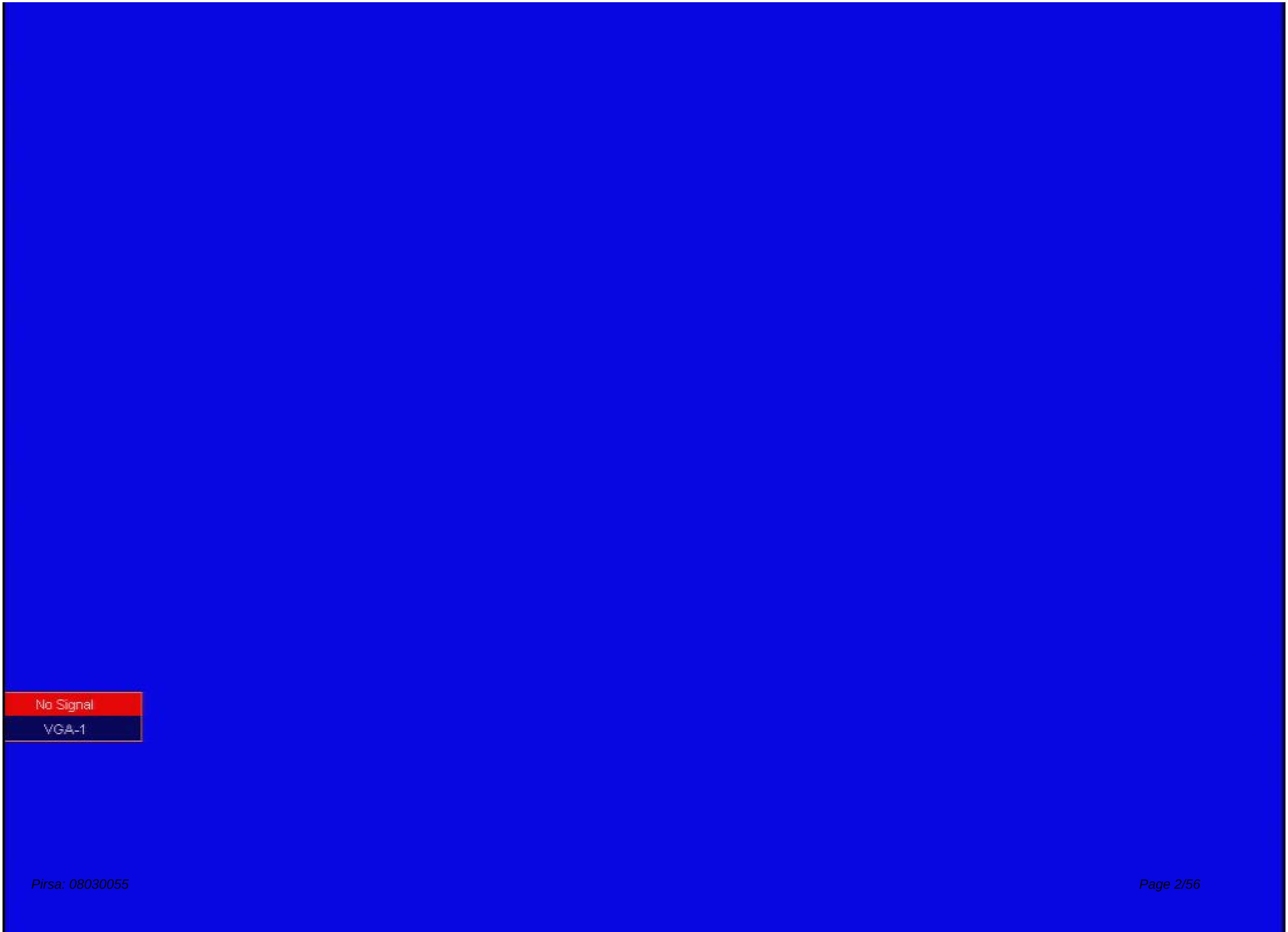
Title: Secondary Anistropy Contributions to the Bispectrum

Date: Mar 08, 2008 05:45 PM

URL: http://pirsa.org/08030055

Abstract:

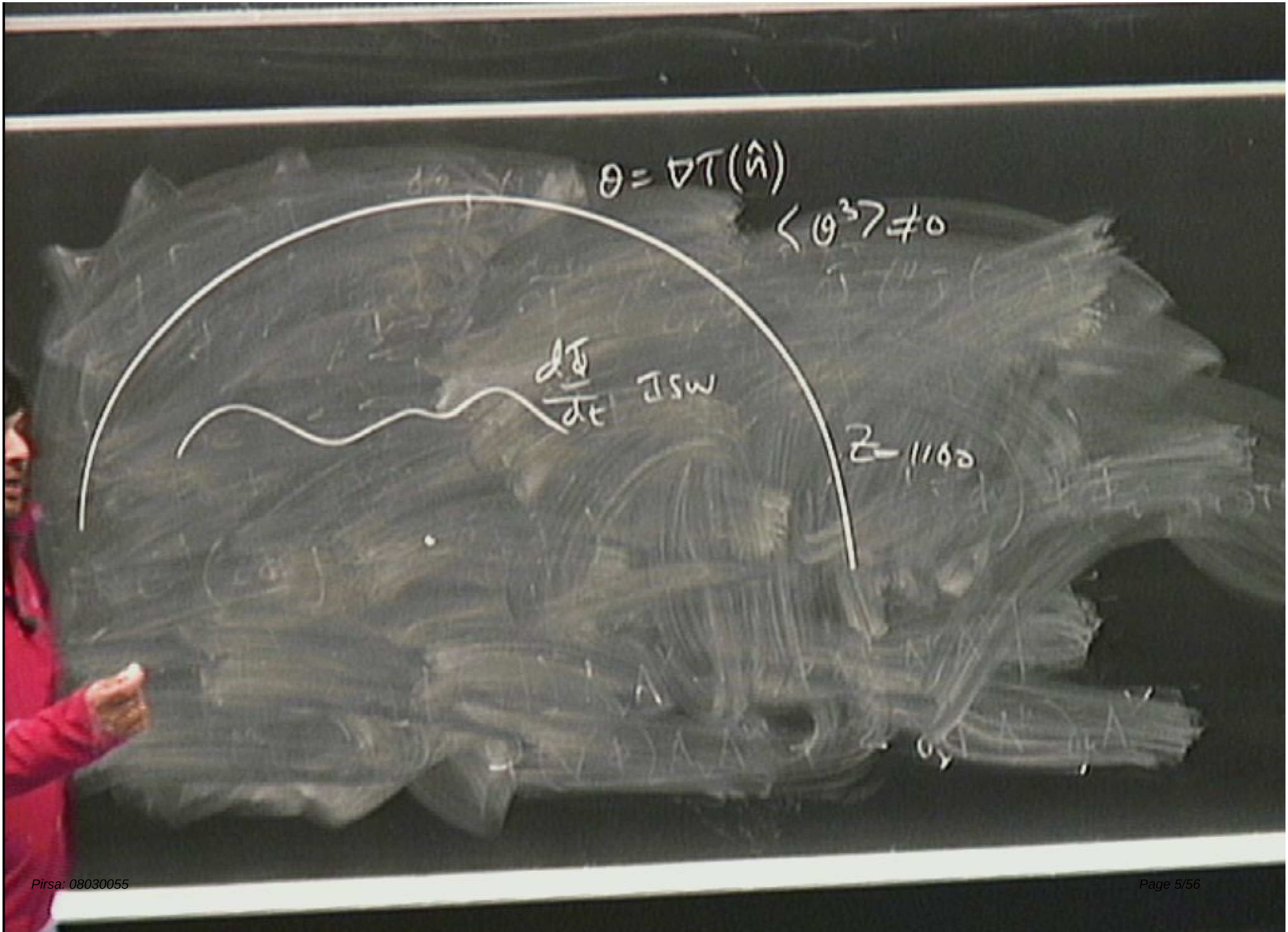

No Signal
VGA-1

No Signal

VGA-1

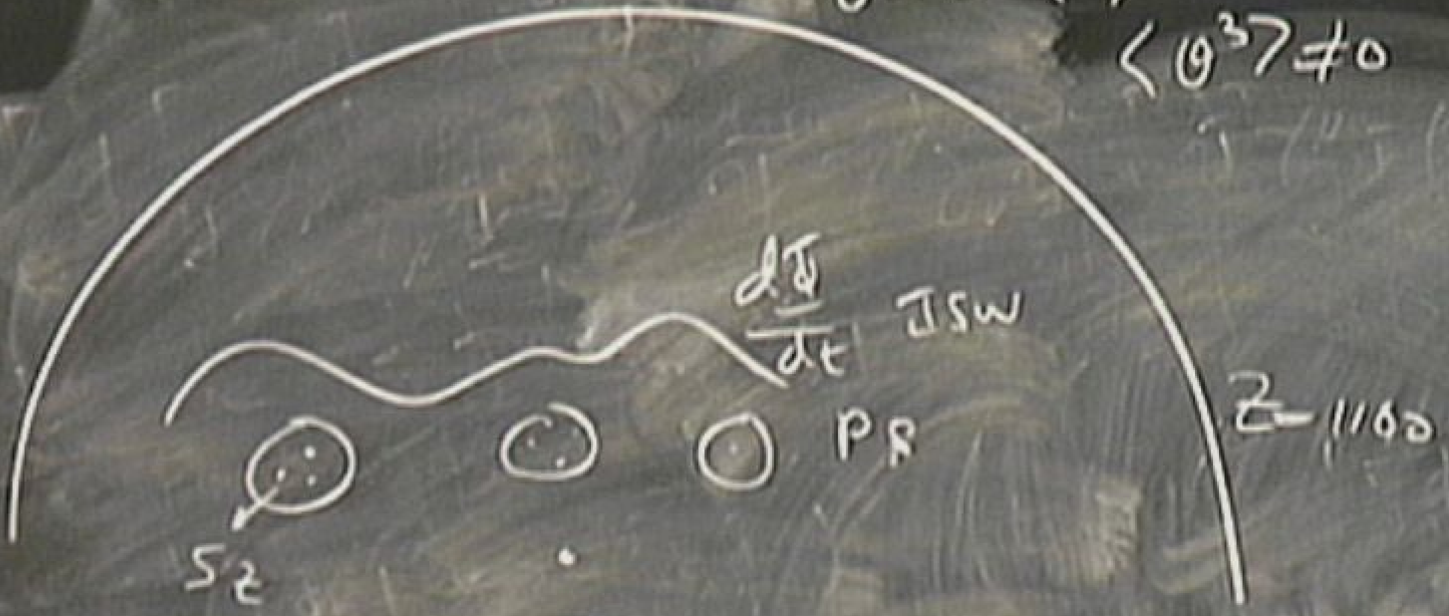
No Signal

VGA-1


$\theta = \nabla T(\hat{n})$
$\langle \theta^3 \rangle \neq 0$
$\frac{d\Phi}{dt}$
ISW
$z \sim 1100$

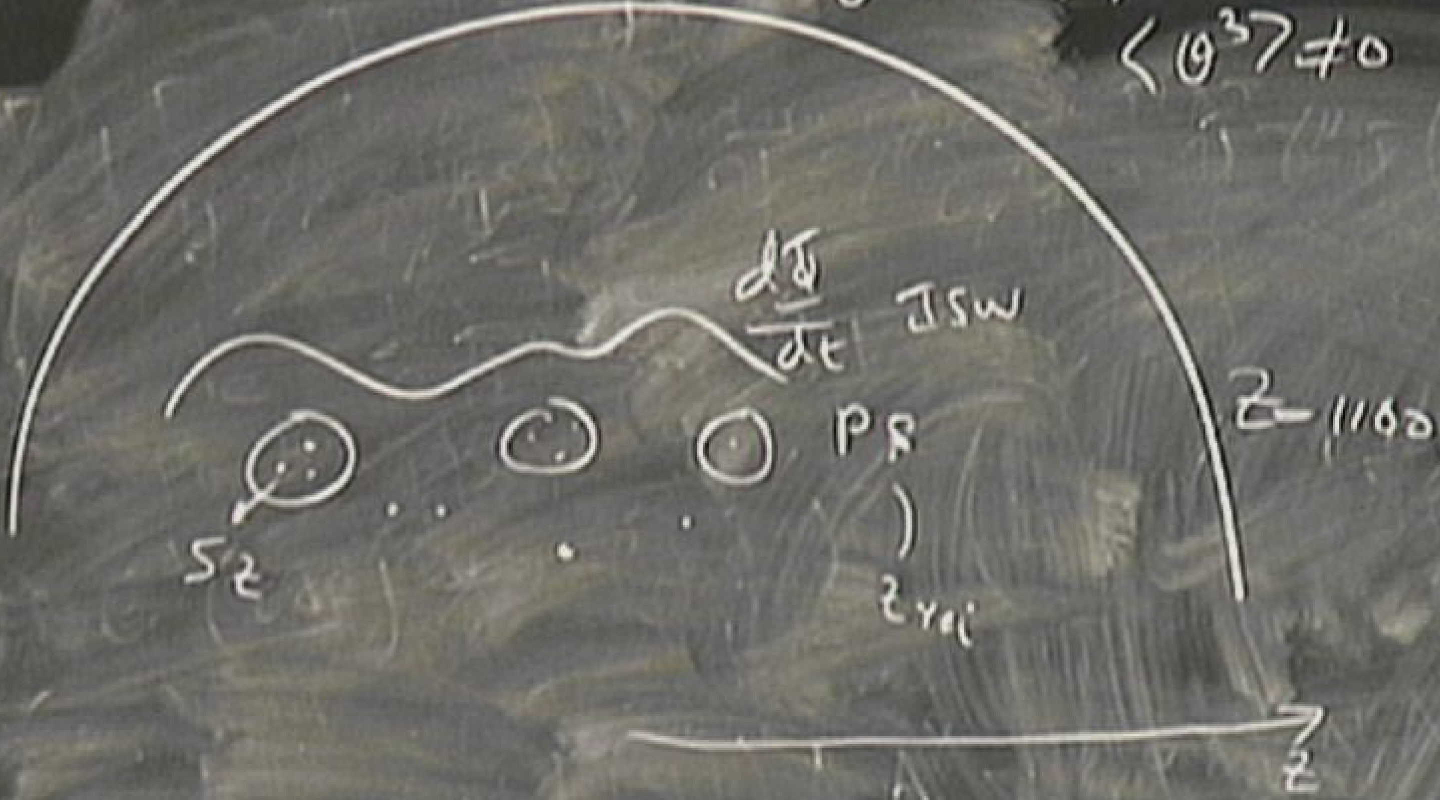
$\theta = \nabla T(\hat{n})$

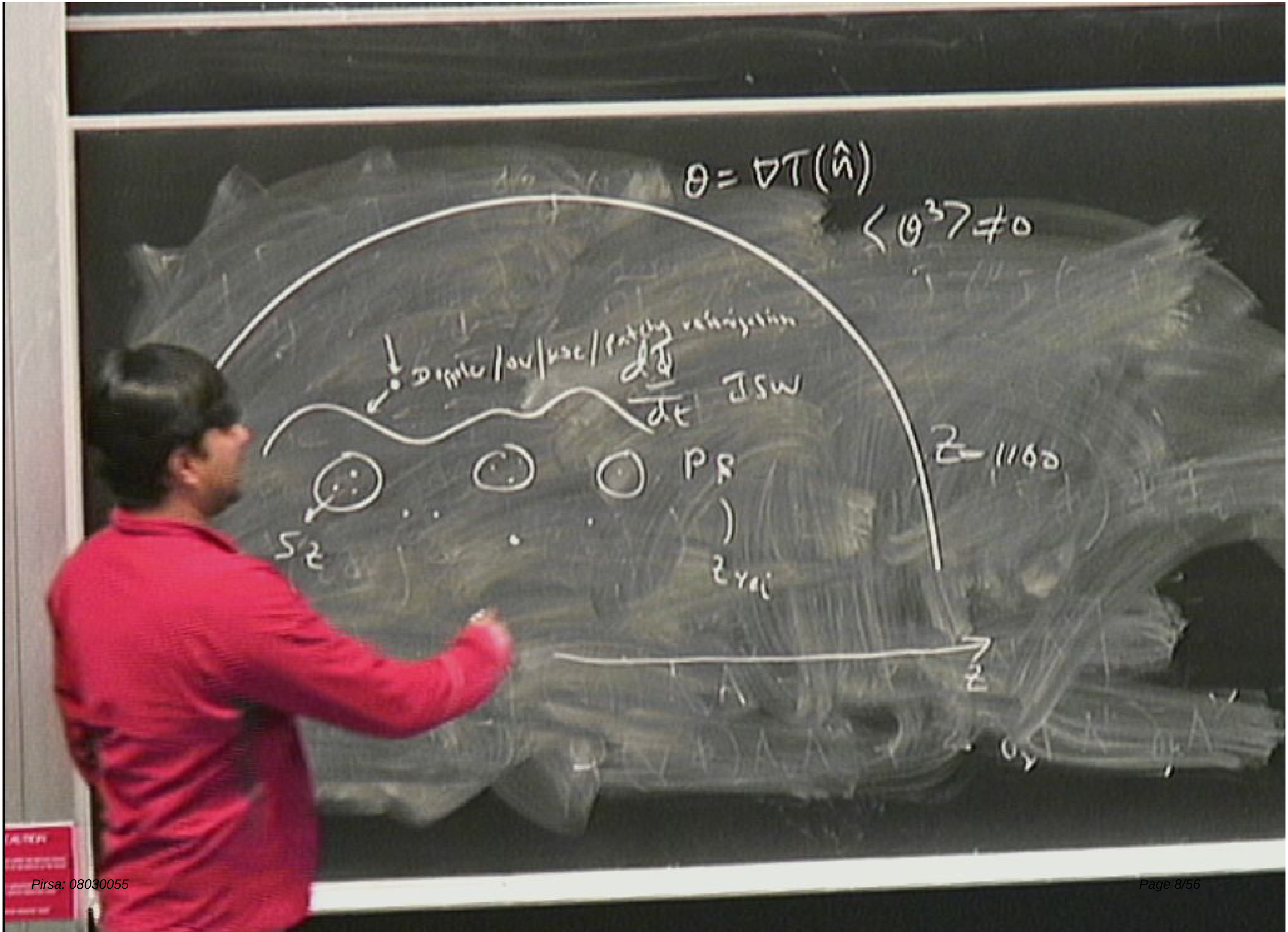
$\langle \theta^3 \rangle \neq 0$

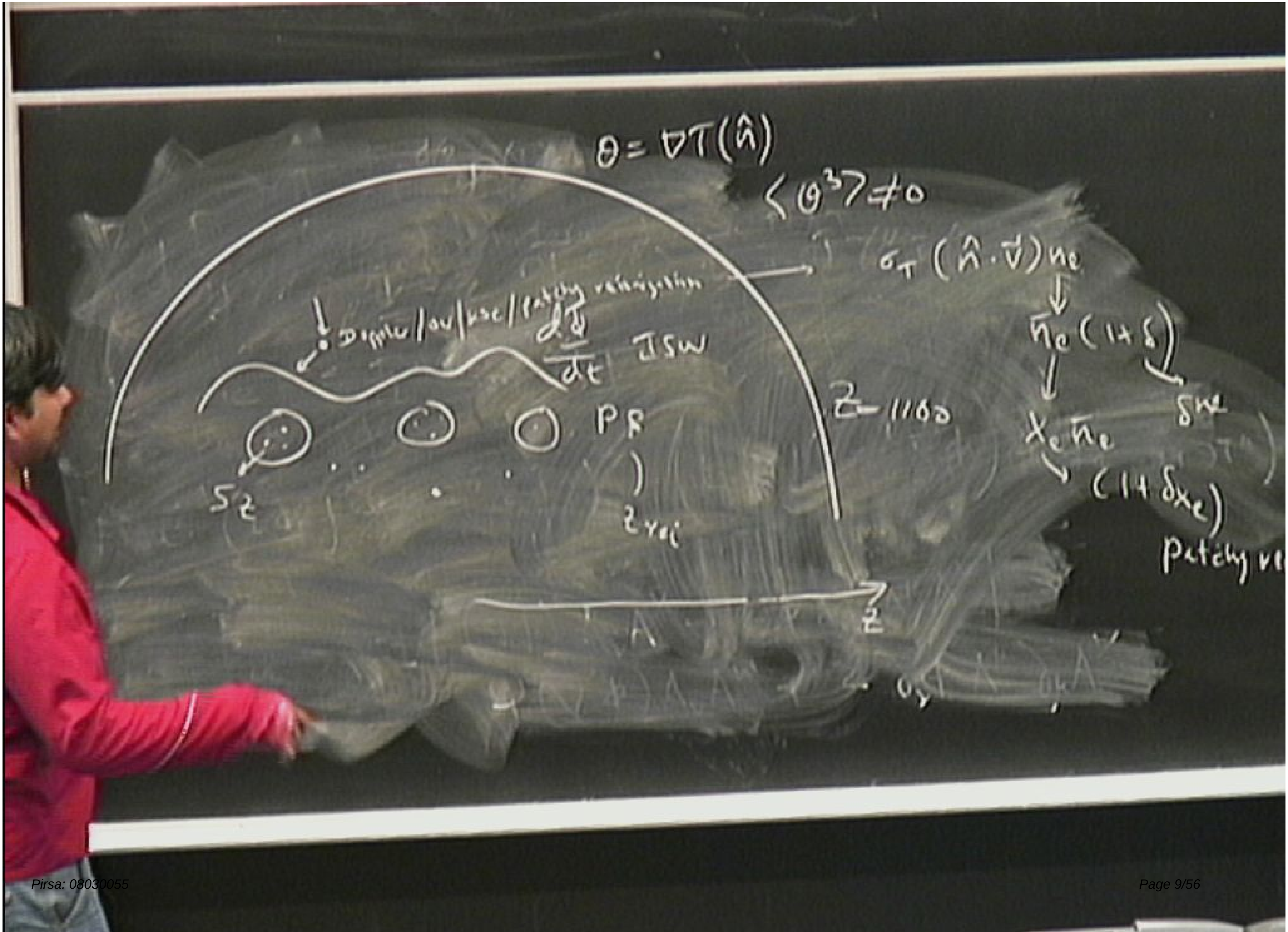


$\theta = \nabla T(\hat{n})$

$\langle \theta^3 \rangle \neq 0$




$\theta = \nabla T(\hat{n})$
$\langle \theta^3 \rangle \neq 0$
Doppler / OV / kSZ / patchy reionization
$\frac{d\Phi}{dt}$ ISW
PS
SZ
z_{rei}
$z \sim 1100$
z
CAUTION



$\theta = \nabla T(\hat{n})$

$\langle \theta^3 \rangle \neq 0$

$\sigma_T (\hat{n} \cdot \vec{v}) n_e$

$\downarrow$

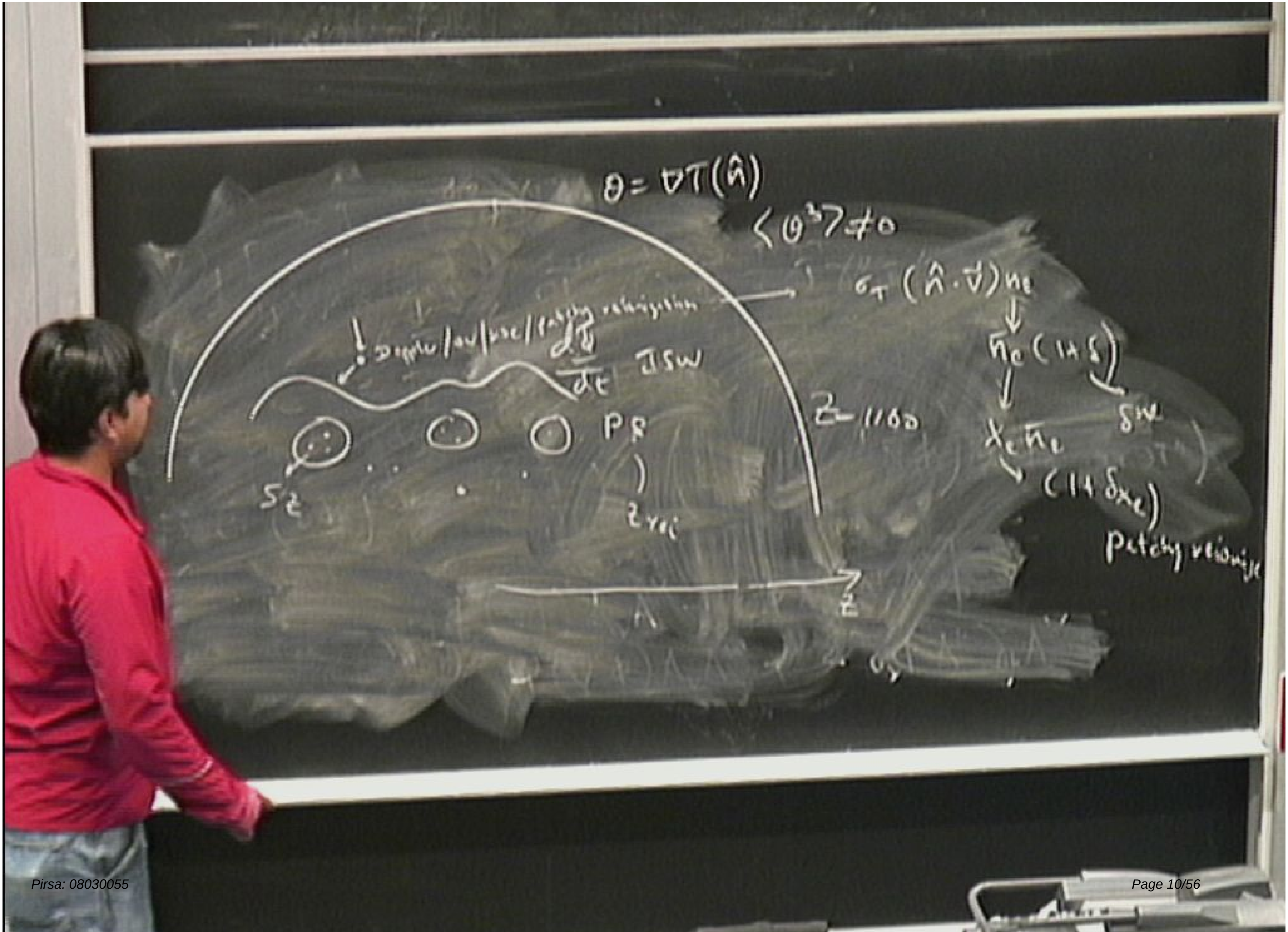
$\bar{n}_e (1 + \delta)$ → δn_e

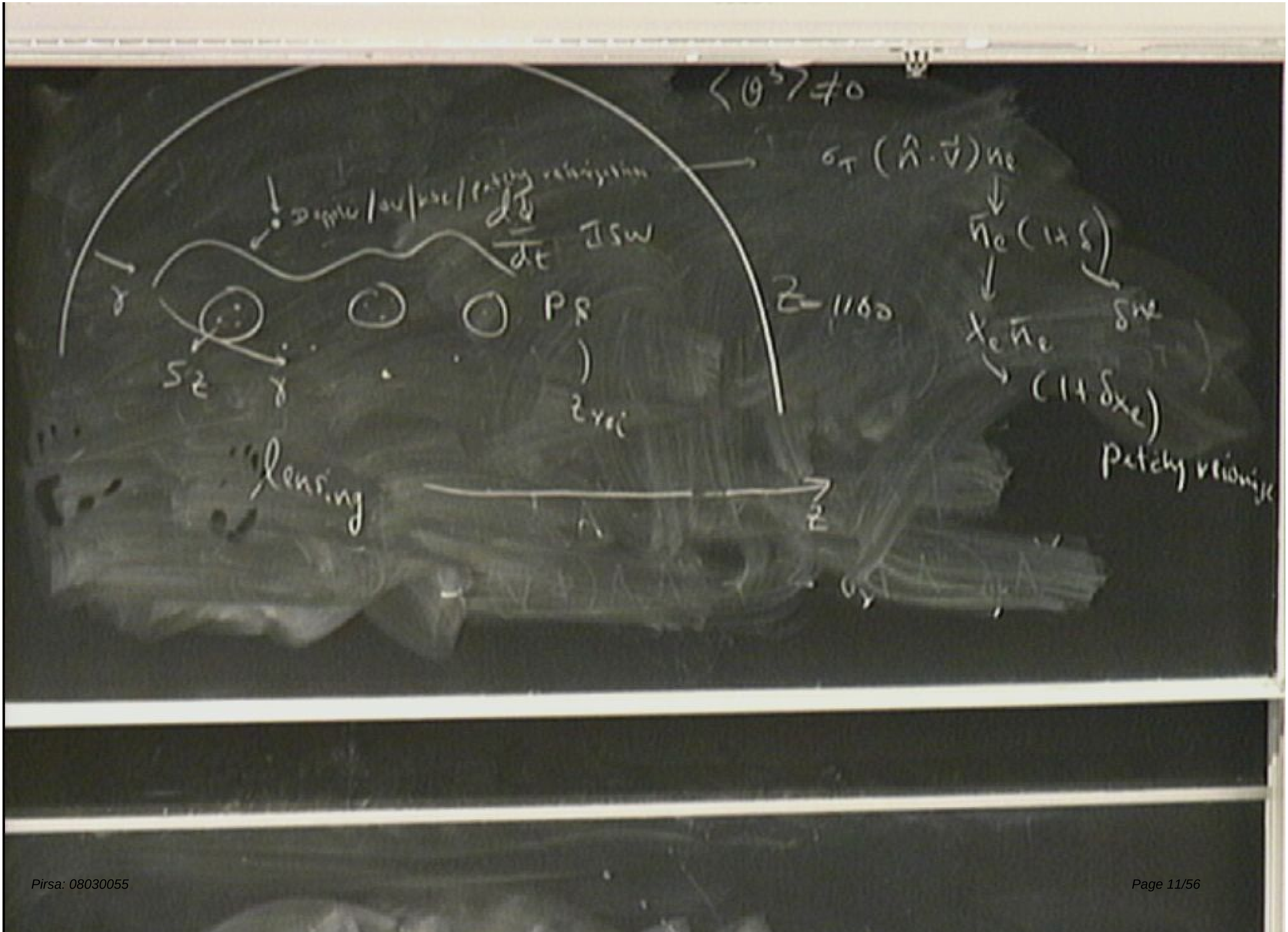
$\downarrow$

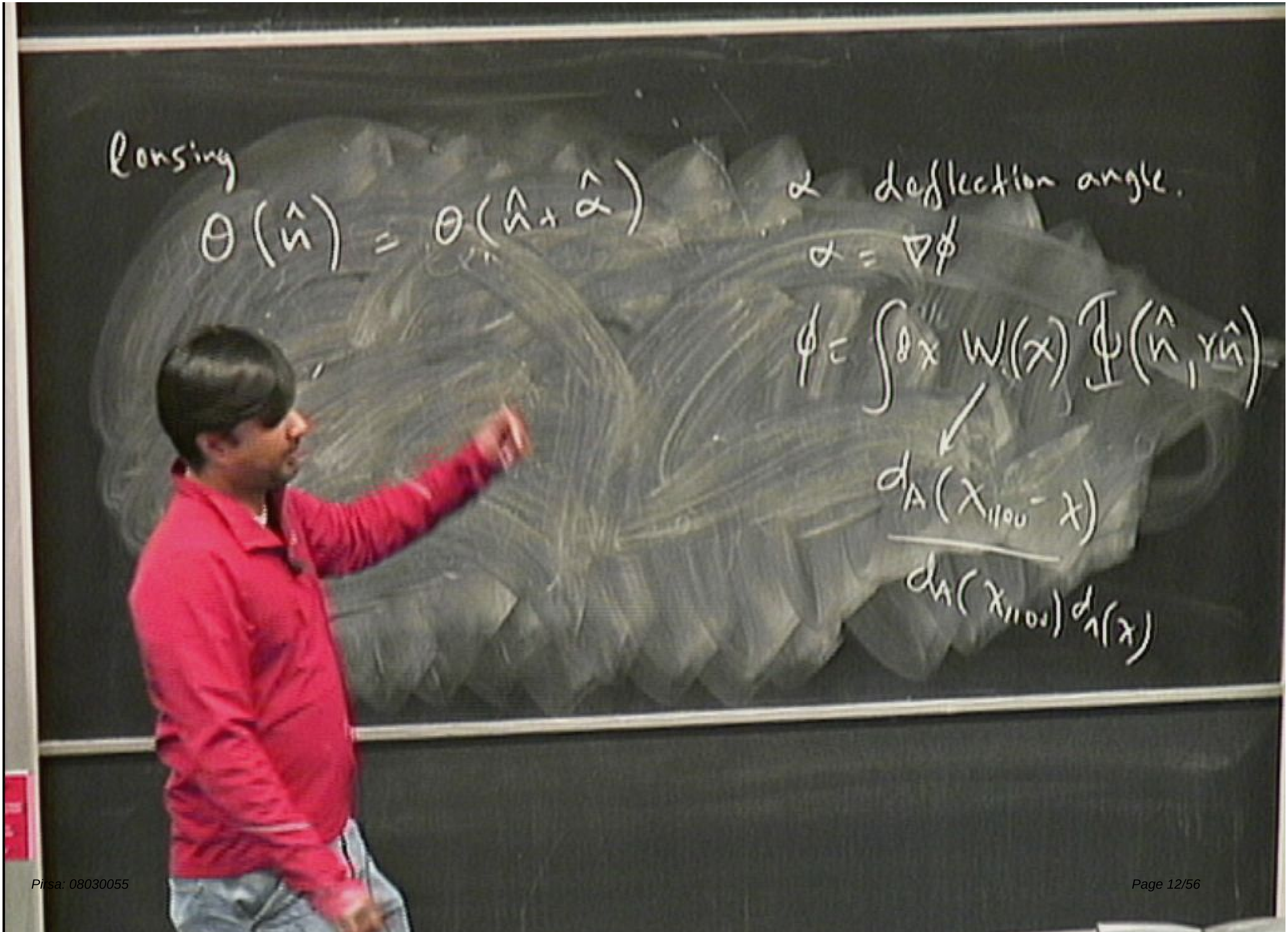
$x_e \bar{n}_e$

→ $(1 + \delta x_e)$

Patchy re


θ = ∇T(n̂)
⟨θ³⟩ ≠ 0
σ_T (n̂·v⃗) n_e
n̄_e (1+δ)
δw
x_e n̄_e
(1+δx_e)
Patchy reionize
Doppler/ov/ksz/patchy reionization
dΦ/dt ISW
PS
SZ
z_rei
z ~ 1100
z


$\langle \theta^3 \rangle \neq 0$
Doppler/OV/kSZ/patchy reionization
$\frac{d\Phi}{dt}$ ISW
γ
PR
S_Z
γ
z_{rei}
lensing
z
$z \sim 1100$
$\sigma_T (\hat{n} \cdot \vec{v}) n_e$
$\bar{n}_e (1+\delta)$
δn_e
$x_e \bar{n}_e$
$(1+\delta x_e)$
patchy reionization



lensing

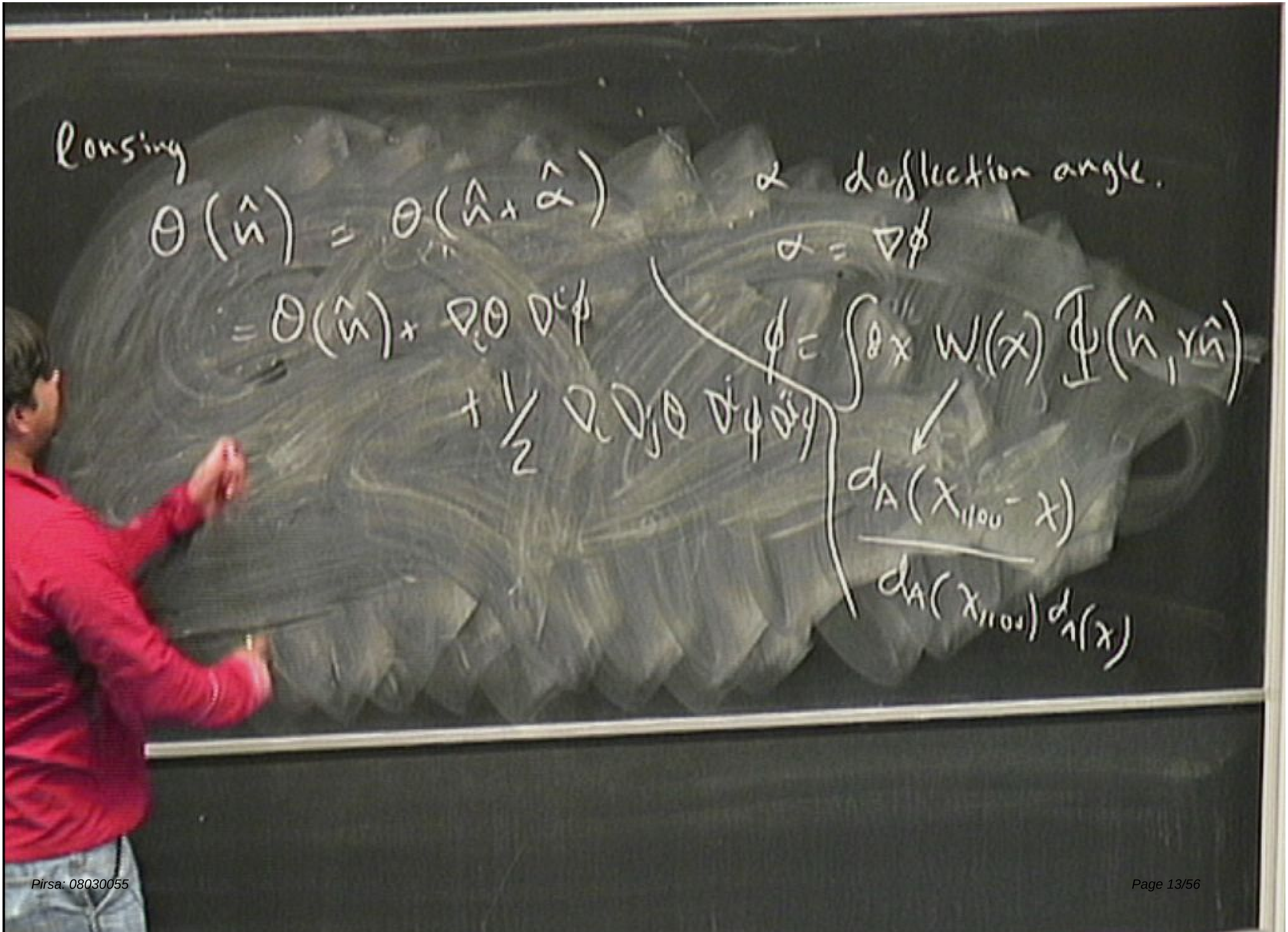
$$\Theta(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

α deflection angle.

$$\alpha = \nabla\phi$$

$$\phi = \int d\chi \, W(\chi) \, \Phi(\hat{n}, r\hat{n})$$

$$\frac{d_A(\chi_{lss} - \chi)}{d_A(\chi_{lss}) \, d_A(\chi)}$$



lensing

$$\Theta(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

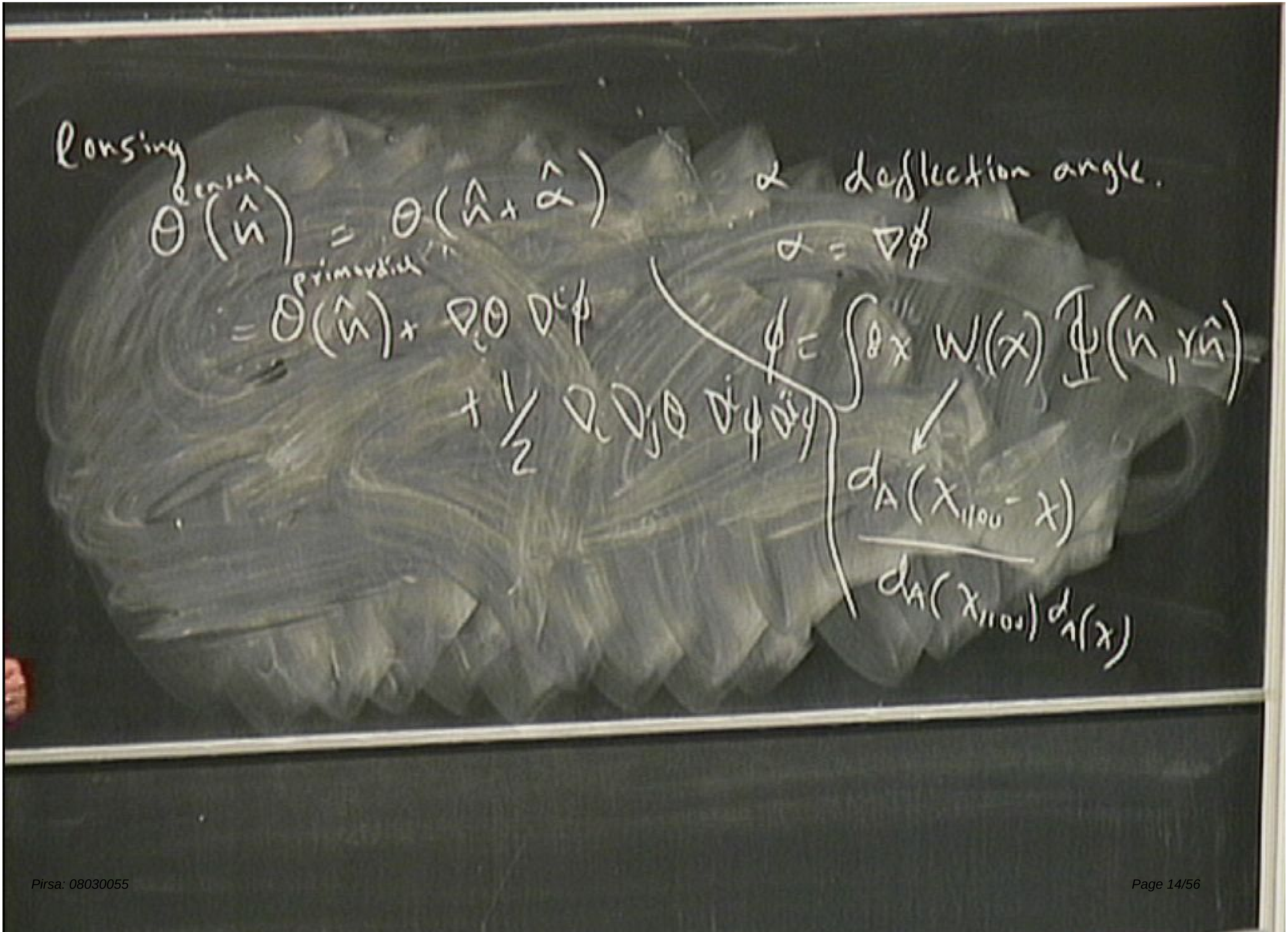
α deflection angle.

$$= \Theta(\hat{n}) + \nabla_i \Theta \, \nabla^i \phi + \frac{1}{2} \nabla_i \nabla_j \Theta \, \nabla^i \phi \, \nabla^j \phi$$

$$\alpha = \nabla \phi$$

$$\phi = \int d\chi \, W(\chi) \, \Phi(\hat{n}, r\hat{n})$$

$$\frac{d_A(\chi_{1100} - \chi)}{d_A(\chi_{1100}) \, d_A(\chi)}$$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \nabla_i \Theta \nabla^i \phi$$

$$+ \frac{1}{2} \nabla_i \nabla_j \Theta \nabla^i \phi \nabla^j \phi$$

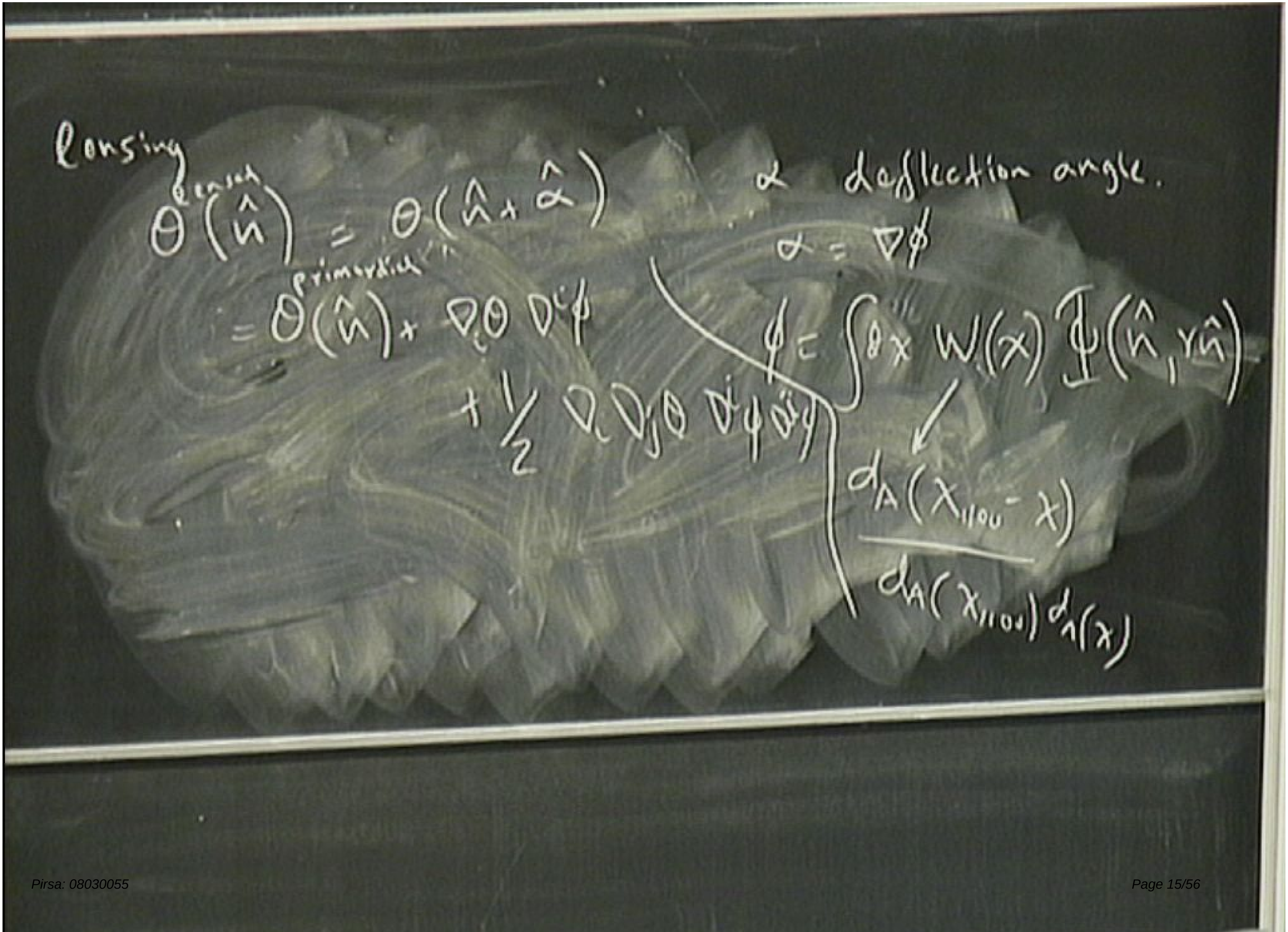
α deflection angle.

$$\alpha = \nabla \phi$$

$$\phi = \int d\chi \, W(\chi) \, \Phi(\hat{n}, r\hat{n})$$

$$\swarrow$$

$$\frac{d_A(\chi_{\rm llou} - \chi)}{d_A(\chi_{\rm llou}) \, d_A(\chi)}$$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \nabla_i \Theta \nabla^i \phi$$

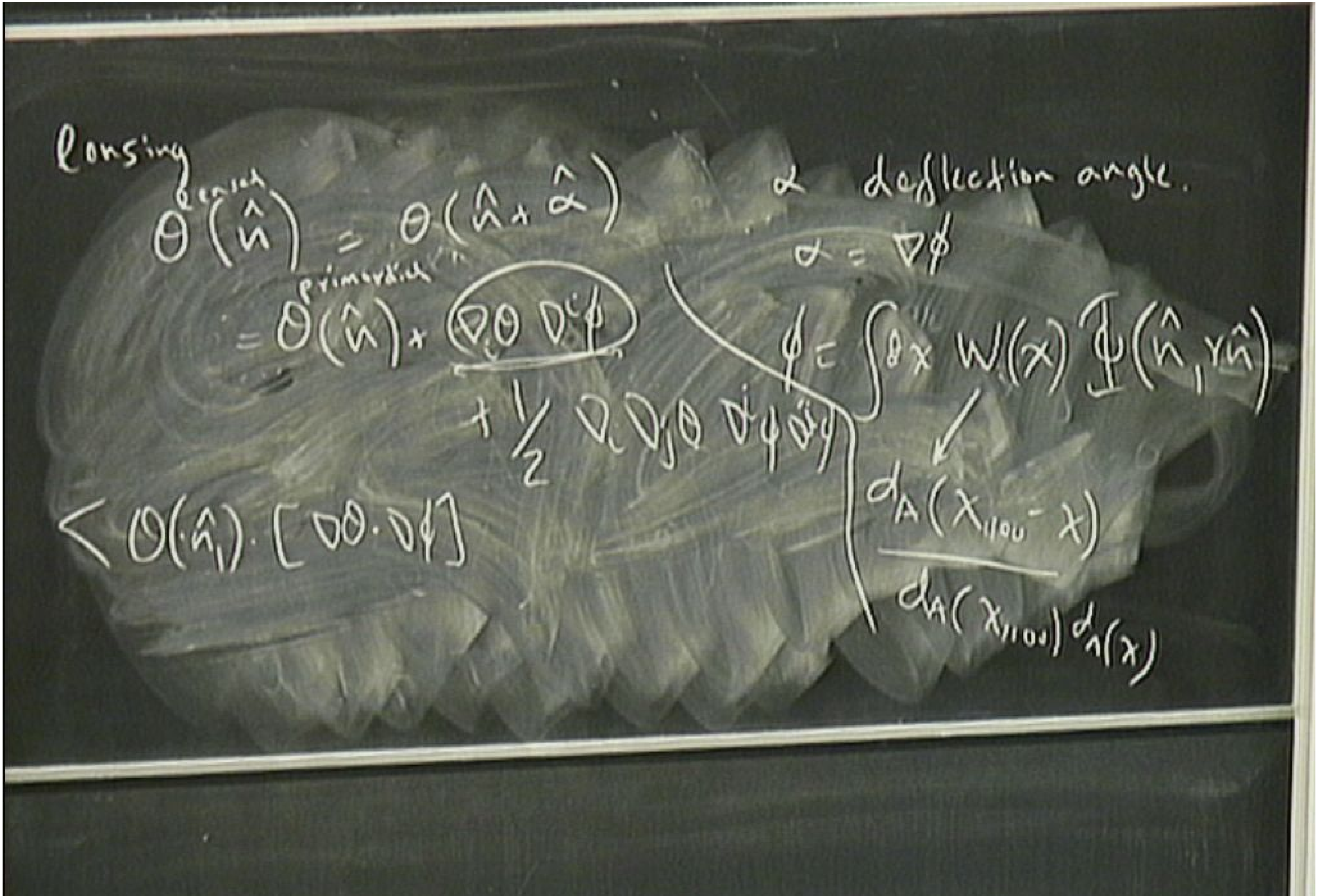
$$+ \frac{1}{2} \nabla_i \nabla_j \Theta \nabla^i \phi \nabla^j \phi$$

α deflection angle.

$$\alpha = \nabla \phi$$

$$\phi = \int d\chi \, W(\chi) \, \Phi(\hat{n}, r\hat{n})$$

$$W(\chi) \swarrow \frac{d_A(\chi_{1100} - \chi)}{d_A(\chi_{1100}) \, d_A(\chi)}$$



lensing

lensed

$\Theta(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$ α deflection angle.

primordial

$= \Theta(\hat{n}) + \boxed{\nabla_i\Theta\, \nabla^i\phi}$

$+ \frac{1}{2} \nabla_i \nabla_j \Theta\, \nabla^i\phi\, \nabla^j\phi$

$\alpha = \nabla\phi$

$\phi = \int d\chi\, W(\chi)\, \Phi(\hat{n}, \chi\hat{n})$

$$\frac{d_A(\chi_{1100} - \chi)}{d_A(\chi_{1100})\, d_A(\chi)}$$

$< \Theta(\hat{n}_1) \cdot [\nabla\Theta \cdot \nabla\phi]$

lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n}+\hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \boxed{\nabla_i\Theta\,\nabla^i\phi}$$

$$+ \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

$$\langle \Theta(\hat{n}_1)\cdot[\nabla\Theta\cdot\nabla\phi]\,\Theta^{\text{sec}}\rangle$$

α deflection angle.

$$\alpha = \nabla\phi$$

$$\phi = \int d\chi\, W(\chi)\,\Phi(\hat{n}, r\hat{n})$$

$$\swarrow$$

$$\frac{d_A(\chi_{\text{llou}}-\chi)}{d_A(\chi_{\text{llou}})\,d_A(\chi)}$$

lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n}+\hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \boxed{\nabla_i\Theta\,\nabla^i\phi} + \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

α deflection angle.

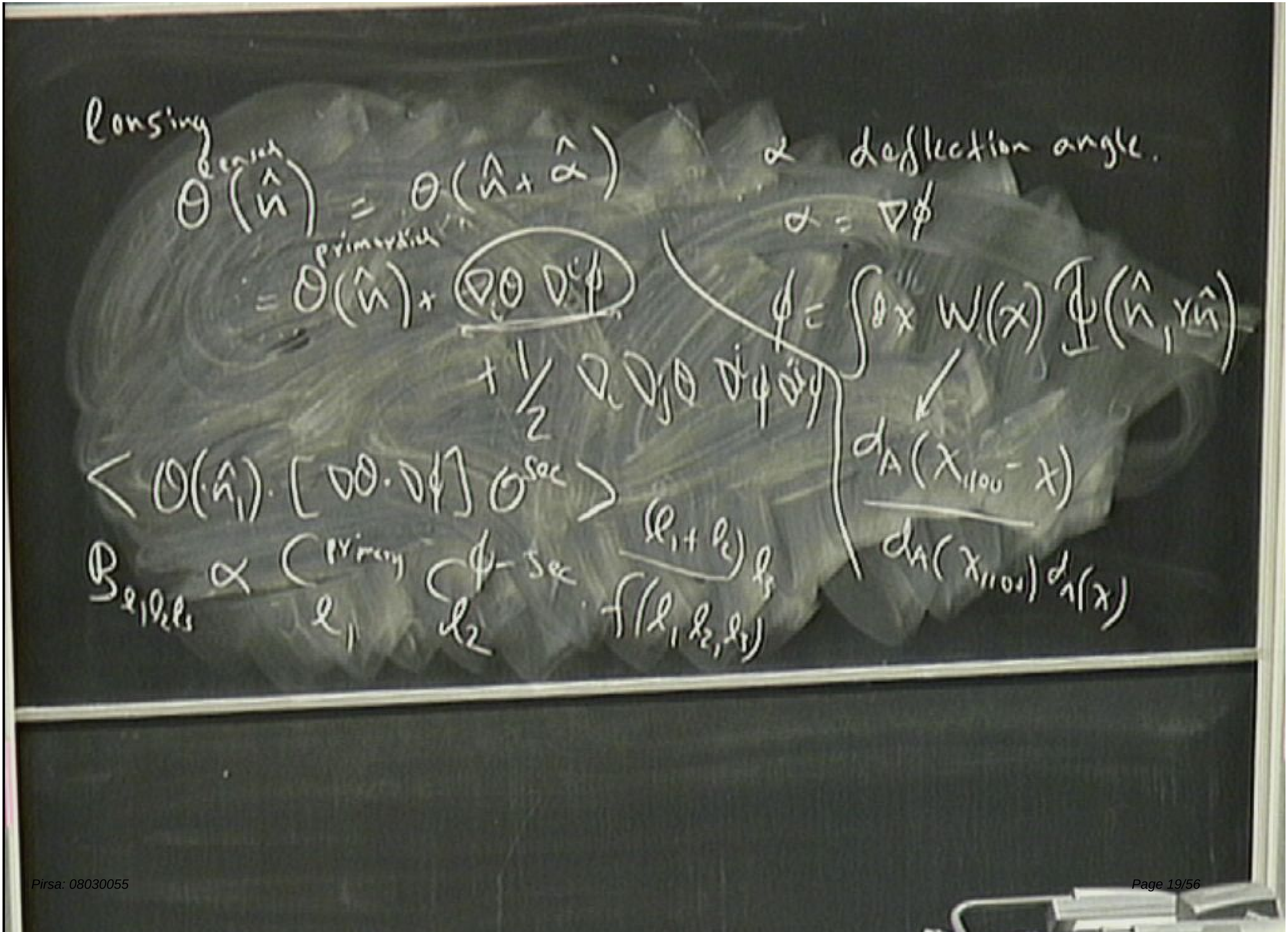
$$\alpha = \nabla\phi$$

$$\phi = \int d\chi\, W(\chi)\, \Phi(\hat{n}, r\hat{n})$$

$$W(\chi) \swarrow \frac{d_A(\chi_{1100}-\chi)}{d_A(\chi_{1100})\,d_A(\chi)}$$

$$\langle \Theta(\hat{n}_1)\,[\nabla\Theta\cdot\nabla\phi]\,\Theta^{\text{sec}} \rangle$$

$$B_{\ell_1\ell_2\ell_3} \propto C^{\text{primary}}_{\ell_1}\, C^{\phi-\text{sec}}_{\ell_2}\, \overset{(\ell_1+\ell_2)\,\ell_3}{f(\ell_1,\ell_2,\ell_3)}$$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

α deflection angle.

$$\alpha = \nabla\phi$$

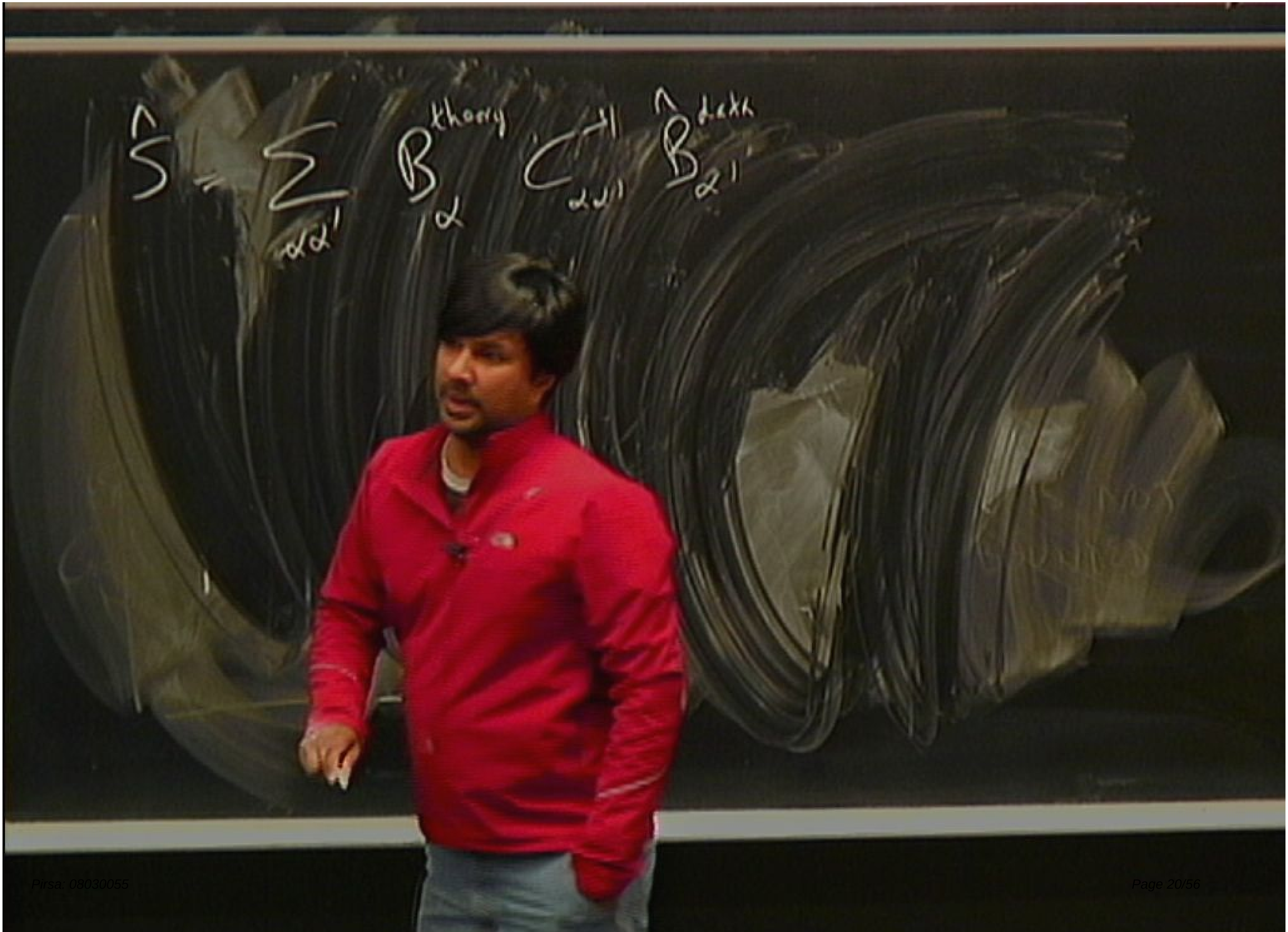
$$= \Theta^{\text{primordial}}(\hat{n}) + \underline{\boxed{\nabla_i\Theta\,\nabla^i\phi}} + \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

$$\phi = \int d\chi\, W(\chi)\, \Phi(\hat{n}, r\hat{n})$$

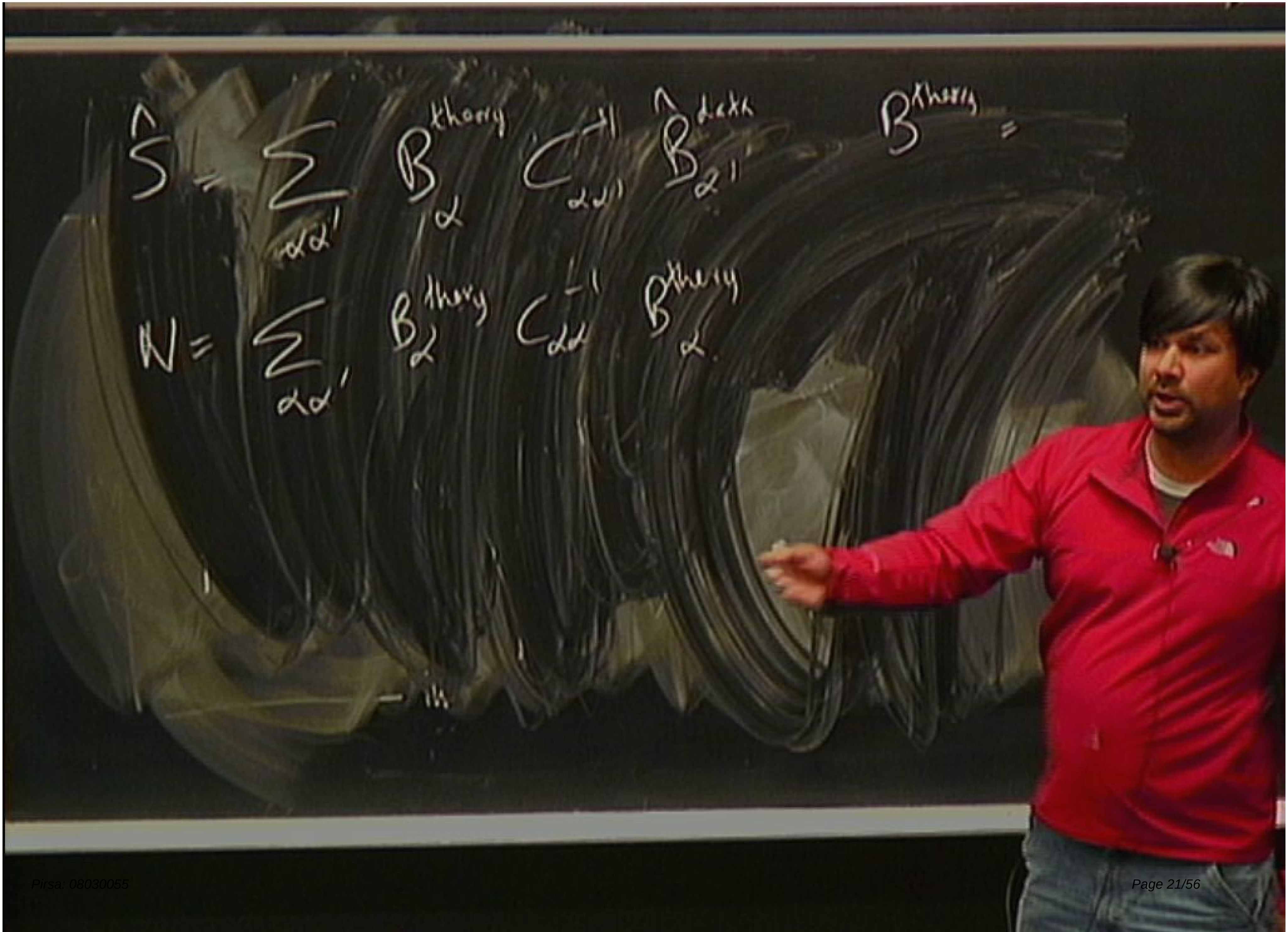
$$W \swarrow \frac{d_A(\chi_{1100} - \chi)}{d_A(\chi_{1100})\, d_A(\chi)}$$

$$\langle \Theta(\hat{n}_1)\cdot[\nabla\Theta\cdot\nabla\phi]\,\Theta^{\text{sec}} \rangle$$

$$B_{\ell_1\ell_2\ell_3} \propto C^{\text{primary}}_{\ell_1}\, C^{\phi-\text{sec}}_{\ell_2} \cdot \underline{(\ell_1+\ell_2)}\,\ell_3 \; f(\ell_1,\ell_2,\ell_3)$$

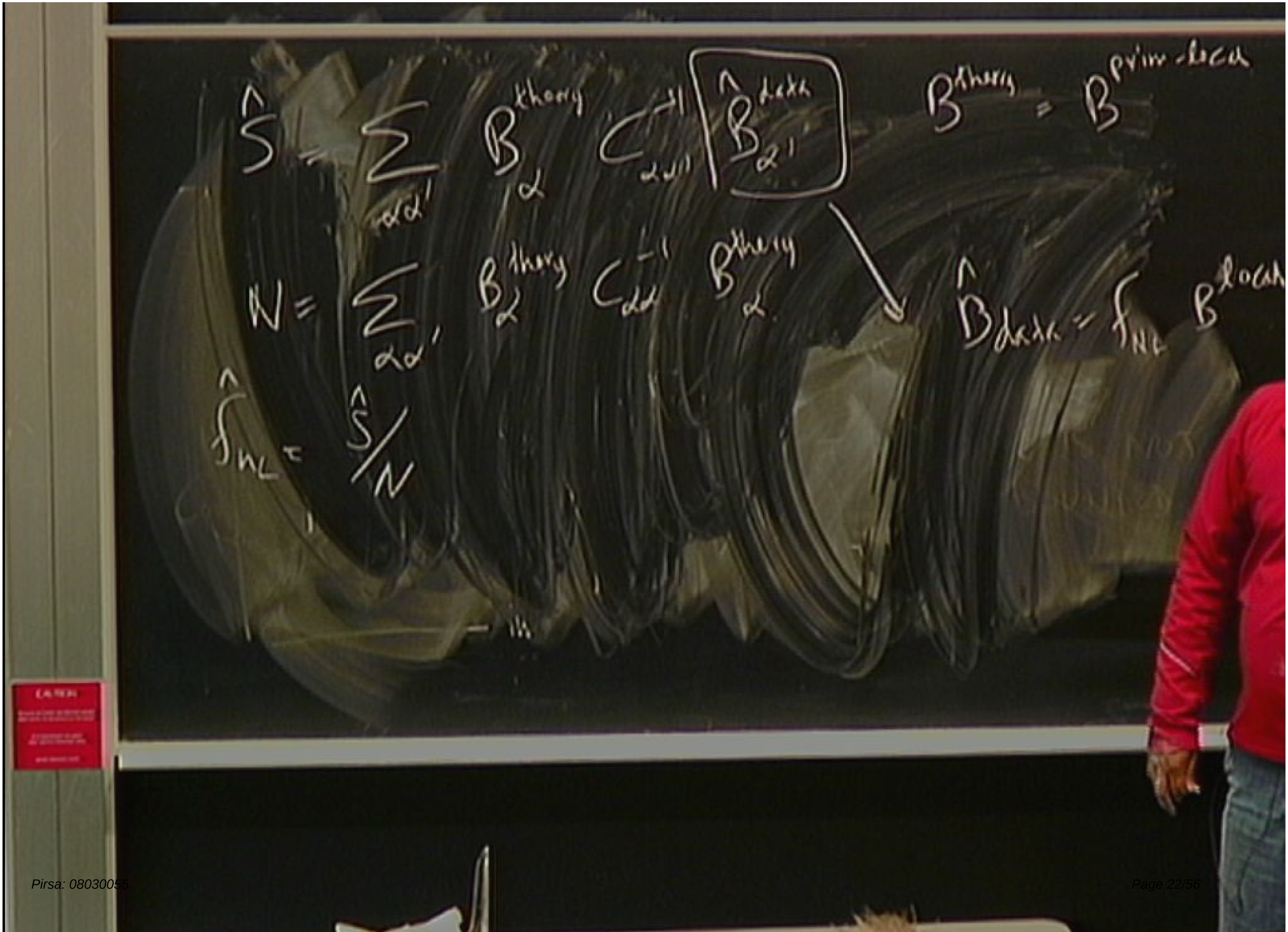


$$\hat{S} = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} \hat{B}^{data}_{\alpha'}$$



$$\hat{S} = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} \hat{B}^{data}_{\alpha'} \qquad B^{theory} =$$

$$N = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} B^{theory}_{\alpha}$$



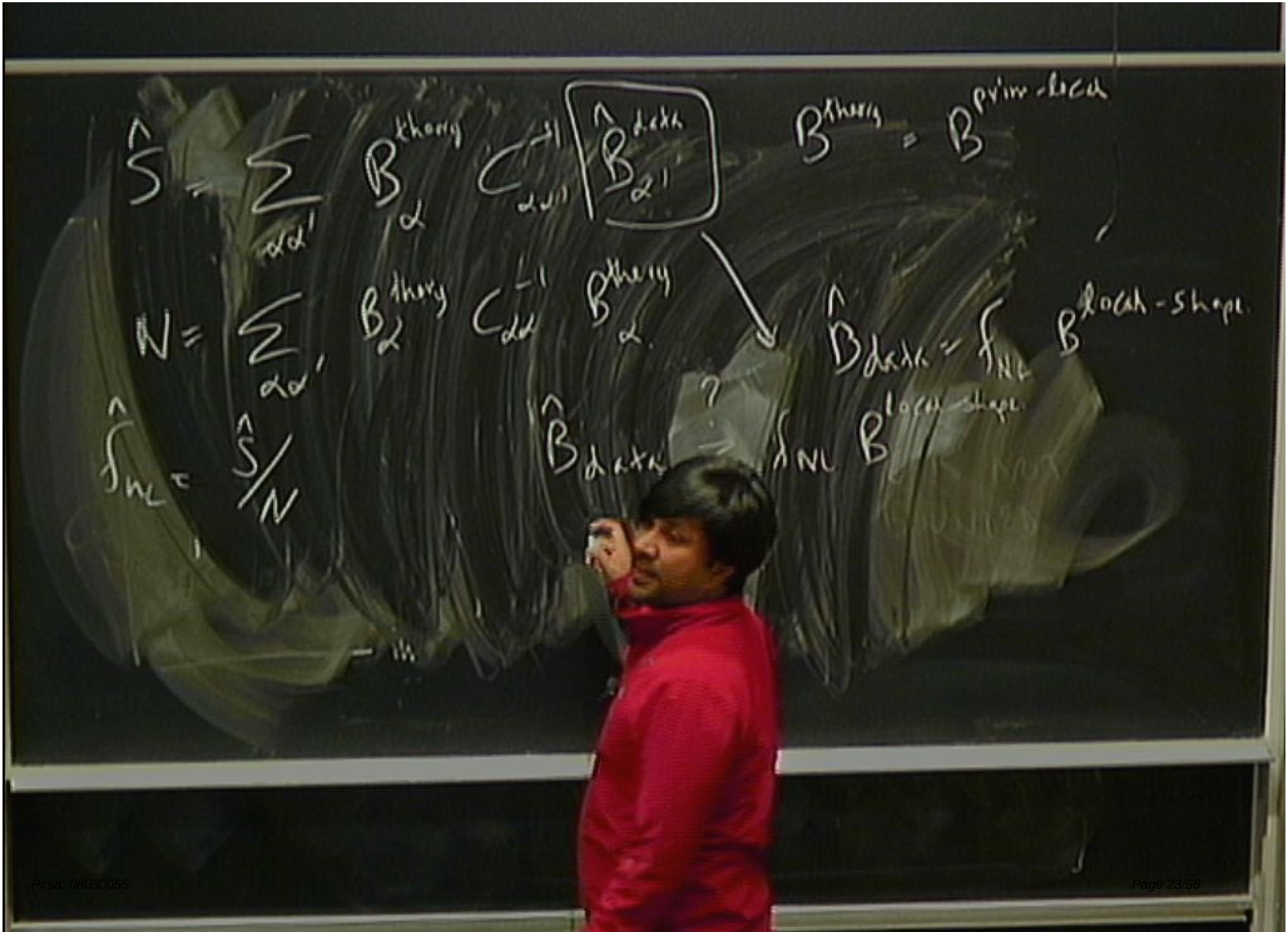
$$\hat{S} = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} \boxed{\hat{B}^{data}_{\alpha'}}$$

$$B^{theory} = B^{prim-local}$$

$$N = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} B^{theory}_{\alpha}$$

$$\hat{B}_{data} = f_{NL} \; B^{loca}$$

$$\hat{f}_{NL} = \hat{S}/N$$



$$\hat{S} = \sum_{\alpha\alpha'} B^{theory}_{\alpha} \, C^{-1}_{\alpha\alpha'} \boxed{\hat{B}^{data}_{\alpha'}}$$

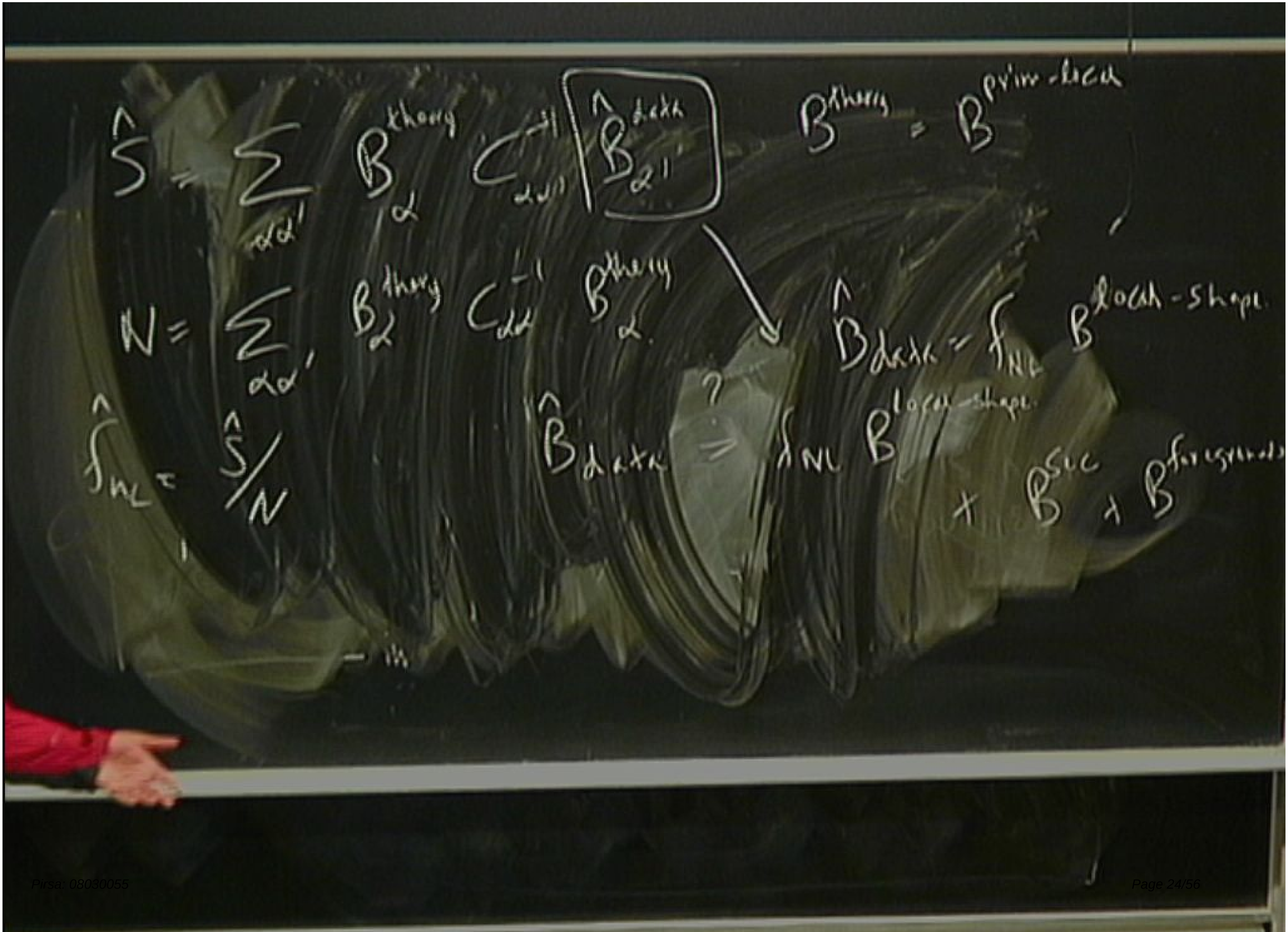
$$B^{theory} = B^{prim-local}$$

$$N = \sum_{\alpha\alpha'} B^{theory}_{\alpha} \, C^{-1}_{\alpha\alpha'} \, B^{theory}_{\alpha}$$

$$\hat{B}_{data} = f_{NL} \, B^{local-shape}$$

$$\hat{f}_{NL} = \hat{S}/N$$

$$\hat{B}_{data} \overset{?}{=} f_{NL} \, B^{local-shape}$$



$$\hat{S} = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} \boxed{\hat{B}^{data}_{\alpha'}}$$

$$B^{theory} = B^{prim-local}$$

$$N = \sum_{\alpha\alpha'} B^{theory}_{\alpha} C^{-1}_{\alpha\alpha'} B^{theory}_{\alpha}$$

$$\hat{B}_{data} = f_{NL} B^{local-shape}$$

$$\hat{f}_{NL} = \hat{S}/N$$

$$\hat{B}_{data} \overset{?}{=} f_{NL} B^{local-shape} + B^{sec} + B^{foregrounds}$$

lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n}+\hat{\alpha})$$

α deflection angle.

$$= \Theta^{\text{primordial}}(\hat{n}) + \boxed{\nabla_i\Theta\,\nabla^i\phi} + \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

$$\alpha = \nabla\phi$$

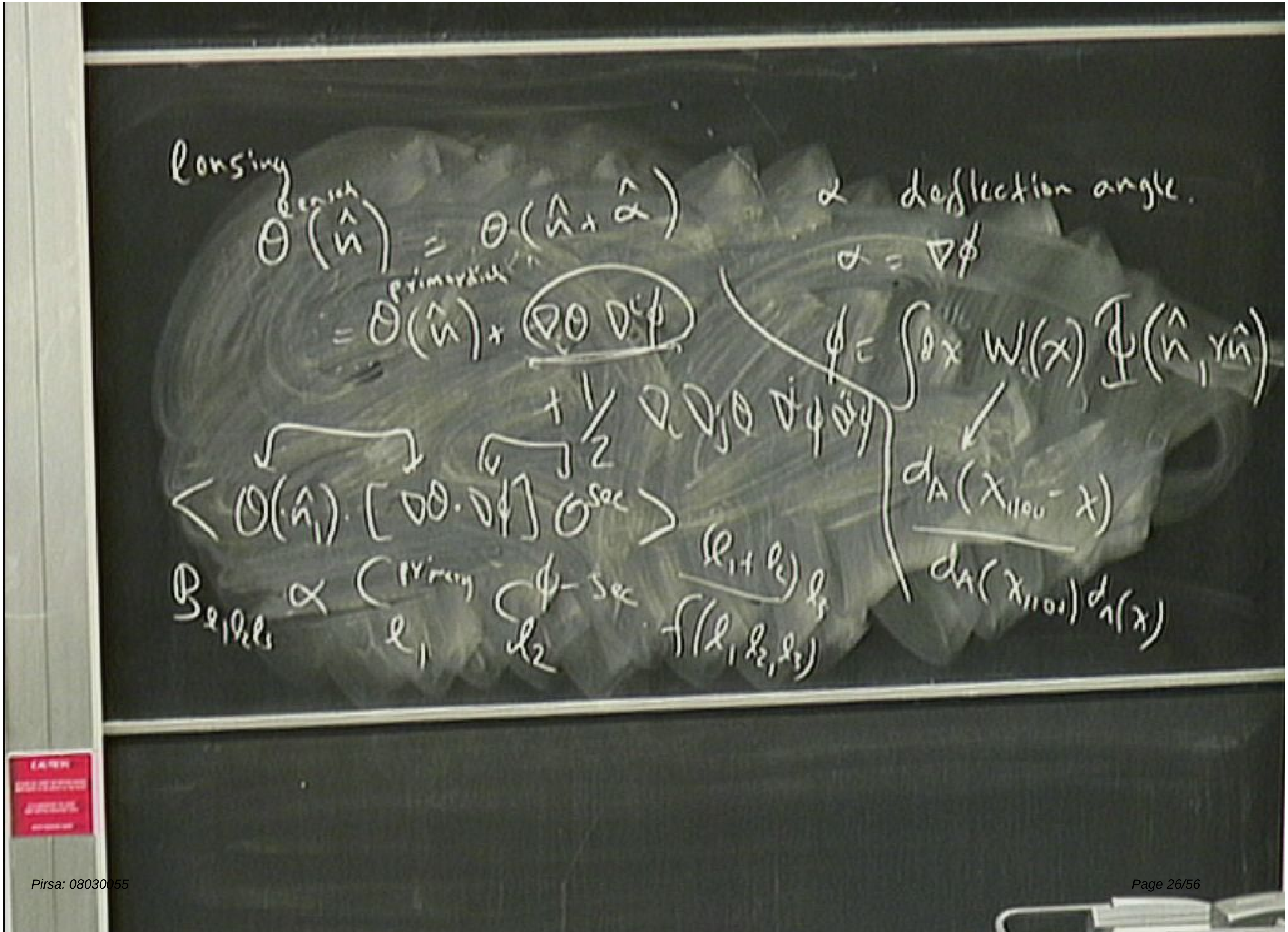
$$\phi = \int dx\, W(x)\, \Phi(\hat{n}, r\hat{n})$$

$$\swarrow$$

$$\frac{d_A(\chi_{1100}-x)}{d_A(\chi_{1100})\, d_A(x)}$$

$$\langle \Theta(\hat{n}_1)\cdot[\nabla\Theta\cdot\nabla\phi]\,\Theta^{\text{sec}}\rangle$$

$$B_{\ell_1\ell_2\ell_3} \propto C^{\text{primary}}_{\ell_1}\, C^{\phi-\text{sec}}_{\ell_2}\, \underbrace{(\ell_1+\ell_2)\,\ell_3}_{f(\ell_1,\ell_2,\ell_3)}$$



Lensing

$$\Theta^{\rm lensed}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

$$= \Theta^{\rm primordial}(\hat{n}) + \underline{\boxed{\nabla\Theta\, \nabla^i\phi}} + \frac{1}{2} \nabla_i \nabla_j \Theta\, \nabla^i\phi\, \nabla^j\phi$$

$$\langle \Theta(\hat{n}_1) \cdot [\nabla\Theta \cdot \nabla\phi]\, \Theta^{\rm sec} \rangle$$

$$B_{\ell_1 \ell_2 \ell_3} \propto C^{\rm primary}_{\ell_1}\, C^{\phi-{\rm sec}}_{\ell_2}\, \frac{(\ell_1 + \ell_2)\, \ell_3}{f(\ell_1, \ell_2, \ell_3)}$$

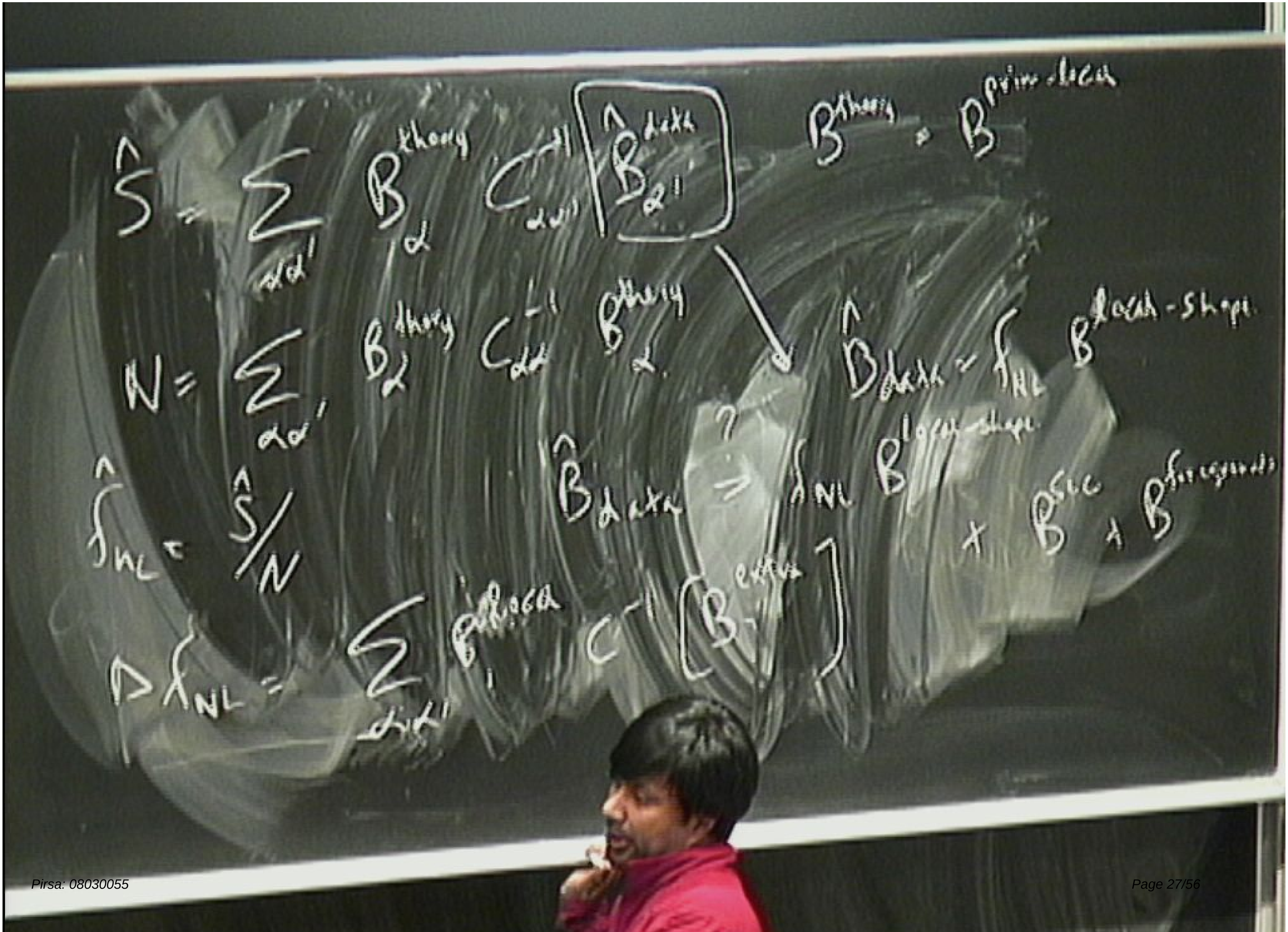
α deflection angle.

$$\alpha = \nabla\phi$$

$$\phi = \int d\chi\, W(\chi)\, \Phi(\hat{n}, r\hat{n})$$

$$\swarrow$$

$$\frac{d_A(\chi_{\rm lss} - \chi)}{d_A(\chi_{\rm lss})\, d_A(\chi)}$$



$$\hat{S} = \sum_{\alpha\alpha'} B^{\text{theory}}_{\alpha} C^{-1}_{\alpha\alpha'} \boxed{\hat{B}^{\text{data}}_{\alpha'}}$$

$$B^{\text{theory}} = B^{\text{prim-local}}$$

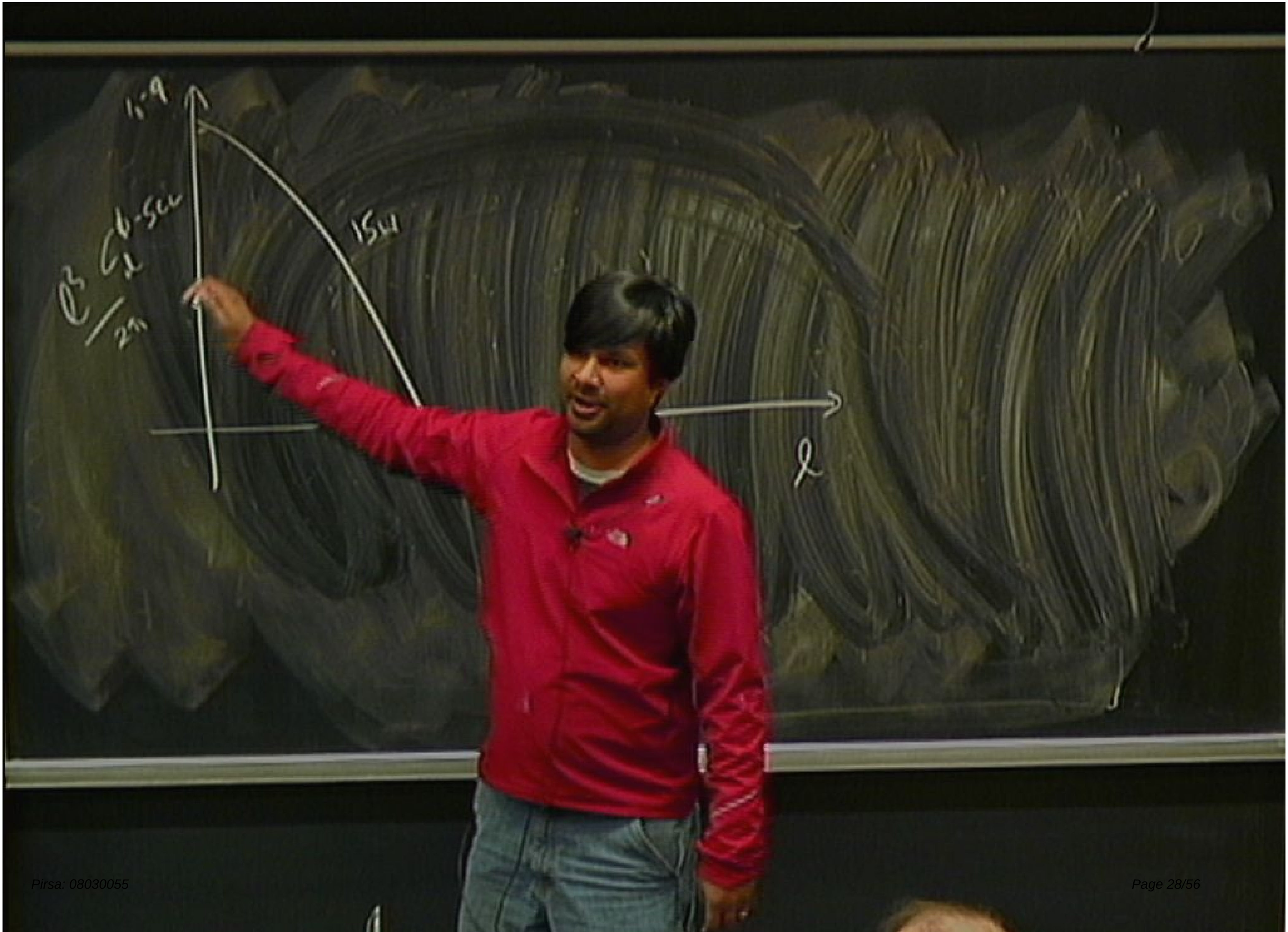
$$N = \sum_{\alpha\alpha'} B^{\text{theory}}_{\alpha} C^{-1}_{\alpha\alpha'} B^{\text{theory}}_{\alpha'}$$

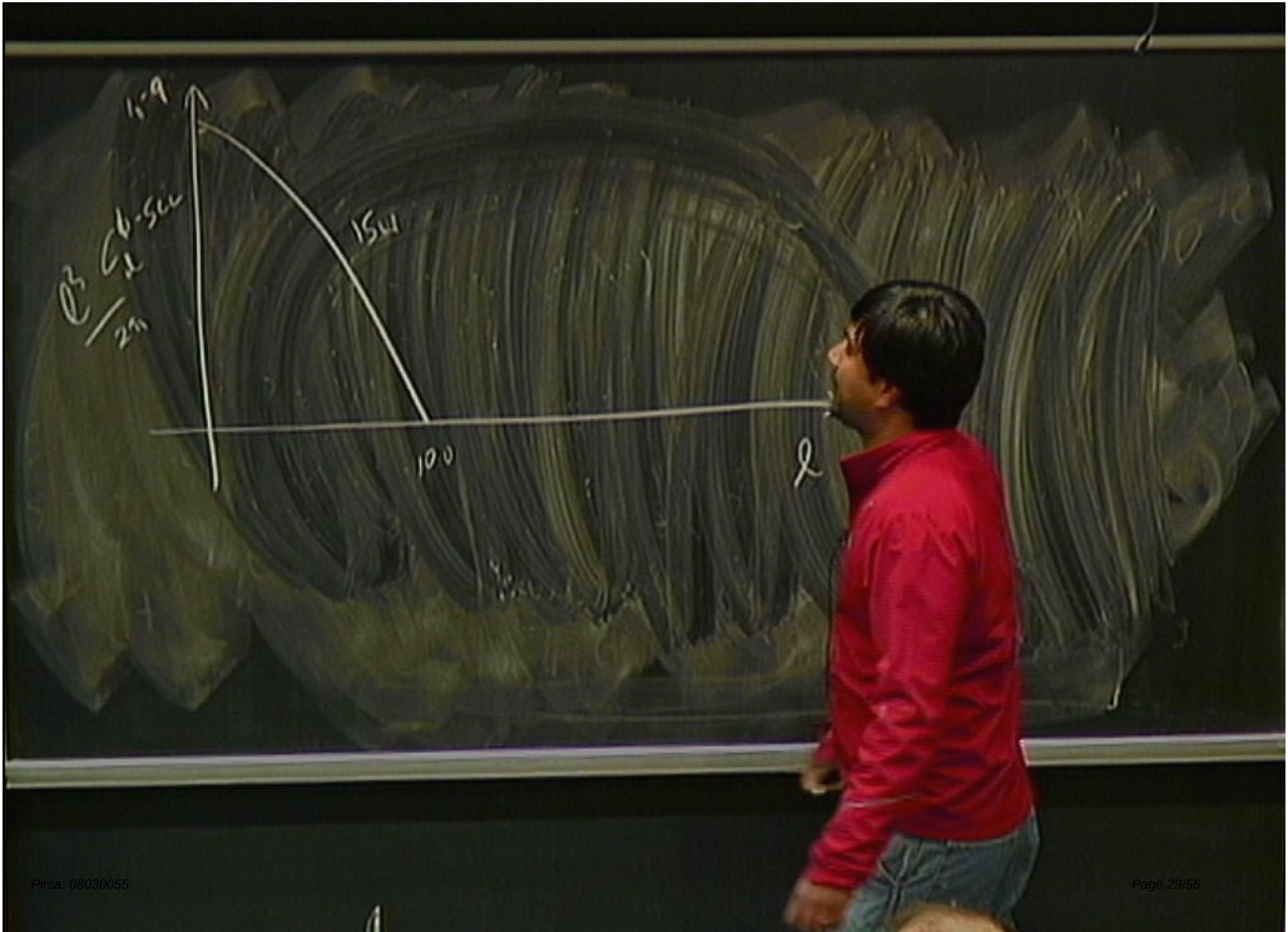
$$\hat{B}_{\text{data}} = f_{NL} B^{\text{local-shape}}$$

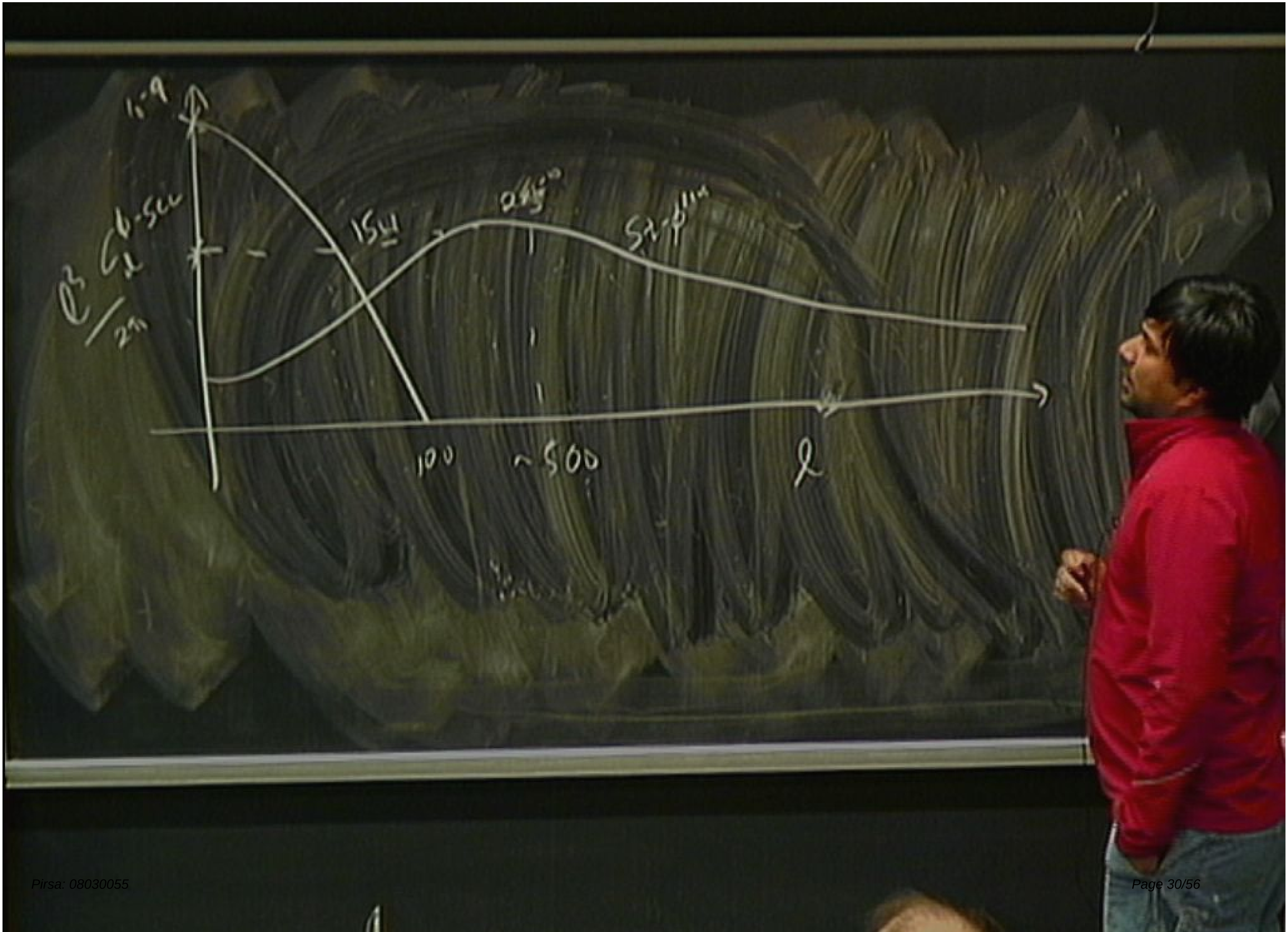
$$\hat{f}_{NL} = \hat{S}/N$$

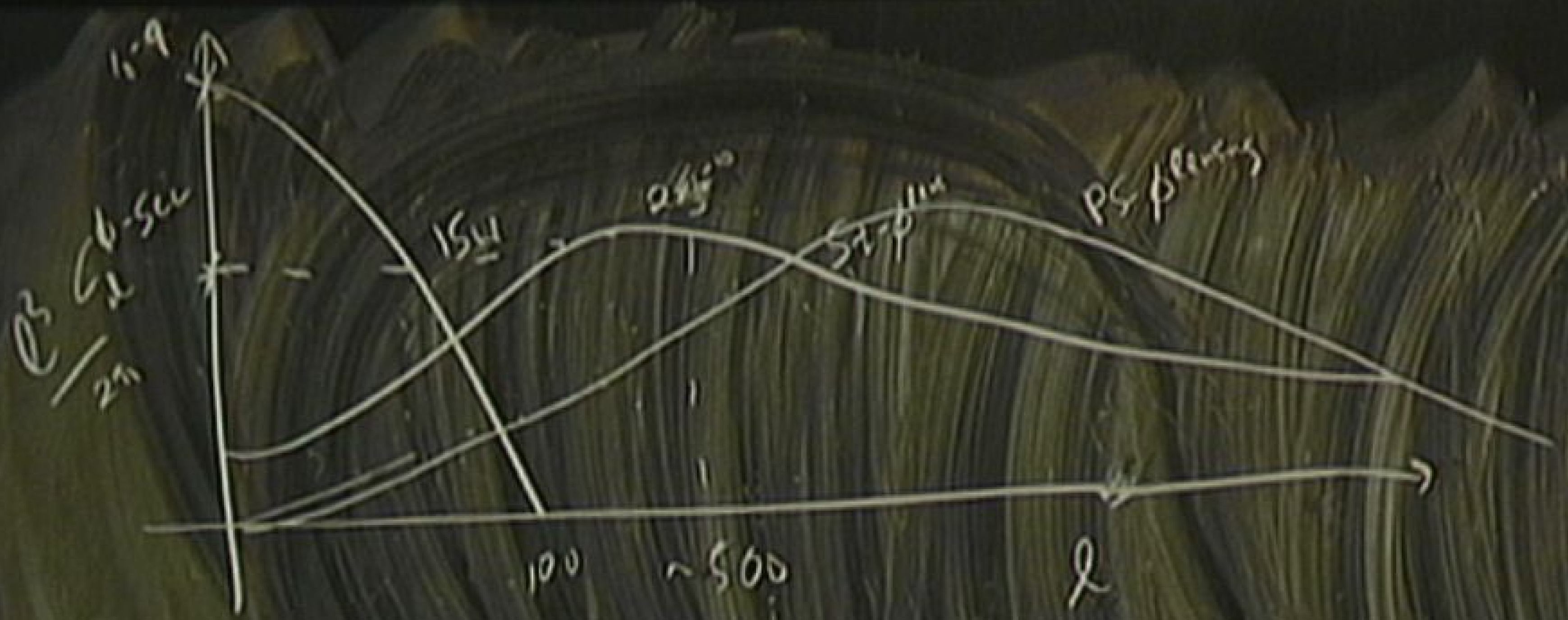
$$\hat{B}_{\text{data}} \overset{?}{=} f_{NL} B^{\text{local-shape}} + B^{\text{SLC}} + B^{\text{foregrounds}}$$

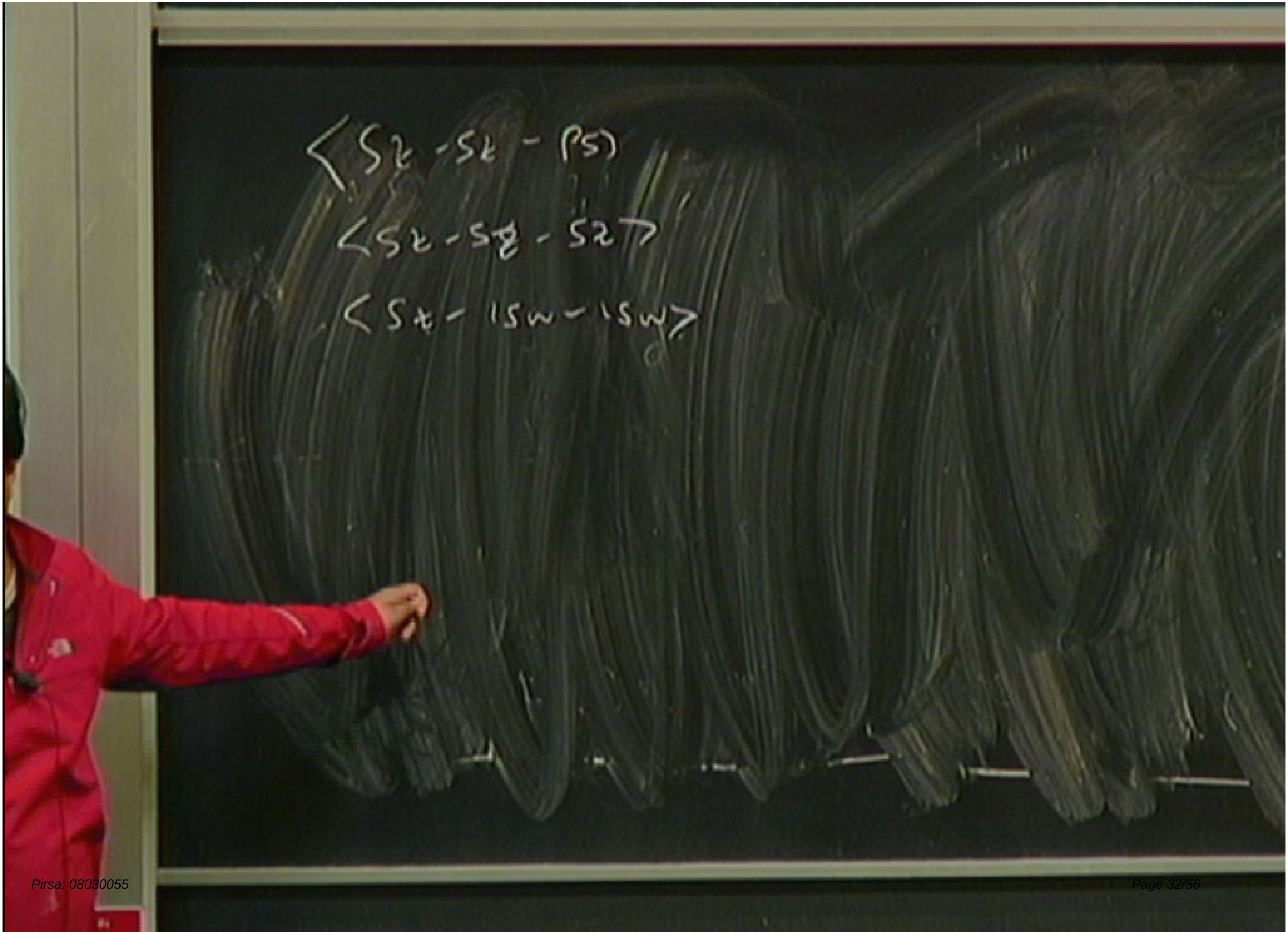
$$\Delta f_{NL} = \sum_{ii'} B^{\text{local}}_{i} C^{-1} \left[B^{\text{extra}}_{i'} \right]$$


1.9
$\ell^3 C_\ell^{b\text{-}sec} / 2\pi$
15u
ℓ


10^{-9}
$\ell^3 C_\ell^{b\text{-}scal}/2\pi$
15M
100
ℓ


1.9
ℓ³ C_ℓ^{b-scu} / 2π
15μK
0.5°
5′-8′
100
~500
ℓ

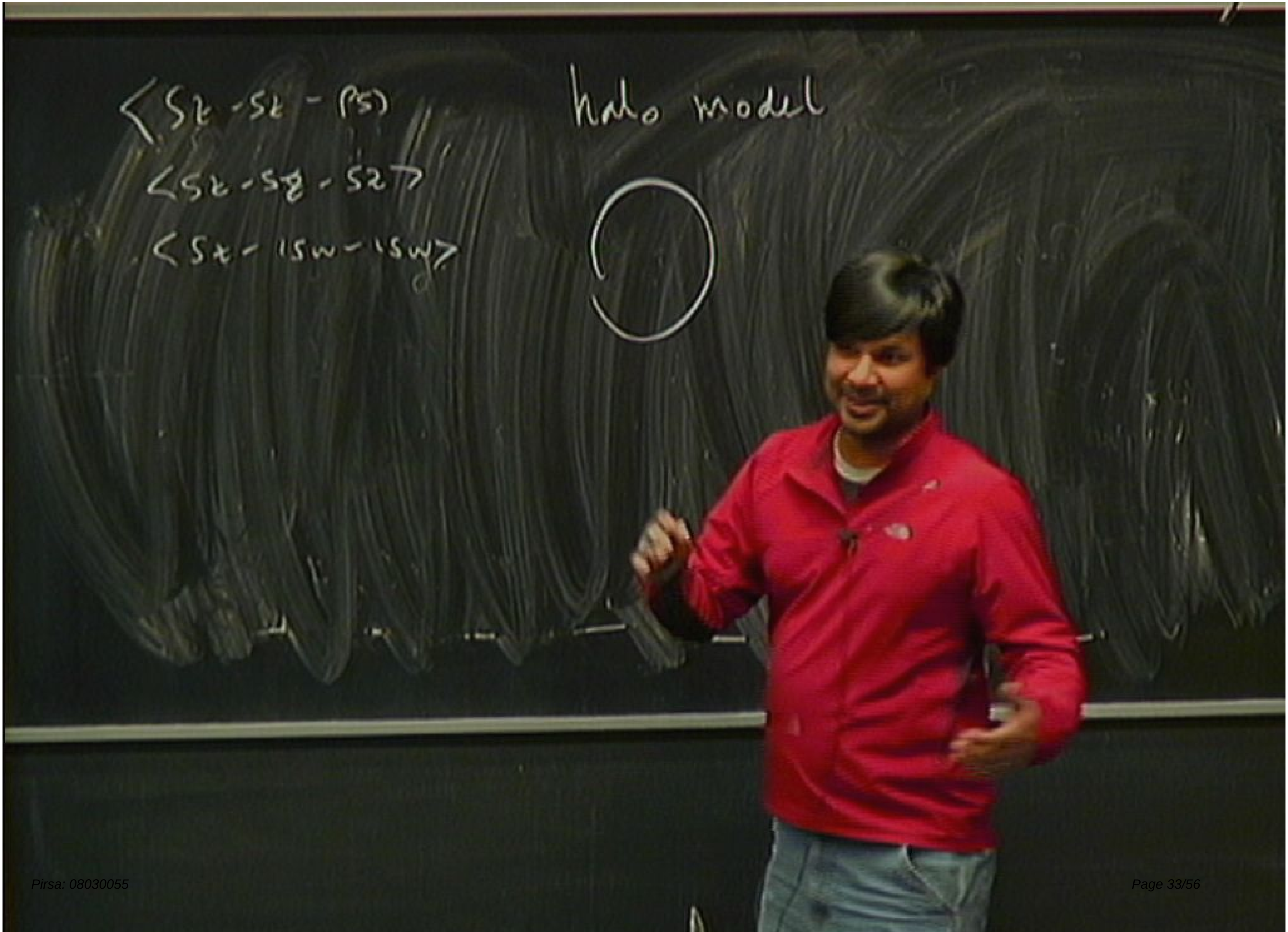

1e-9
$\ell^3 C_\ell^{b\text{-}sca} / 2\pi$
15uK
2×10⁻¹⁰
SZ-flux
PS flux
100
~500
ℓ

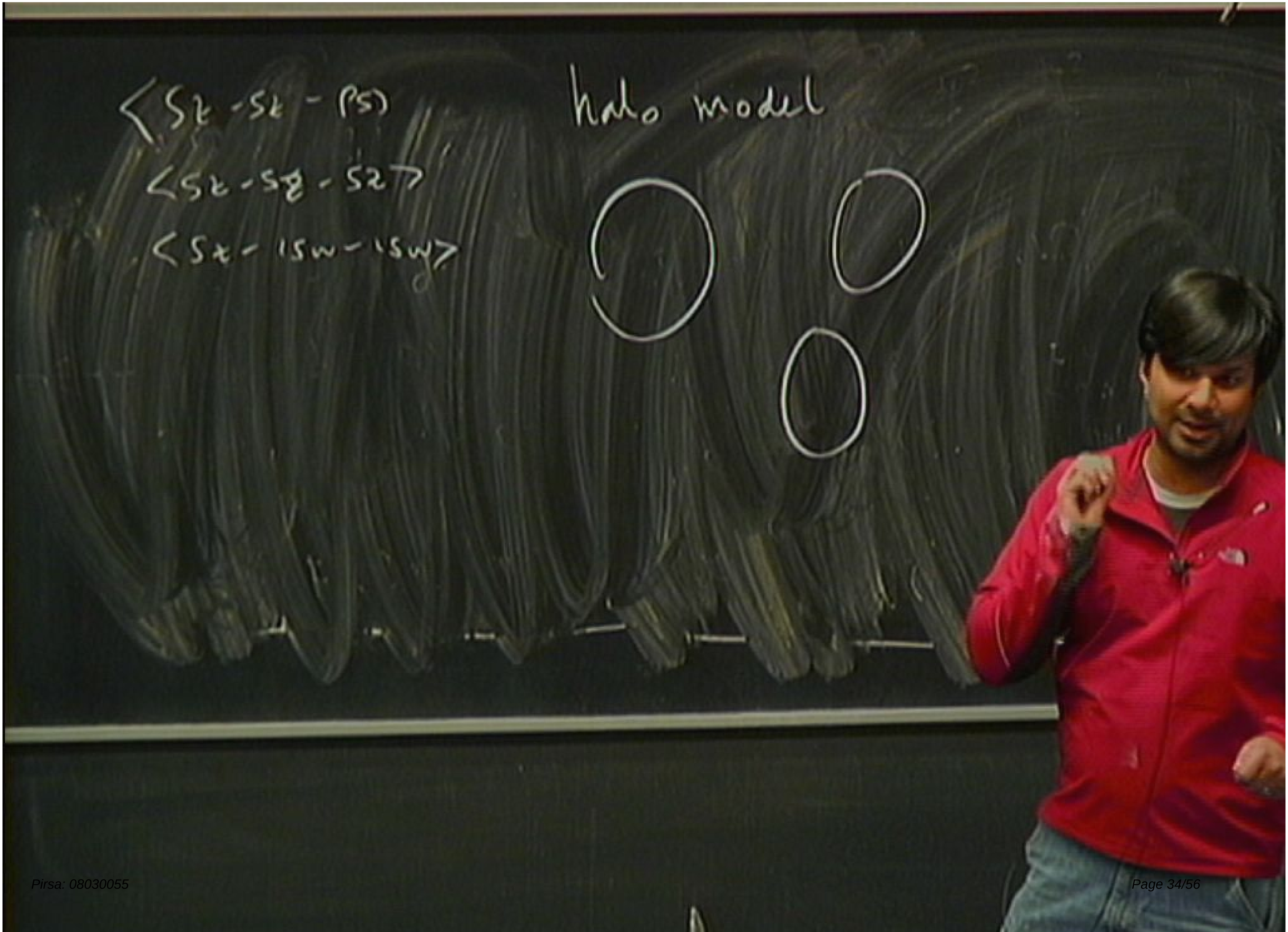


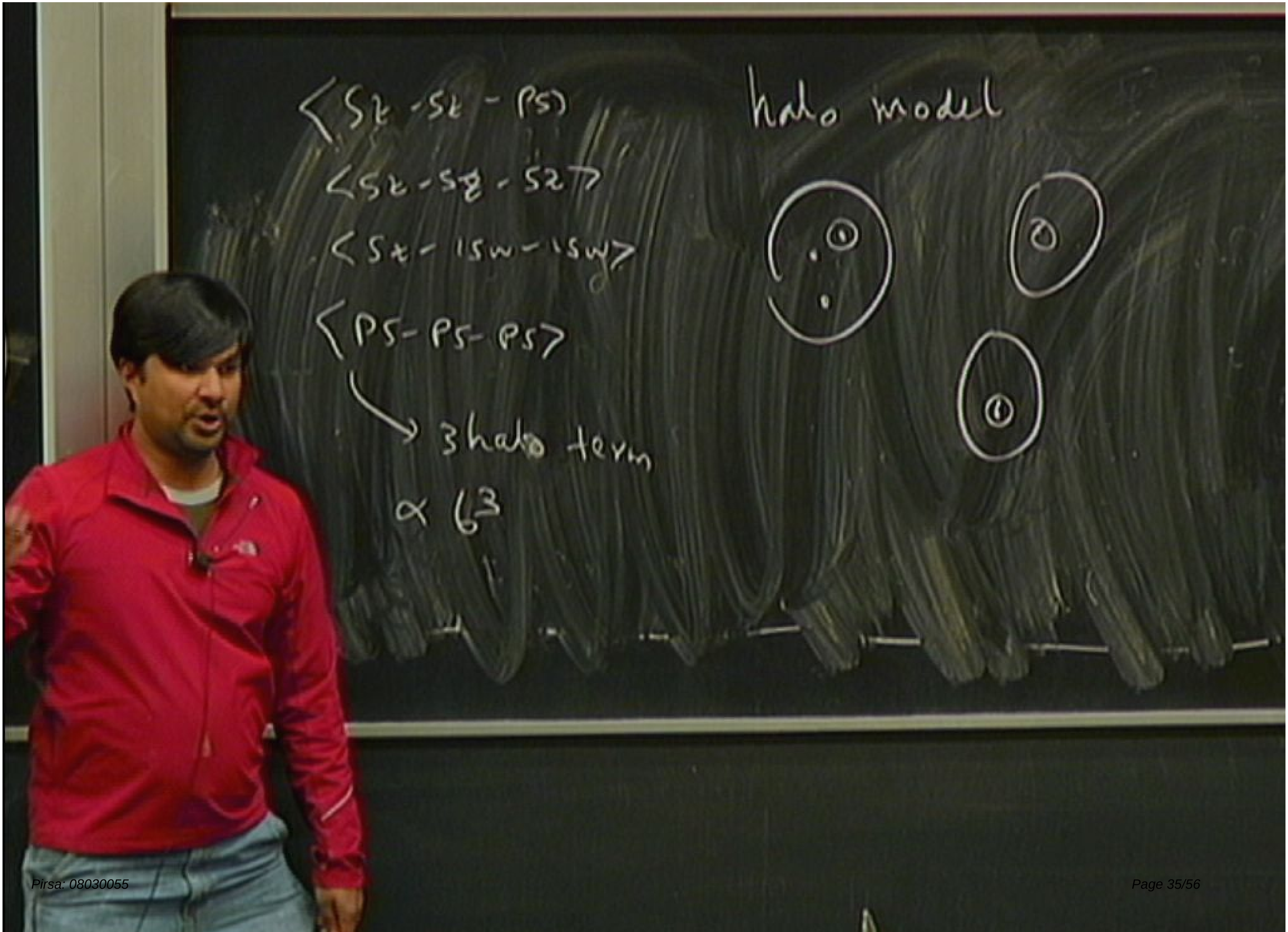
$\langle St - St - Ps)$

$\langle St - Sg - Sz\rangle$

$\langle St - 1Sw - 1Sw\rangle$


< St - St - (PS)
< St - Sg - Sz >
< St - |Sw - |Sw >
halo model


halo model
<St - St - PS)
<St - Sg - Sz>
<St - ISw - ISw>



$\langle Sz - Sz - PS \rangle$

$\langle Sz - Sz - Sz \rangle$

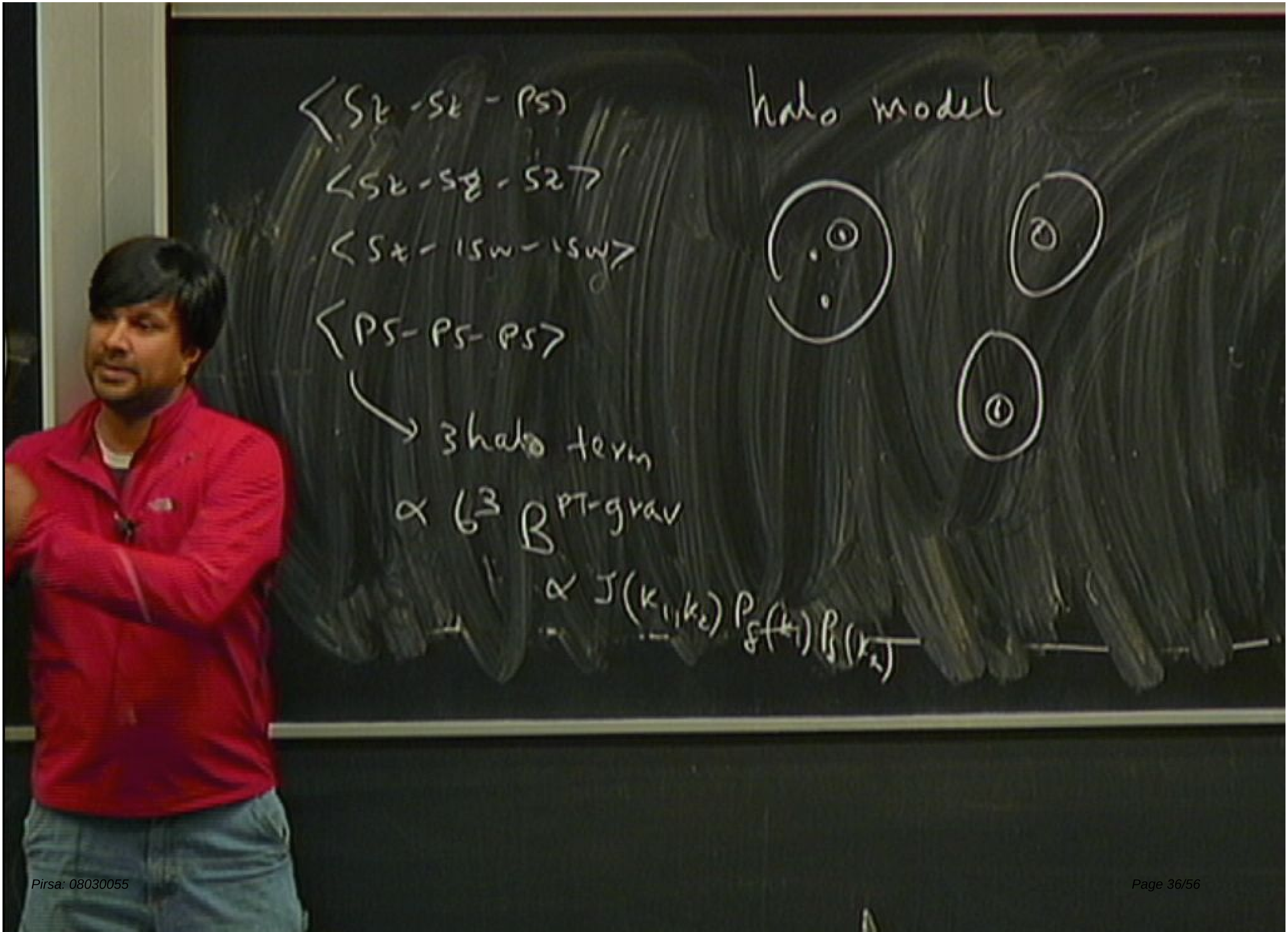
$\langle Sz - ISW - ISW \rangle$

$\langle PS - PS - PS \rangle$

$\searrow$ 3 halo term

$\propto b^3$

halo model



$\langle Sz - Sz - PS\rangle$

$\langle Sz - Sz - Sz\rangle$

$\langle Sz - 1Sw - 1Sw\rangle$

$\langle PS - PS - PS\rangle$

$\searrow$ 3 halo term

$\propto \sigma^3 B^{PT\text{-}grav}$

$\propto J(k_1,k_2)\, P_\delta(k_1)\, P_\delta(k_2)$

halo model

$\langle Sz - Sz - PS \rangle$

$\langle Sz - Sz - Sz \rangle$

$\langle Sz - ISW - ISW \rangle$

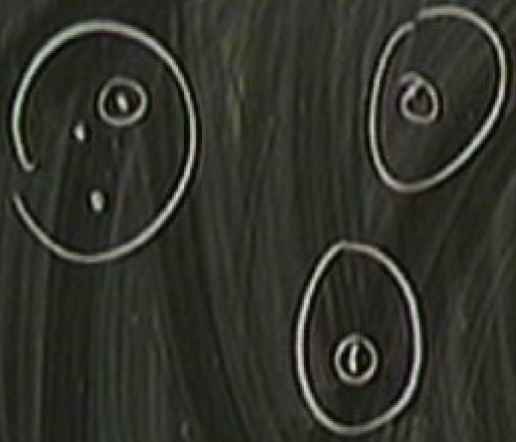
$\langle PS - PS - PS \rangle$

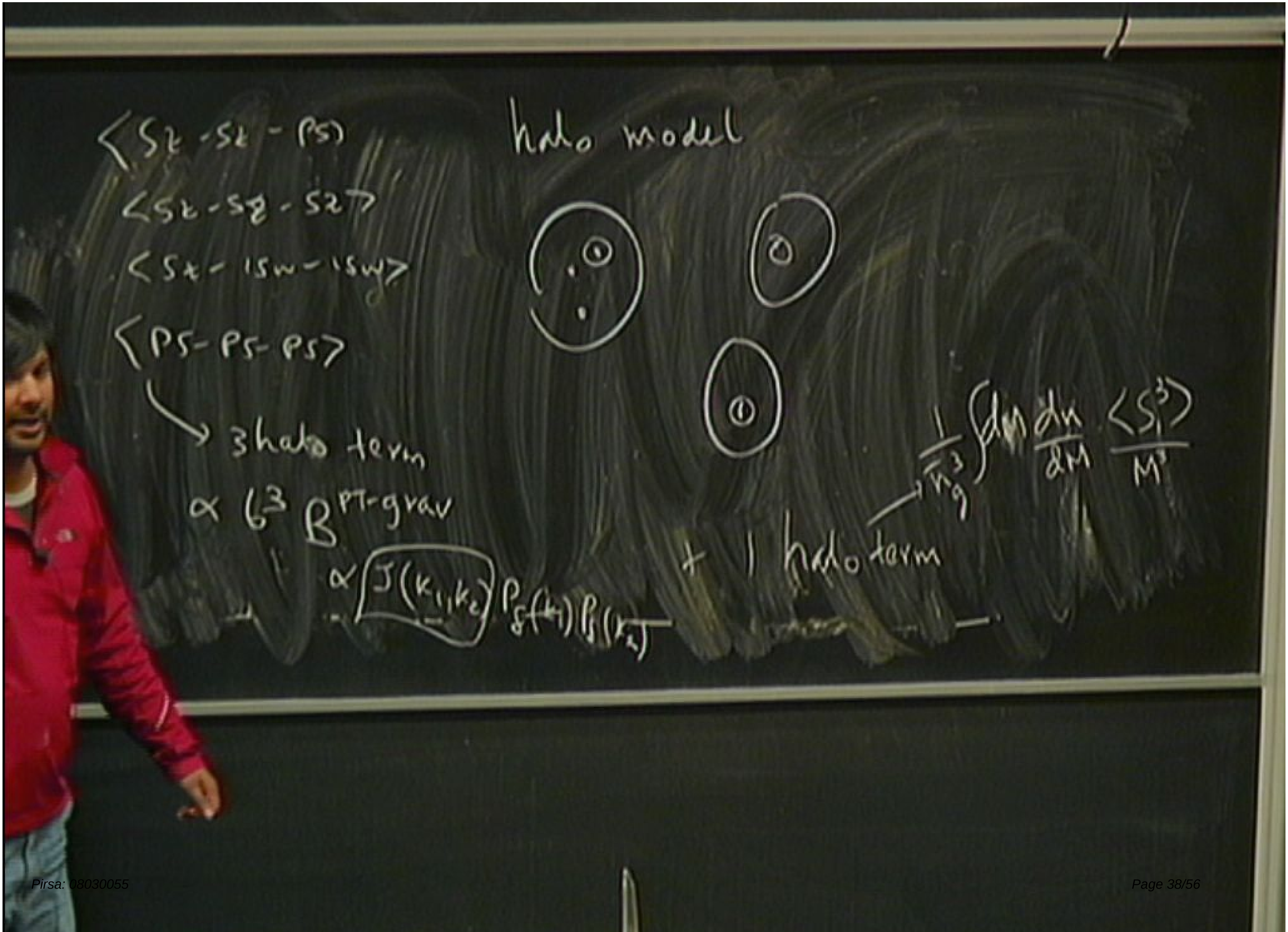
$\searrow$ 3 halo term

$\propto b^3 B^{PT\text{-}grav}$

$\propto \boxed{J(k_1,k_2)} P_\delta(k_1) P_\delta(k_2)$

halo model





halo model

$\langle St - St - PS \rangle$

$\langle St - Sz - Sz \rangle$

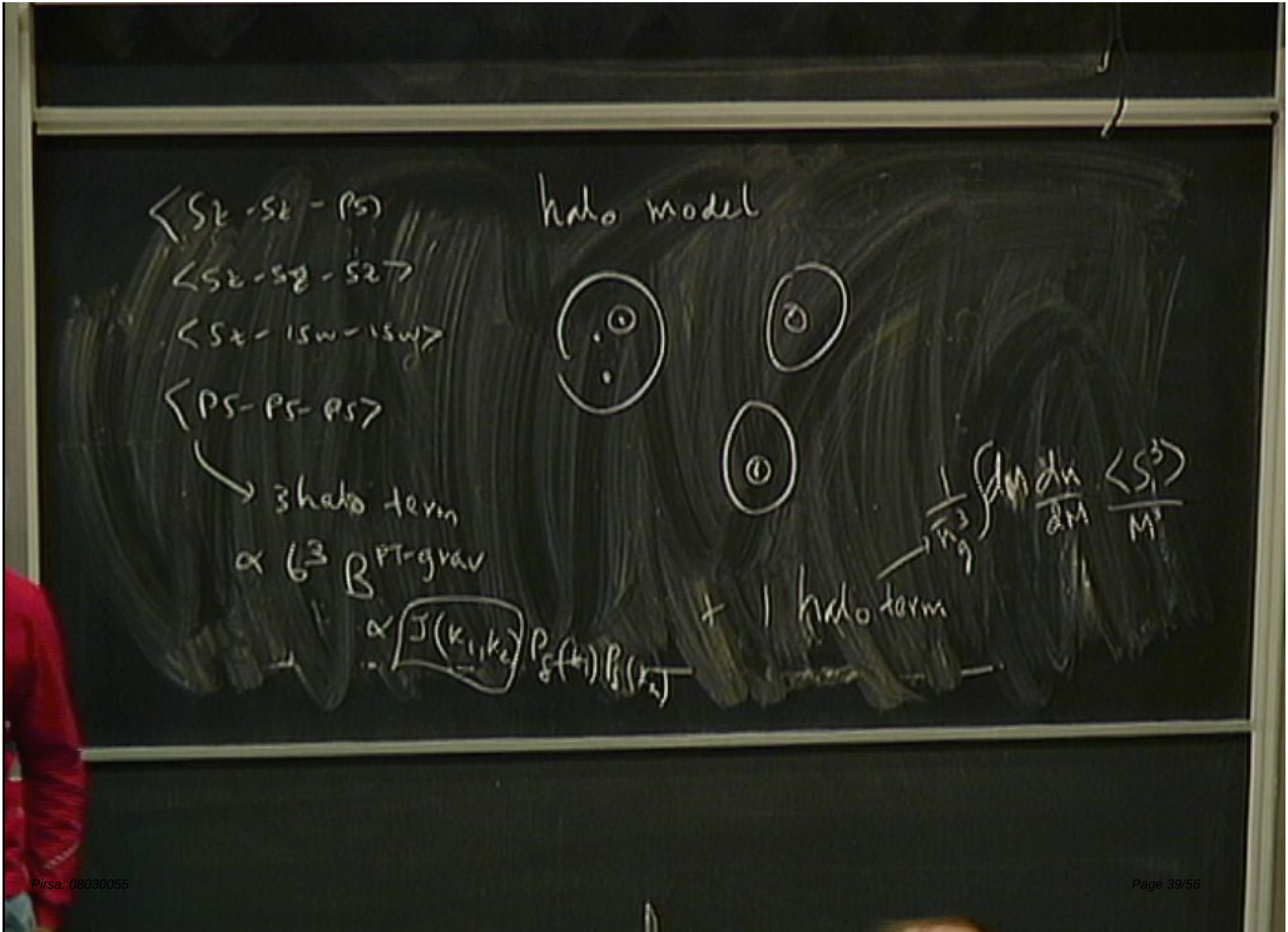
$\langle St - 1Sw - 1Sw \rangle$

$\langle PS - PS - PS \rangle$

→ 3 halo term

$\propto \sigma^3 B^{PT\text{-}grav}$

$\propto \boxed{J(k_1,k_2)} P_\delta(k_1) P_\delta(k_2)$ + 1 halo term → $\frac{1}{\bar{n}_g^3}\int dm \frac{dn}{dM} \frac{\langle S^3 \rangle}{M^3}$



halo model

$\langle SZ - SZ - PS \rangle$

$\langle SZ - SZ - SZ \rangle$

$\langle SZ - ISW - ISW \rangle$

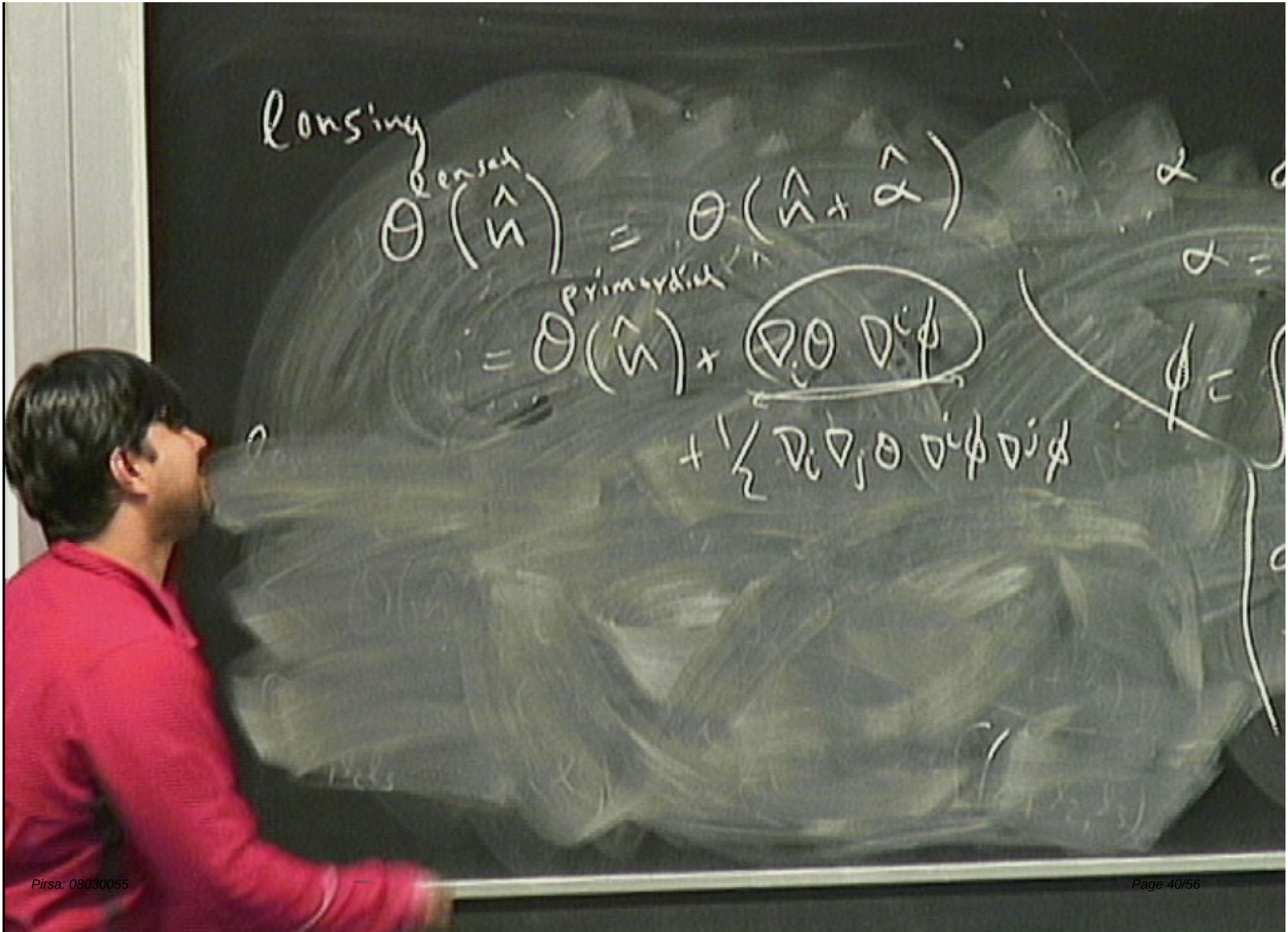
$\langle PS - PS - PS \rangle$

$\searrow$ 3 halo term

$\propto \sigma^3 \, B^{PT\text{-}grav}$

$\propto \boxed{J(k_1,k_2)} \, P_\delta(k_1) \, P_\delta(k_2)$

$+$ 1 halo term $\rightarrow \frac{1}{\bar{n}_g^3} \int dM \frac{dn}{dM} \frac{\langle S^3 \rangle}{M^3}$



lensing

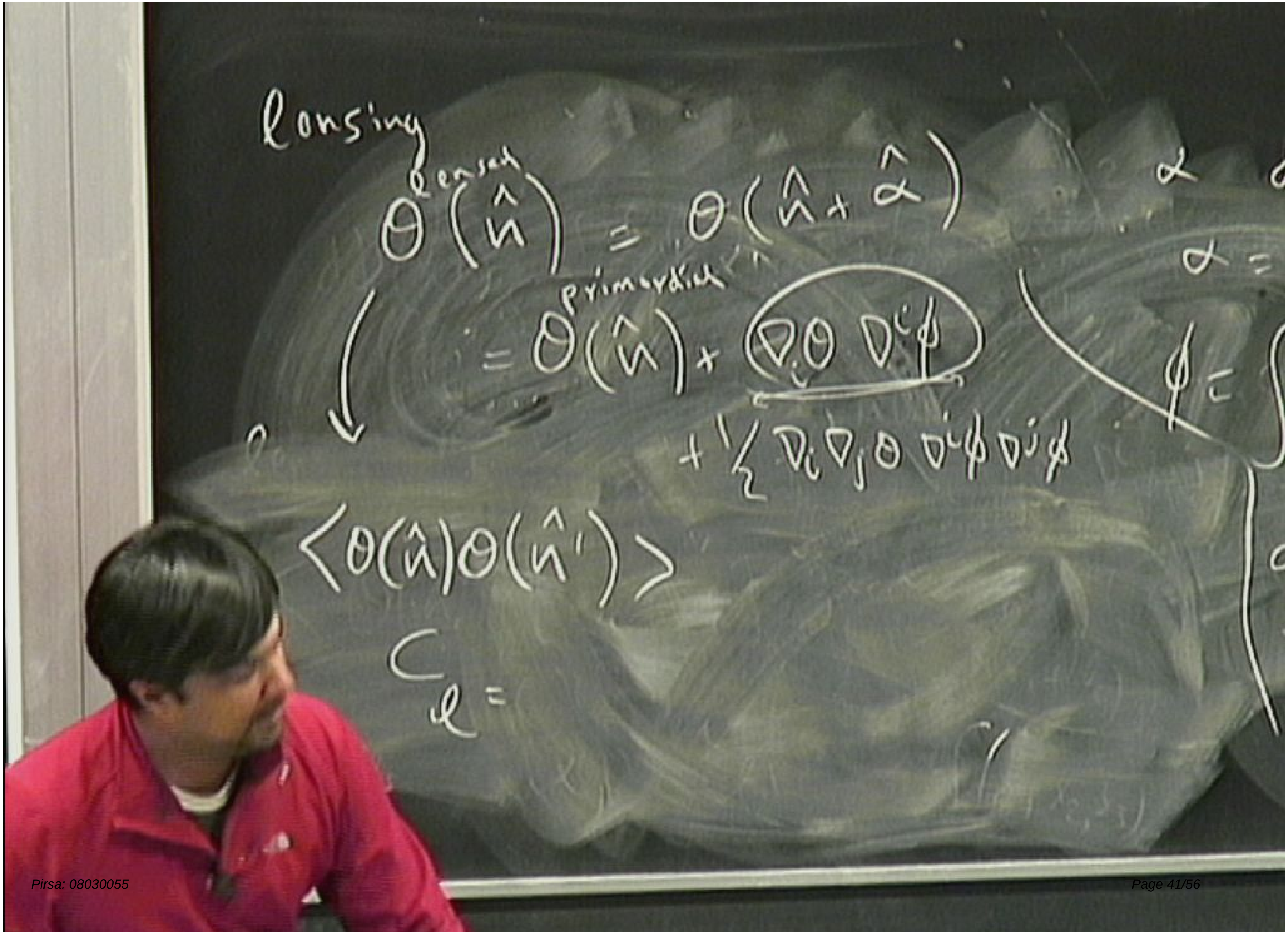
$$\overset{\text{lensed}}{\Theta}(\hat{n}) = \Theta(\hat{n}+\hat{\alpha})$$

$$= \overset{\text{primordial}}{\Theta}(\hat{n}) + \boxed{\nabla_i\Theta\,\nabla^i\phi} + \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

α

$\alpha =$

$\phi =$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n}+\hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \underline{\boxed{\nabla_i\Theta\,\nabla^i\phi}}$$

$$+ \tfrac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

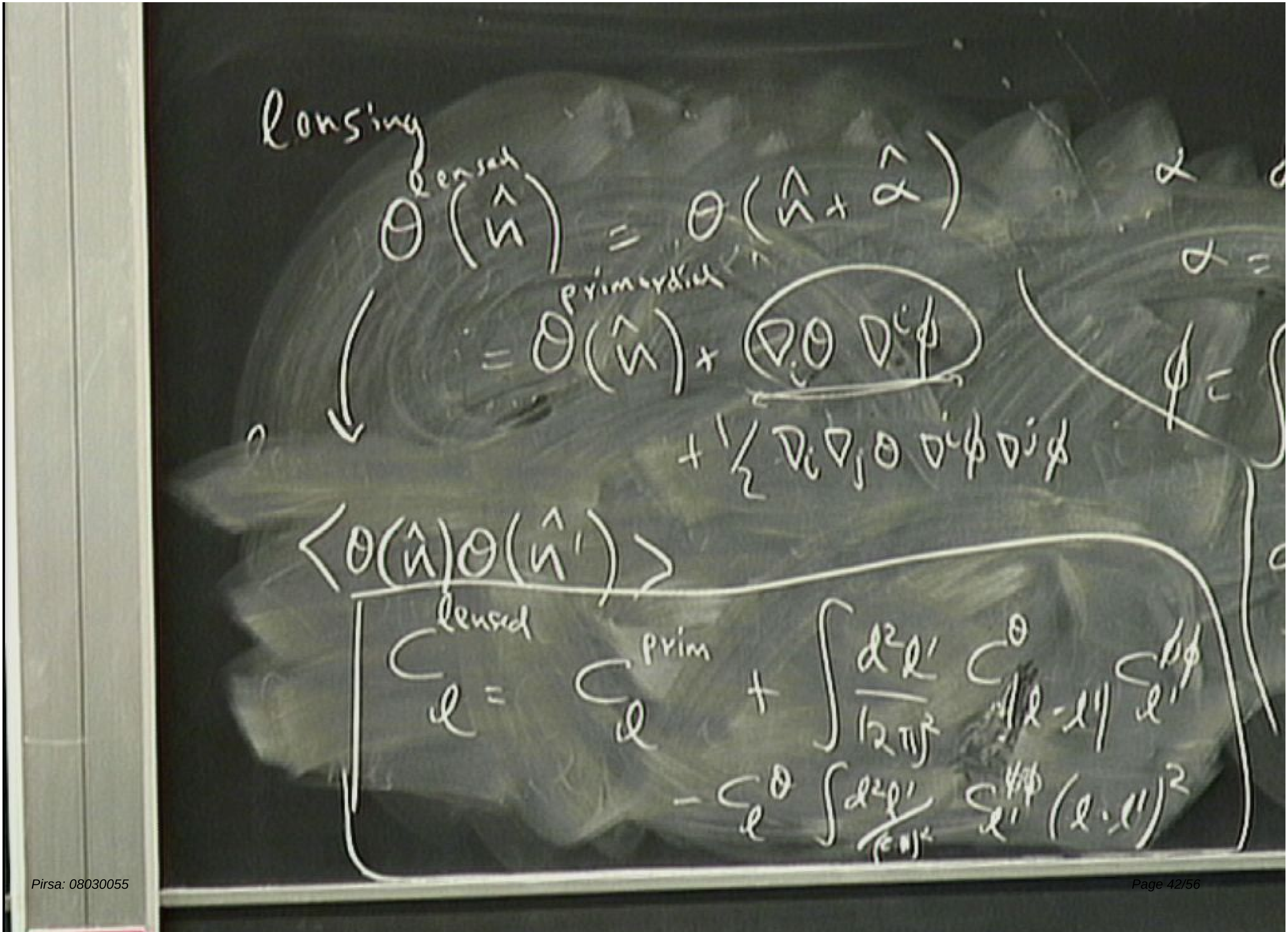
$$\langle\Theta(\hat{n})\Theta(\hat{n}')\rangle$$

$$C_\ell =$$

α

$\alpha =$

$\phi =$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \nabla_i\Theta\, \nabla^i\phi$$

$$+ \tfrac{1}{2} \nabla_i\nabla_j\Theta\, \nabla^i\phi\, \nabla^j\phi$$

α

$\alpha =$

$\phi =$

$$\langle \Theta(\hat{n})\Theta(\hat{n}') \rangle$$

$$C_\ell^{\text{lensed}} = C_\ell^{\text{prim}} + \int \frac{d^2\ell'}{(2\pi)^2}\, C^{\Theta}_{|\ell-\ell'|}\, C_{\ell'}^{\phi\phi}$$

$$- C_\ell^{\Theta} \int \frac{d^2\ell'}{(2\pi)^2}\, C_{\ell'}^{\phi\phi}\, (\ell\cdot\ell')^2$$

lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

α deflection angle.

$$\alpha = \nabla\phi$$

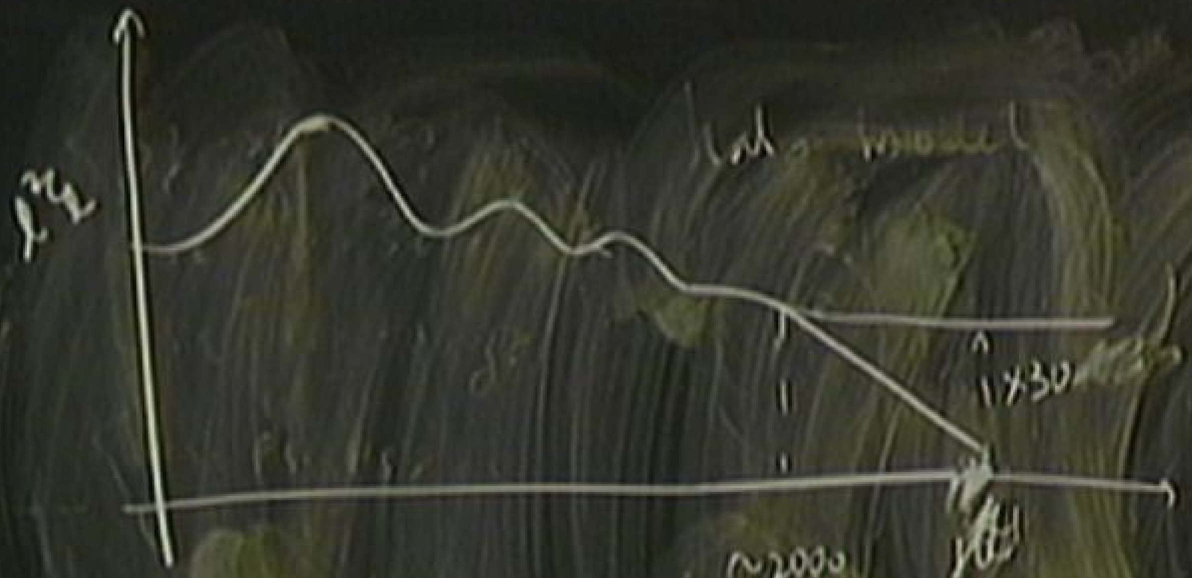
$$= \Theta^{\text{primordial}}(\hat{n}) + \nabla_i\Theta\,\nabla^i\phi + \frac{1}{2}\nabla_i\nabla_j\Theta\,\nabla^i\phi\,\nabla^j\phi$$

$$\phi = \int d\chi\, W(\chi)\,\Phi(\hat{n}, r\hat{n})$$

$$\frac{d_A(\chi_{\text{dec}} - \chi)}{d_A(\chi_{\text{dec}})\,d_A(\chi)}$$

$$\langle\Theta(\hat{n})\Theta(\hat{n}')\rangle$$

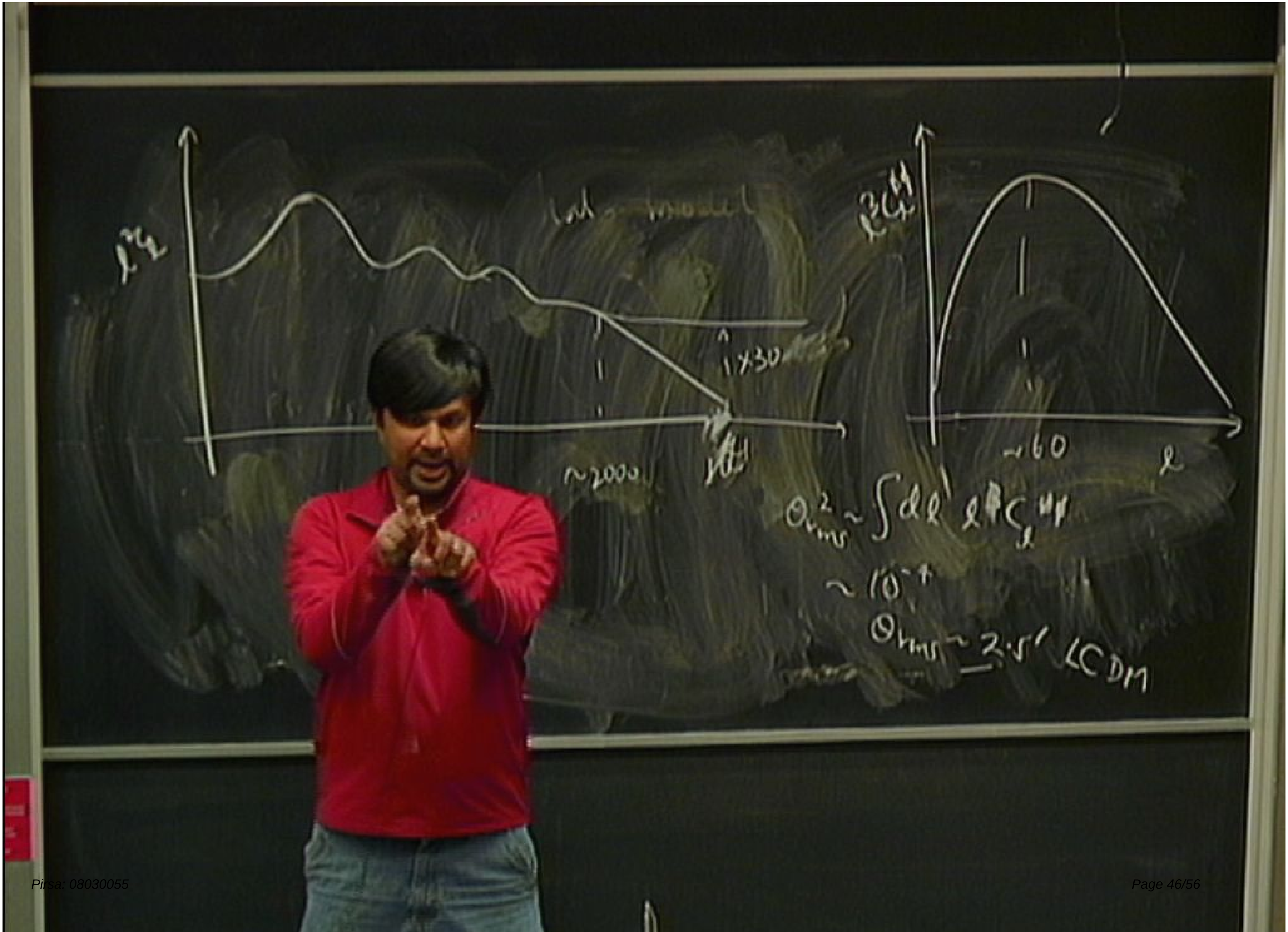
$$C_\ell^{\text{lensed}} = C_\ell^{\text{prim}} + \int\frac{d^2\ell'}{(2\pi)^2}\,C^{\Theta}_{|\ell-\ell'|}\,C^{\phi\phi}_{\ell'} - C_\ell^{\Theta}\int\frac{d^2\ell'}{(2\pi)^2}\,C^{\phi\phi}_{\ell'}\,(\ell\cdot\ell')^2$$


$l^2 C_l$
Std. model
1×30
~2000

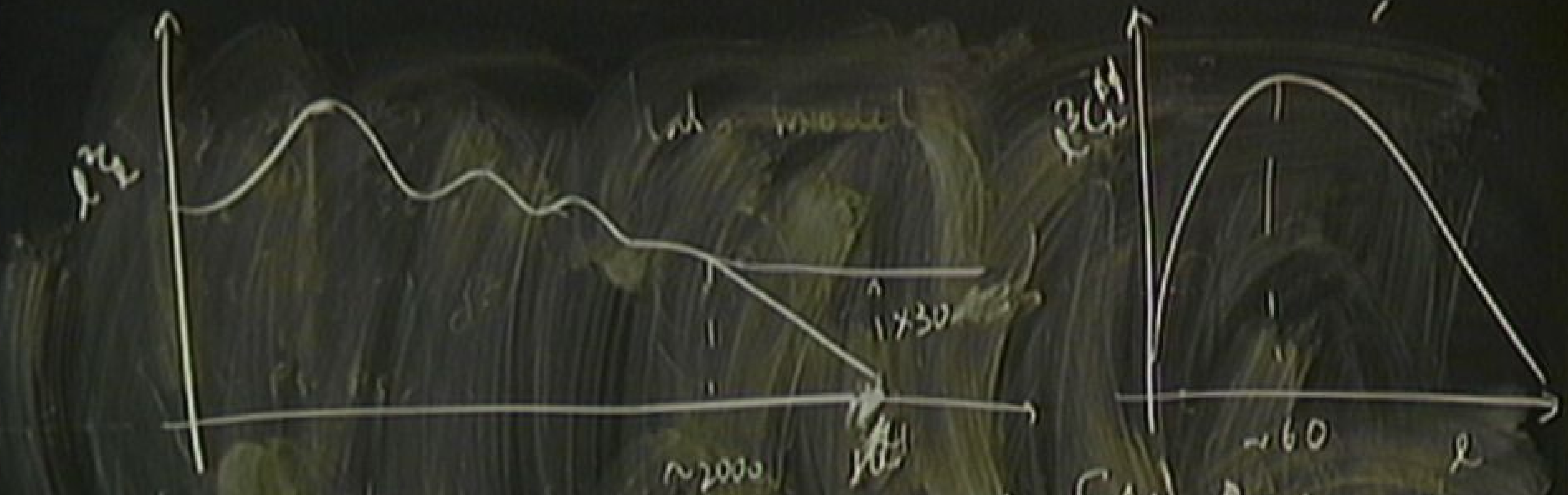
$$m + \int \frac{d^2\ell'}{(2\pi)^2} C^{\theta}_{|\ell-\ell'|} C^{\phi\phi}_{\ell'}$$

$$- C^{\theta}_{\ell} \int \frac{d^2\ell'}{(2\pi)^2} C^{\phi\phi}_{\ell'} (\ell\cdot\ell')^2$$

$$\frac{d_A}{d}$$



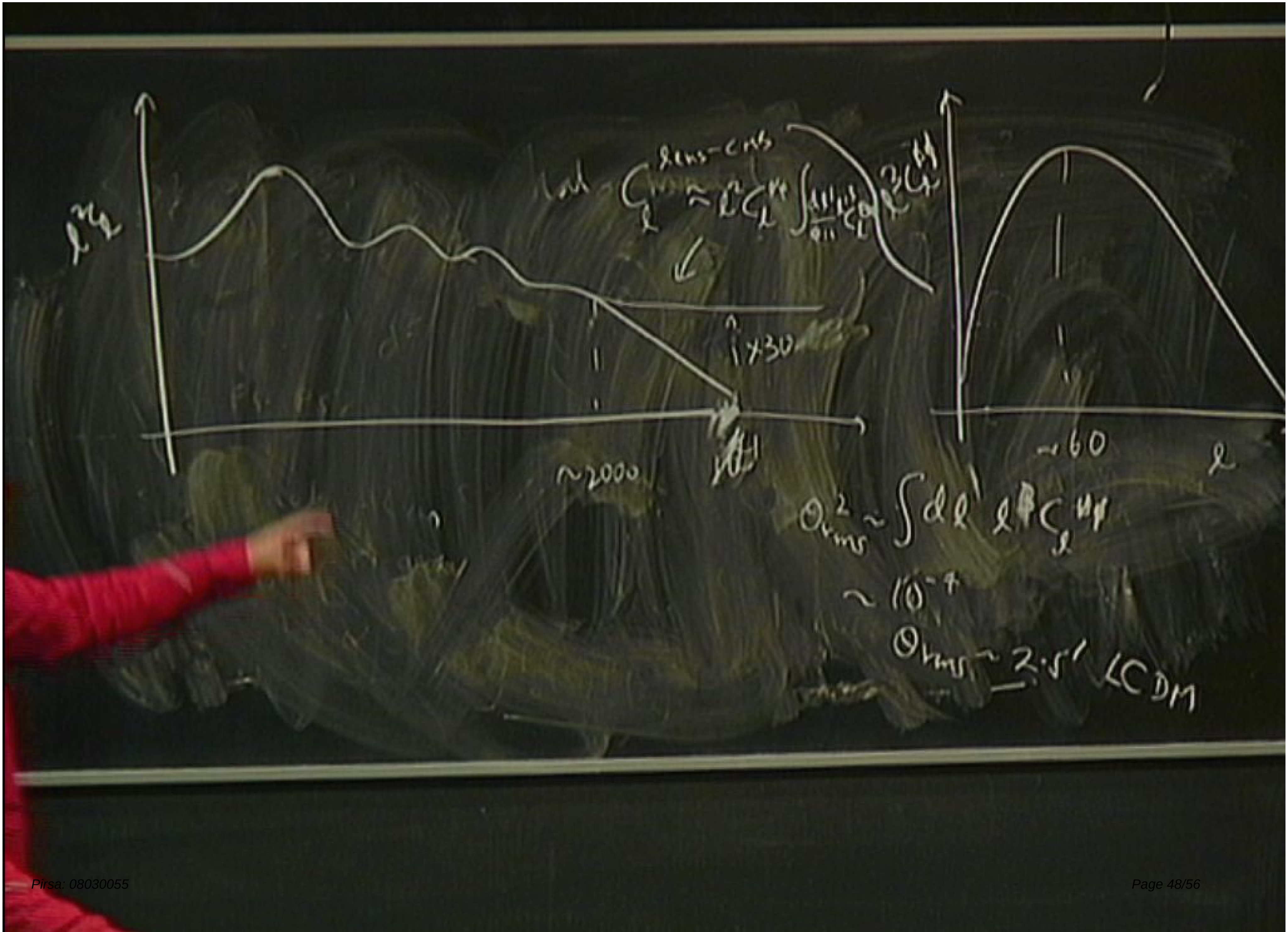
l²C_l
LCDM model
×30
~2000
~10⁴
l²C_l^φφ
~60
l
Θ²_rms ~ ∫dl l³C_l^φφ
~ 10⁻⁷
Θ_rms ~ 2.5' LCDM



$$\Theta_{rms}^2 \sim \int d\ell\, \ell\, C_\ell^{\psi\psi}$$

$$\sim 10^{-7}$$

$$\Theta_{rms} \sim 2.5' \quad \text{LCDM}$$

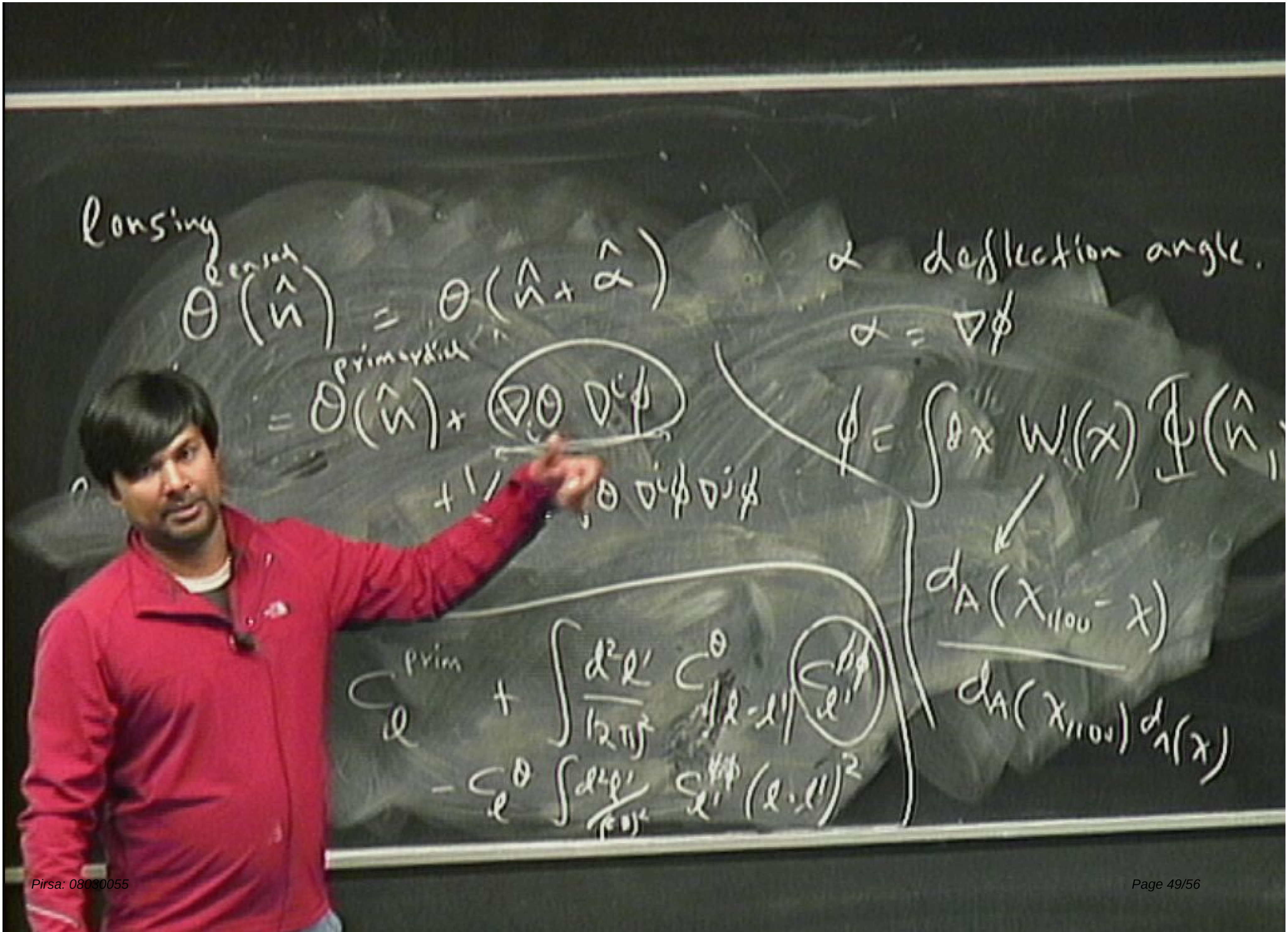


$$C_\ell^{\text{lens-CMB}} \sim \ell C_\ell^{TT} \int \frac{d\ell'}{\ldots} C_{\ell'} \ldots C_\ell^{\phi\phi}$$

$$\Theta_{rms}^2 \sim \int d\ell\, \ell^3 C_\ell^{\phi\phi}$$

$$\sim 10^{-7}$$

$$\Theta_{rms} \sim 2.5' \quad \Lambda CDM$$



lensing

$$\Theta^{\text{lensed}}(\hat{n}) = \Theta(\hat{n} + \hat{\alpha})$$

α deflection angle.

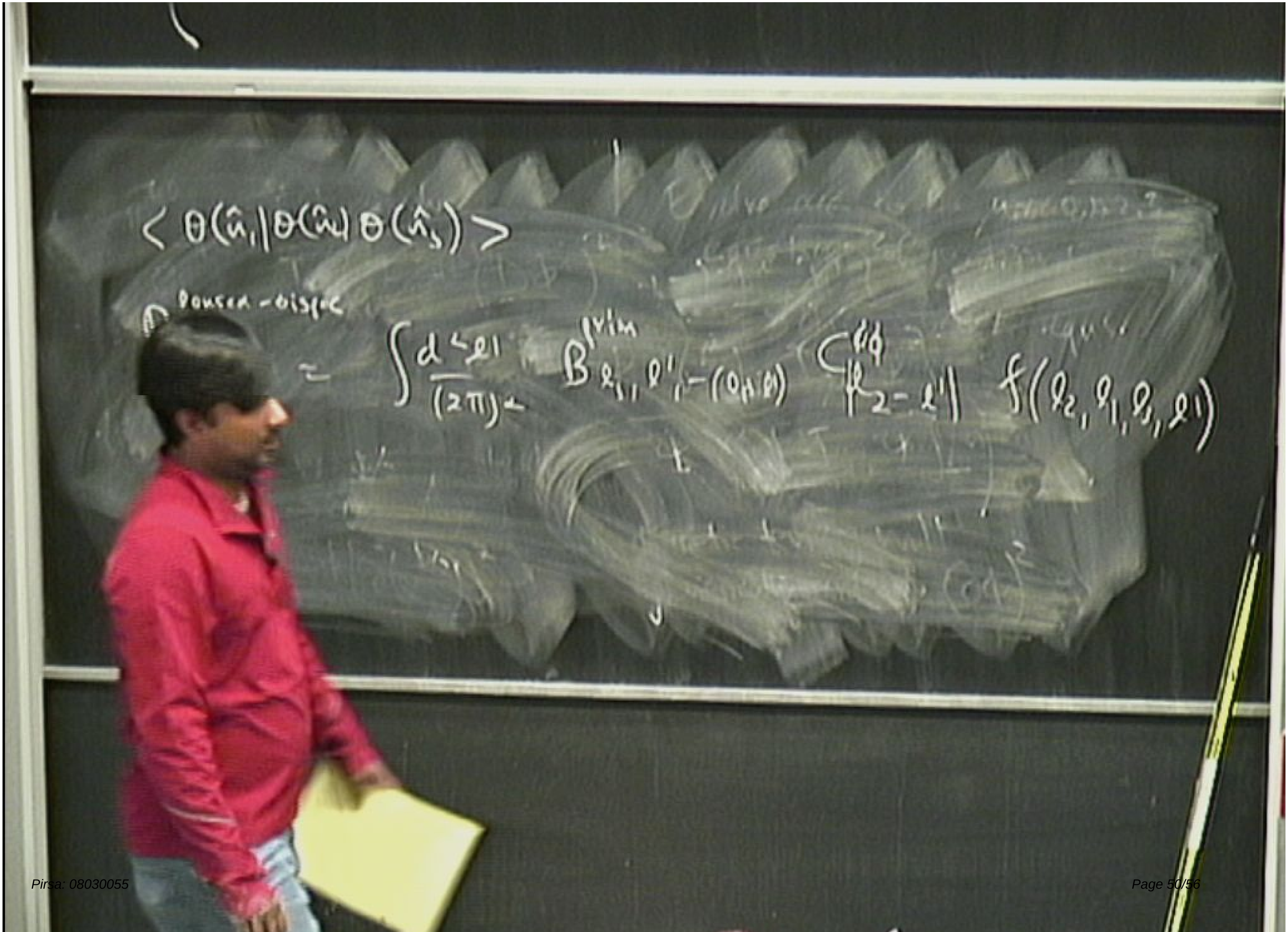
$$\alpha = \nabla\phi$$

$$= \Theta^{\text{primordial}}(\hat{n}) + \boxed{\nabla_i\Theta\, \nabla^i\phi} + 1/ \ \Theta\, \nabla^i\phi\, \nabla^j\phi$$

$$\phi = \int d\chi\, W(\chi)\, \Phi(\hat{n},$$

$$W \rightarrow \frac{d_A(\chi_{1100} - \chi)}{d_A(\chi_{1100})\, d_A(\chi)}$$

$$C_\ell^{\text{prim}} + \int \frac{d^2\ell'}{(2\pi)^2}\, C^\Theta_{|\ell-\ell'|}\, \boxed{C^{\phi\phi}_{\ell'}} - C_\ell^\Theta \int \frac{d^2\ell'}{(2\pi)^2}\, C^{\phi\phi}_{\ell'}\, (\ell\cdot\ell')^2$$



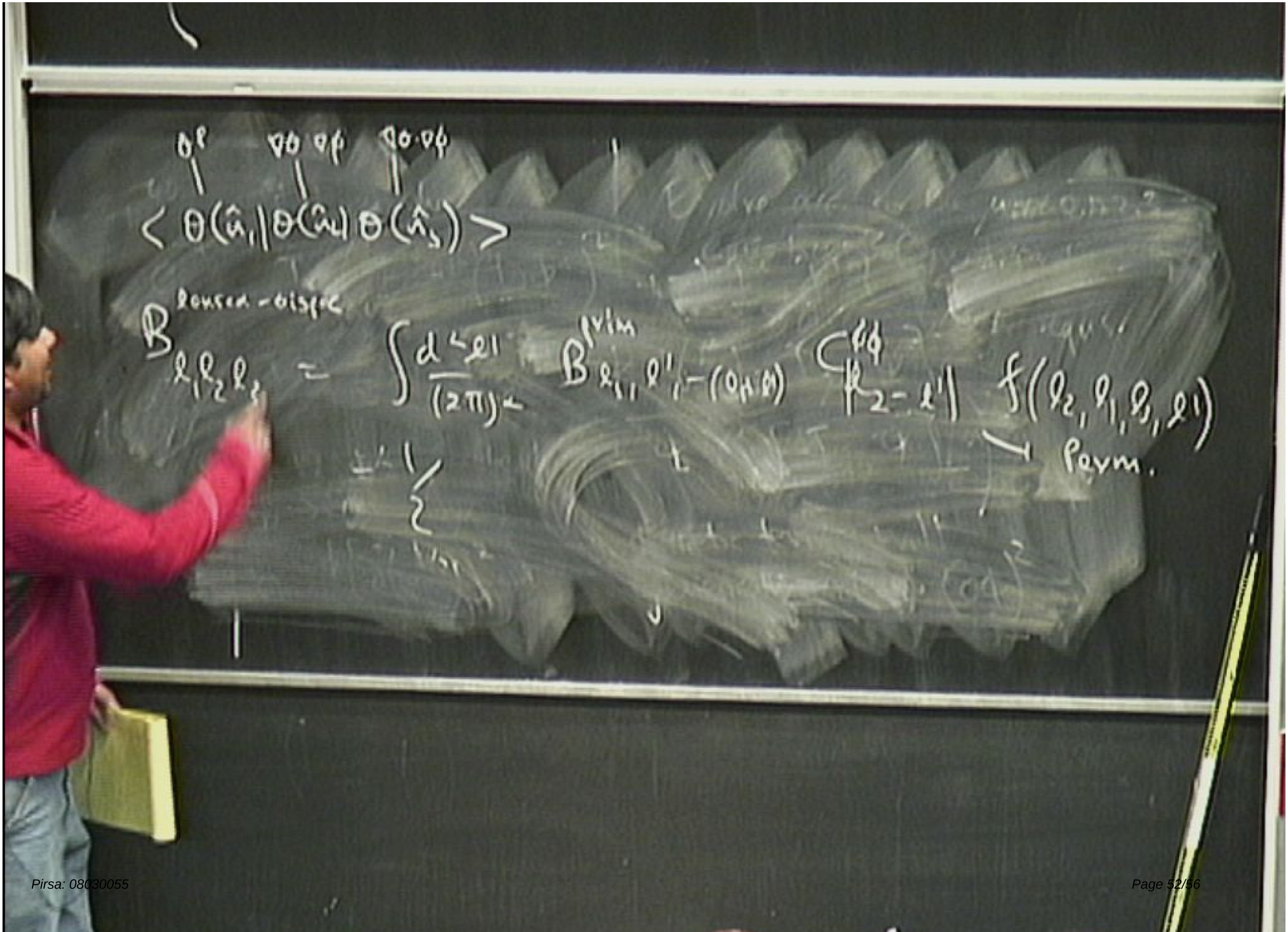
$$\langle \Theta(\hat{n}_1)\Theta(\hat{n}_2)\Theta(\hat{n}_3)\rangle$$

Poisson-discrete

$$= \int \frac{d^2 l'}{(2\pi)^2} B^{lvim}_{l_1, l', -(l_1+l')} C^{\phi\phi}_{|l_2 - l'|} f(l_2, l_1, l_3, l')$$

$$\langle \overset{\theta^{\ell}}{\theta(\hat{n}_1)}\,\overset{\nabla\theta\;\nabla\phi}{\theta(\hat{n}_2)}\,\overset{\nabla\theta\cdot\nabla\phi}{\theta(\hat{n}_3)} \rangle$$

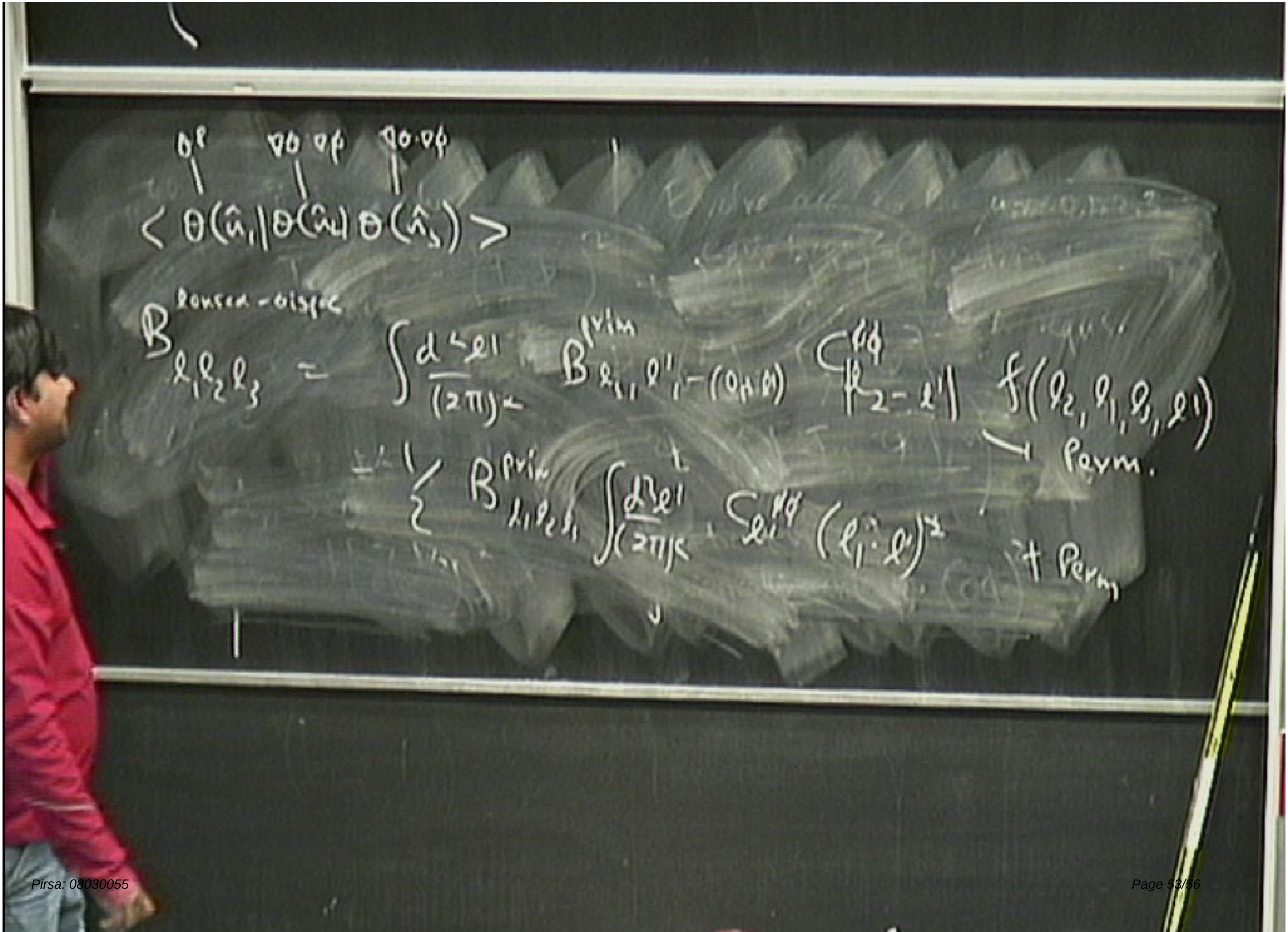
$$B^{\text{lensed-bispec}}_{\ell_1\ell_2\ell_3} = \int \frac{d^2\ell'}{(2\pi)^2}\, B^{\text{prim}}_{\ell_1,\ell',-(\ell_1+\ell')}\, C^{\phi\phi}_{|\ell_2-\ell'|}\, f(\ell_2,\ell_1,\ell_3,\ell')$$



θ^{ℓ} $\nabla\theta\cdot\nabla\phi$ $\nabla\theta\cdot\nabla\phi$

$$\langle \Theta(\hat{n}_1)\Theta(\hat{n}_2)\Theta(\hat{n}_3)\rangle$$

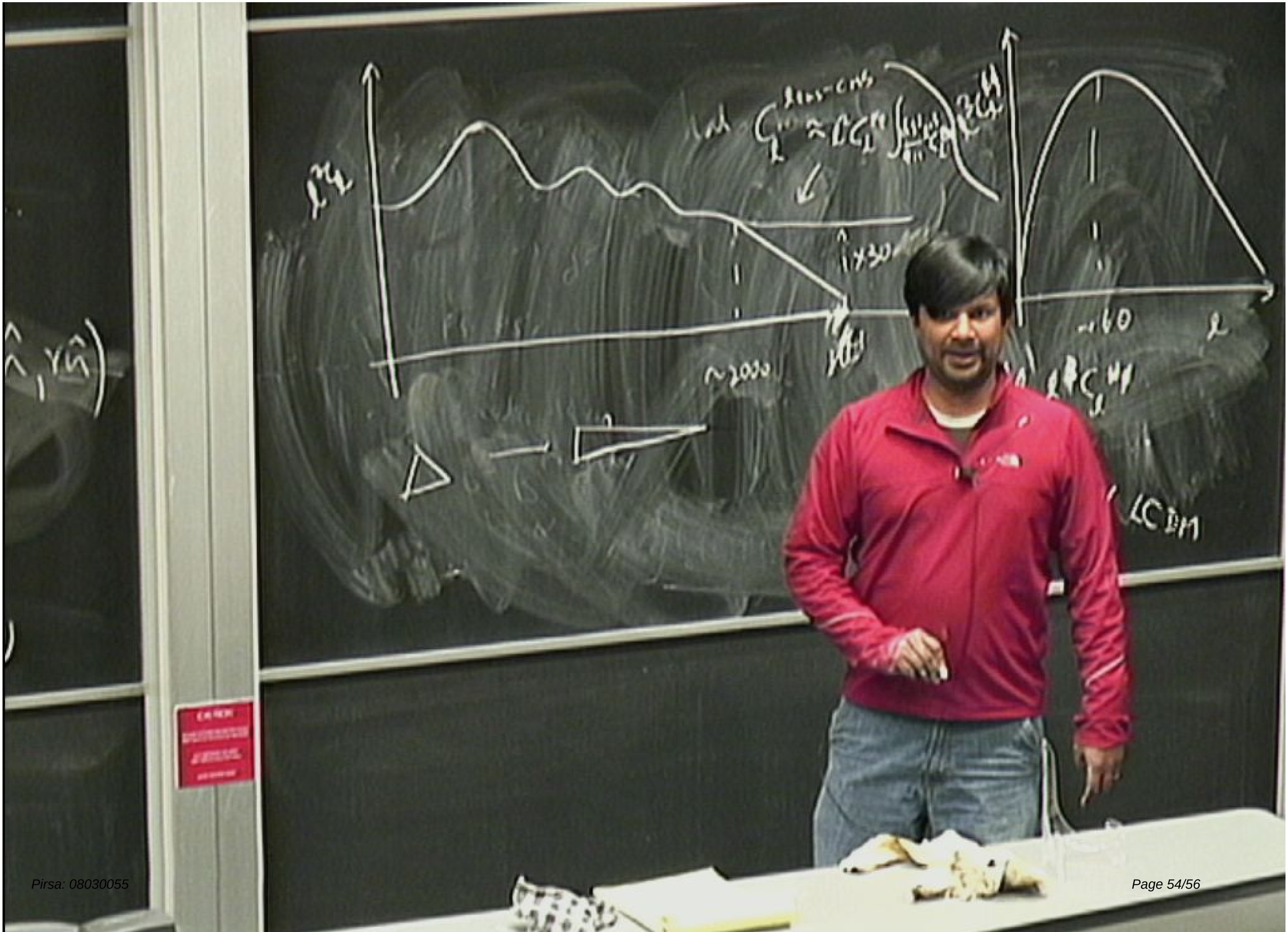
$$B^{\text{lensed-bispec}}_{\ell_1\ell_2\ell_3} = \int \frac{d^2\ell'}{(2\pi)^2} B^{\text{prim}}_{\ell_1,\ell',-(\ell_1+\ell)} C^{\phi\phi}_{|\ell_2-\ell'|} f(\ell_2,\ell_1,\ell_3,\ell') \rightarrow \text{Perm.}$$

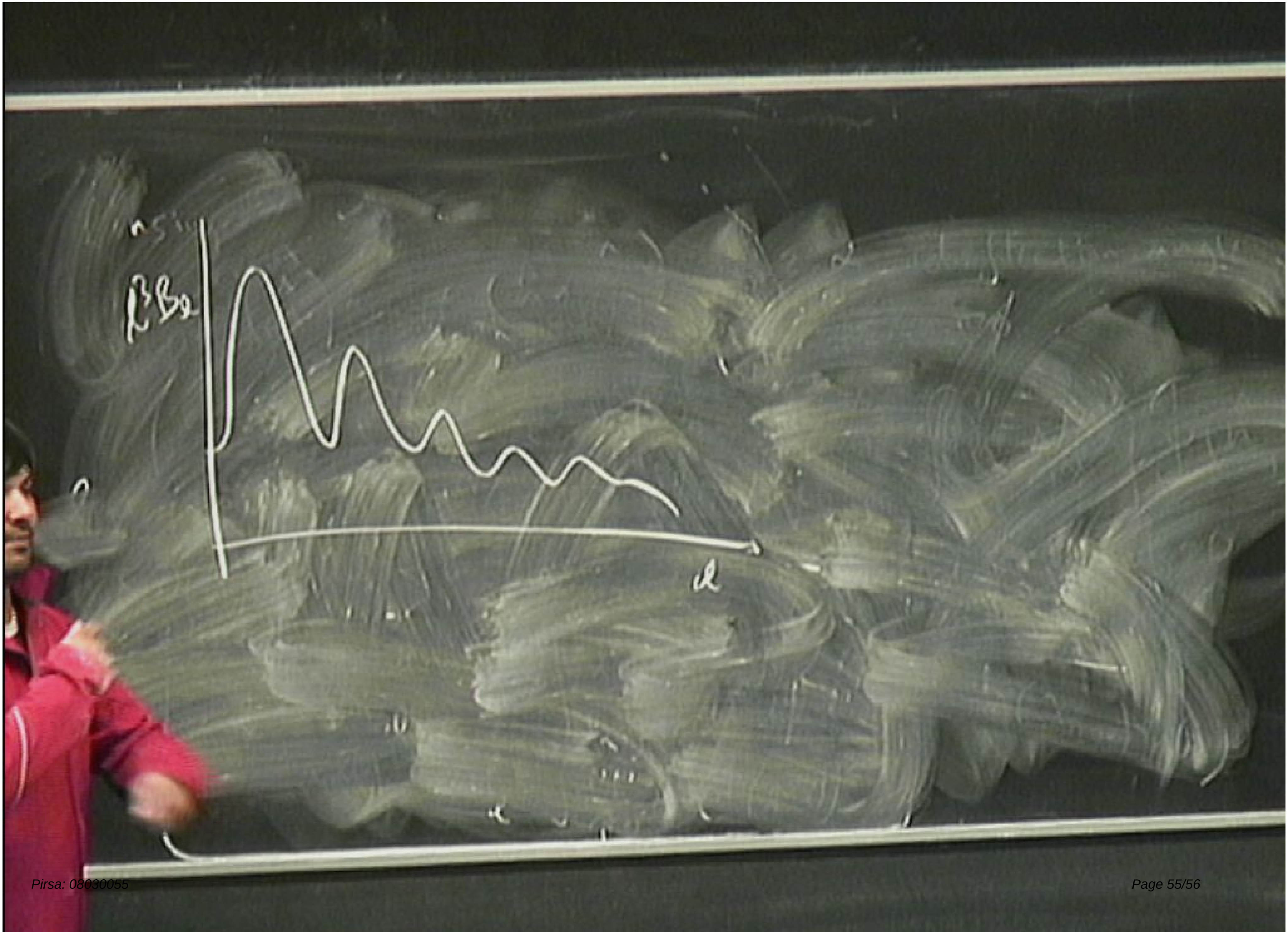


$$\overset{\theta^P}{\langle \Theta(\hat n_1)}\,\overset{\nabla\theta\cdot\nabla\phi}{\Theta(\hat n_2)}\,\overset{\nabla\theta\cdot\nabla\phi}{\Theta(\hat n_3)\rangle}$$

$$B^{\text{lensed-ISW}}_{l_1 l_2 l_3} = \int \frac{d^2 l'}{(2\pi)^2} B^{\text{prim}}_{l_1, l', -(l_1+l')} C^{\phi\phi}_{|l_2 - l'|} f(l_2, l_1, l_3, l') + \text{Perm.}$$

$$\sim \left\{ B^{\text{prim}}_{l_1 l_2 l_3} \int \frac{d^2 l'}{(2\pi)^2} C^{\phi\phi}_{l'} (\hat l_1 \cdot l')^2 \right. + \text{Perm}$$


~2000
×30
~60
ℓ
ΛCDM


$\ell^3 B_\ell$
ℓ


$\ell^3 B_\ell$
ℓ