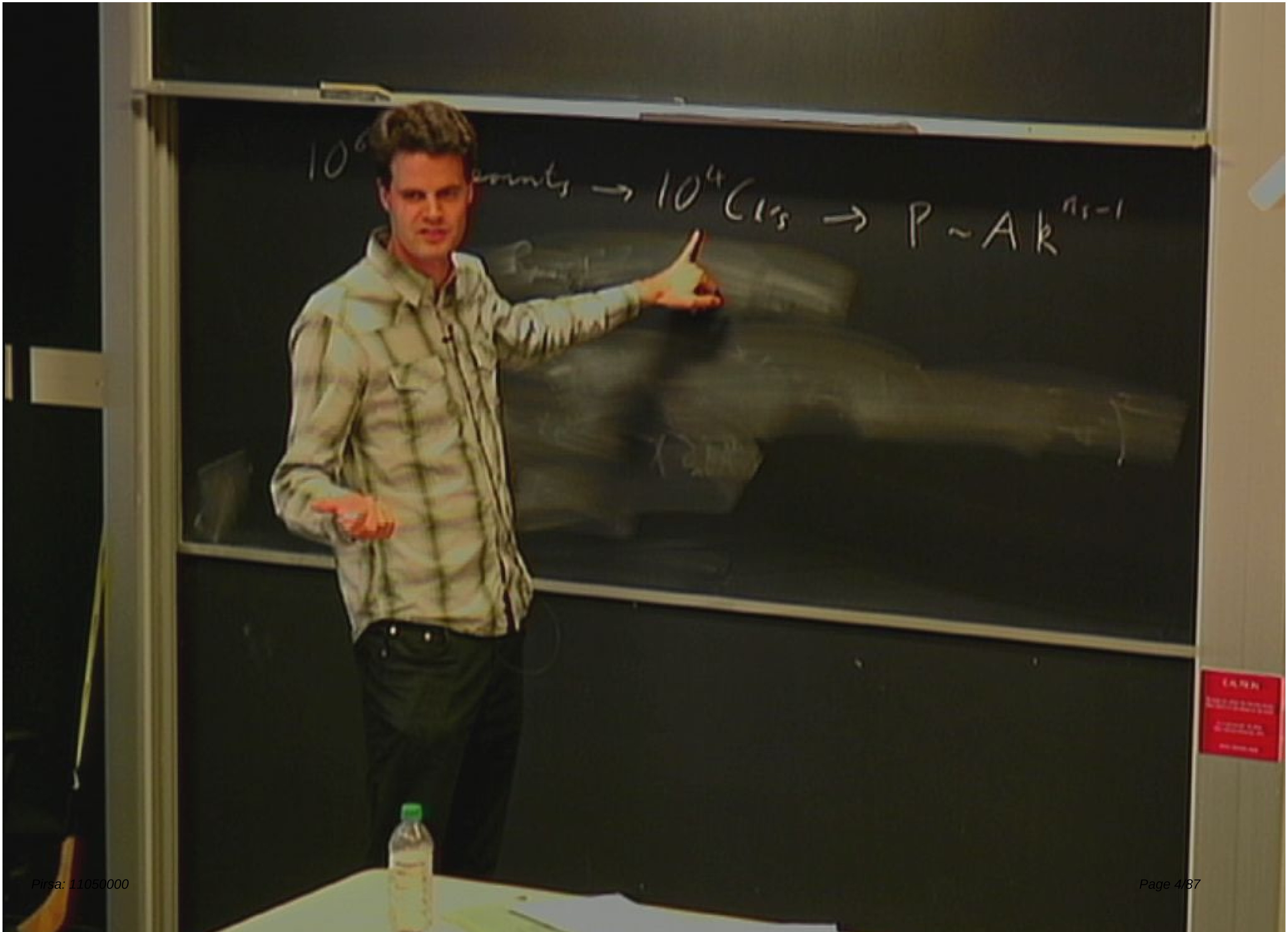
Date: May 17, 2011 02:00 PM

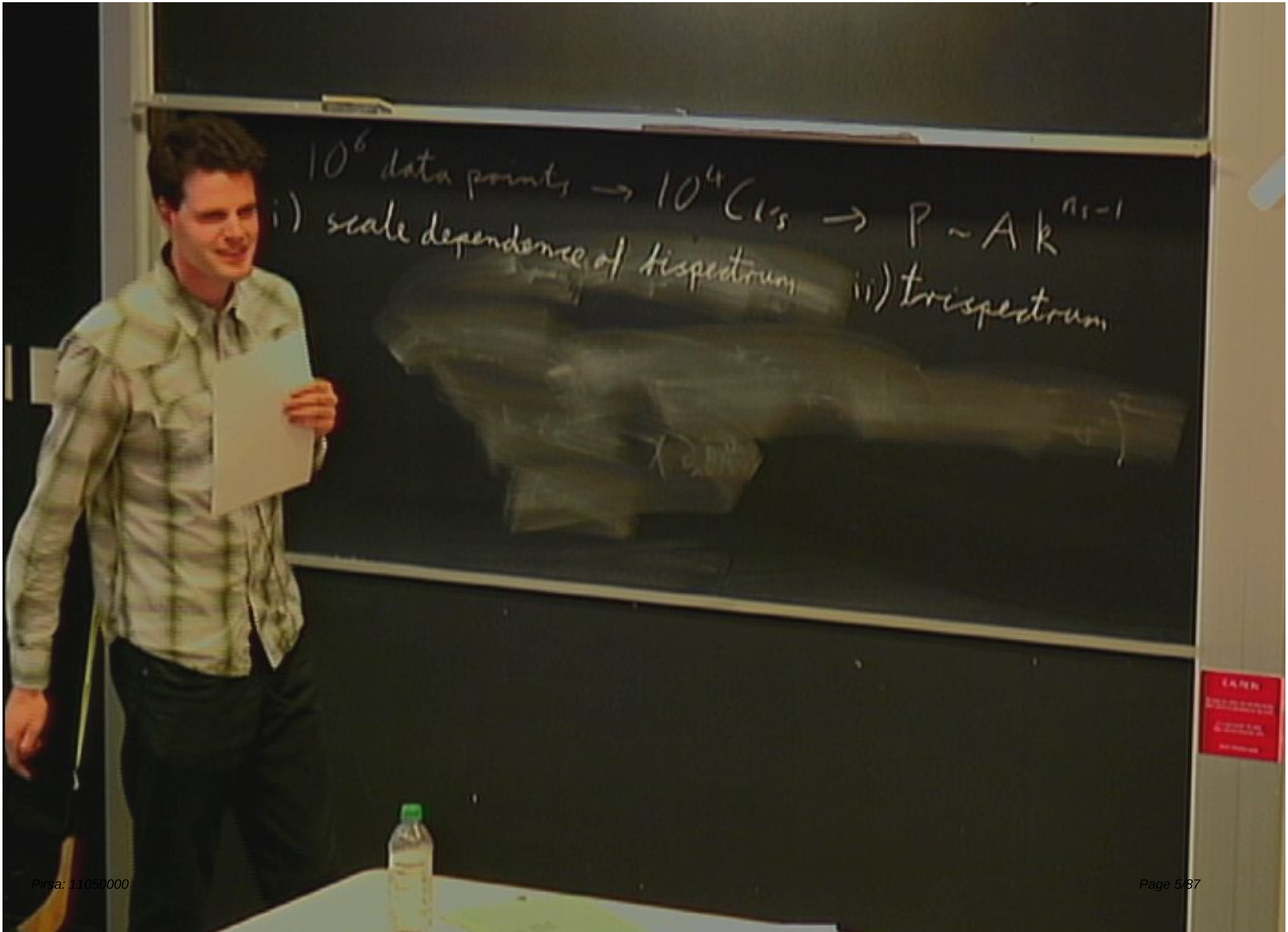
URL: http://pirsa.org/11050000

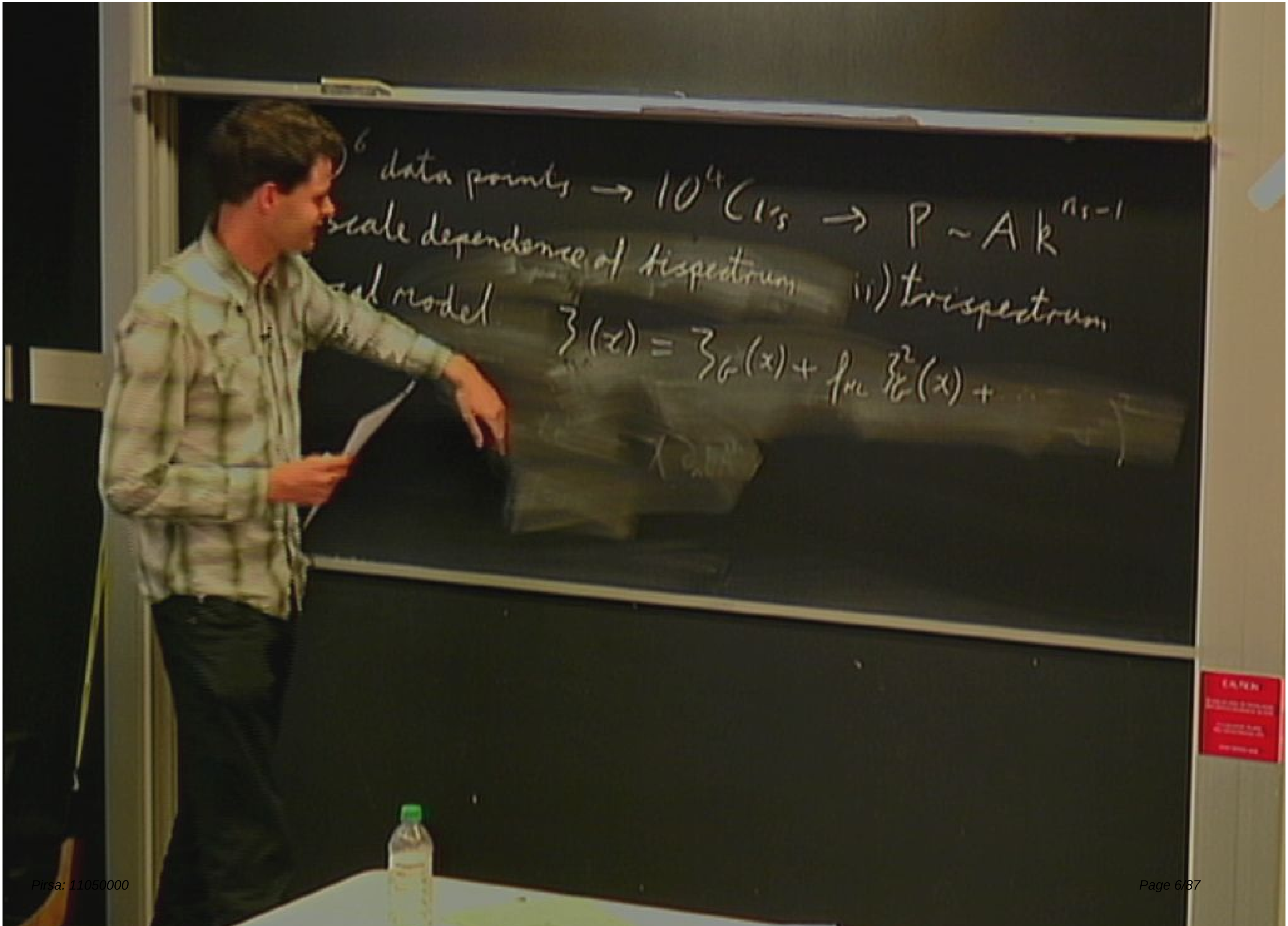
Abstract: The model of local non-Gaussianity, parameterized by the constant non-linearity parameter fNL, is an extremely popular description of non-Gaussianity. However, a mild scale-dependence of fNL is natural. This scale dependence is a new observable, potentially detectable with the Planck satellite, which helps to further discriminate between models of inflation. It is sensitive to properties of the early universe which are not probed by the standard observables. In a complementary way, the trispectrum also contains important information about non-Gaussianity which the bispectrum does not capture. We explicitly calculate the scale dependence and trispectrum in several models including one with a very large infrared-loop contribution to the bispectrum and in various realizations of the curvaton scenario.

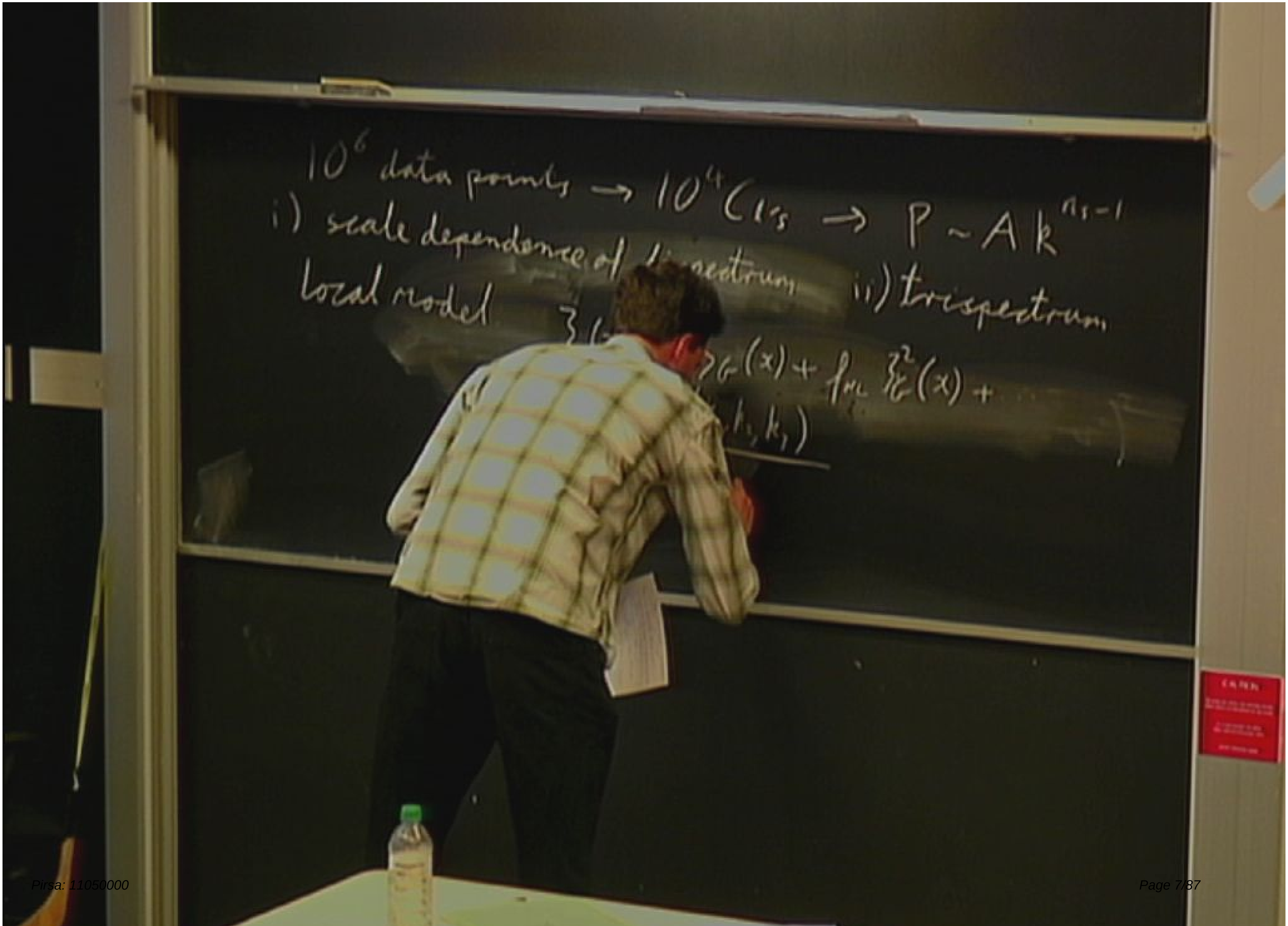

et al 1007.4277
curvaton C.B. et al 1007.5148 + in preperation
collaborators: Engqvist, Gerstenlauer, Nurmi, Takahashi, Tasinato
Wands

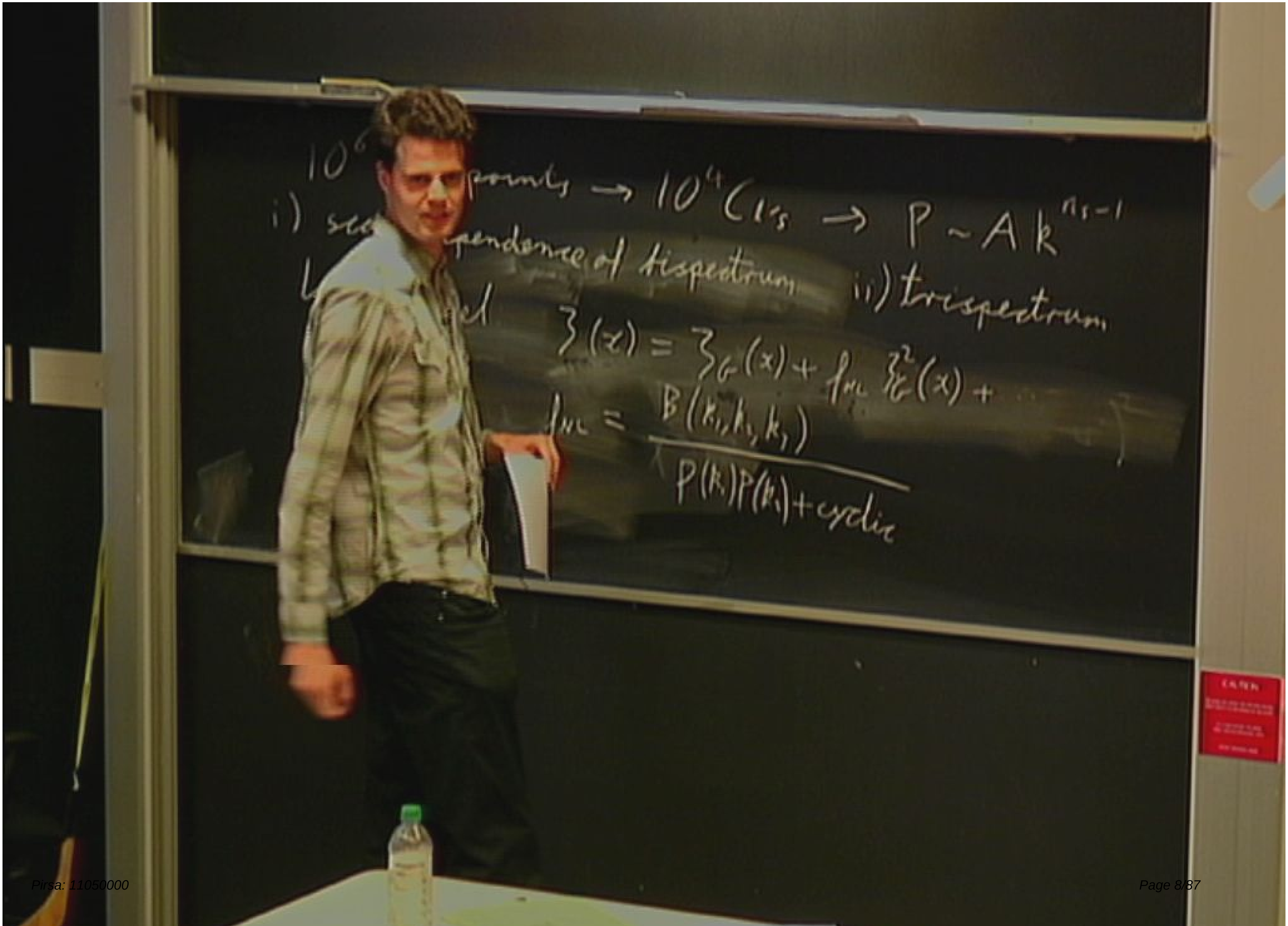

10^6 data
10^4 C_l's → $P \sim A k^{n_s - 1}$

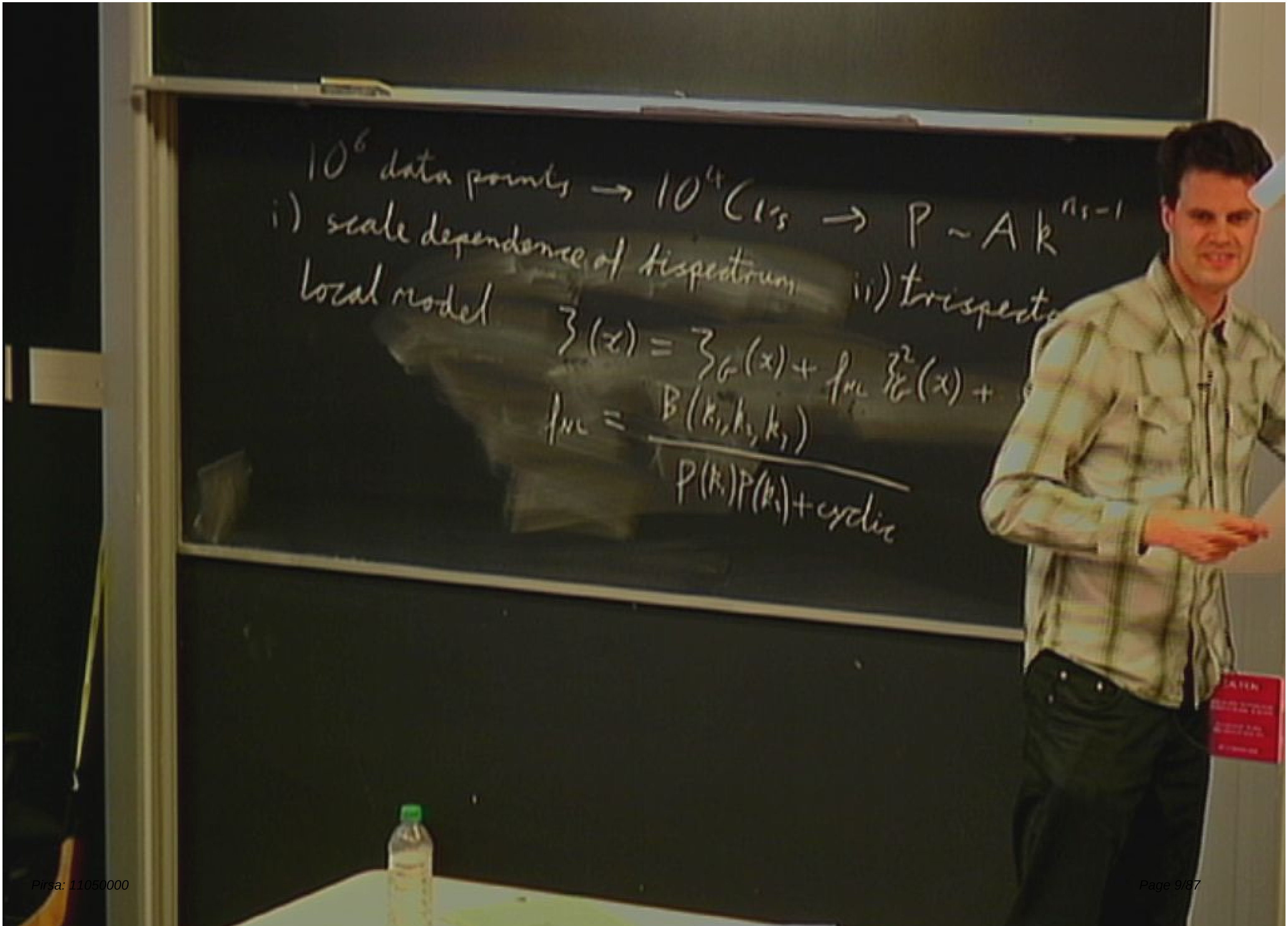

10^4 Cl's → $P \sim A k^{n_s - 1}$


10^6 data points → 10^4 Cl's → P ~ A k^(ns-1)
i) scale dependence of bispectrum
ii) trispectrum


data points → 10^4 Cl's → P ~ A k^(ns-1)
scale dependence of bispectrum
ii) trispectrum
model
ζ(x) = ζ_G(x) + f_NL ζ_G^2(x) +


10^6 data points → 10^4 Cl's
i) scale dependence of
P ~ A k^(ns-1)
local model
ii) trispectrum


points → 10^4 Cl's → P ~ A k^(ns-1)
i)
pendence of bispectrum
ii) trispectrum
ζ(x) = ζG(x) + fNL ζG²(x) +
fNL = B(k1,k2,k3) / P(k1)P(k2)+cyclic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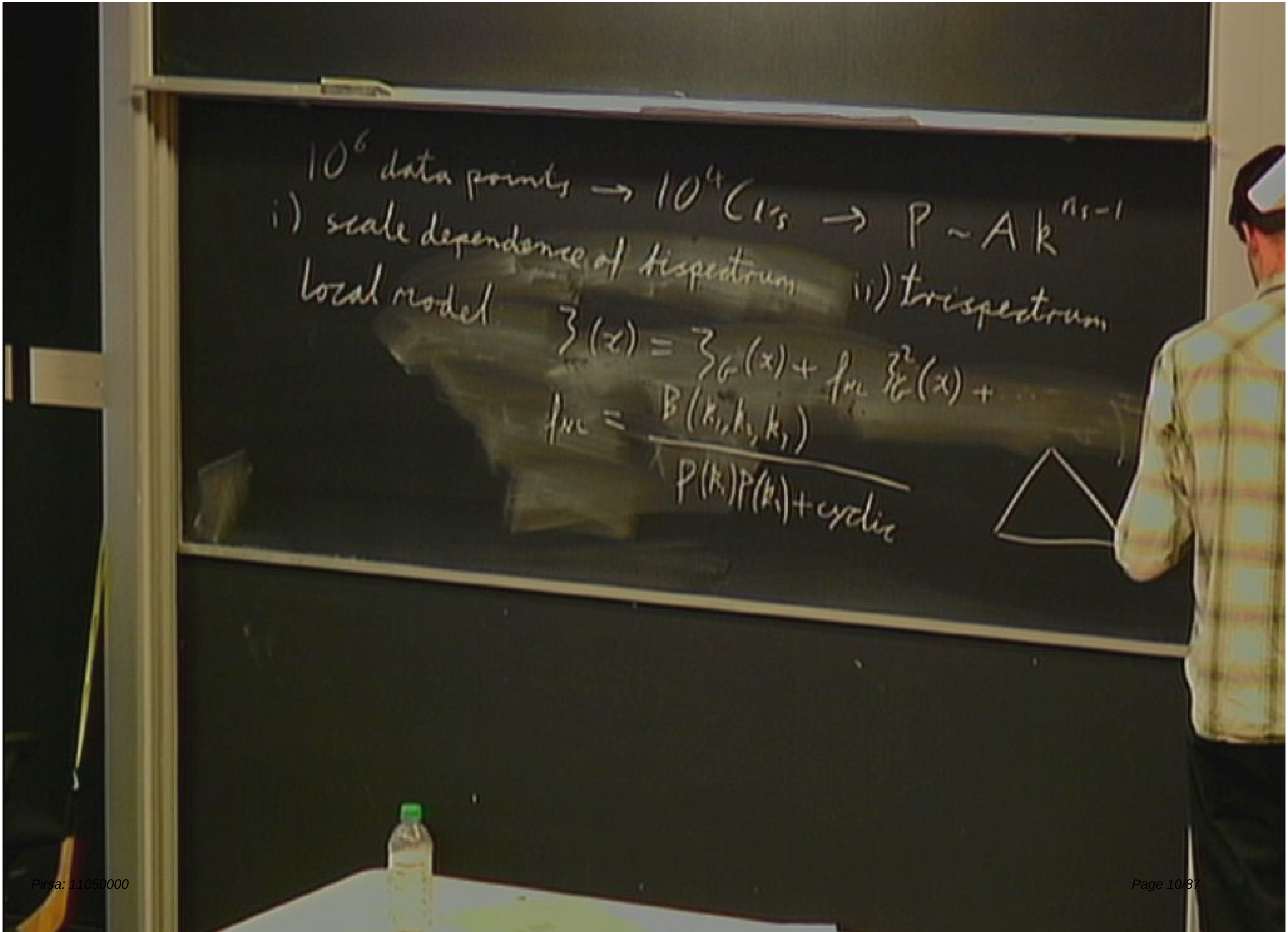

10^6 data points → 10^4 Cl's → P ~ A k^(ns-1)
i) scale dependence of bispectrum
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local model
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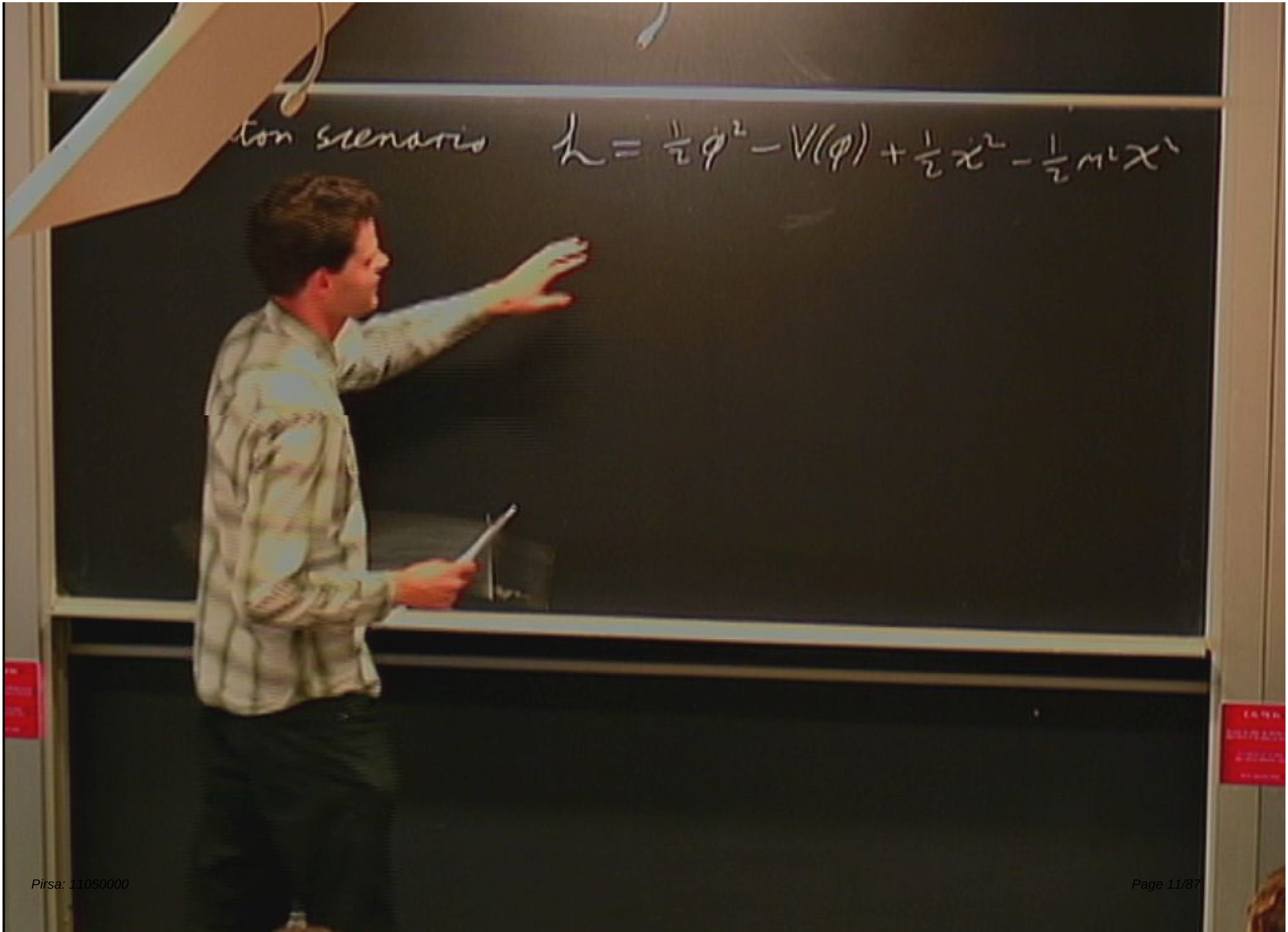
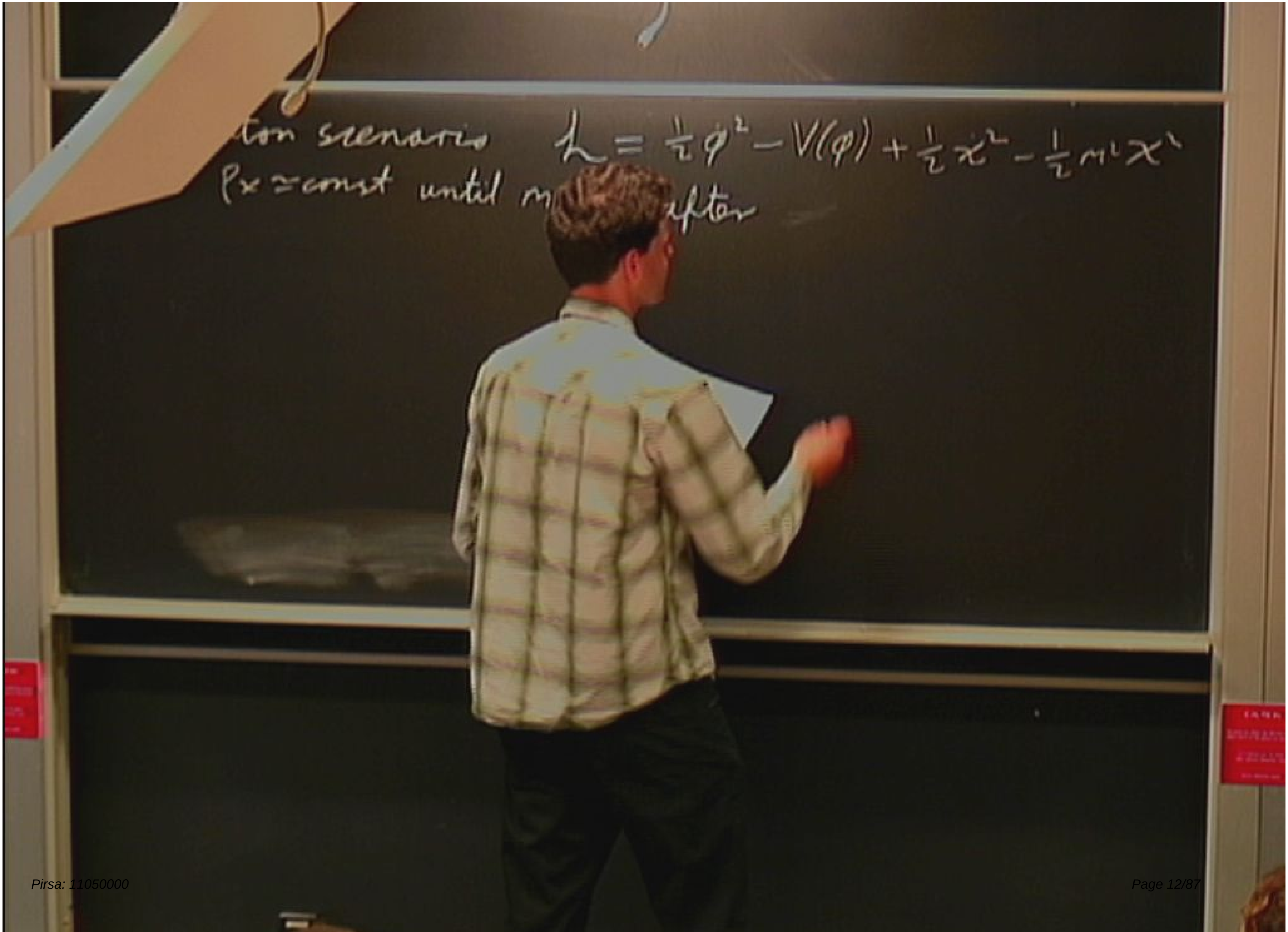
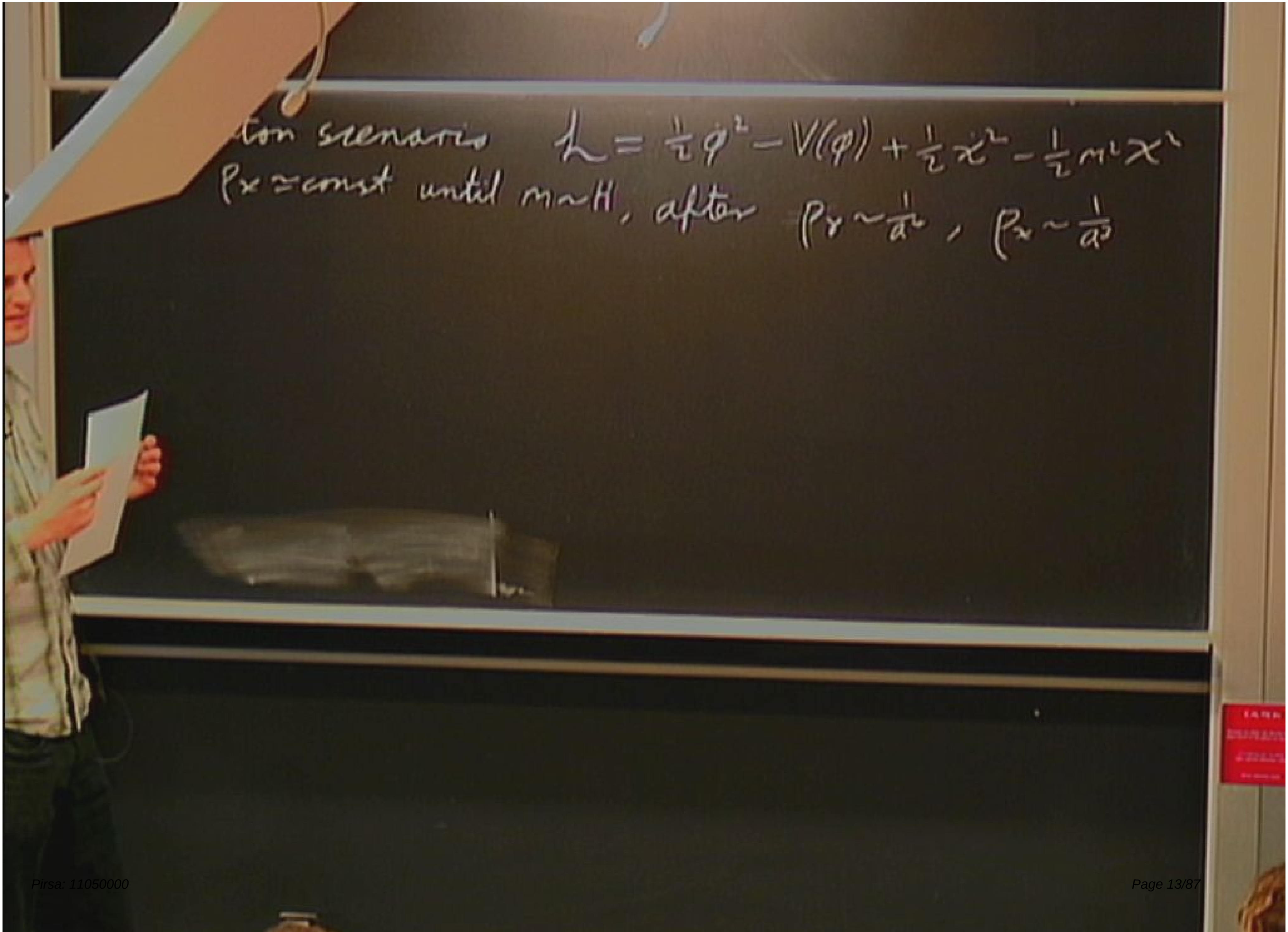
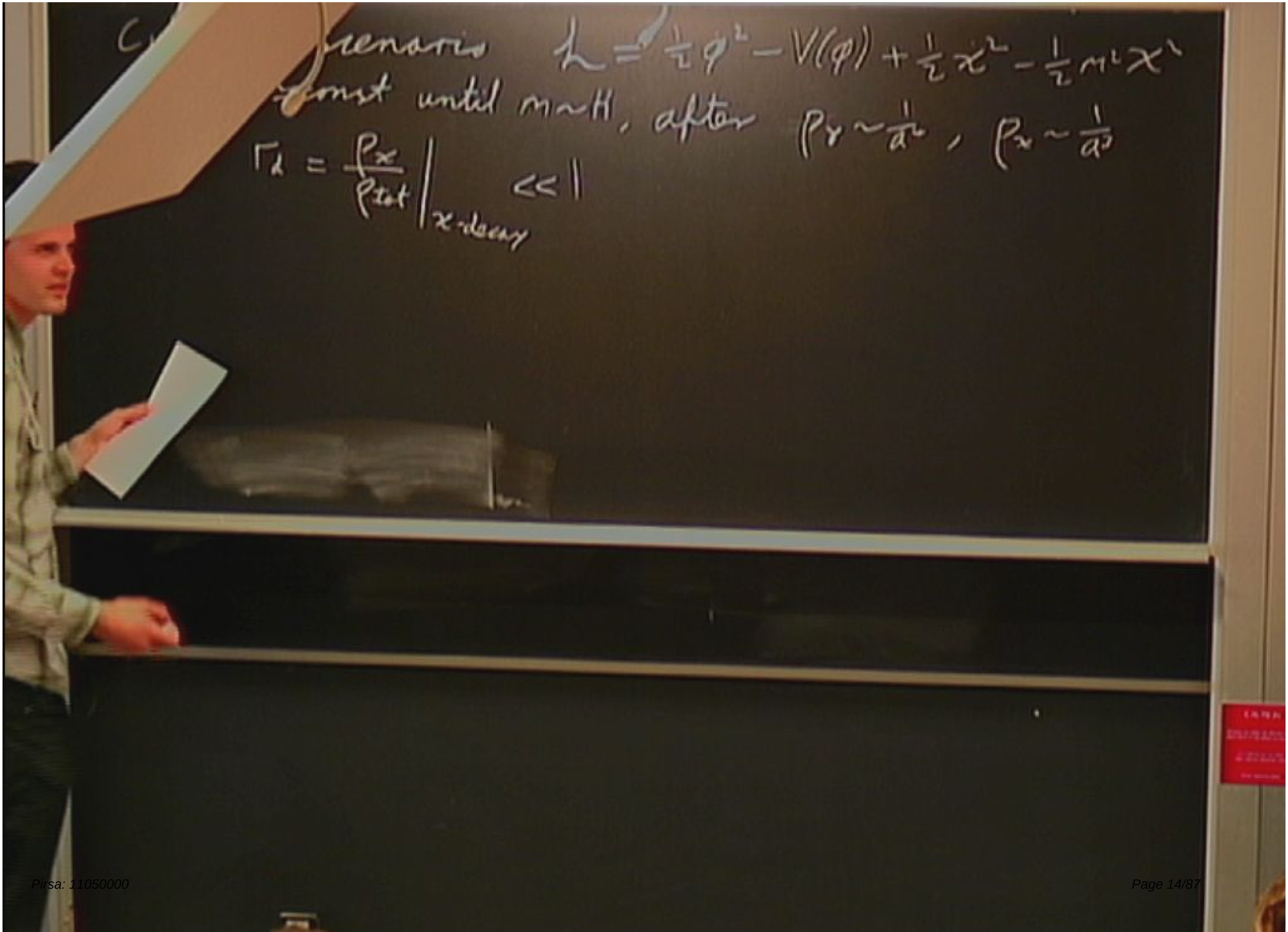
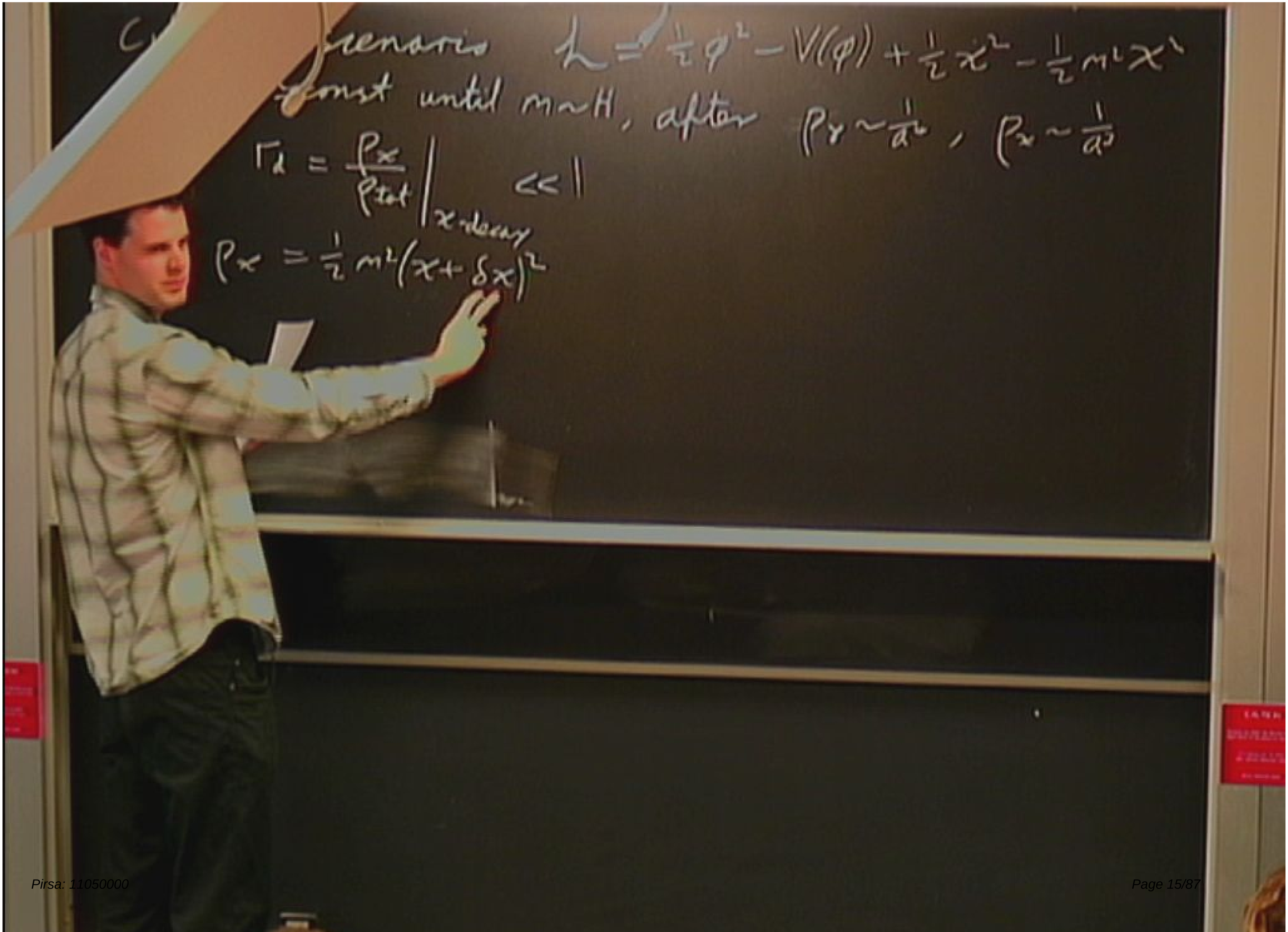
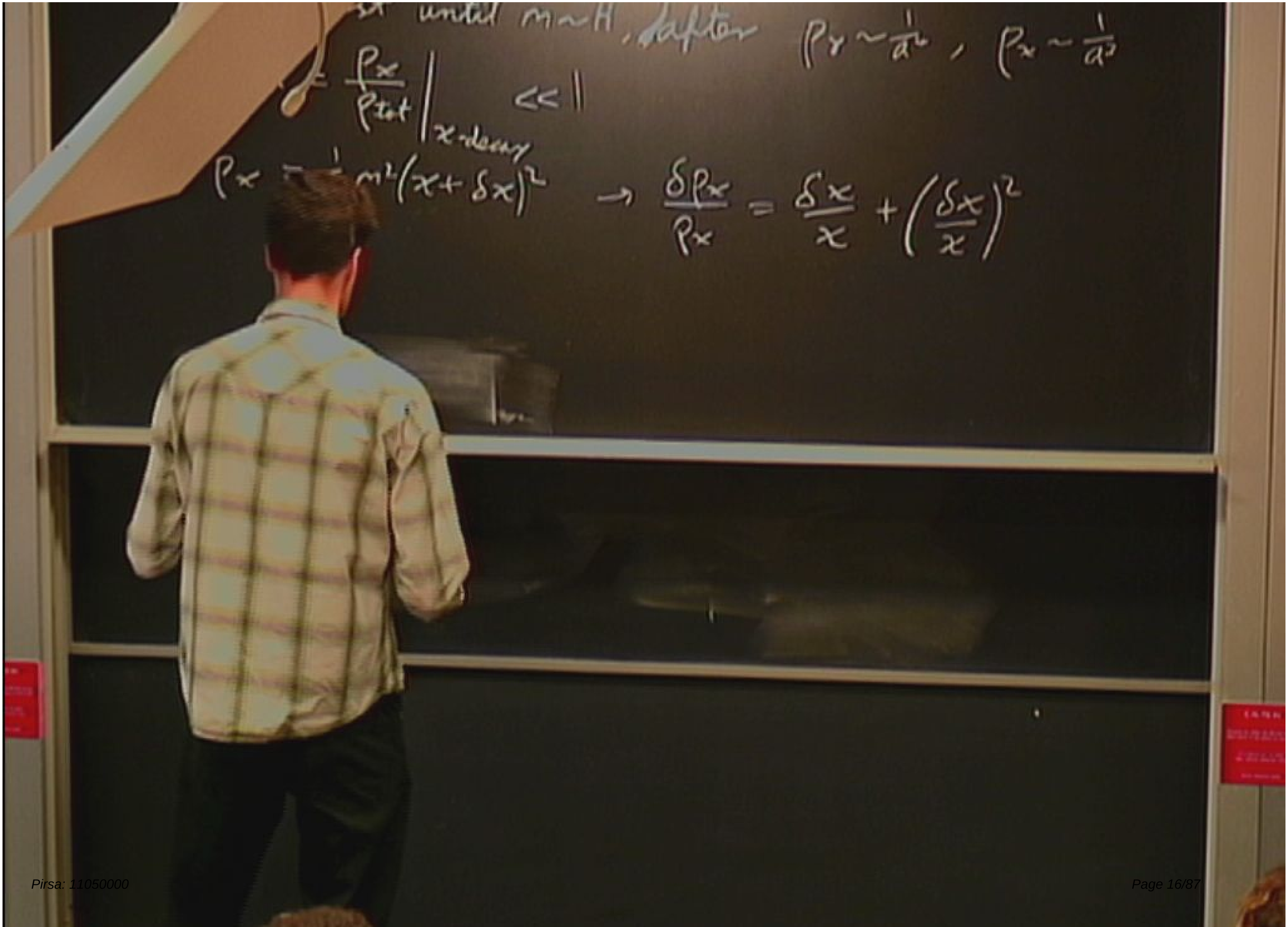

ton scenario
$\mathcal{L} = \frac{1}{2}\varphi^2 - V(\varphi) + \frac{1}{2}\chi^2 - \frac{1}{2}m^2\chi^2$

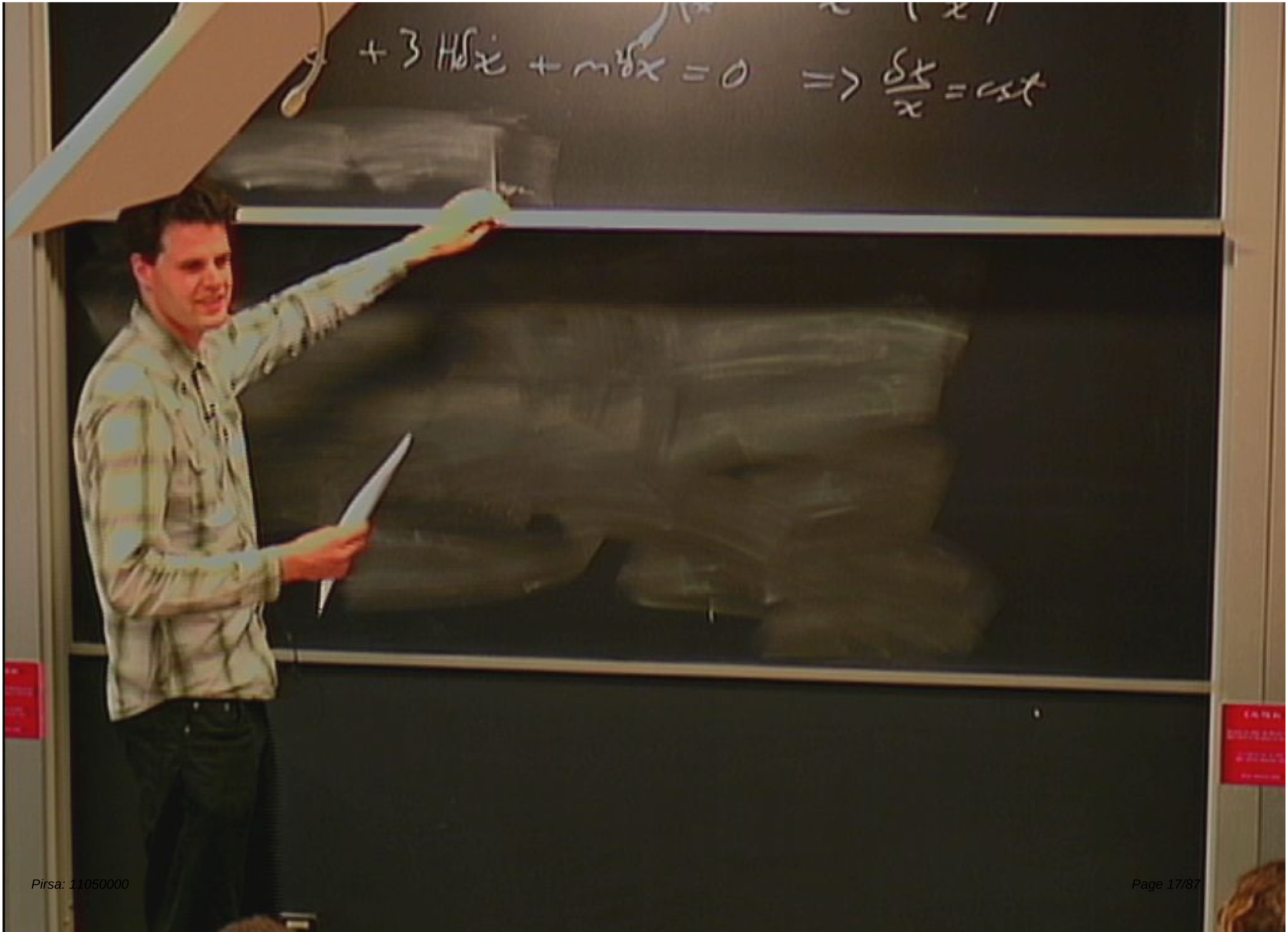

ton scenario
L = ½ φ̇² − V(φ) + ½ χ̇² − ½ m² χ²
ρχ ≃ const until m
fter

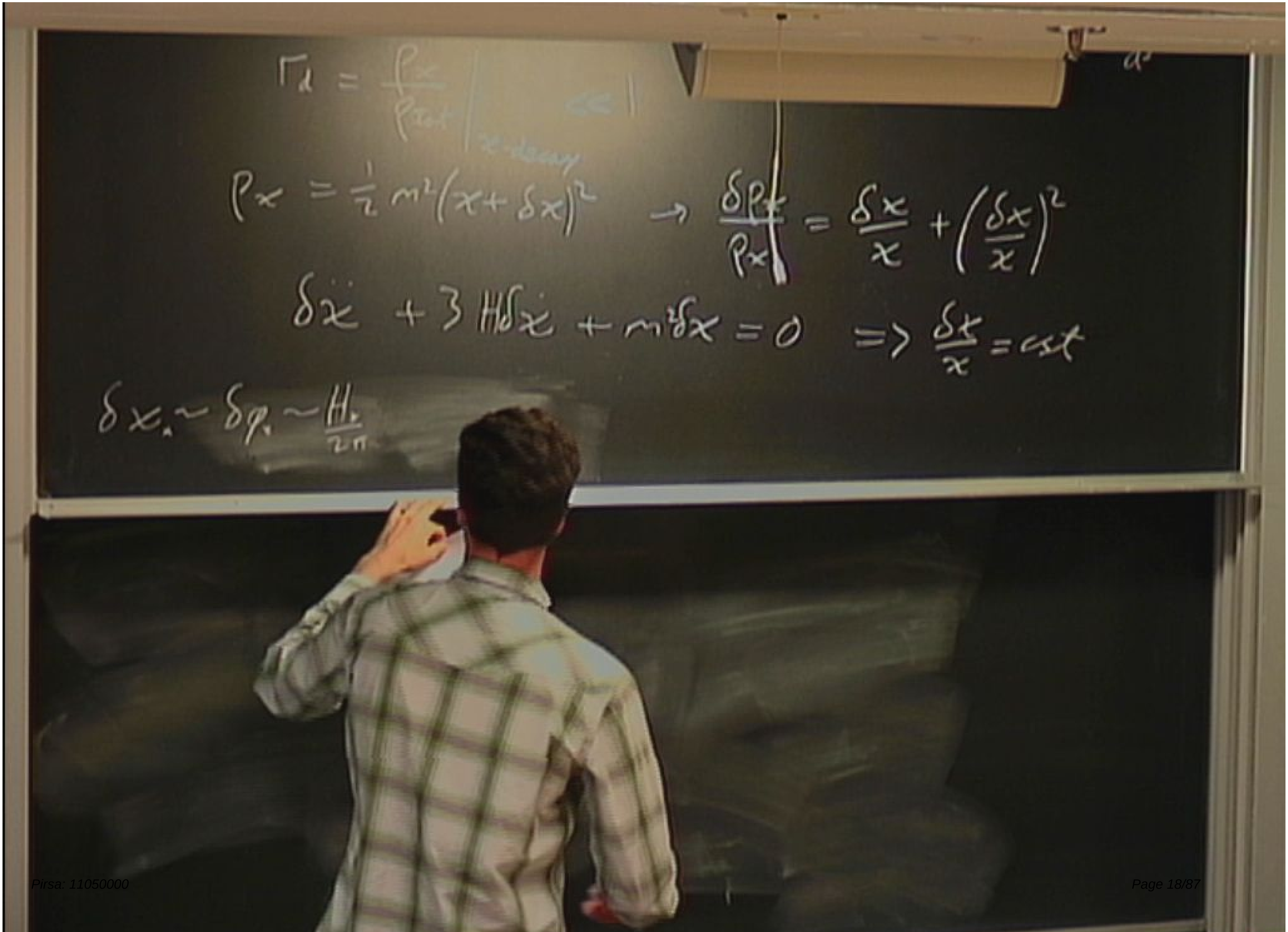

ton scenario $\mathcal{L} = \frac{1}{2}\dot{\varphi}^2 - V(\varphi) + \frac{1}{2}\dot{\chi}^2 - \frac{1}{2}m^2\chi^2$
$\rho_\chi \simeq$ const until $m \sim H$, after $\rho_r \sim \frac{1}{a^4}$, $\rho_\chi \sim \frac{1}{a^3}$

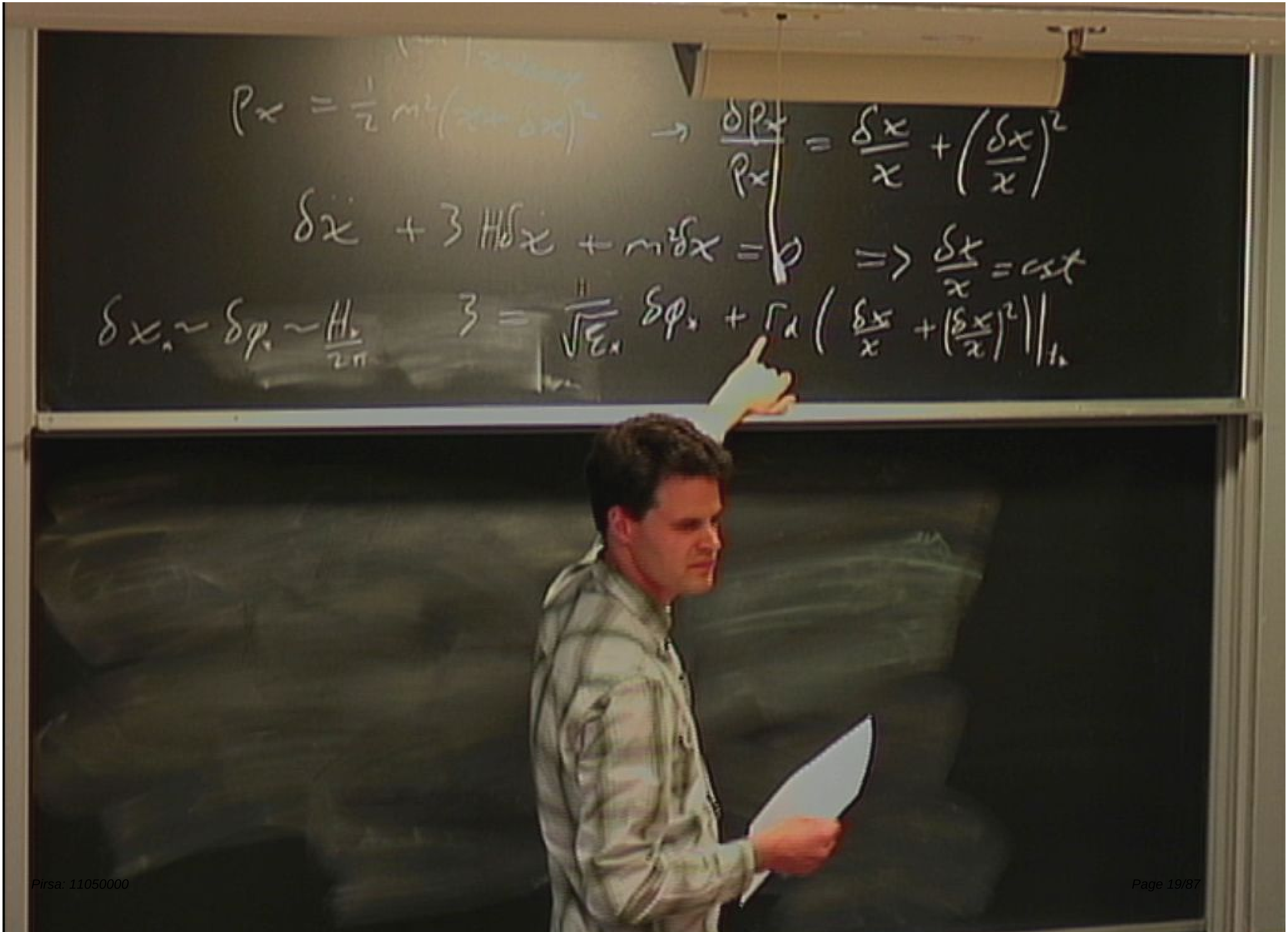

scenario $\mathcal{L} = \frac{1}{2}\dot{\varphi}^2 - V(\varphi) + \frac{1}{2}\dot{\chi}^2 - \frac{1}{2}m^2\chi^2$
const until $m \sim H$, after $\rho_\gamma \sim \frac{1}{a^4}$, $\rho_\chi \sim \frac{1}{a^3}$
$r_\chi = \frac{\rho_\chi}{\rho_{tot}}\Big|_{\chi\text{-decay}} \ll 1$

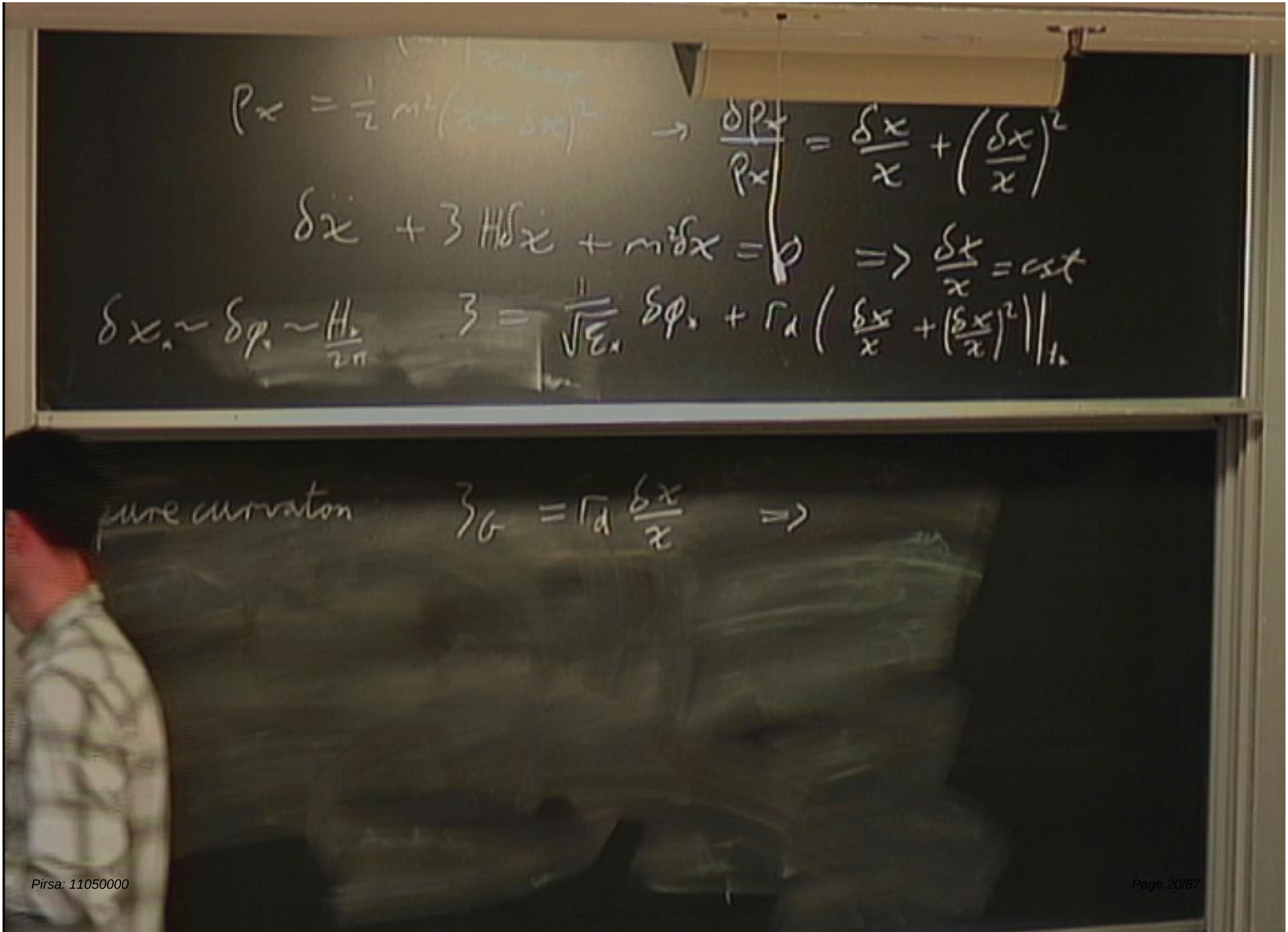

scenario $\mathcal{L} = \frac{1}{2}\dot\varphi^2 - V(\varphi) + \frac{1}{2}\dot\chi^2 - \frac{1}{2}m^2\chi^2$
const until $m \sim H$, after $\rho_\gamma \sim \frac{1}{a^4}$, $\rho_\chi \sim \frac{1}{a^3}$
$r_d = \frac{\rho_\chi}{\rho_{tot}}\Big|_{\chi\ decay} \ll 1$
$\rho_\chi = \frac{1}{2}m^2(\chi + \delta\chi)^2$


until m~H, after ρ_γ ~ 1/a^4 , ρ_x ~ 1/a^3
ρ_x/ρ_tot |_{x-decay} << 1
ρ_x = ½ m²(x+δx)² → δρ_x/ρ_x = δx/x + (δx/x)²


+ 3 Hδẋ + m²δx = 0 => δx/x = cst


$\Gamma_x = \frac{\rho_x}{\rho_{tot}}\Big|_{x\text{-decay}} \ll 1$
$\rho_x = \frac{1}{2} m^2 (x + \delta x)^2 \rightarrow \frac{\delta \rho_x}{\rho_x} = \frac{\delta x}{x} + \left(\frac{\delta x}{x}\right)^2$
$\delta \ddot{x} + 3 H \delta \dot{x} + m^2 \delta x = 0 \Rightarrow \frac{\delta x}{x} = cst$
$\delta x_* \sim \delta \varphi_* \sim \frac{H_*}{2\pi}$


ρχ = ½ m²(χ + δχ)² → δρχ/ρχ = δχ/χ + (δχ/χ)²
δχ̈ + 3Hδχ̇ + m²δχ = 0 ⇒ δχ/χ = cst
δχ* ~ δφ* ~ H*/2π
ζ = H/√ε* δφ* + rχ (δχ/χ + (δχ/χ)²)|t*

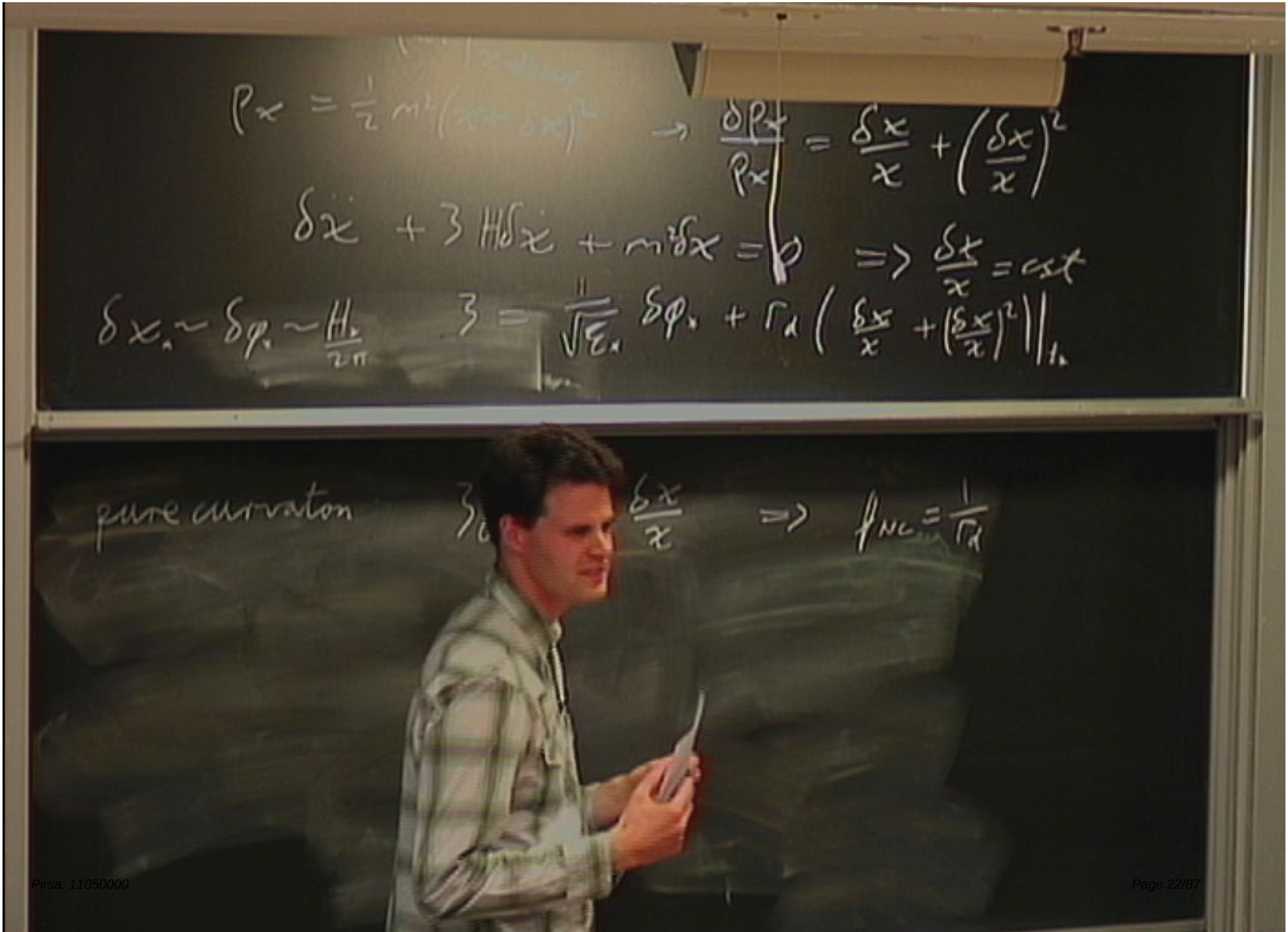

$\rho_\chi = \frac{1}{2} m^2 (\chi + \delta\chi)^2 \rightarrow \frac{\delta\rho_\chi}{\rho_\chi} = \frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2$
$\delta\ddot{\chi} + 3H\delta\dot{\chi} + m^2\delta\chi = 0 \Rightarrow \frac{\delta\chi}{\chi} = cst$
$\delta\chi_* \sim \delta\varphi_* \sim \frac{H_*}{2\pi}$
$\zeta = \frac{1}{\sqrt{\epsilon_*}}\delta\varphi_* + r_d\left(\frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2\right)\Big|_{t_*}$
pure curvaton $\zeta_\sigma = r_d \frac{\delta\chi}{\chi} \Rightarrow$

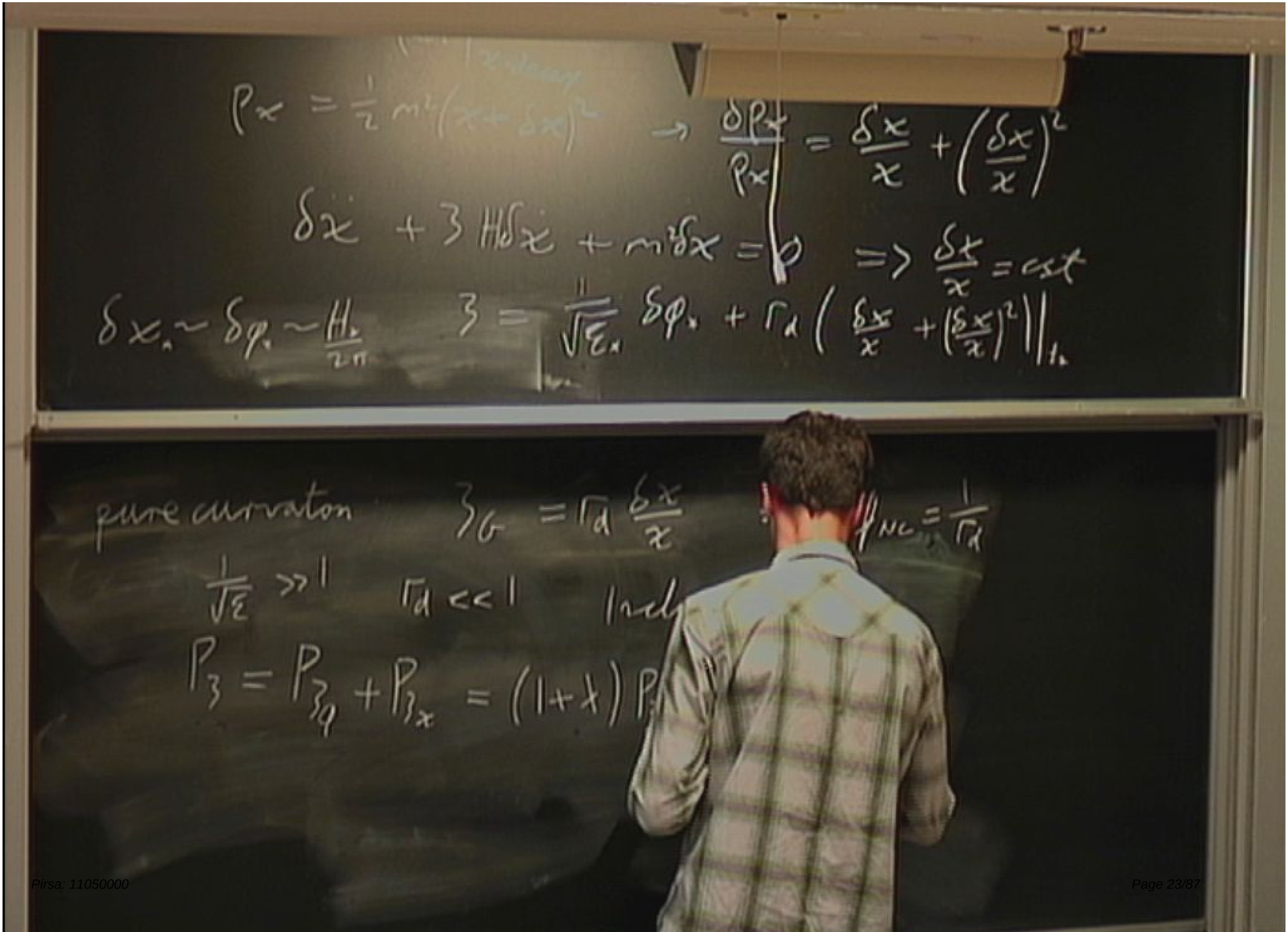
$$\rho_\chi = \frac{1}{2} m^2 (\text{[illegible]})^2 \rightarrow \frac{\delta\rho_\chi}{\rho_\chi} = \frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2$$

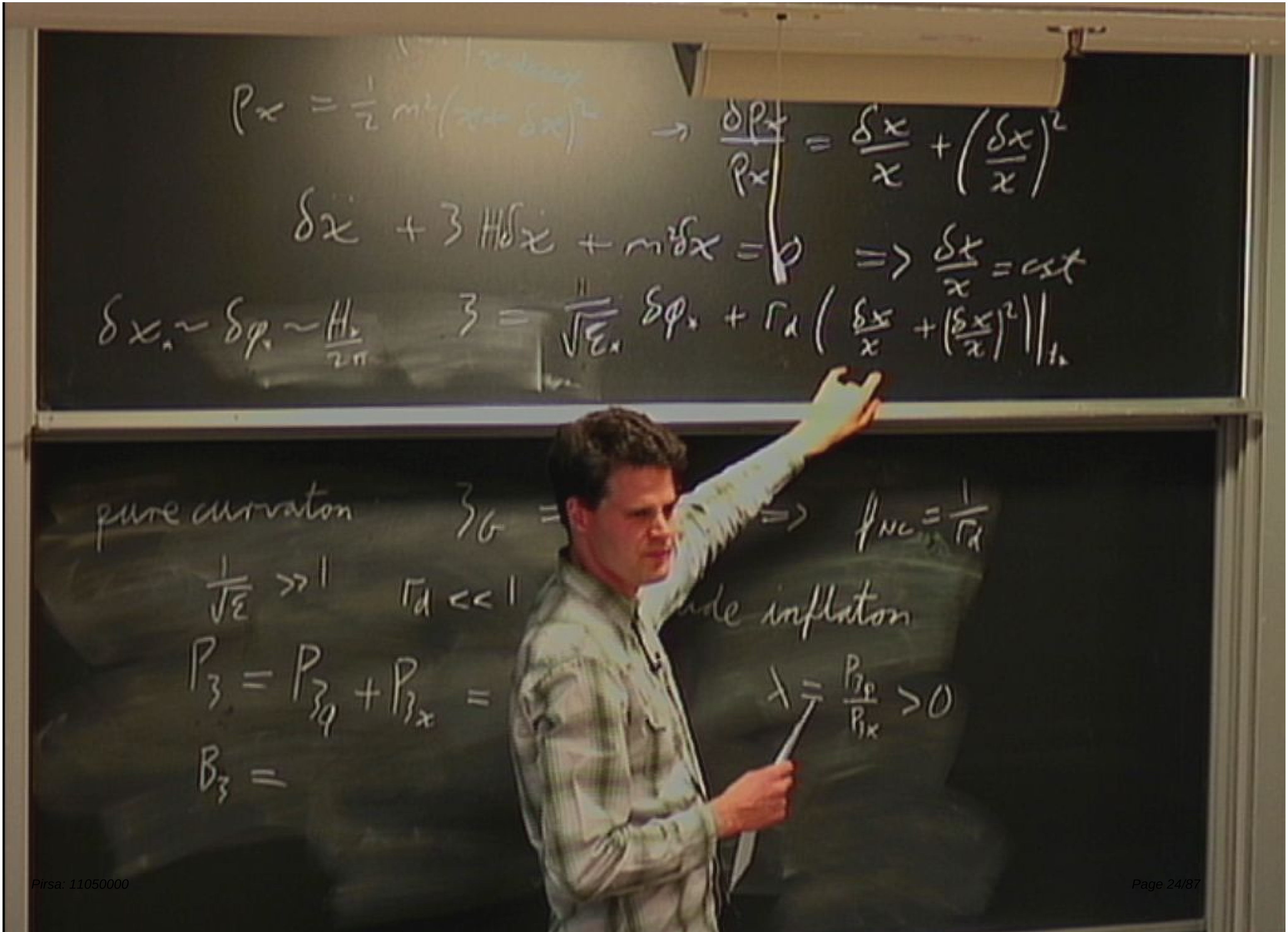
$$\delta\ddot{\chi} + 3H\delta\dot{\chi} + m^2\delta\chi = 0 \Rightarrow \frac{\delta\chi}{\chi} = cst$$

$$\delta\chi_* \sim \delta\varphi_* \sim \frac{H_*}{2\pi} \qquad \zeta = \frac{1}{\sqrt{\varepsilon_*}}\delta\varphi_* + r_d\left(\frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2\right)\Big|_{t_*}$$

pure curvaton $\zeta_\sigma = r_d \frac{\delta\chi}{\chi} \Rightarrow$


ρχ = ½ m²(
→ δρχ/ρχ = δχ/χ + (δχ/χ)²
δχ̈ + 3Hδχ̇ + m²δχ = 0 ⇒ δχ/χ = cst
δχ* ~ δφ* ~ H*/2π
ζ = 1/√ε* δφ* + rχ (δχ/χ + (δχ/χ)²)|t*
pure curvaton
⇒ fNL = 1/rχ


ρχ = ½ m² (χ + δχ)² → δρχ/ρχ = δχ/χ + (δχ/χ)²
δχ̈ + 3Hδχ̇ + m²δχ = 0 ⇒ δχ/χ = cst
δχ* ~ δφ* ~ H*/2π   ζ = 1/√ε* δφ* + r_d (δχ/χ + (δχ/χ)²)|t*
pure curvaton   ζ_σ = r_d δχ/χ   f_NL = 1/r_d
1/√ε >> 1   r_d << 1
P_ζ = P_ζφ + P_ζχ = (1+λ) P


pure curvaton
inflaton

$$\rho_\chi = \frac{1}{2} m^2 (\ldots)^2 \rightarrow \frac{\delta\rho_\chi}{\rho_\chi} = \frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2$$

$$\delta\ddot{\chi} + 3H\delta\dot{\chi} + m^2\delta\chi = 0 \implies \frac{\delta\chi}{\chi} = cst$$

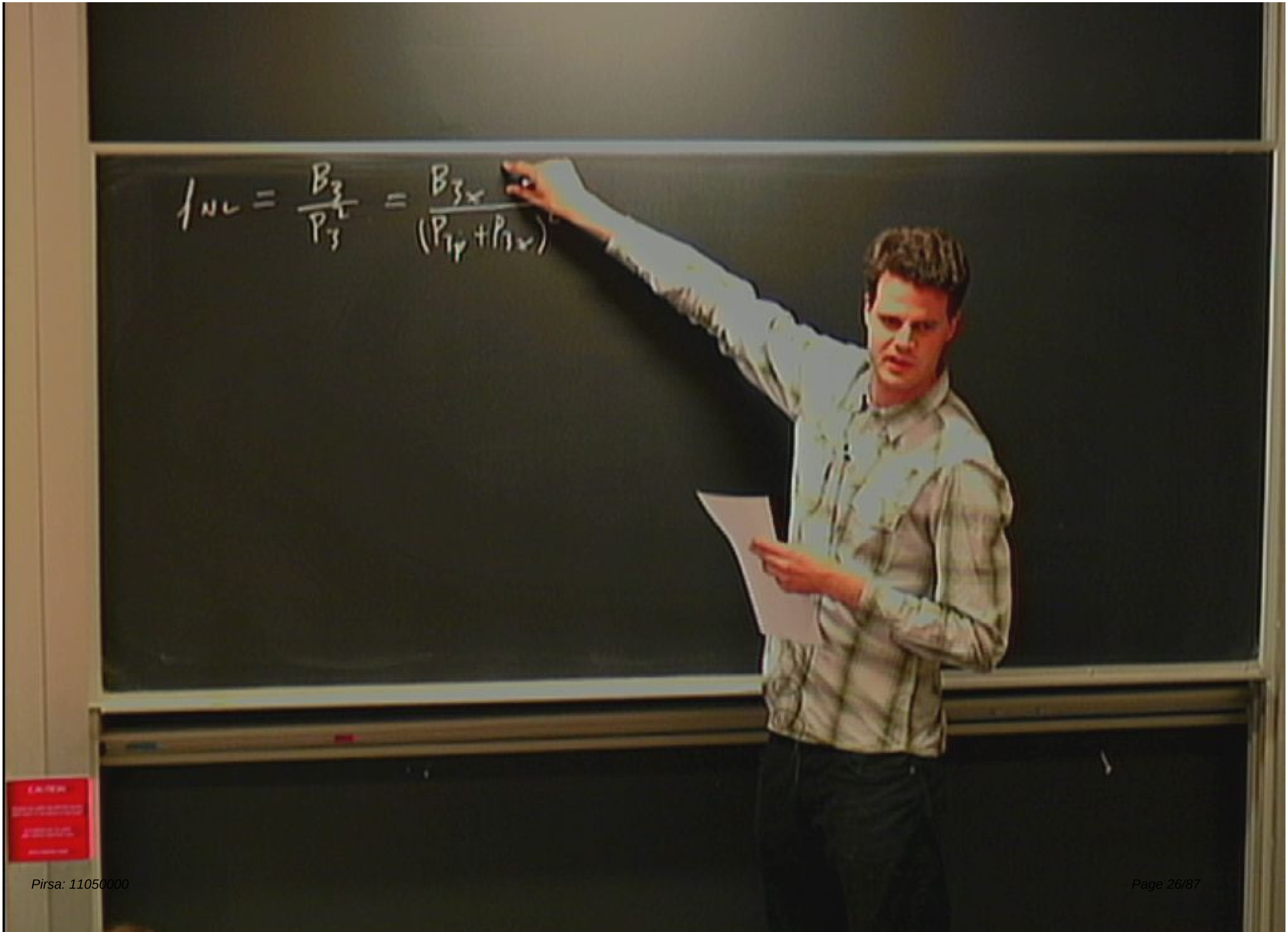
$$\delta\chi_* \sim \delta\varphi_* \sim \frac{H_*}{2\pi} \qquad \zeta = \frac{1}{\sqrt{\varepsilon_*}}\delta\varphi_* + r_\chi\left(\frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2\right)\Bigg|_{t_*}$$

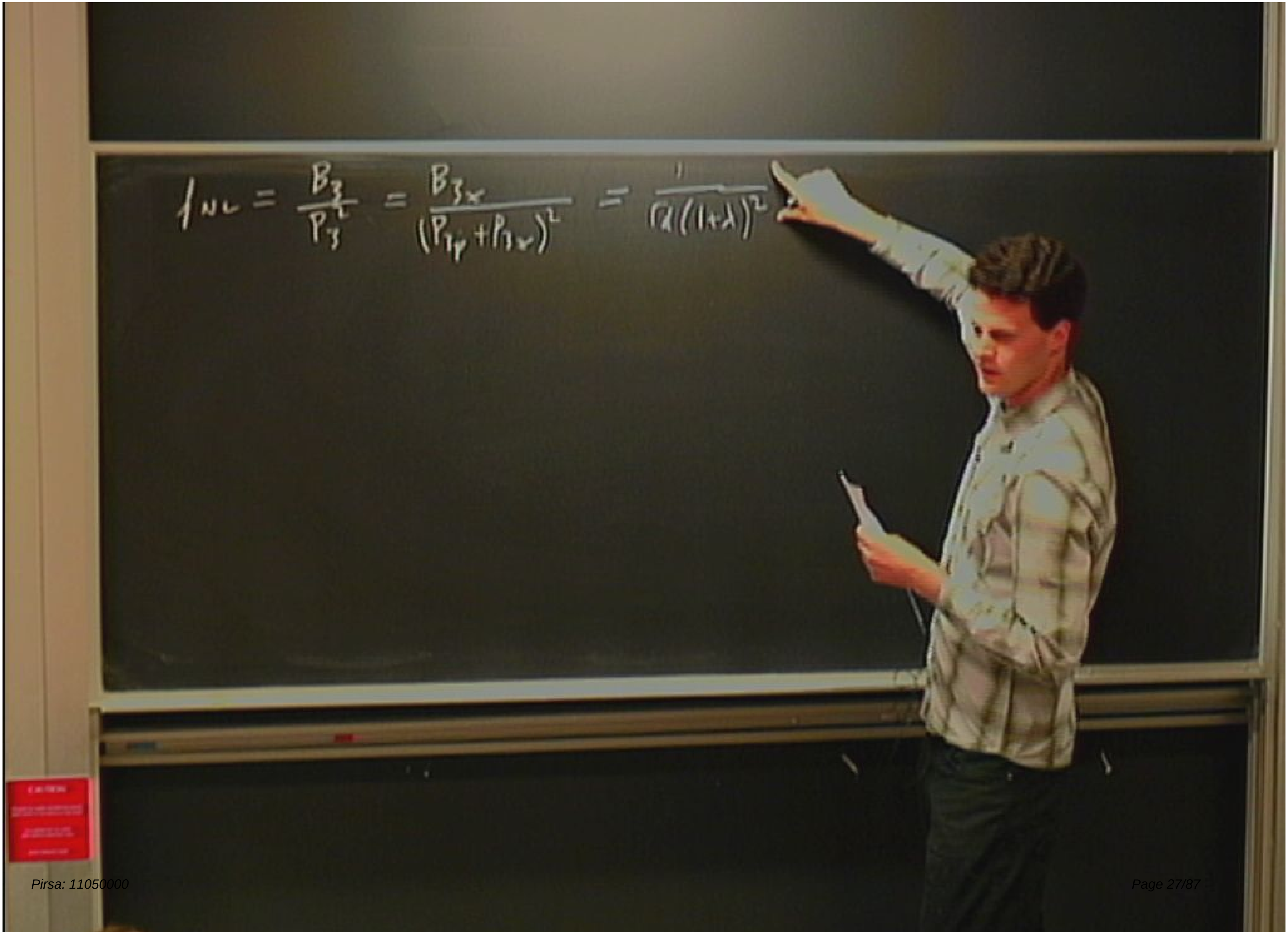
pure curvaton $\zeta_\sigma = r_\chi \frac{\delta\chi}{\chi} \implies f_{NL} = \frac{1}{r_\chi}$

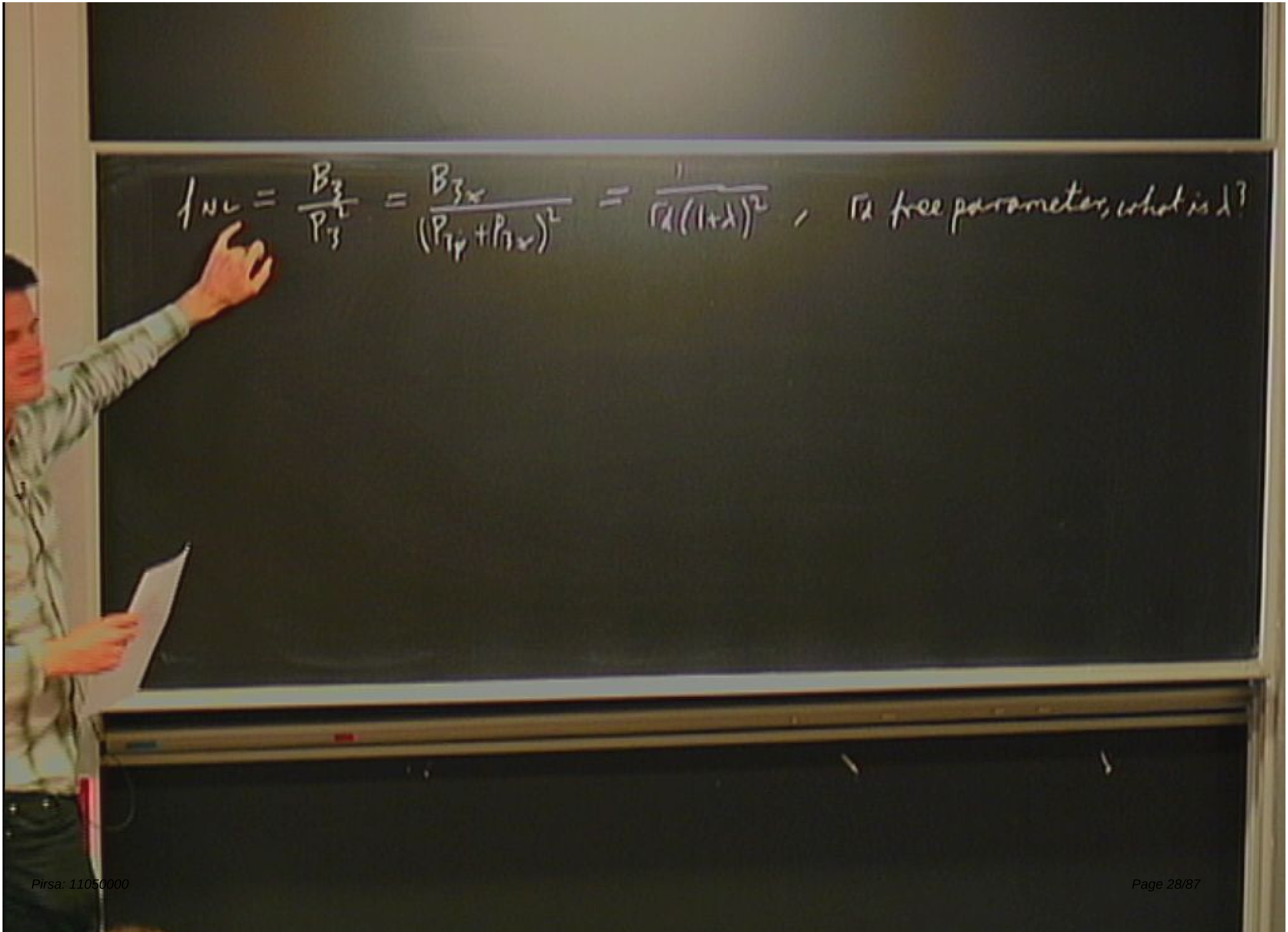
$\frac{1}{\sqrt{\varepsilon}} \gg 1 \qquad r_\chi \ll 1$ Include inflaton

$$P_\zeta = P_{\zeta_\varphi} + P_{\zeta_\chi} = (1+\lambda) P_{\zeta_\chi} \qquad \lambda = \frac{P_{\zeta_\varphi}}{P_{\zeta_\chi}} > 0$$

$$B_\zeta = B_{\zeta_\chi} =$$


$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta\chi}}{(P_{\zeta\phi} + P_{\zeta\chi})}$


fNL = B3 / P3^2 = B3σ / (P3φ + P3σ)^2 = 1 / (√λ(1+λ)^2)


$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta\sigma}}{((P_{\zeta\phi} + P_{\zeta\sigma}))^2} = \frac{1}{\sqrt{\lambda}((1+\lambda))^2}$, $\sqrt{\lambda}$ free parameter, what is λ?

$$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta\sigma}}{(P_{\zeta\phi} + P_{\zeta\sigma})^2} = \frac{1}{r_\lambda (1+\lambda)^2}, \quad r_\lambda \text{ free parameter, what is } \lambda?$$

2 ways

10^6 data points $\rightarrow$ 10^4 C_ℓ's $\rightarrow$ $P \sim A k^{n_s - 1}$

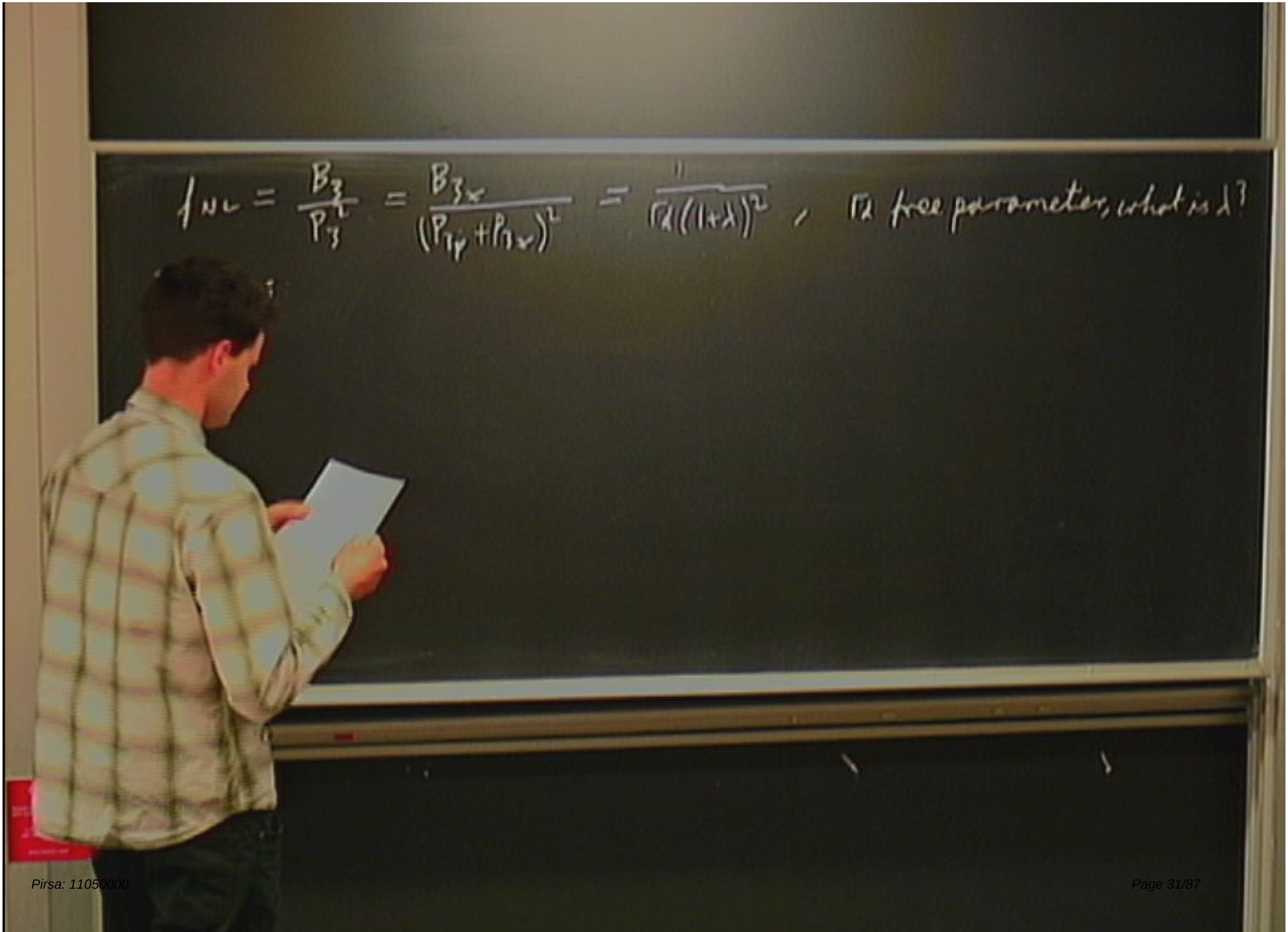
i) scale dependence of bispectrum

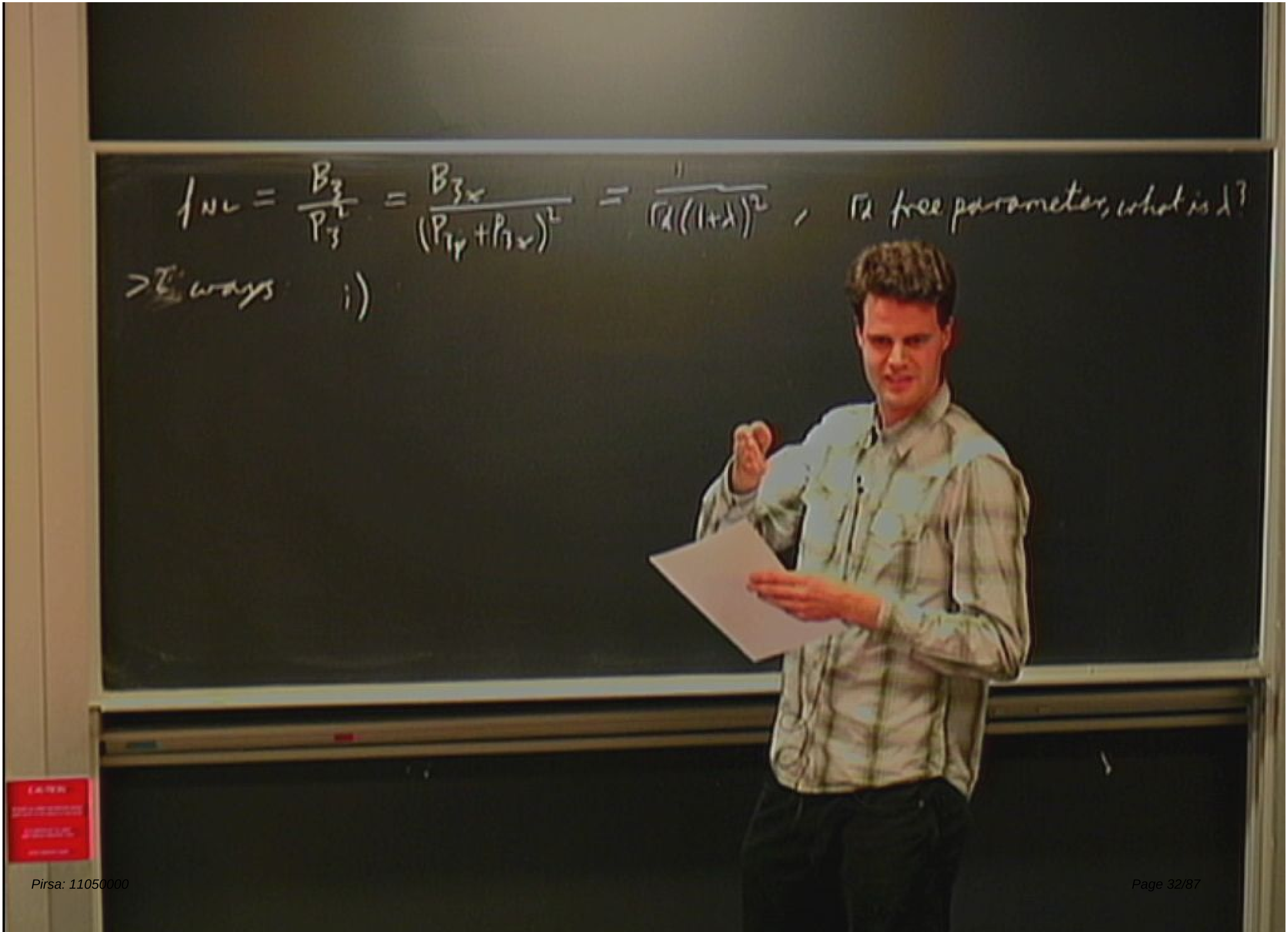
ii) trispectrum

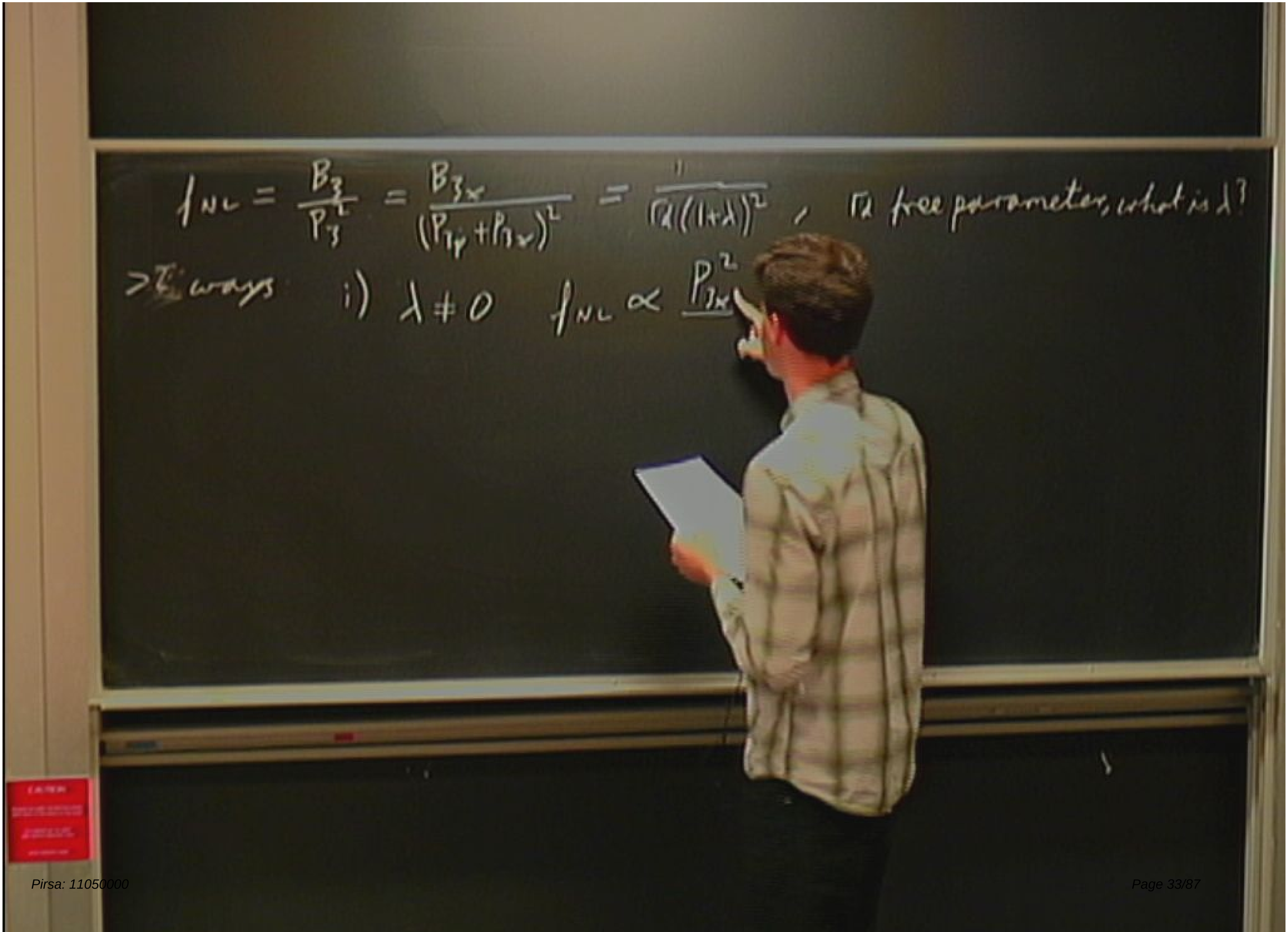
local model

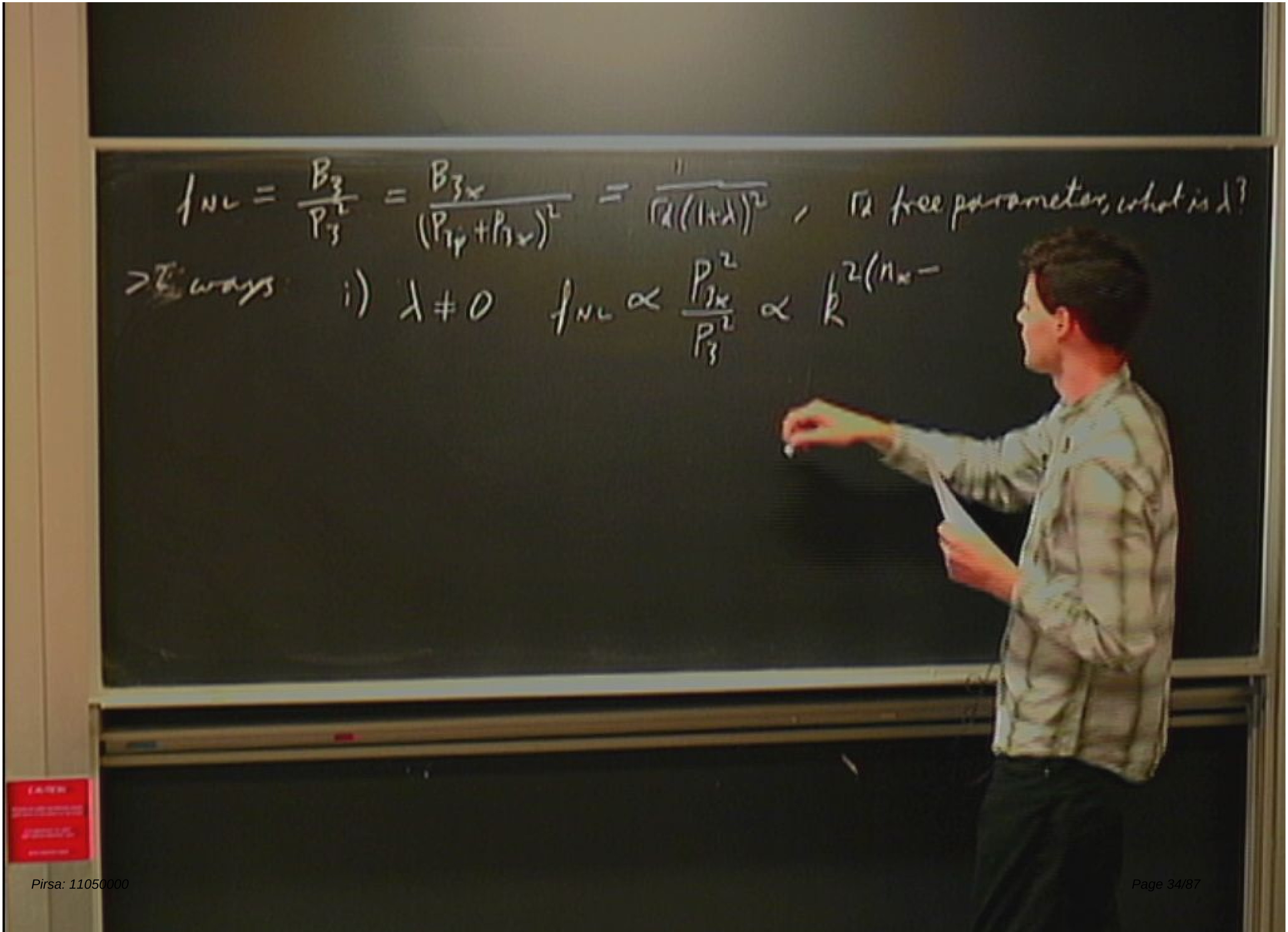
$$\zeta(x) = \zeta_G(x) + f_{NL}\,\zeta_G^2(x) + \ldots$$

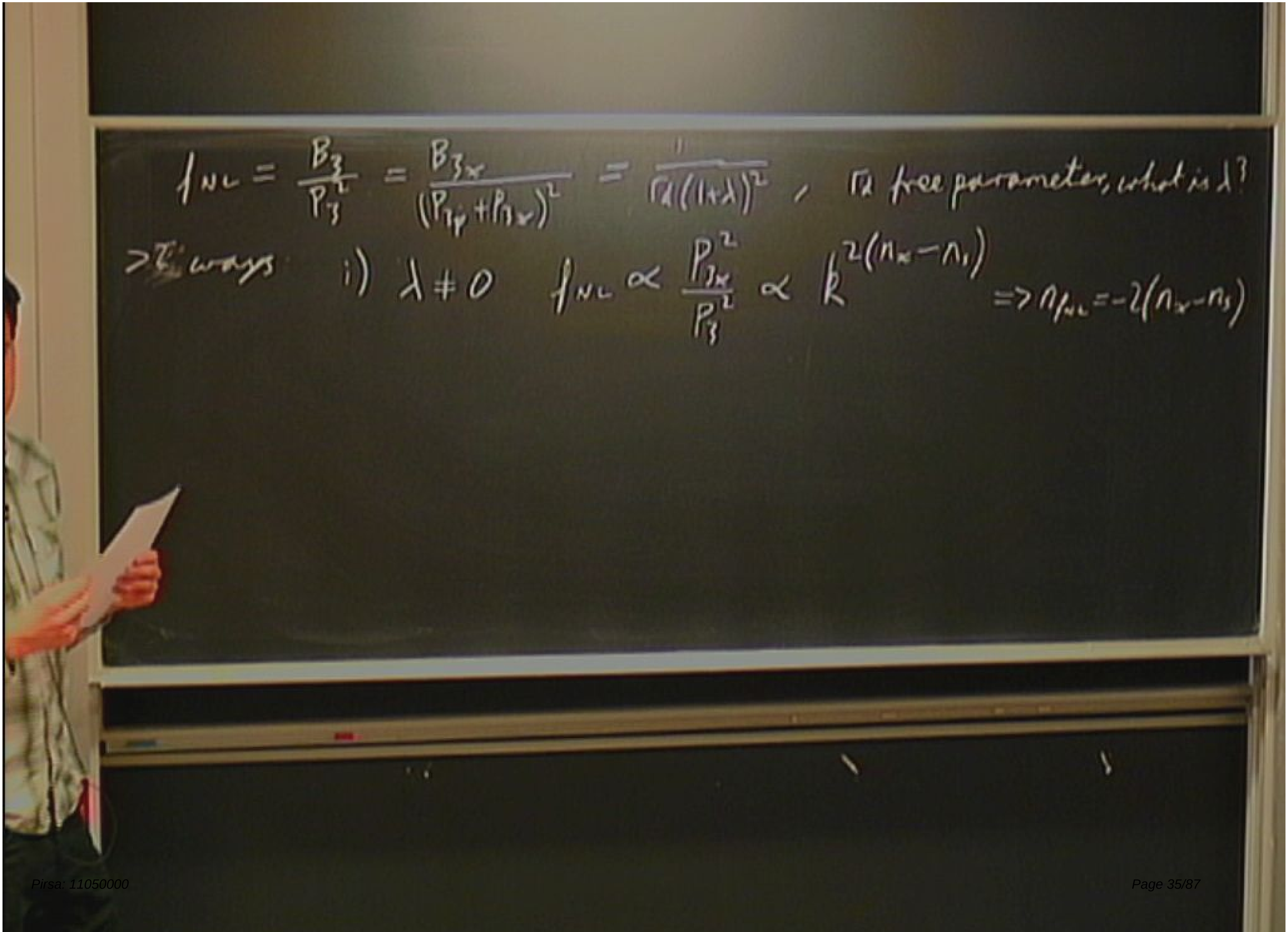
$$f_{NL} = \frac{B(k_1,k_2,k_3)}{P(k_1)P(k_2) + \text{cyclic}}$$

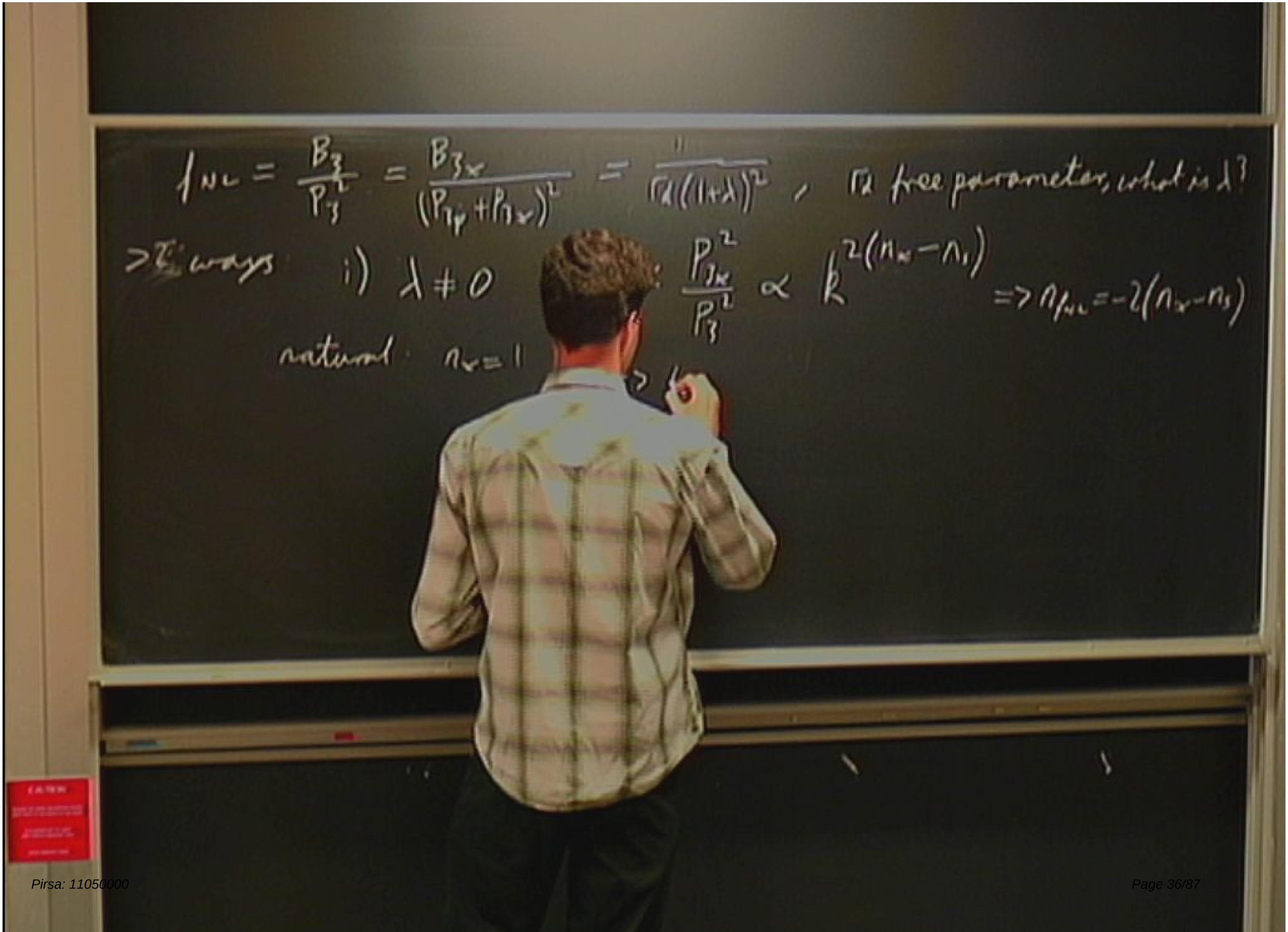

$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta *}}{(P_{\zeta\varphi} + P_{\zeta *})^2} = \frac{1}{\sqrt{\lambda}((1+\lambda))^2}$, $\sqrt{\lambda}$ free parameter, what is λ?

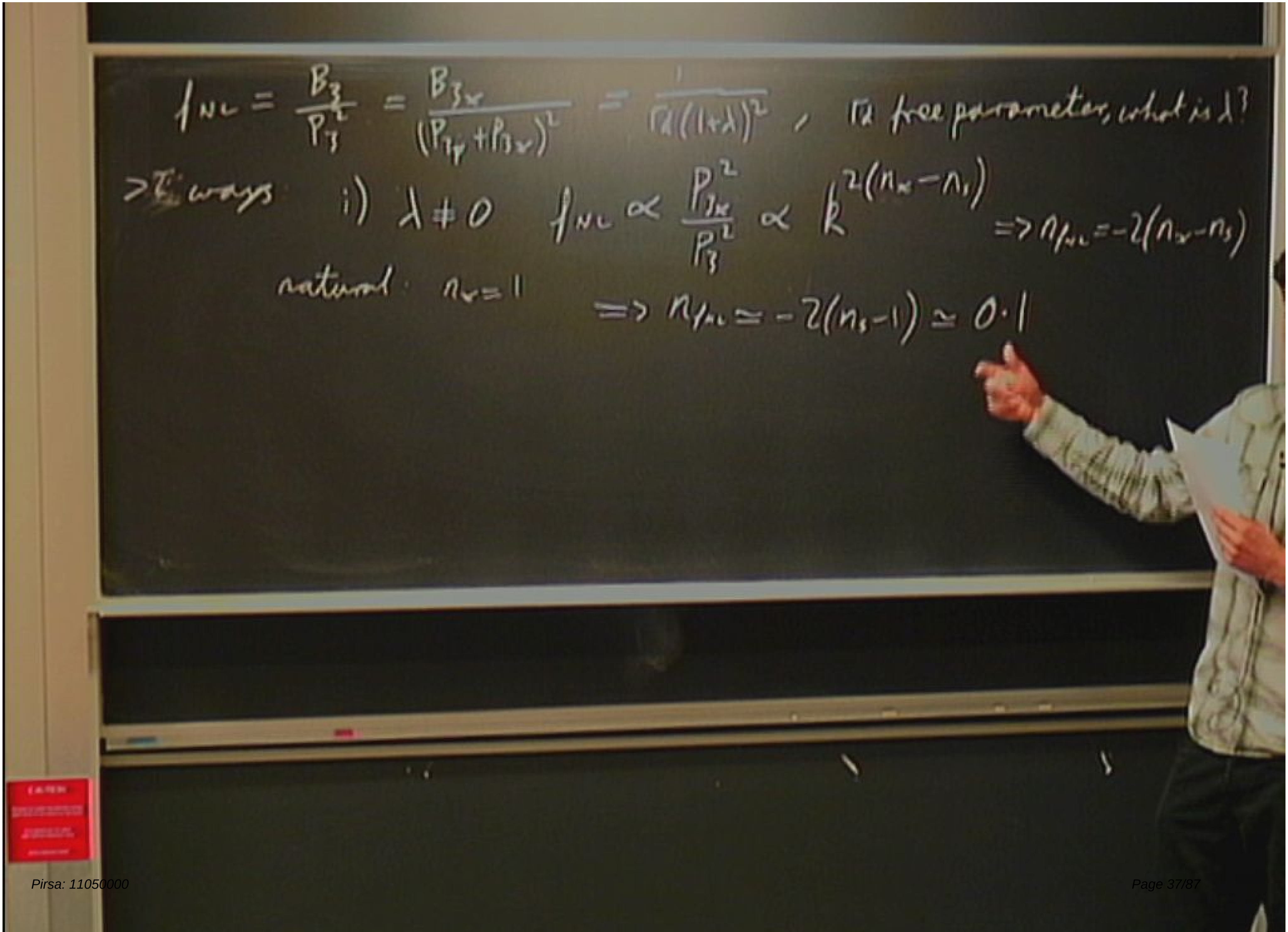

fNL = Bζ / Pζ² = Bζσ / ((Pζφ + Pζσ))² = 1 / √λ((1+λ))² , √λ free parameter, what is λ?
ways ;)

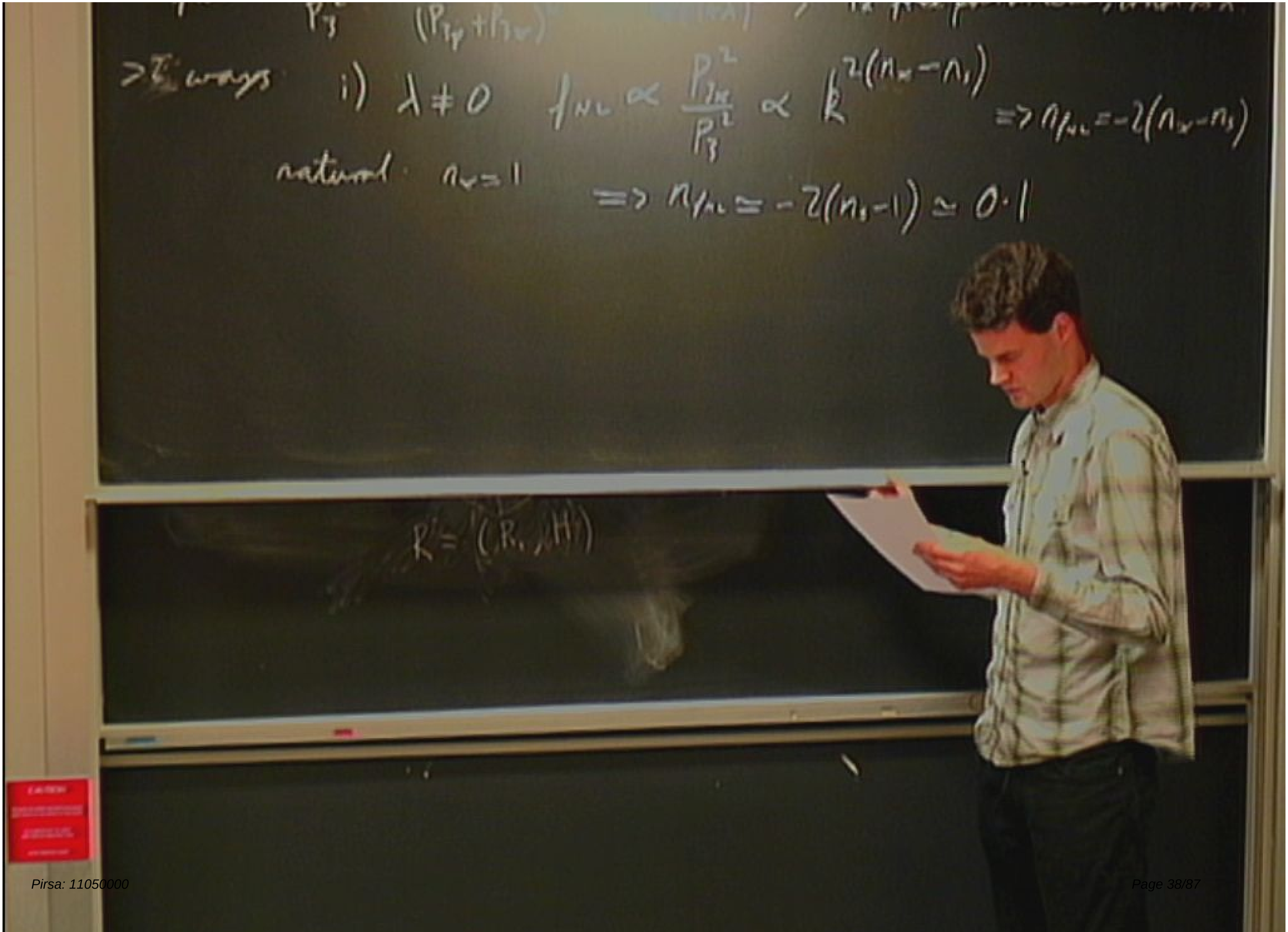

$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta\sigma}}{(P_{\zeta\phi}+P_{\zeta\sigma})^2} = \frac{1}{r_\lambda((1+\lambda))^2}$, r_λ free parameter, what is λ?
ways
i) $\lambda \neq 0$ $f_{NL} \propto P_{\zeta\sigma}^2$

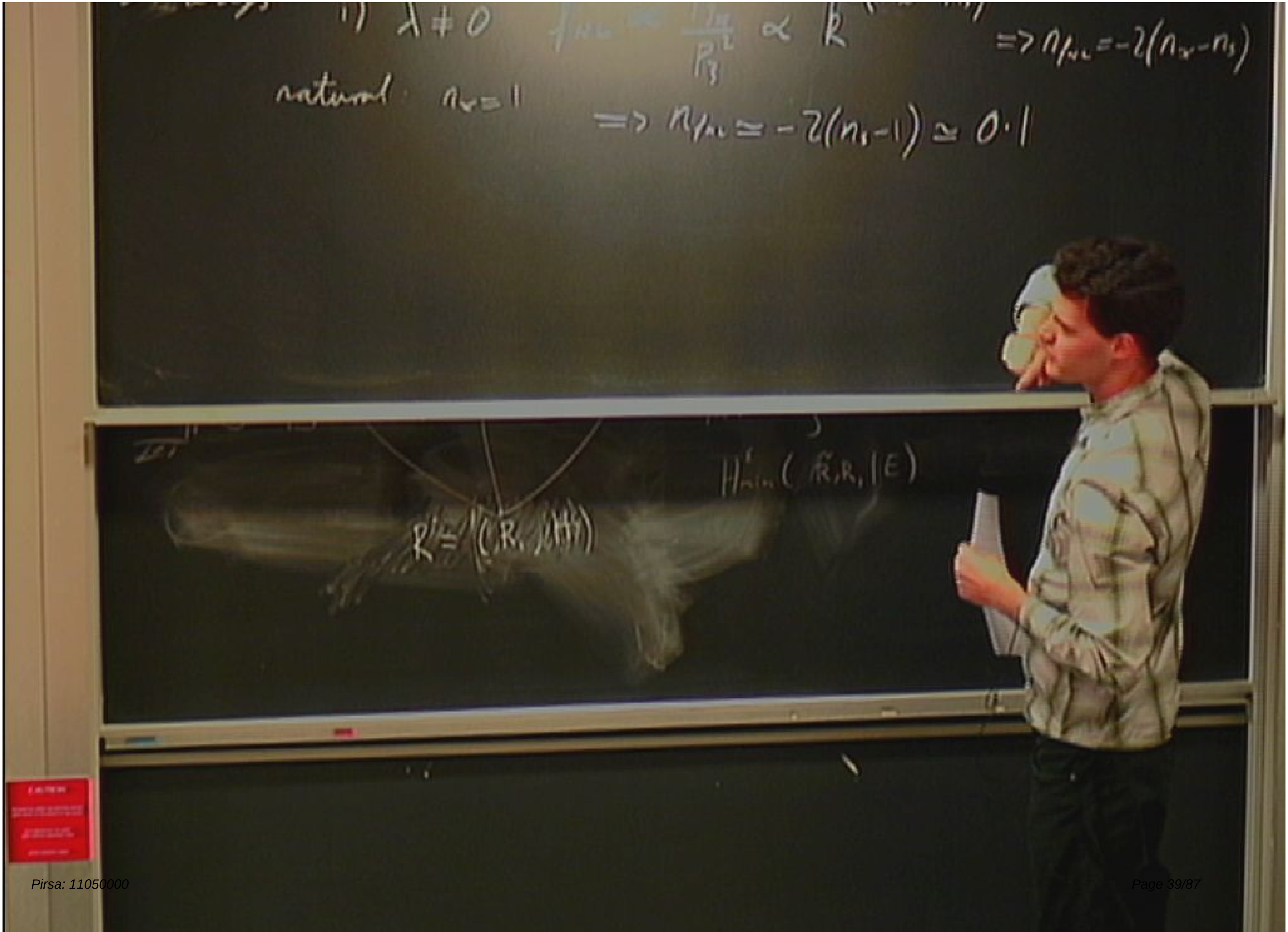

$f_{NL} = \frac{B_3}{P_3^2} = \frac{B_{3\sigma}}{(P_{3\phi}+P_{3\sigma})^2} = \frac{1}{r\lambda(1+\lambda)^2}$, $r\lambda$ free parameter, what is λ?
ways i) $\lambda \neq 0$ $f_{NL} \propto \frac{P_{3\sigma}^2}{P_3^2} \propto k^{2(n_\sigma -}$

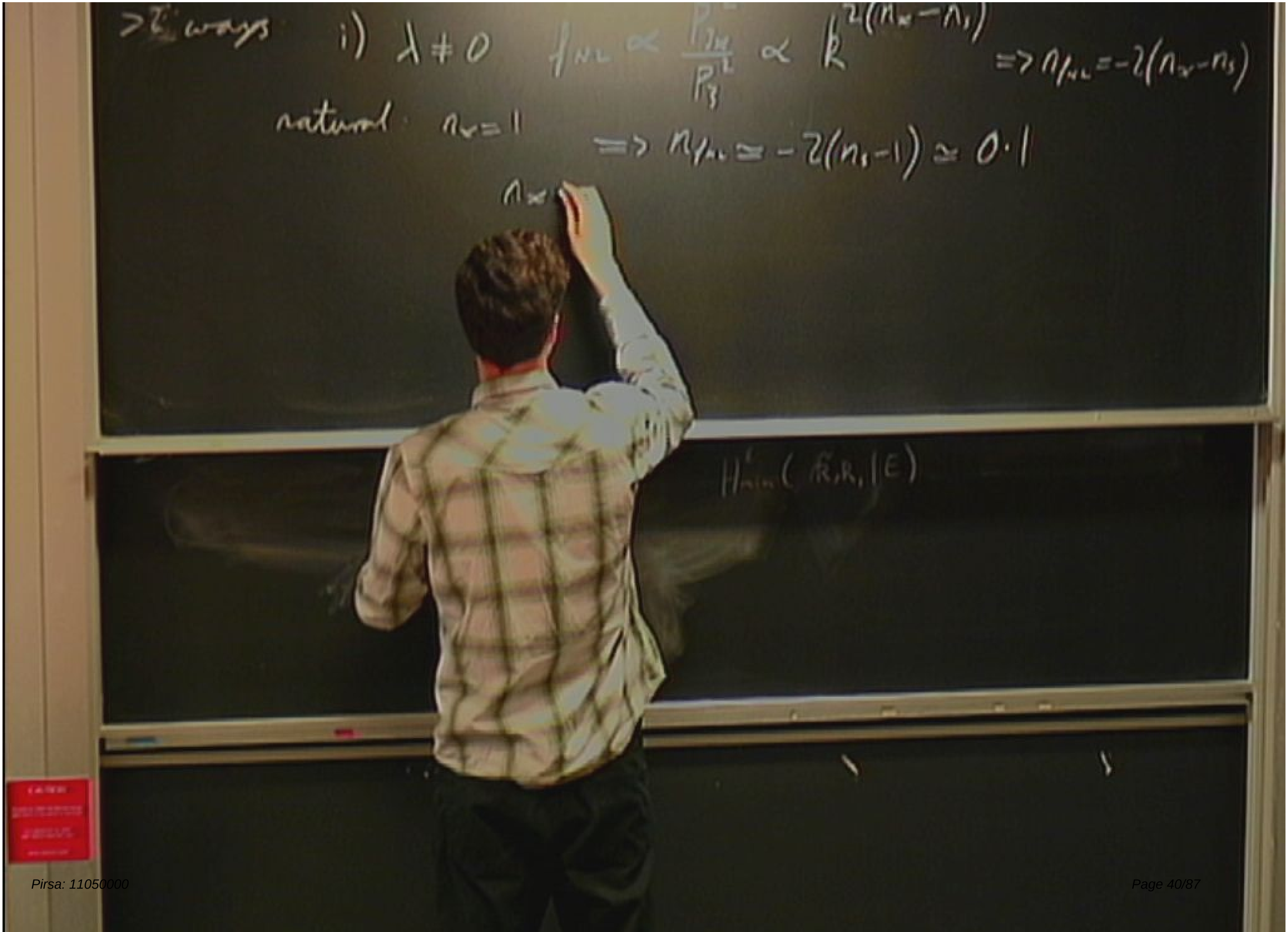

f_NL = B_ζ / P_ζ^2 = B_ζσ / (P_ζφ + P_ζσ)^2 = 1 / (r_λ (1+λ)^2) , r_λ free parameter, what is λ?
> Two ways
i) λ ≠ 0   f_NL ∝ P_ζσ^2 / P_ζ^2 ∝ k^{2(n_σ − n_1)}
=> n_fNL = −2(n_σ − n_1)


r_λ free parameter, what is λ?
ways
i) λ ≠ 0
natural
n_σ = 1

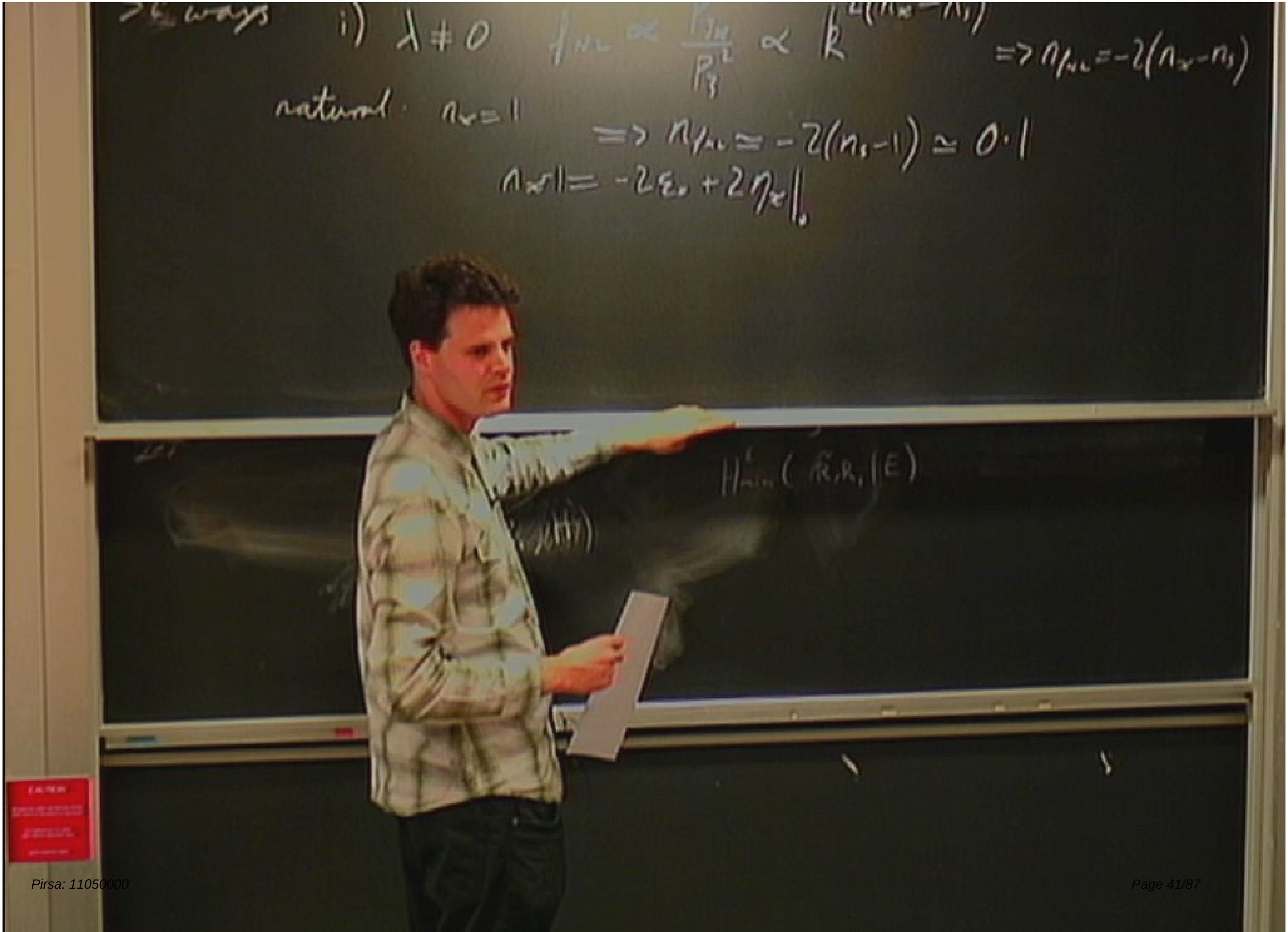

$f_{NL} = \frac{B_\zeta}{P_\zeta^2} = \frac{B_{\zeta\sigma}}{(P_{\zeta\phi} + P_{\zeta\sigma})^2} = \frac{1}{r_\lambda (1+\lambda)^2}$, r_λ free parameter, what is λ?
> Two ways
i) $\lambda \neq 0$ $f_{NL} \propto \frac{P_{\zeta\sigma}^2}{P_\zeta^2} \propto k^{2(n_\sigma - n_s)}$
$\Rightarrow n_{f_{NL}} = -2(n_\sigma - n_s)$
natural: $n_\sigma = 1$
$\Rightarrow n_{f_{NL}} \simeq -2(n_s - 1) \simeq 0.1$

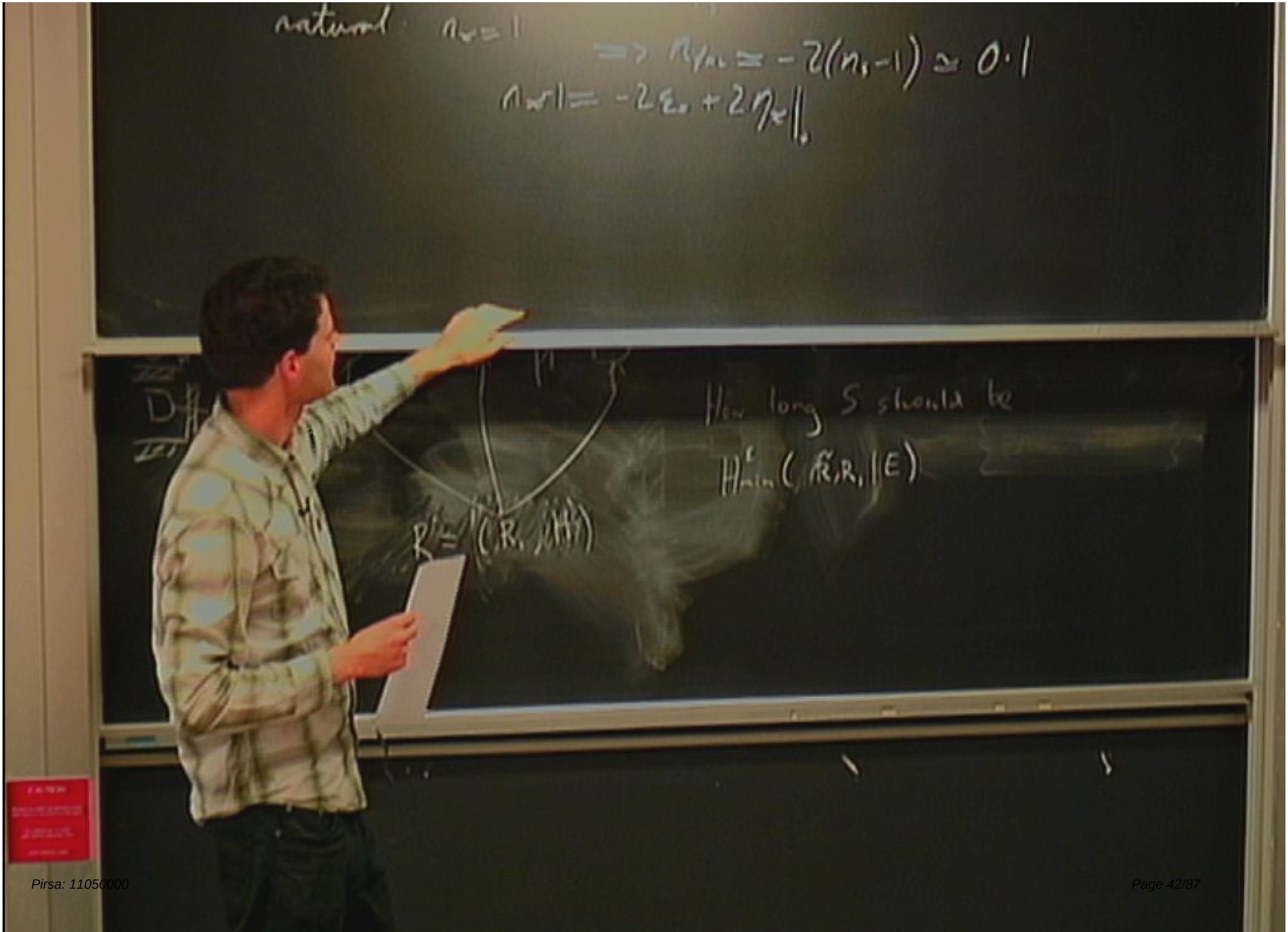

ways i) λ ≠ 0 f_NL ∝ P_ζv^2 / P_ζ^2 ∝ k^2(n_v − n_s)
=> n_f_NL = −2(n_v − n_s)
natural · n_v = 1
=> n_f_NL ≃ −2(n_s − 1) ≃ 0·1
R' = (R, H)

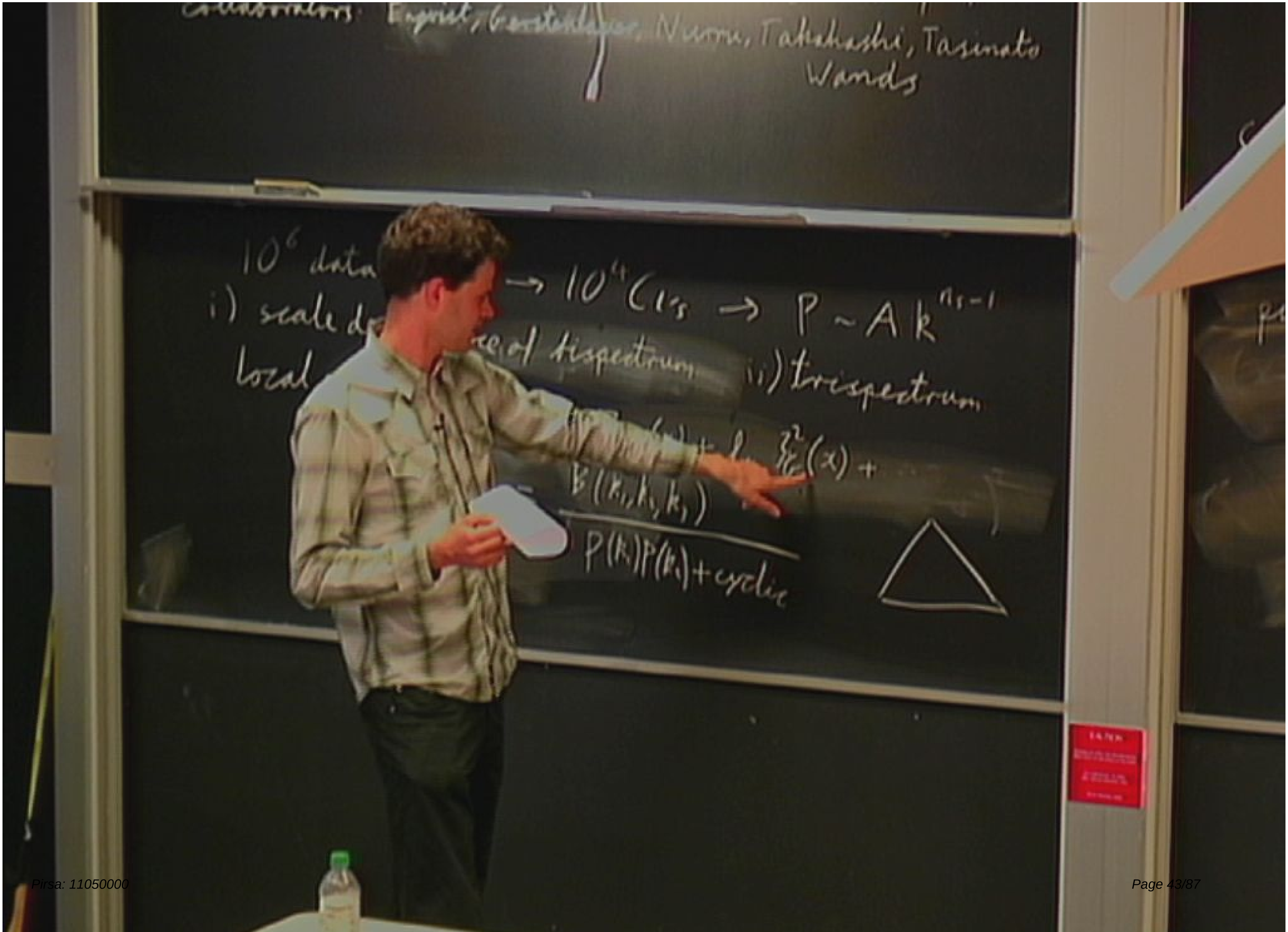

natural: n_T = 1
=> n_fNL ≃ -2(n_s - 1) ≃ 0.1
=> n_fNL = -2(n_T - n_s)

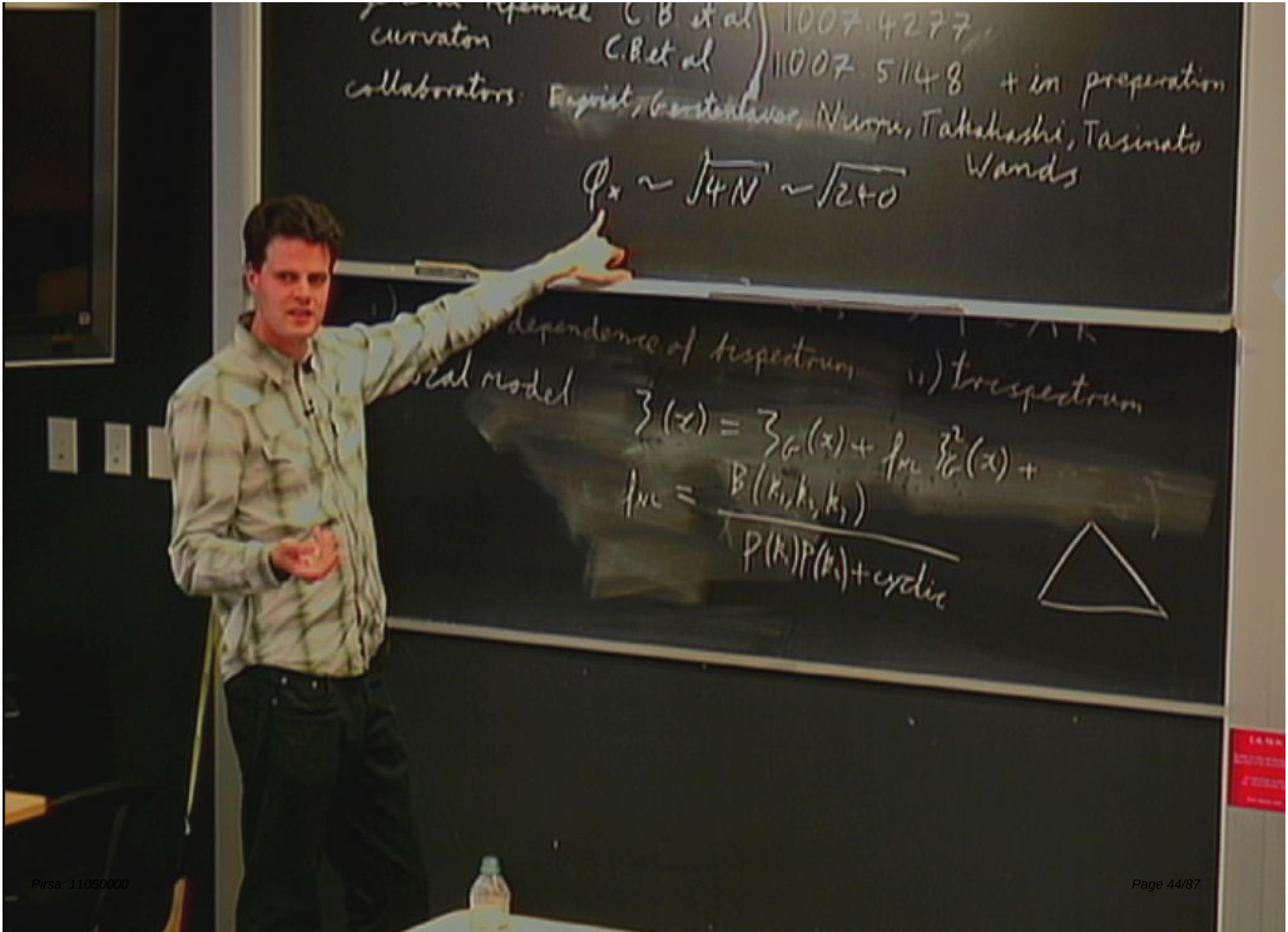


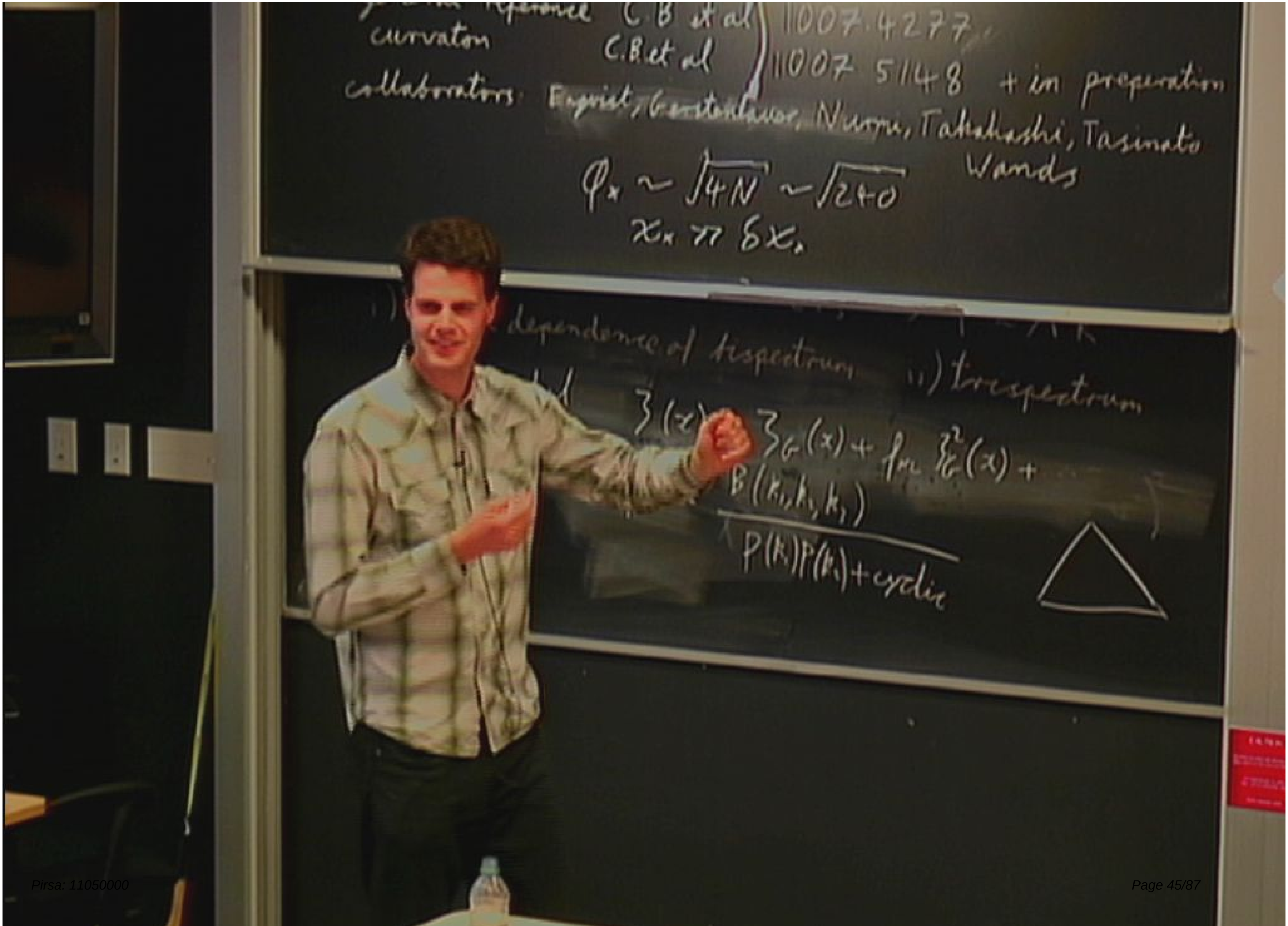
ways
i) λ ≠ 0
natural
≃ 0.1

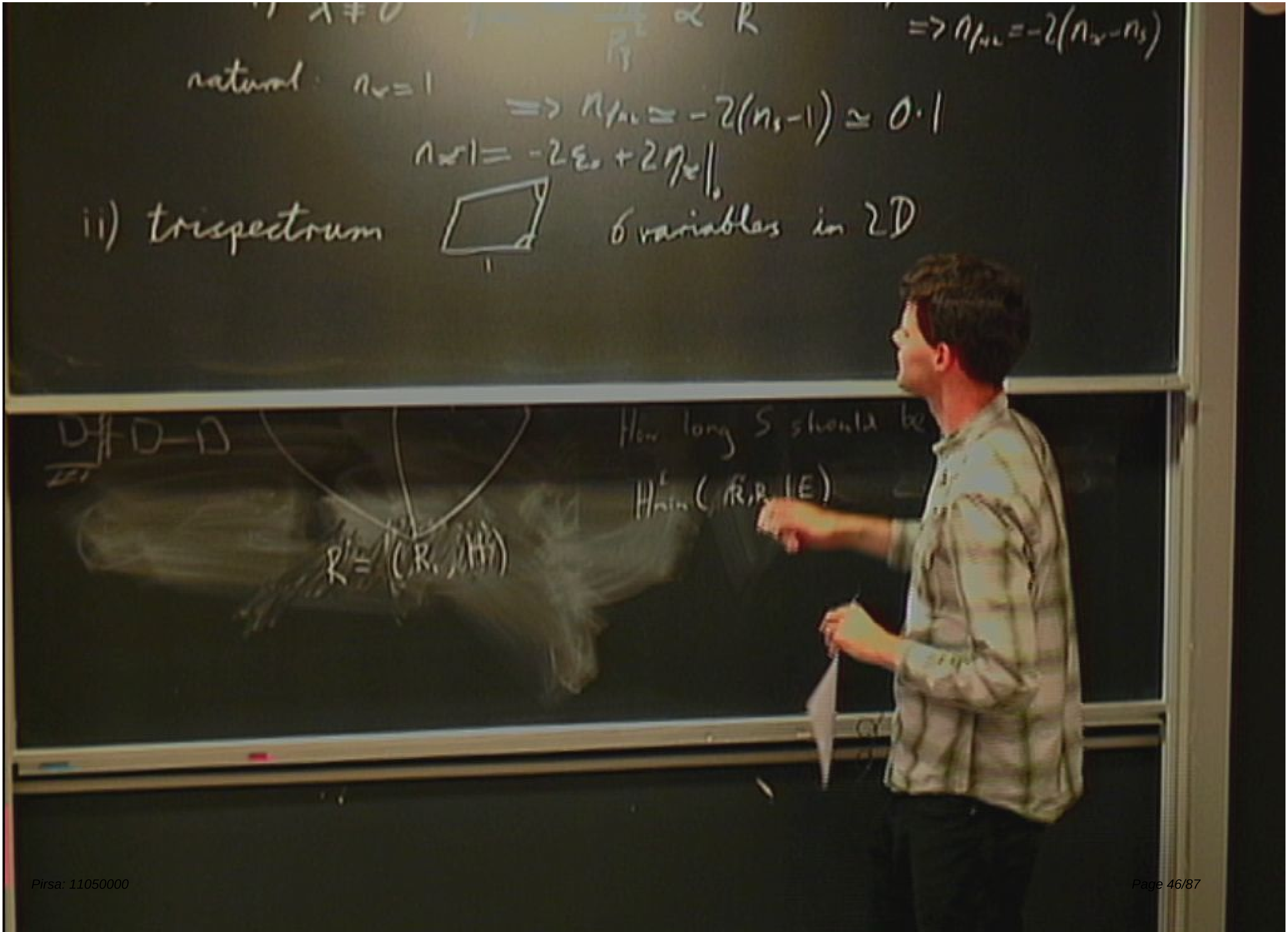

i) λ ≠ 0
natural
⇒ n ≃ −2(n_s − 1) ≃ 0·1

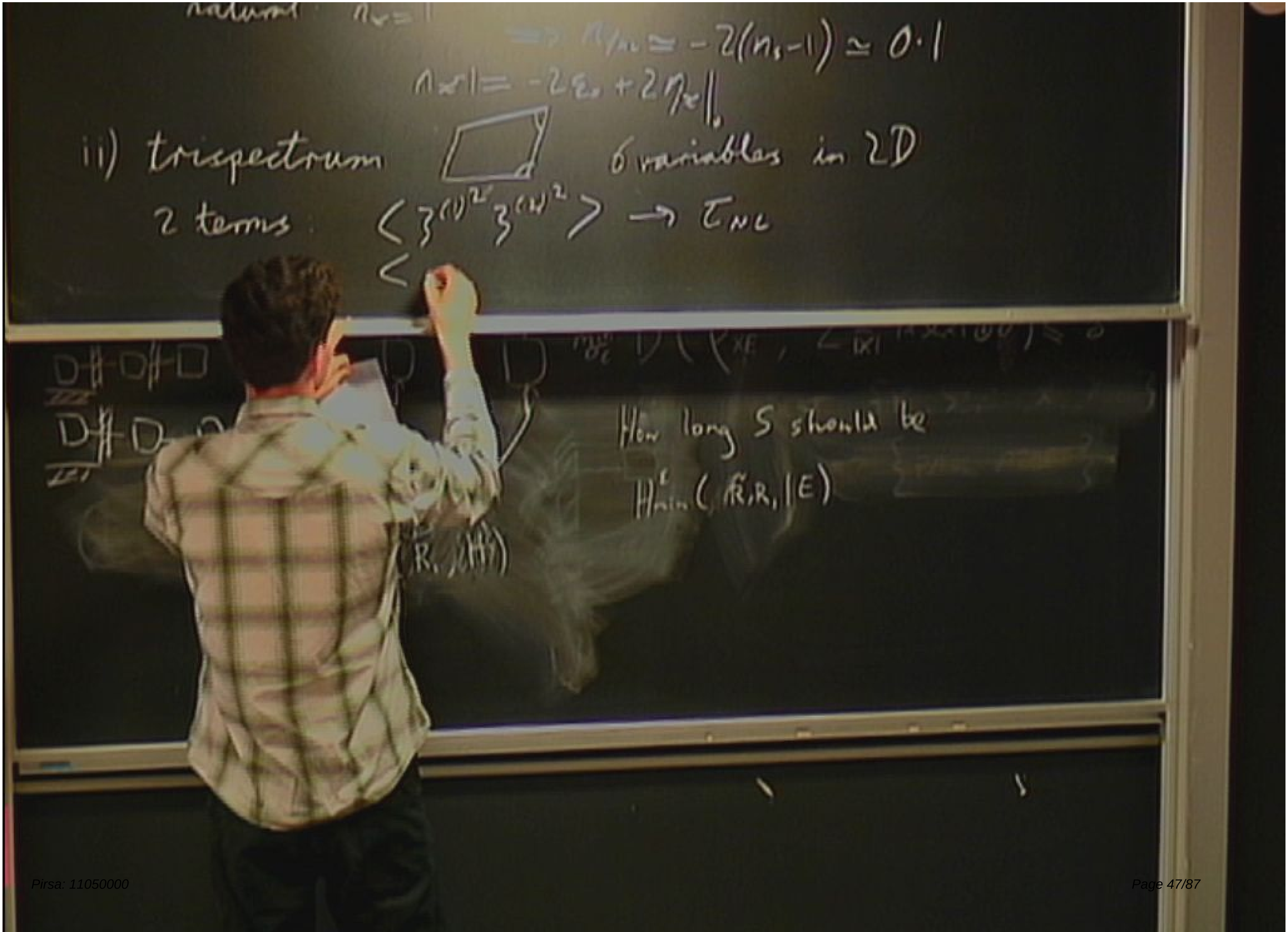

How long S should be

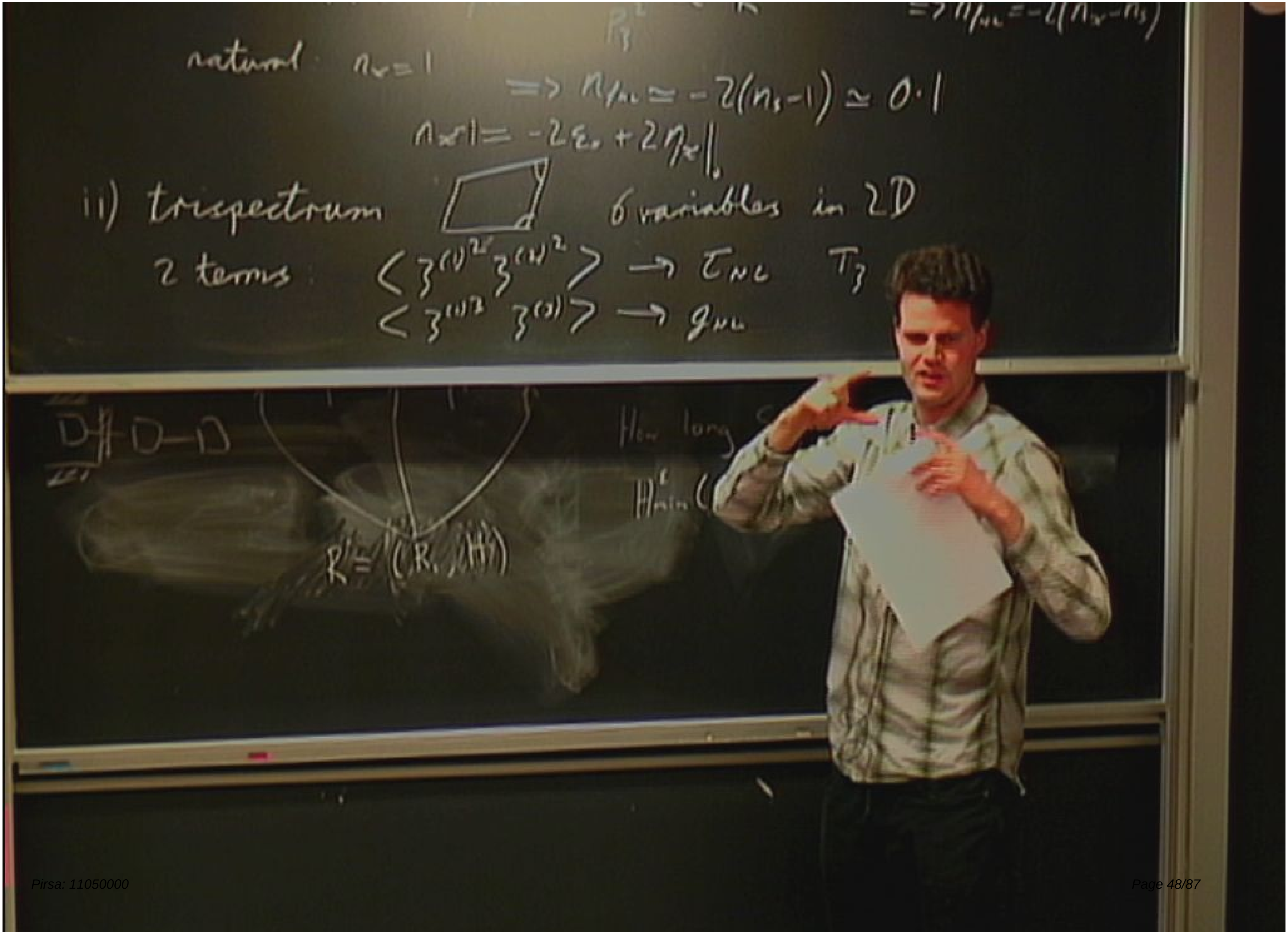

Tasinato
Wands
10^6 data
→ 10^4 Cl's → P ~ A k^{ns-1}
i) scale d
local
ii) trispectrum
P(k)P(k)+cyclic

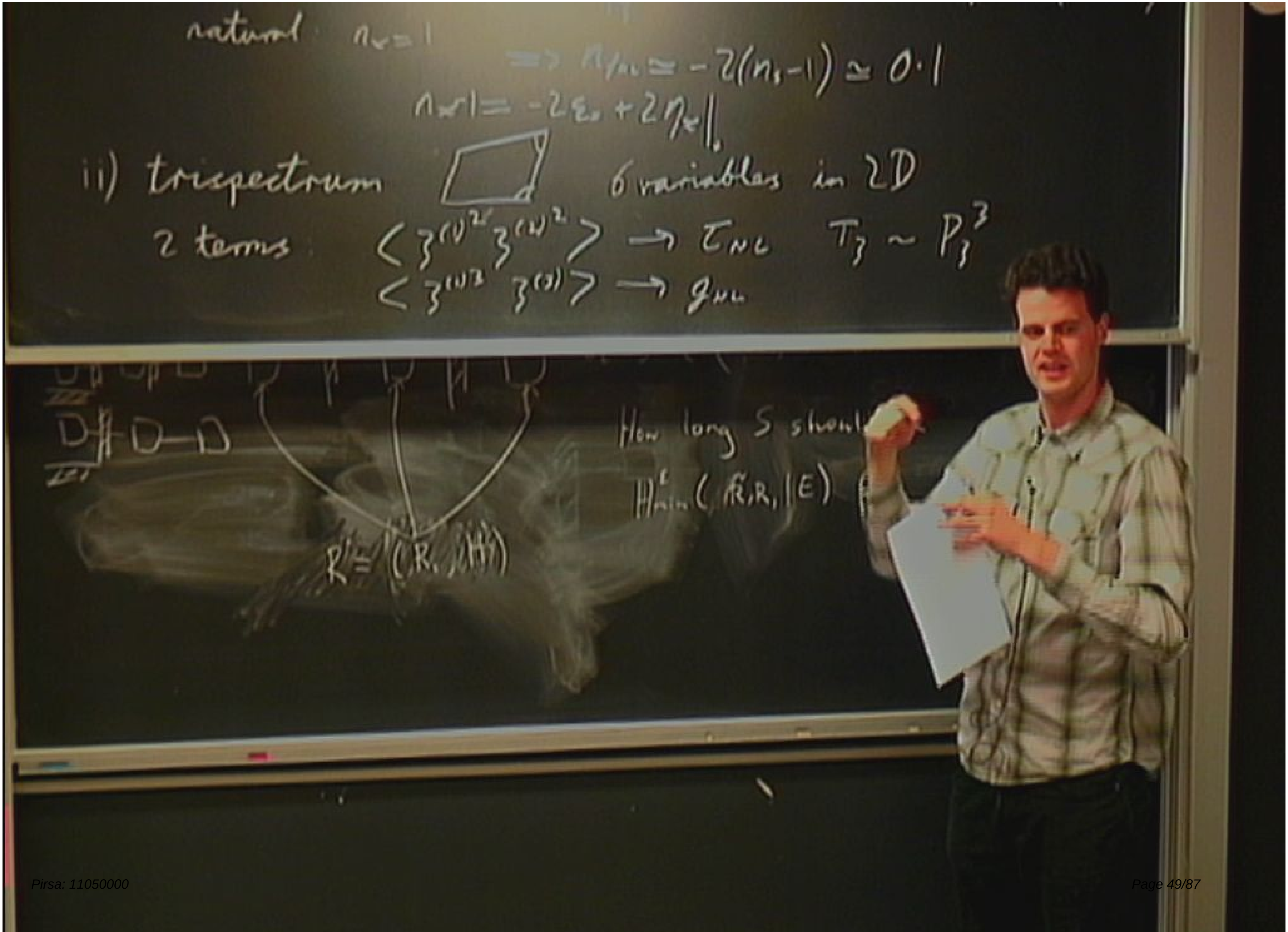

curvaton
C.B et al
1007.4277
1007.5148 + in preparation
collaborators
Nurmi, Takahashi, Tasinato
Wands
dependence of bispectrum
ii) trispectrum
model
P(k)P(k)+cyclic

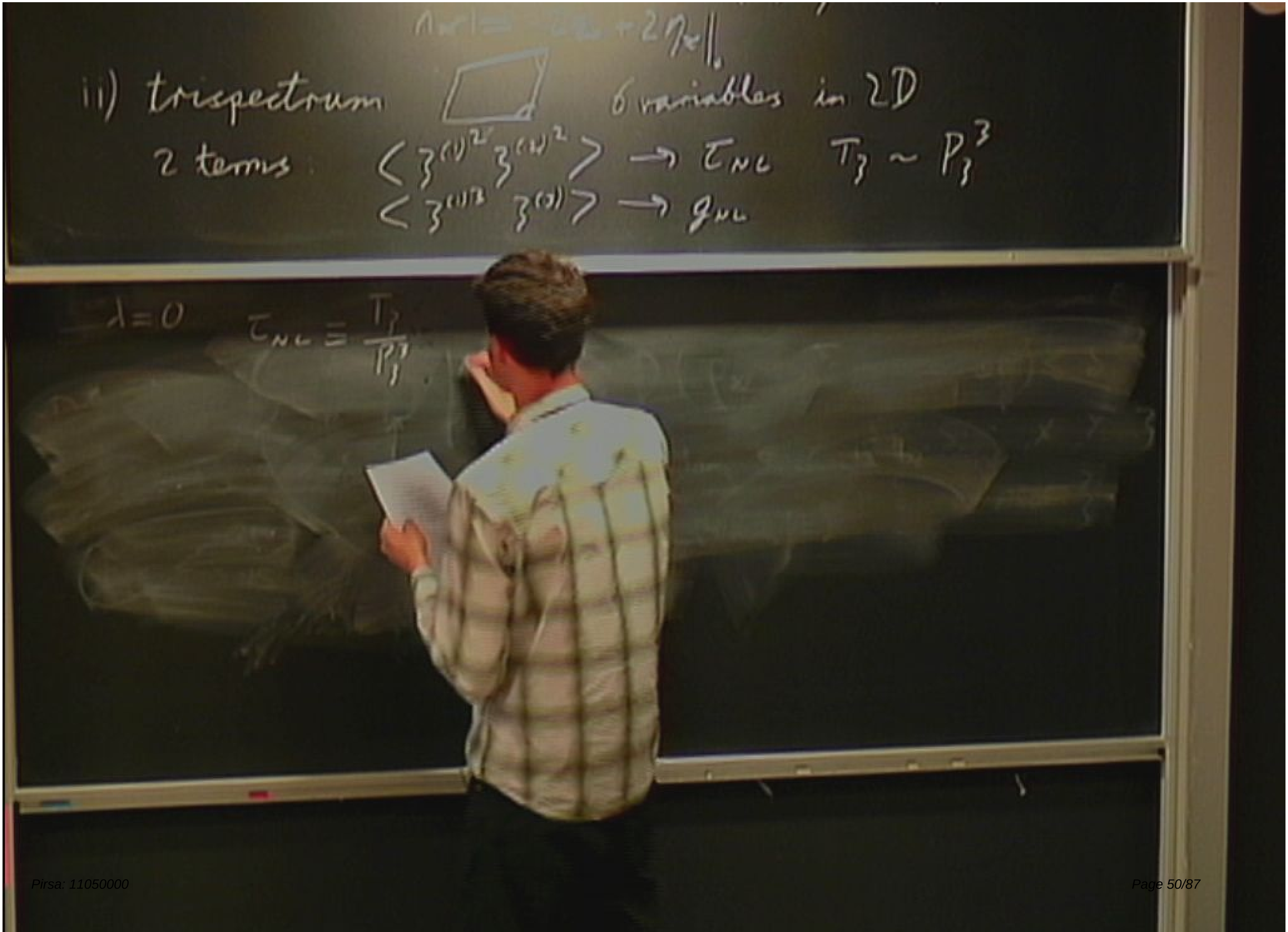

C.B et al 1007.4277
curvaton C.B.et al 1007 5148 + in preparation
collaborators: Nurmi, Takahashi, Tasinato
Wands
dependence of bispectrum
ii) trispectrum
P(k)P(k)+cyclic

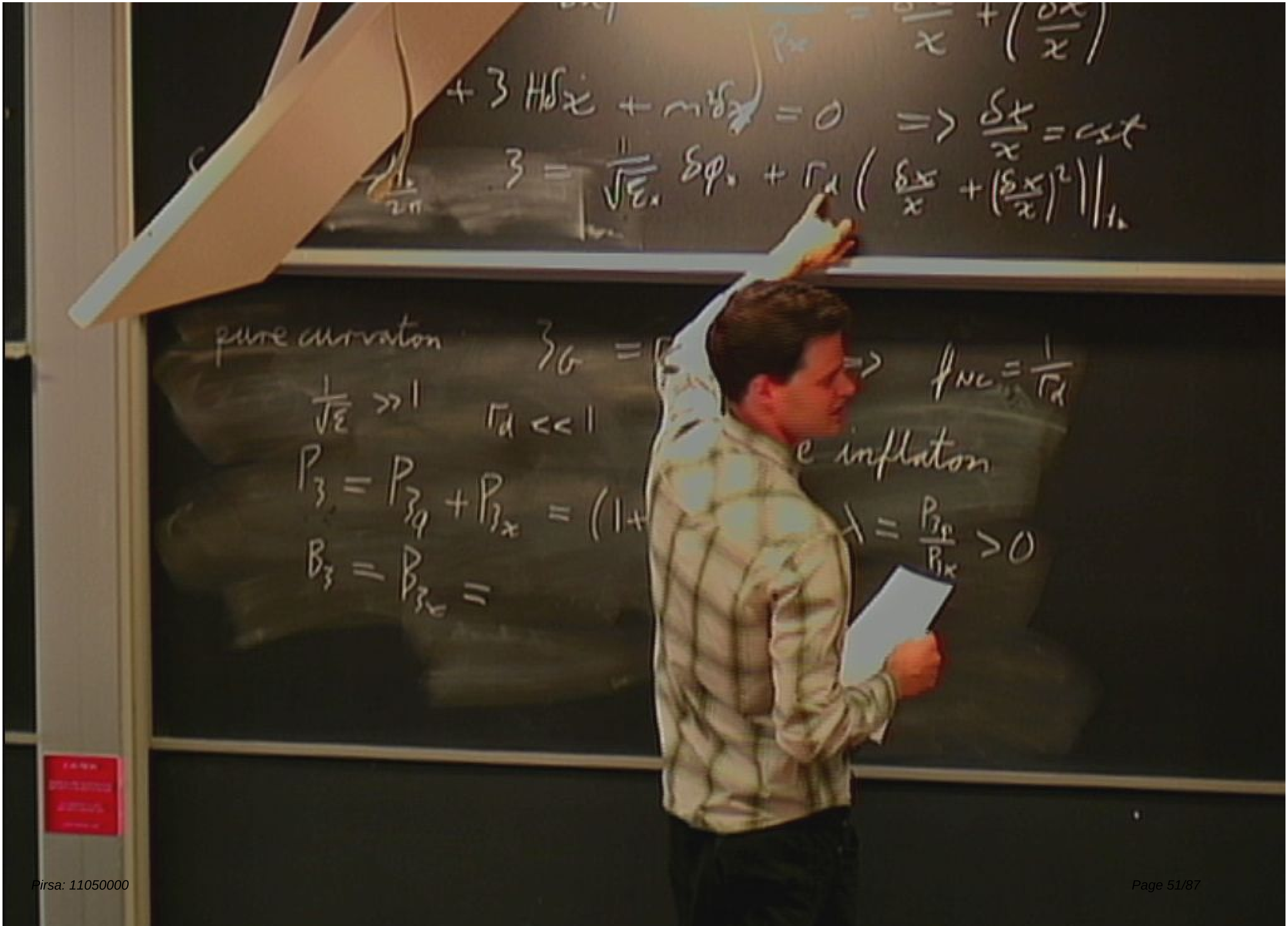

=> n_fNL = -2(n_x - n_s)
natural: n_x = 1
=> n_fNL ≃ -2(n_s - 1) ≃ 0.1
n_x - 1 = -2ε_0 + 2η_x|_0
ii) trispectrum
6 variables in 2D
How long S should be

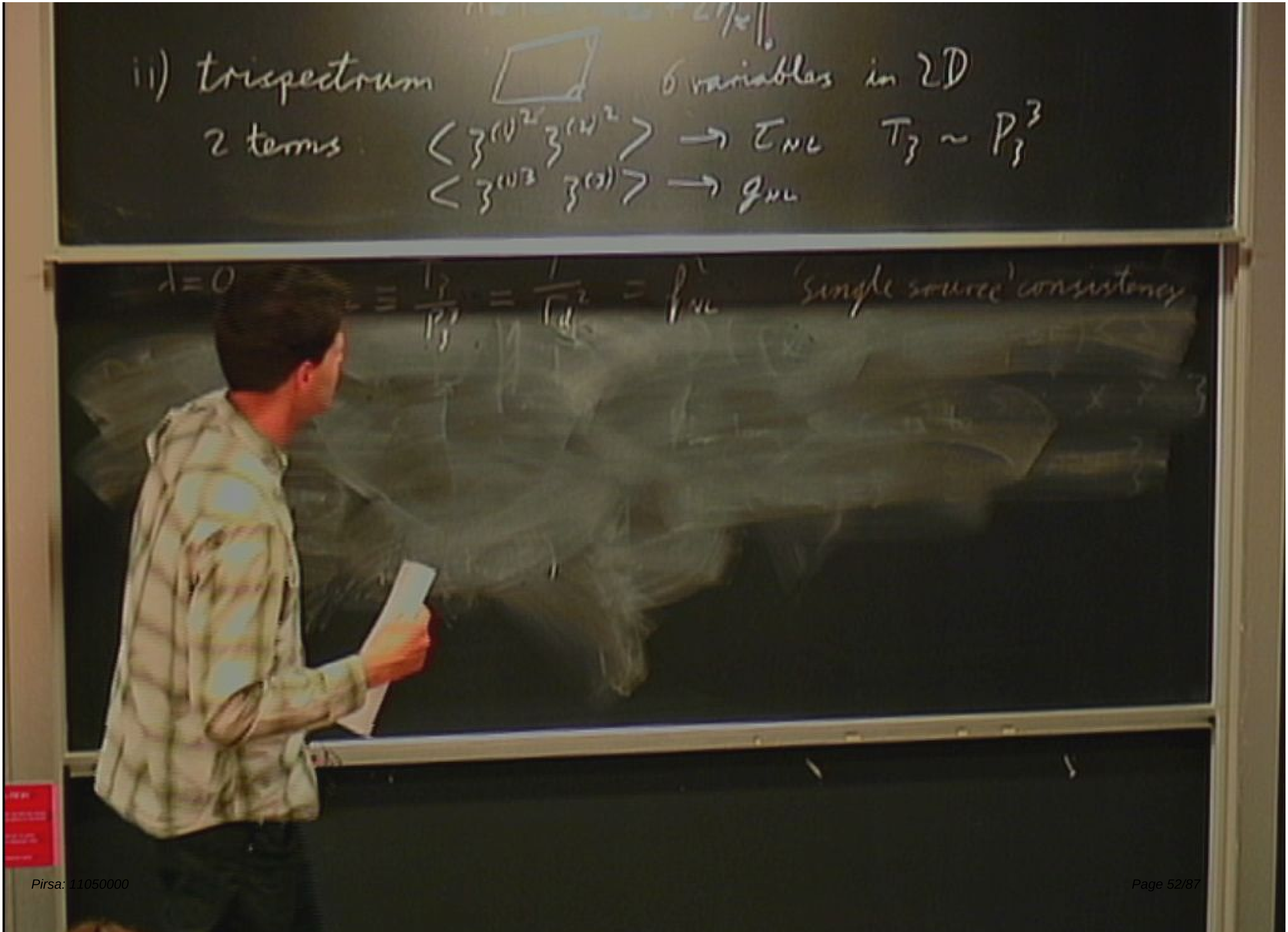

ii) trispectrum
6 variables in 2D
2 terms
How long S should be

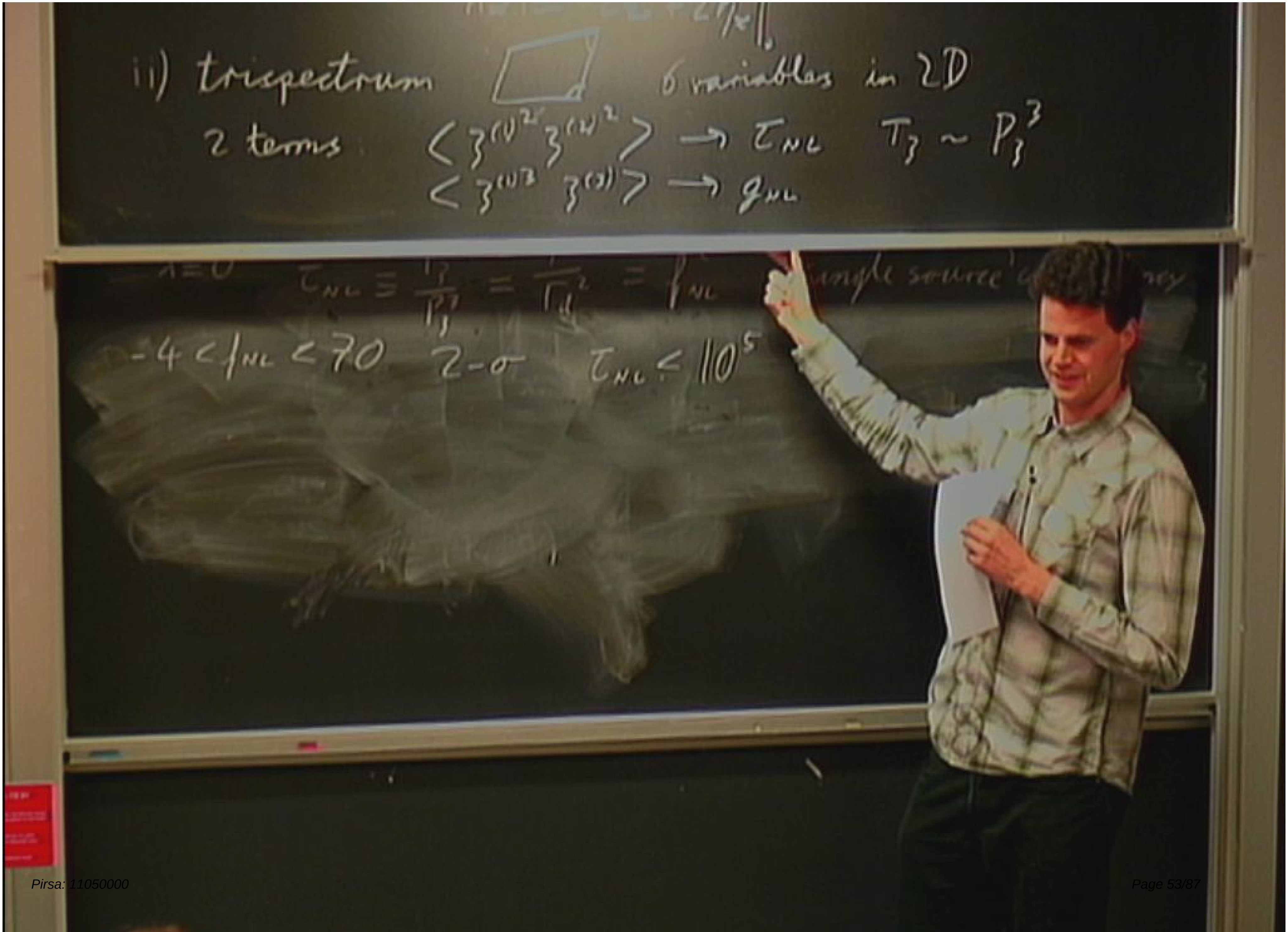

natural
ii) trispectrum
6 variables in 2D
2 terms
How long

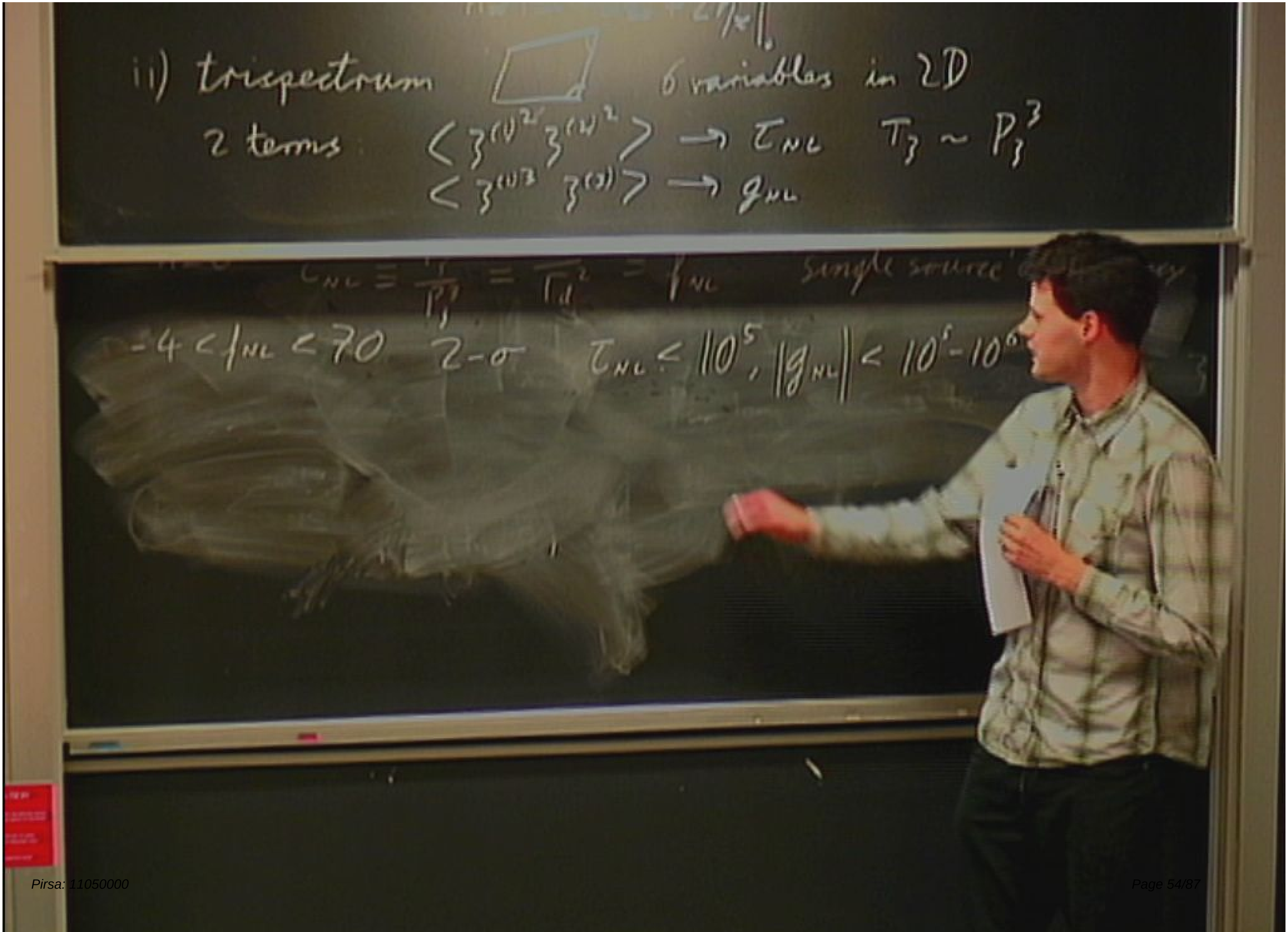

natural
ii) trispectrum
6 variables in 2D
2 terms
How long S should

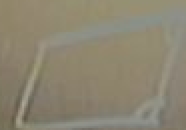

ii) trispectrum
6 variables in 2D
2 terms $\langle \zeta^{(1)2} \zeta^{(2)2} \rangle \to \tau_{NL}$
$T_3 \sim P_3^3$
$\langle \zeta^{(1)3} \zeta^{(3)} \rangle \to g_{NL}$
$\lambda = 0$
$\tau_{NL} = \frac{T_3}{P_3^3}$


pure curvaton
inflaton


ii) trispectrum
6 variables in 2D
2 terms $\langle \zeta^{(1)^2} \zeta^{(2)^2} \rangle \rightarrow \tau_{NL}$ $T_\zeta \sim P_\zeta^3$
$\langle \zeta^{(1)^3} \zeta^{(2)} \rangle \rightarrow g_{NL}$
'single source' consistency


ii) trispectrum 6 variables in 2D
2 terms <ζ(1)² ζ(1)²> → τNL Tζ ~ Pζ³
<ζ(1)³ ζ(1)> → gNL
-4 < fNL < 70 2-σ τNL < 10⁵


ii) trispectrum
6 variables in 2D
2 terms
→ τNL
→ gNL
2-σ

ii) trispectrum  6 variables in 2D

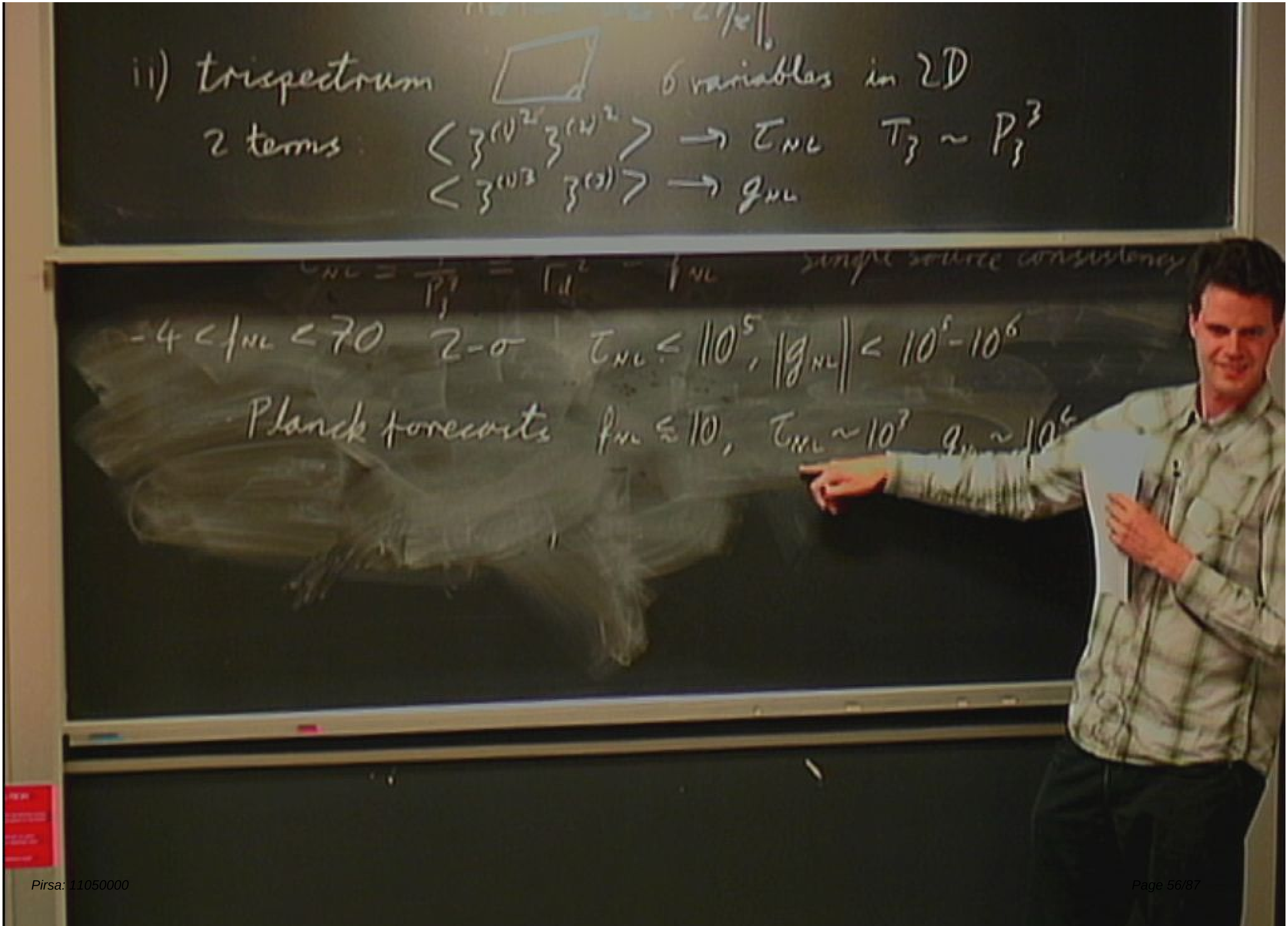
2 terms $\langle \zeta^{(1)2} \zeta^{(1)2} \rangle \rightarrow \tau_{NL}$ $\quad T_\zeta \sim P_\zeta^3$

$\langle \zeta^{(1)3} \zeta^{(2)} \rangle \rightarrow g_{NL}$

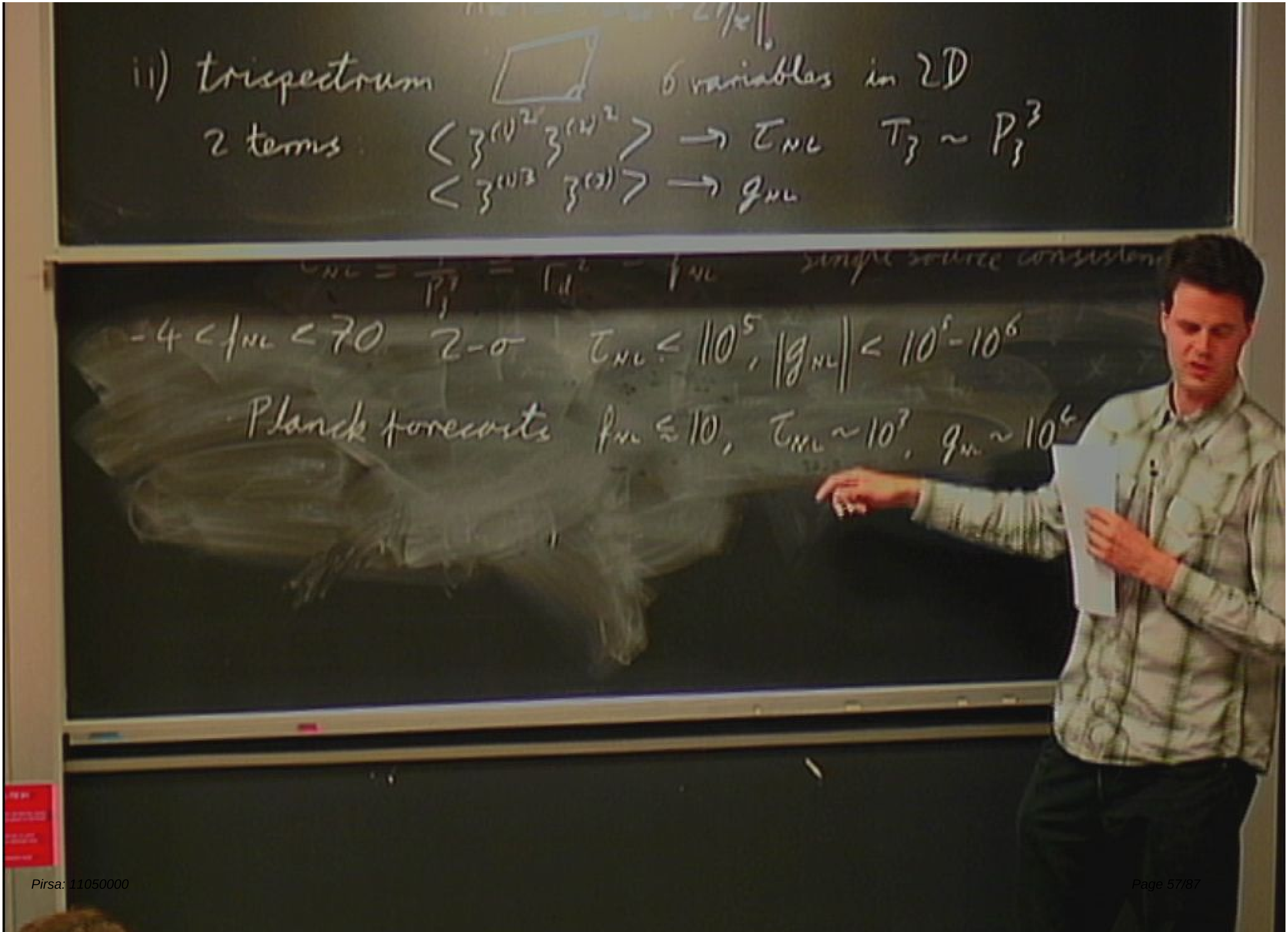
$\tau_{NL} \equiv \frac{1}{P_\zeta^3} = \overline{T_d}^2 = f_{NL}$ single source consistency

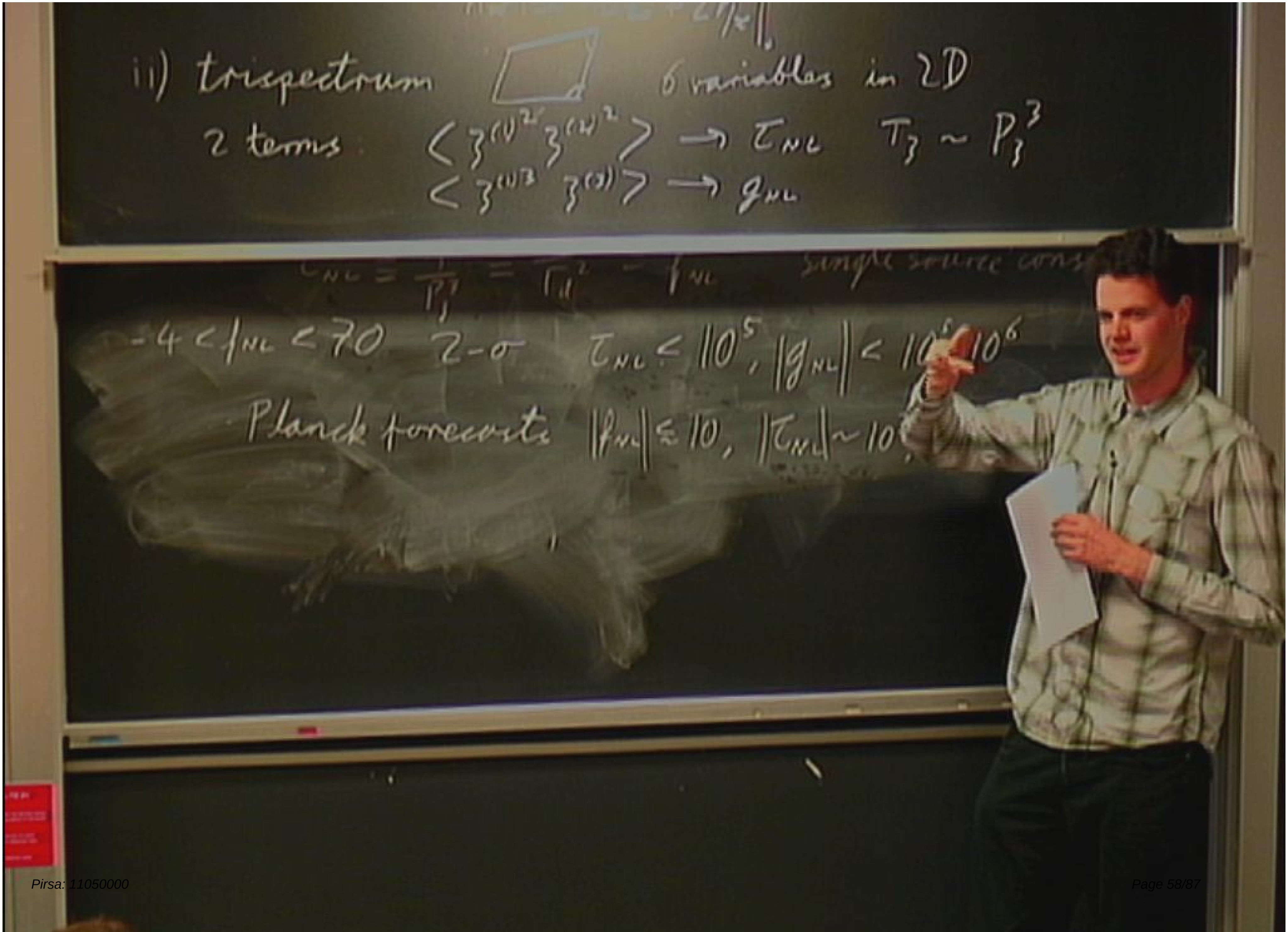
$-4 < f_{NL} < 70$ 2-σ $\quad \tau_{NL} < 10^5, \ |g_{NL}| < 10^5 - 10^6$

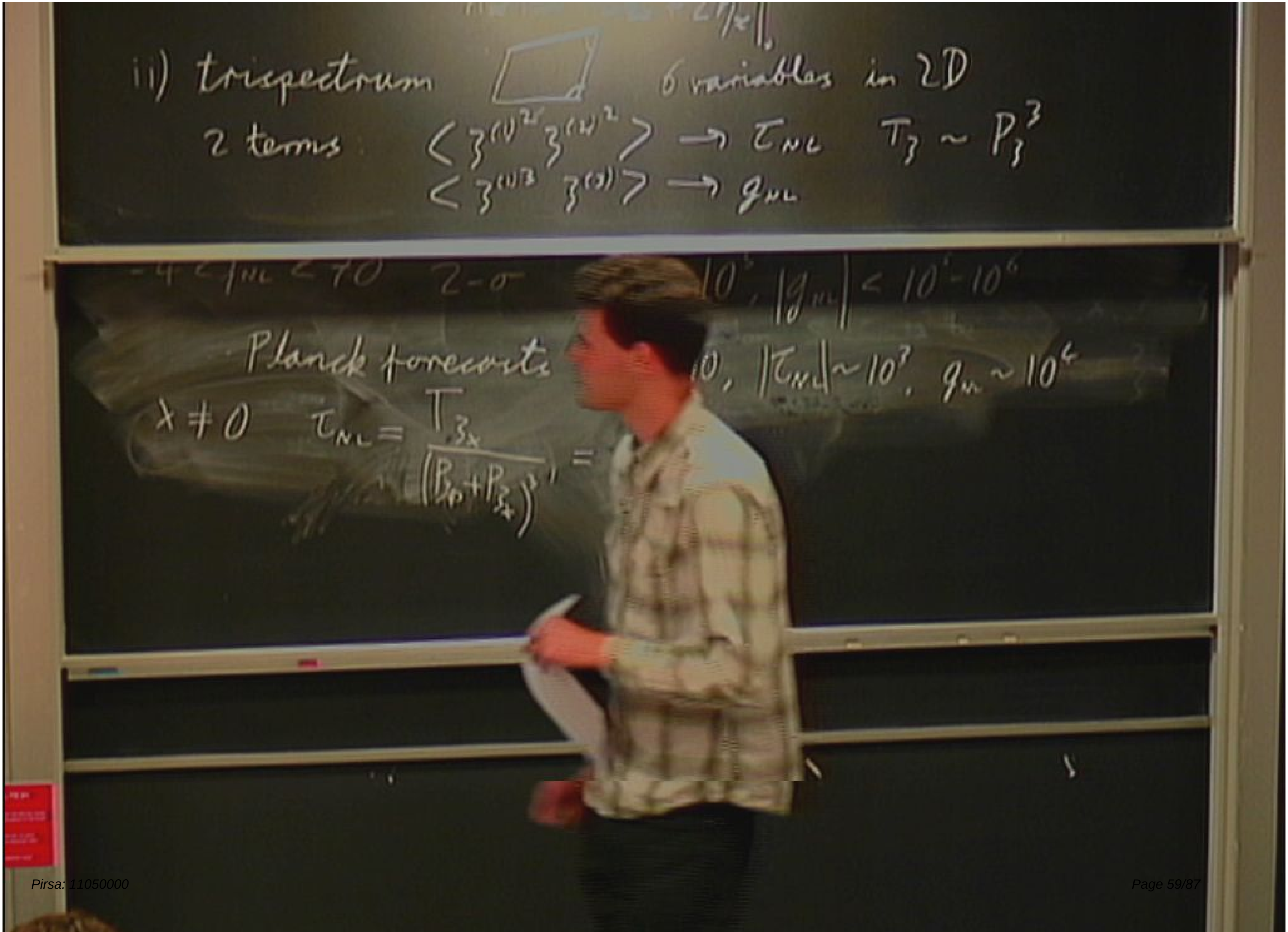
Planck



ii) trispectrum 6 variables in 2D
2 terms <ζ(1)2 ζ(1)2> → τNL T3 ~ P3 3
<ζ(1)3 ζ(3)> → gNL
single source consistency
-4 < fNL < 70 2-σ τNL ≤ 10^5, |gNL| < 10^5-10^6
Planck forecasts fNL ≲ 10, τNL ~ 10^3


ii) trispectrum 6 variables in 2D
2 terms ⟨ζ(1)2 ζ(1)2⟩ → τNL Tζ ~ Pζ3
⟨ζ(1)3 ζ(2)⟩ → gNL
-4 < fNL < 70 2-σ τNL ≤ 105, |gNL| < 105-106
Planck forecasts fNL ≲ 10, τNL ~ 103, gNL ~ 104


ii) trispectrum 6 variables in 2D
2 terms <ζ(1)2 ζ(1)2> → τNL Tζ ~ Pζ3
<ζ(1)3 ζ(3)> → gNL
-4 < fNL < 70 2-σ τNL < 105, |gNL| < 10 10
Planck forecasts |fNL| ≲ 10, |τNL| ~ 10


ii) trispectrum 6 variables in 2D
2 terms $\langle \zeta^{(1)2} \zeta^{(2)2} \rangle \to \tau_{NL}$ $T_\zeta \sim P_\zeta^3$
$\langle \zeta^{(1)3} \zeta^{(2)} \rangle \to g_{NL}$
2-σ
$|g_{NL}| < 10^5 - 10^6$
Planck forecasts
$|\tau_{NL}| \sim 10^3$, $g_{NL} \sim 10^4$
$\lambda \neq 0$ $\tau_{NL} = \frac{T_{\zeta\chi}}{(P_{\zeta\phi} + P_{\zeta\chi})^3} =$

ii) trispectrum  6 variables in 2D

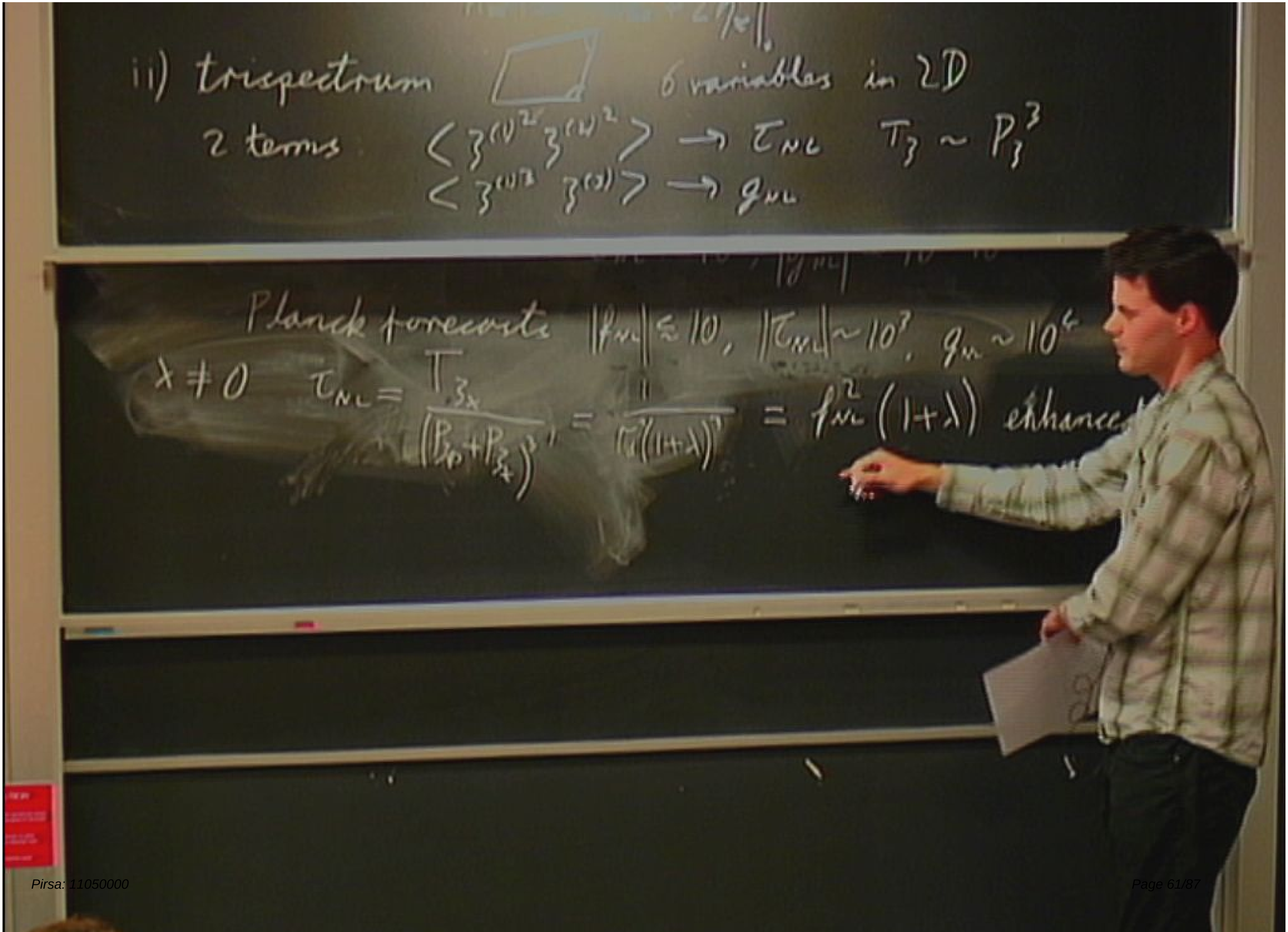
2 terms $\langle \zeta^{(1)^2} \zeta^{(1)^2} \rangle \to \tau_{NL}$ $\quad T_\zeta \sim P_\zeta^3$

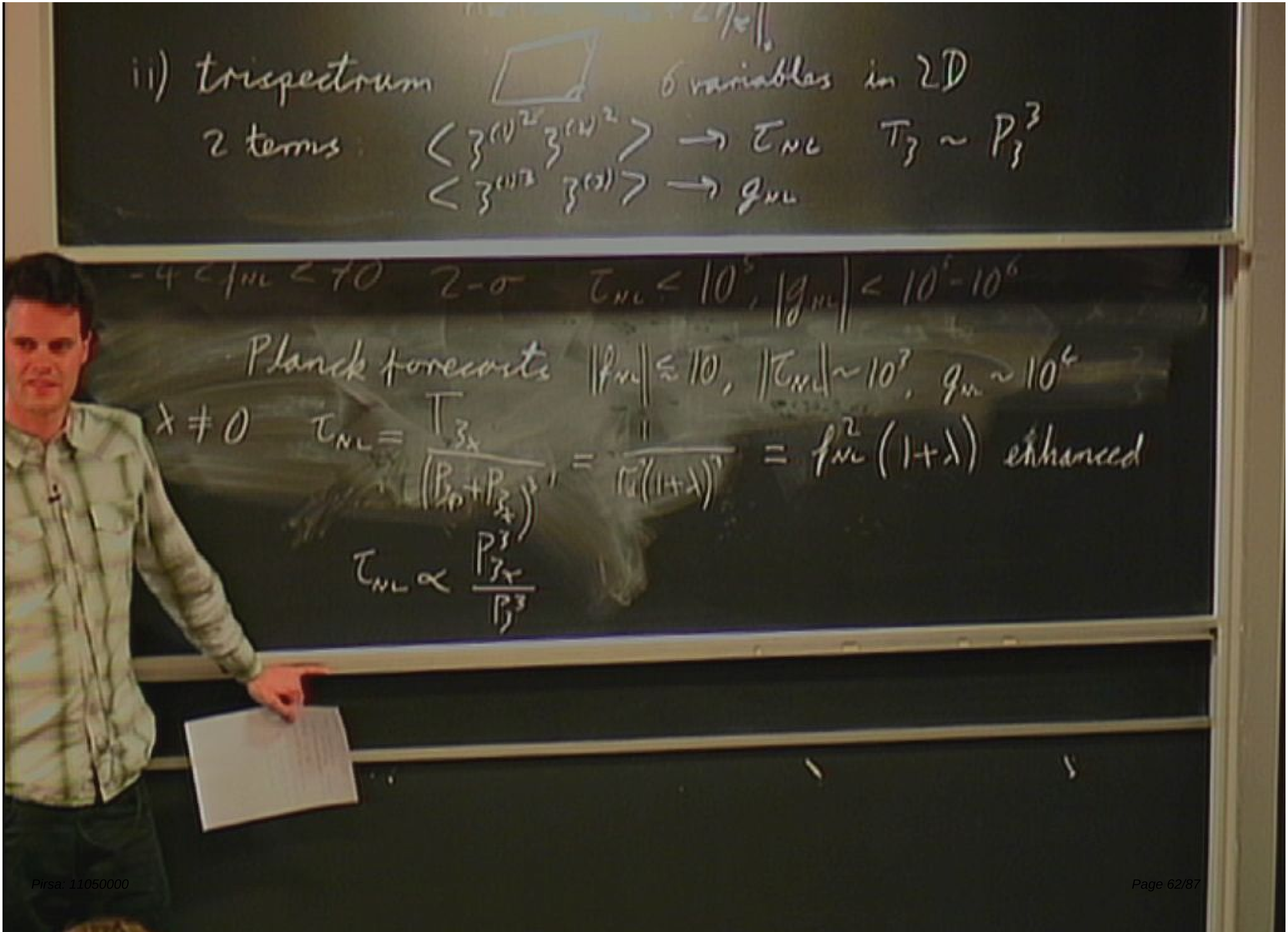
$\langle \zeta^{(1)^3} \zeta^{(3)} \rangle \to g_{NL}$

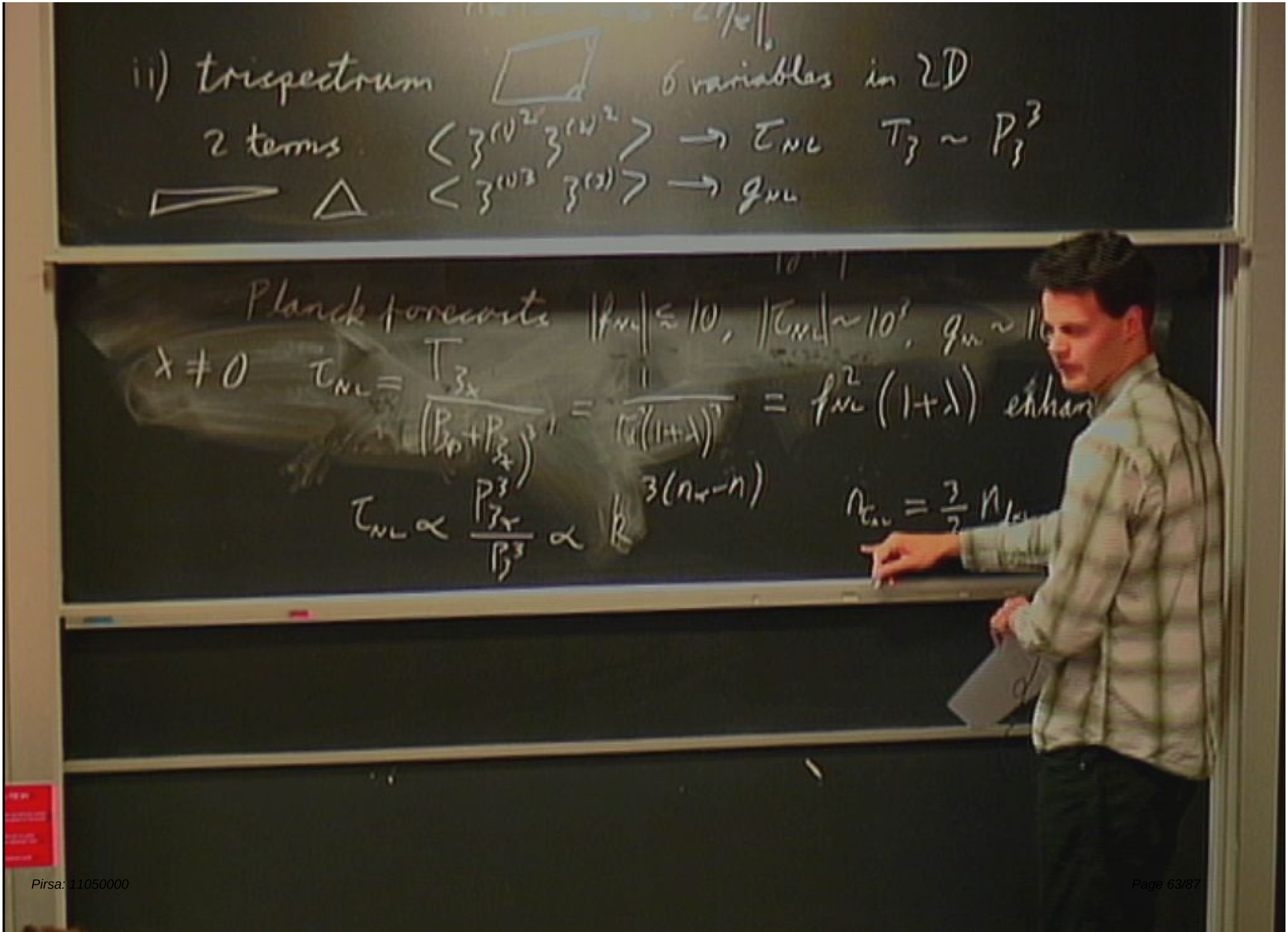
$-4 < f_{NL} < 80$ 2-σ $\quad \tau_{NL} < 10^5, \; |g_{NL}| < 10^5 - 10^6$

Planck forecasts $|f_{NL}| \lesssim 10, \; |\tau_{NL}| \sim 10^3, \; g_{NL} \sim 10^4$

$\lambda \neq 0 \quad \tau_{NL} = \frac{T_{\zeta_\chi}}{(P_{\zeta_\phi} + P_{\zeta_\chi})^3} = \frac{1}{r^3(1+\lambda)^3}$


ii) trispectrum
6 variables in 2D
2 terms $\langle \zeta^{(1)2} \zeta^{(2)2} \rangle \rightarrow \tau_{NL}$ $T_\zeta \sim P_\zeta^3$
$\langle \zeta^{(1)3} \zeta^{(2)} \rangle \rightarrow g_{NL}$
Planck forecasts $|f_{NL}| \lesssim 10$, $|\tau_{NL}| \sim 10^3$, $g_{NL} \sim 10^4$
$\lambda \neq 0$ $\tau_{NL} = \frac{T_{\zeta_\chi}}{(P_{\zeta_\phi} + P_{\zeta_\chi})^3} = f_{NL}^2 (1+\lambda)$ enhance


ii) trispectrum 6 variables in 2D
2 terms
Planck forecasts
enhanced


ii) trispectrum 6 variables in 2D
2 terms
→ τNL
→ gNL
Planck forecasts
enhan

ii) trispectrum — 6 variables in 2D

2 terms $\langle \zeta^{(1)2} \zeta^{(1)2} \rangle \to \tau_{NL}$ $\quad T_\zeta \sim P_\zeta^3$

$\langle \zeta^{(1)3} \zeta^{(2)} \rangle \to g_{NL}$

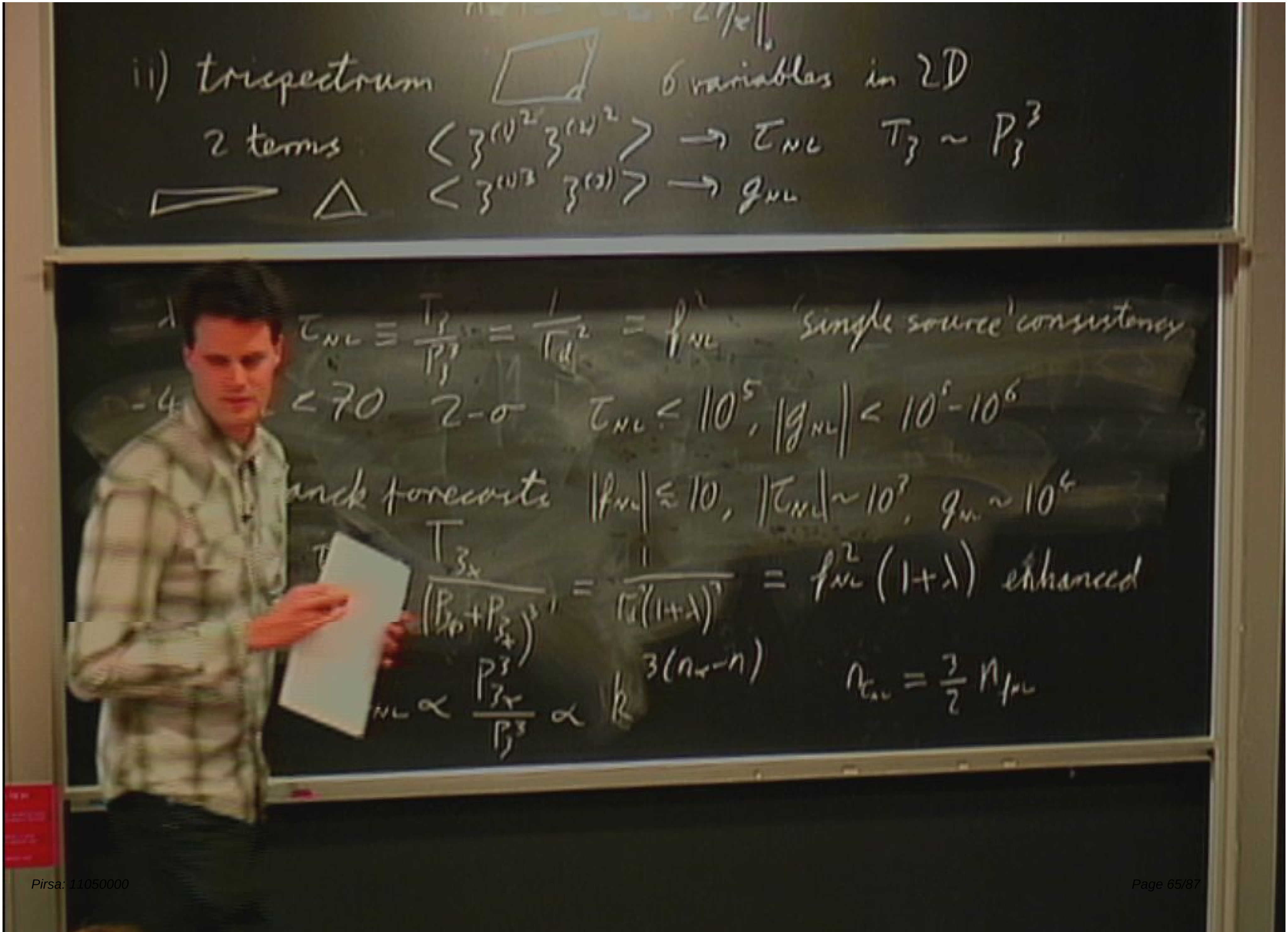
$\lambda = 0$ $\quad \tau_{NL} \equiv \frac{T_\zeta}{P_\zeta^3} = \frac{1}{r_d^2} = f_{NL}^2$ 'single source' consistency

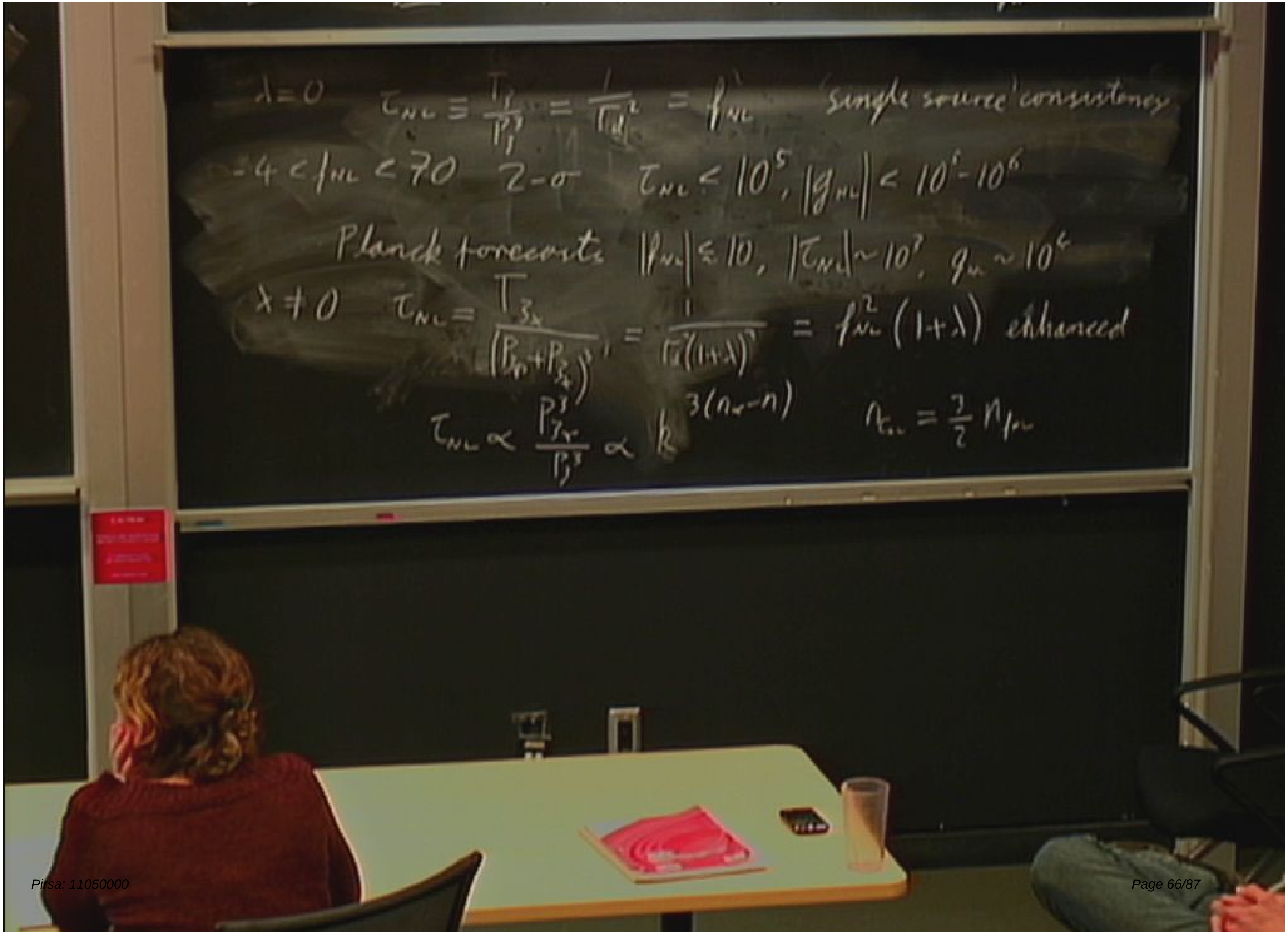
$-4 < f_{NL} < 70$ $\quad 2\text{-}\sigma$ $\quad \tau_{NL} < 10^5, \; |g_{NL}| < 10^5\text{-}10^6$

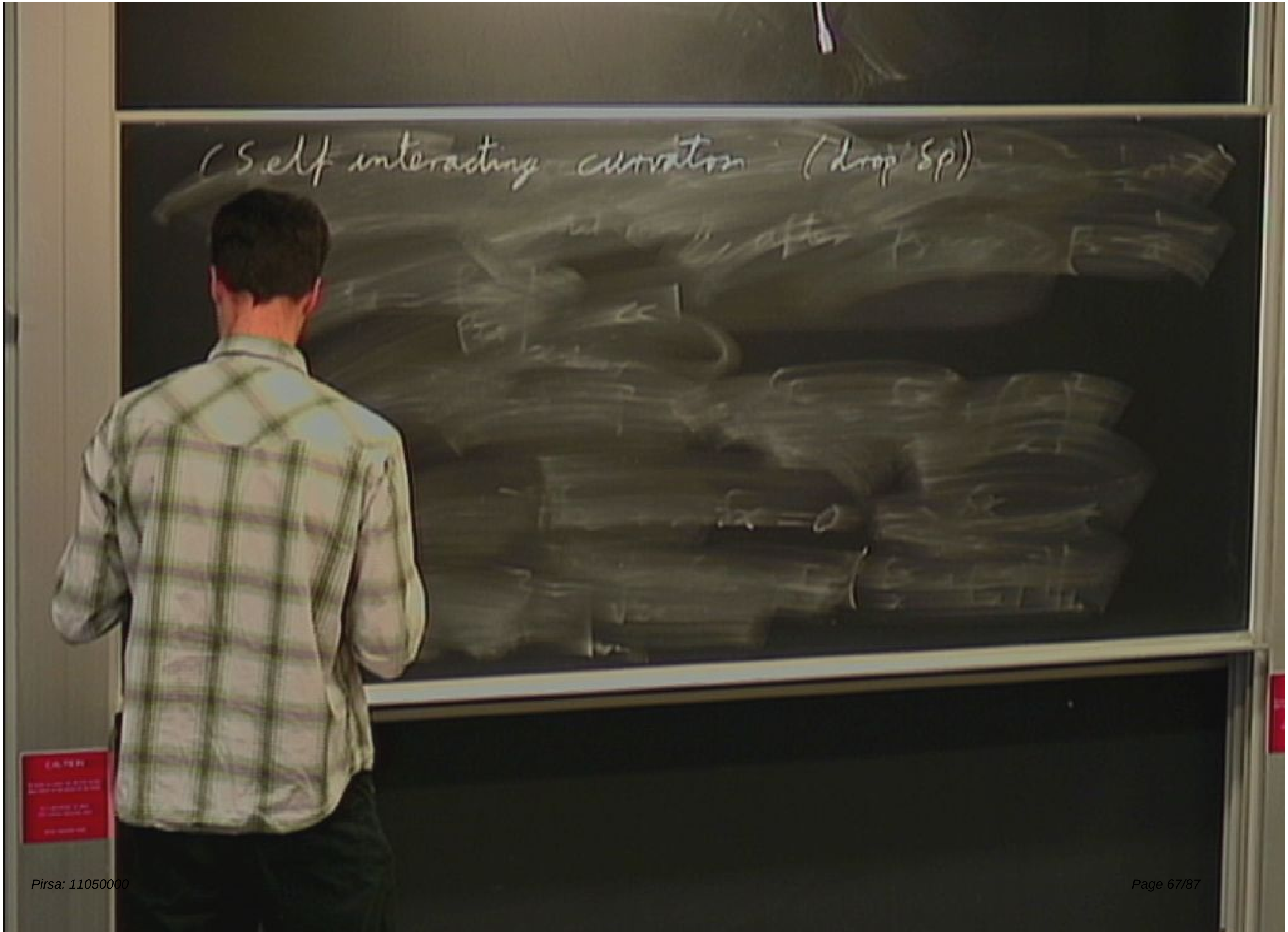
Planck forecasts $|f_{NL}| \lesssim 10, \; |\tau_{NL}| \sim 10^3, \; g_{NL} \sim 10^4$

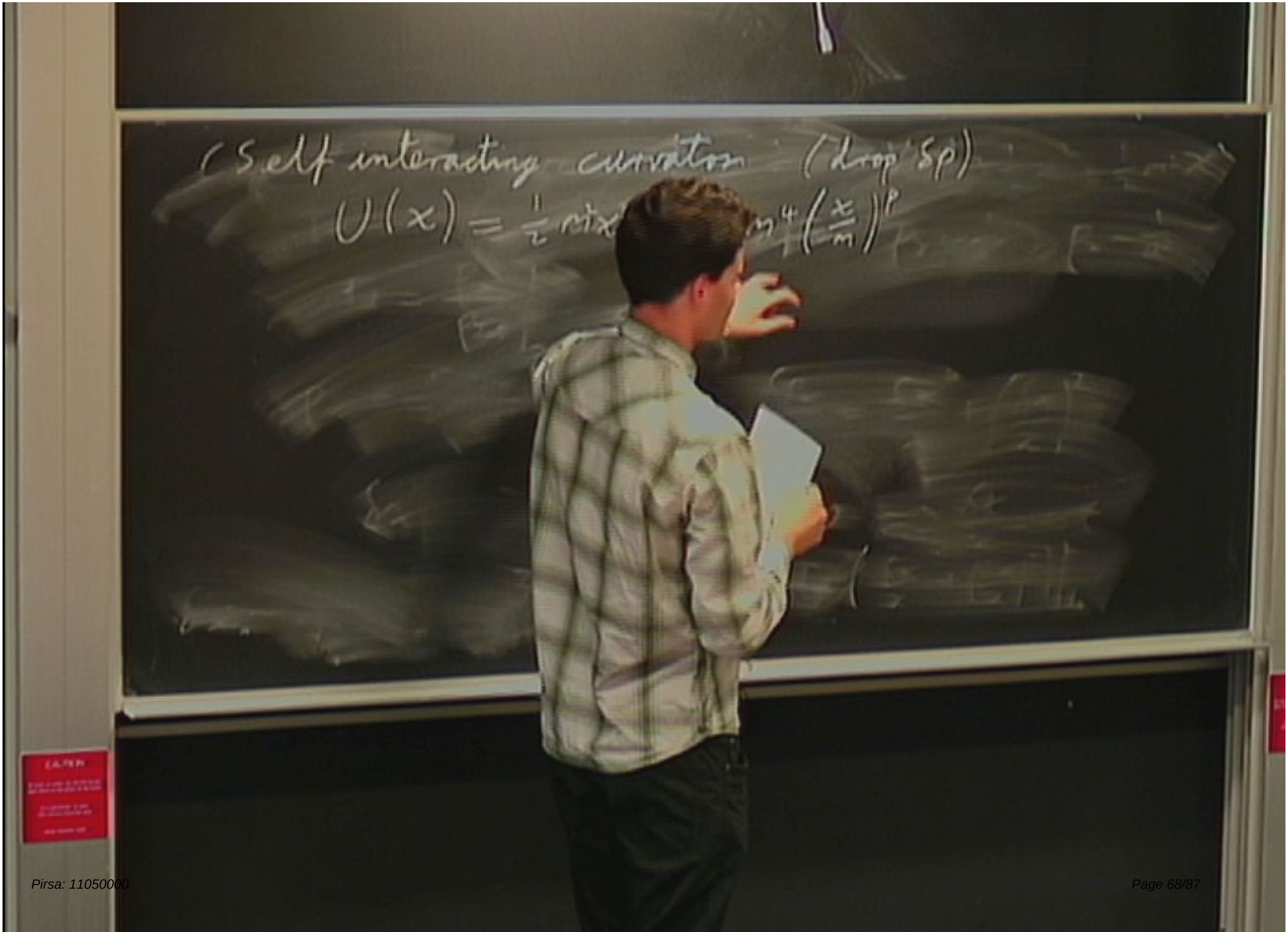
$\lambda \neq 0$ $\quad \tau_{NL} = \frac{T_{\zeta_\sigma}}{(P_{\zeta_\phi} + P_{\zeta_\sigma})^3} = \frac{1}{r_d^2 (1+\lambda)^3} = f_{NL}^2 (1+\lambda)$ enhanced

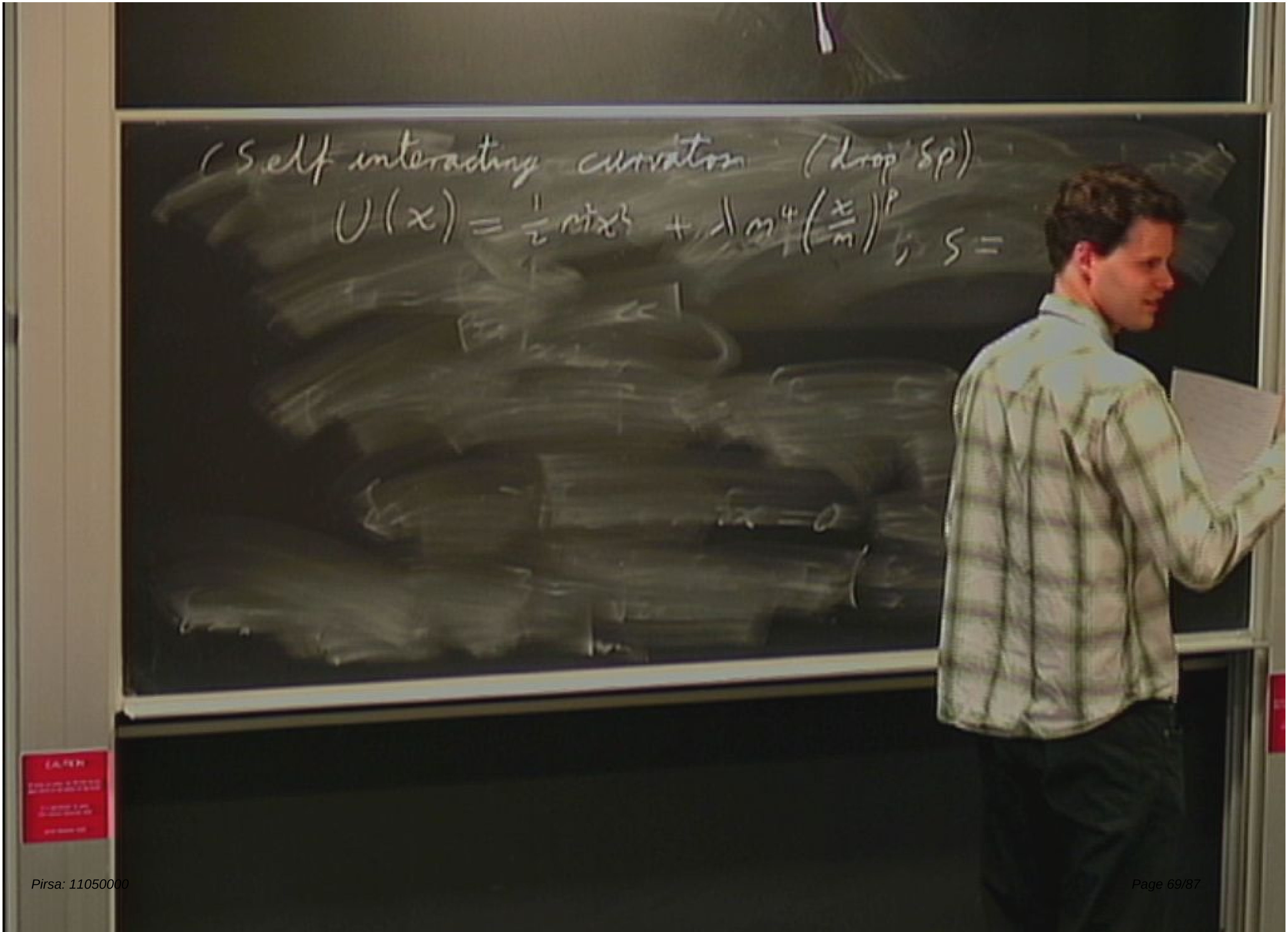
$\tau_{NL} \propto \frac{P_{\zeta_\sigma}^3}{P_\zeta^3} \propto k^{3(n_\sigma - n)}$ $\qquad n_{\tau_{NL}} = \frac{3}{2} n_{f_{NL}}$

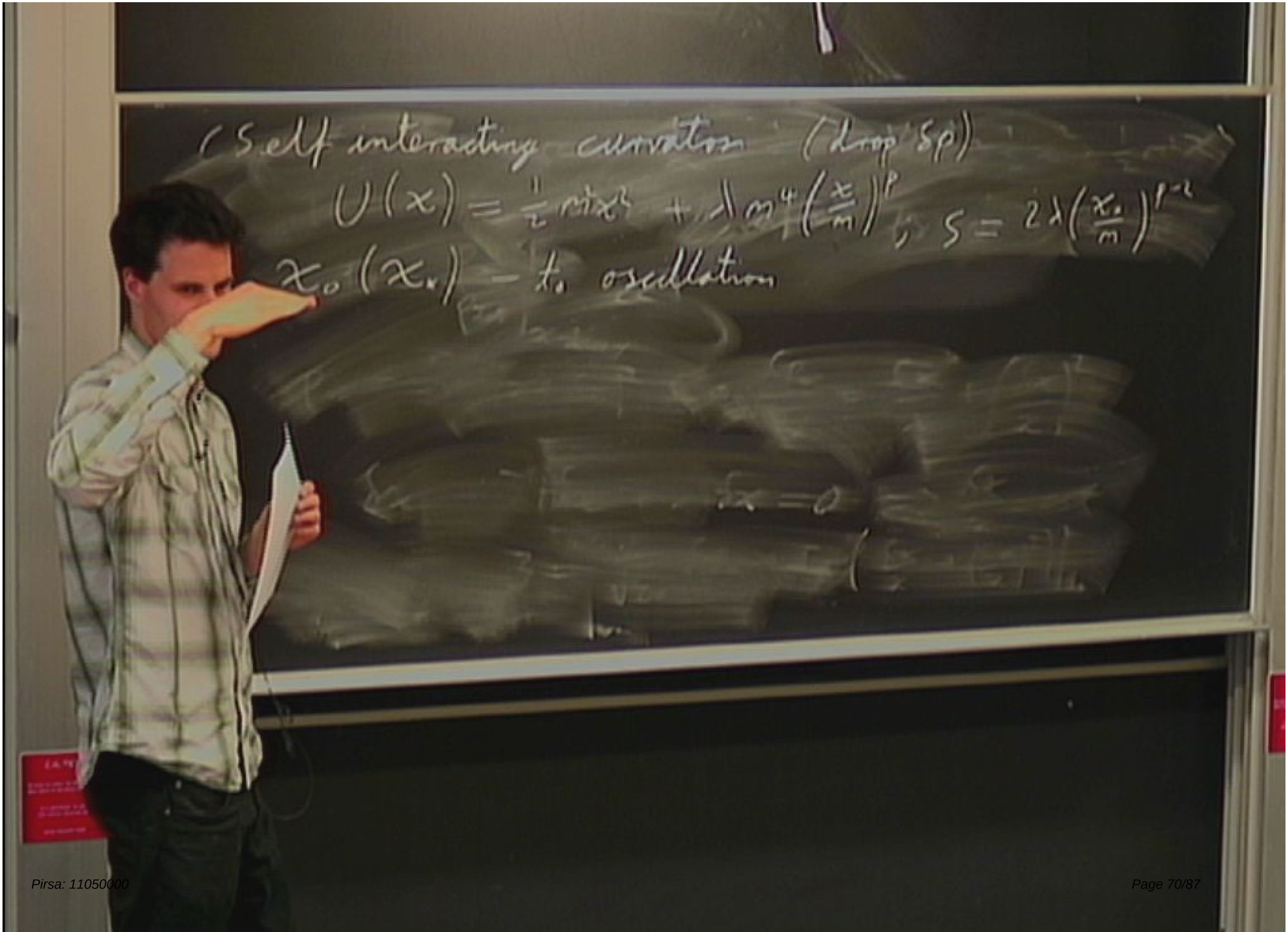

ii) trispectrum
6 variables in 2D
2 terms
< ζ(1)² ζ(2)² > → τNL   Tζ ~ Pζ³
< ζ(1)³ ζ(2) > → gNL
τNL ≡ Tζ / Pζ³ = 1 / r² = fNL
'single source' consistency
< 70   2-σ   τNL < 10⁵, |gNL| < 10⁵-10⁶
forecasts |fNL| ≤ 10, |τNL| ~ 10³, gNL ~ 10⁶
= fNL² (1+λ) enhanced
3(nσ-n)
nτNL = 3/2 nfNL

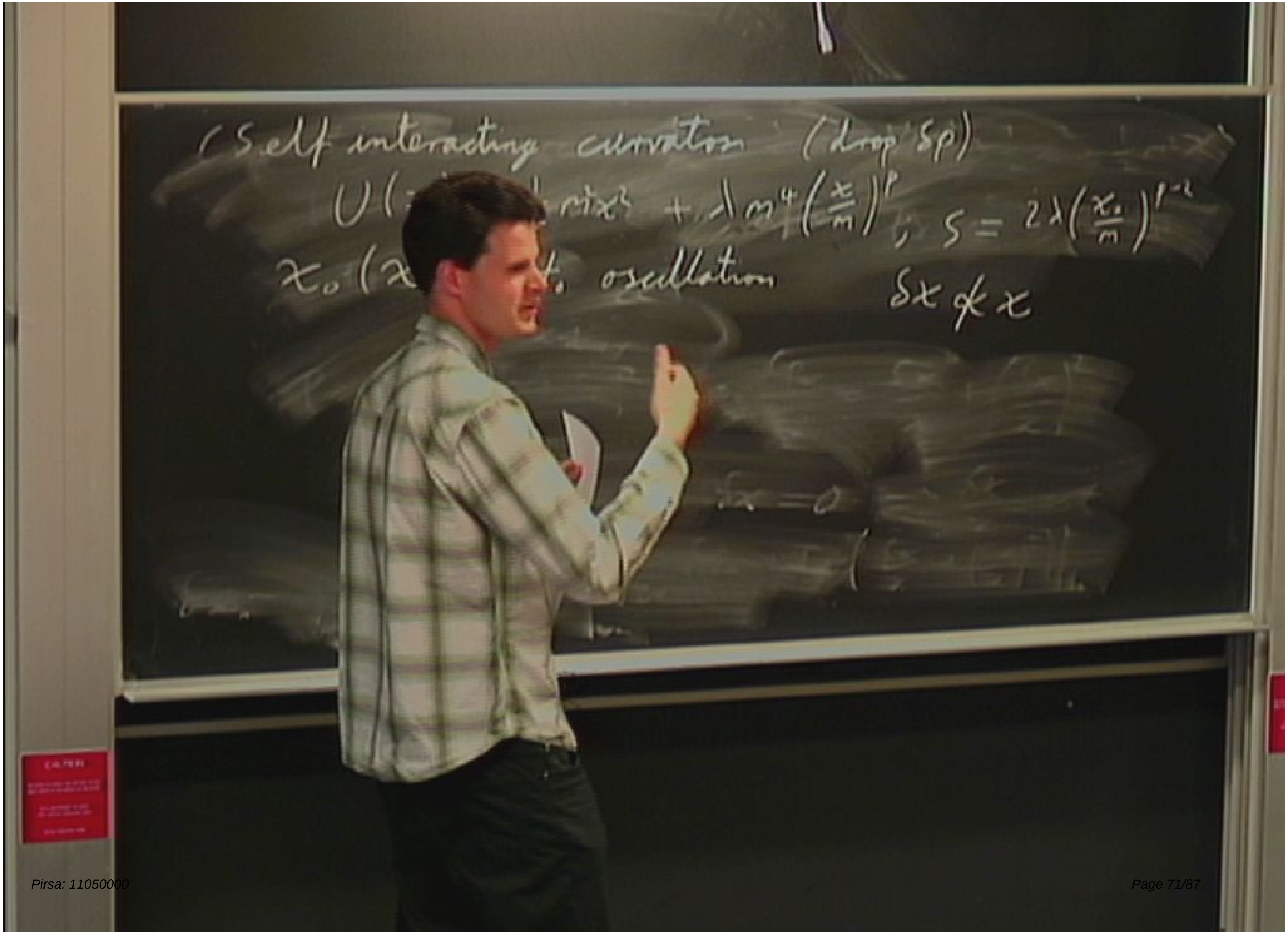

λ=0
single source' consistency
-4 < f_NL < 70 2-σ τ_NL < 10^5, |g_NL| < 10^5-10^6
Planck forecasts |f_NL| ≤ 10, |τ_NL| ~ 10^3, g_NL ~ 10^4
λ≠0
= f_NL^2 (1+λ) enhanced

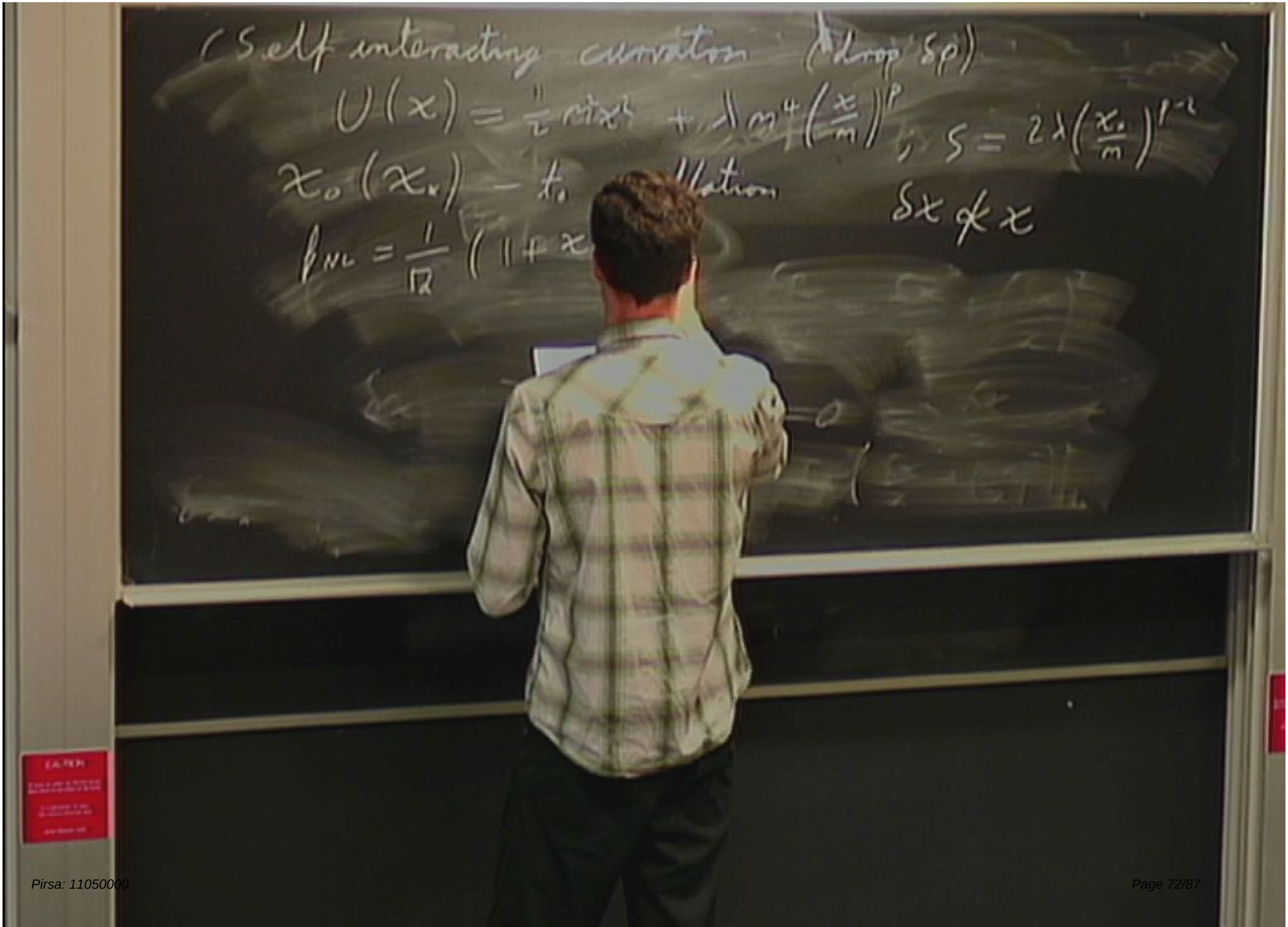

(Self interacting curvaton (drop Sp)

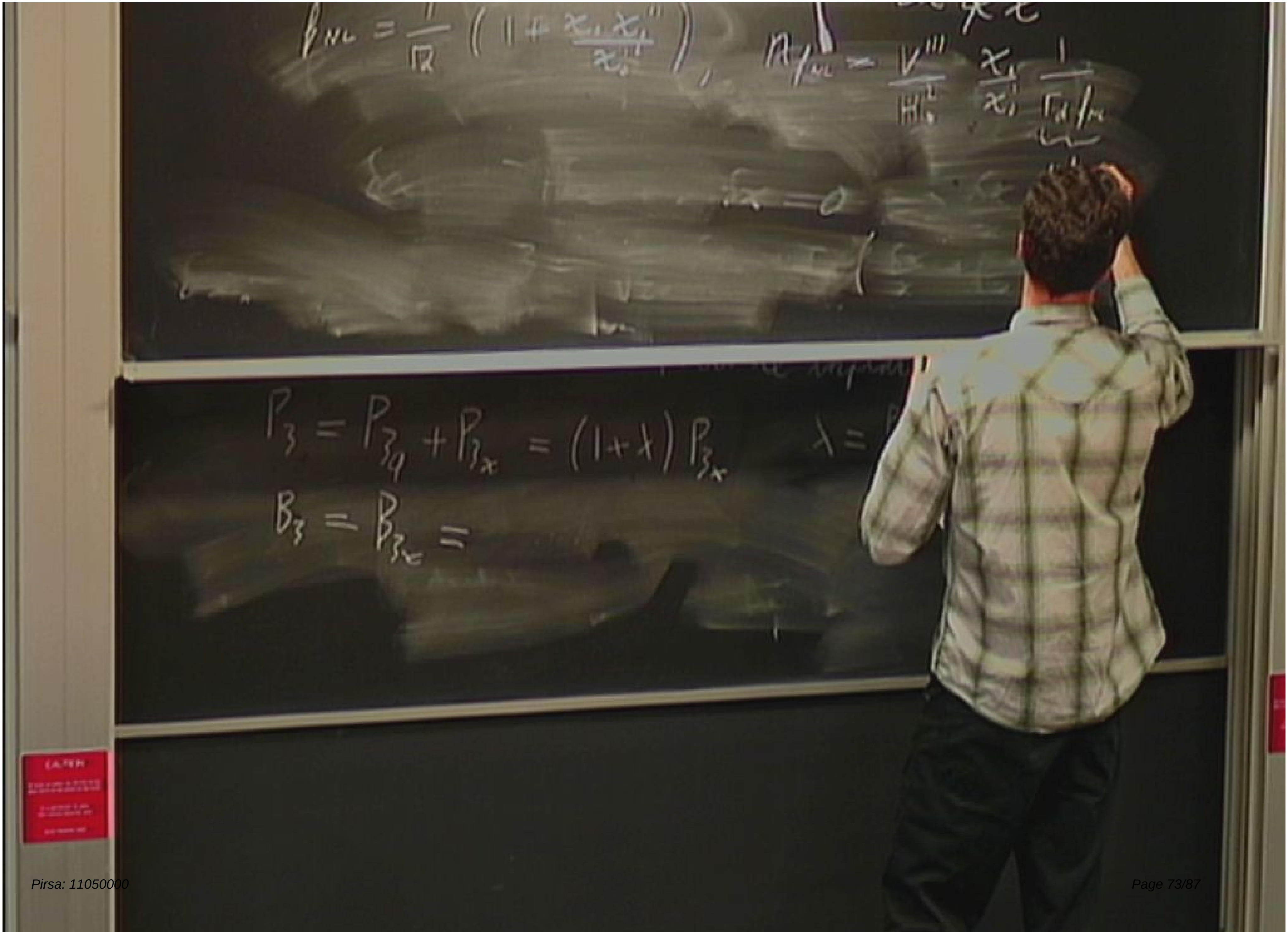

(Self interacting curvaton (drop 'sp)

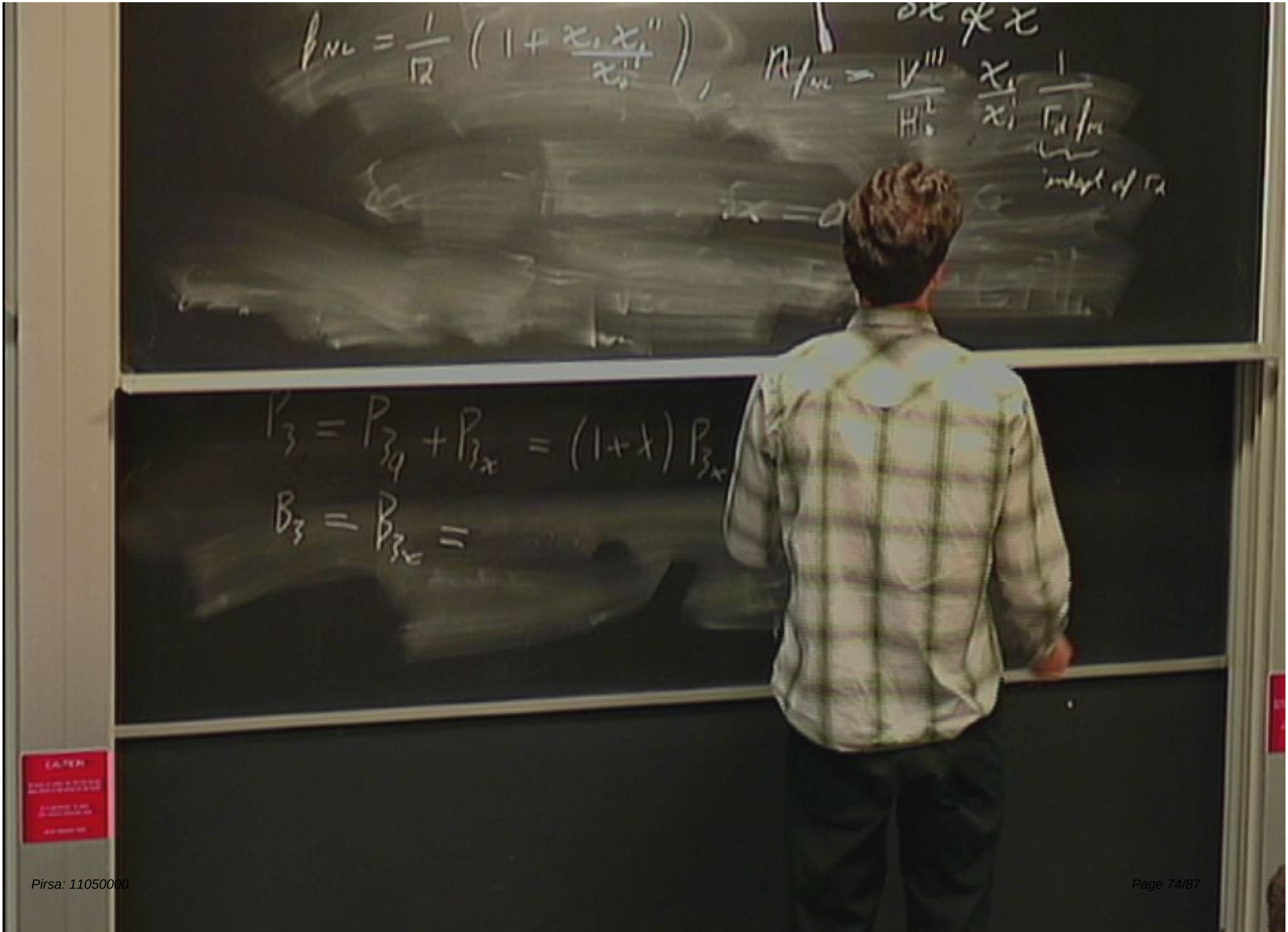

(Self interacting curvaton (drop δρ)
U(x) = ½ m²x² + λ m⁴ (x/m)^p ; s =

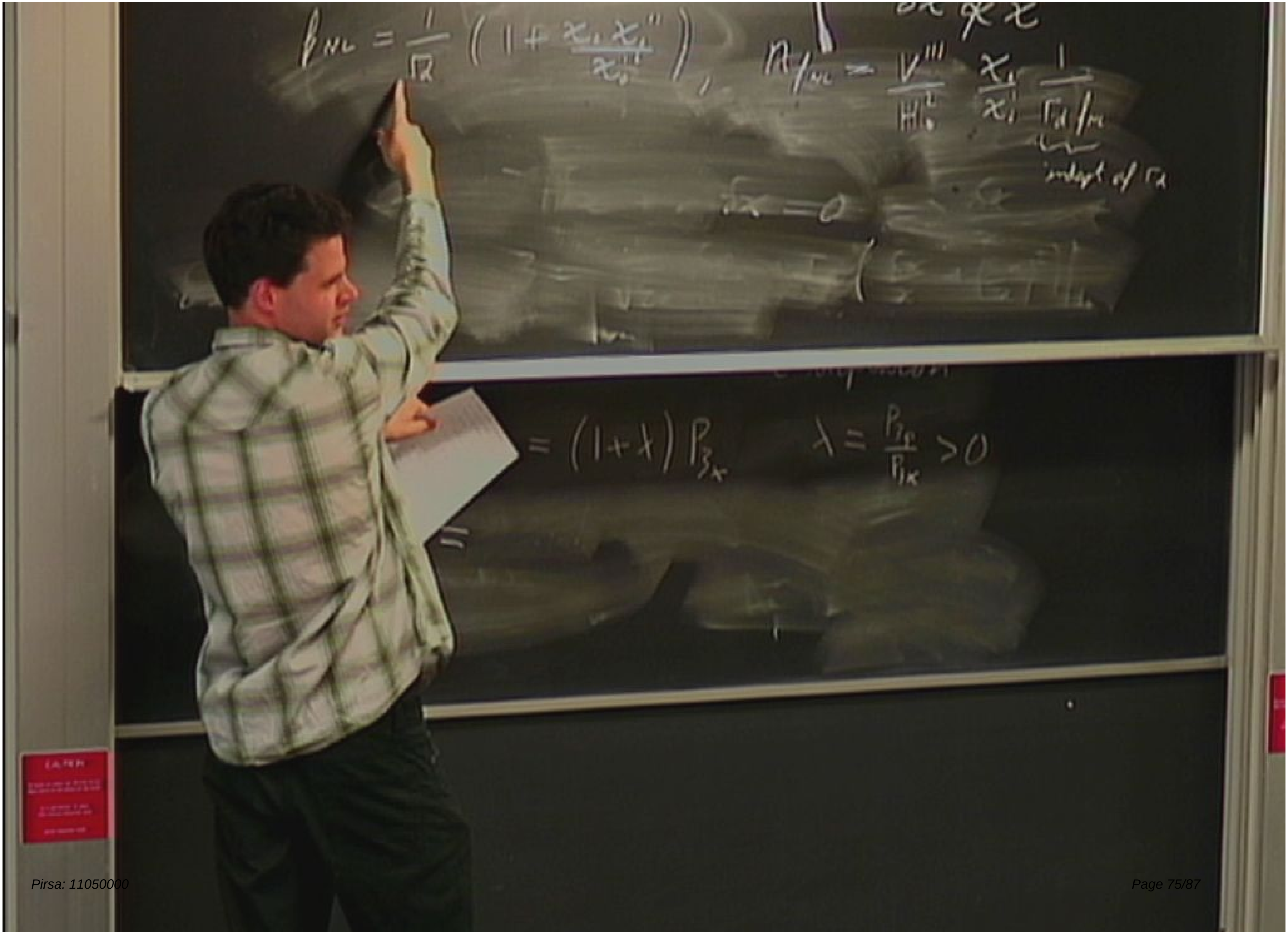

(Self interacting curvaton (drop Sρ)
U(x) = ½ m²x² + λm⁴(x/m)^p ; s = 2λ(x₀/m)^(p-2)
x₀(x*) — t₀ oscillation

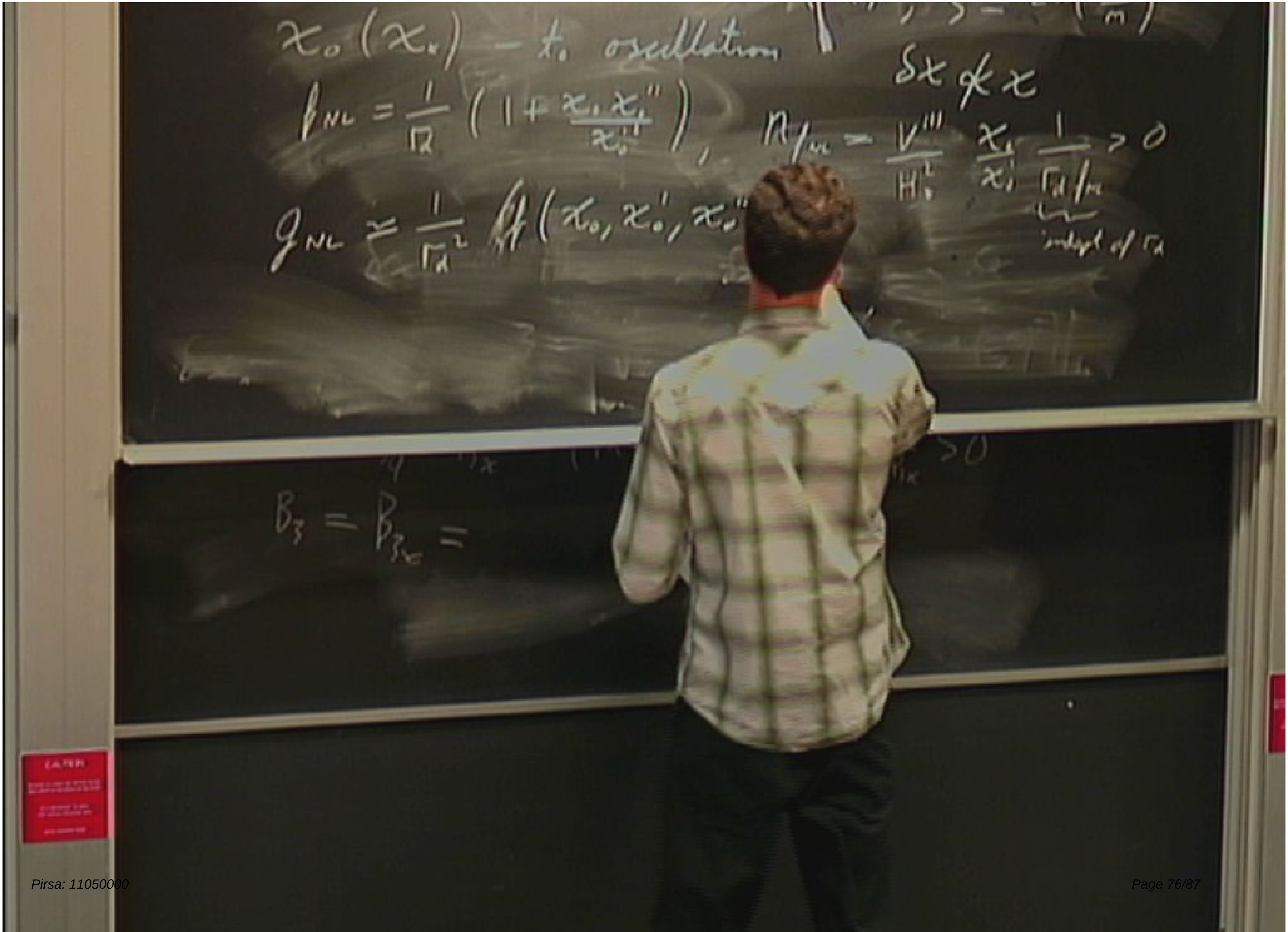

(Self interacting curvaton (drop δρ)
oscillation
δx ∝̸ x

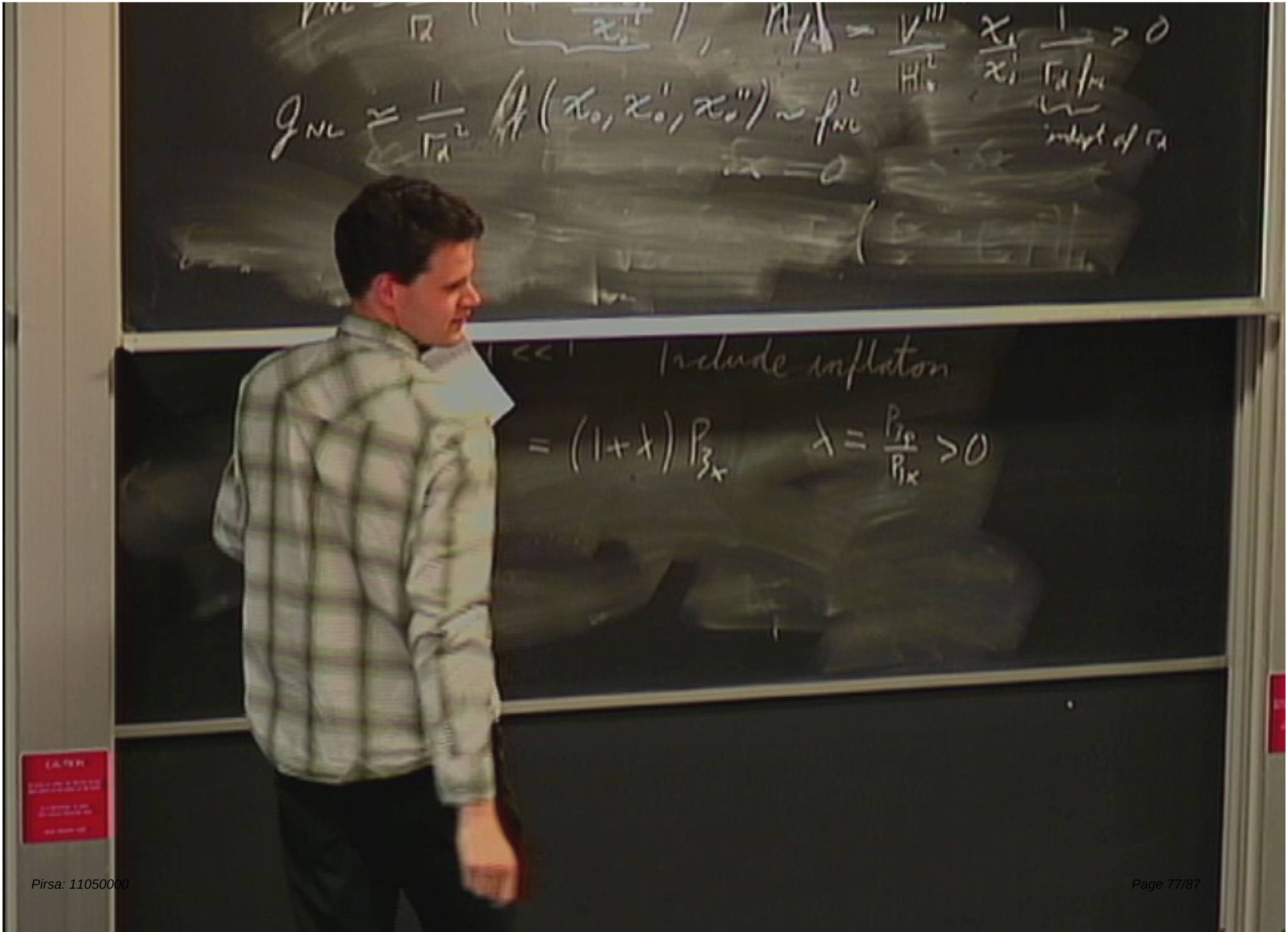

(Self interacting curvaton (drop δρ))
U(x) = ½ m²x² + λ m⁴ (x/m)^p
s = 2λ (x₀/m)^{p-2}
x₀(x*) − t₀
δx ∝̸ x

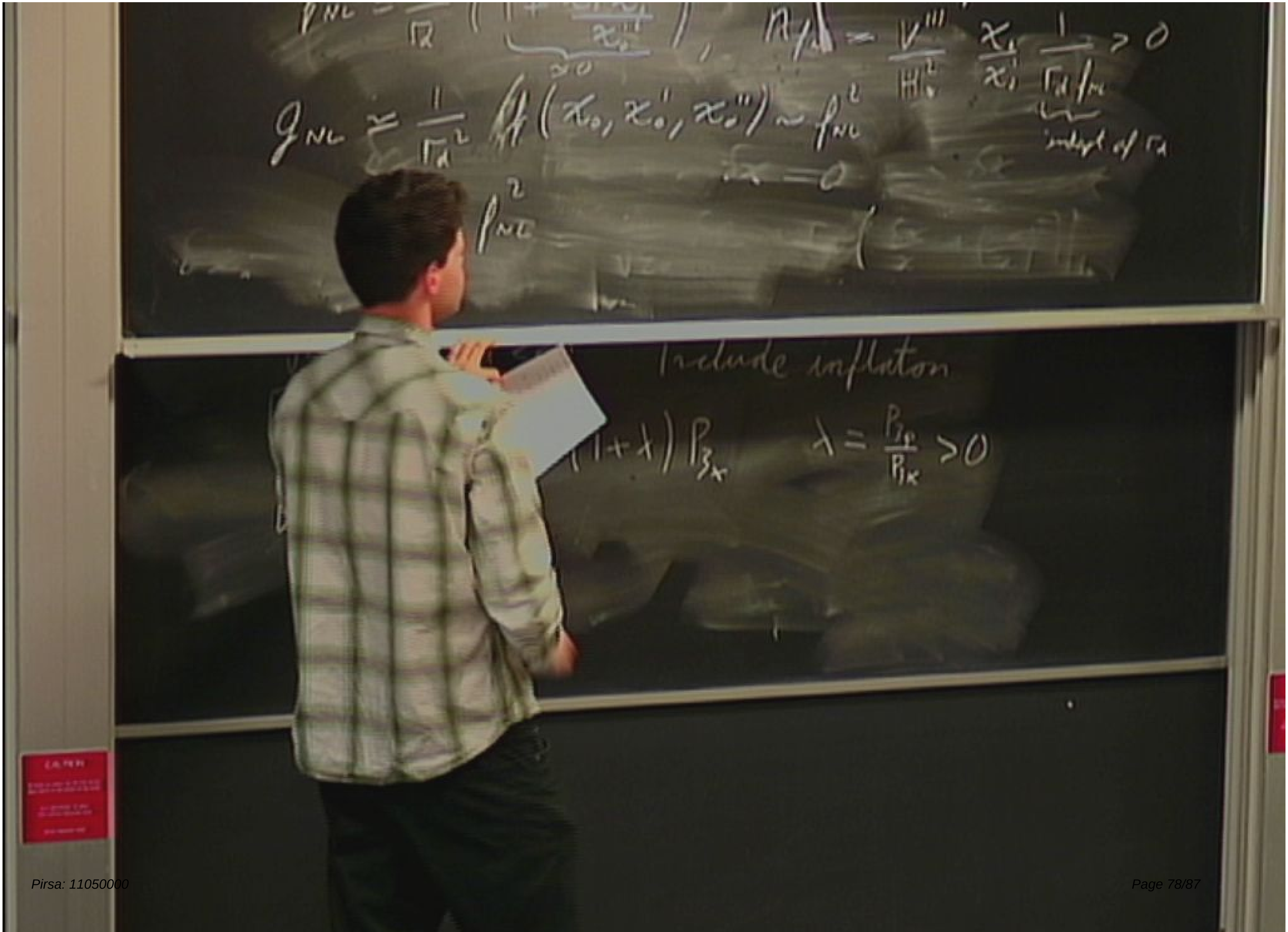

P3 = P3q + P3x = (1+λ) P3x
B3 = B3x =


$f_{NL} = \frac{1}{r_2}\left(1 + \frac{x_1 x_1''}{x_1'^2}\right)$, $n_{f_{NL}} = \frac{V'''}{H_*^2}\frac{x_1}{x_1'}\frac{1}{r_2 f_{NL}}$
indept of r_2
$P_\zeta = P_{\zeta_q} + P_{\zeta_x} = (1+\lambda)P_{\zeta_x}$
$B_\zeta = B_{\zeta_x} =$

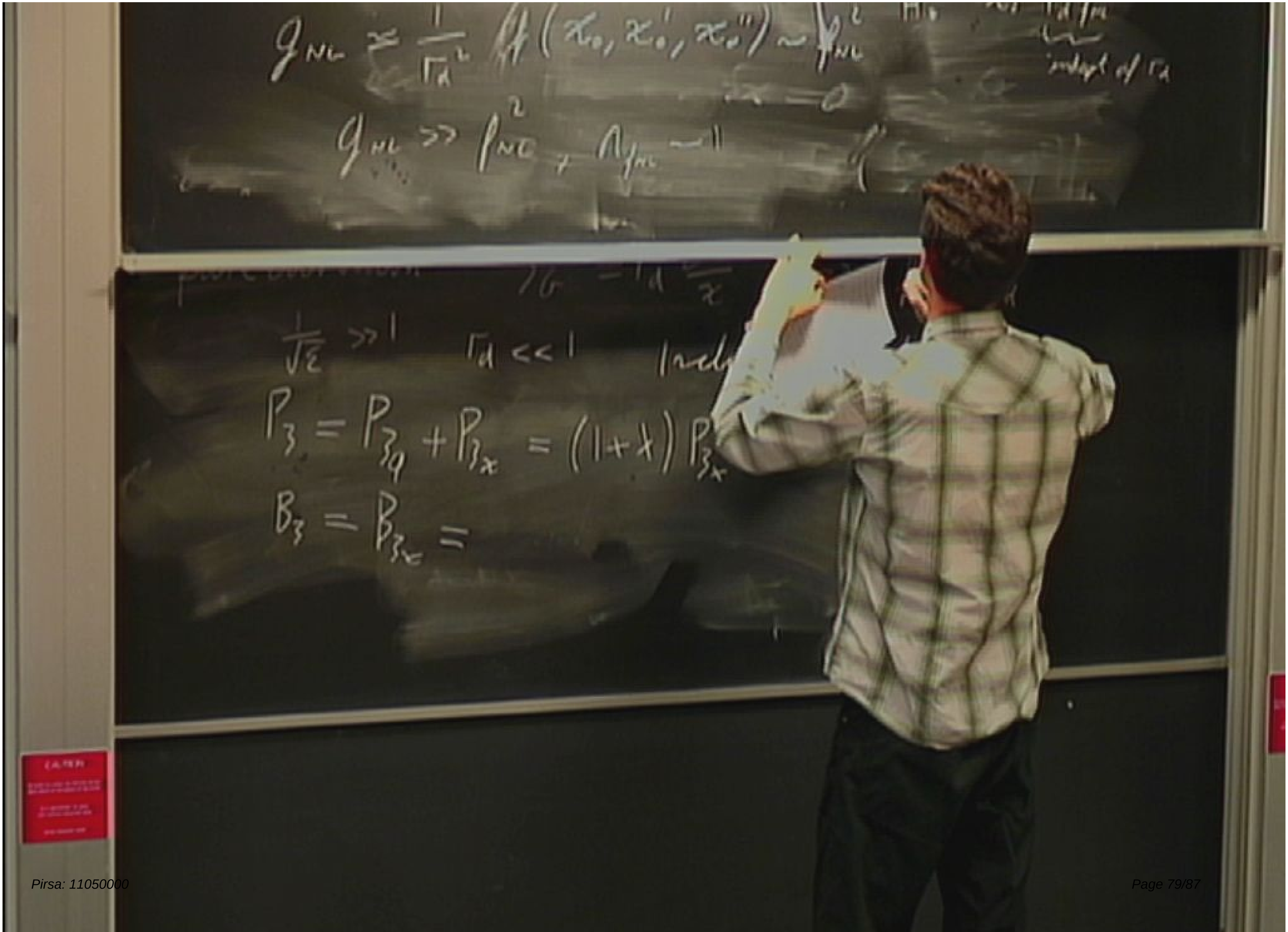


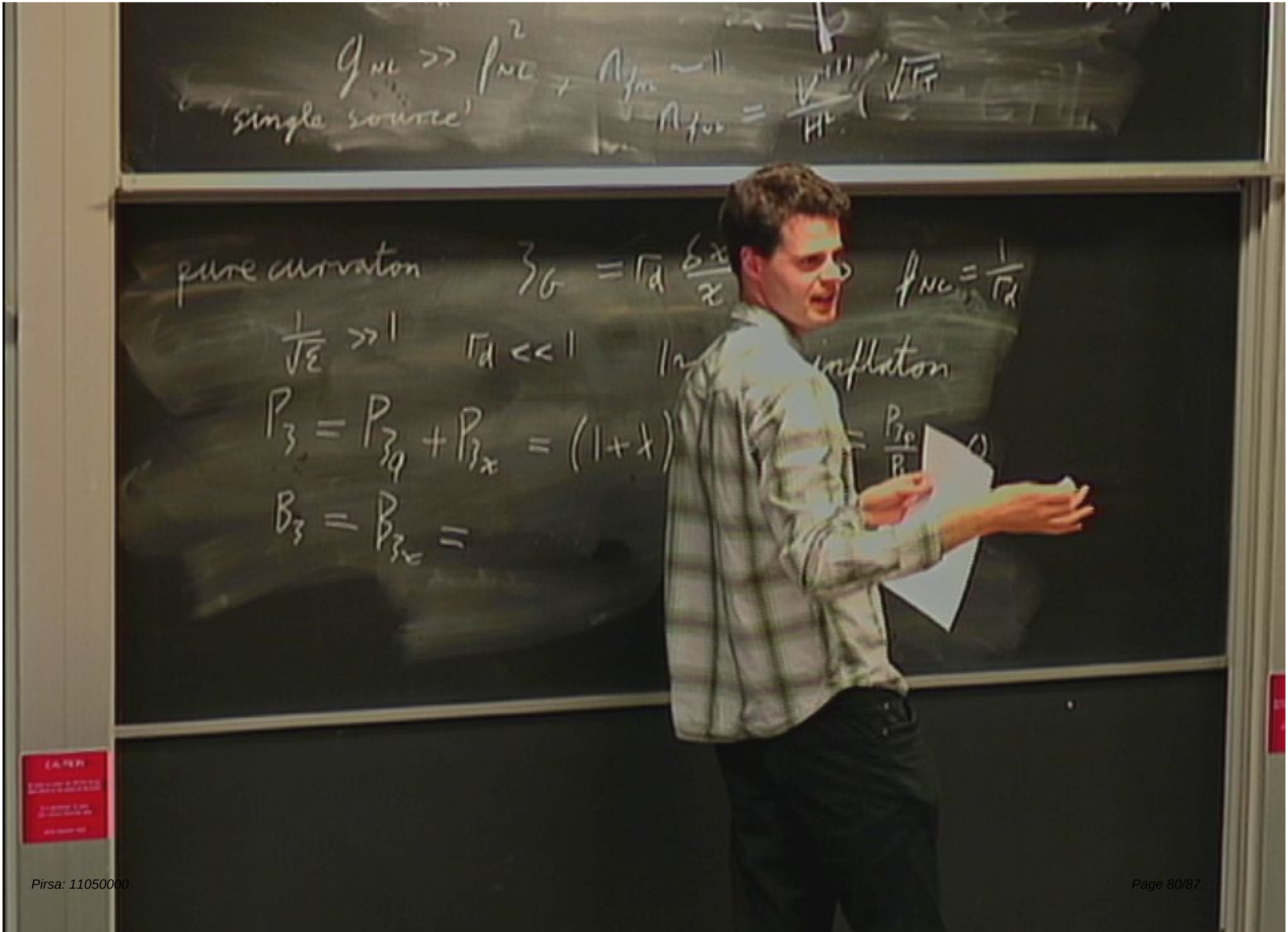

x₀ (x*) — to oscillation
δx ∝ x
fNL = 1/Γd (1 + x₀ x₁''/x₀'²) ,
gNL ≃ 1/Γd² f (x₀, x₀', x₀''
indept of Γd
Bζ = Bζx =

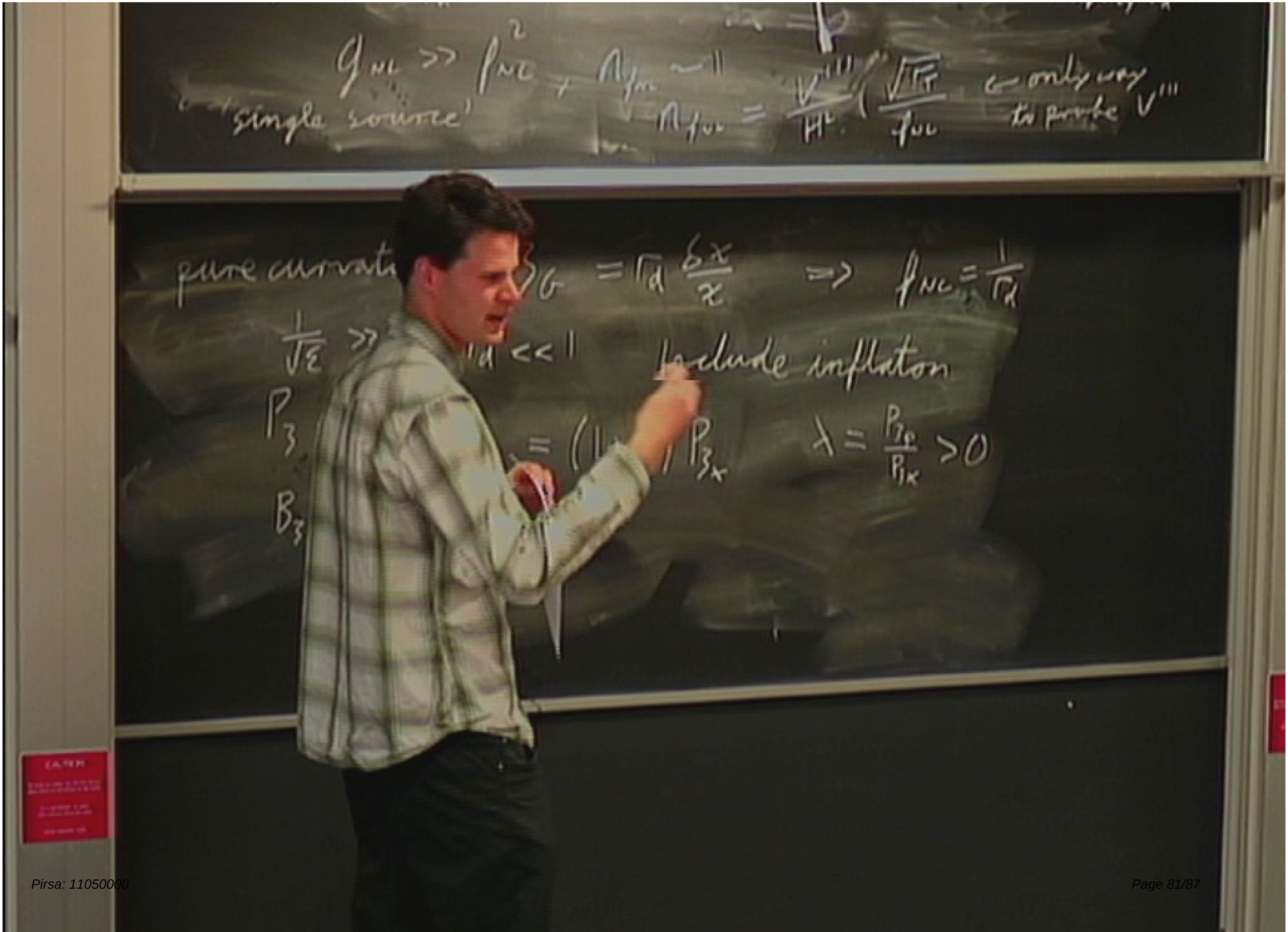

Include inflaton
= (1+λ) P_ζχ
λ = P_ζφ / P_ζχ > 0

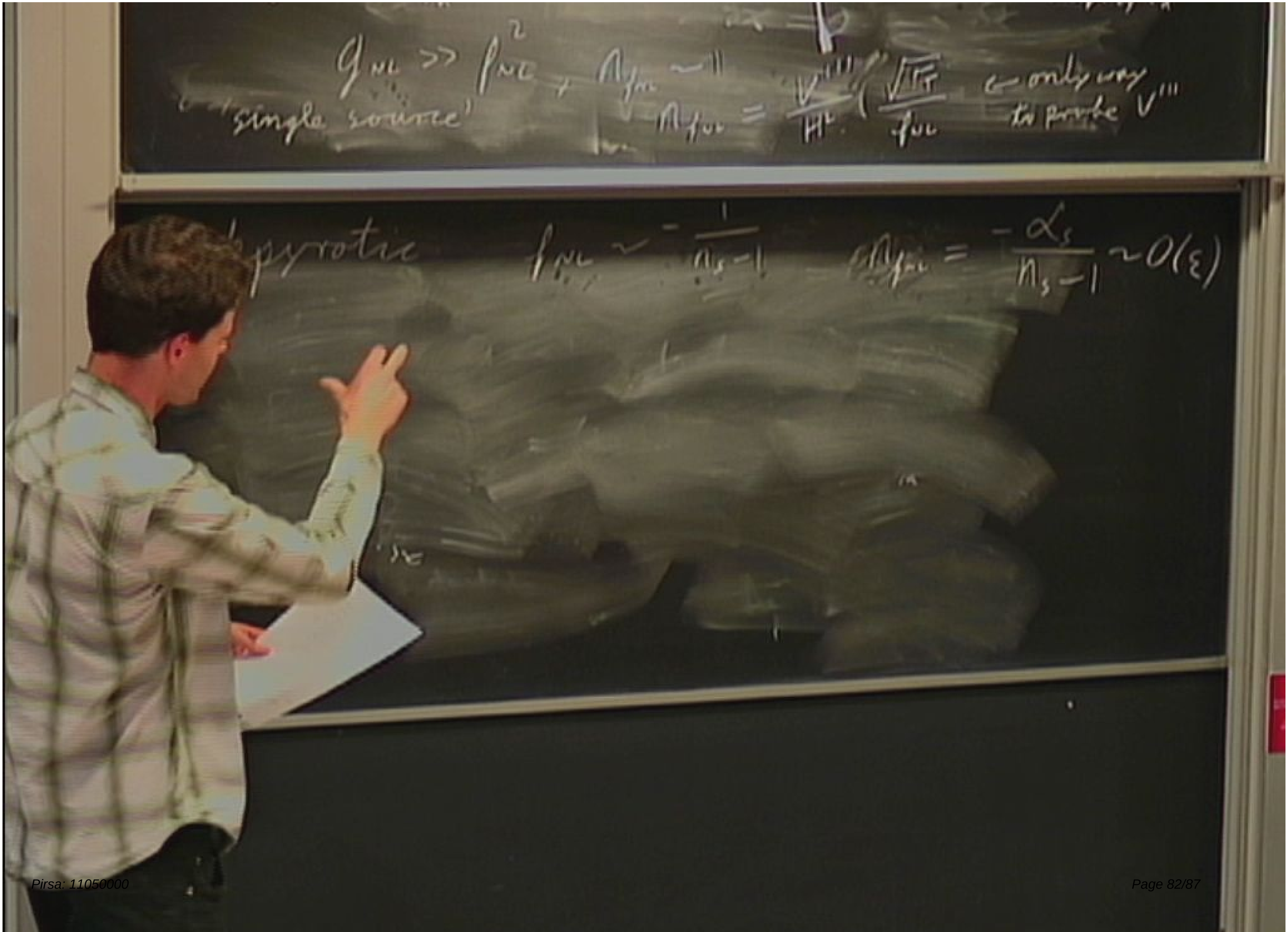


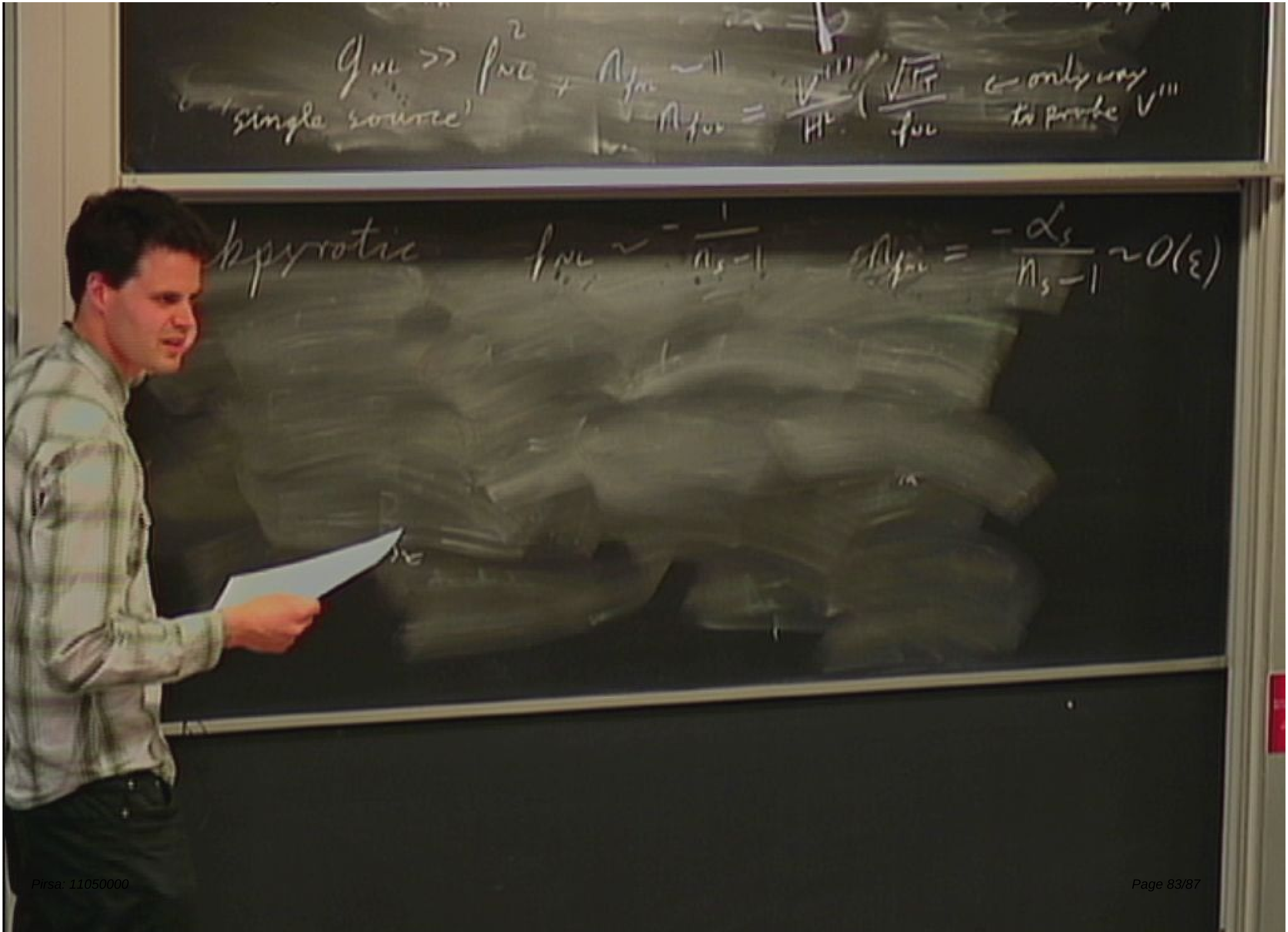
g_NL ≃ 1/r_d^2 A(x_0, x_0', x_0'') ~ f_NL^2
indep't of r_d
Include inflaton
(1+λ) P_ζχ
λ = P_ζφ / P_ζχ > 0

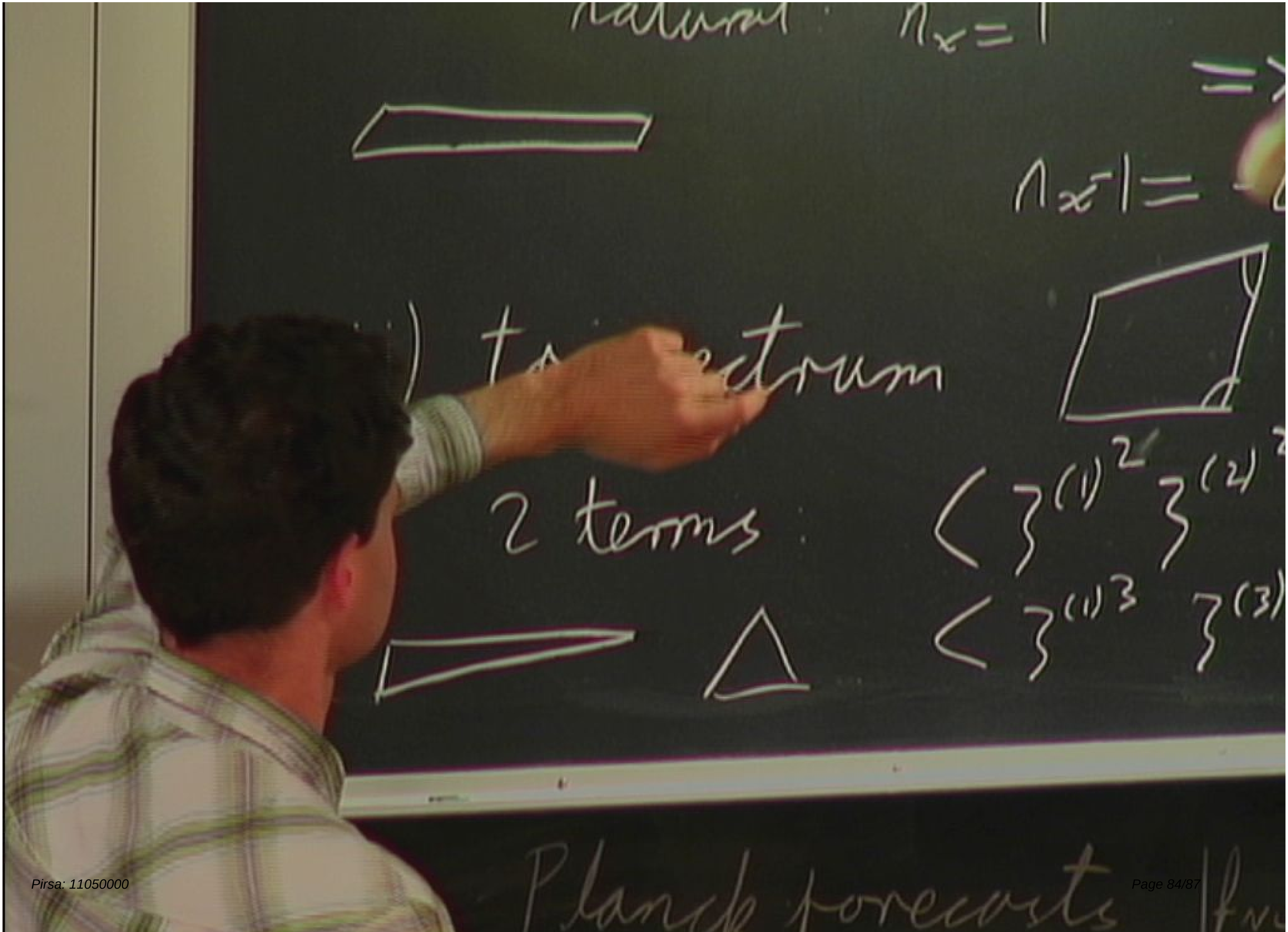

g_NL >> f_NL^2
P_3 = P_3q + P_3x = (1+x) P_3x
B_3 = B_3x =
CAUTION

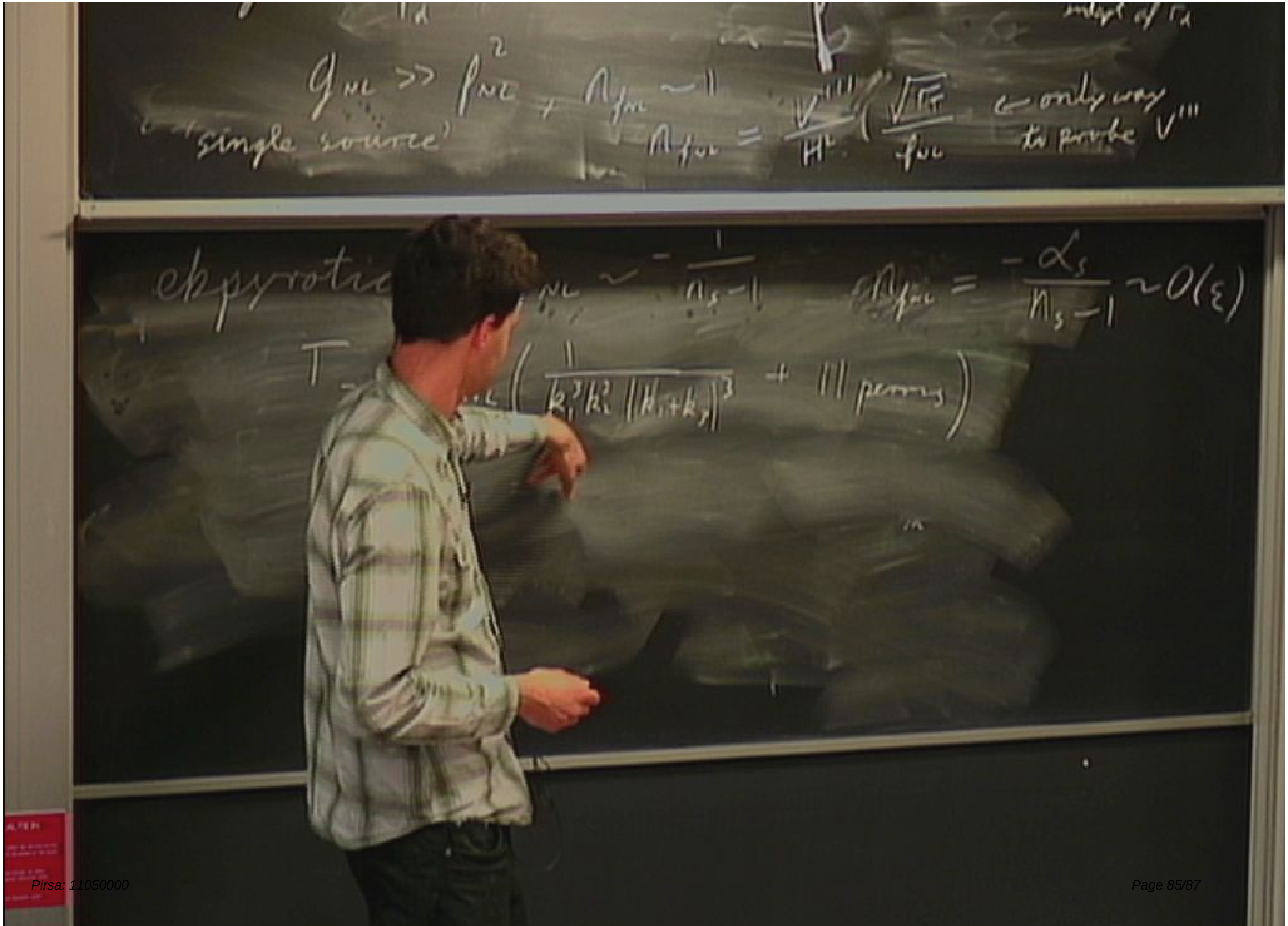

'single source'
pure curvaton
inflaton

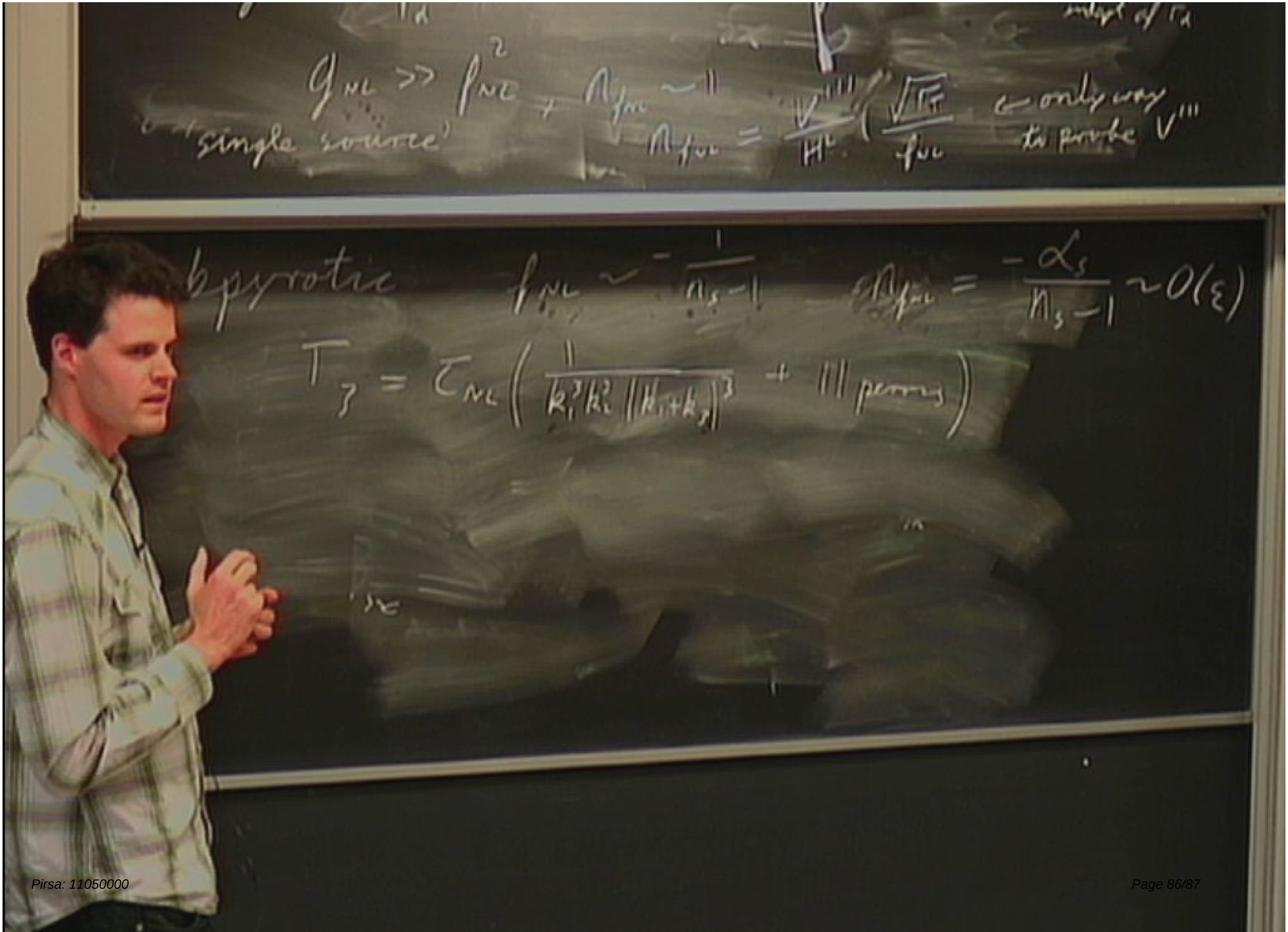

'single source'
← only way to probe V'''
pure curvat
include inflaton


g_NL >> f_NL^2 + n_fNL ~ 1
'single source'
n_fNL = V'''/H^2 (√ε / f_NL)
← only way to probe V'''
pyrotic
f_NL ~ - 1/(n_s - 1)
n_fNL = - α_s/(n_s - 1) ~ O(ε)

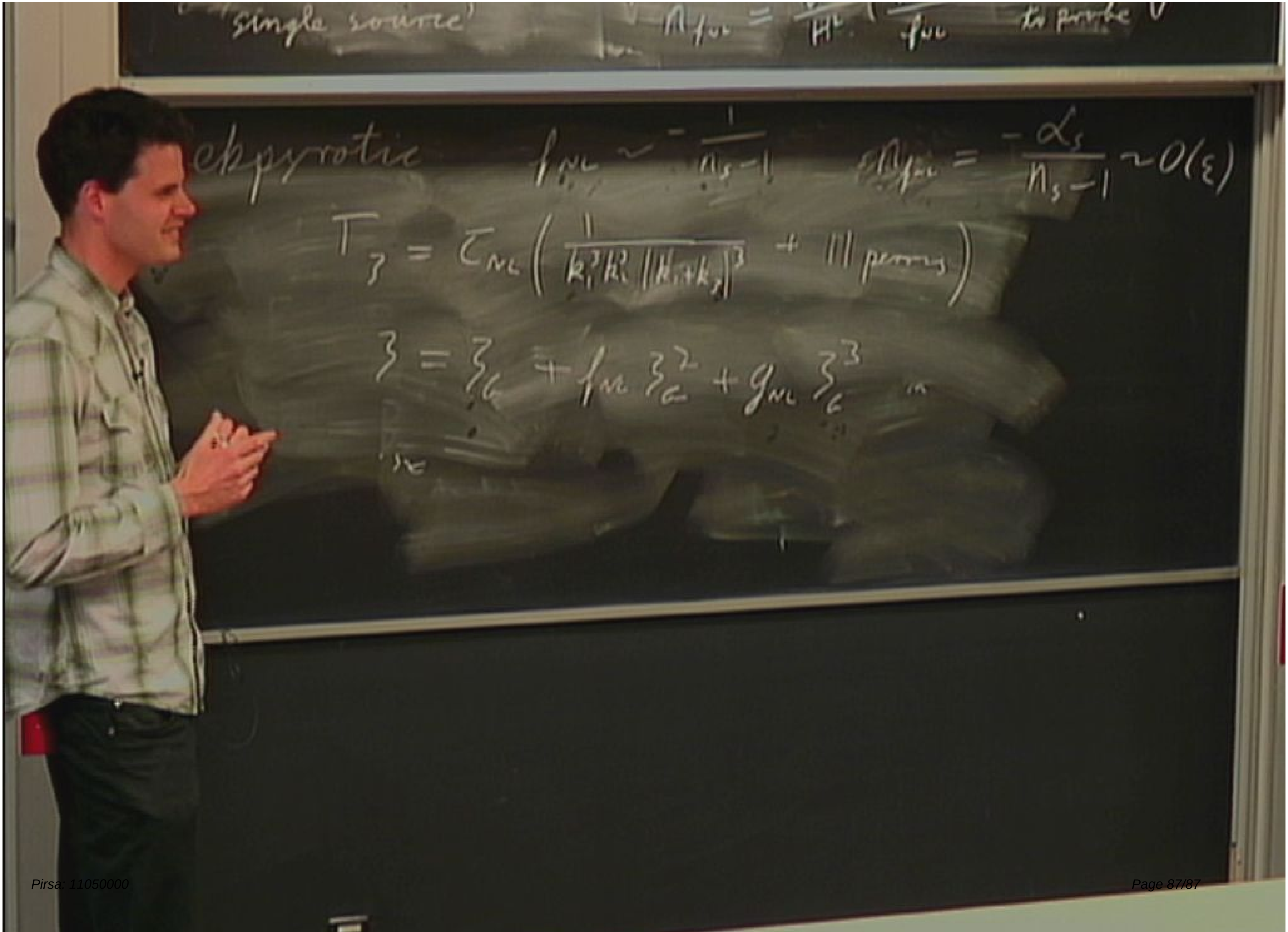

single source
only way to probe V'''
ekpyrotic


2 terms
Planck forecasts


'single source'
← only way
to probe V'''
ekpyrotic
+ 11 perms



g_NL >> f_NL^2 , n_fNL ~ 1
n_fNL = V'''/H^2 (√P_ζ / f_NL)
← only way to probe V'''
'single source'
ekpyrotic f_NL ~ - 1/(n_s - 1)
n_fNL = - α_s/(n_s - 1) ~ O(ε)
T_3 = τ_NL (1/(k_1^3 k_2^3 |k_1+k_3|^3) + 11 perms)


single source
ekpyrotic f_NL ~ 1/(n_s − 1)   n_fNL = −α_s/(n_s − 1) ~ O(ε)
T_3 = τ_NL (1/(k_1^3 k_2^3 |k_1+k_2|^3) + 11 perms)
ζ = ζ_G + f_NL ζ_G^2 + g_NL ζ_G^3