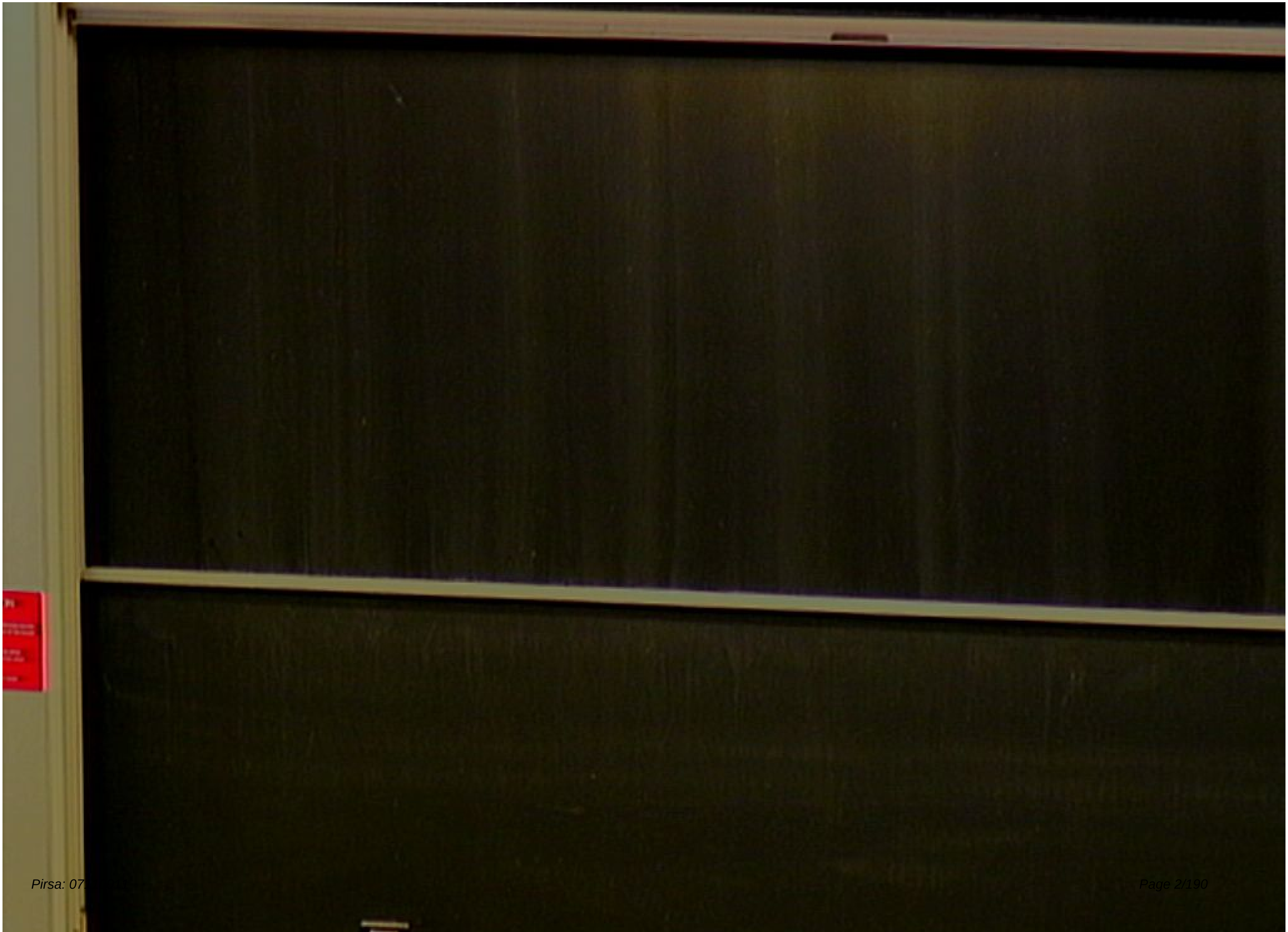
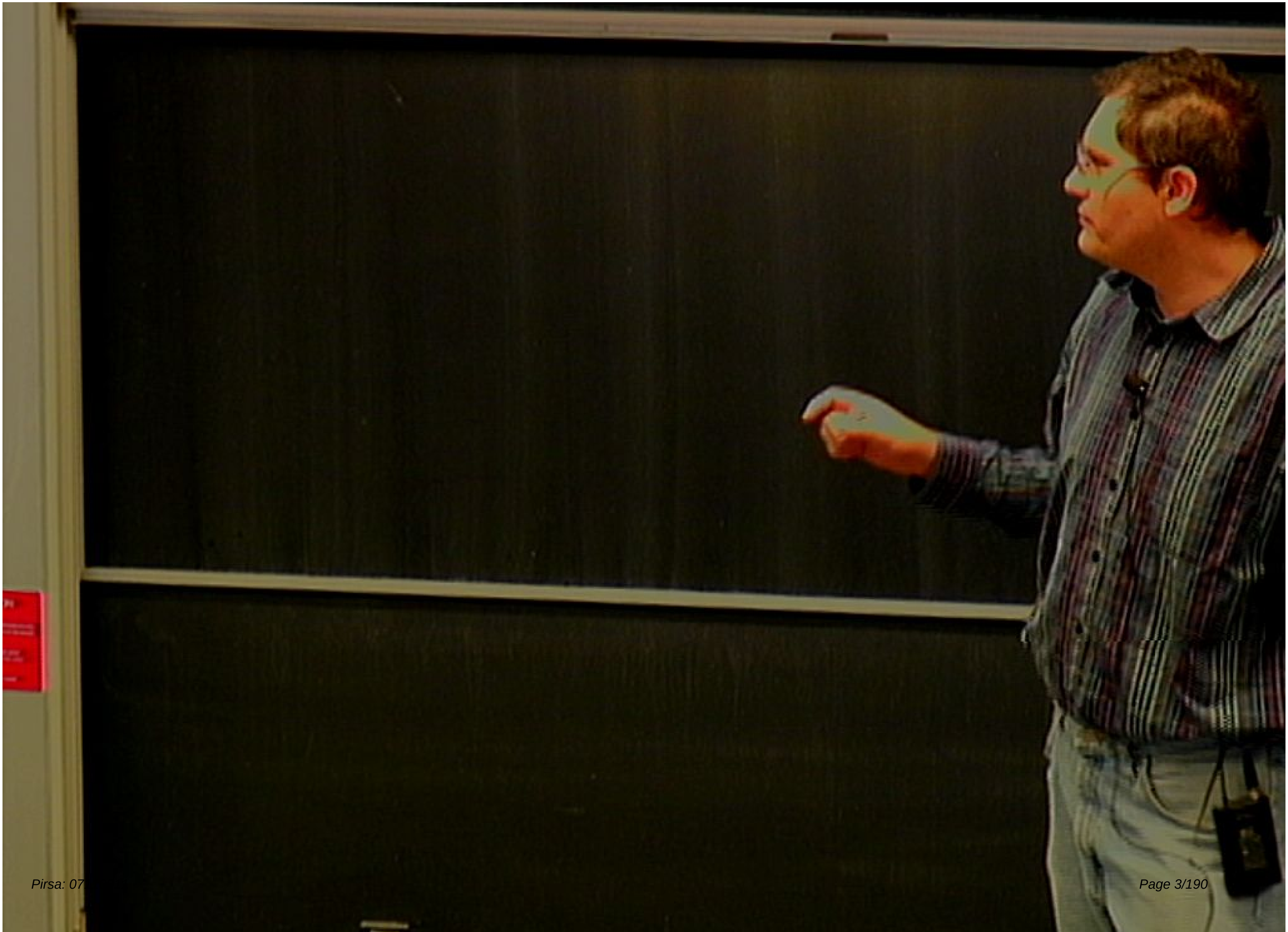
Title: Intro to Supersymmetry 15

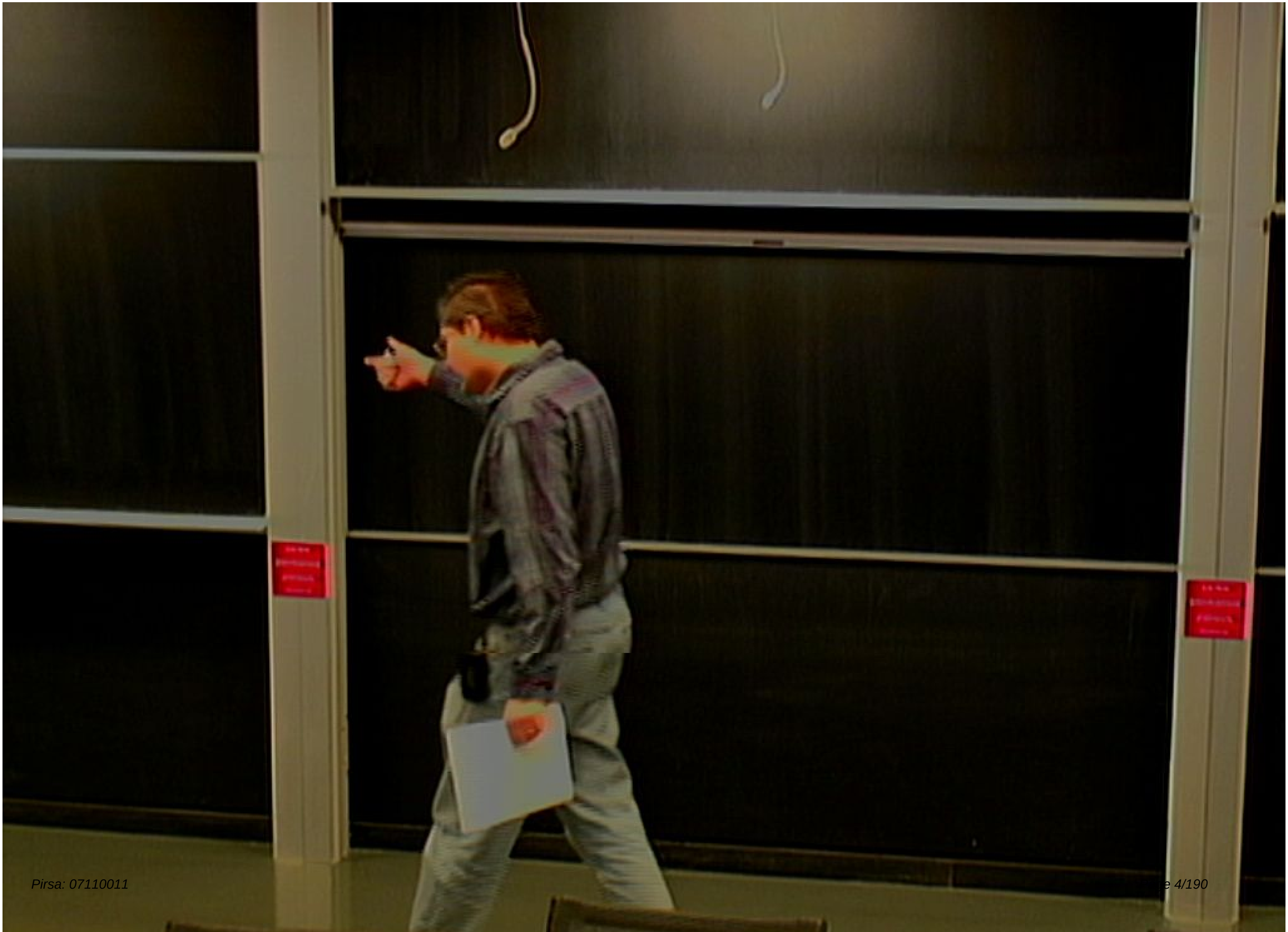
Date: Nov 06, 2007 12:30 PM

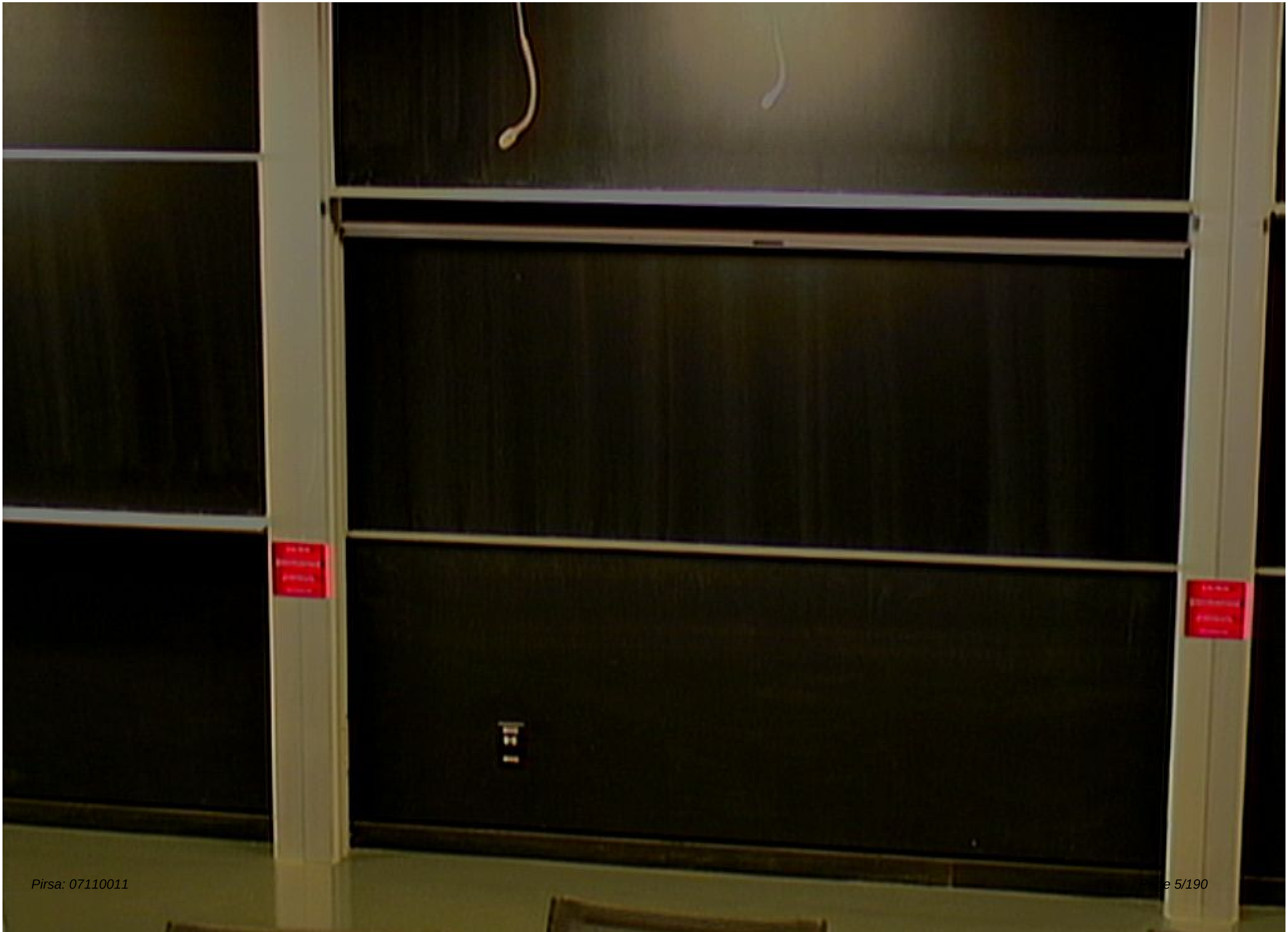
URL: http://pirsa.org/07110011

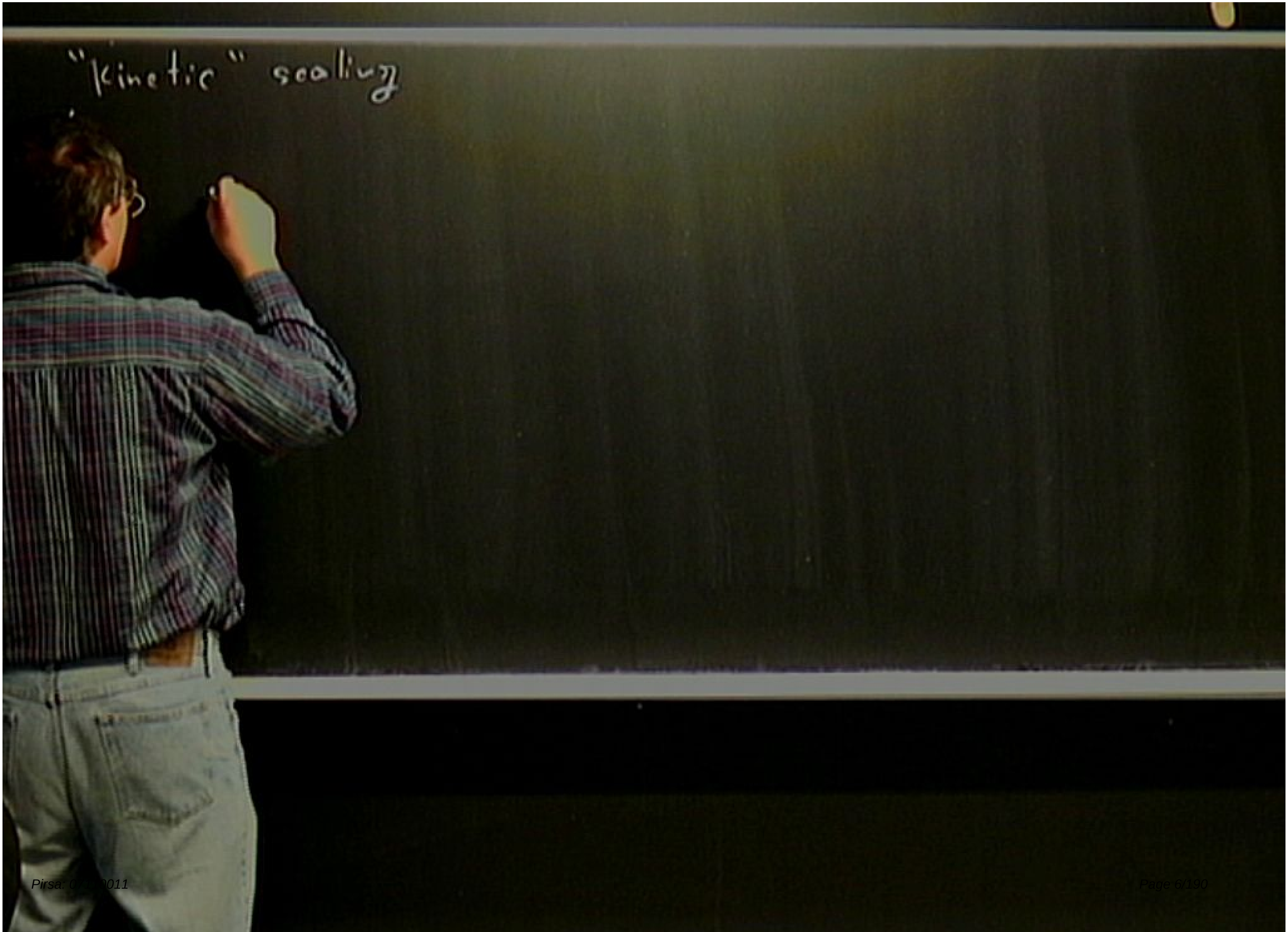
Abstract:

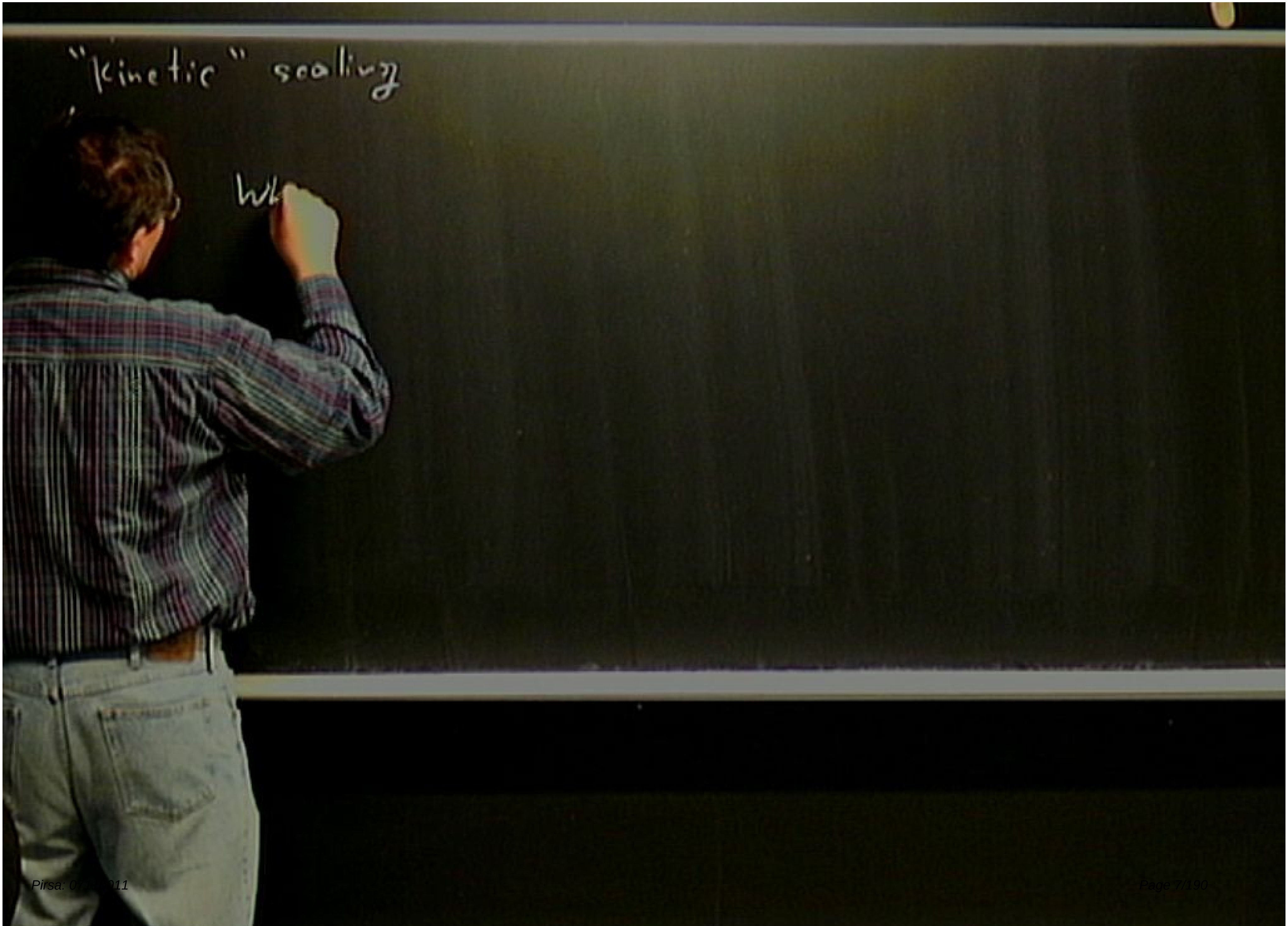









"kinetic" scaling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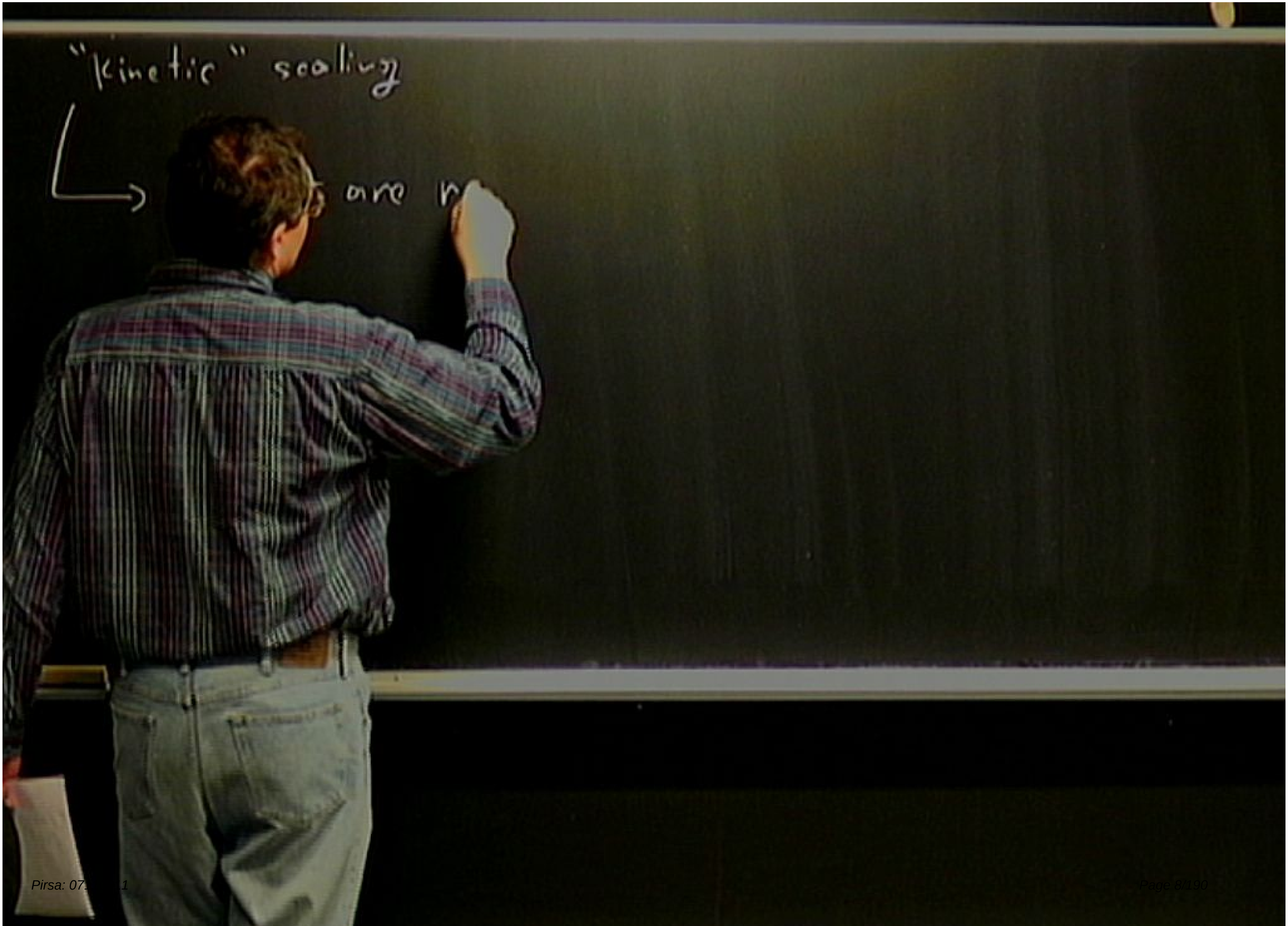
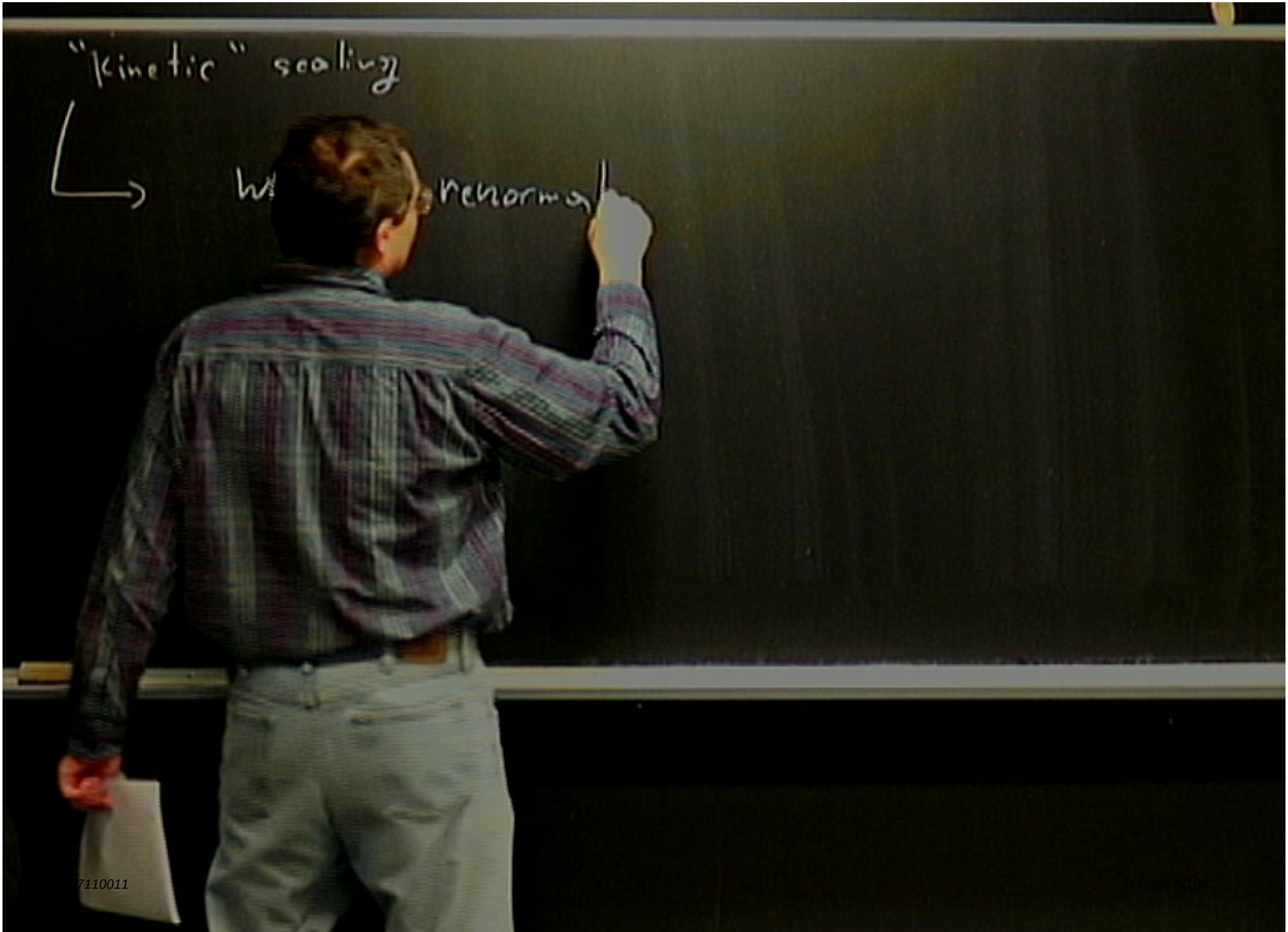

"kinetic" scaling
are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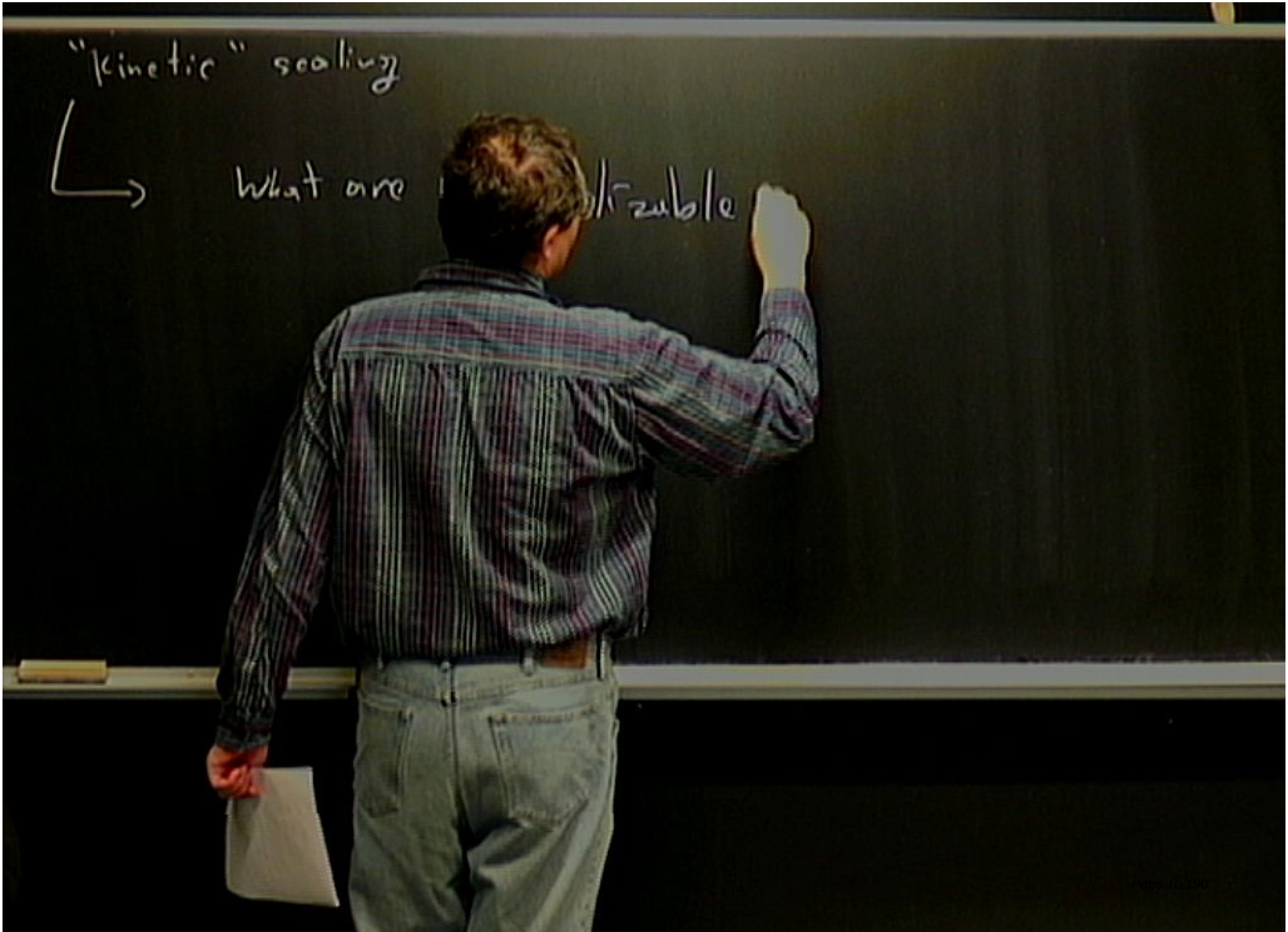
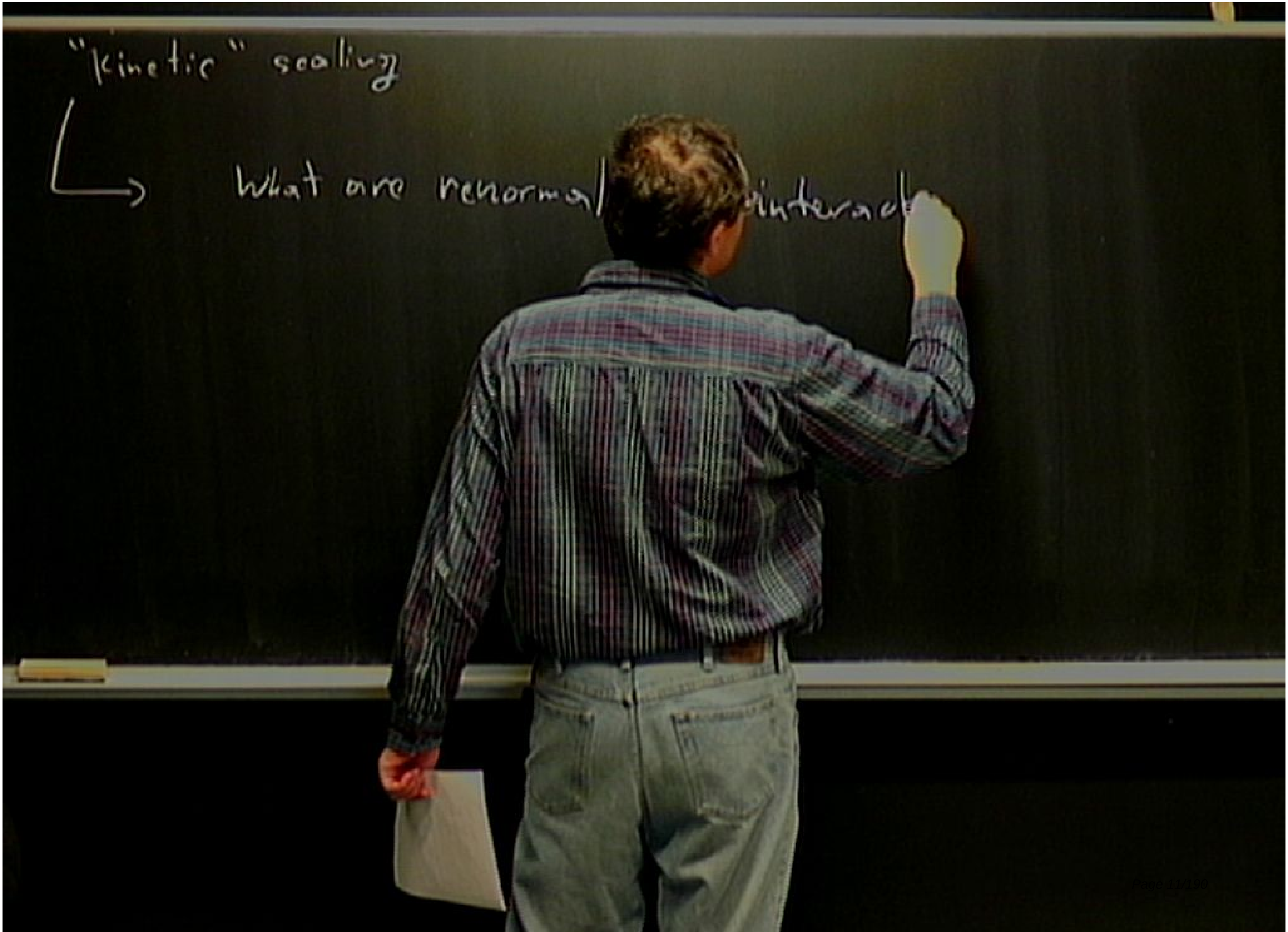
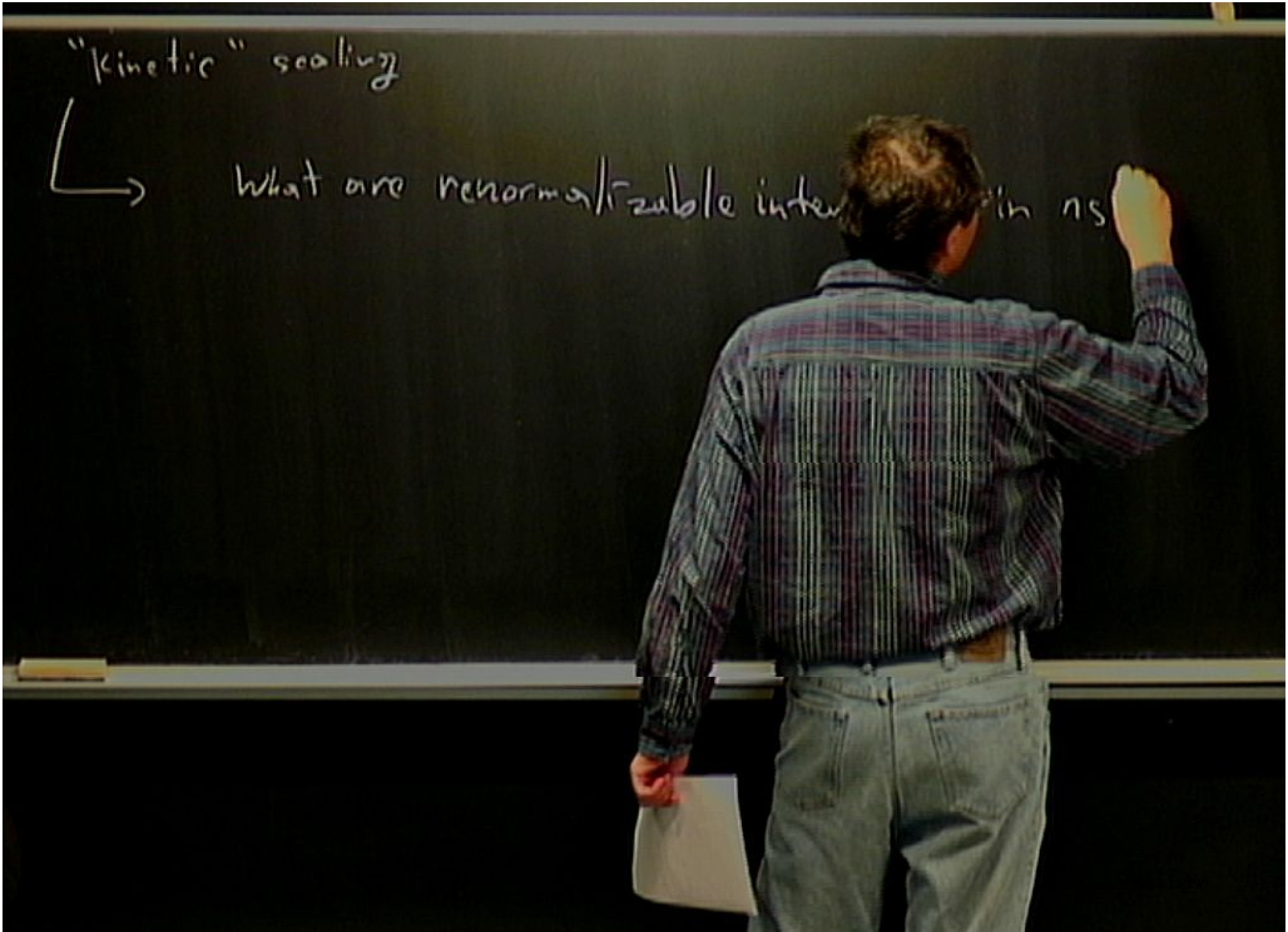
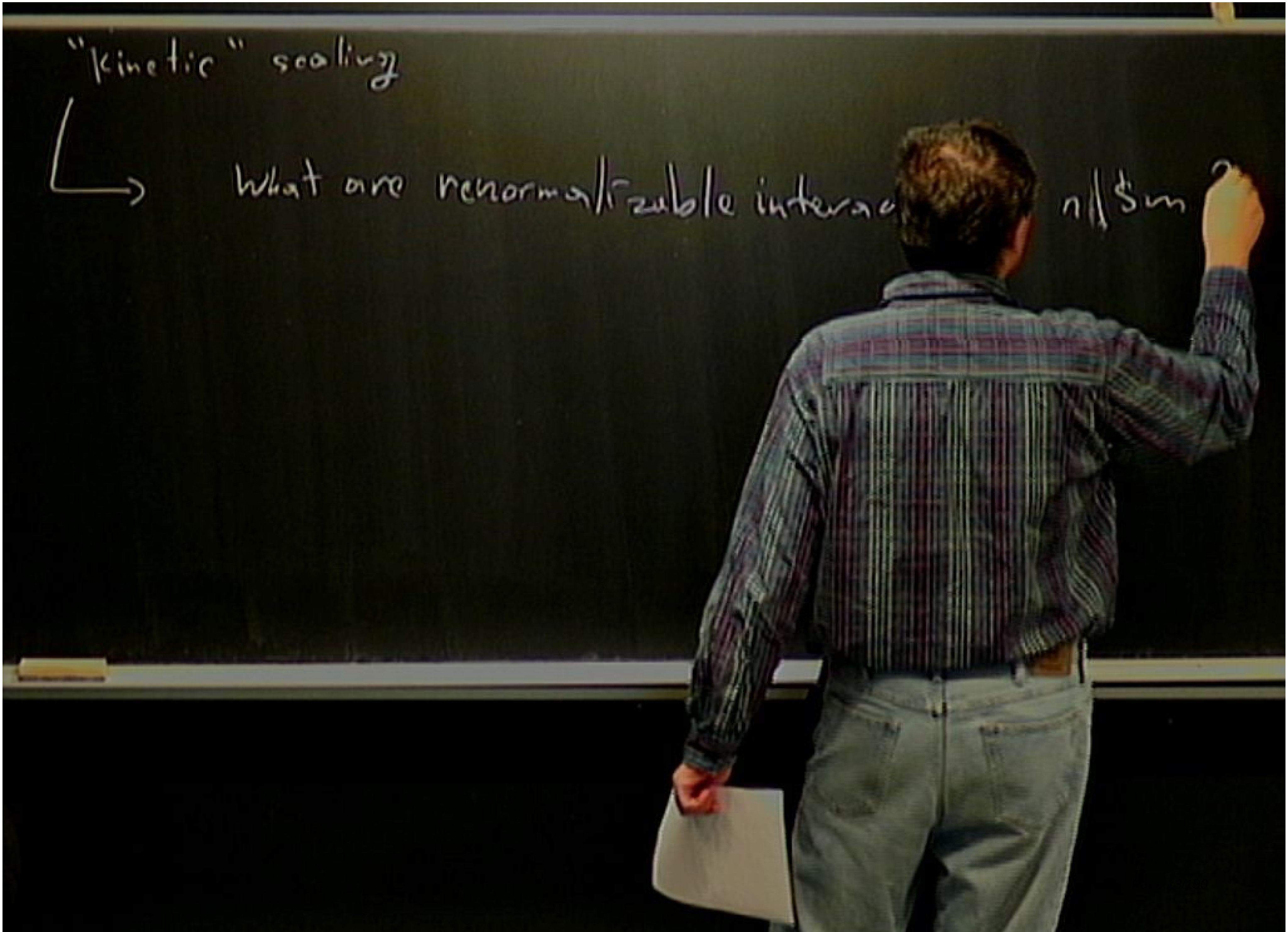
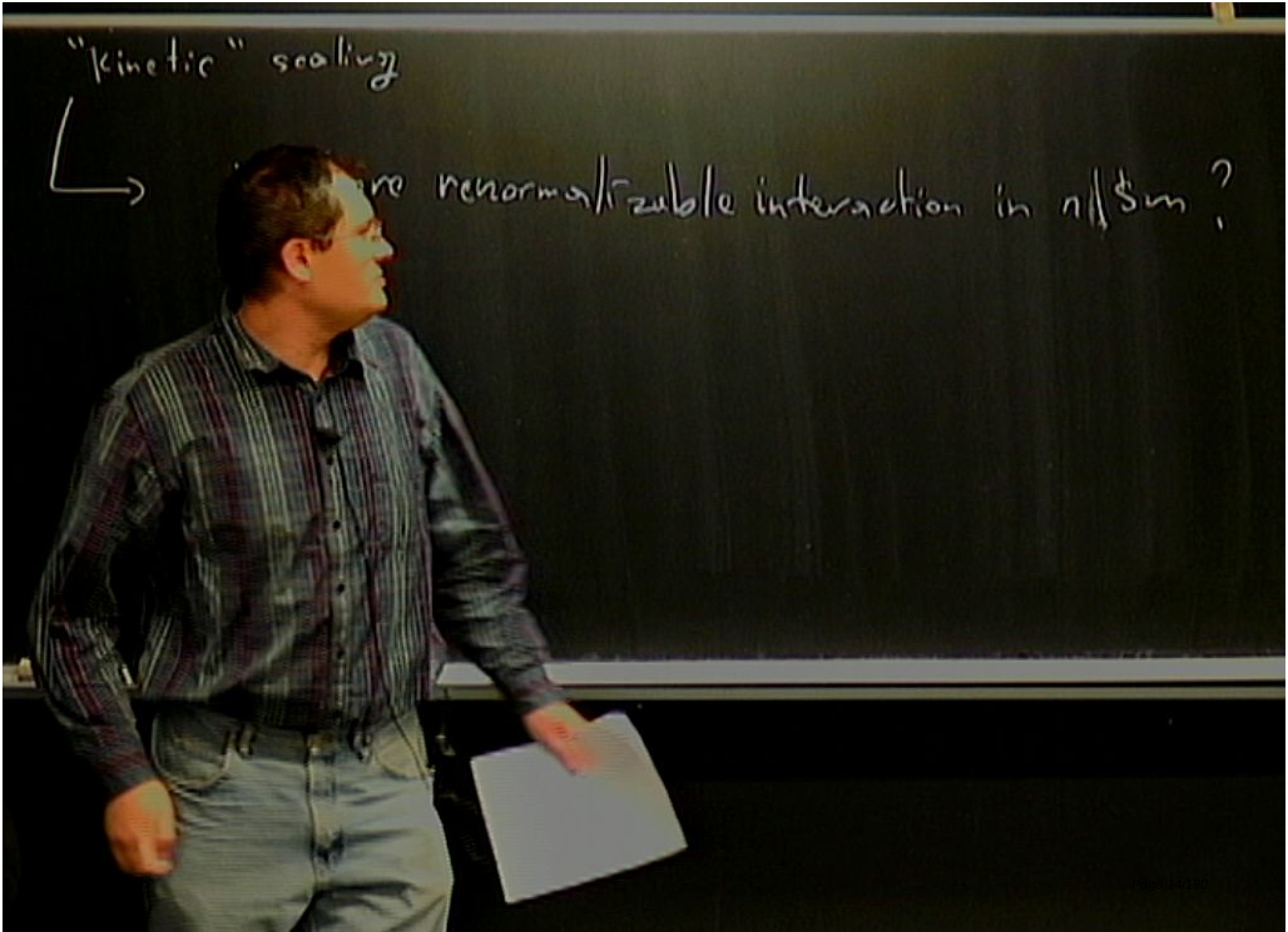

"kinetic" scaling
What are


"kinetic" scaling
What are renormal
interact


"kinetic" scaling
What are renormalizable inter
in ns

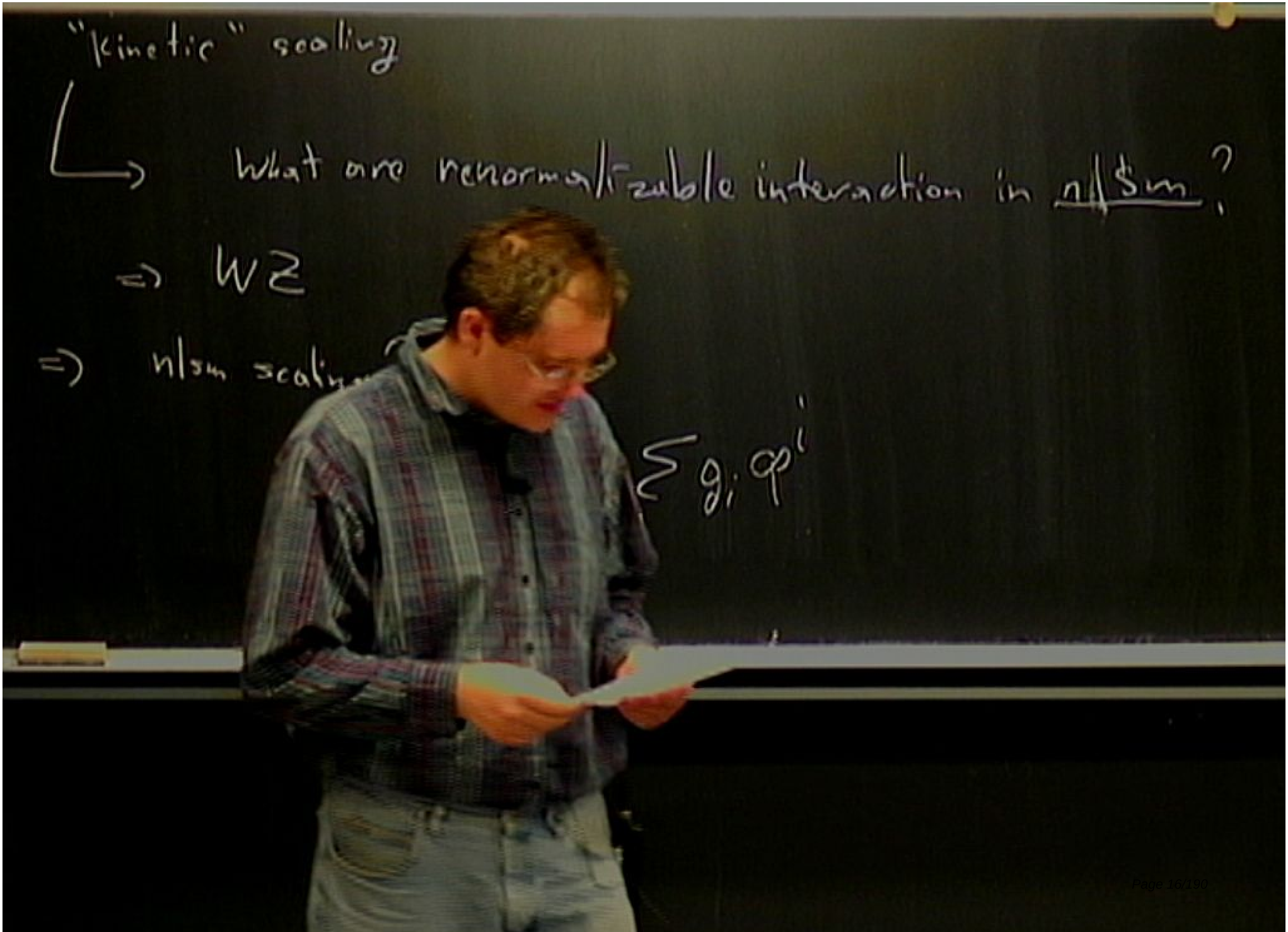

"kinetic" scaling
What are renormalizable interac
nlσm ?


"kinetic" scaling
renormalizable interaction in

"kinetic" scaling

$\hookrightarrow$ What are renormalizable interaction in n=1 Sym ?

$\Rightarrow$ WZ


"kinetic" scaling
What are renormalizable interaction in nlsm?
⇒ WZ
⇒ nlsm scalin
Σ g_i φ^i

"kinetic" scaling

↳ What are renormalizable interaction in nlsm?

⇒ WZ

⇒ nlsm scaling?

$$W(\varphi) = \sum_i g_i \varphi^i$$

infinite # of term

⇒ nonrenorm interact

NLSM $\Rightarrow$ must be an effective field theory.

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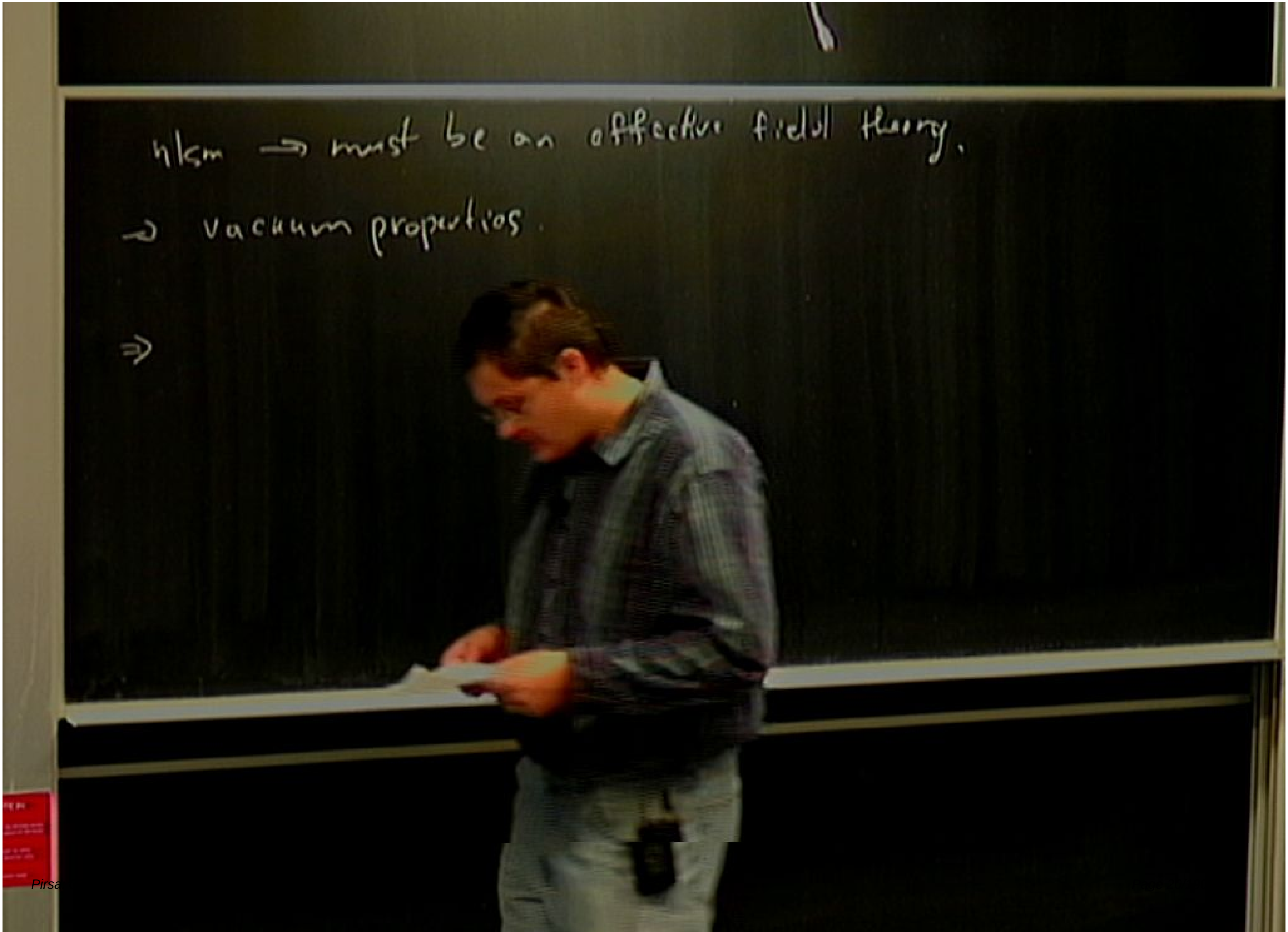
$\rightarrow$ vacuum properties.


nlsm ⇒ must be an effective field theory.
→ vacuum properties.
⇒

nlsm $\Rightarrow$ must be an effective field theory.

$\Rightarrow$ vacuum properties

$\Rightarrow$ kinetic terms should no matter

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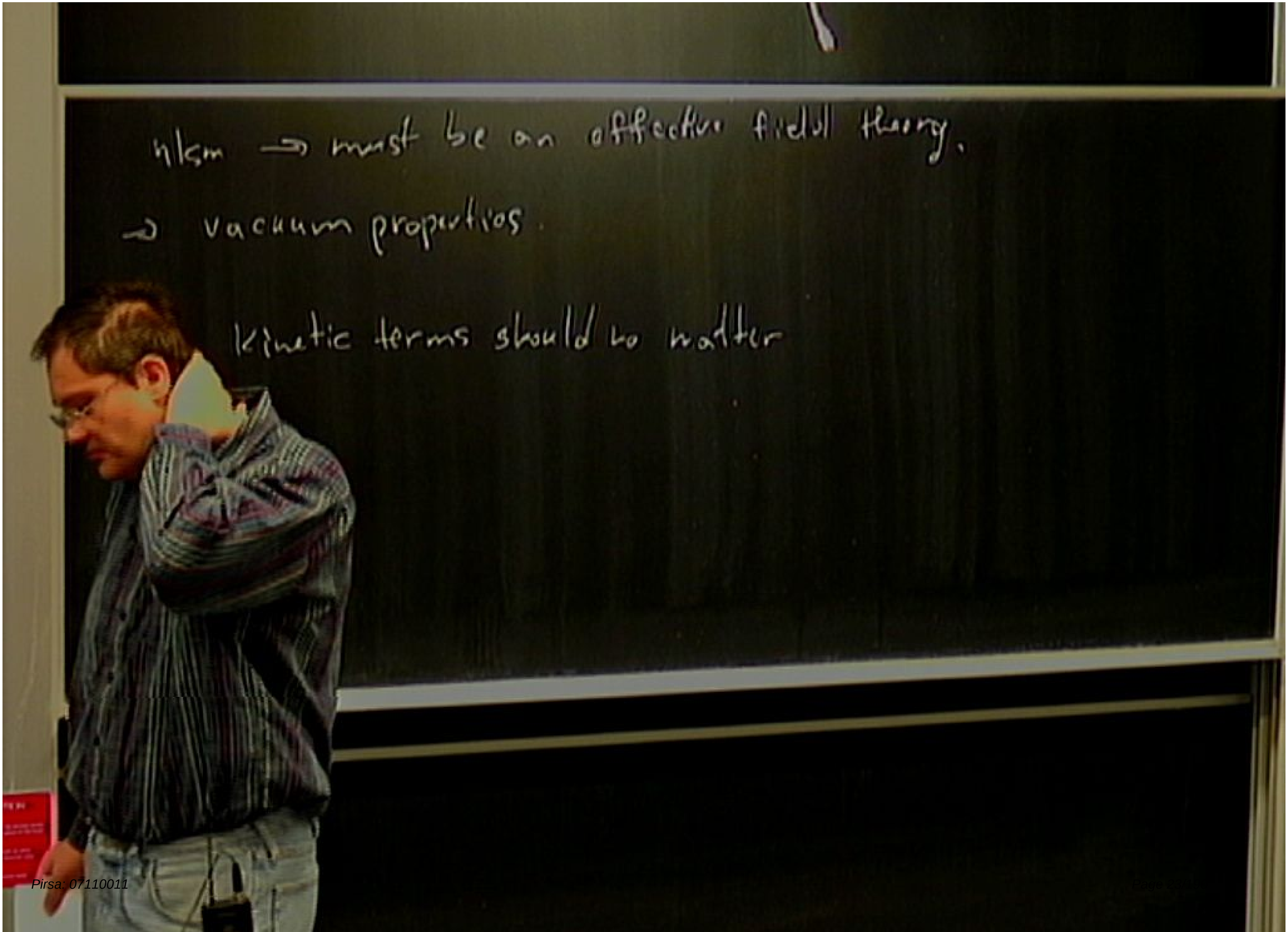
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$$[\varphi] = 0$$

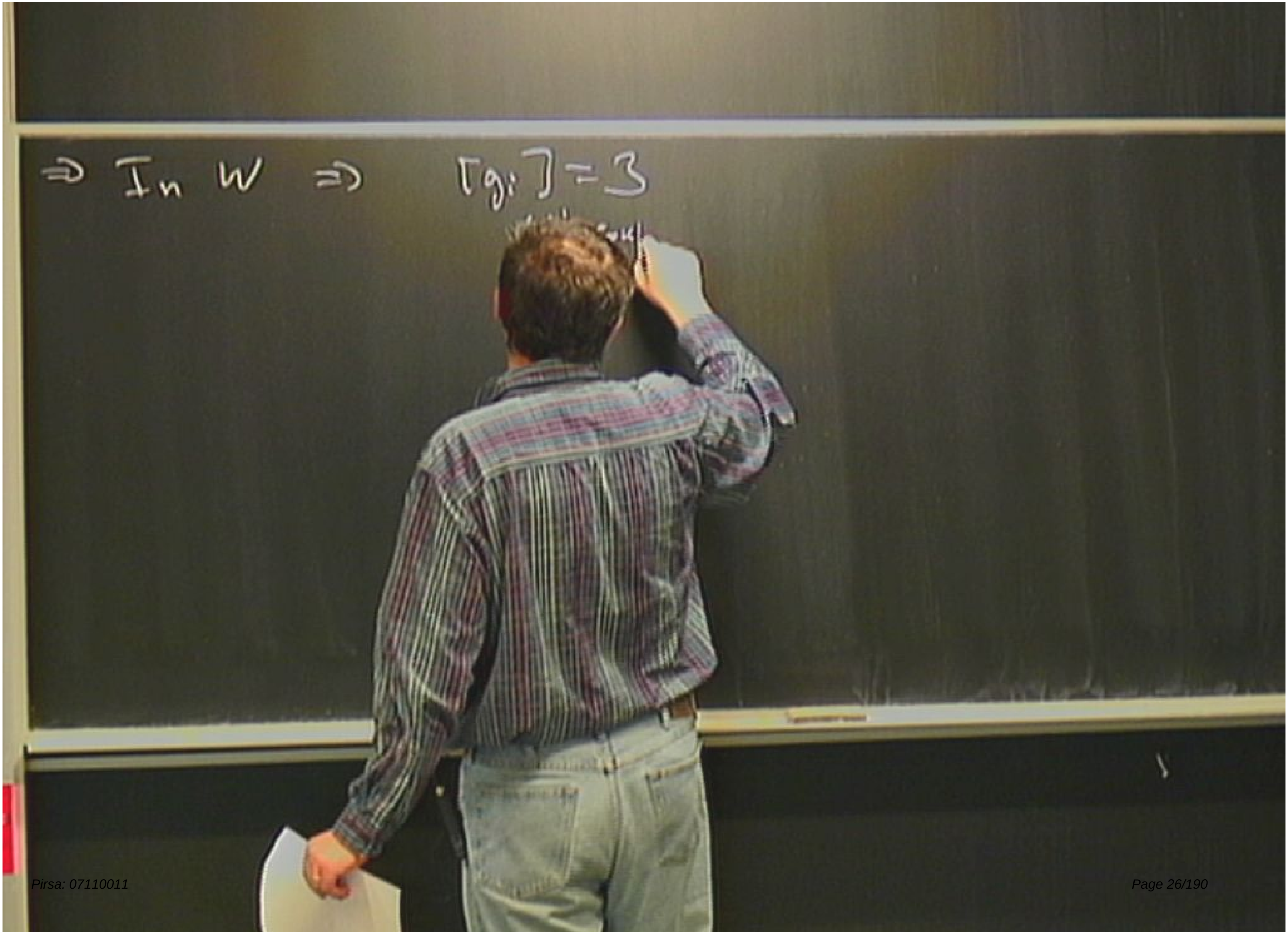
nlsm $\Rightarrow$ must be an effective field theory.

$\rightarrow$ vacuum properties

$\Rightarrow$ kinetic terms should no matter

$$[\varphi] = 0$$

$\uparrow$ dimensionless assignment


⇒ In W ⇒ [gi] = 3

$\Rightarrow$ In W $\Rightarrow$ $[g_i] = 3$

(all couplings are equally important).

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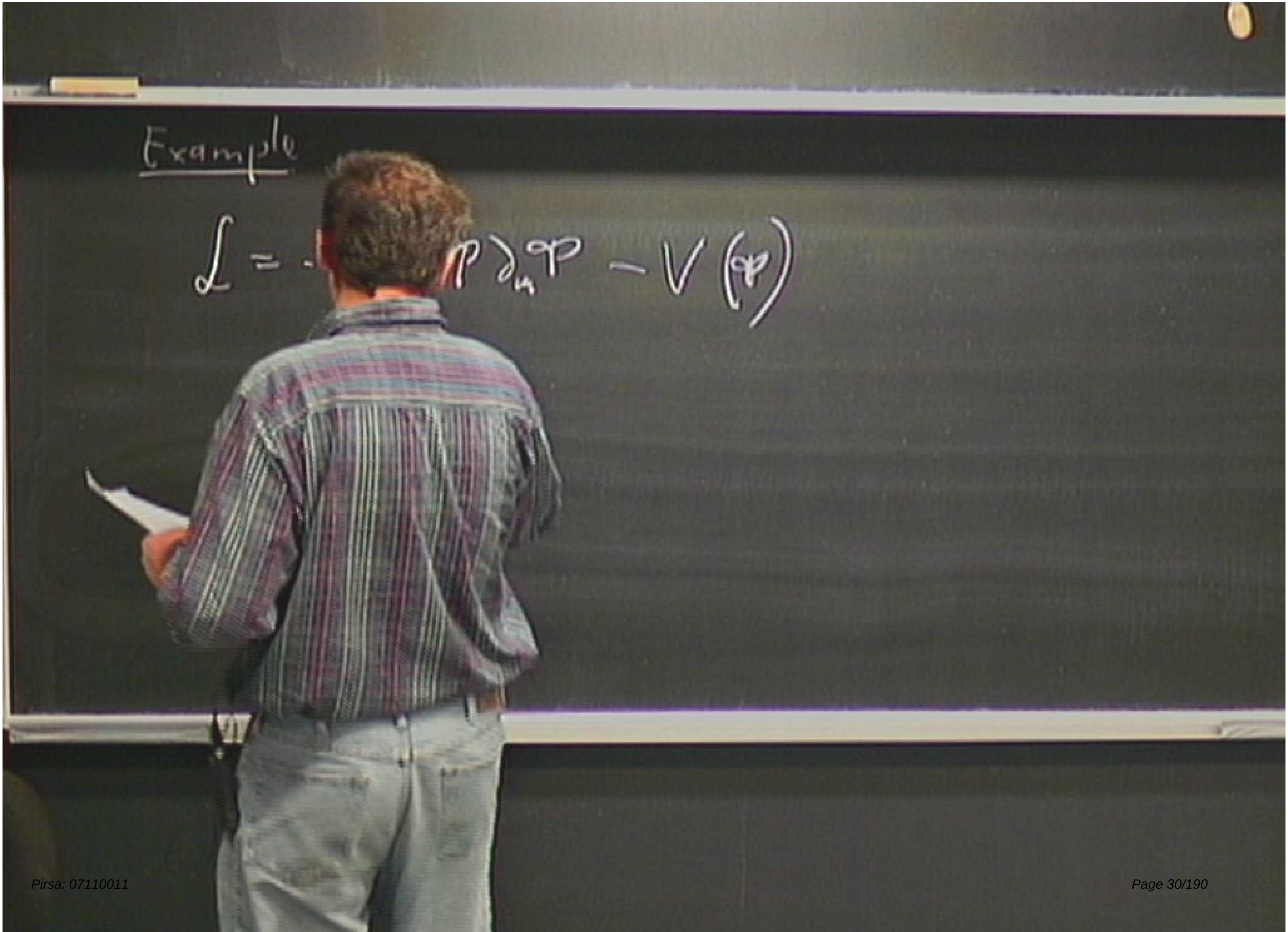
$\Rightarrow$ $\Rightarrow$ all term have scaling dim $+2$

$\Rightarrow$ In W $\Rightarrow$ $[g_i] = 3$

$[h] = 3$ (all couplings are equally important).

$\Rightarrow$ In K $\Rightarrow$ all term have scaling dim $+2$

$[K] = 2$


Example

Example

$$\mathcal{L} = -\frac{1}{2}\partial^\mu\varphi\,\partial_\mu\varphi - V(\varphi)$$

$$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \lambda\varphi^8 \qquad m^2 > 0$$

$$\lambda > 0$$

Example

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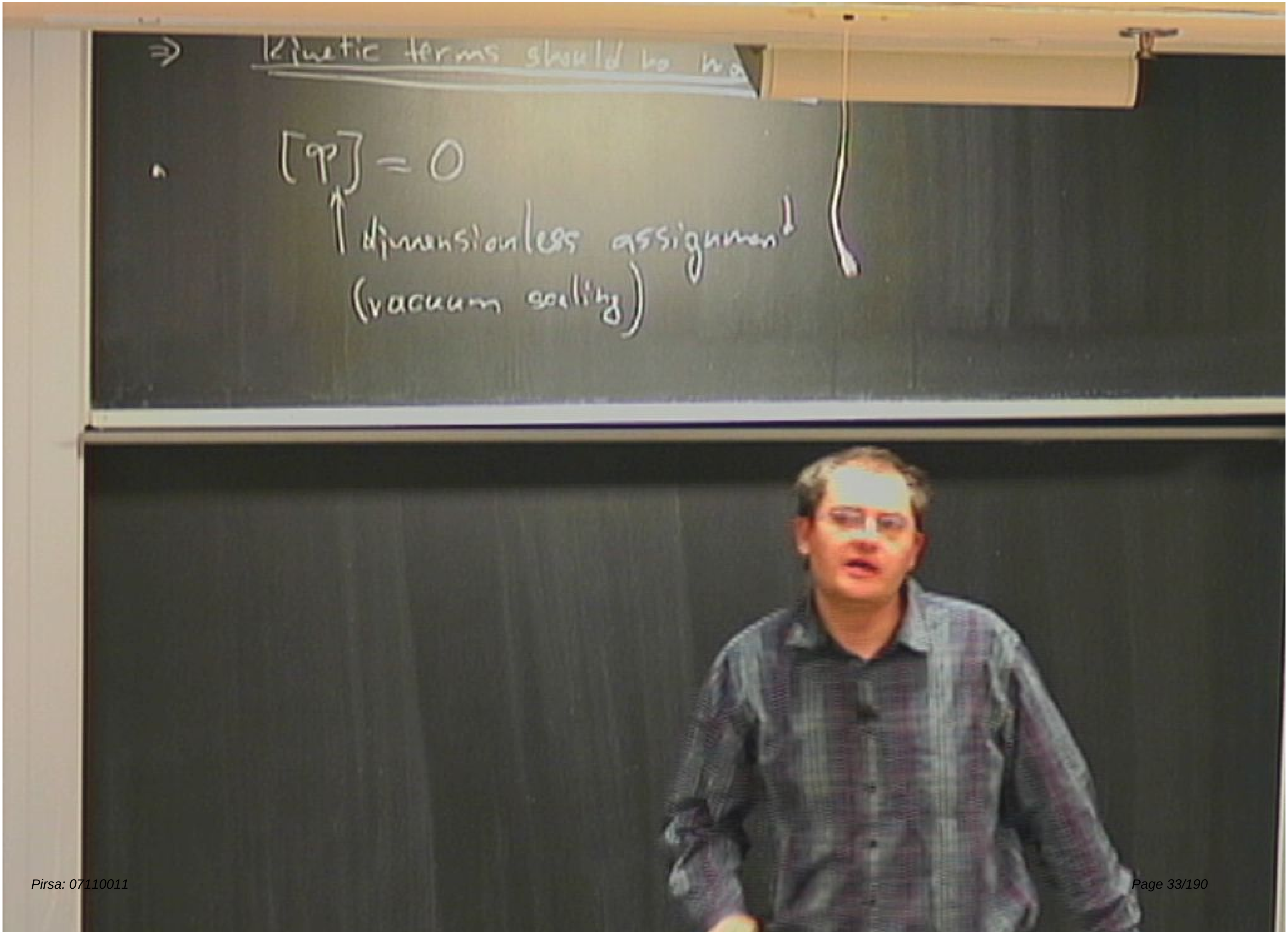
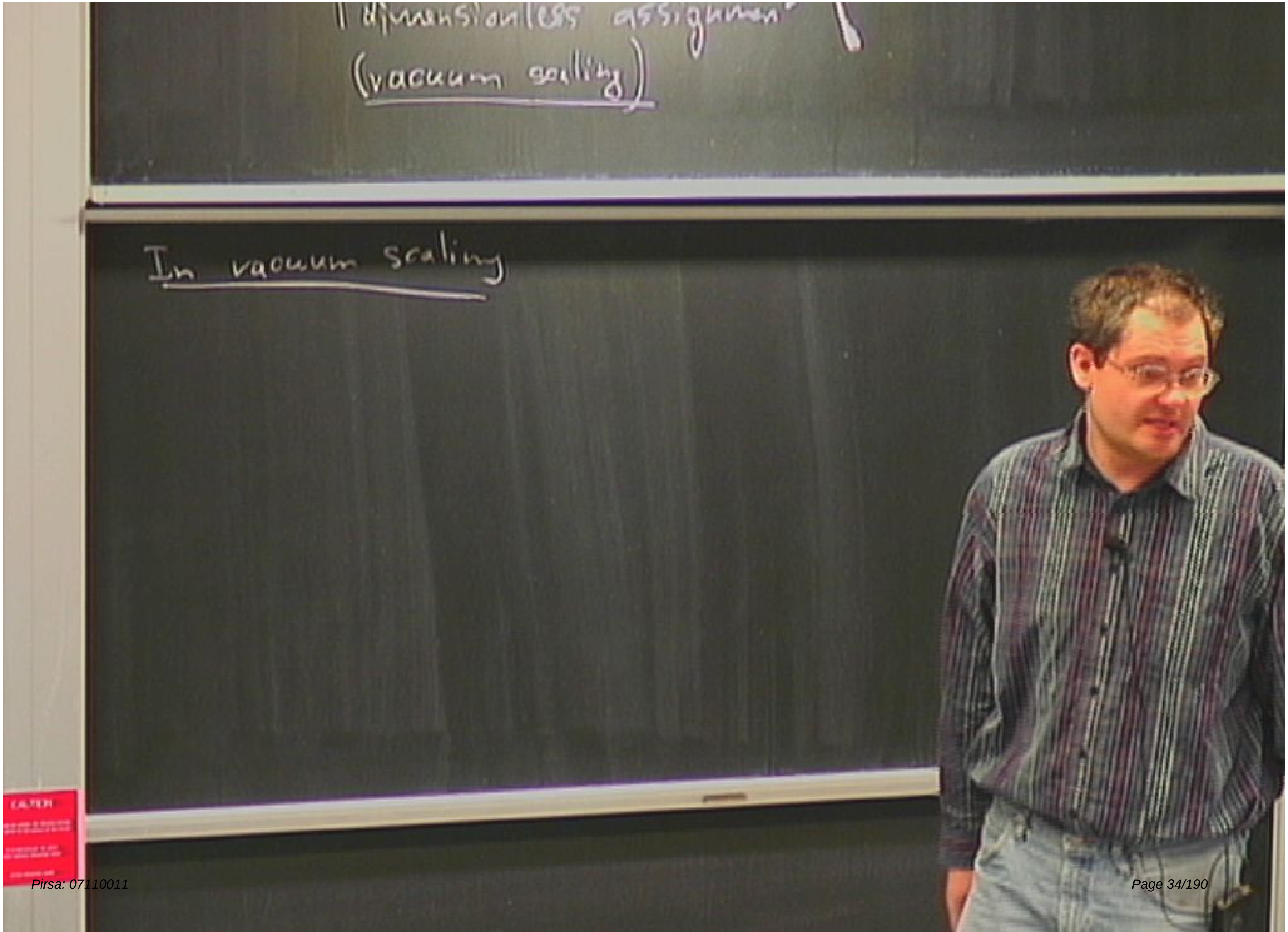
$$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \lambda\varphi^8 \qquad m^2>0 \quad \lambda>0$$

$\Rightarrow$ If we are to use kinetic scaling $\quad [\mathcal{L}] = 4$

$[\varphi] = 1 \qquad [\lambda] = -4$


⇒ Kinetic terms should be ha
[φ] = 0
dimensionless assignment
(vacuum scaling)


dimensionless assignment
(vacuum scaling)
In vacuum scaling

"dimensionless assignment"
(vacuum scaling)

In vacuum scaling

$$\hat{\varphi} = \frac{\varphi}{\Lambda}$$

dimensionless assignment

(vacuum scaling)

In vacuum scaling

$\hat{p} = \frac{p}{\Lambda}$ $\to$ cut off scale of eff. field theory.

dimensionless assignment
(vacuum scaling)

In vacuum scaling $\quad [\hat{\varphi}] = 0$

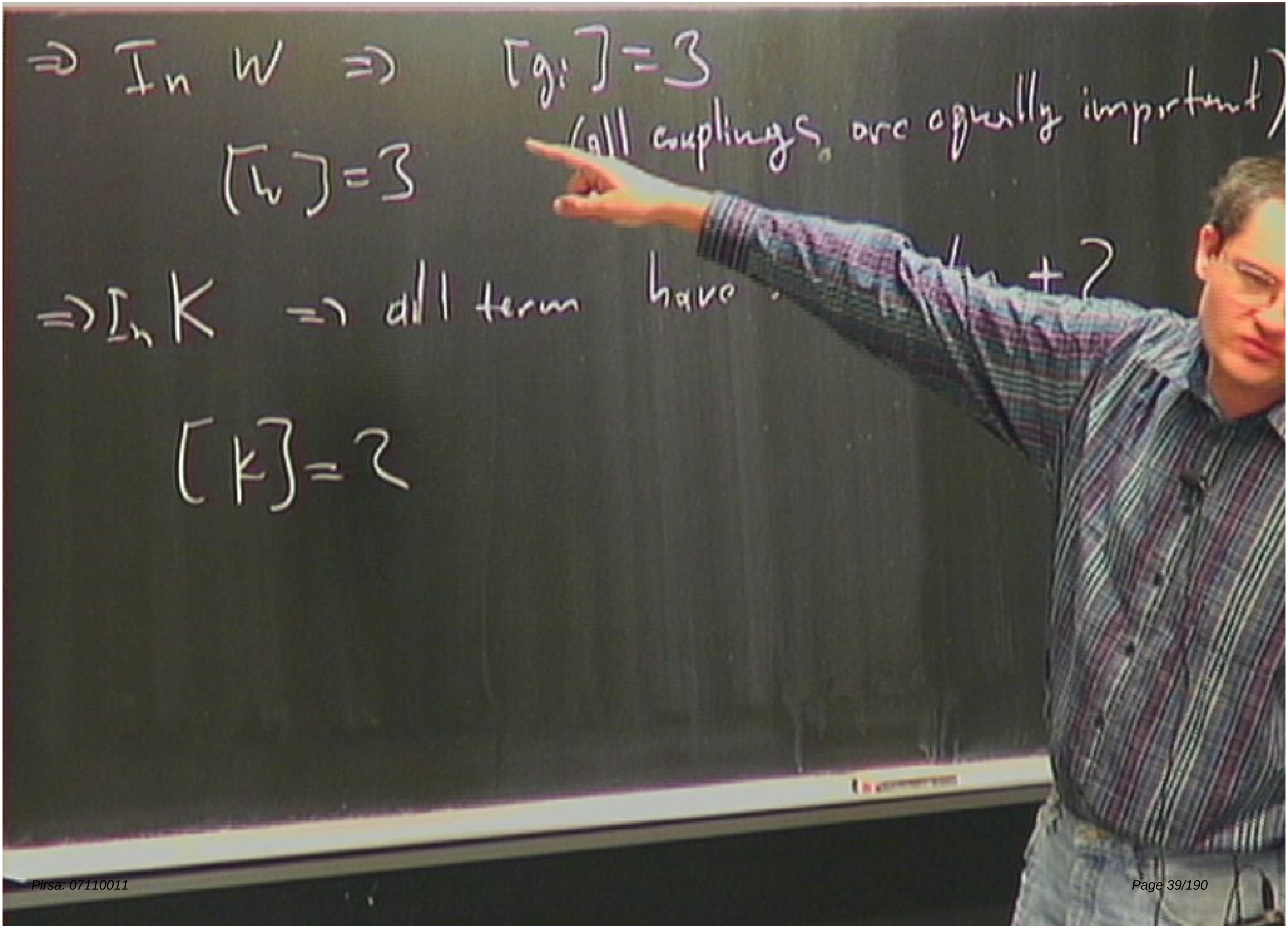
$\hat{\varphi} = \dfrac{\varphi}{\Lambda}$ $\longrightarrow$ cut off scale of eff. field theory.

("dimensionless assignment"
(vacuum scaling))

In vacuum scaling $\qquad [\hat{\varphi}] = 0$

$$\hat{\varphi} = \frac{\varphi}{\Lambda} \to \text{cut off scale of eff. field theory.}$$

$$\mathcal{L} = -\frac{\Lambda^2}{2}\partial_\mu\hat{\varphi}\,\partial^\mu\hat{\varphi} + \frac{m^2\Lambda^2}{2}\hat{\varphi}^2 - \lambda\Lambda^8(\hat{\varphi})^8$$


⇒ In W ⇒ [g_i] = 3
(all couplings are equally important)
[λ] = 3
⇒ In K ⇒ all term have
+ 2
[k] = 2

vacuum scaling

$$[\hat{\varphi}] = 0$$

$\hat{\varphi} = \dfrac{\varphi}{\Lambda} \rightarrow$ cut off scale of eff. field theory.

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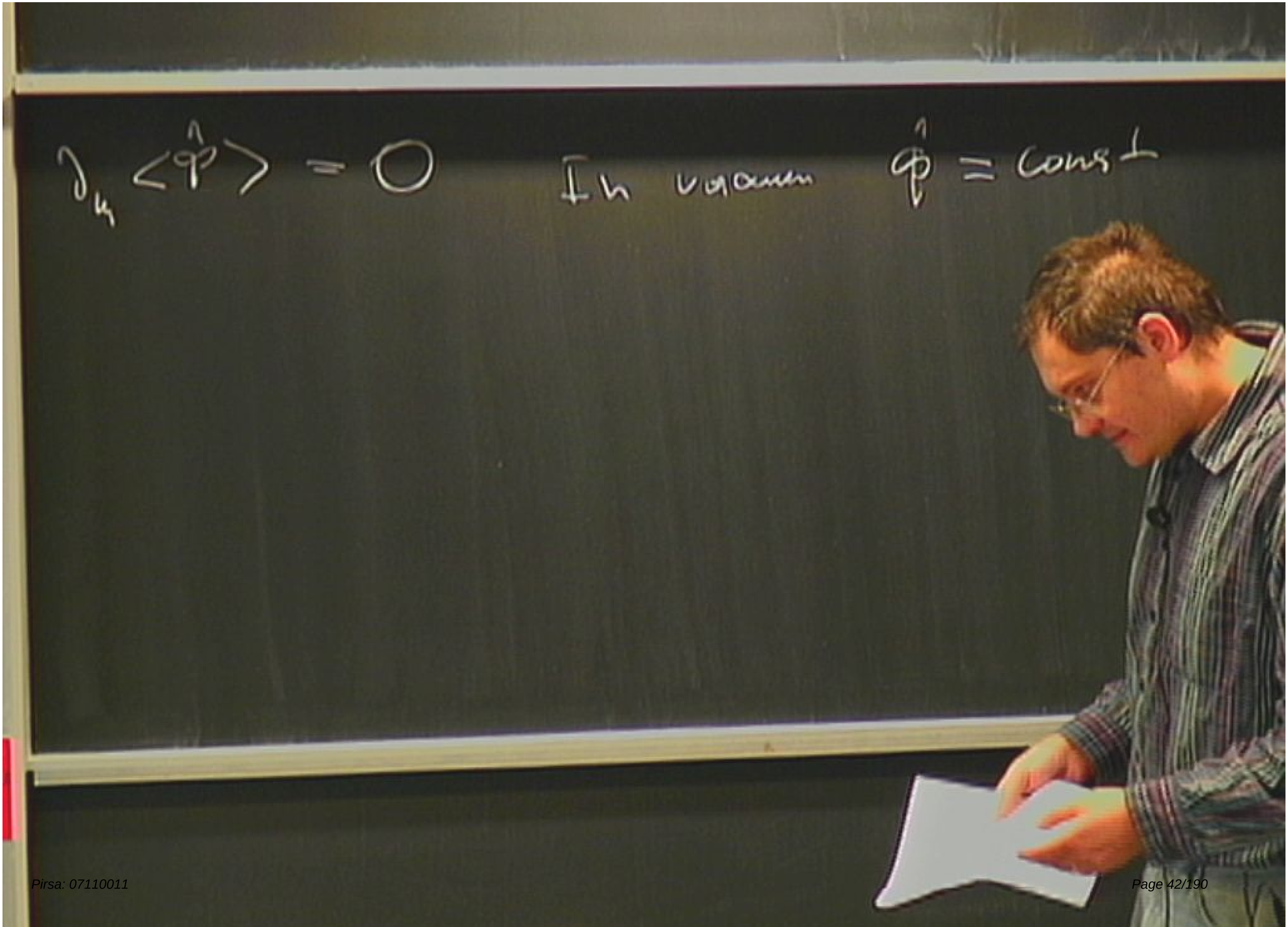
$[m^2\Lambda^2] = +4 \qquad [\lambda\Lambda^8] = -4+8 = 4$

In vacuum scaling $\qquad [\hat{\varphi}] = 0$

$\hat{\varphi} = \dfrac{\varphi}{\Lambda} \to$ cut off scale of eff. field theory.

$$\mathcal{L} = -\frac{\Lambda^2}{2}\partial_\mu\hat{\varphi}\,\partial^\mu\hat{\varphi} + \underbrace{\frac{m^2\Lambda^2}{2}}_{[m^2\Lambda^2]=+4}\hat{\varphi}^2 - \underbrace{\lambda\Lambda^8}_{[\lambda\Lambda^8] = -4+8=4}(\hat{\varphi})^8$$


$\partial_\mu \langle \hat{\varphi} \rangle = 0$
In vacuum $\hat{\varphi} = \mathrm{const}$

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$$\hat{\varphi} \propto \varphi_0 \cdot e^{i\omega t - i\vec{k}\vec{x}}$$

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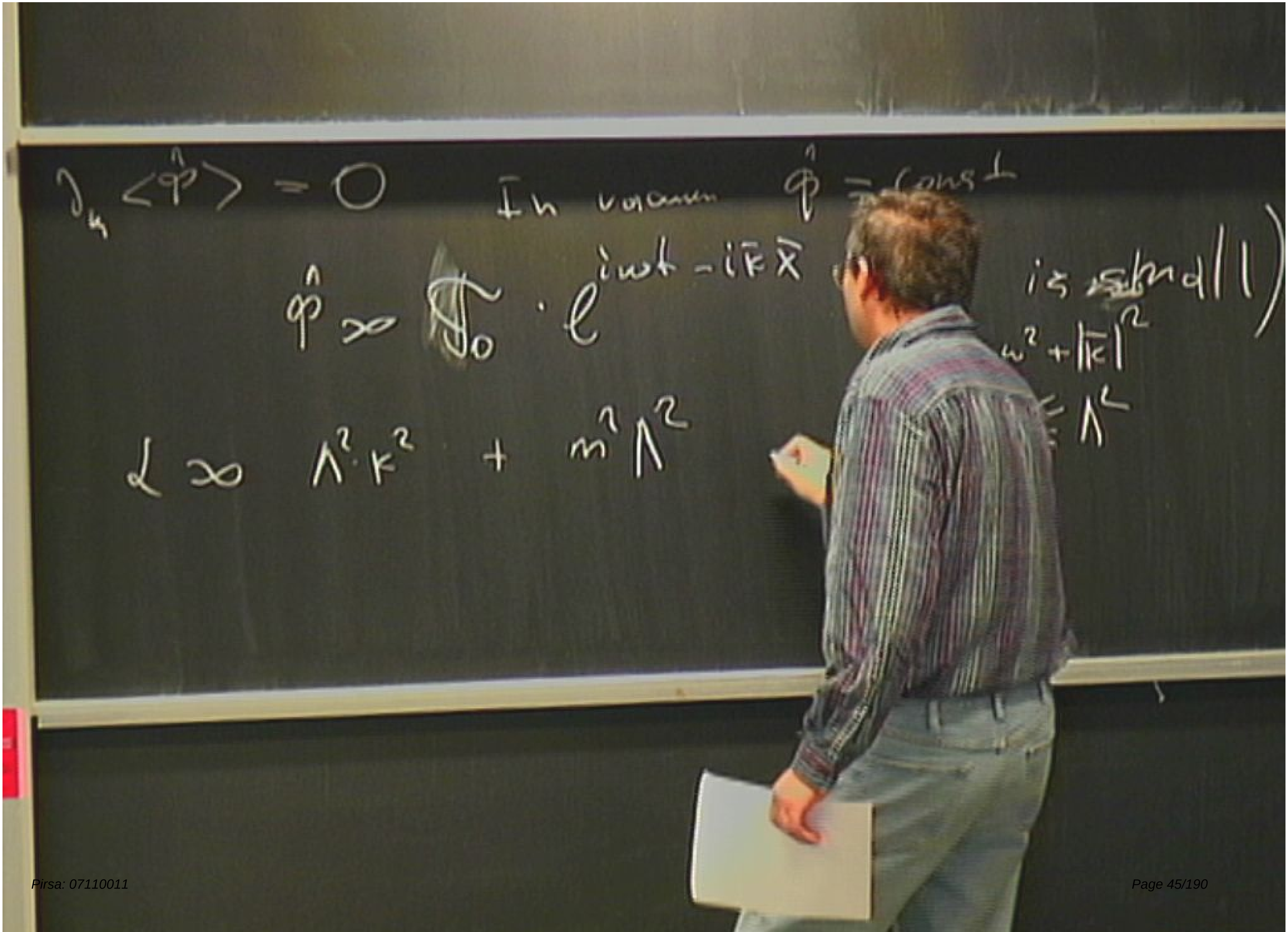
$$k^2 = -\omega^2 + |\vec{k}|^2$$

$$k^2 \ll \Lambda^2$$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In vacuum $\hat{\varphi}$ = const
$\hat{\varphi} \propto \varphi_0 \cdot e^{i\omega t - i\bar{k}\bar{x}}$
is small)
$\omega^2 + |\bar{k}|^2$
$\leq \Lambda^2$
$\mathcal{L} \propto \Lambda^2 \cdot k^2 + m^2 \Lambda^2$

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$$\hat{\varphi} \propto \varphi_0 \cdot e^{i\omega t - i\vec{k}\vec{x}} \quad (k^2 \text{ is small})$$

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$$\mathcal{L} \propto \Lambda^2 \cdot k^2 + m^2 \Lambda^2 + \lambda \Lambda^8 \qquad k^2 \lll \Lambda^2$$

In the limit $\frac{|k^2|}{\Lambda^2} \to 0$ $\frac{|k^4|}{m^2} \to 0$

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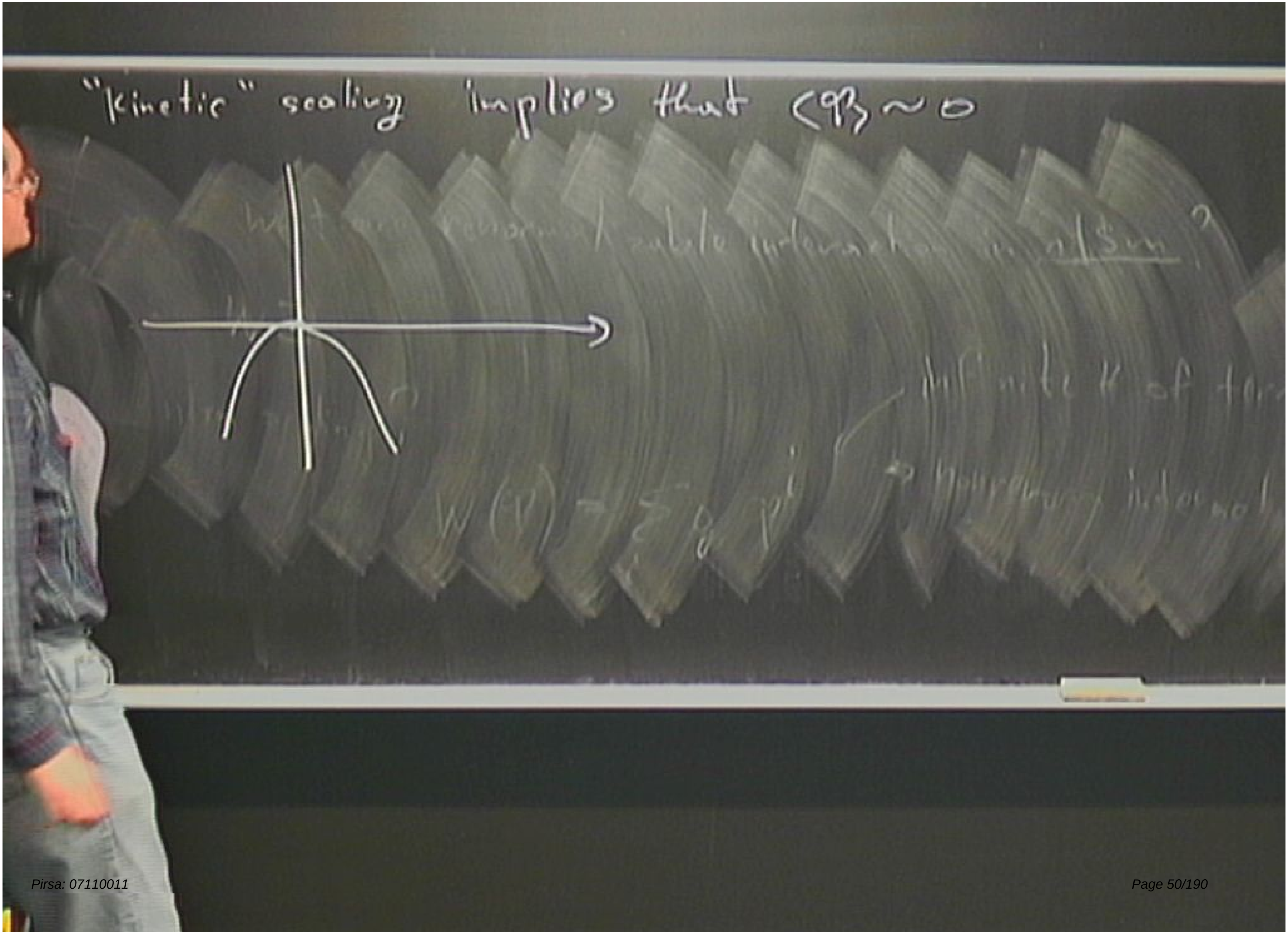
In the limit $\frac{|k^2|}{\Lambda^2} \to 0$ $\quad \frac{|k^4|}{m^2} \to 0$ (low energy) "kinetic" scaling implies that $\langle \phi \rangle \sim 0$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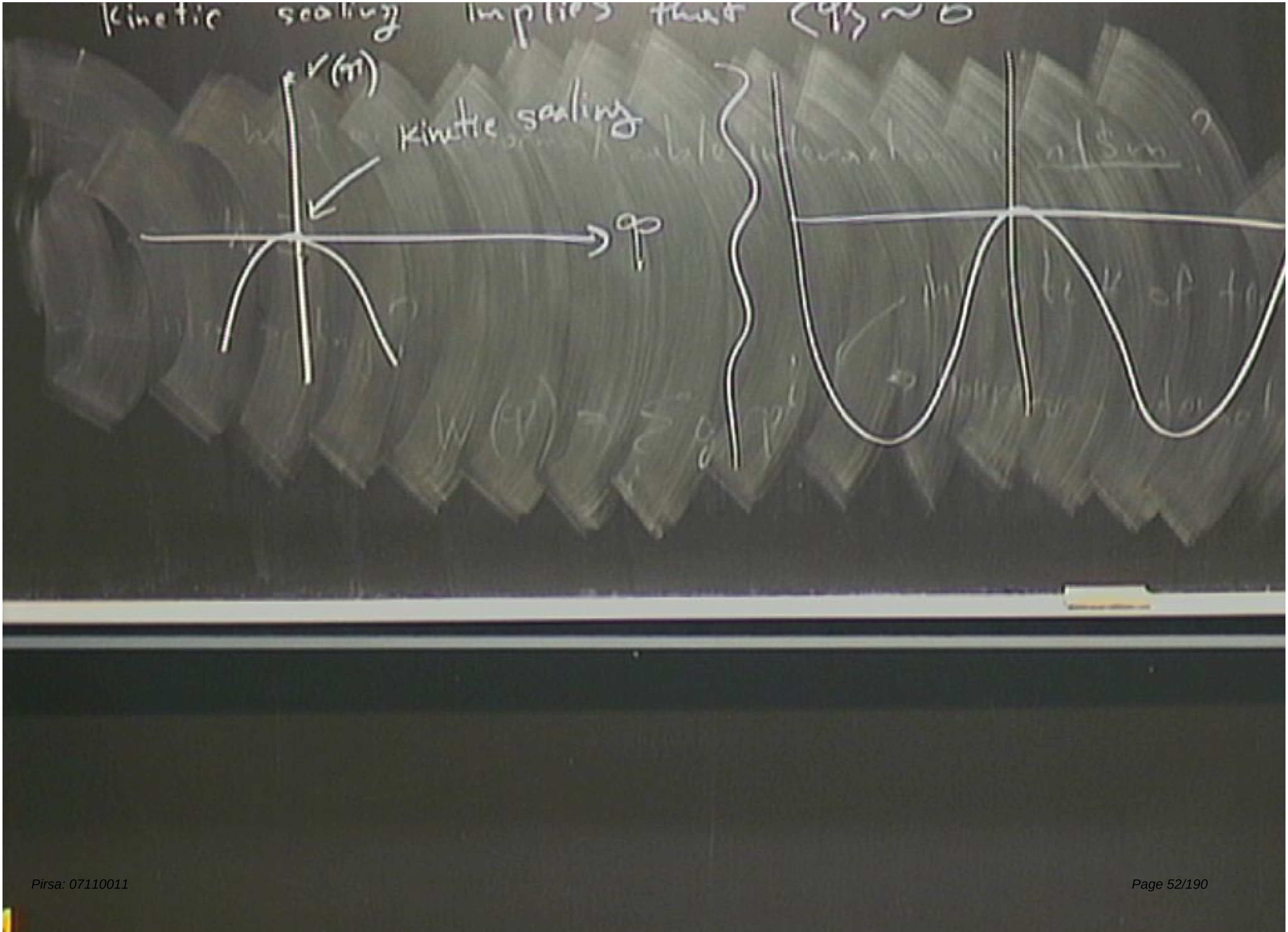
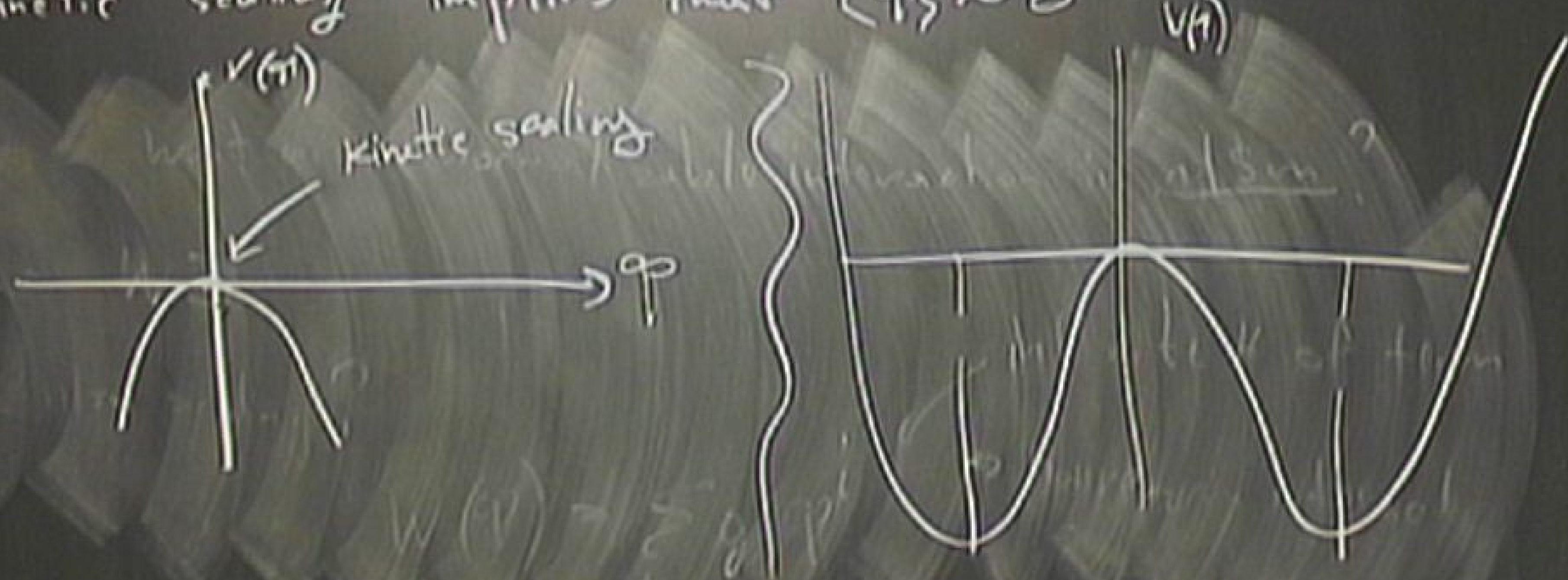

Kinetic scaling implies that ⟨φ⟩ ~ 0
Kinetic scaling
φ

"Kinetic" scaling implies that $\langle \varphi \rangle \sim 0$



$$V'(\varphi)\Big|_{\varphi=\varphi_v}=0 \qquad -m^2\varphi_v + 8\lambda\varphi_v^7 = 0$$

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$$\varphi_v = \pm\left(\frac{m^2}{8\lambda}\right)^{1/6}$$

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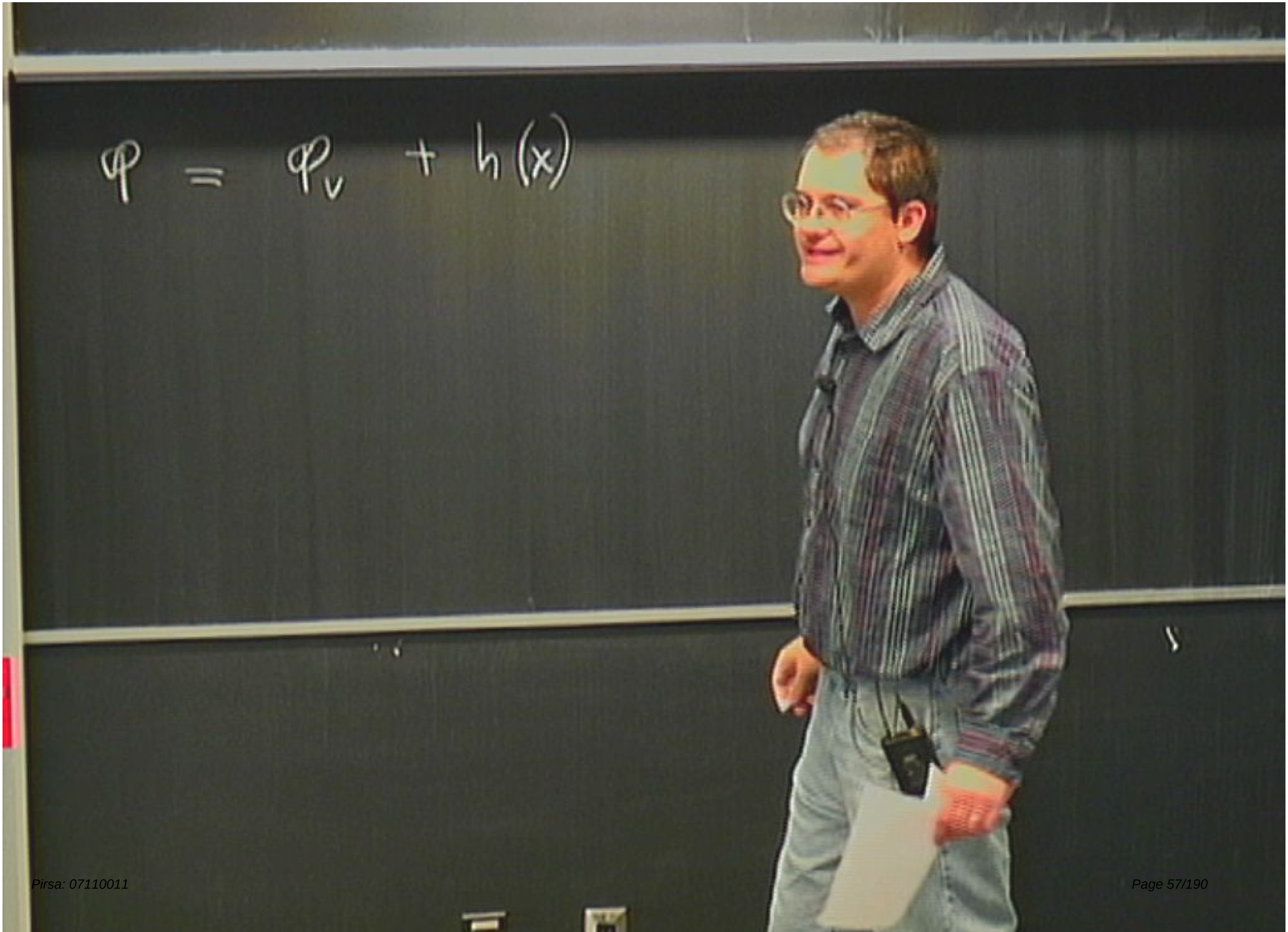
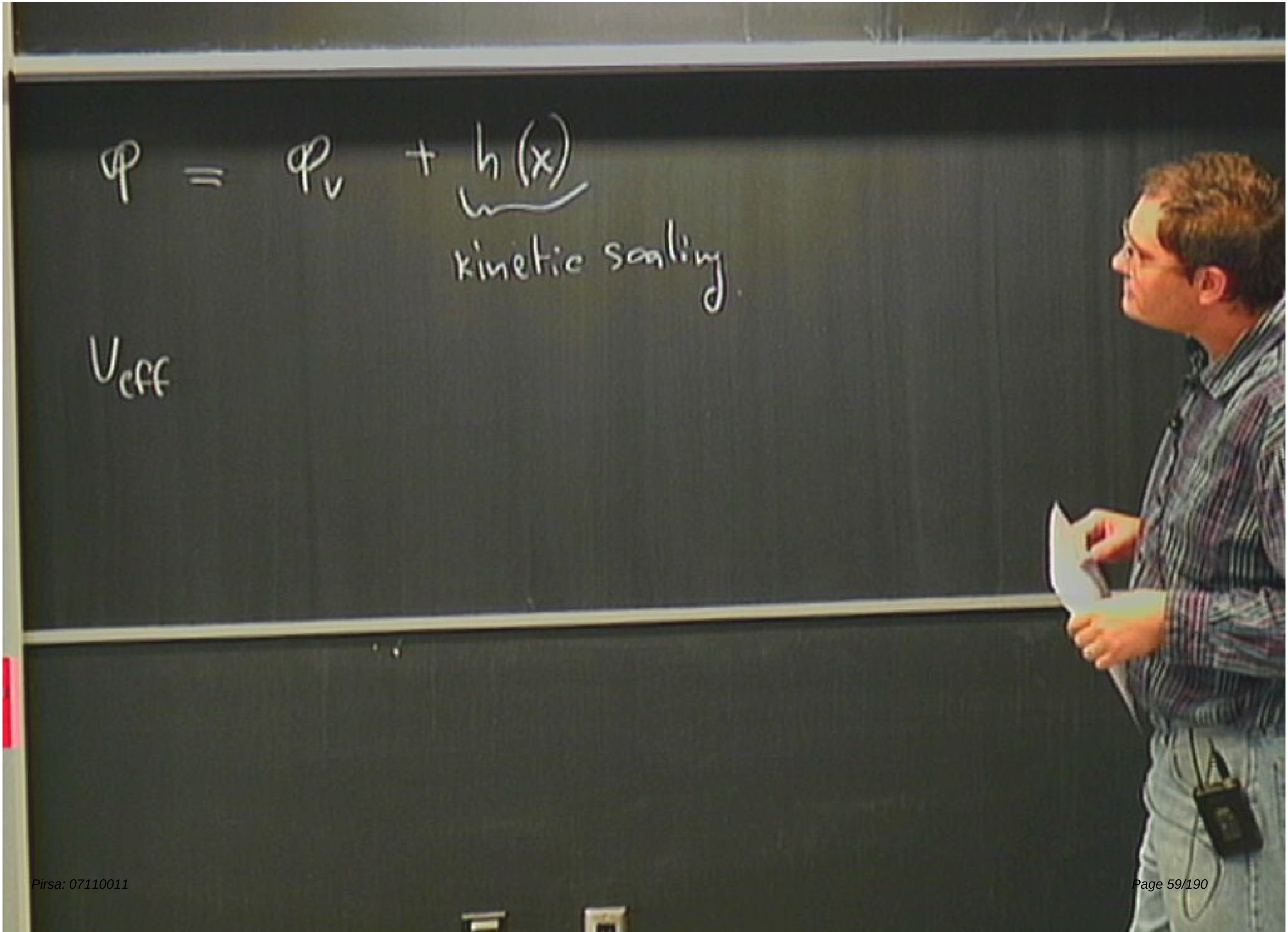
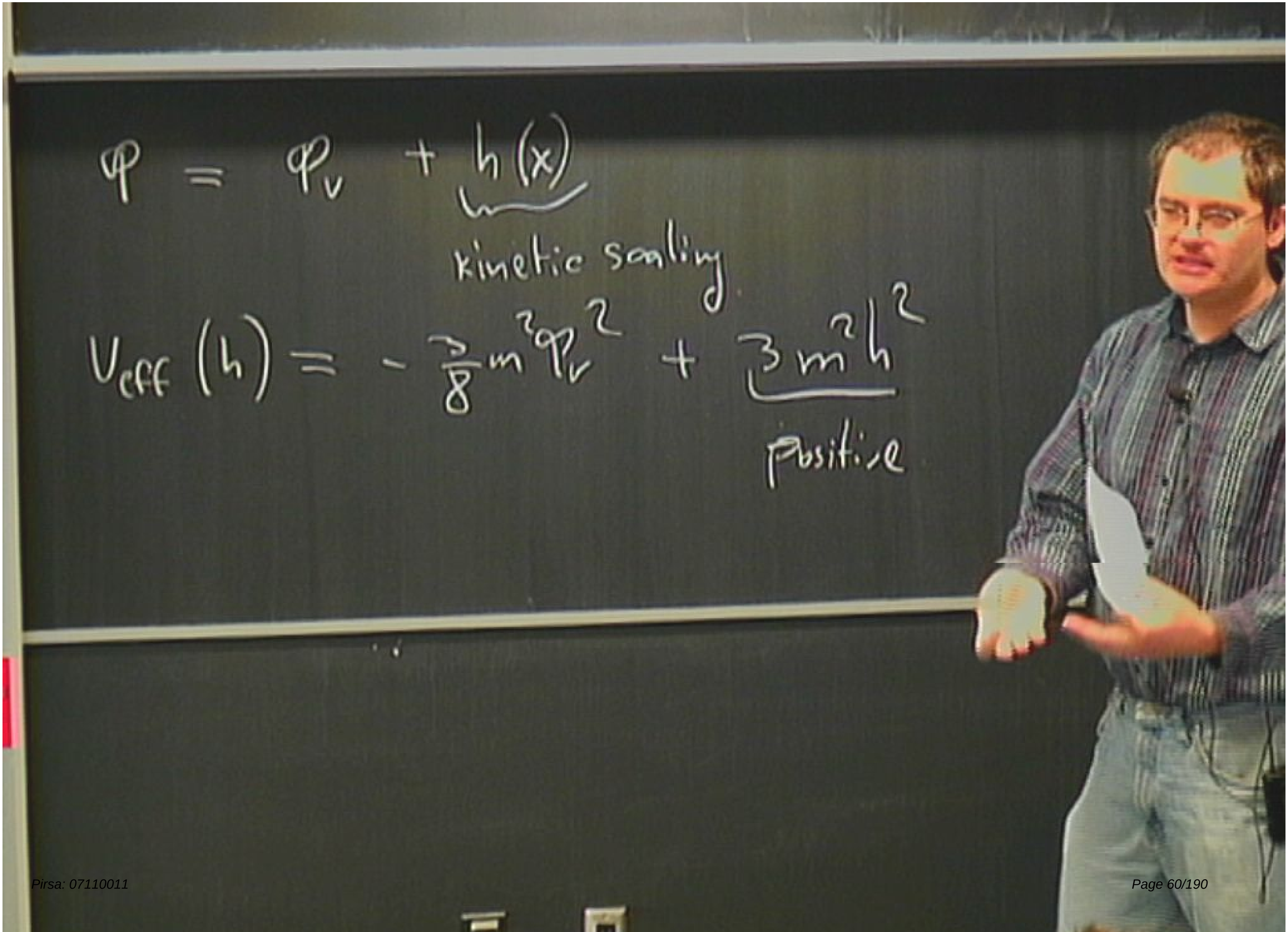
$\varphi \leftrightarrow -\varphi$ is spontaneously broken


$\varphi = \varphi_v + h(x)$

$$\varphi = \varphi_v + \underbrace{h(x)}_{\text{kinetic scaling}}$$


$\varphi = \varphi_v + \underbrace{h(x)}$
kinetic scaling
V_{eff}


$\varphi = \varphi_v + \underbrace{h(x)}_{\text{kinetic scaling}}$
$V_{eff}(h) = -\frac{3}{8} m^2 \varphi_v^2 + \underbrace{3 m^2 h^2}_{\text{positive}}$

$$\varphi = \varphi_v + \underbrace{h(x)}_{\text{kinetic scaling}}$$

$$V_{eff}(h) = -\frac{3}{8} m^2 \varphi_v^2 + \underbrace{3 m^2 h^2}_{\text{positive}} + 56 \lambda \varphi_v^5 h^3 + 70 \lambda \varphi_v^4 h^4 + O(h^5)$$

$$\varphi = \varphi_v + \underbrace{h(x)}$$

kinetic scaling

$$V_{eff}(h) = \left(-\frac{3}{8} m^2 \varphi_v^2 + \underline{3 m^2 h^2} + 56 \lambda \varphi_v^5 h^3 + 70 \lambda \varphi_v^4 h^4 \right) + O(h^5)$$

positive

$$\varphi = \varphi_v + \underbrace{h(x)}$$

$$|h| \ll |\varphi_v|$$

kinetic scaling

$$V_{eff}(h) = -\frac{3}{8} m^2 \varphi_v^2 + 3 m^2 h^2 + 56 \lambda \varphi_v^5 h^3 + 70 \lambda \varphi_v^4 h^4 + O(h^5)$$

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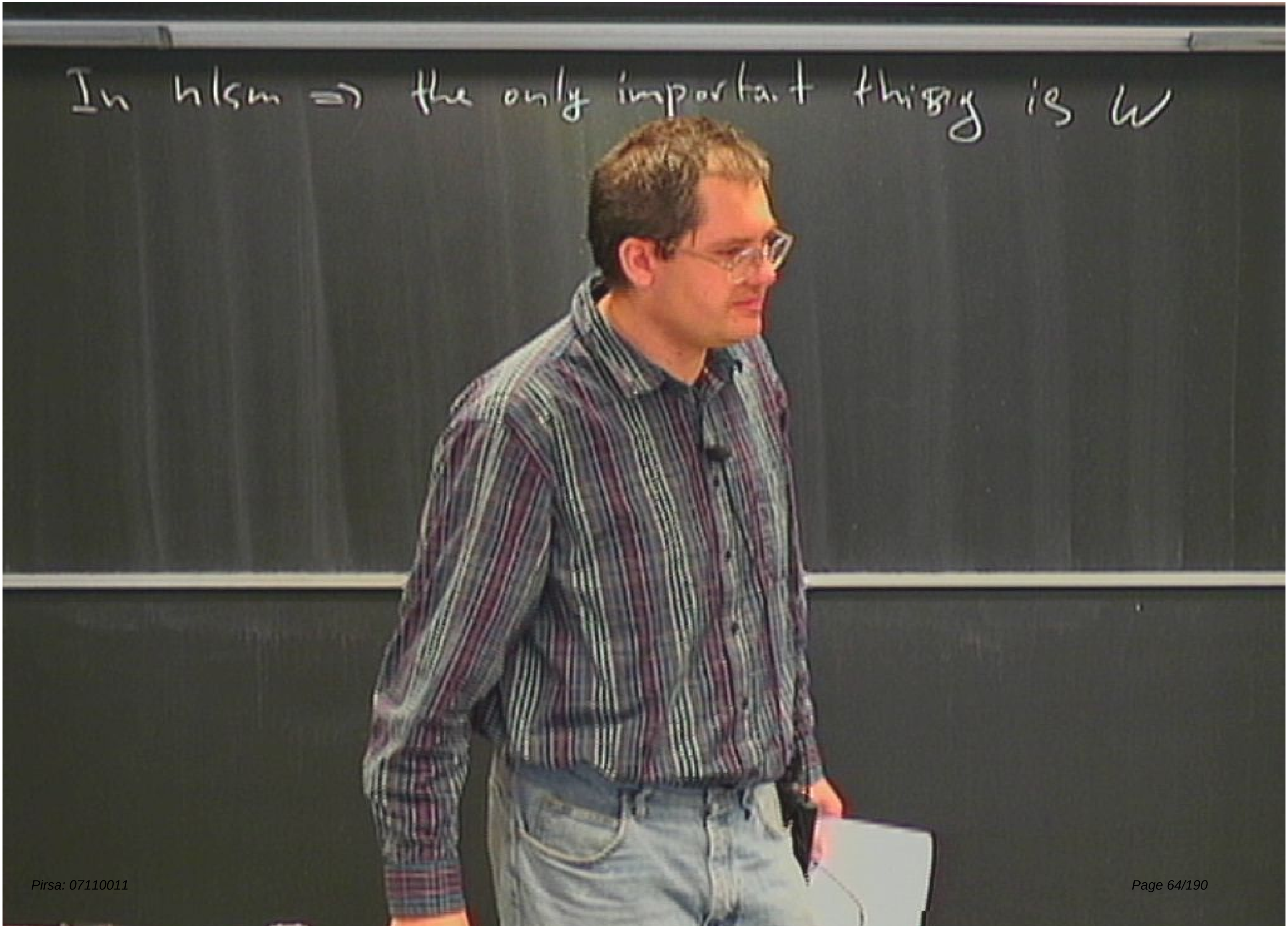
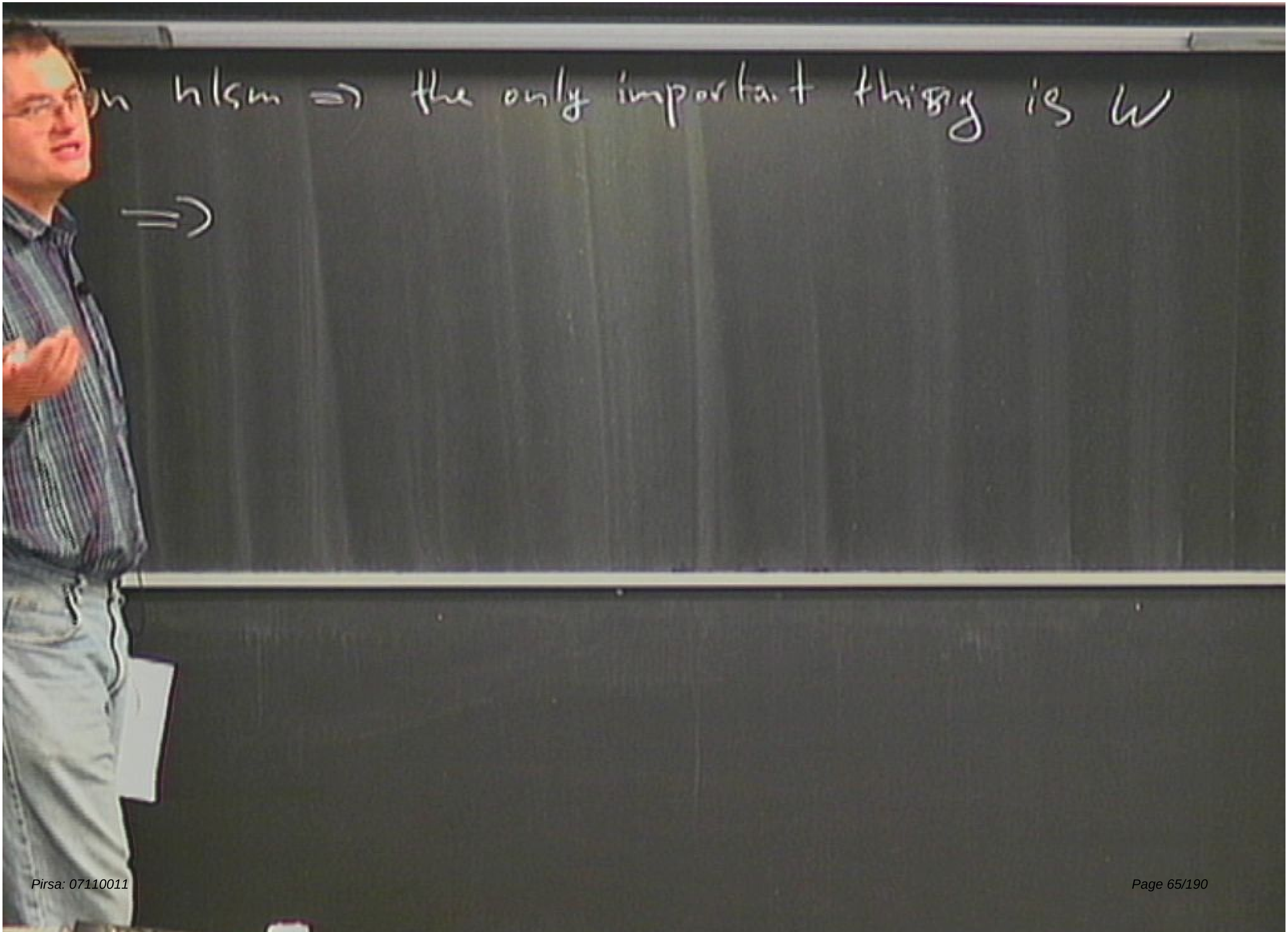

In nlsm ⇒ the only important thing is ω


on hlsm ⇒ the only important thing is W
⇒

In nlsm $\Rightarrow$ the only important thing is W

$\Rightarrow$ we can use classical Kähler potential

In NLSM ⇒ the only important thing is W

⇒ we can use classical Kähler potential

⇒ In SUSY QFT W does not receive quantum correction.

Claim: <u>If</u> SUSY is unbroken field theory.

nlsm If SUSY in unbroken classical vaca survive quantum corrections.

Selection rules and nonren. thms

$\Rightarrow$ nlsm.

nlsm If SUSY in unbroken classical vacua
survive quantum corrections.

Selection rules and nonrenorm theorem

$\Rightarrow$ nlsm might have some global symmetries.

<u>If</u> SUSY in unbroken classical vacua
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<u>Selection rules and nonrenorm. theorem</u>

$\Rightarrow$ nlsm. might have some global symmetries.

$\Rightarrow$ Global sym must commute

nlsm If SUSY in unbroken classical vacua survive quantum corrections.

Selection rules and nonren. thorem

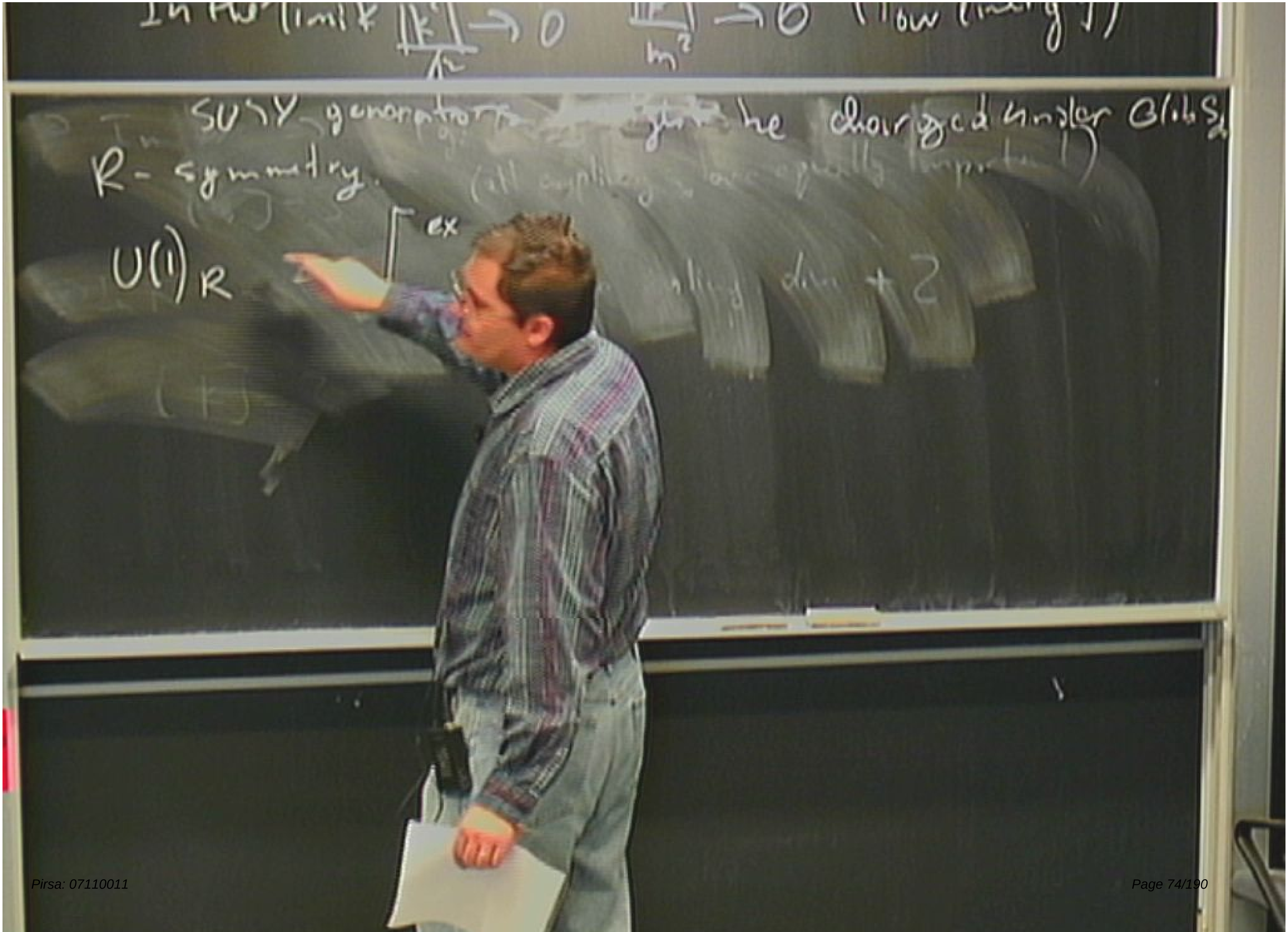
$\Rightarrow$ nlsm. might have some global symmetries.

$\Rightarrow$ Global sym must commute with Poincare symm.

SUSY generators [illegible] the charged under Glob S

(all couplings [illegible] equally important!)

have [illegible] dim + 2


R- symmetry.
U(1)R

In this limit $\frac{|k|}{\Lambda^2} \to 0$ $\frac{|\lambda|}{m^2} \to 0$ (flow limit ...)

SUSY generators ... be charged under global symmetry

R-symmetry.

$U(1)_R$

[In extended SUSY model R-symmetry can become non-abelian.

$N=2 \Rightarrow SU(2)_R$

$N=4 \Rightarrow SU(4)_R \sim$

$AdS_5 \times S^5$ $SO(6)$

In the limit $\frac{1}{\Lambda^2} \to 0$ $\frac{1}{m^2} \to 0$ (low energy)

SUSY generators can be charged under global R-symmetry.

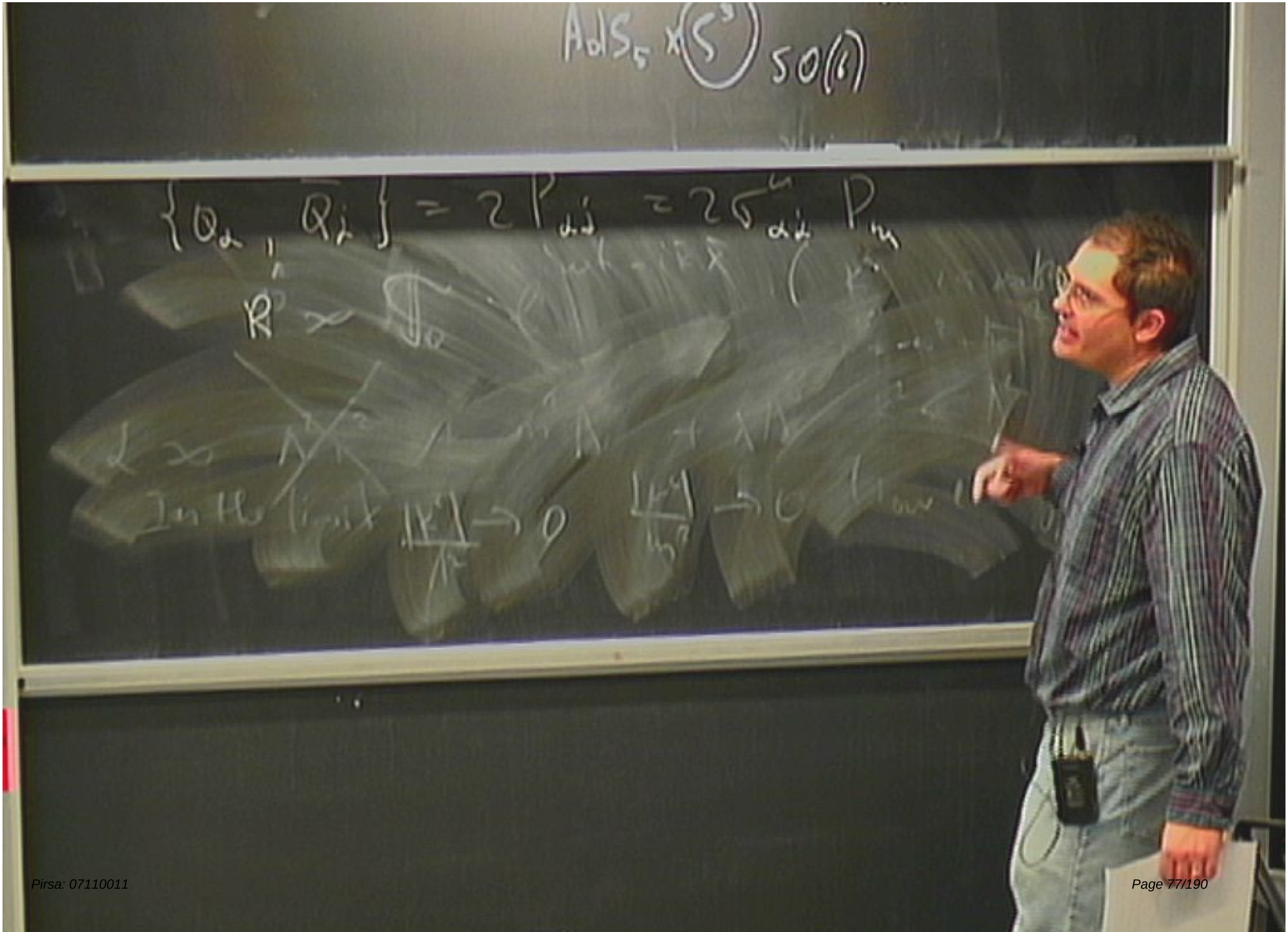
$U(1)_R$

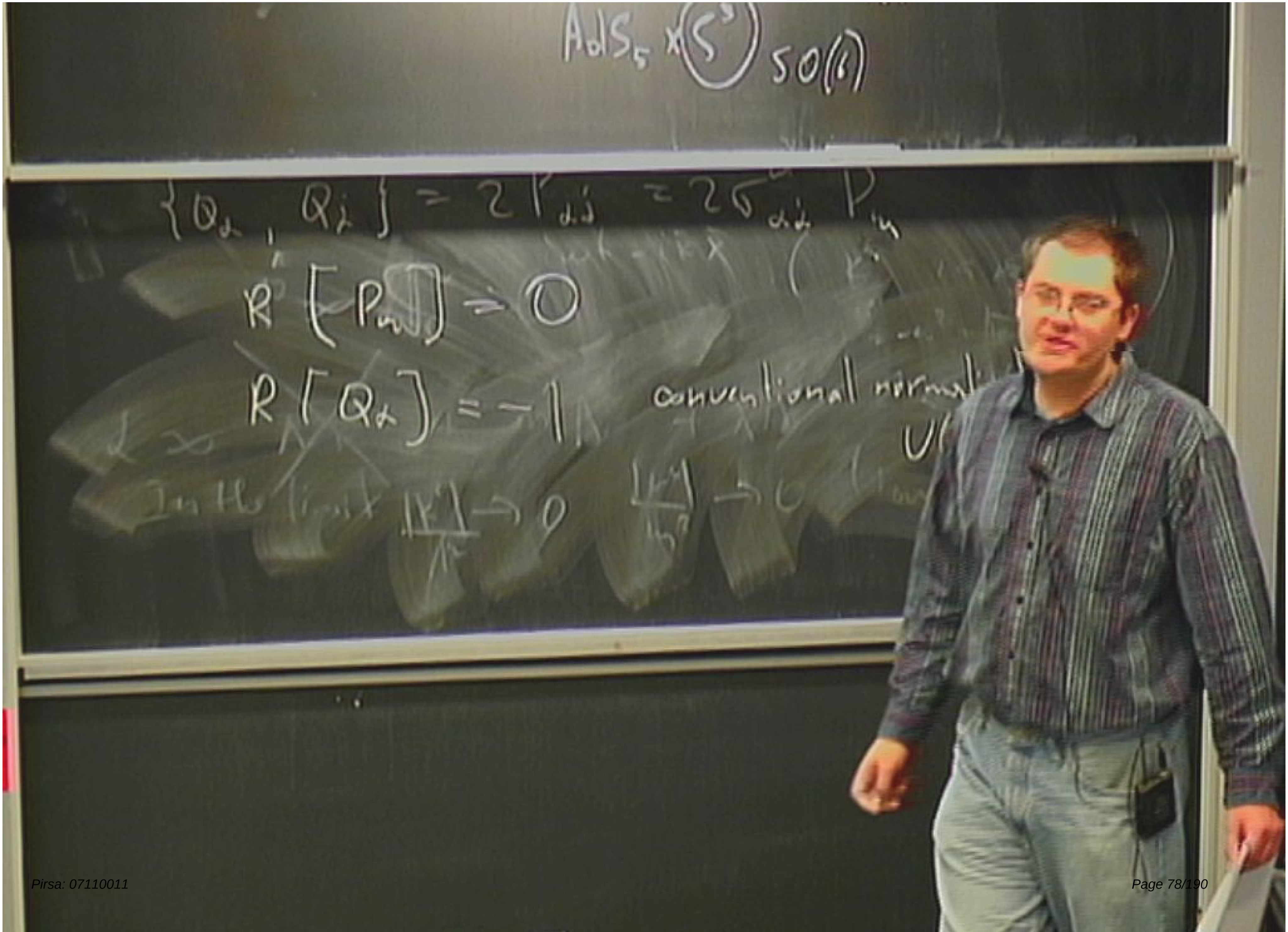
[In extended SUSY model R-symmetry can become non-abelian

$N=2 \Rightarrow SU(2)_R$

$N=4 \Rightarrow SU(4)_R \sim SO(6)_R$

$AdS_5 \times S^5$ $SO(6)$


$AdS_5 \times S^5$ $SO(6)$
$\{Q_\alpha, \bar{Q}_{\dot\alpha}\} = 2P_{\alpha\dot\alpha} = 2\sigma^\mu_{\alpha\dot\alpha} P_\mu$
In the limit


AdS5 × S5 SO(6)
{Qα, Qα̇} = 2Pαα̇ = 2σαα̇ Pμ
R[Pμ] = 0
R[Qα] = −1 conventional normal

$AdS_5 \times S^5 \quad SO(6)$

$\{Q_\alpha, \bar{Q}_{\dot\alpha}\} = 2\Gamma_{\alpha\dot\alpha} = 2\sigma^{\mu}_{\alpha\dot\alpha} P_\mu$

$R[P_\mu] = 0$

$R[Q_\alpha] = -1$ conventional normalization of $U(1)_B$

$AdS_5 \times S^5 \quad SO(6)$

$\{Q_\alpha, \bar{Q}_{\dot\alpha}\} = 2 P_{\alpha\dot\alpha} = 2\sigma^m_{\alpha\dot\alpha} P_m$

$R[P_m] = 0$

$R[Q_\alpha] = -1$ conventional normalization of $U(1)_R$

$R[\bar{Q}_{\dot\alpha}] = +1$

Show:

$$[R, Q_\alpha] = -Q_\alpha$$

$$[R, \bar{Q}_{\dot\alpha}] = +\bar{Q}_{\dot\alpha}$$

Selection rule and nonrenorm. theorem

$\Rightarrow$ ntsm. might have some global symmetries.

$\Rightarrow$ Global sym must commute with Poincare symm

$\Rightarrow$ Global sym are not required to commute with SUSY

Show: implies that $\langle\varphi\rangle \sim 0$

$$[R, Q_\alpha] = -Q_\alpha$$

$$[R, \bar{Q}_{\dot\alpha}] = +\bar{Q}_{\dot\alpha}$$

$$[R, P_\mu] = 0$$ (Coleman-Mandula theorem)

$[R, Q_\alpha] |n\rangle$

vacuum

global symmetry

Poincaré sym

SUSY

$[R, Q_\alpha]|n\rangle = RQ_\alpha|n\rangle - Q_\alpha R|n\rangle$

$R(|n\rangle) = r$

$$[R, Q_\alpha]\,|n\rangle = R Q_\alpha |n\rangle - Q_\alpha R |n\rangle$$

$$R\big(|n\rangle\big) = r$$

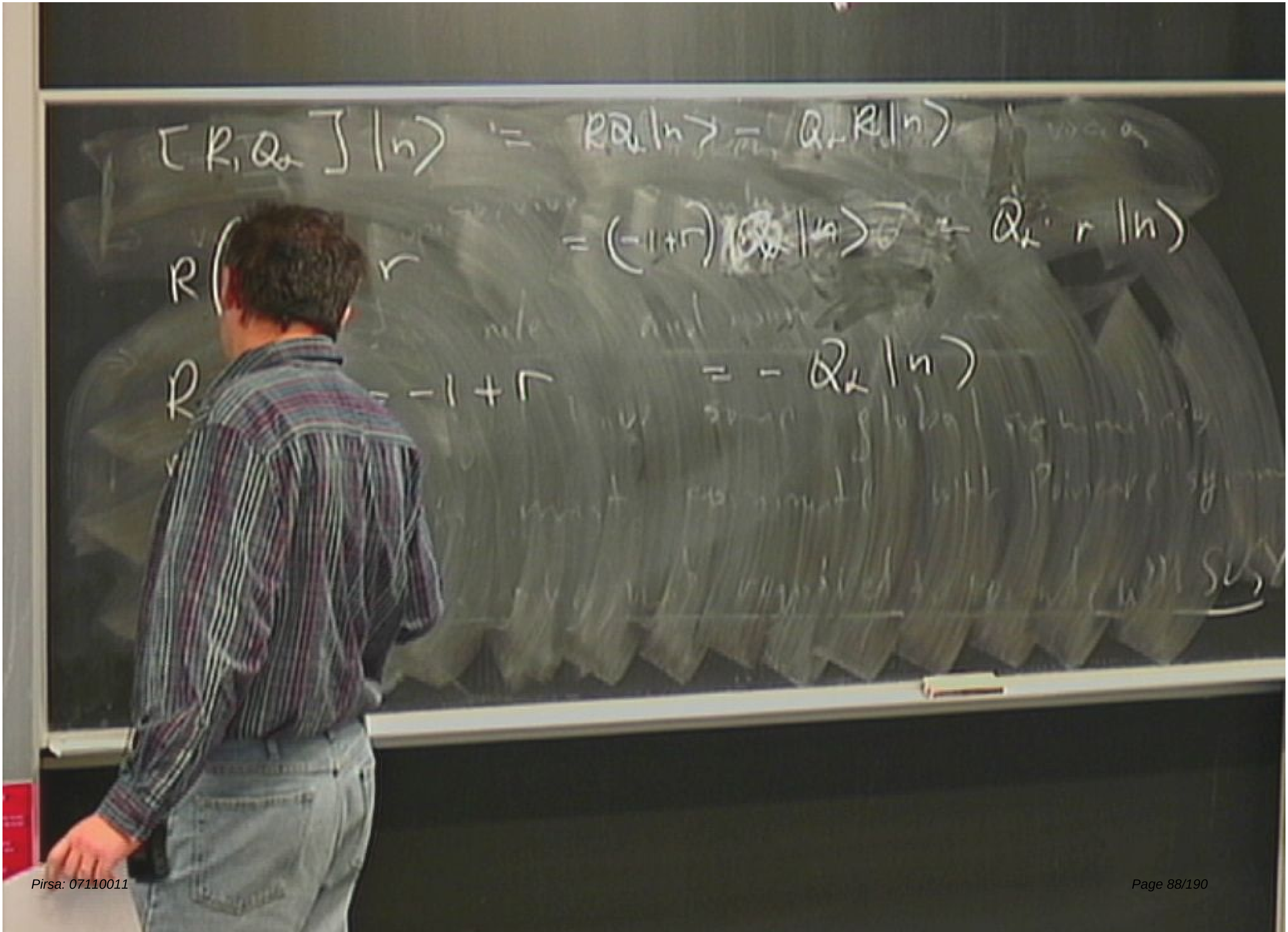
$$R\big(Q_\alpha |n\rangle\big) = -1 + r$$

$$[R, Q_\alpha]\,|n\rangle = R Q_\alpha |n\rangle - Q_\alpha R\,|n\rangle$$

$$= (-1 + r)\, Q_\alpha |n\rangle$$

$$R(|n\rangle) = r$$

$$R(Q_\alpha |n\rangle) = -1 + r$$

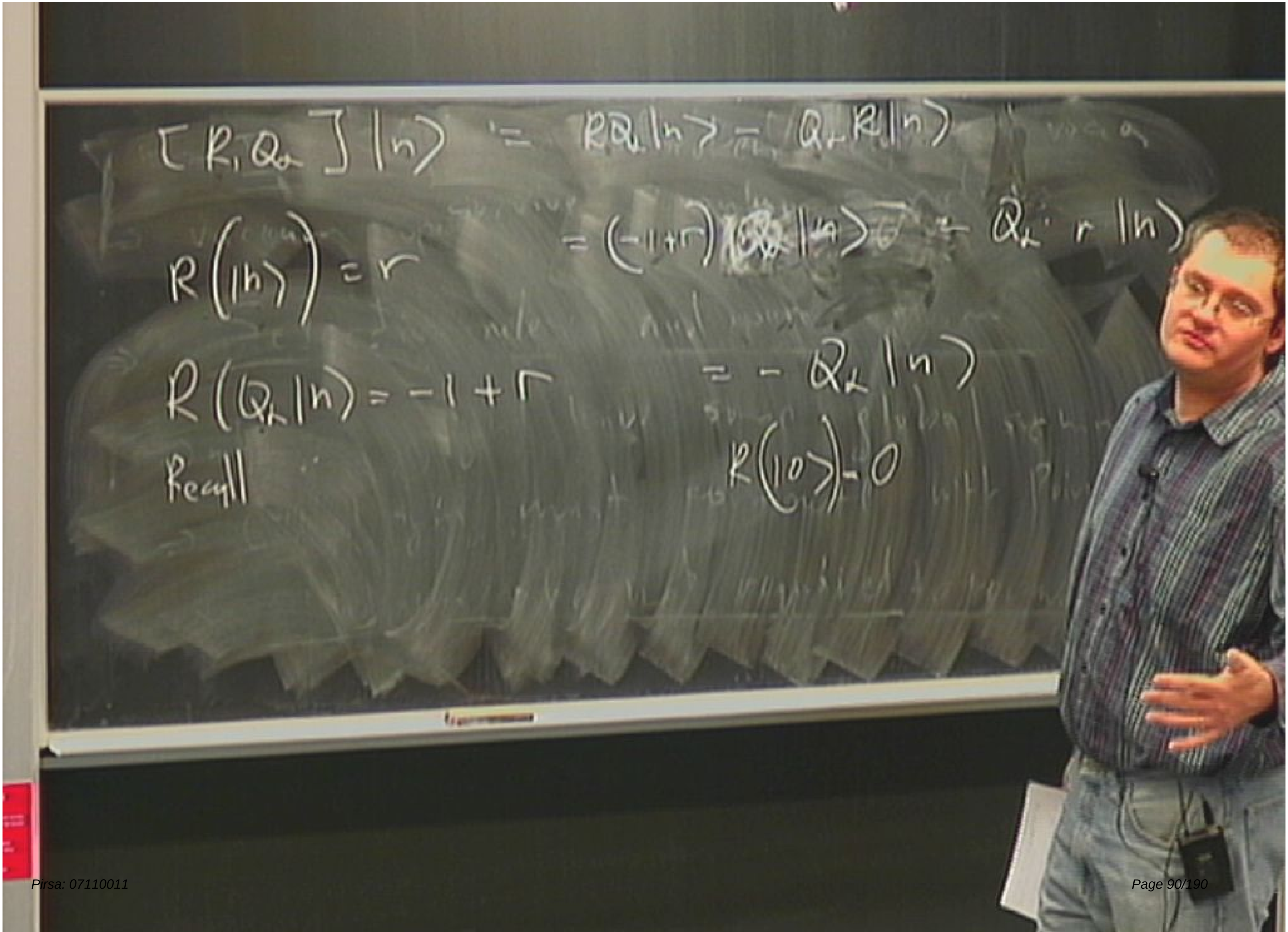

[R, Qα] |n⟩ = RQα |n⟩ − Qα R |n⟩
R(r = (−1+r) Qα |n⟩ − Qα r |n⟩
R = −1 + r = − Qα |n⟩

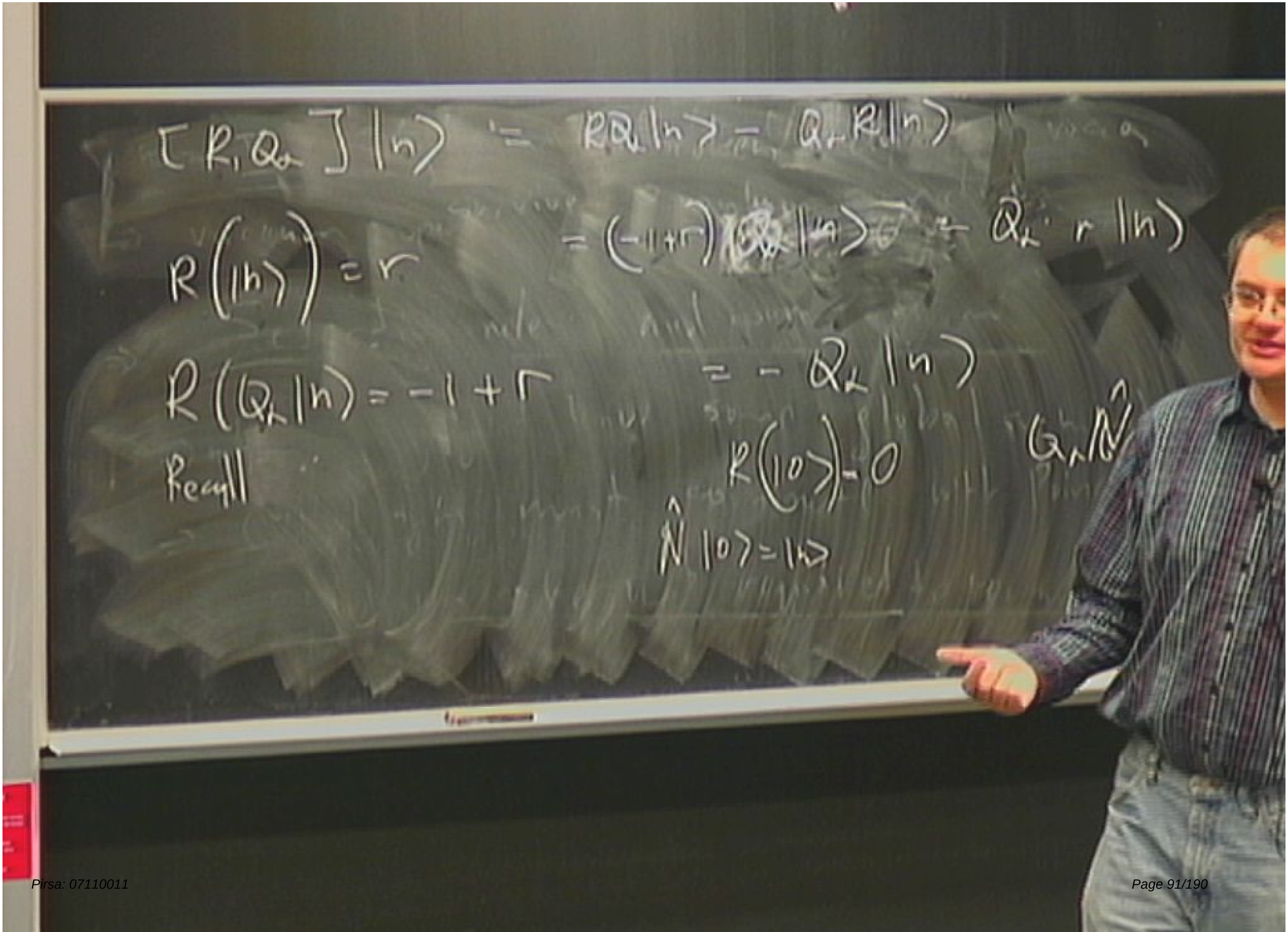
$$[R, Q_\alpha]\,|n\rangle = R Q_\alpha |n\rangle - Q_\alpha R |n\rangle$$

$$R\big(|n\rangle\big) = r \qquad = (-1+r)\, Q_\alpha |n\rangle - Q_\alpha\, r\, |n\rangle$$

$$R\big(Q_\alpha|n\rangle\big) = -1 + r \qquad = -\,Q_\alpha |n\rangle$$

Recall


[R, Q_L] |n> = R Q_L |n> − Q_L R |n>
= (−1 + r) Q_L |n> − Q_L r |n>
= − Q_L |n>
R(|n>) = r
R(Q_L |n>) = −1 + r
Recall
R(|0>) = 0



[R, Q_-] |n> = R Q_- |n> - Q_- R |n>
= (-1+r) Q_- |n> - Q_- r |n>
R(|n>) = r
= - Q_- |n>
R(Q_- |n>) = -1 + r
Q_- N̂
Recall
R(|0>) = 0
N̂ |0> = |n>

$[R, Q_\alpha]\,|n\rangle = R Q_\alpha |n\rangle - Q_\alpha R |n\rangle$

$= (-1+r)\, Q_\alpha |n\rangle - Q_\alpha\, r\, |n\rangle$

$R(|n\rangle) = r$

$= -Q_\alpha |n\rangle$

$R(Q_\alpha |n\rangle) = -1 + r$

Recall

$R(|0\rangle) = 0$

$Q_\alpha \hat{N}$

$\hat{N}\,|0\rangle = |n\rangle$

$R(\hat{N}) = r$

$R(Q_\alpha) = -1$

$R(N) = 1$

$R(a_n) = -1$

$R(Q_\alpha) = -1$

$$Q_\alpha = \frac{\partial}{\partial \theta^\alpha} - i\sigma^\mu_{\alpha\dot\alpha}\bar\theta^{\dot\alpha}\partial_\mu$$

$R(N) = \ldots$

$R(a_n) = -1$

$R(Q_\alpha) = -1$

$$Q_\alpha = \frac{\partial}{\partial \theta^\alpha} - i\,\sigma^{\mu}_{\alpha\dot\alpha}\,\bar\theta^{\dot\alpha}\,\partial_\mu$$

$R(N) = r$

$R(a_n) = -1$

$R(Q_\alpha) = -1$

-1

$$Q_\alpha = \frac{\partial}{\partial \theta^\alpha} - i\,\sigma^\mu_{\alpha\dot{\alpha}}\,\bar{\theta}^{\dot{\alpha}}\,\partial_\mu$$

$R[\theta^\alpha] = +1$

$R(N) = 1$

$R(Q_\alpha) = -1$

$R(Q_\alpha) = -1$

$Q_\alpha = \frac{\partial}{\partial \theta^\alpha} - i \sigma^\mu_{\alpha\dot\alpha} \bar\theta^{\dot\alpha} \partial_\mu$

$R[\theta^\alpha] = +1$

$R(N) = 1$

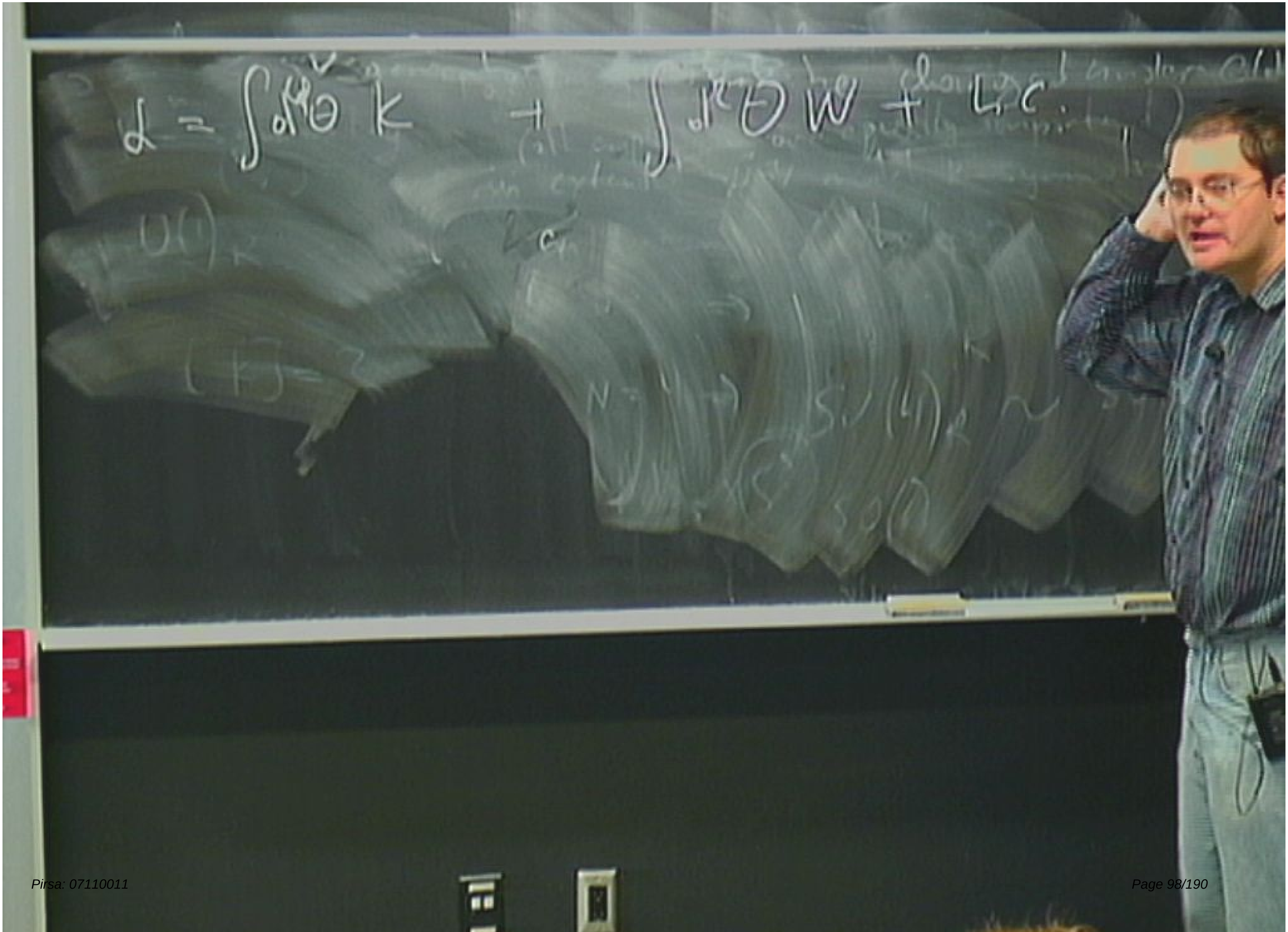
$R(a_n) = -1$

$R(Q_\alpha) = -1$

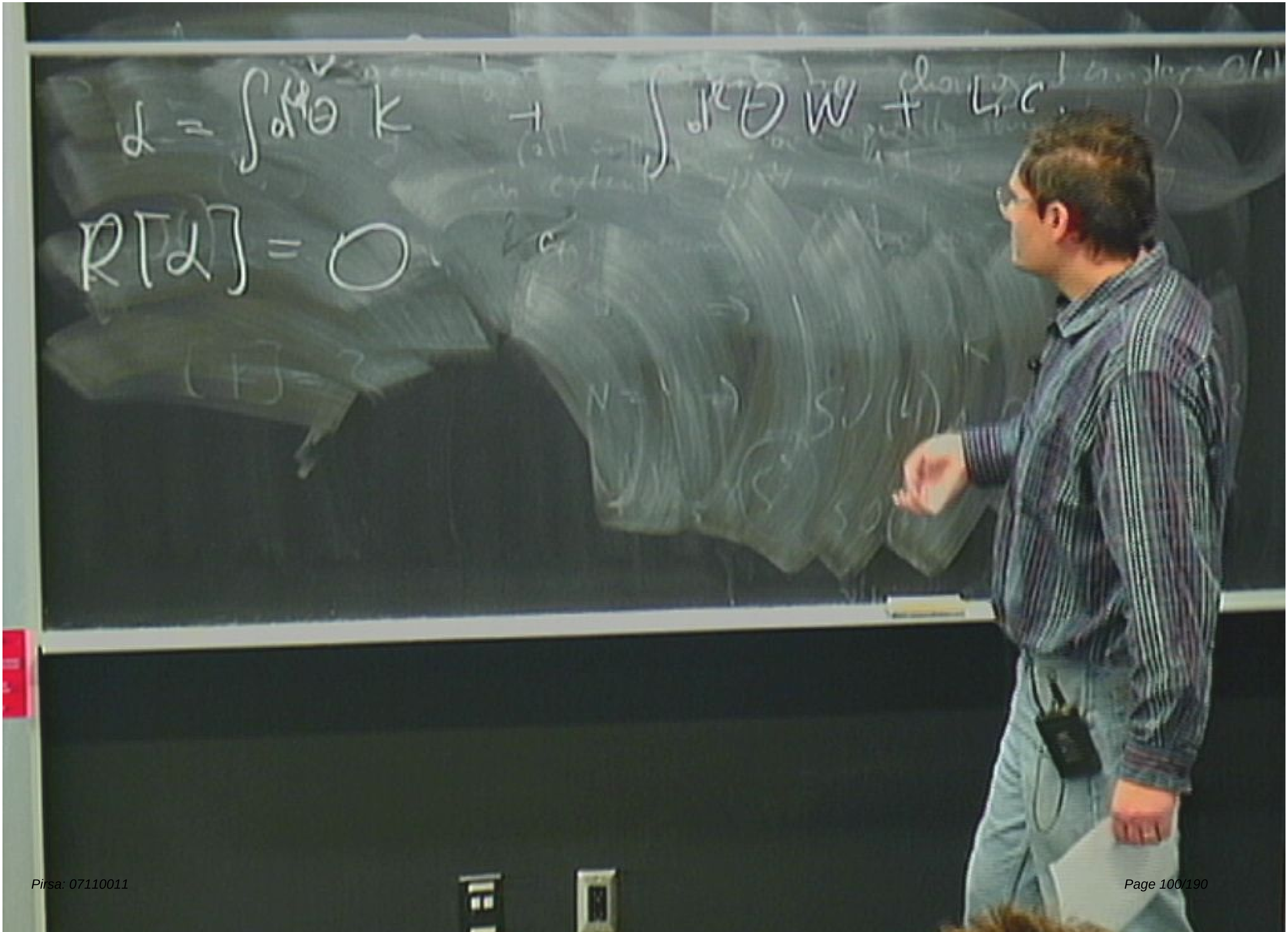
$$Q_\alpha = \frac{\partial}{\partial\theta^\alpha} - i\,\sigma^\mu_{\alpha\dot\alpha}\,\bar\theta^{\dot\alpha}\,\partial_\mu$$

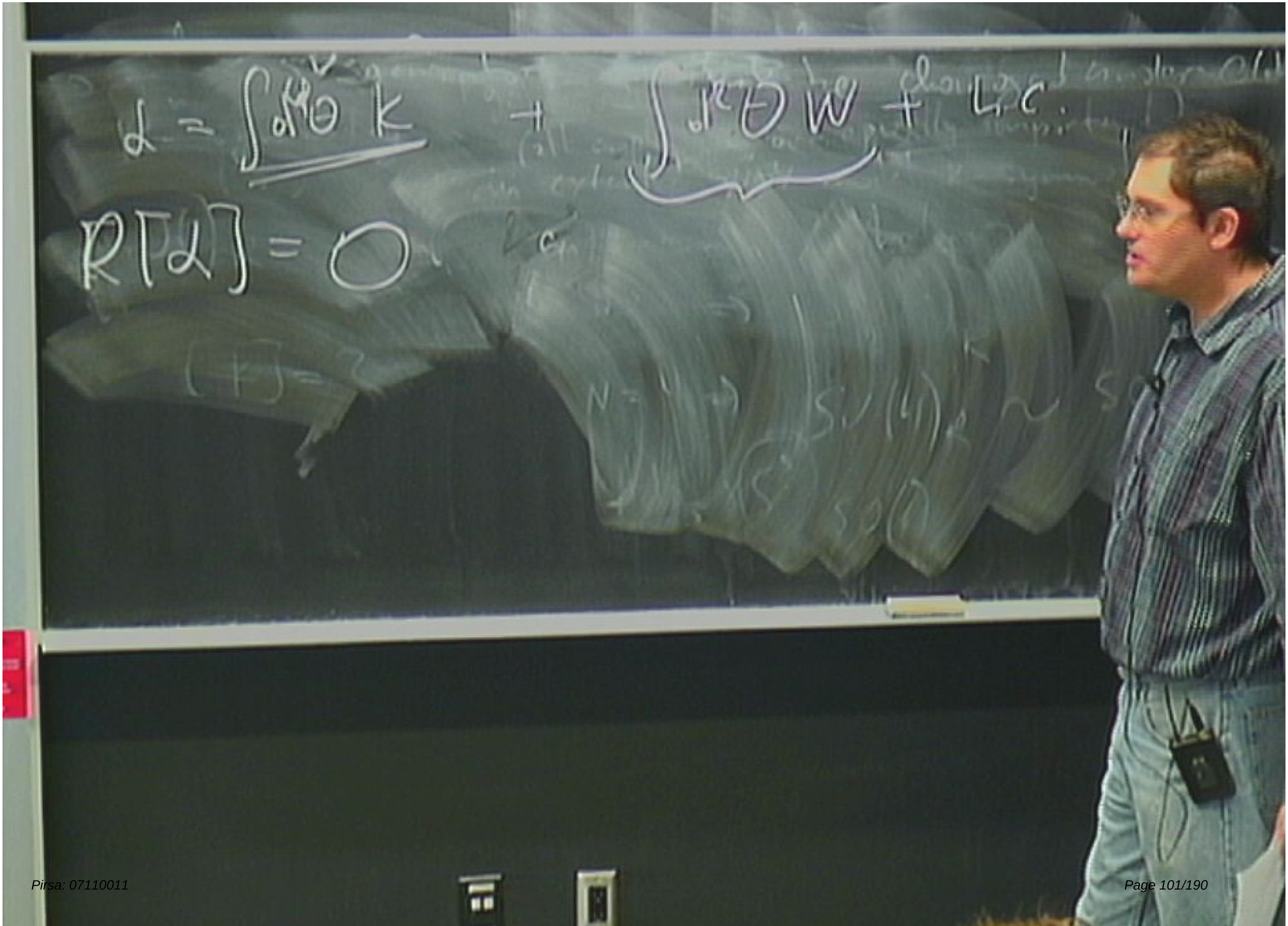
$R(\theta^\alpha) = +1$

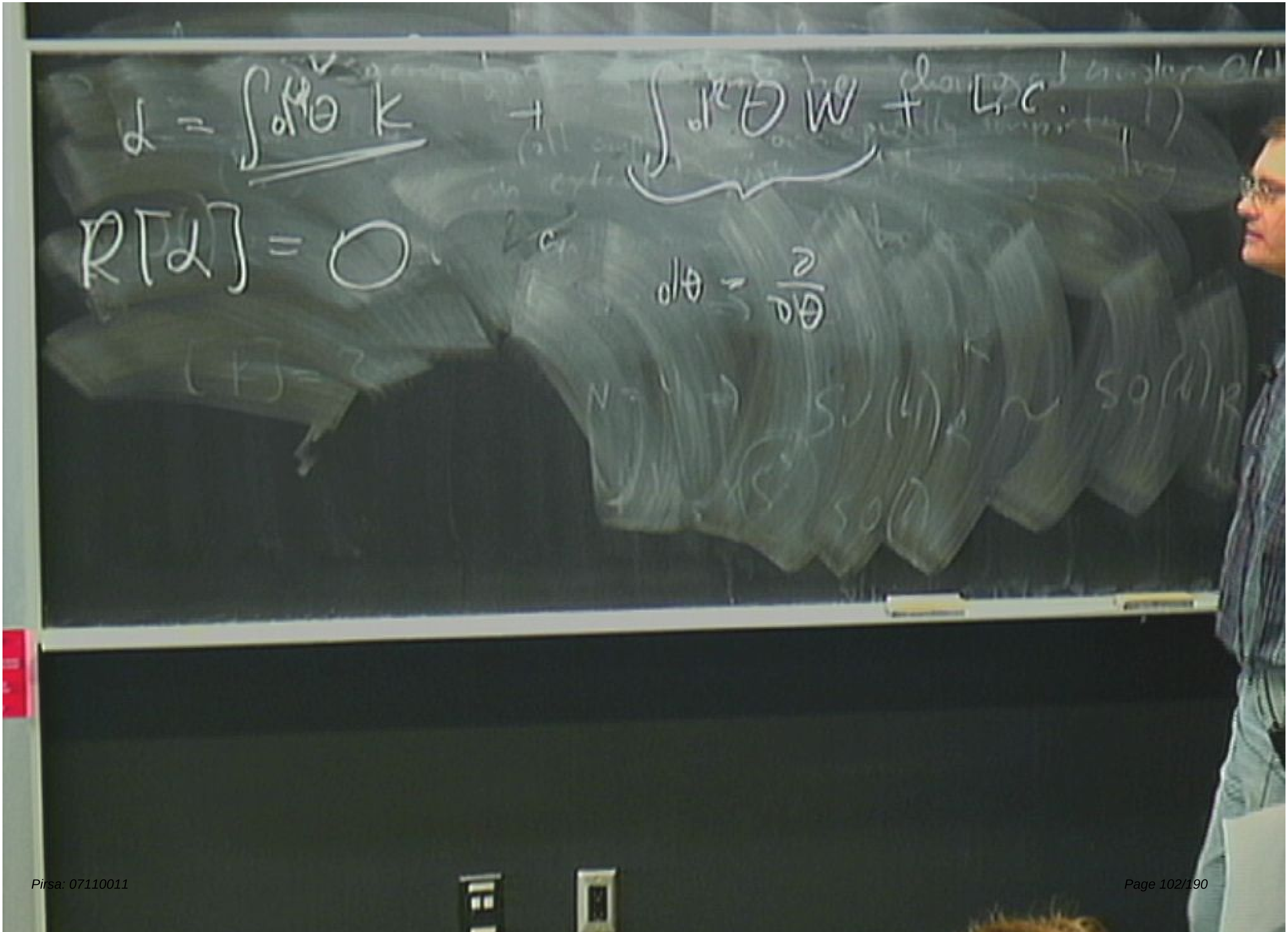
$R(\bar\theta^{\dot\alpha}) = -1$

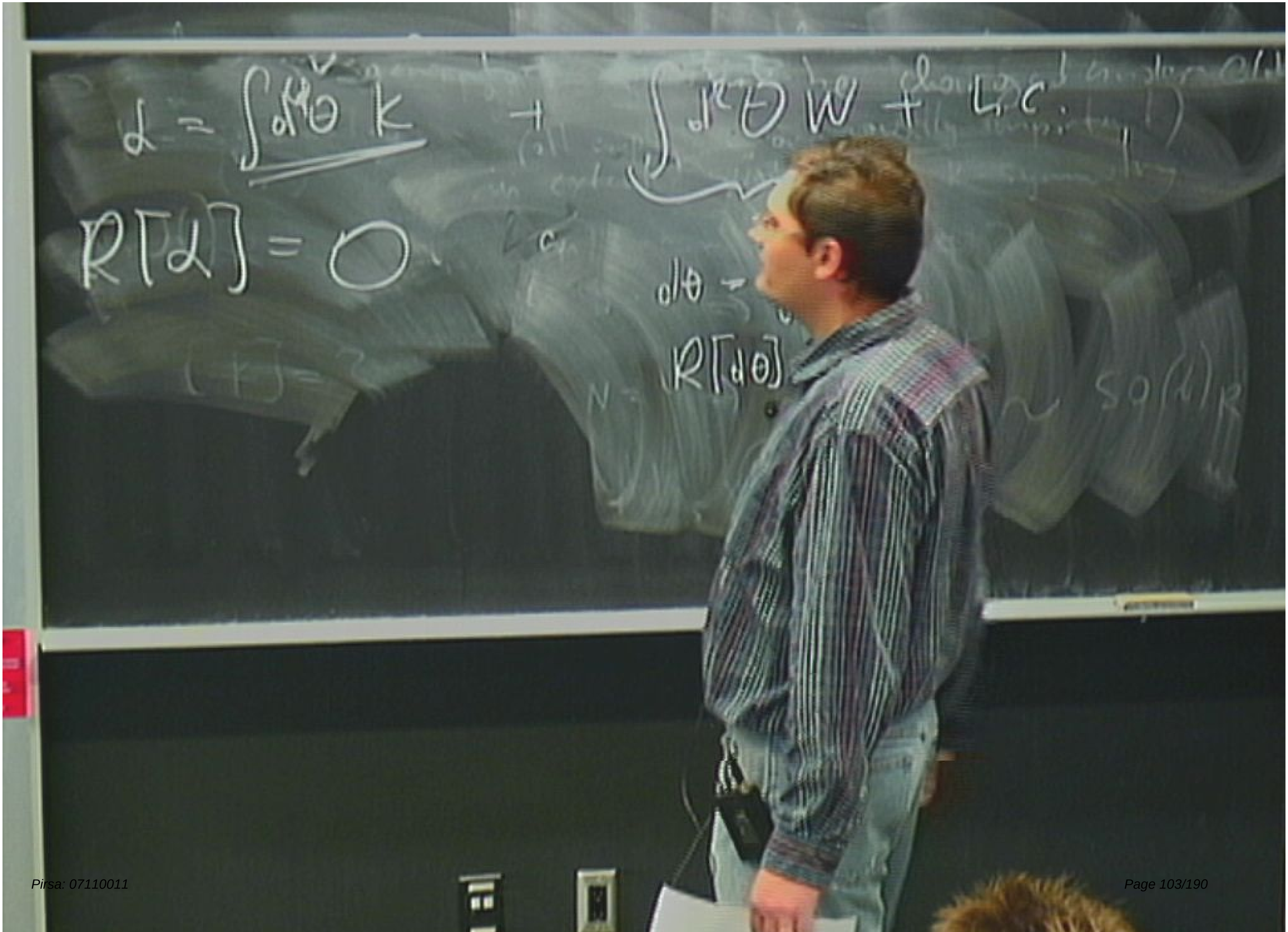

$\mathcal{L} = \int d^4\theta\, K + \int d^2\theta\, W + h.c.$

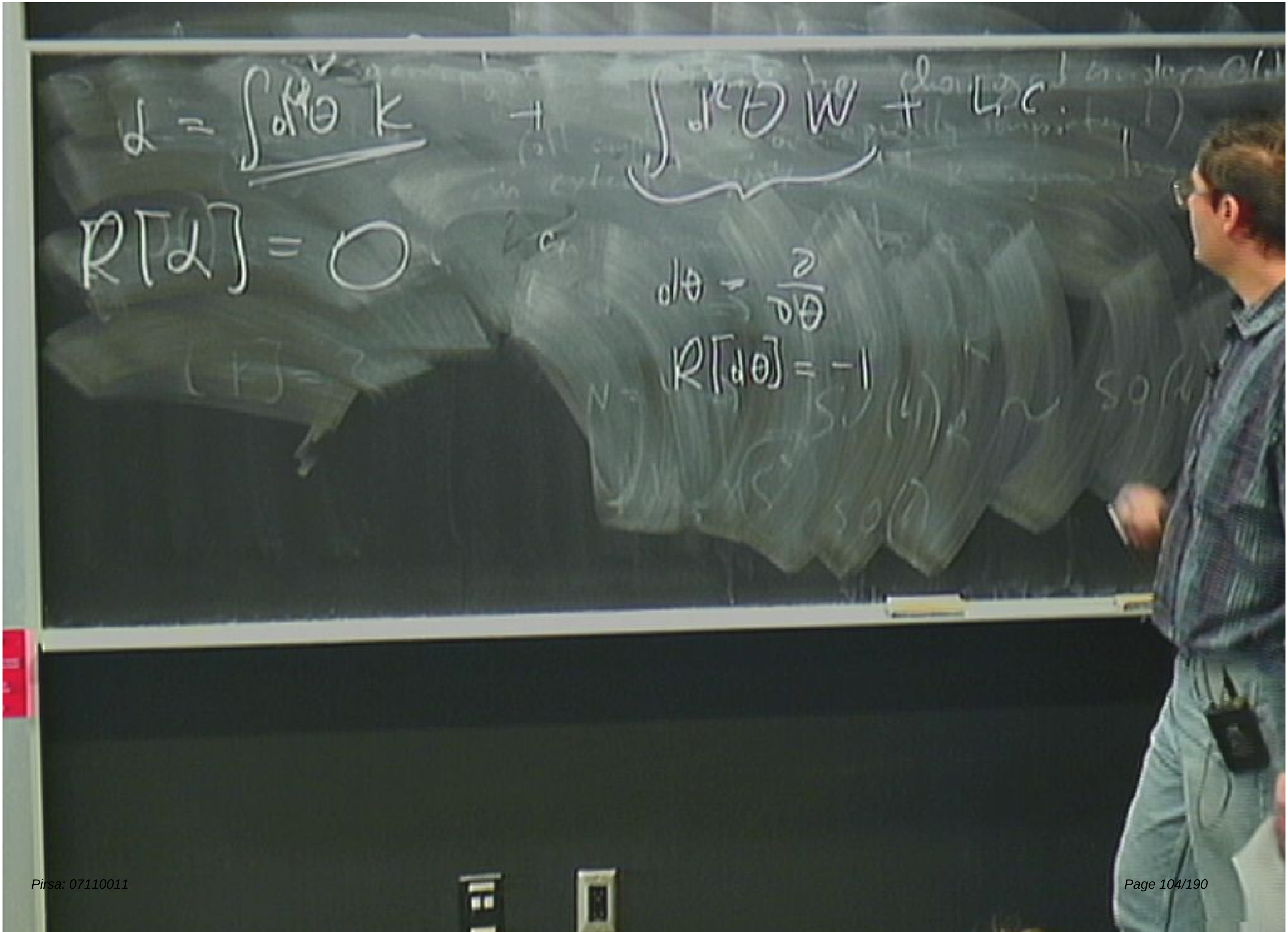
$$\mathcal{L} = \int d^4\theta \, K + \int d^2\theta \, W + h.c.$$


$\mathcal{L} = \int d^4\theta\, K + \int d^2\theta\, W + h.c.$
$R[\mathcal{L}] = 0$


α = ∫ dRΘ K + ∫ dRΘ W + c.c.
R[α] = 0


α = ∫ d⁴θ K + ∫ d²θ W + c.c.
R[α] = 0
dθ = ∂/∂θ


α = ∫ dᴷθ K + ∫ dᴷθ W + c.c.
R[α] = 0
dθ =
R[dθ]


α = ∫ d^k θ K + ∫ d^k θ W + c.c.
R[α] = 0
dθ = ∂/∂θ
R[dθ] = −1

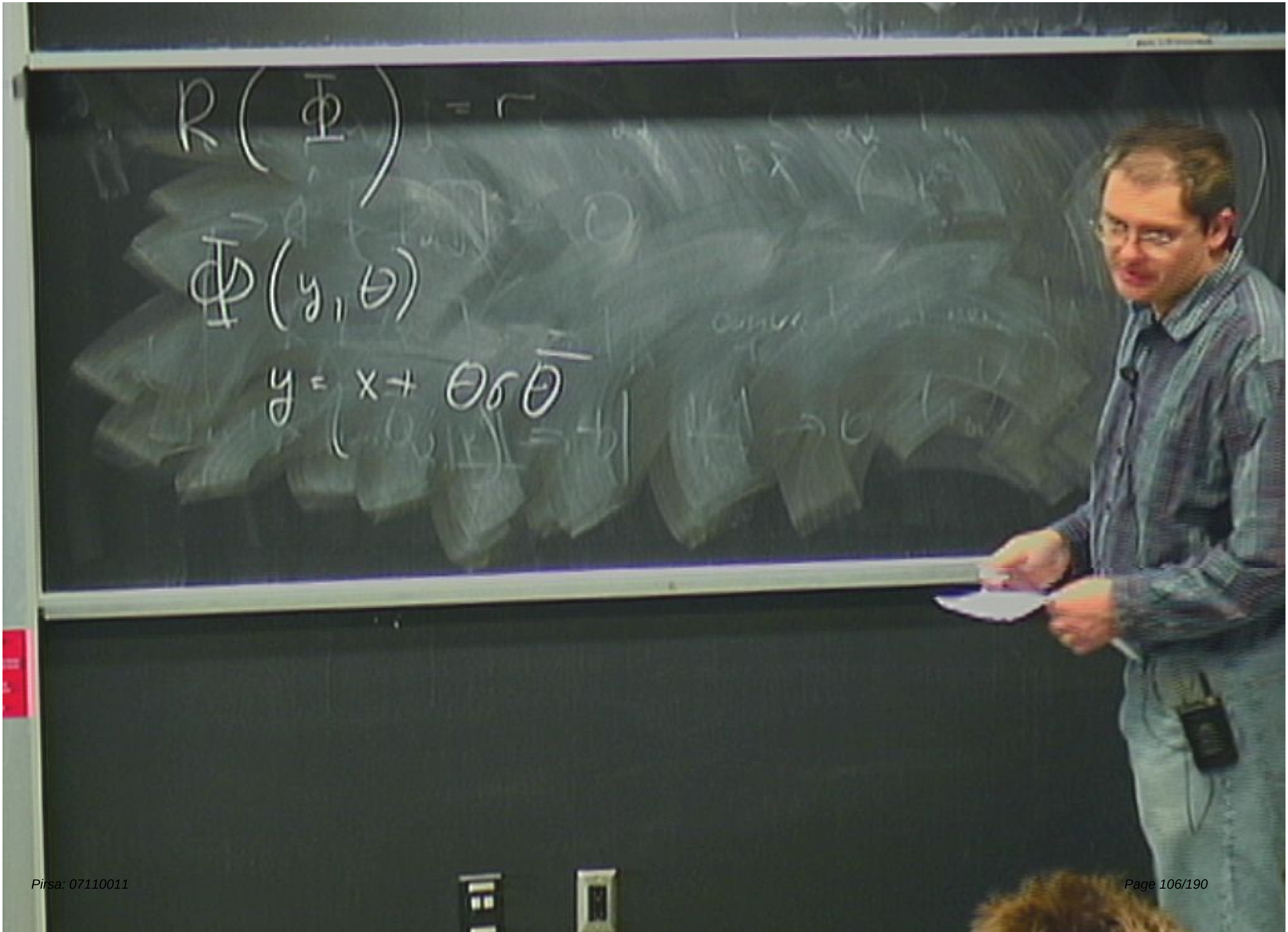
$$\alpha = \underline{\int d^4\theta\, K} + \underbrace{\int d^2\theta\, W}_{} + \text{h.c.}$$

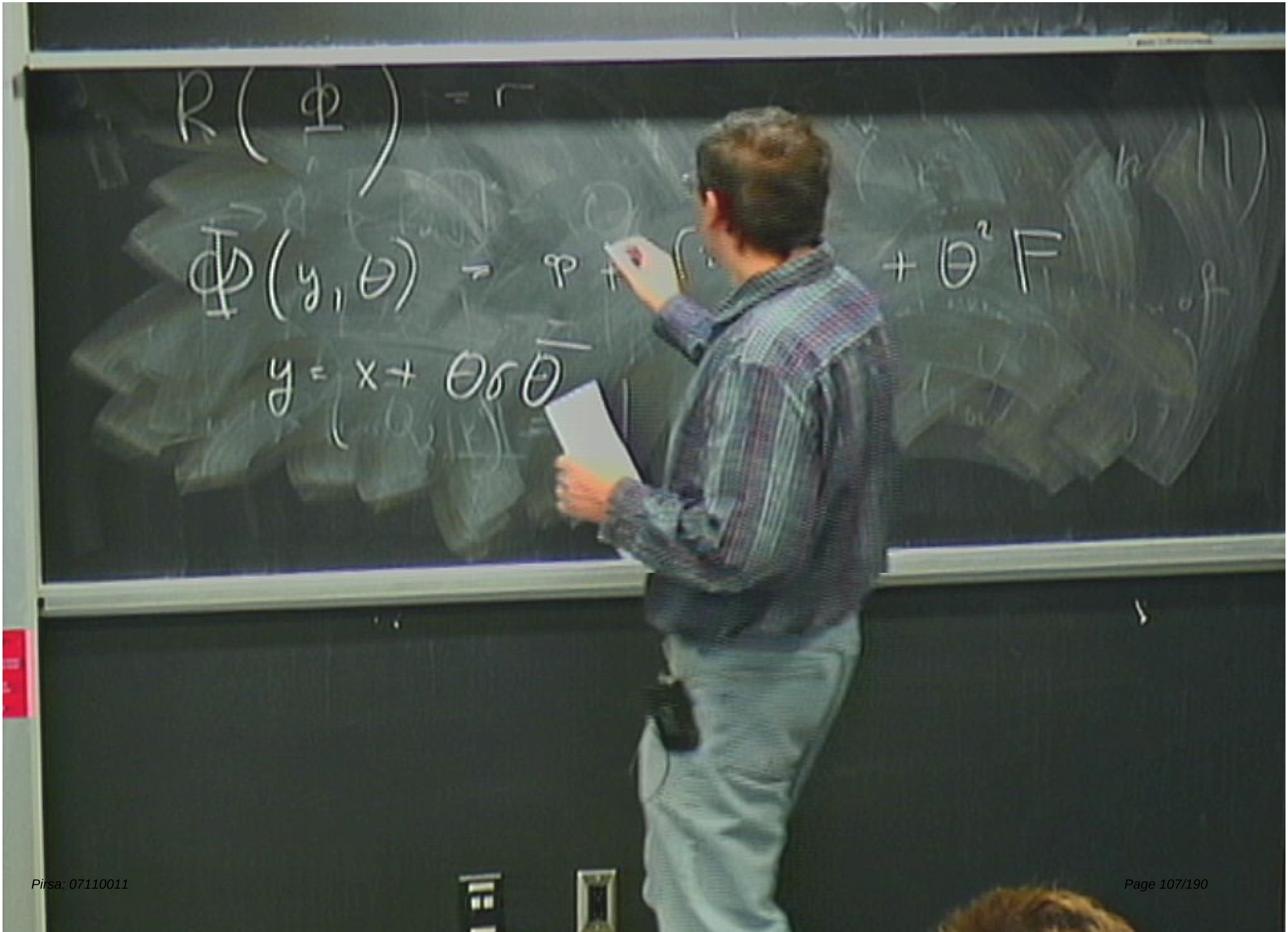
$$R[\alpha] = 0$$

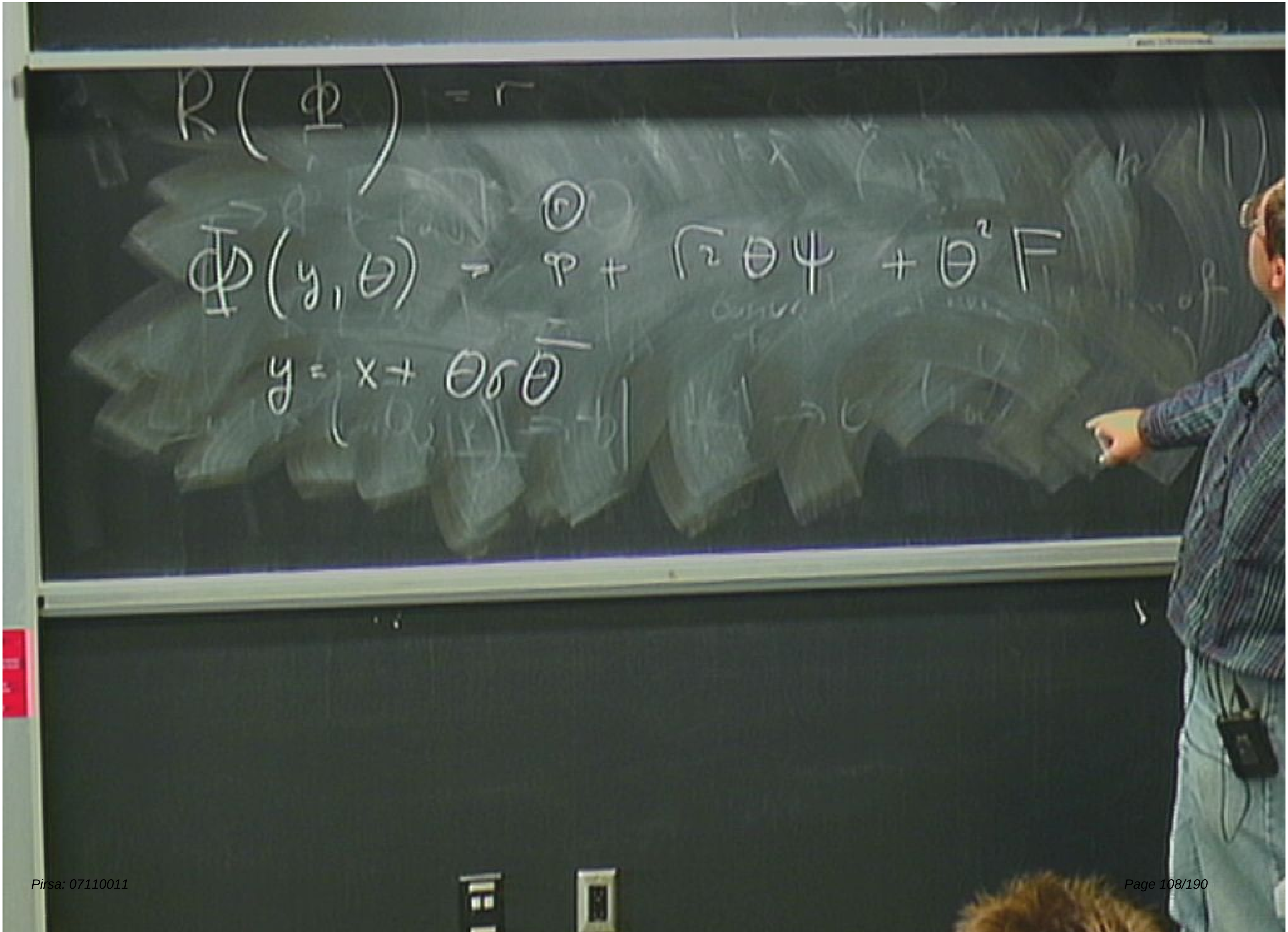
$$d\theta \sim \frac{\partial}{\partial\theta}$$

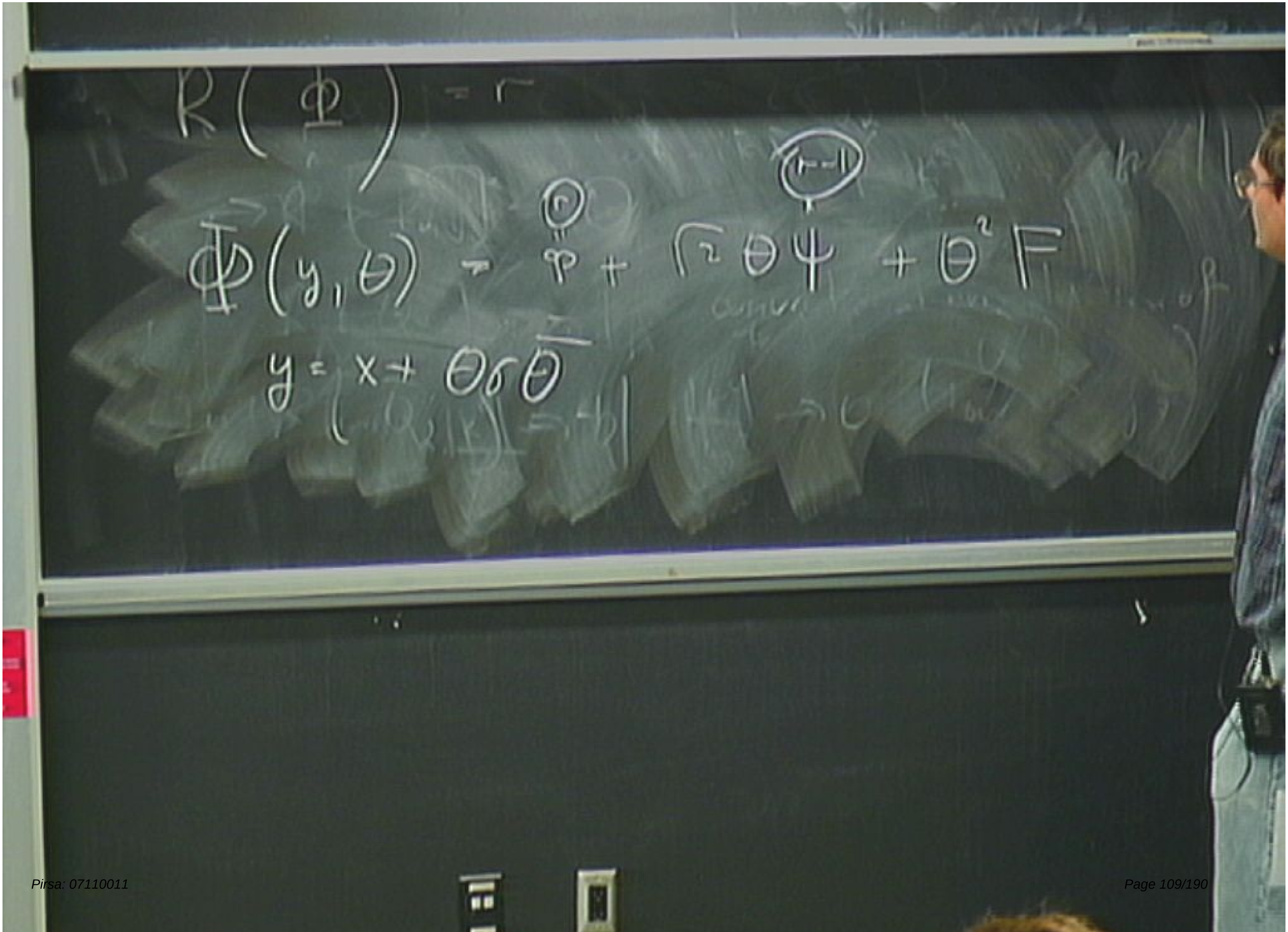
$$R[d\theta] = -1 \qquad R[d^2\theta] = -2$$

$$\boxed{R[W] = +2}$$


R(Φ) = ∫
Φ(y, θ)
y = x + θσθ̄


$y = x + \theta\sigma\bar{\theta}$


$R(\Phi) = r$
$\Phi(y,\theta) = \varphi + \sqrt{2}\,\theta\psi + \theta^2 F$
$y = x + \theta\sigma\bar{\theta}$



$R(\Phi) = r$
$\Phi(y,\theta) = \varphi + \sqrt{2}\,\theta\psi + \theta^2 F$
$y = x + \theta\sigma\bar{\theta}$

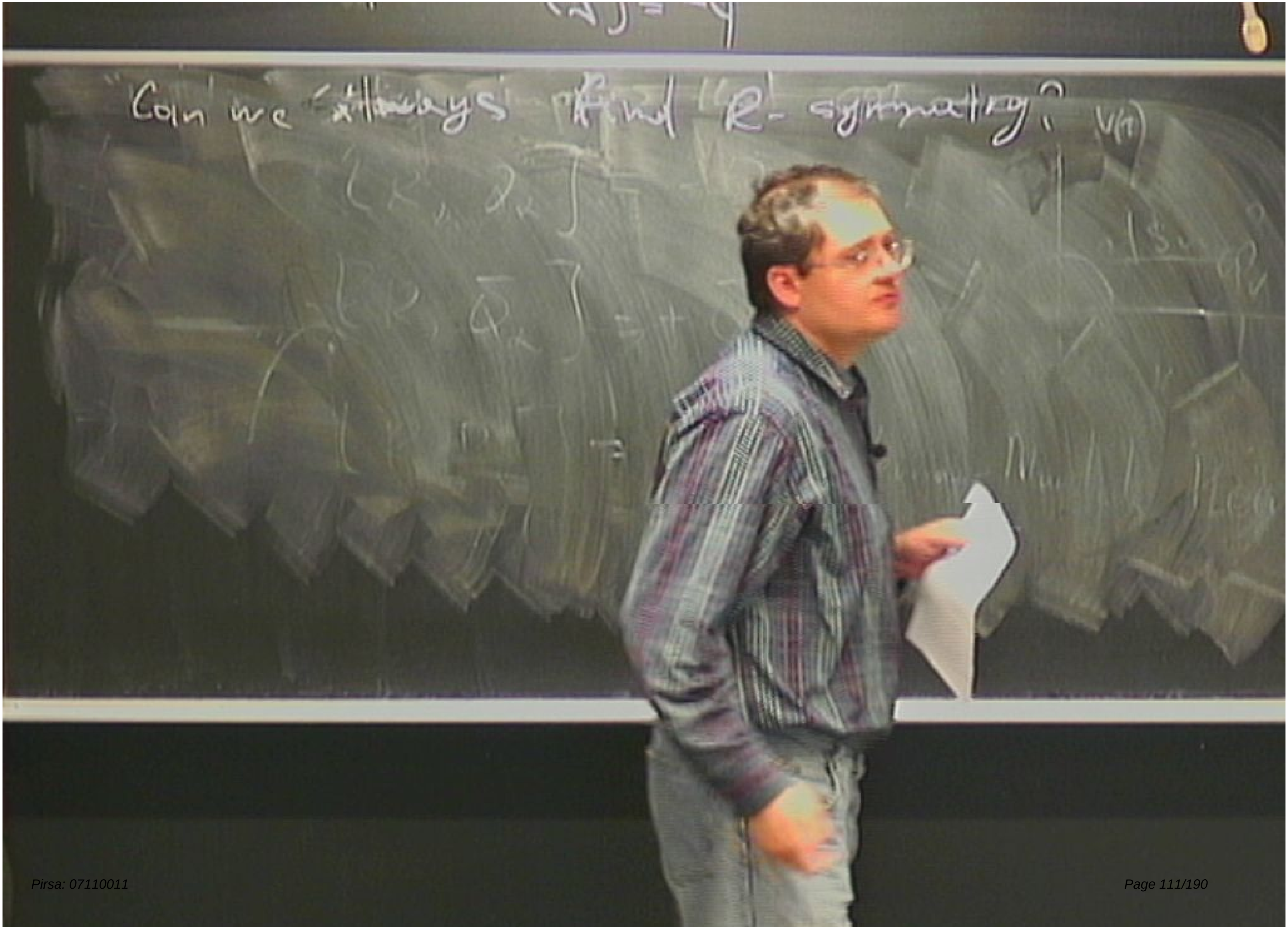
$$R(\Phi) = r$$

$$\Phi(y,\theta) = \overset{(r)}{\varphi} + \sqrt{2}\,\theta\overset{(r-1)}{\psi} + \theta^2 \overset{(r-2)}{F}$$

$$y = x + \theta\sigma\bar\theta$$

$$R(\varphi) = r \qquad R(F) = r-2$$

$$R(\psi) = r-1$$



"Can we 'always' find "R-symmetry"?

"Can we 'always' find 'R-symmetry'?

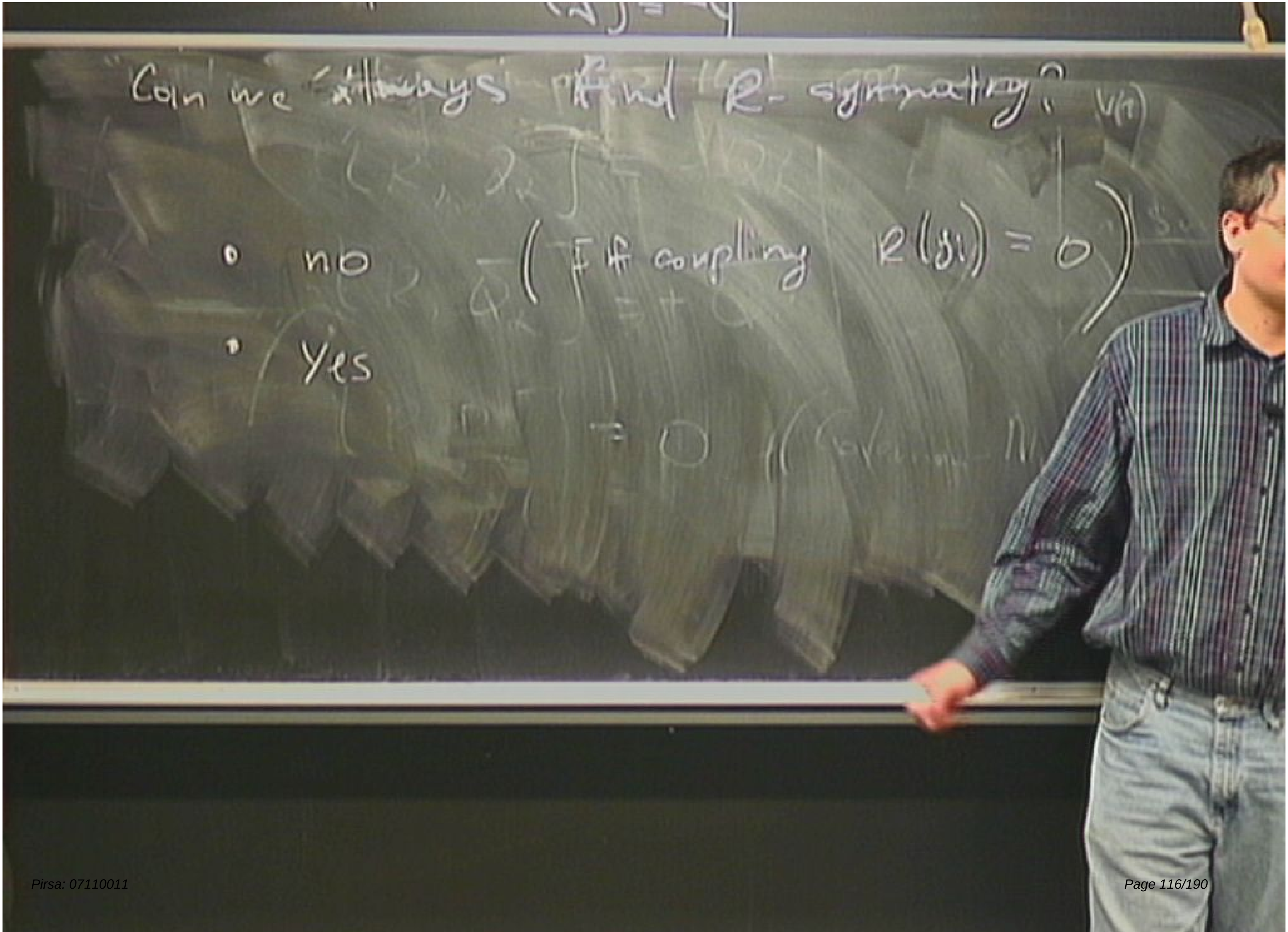
- no
- yes

"Can we 'always' find "R-symmetric"?

- no ($\nexists$ n coupling
- yes

Can we always find R-symmetry?

- no ($\not\exists$ coupling $R(g_i) = 0$)
- yes


Can we 'always' find 'R-symmetry'?
• no (iff coupling R(gi) = 0)
• yes

"Can we 'always' find 'R-symmetric'? $V(\Phi)$

- no $\left(\exists \text{ coupling } R(g_i) = 0 \right)$

$\Downarrow$

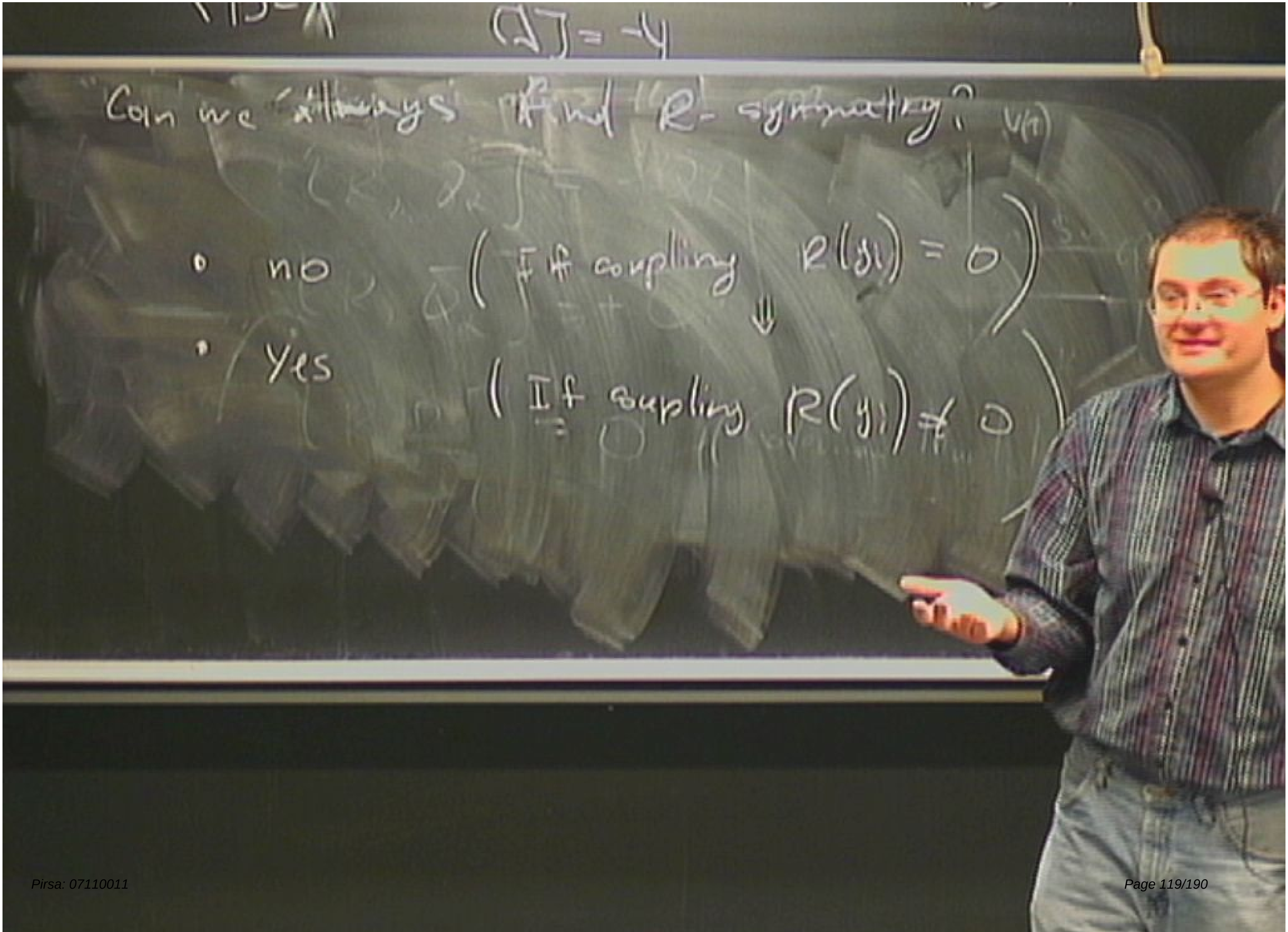
- yes

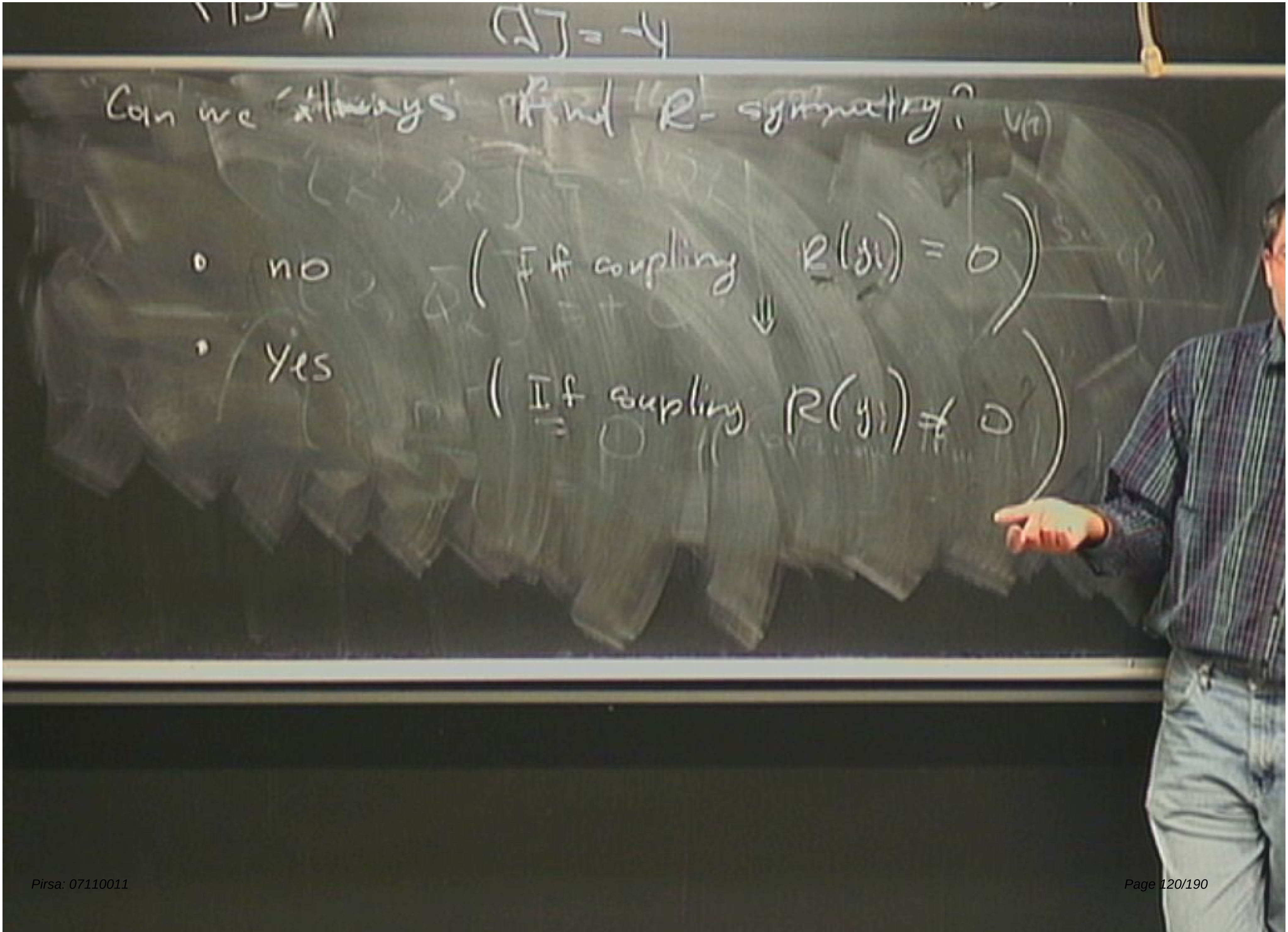
"Can we 'always' find 'R-symmetric'?

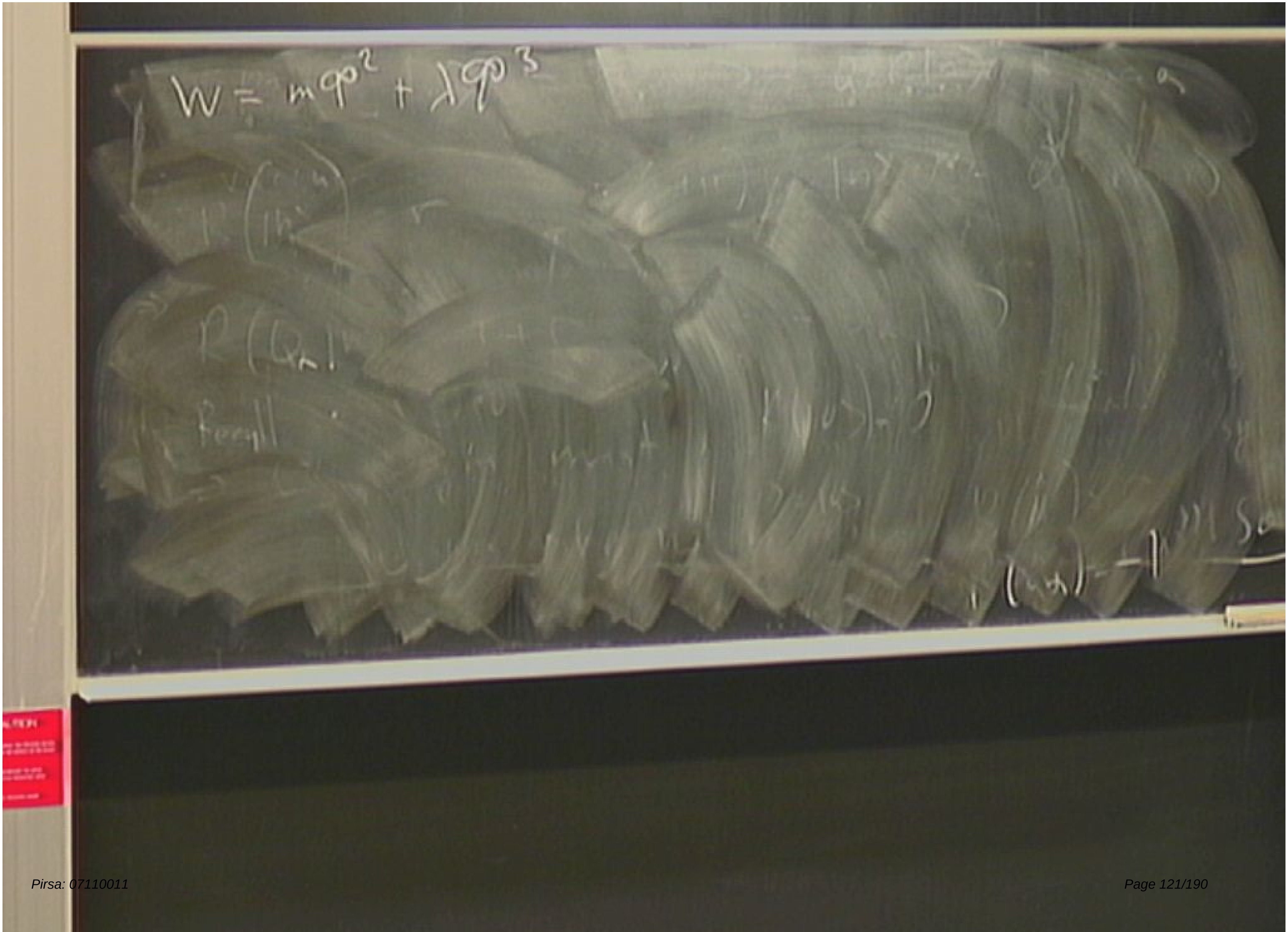
- no (If coupling $R(y_i) = 0$)

$\Downarrow$

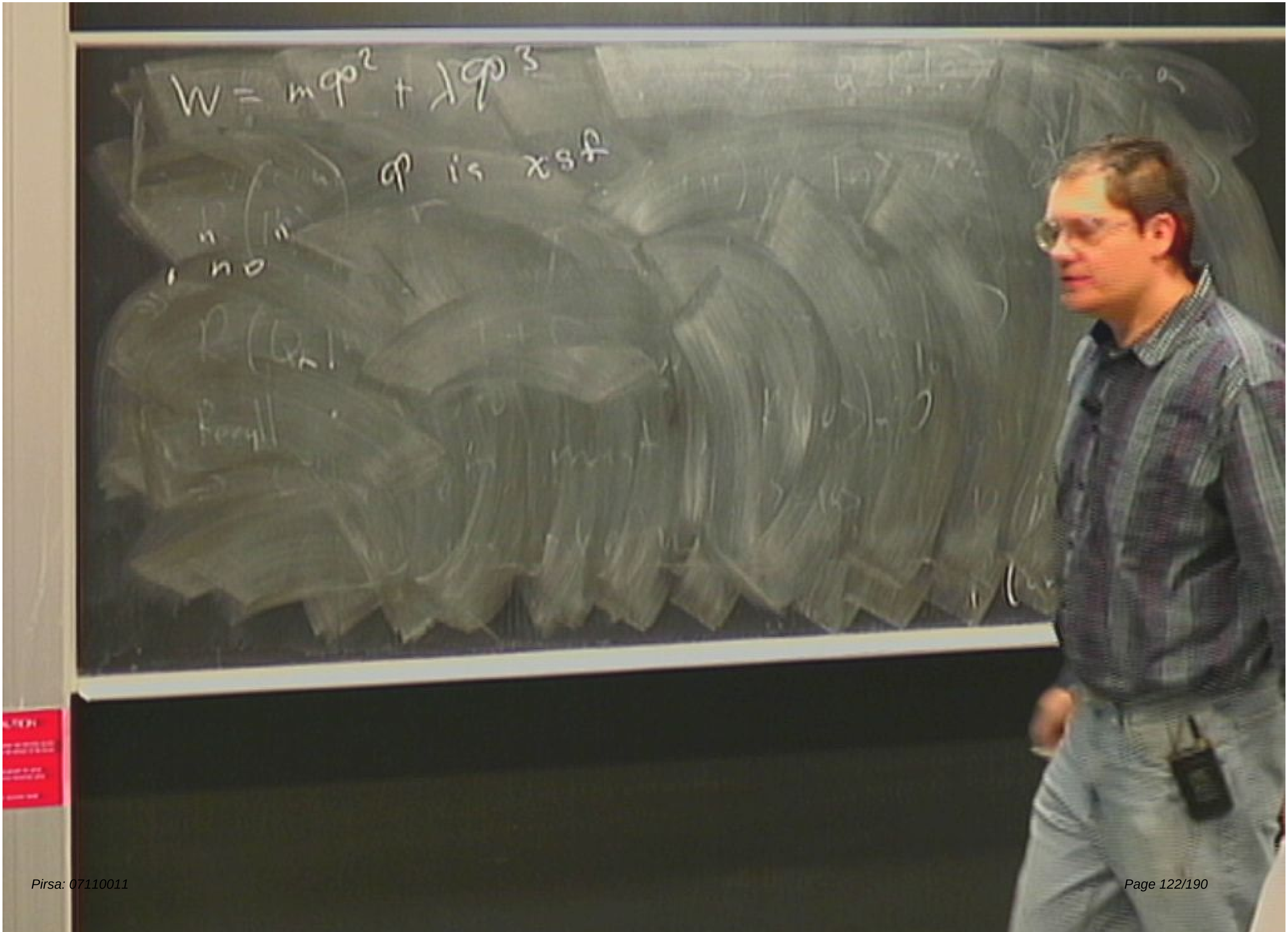
- yes (If coupling $R(y_i) \neq 0$)


Can we "always" find "R-symmetry"?
• no (If coupling R(y_i) = 0)
⇓
• yes (If coupling R(y_i) ≠ 0)


Can we "always" find "R-symmetric"?
• no (If coupling R(y_i) = 0)
⇓
• yes (If coupling R(y_i) ≠ 0)



W = mφ² + λφ³


W = mφ² + λφ³
φ is xsf
no

$$W = m\varphi^2 + \lambda\varphi^3$$

φ is xsf

no

$$R(W) = +2$$

$$W = m\varphi^2 + \lambda\varphi^3$$

φ is xsf

"no"

$$R(W) = +2$$

$$R(m) = 0$$

$$R(\lambda) = 0$$

$W = m\varphi^2 + \lambda \varphi^3$

φ is xsf

$R(m\varphi^2) = R(m) + 2R(\varphi)$

"no"

$R(W) = +2$

$R(m) = 0$

$R(\lambda) = 0$

$R(m) = -1$

$W = m\varphi^2 + \lambda\varphi^3$

φ is xsf

" no "

$R(W) = \underline{\underline{+2}}$

$R(m) = 0$

$R(\lambda) = 0$

$R(m\varphi^2) = R(m) + 2R(\varphi)$

$\Rightarrow R(\varphi) = +1$

$W = m\varphi^2 + \lambda\varphi^3$

φ is xsf

" no "

$R(W) = +2$

$R(m) = 0$

$R(\lambda) = 0$

$R(m\varphi^2) = R(m) + 2R(\varphi)$

$\Rightarrow R(\varphi) = +1$

$R(\lambda\varphi^3) = +2$

$$W = mq^2 + \lambda q^3$$

q is xsf

$$R(W) = +2$$

$$R(m) = 0$$

$$R(\lambda) = 0$$

$$R(mq^2) = R(m) + 2R(q)$$

$$\Rightarrow R(q) = +1$$

$$R(\lambda q^3) = +2$$

$W = mq^2 + \lambda q^3$

q is xsf

" no "

$R(W) = +2$

$R(m) = 0$

$R(\lambda) = 0$

$R(mq^2) = R(m) + 2R(q)$

$\Rightarrow R(q) = +1$

$R(\lambda q^3) = +2 \Rightarrow R(q) =$

$W = m\varphi^2 + \lambda\varphi^3$

φ is xsf

"no"

$R(W) = +2$

$R(m) = 0$

$R(\lambda) = 0$

$R(m\varphi^2) = R(m) + 2R(\varphi)$

$\Rightarrow R(\varphi) = +1$

$R(\lambda\varphi^3) = +2 \Rightarrow R(\varphi) =$

$$W = (m\varphi^2) + \lambda \varphi^3$$

φ is xsf

"no"

$$R(W) = +2$$

$$R(m) = 0$$

$$R(\lambda) = 0$$

$$R(m\varphi^2) = R(m) + 2R(\varphi) = 2$$

$$\Rightarrow R(\varphi) = +1$$

$$R(\lambda\varphi^3) = +2 \Rightarrow R(\varphi) = +\frac{2}{3}$$

$W = m\varphi^2 + \lambda\varphi^3$

φ is xsf

$R(W) = \underline{\underline{+2}}$

$R(m) = 0$

$\underline{R(\lambda) = 0}$

$R(m\varphi^2) = R(m) + 2R(\varphi) = 2$

$\Rightarrow R(\varphi) = +1$

$R(\lambda\varphi^3) = +2 \Rightarrow R(\varphi) = +\frac{2}{3}$

$$W = m\varphi^2 + \lambda\varphi^3$$

φ is xsf

$$R(W) = +2$$

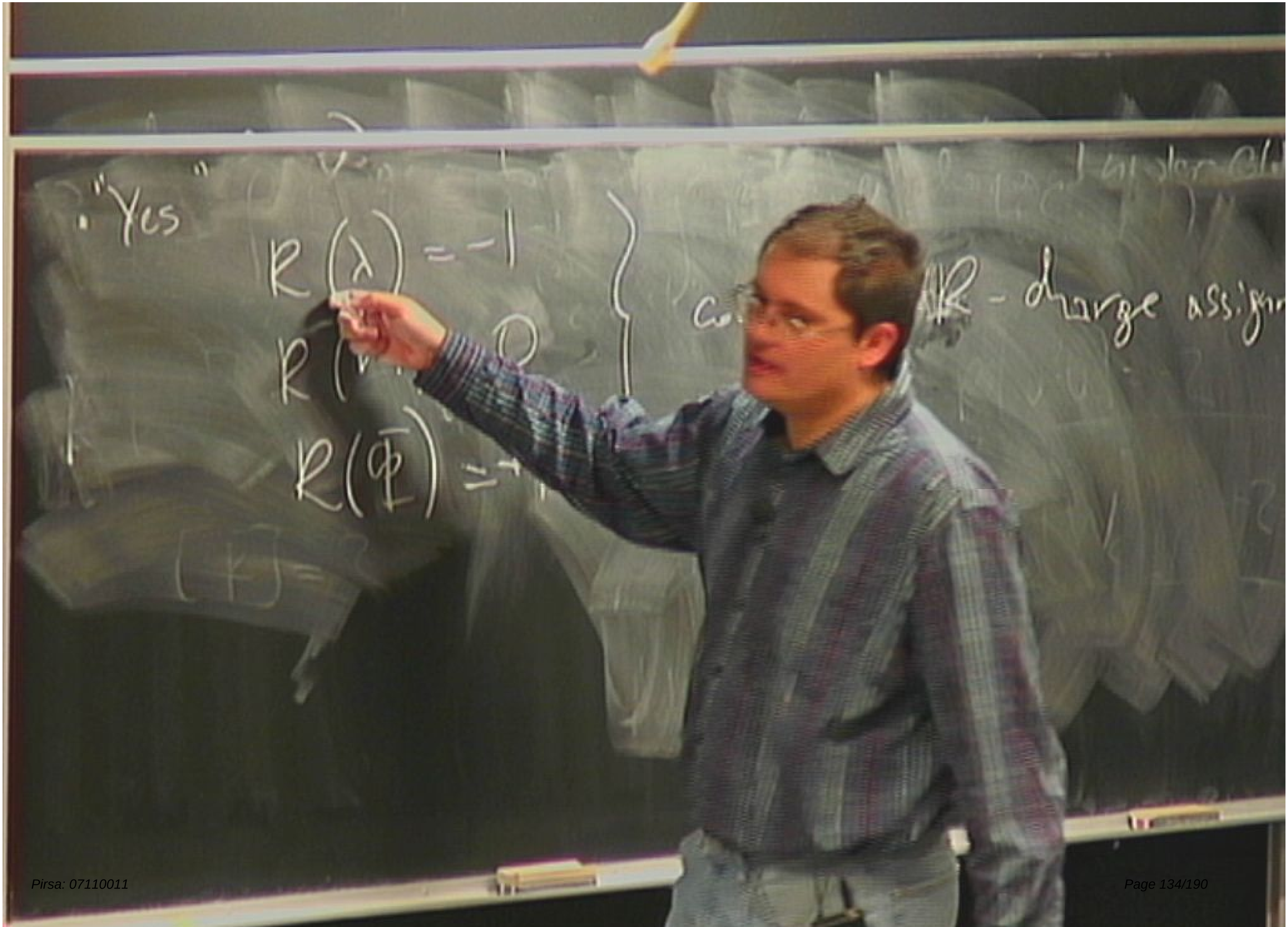
$$R(m) = 0$$

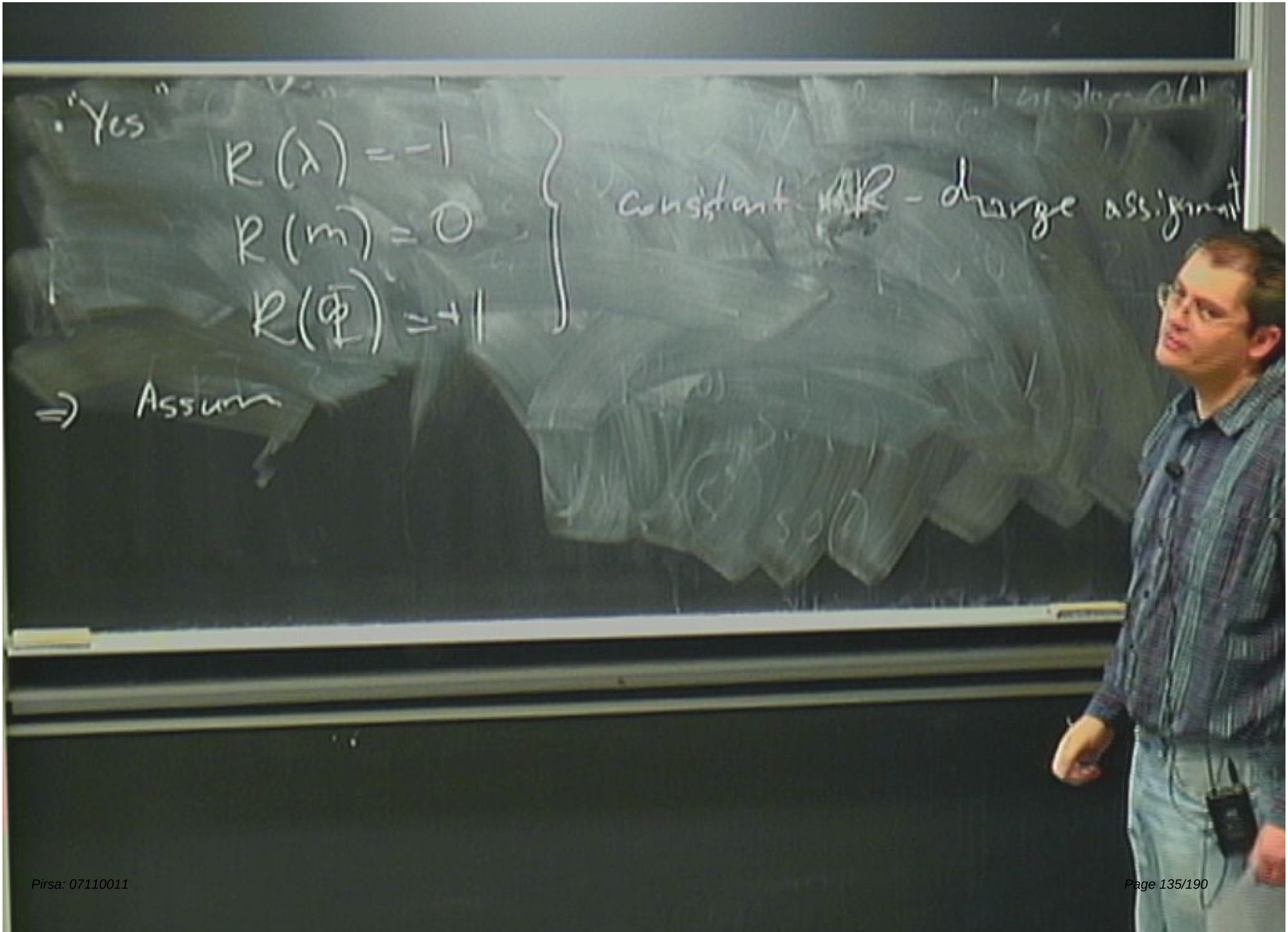
$$R(\lambda) = 0$$

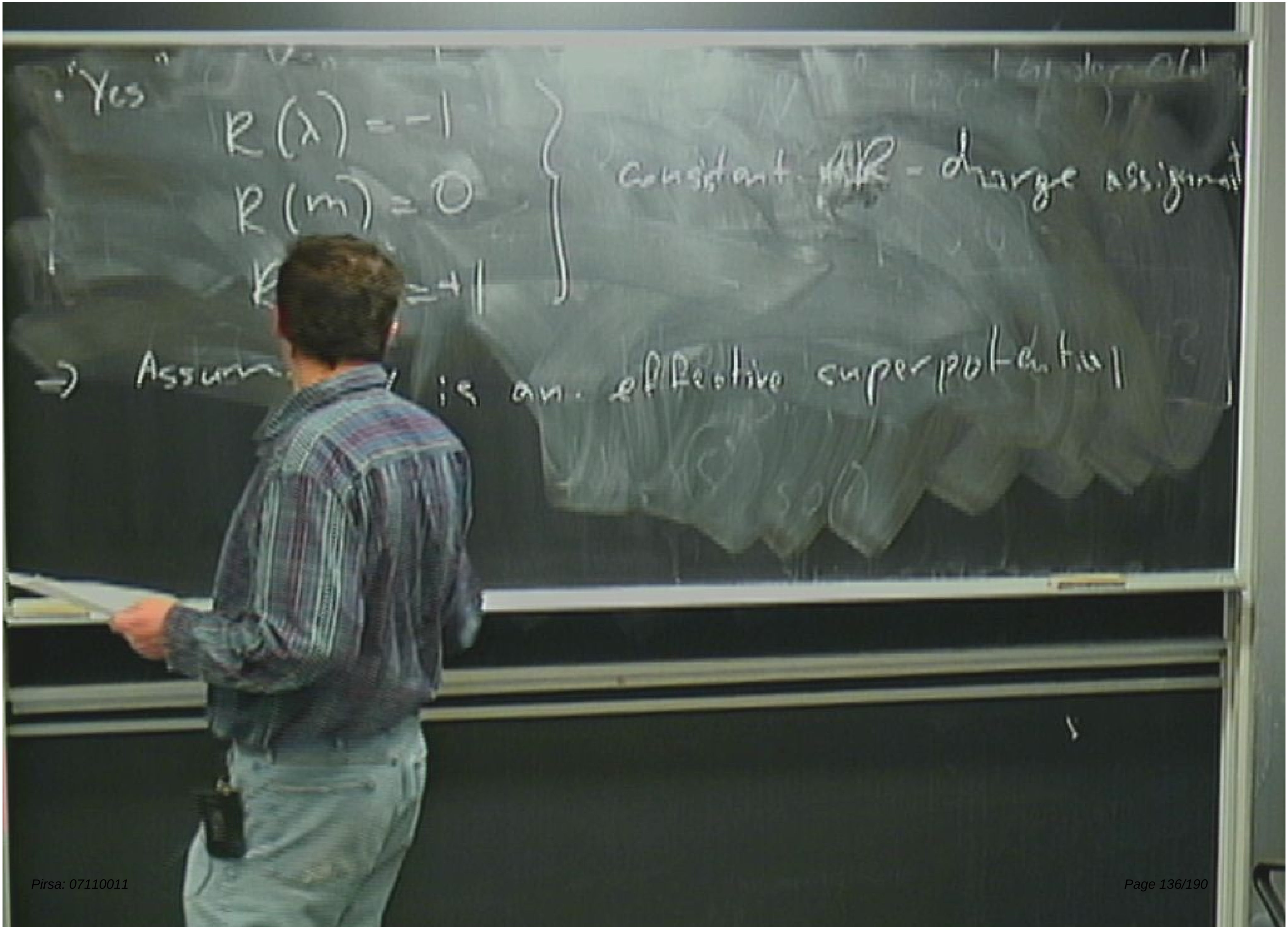
$$R(m\varphi^2) = R(m) + 2R(\varphi) = 2$$

$$\Rightarrow R(\varphi) = +1$$

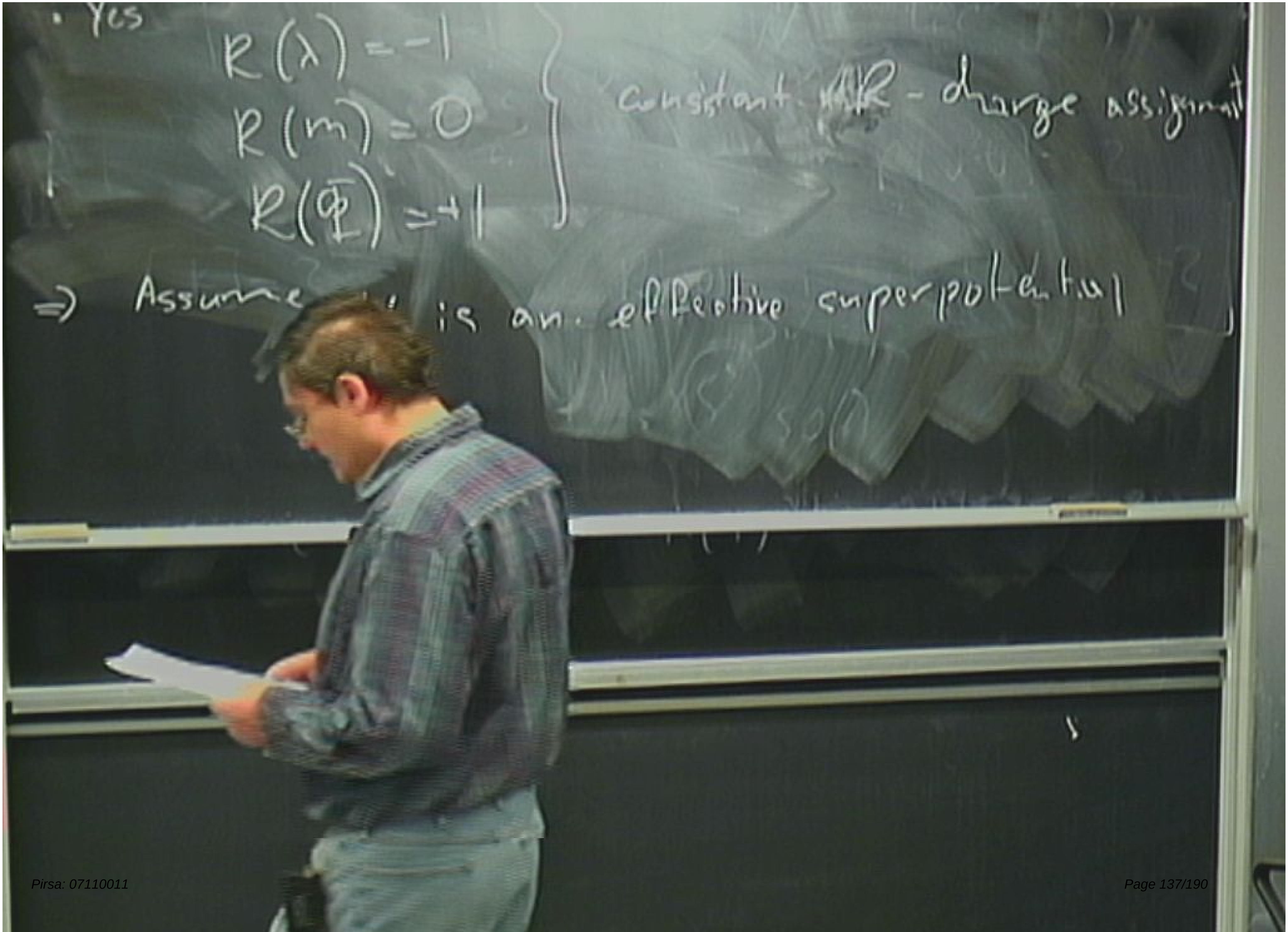
$$R(\lambda\varphi^3) = +2 \Rightarrow R(\varphi) = +\frac{2}{3}$$

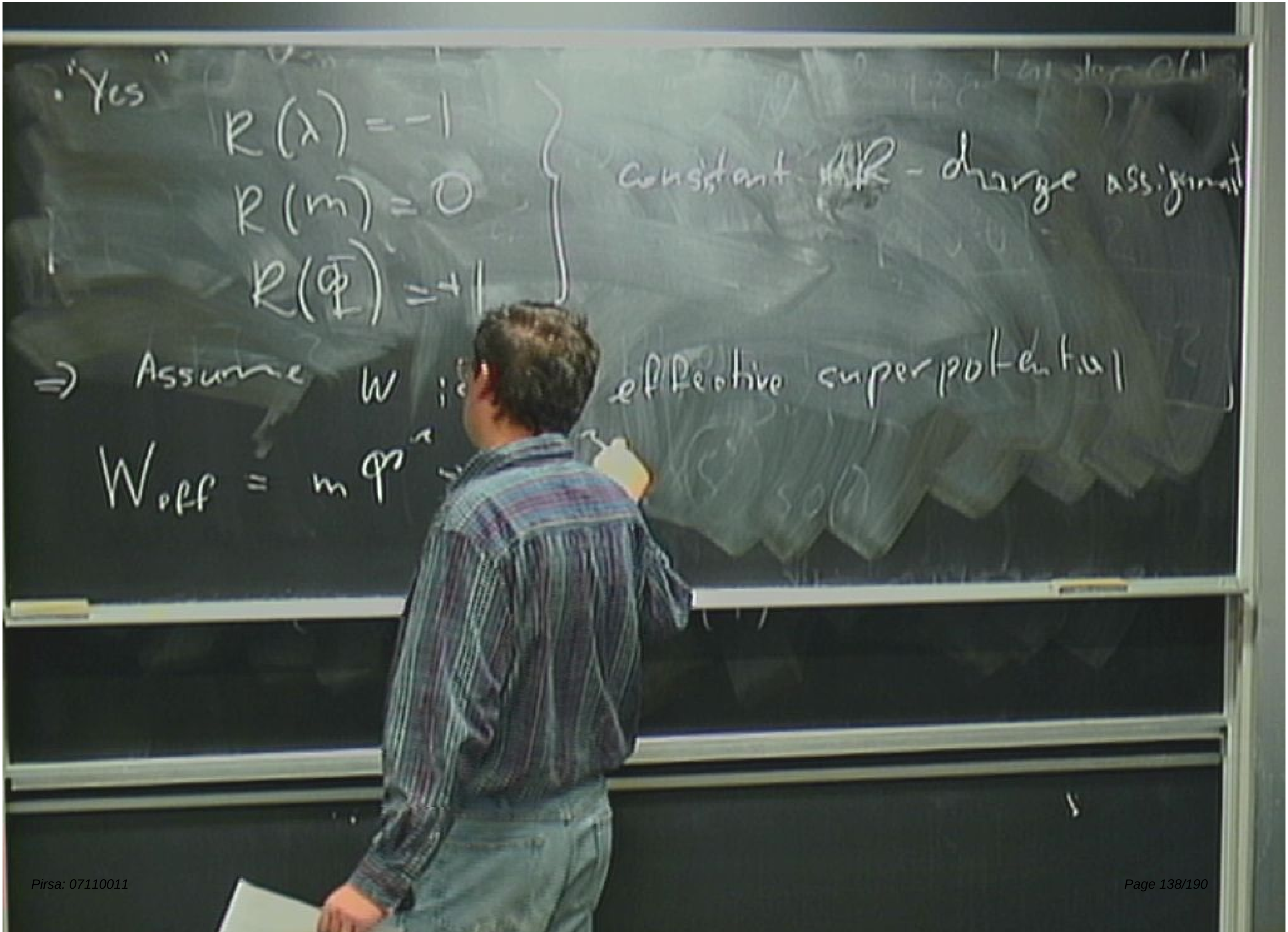

"Yes"
$R(\lambda) = -1$
charge


• "Yes"
R(λ) = -1
R(m) = 0
R(Φ) = +1
consistent R-charge assignmt
⇒ Assum

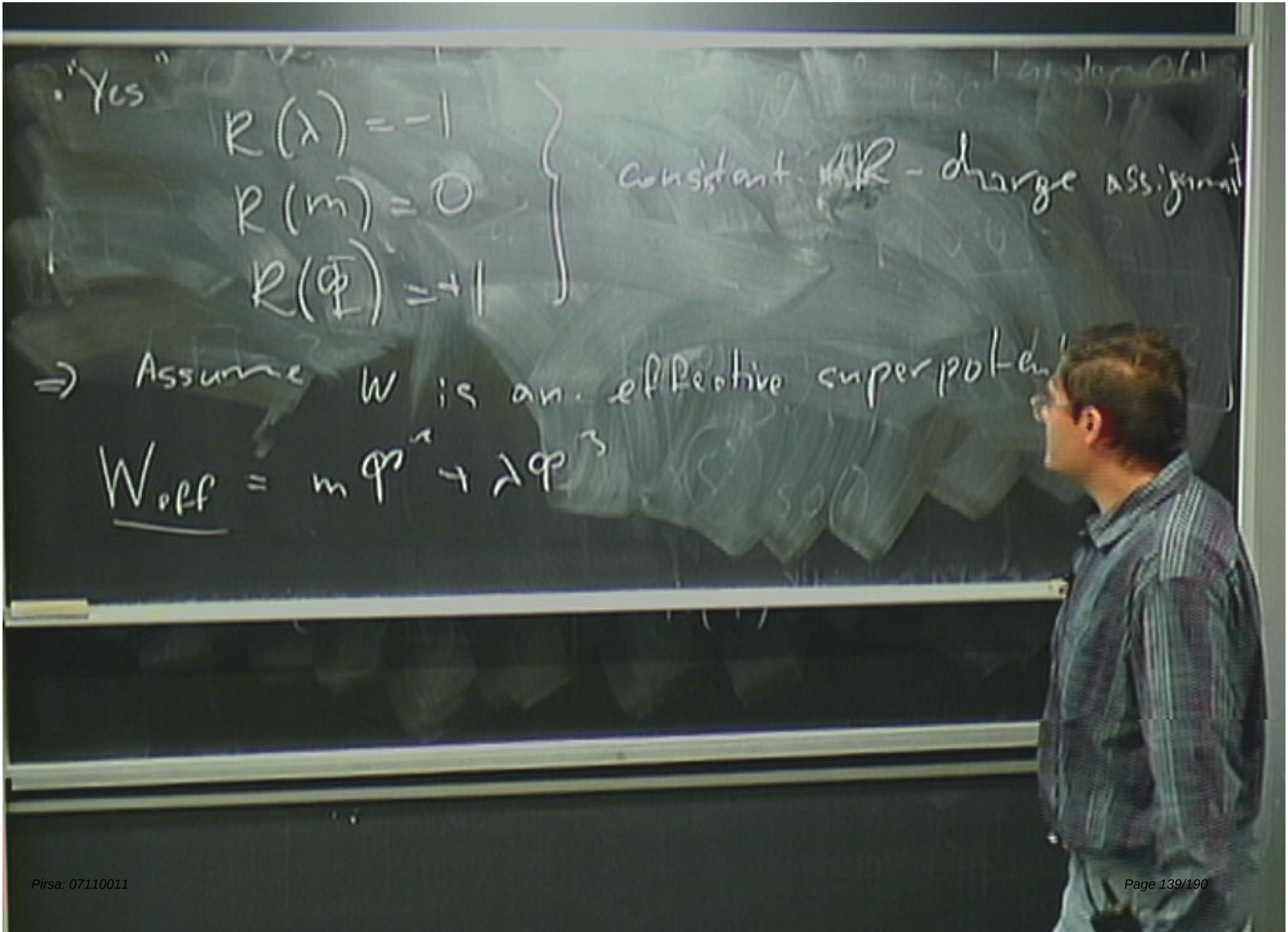


• "Yes"
R(λ) = −1
R(m) = 0
= +1
consistent R-charge assignment
⇒ Assum
is an effective superpotential


• Yes
R(λ) = -1
R(m) = 0
R(Φ) = +1
consistant R - charge assignment
⇒ Assume
is an effective superpotential



• "Yes"
R(λ) = −1
R(m) = 0
R(Φ) = +1
constant R-charge assignment
⇒ Assume W is effective superpotential
W_eff = m Φ^2



• "Yes"
$R(\lambda) = -1$
$R(m) = 0$
$R(\Phi) = +1$
constant R - charge assignment
⇒ Assume W is an effective superpotential
$W_{eff} = m\varphi^2 + \lambda\varphi^3$

• "Yes"

$$R(\lambda) = -1$$
$$R(m) = 0$$
$$R(\Phi) = +1$$

constant R-charge assignment

no

$\Rightarrow$ Assume W is an effective superpotential

$$\underline{W_{eff}} = m\varphi^2 + \lambda\varphi^3 \iff W_{\dots} = m\varphi^2 + \chi\,\Phi^3$$

additional

$$R(\Psi) = r-1$$

· "Yes"

$$\left.\begin{array}{l} R(\lambda) = -1 \\ R(m) = 0 \\ R(\Phi) = +1 \end{array}\right\}$$ constant R-charge assignment

no Φ

$\Rightarrow$ Assume W is an effective superpotential

$$\underline{W_{eff}} = m\varphi^2 + \lambda\varphi^3 \Longleftrightarrow W_{\dots} = m\varphi^2 + \underset{\substack{? \\ \text{additional}}}{\chi}\varphi^3$$

$R(\Psi) = r-1$ $R(\dots)$

· "Yes"

$$R(\lambda) = -1$$
$$R(m) = 0$$
$$R(\Phi) = +1$$

$\Big\}$ constant ~~R~~ - charge assignment

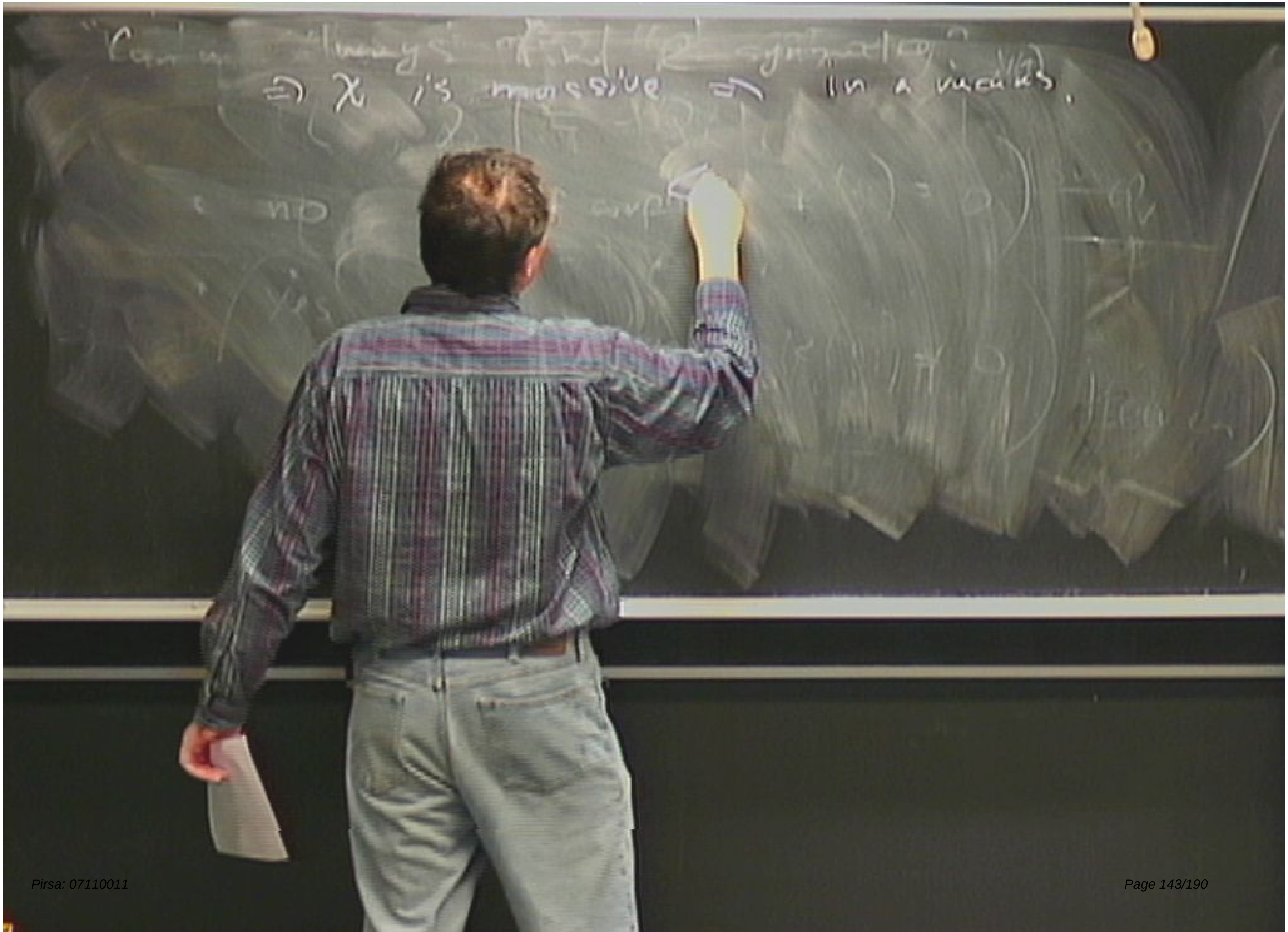
no Φ

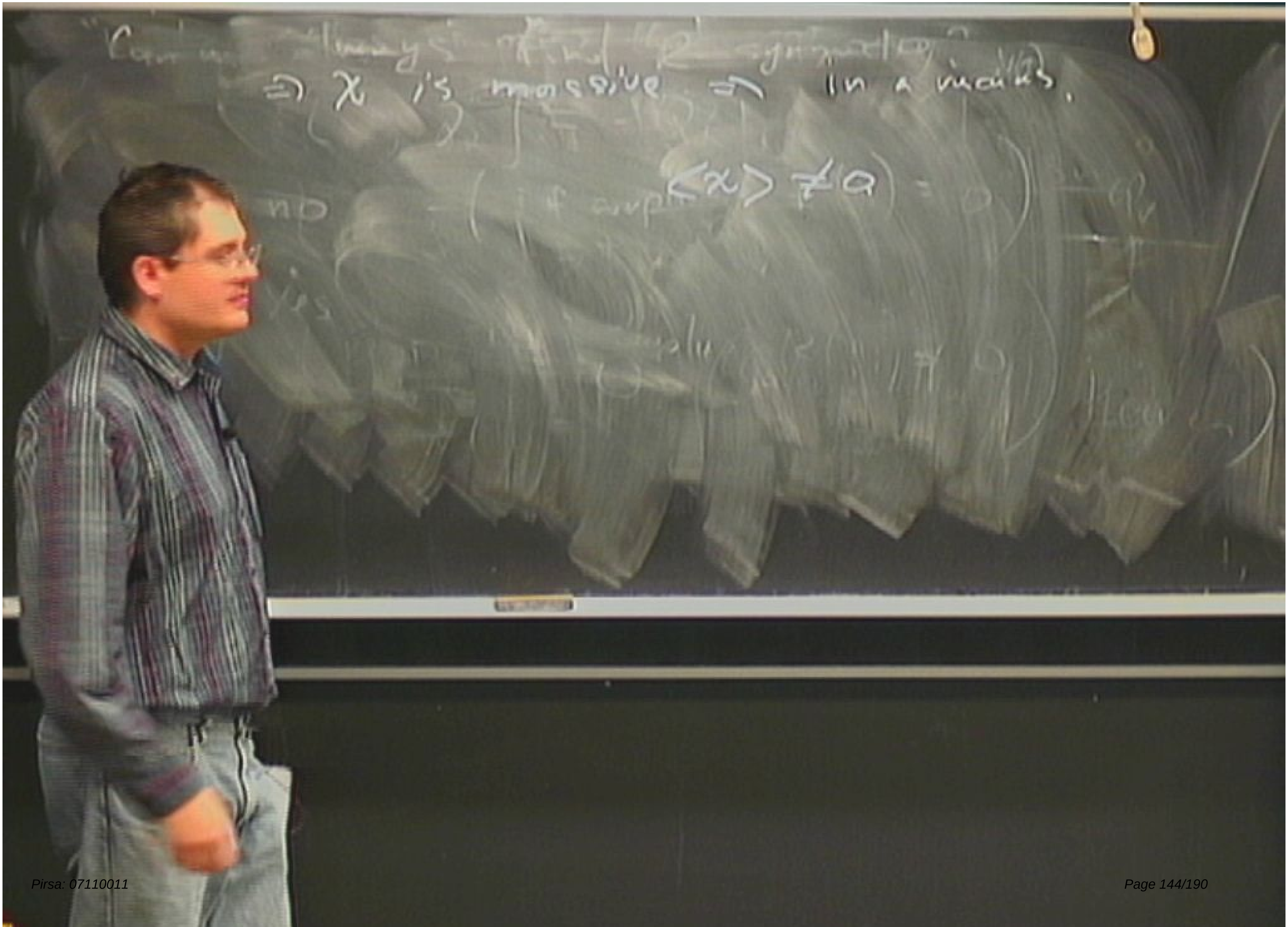
$\Rightarrow$ Assume W is an effective superpotential

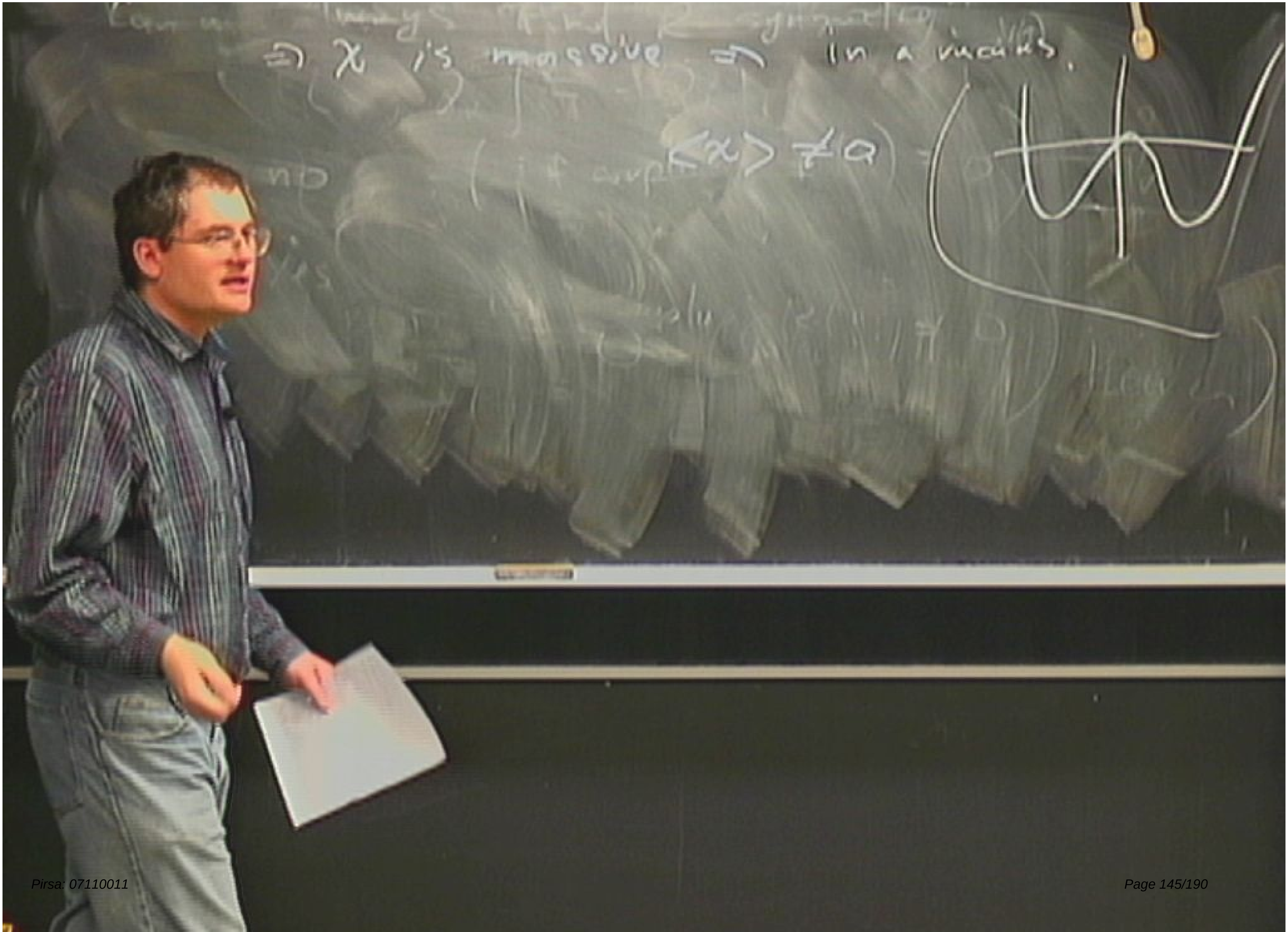
$$\underline{W_{eff}} = m\varphi^2 + \lambda\varphi^3 \Longleftrightarrow W_{microscopic} = m\varphi^2 + \chi\varphi^3 + \ldots$$

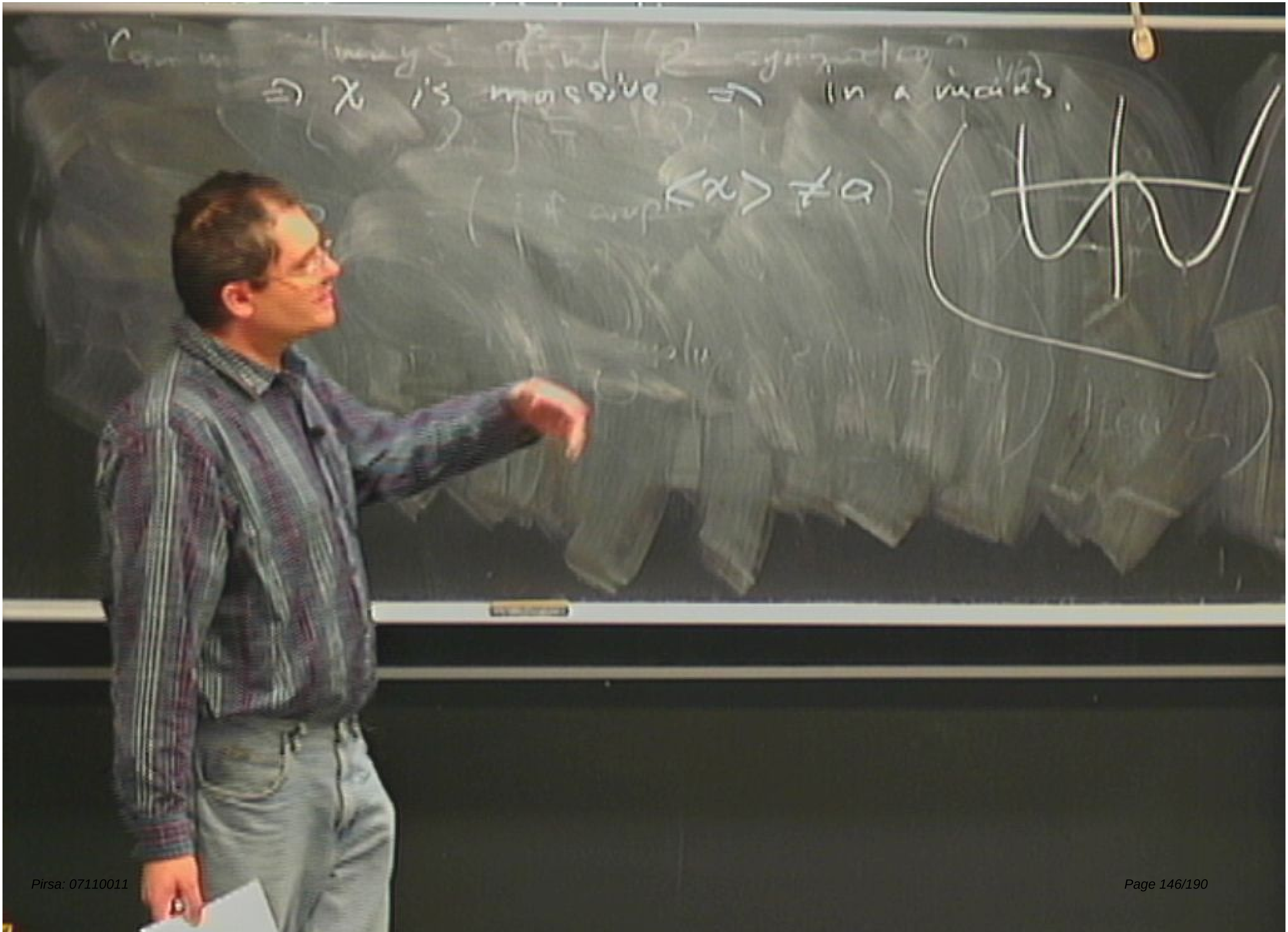
additional ?

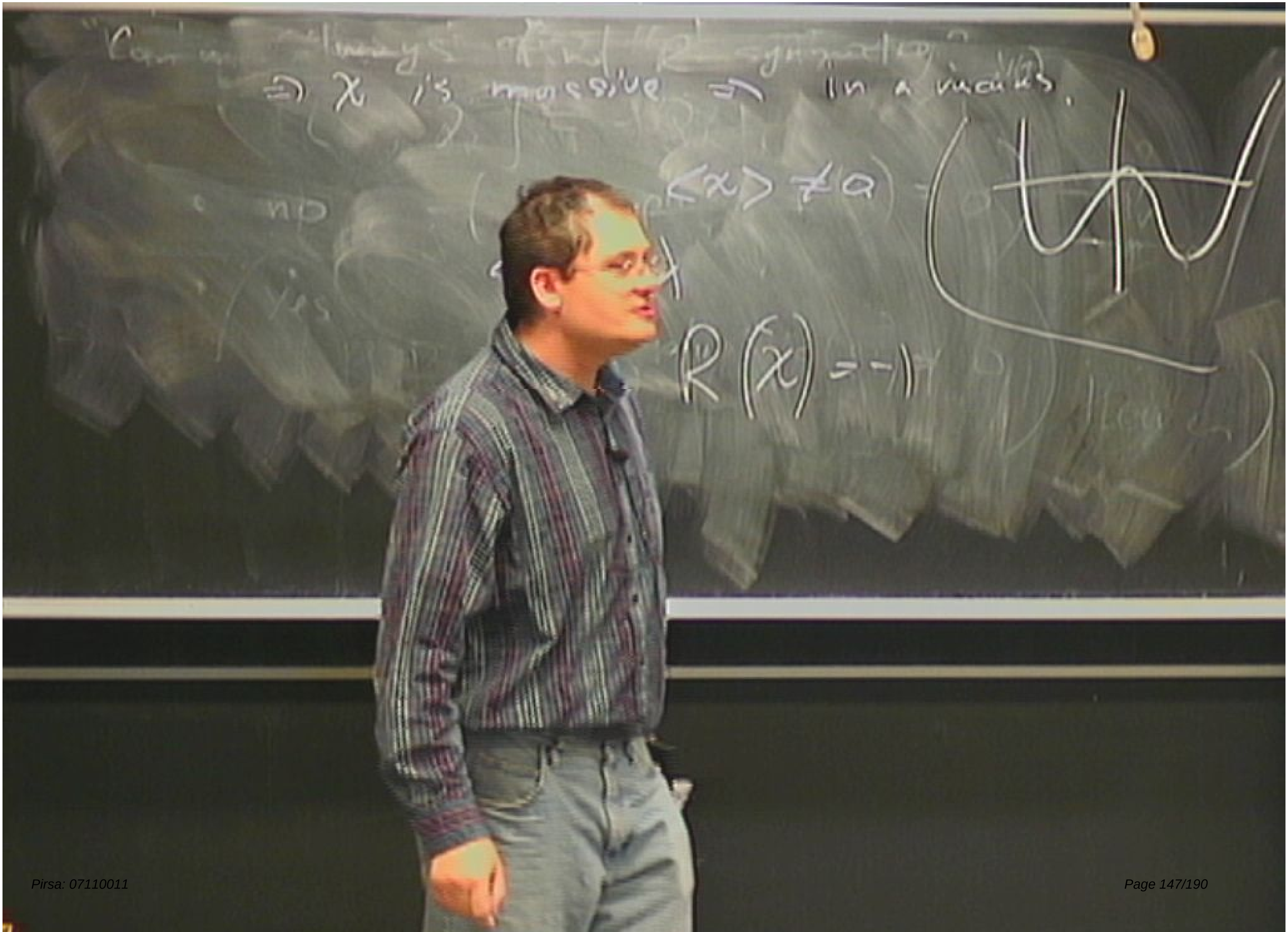
$R(\Psi) = r - 1$


⇒ χ is massive ⇒


⇒ χ is massive ⇒ in a vacuum.
⟨χ⟩ ≠ 0


⇒ χ is massive ⇒ in a vacuum.
⟨x⟩ ≠ 0


⇒ χ is massive ⇒
⟨x⟩ ≠ 0

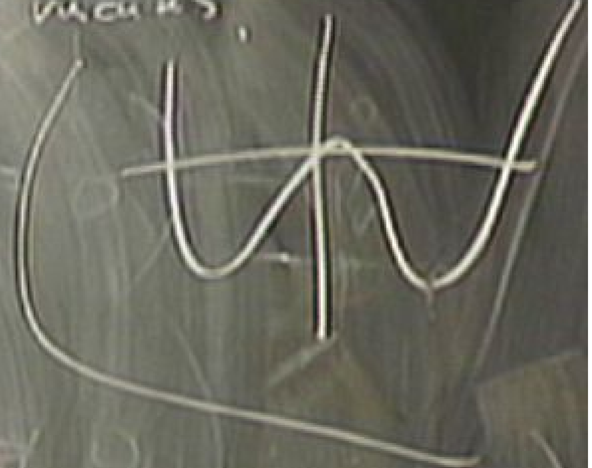

⇒ χ is massive ⇒ in a vacuum
R(x) = −1

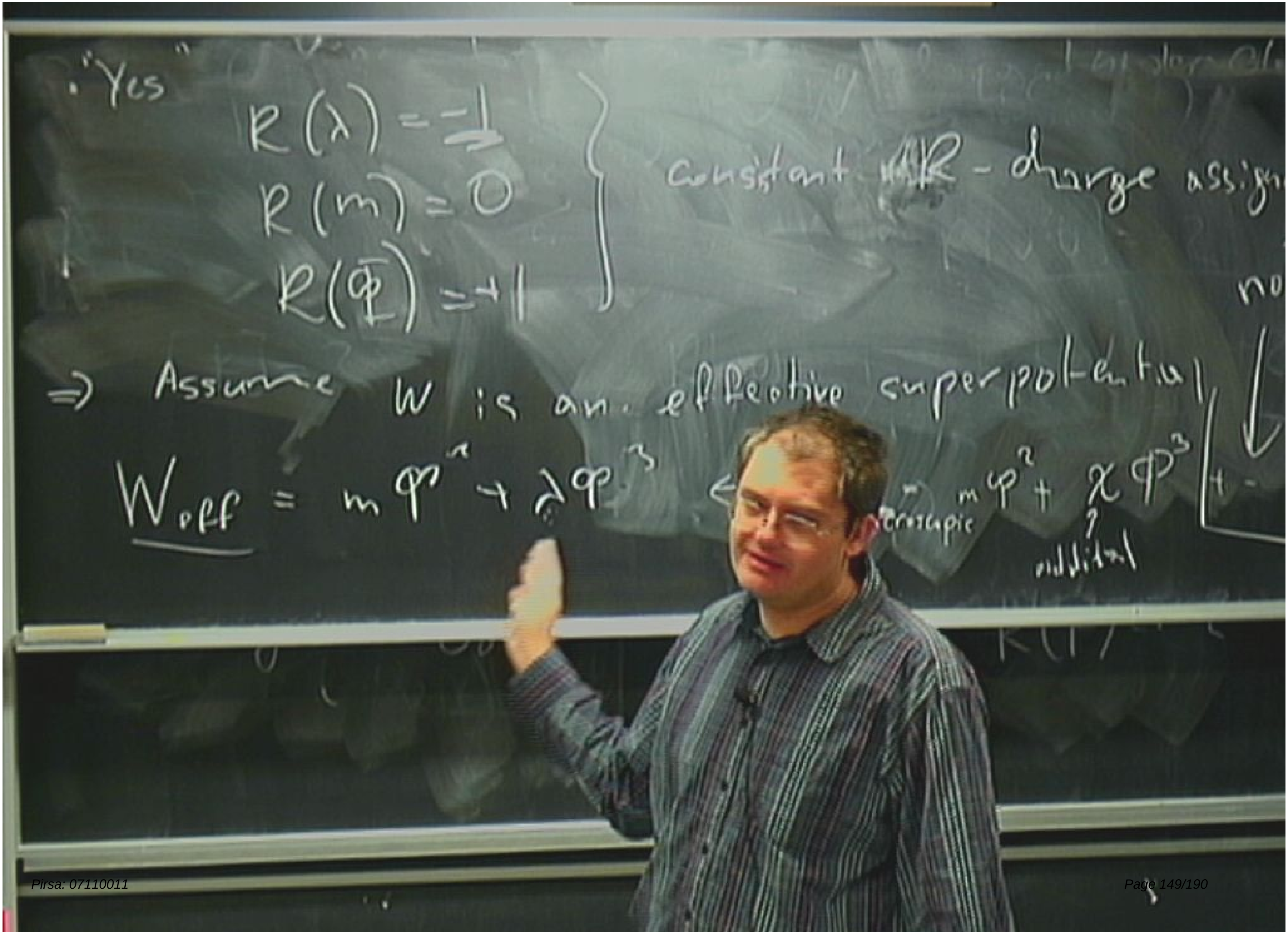
$\Rightarrow \chi$ is massive $\Rightarrow$ in a vacuum.

$\langle x \rangle \neq a$

$\langle x \rangle = \lambda$

$R(x) = -1$

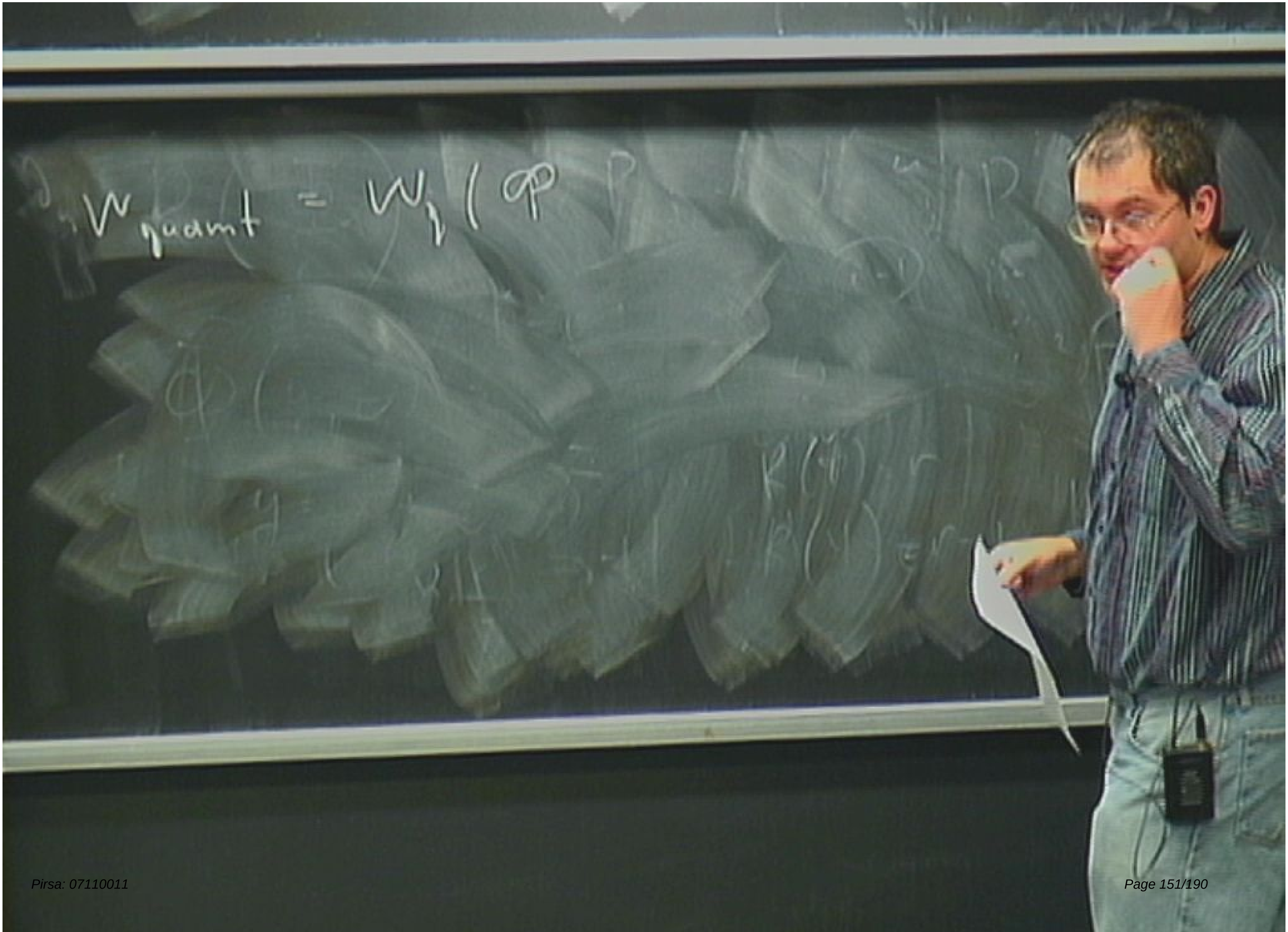


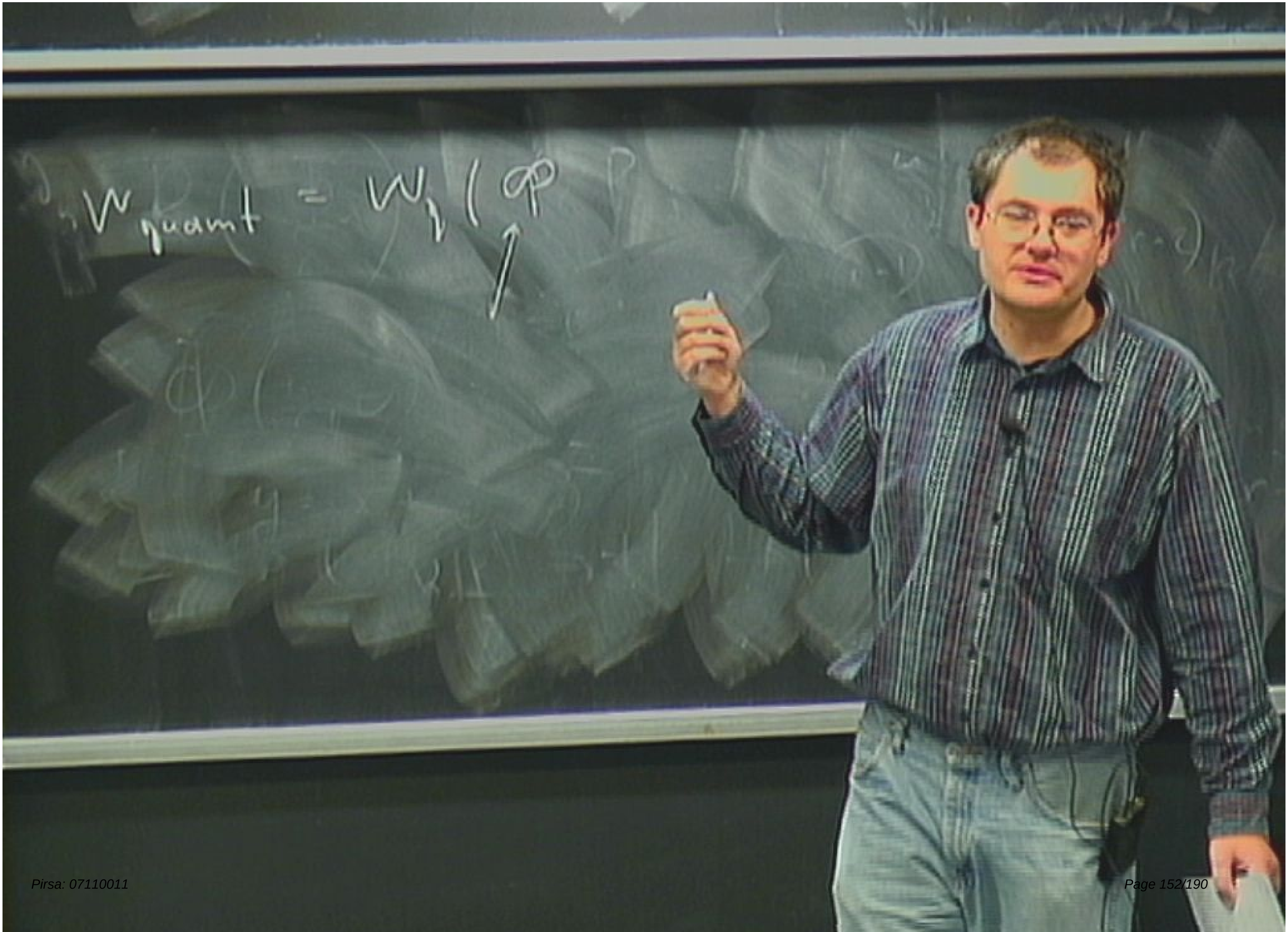

"Yes"
R(λ) = -1
R(m) = 0
R(Φ) = +1
consistant R-charge assign
no
⇒ Assume W is an effective superpotential
W_eff = m φ^2 + λ φ^3 ⇐ m φ^2 + χ φ^3
microscopic
?
additional

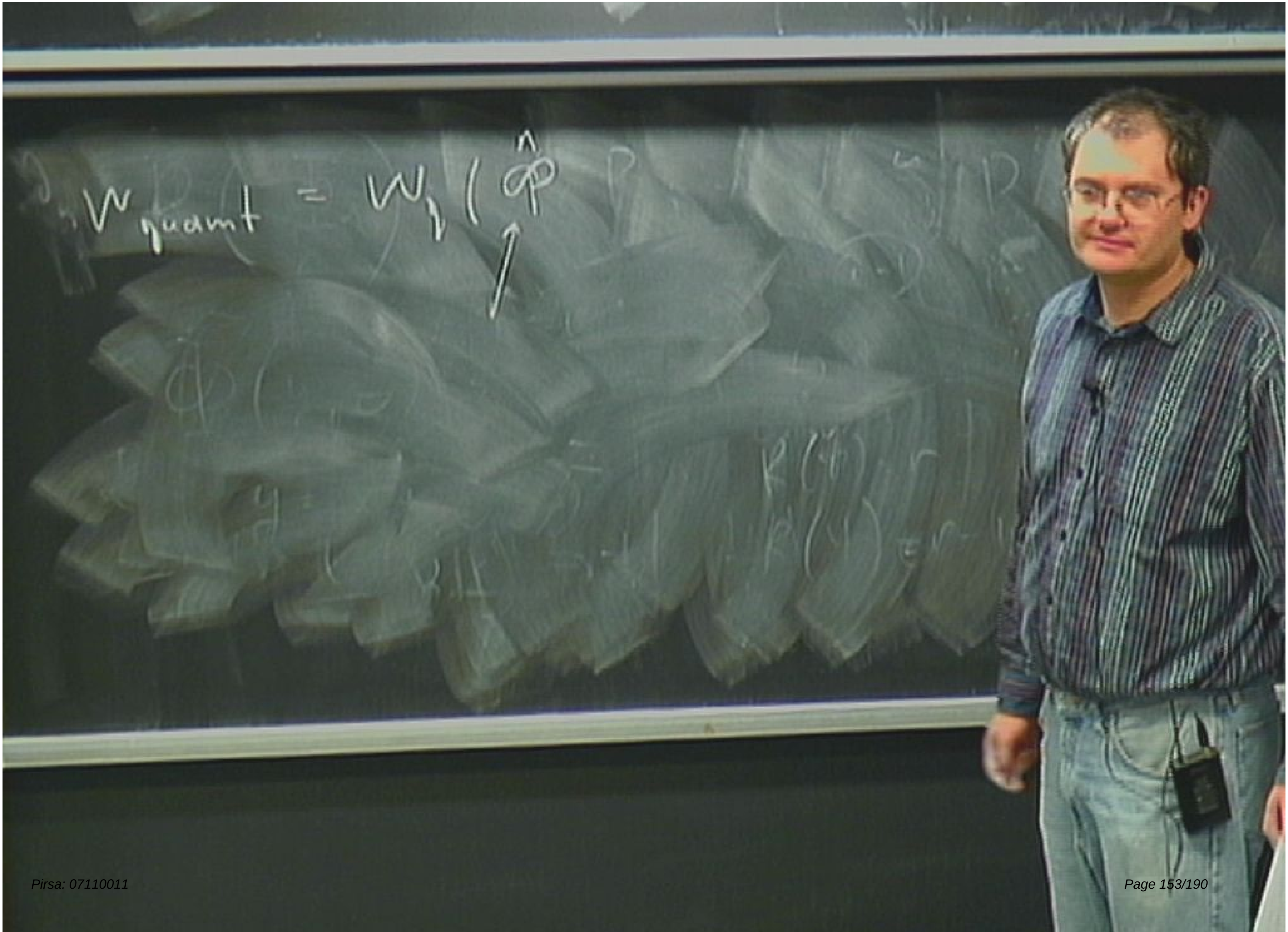
$$W_{classical} = m\varphi^2 + \lambda\varphi^3$$

$$W_{quantum} = m\varphi^2 + \lambda\varphi^3$$

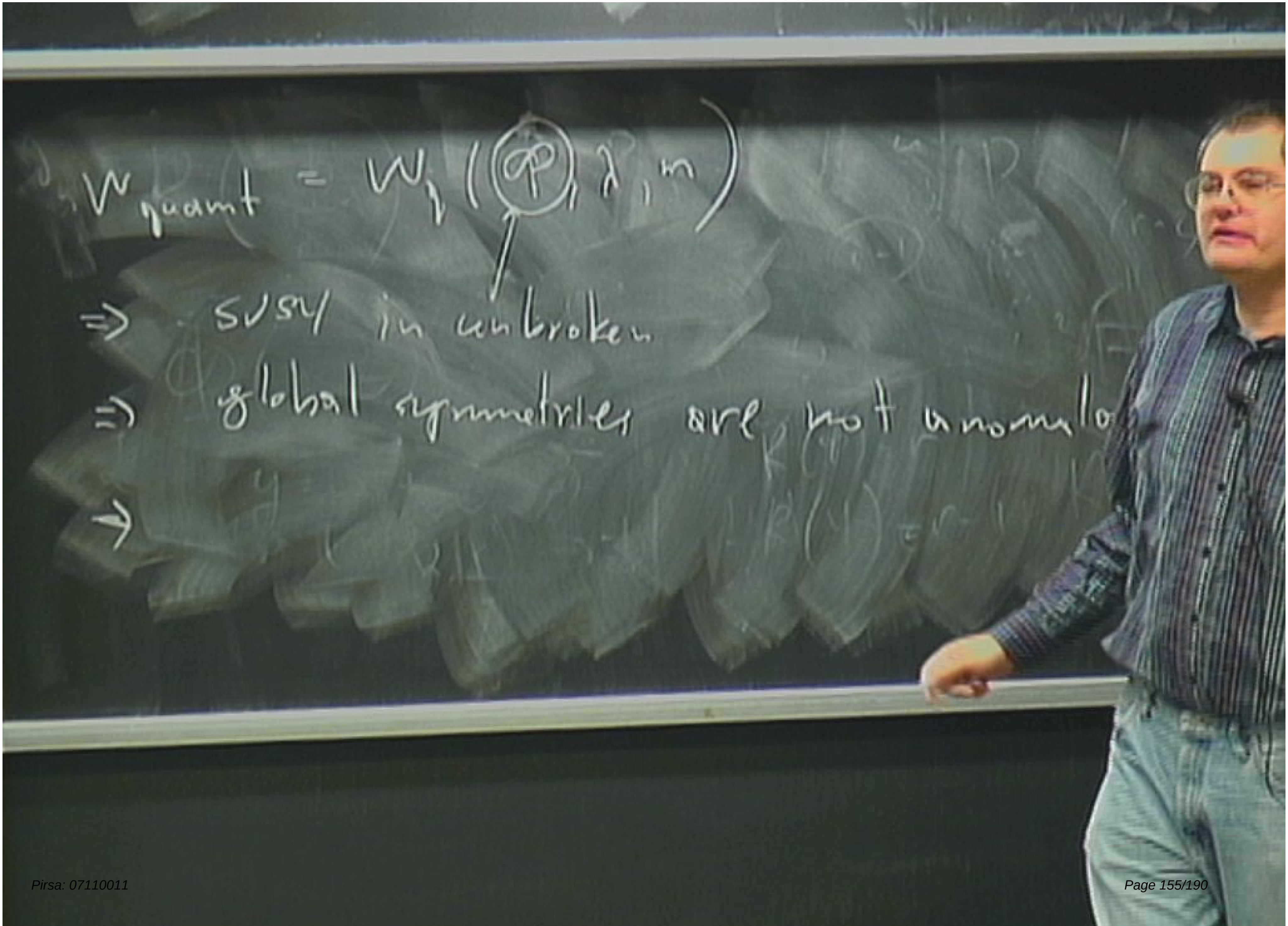
including all perturbative and nonpertu. correct.

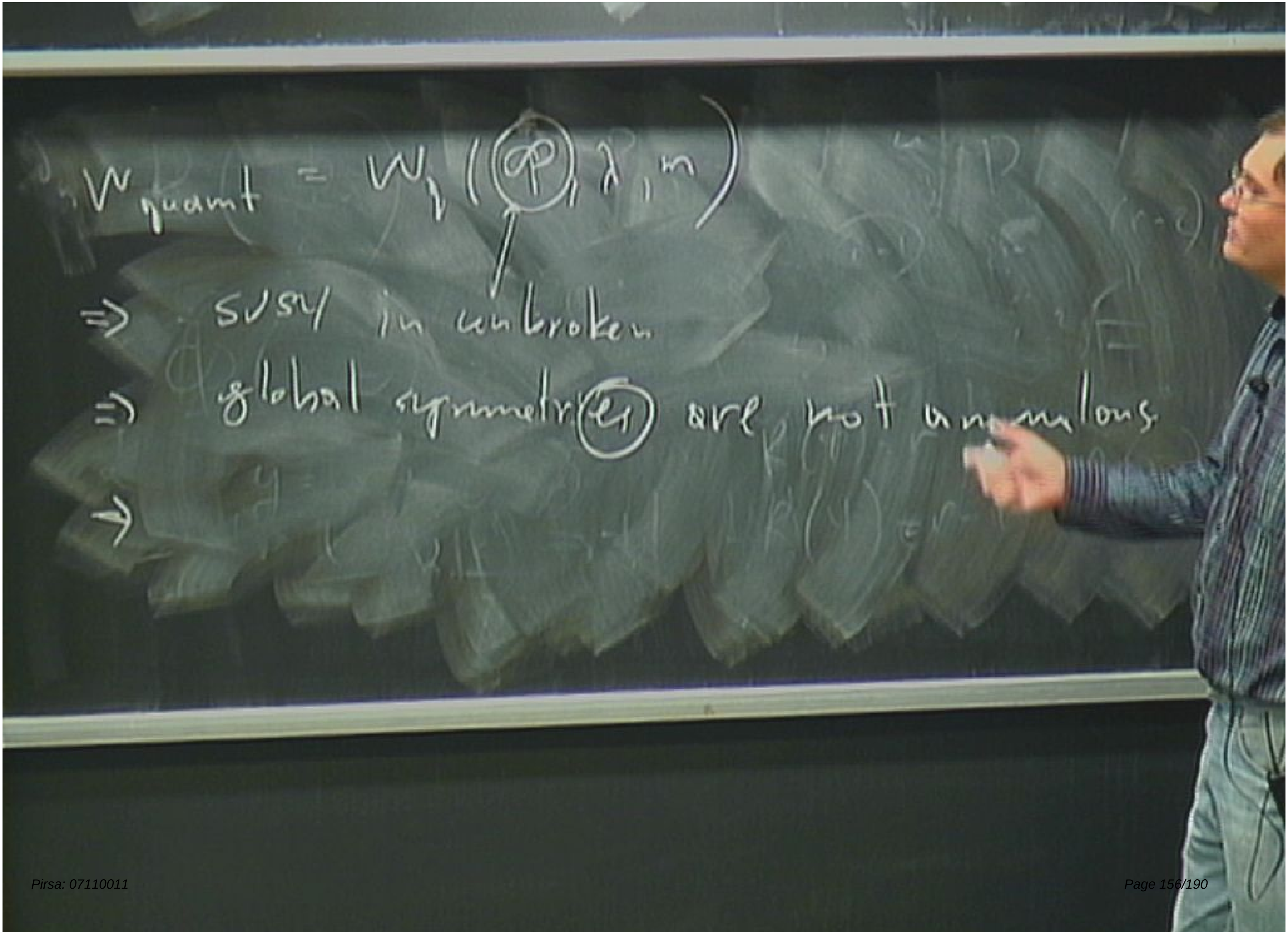

Wquant = Wj (φ




$W_{quant} = W_g(\hat{\varphi}$

$$W_{quant} = W_1(\varphi, \lambda, n)$$


W quant = W (φ, λ, m)
⇒ SUSY in unbroken
⇒ global symmetries are not anomalo
⇒


$W_{quant} = W_1(\varphi, \lambda, m)$
⇒ SUSY is unbroken
⇒ global symmetries are not anomalous
⇒

$\Rightarrow W_{quant} = W_{?}(\varphi, \lambda, m)$

$\Rightarrow$ SUSY is unbroken $U(1)_R$

$\Rightarrow$ global symmetr(ies) are not anomalous

$\Rightarrow$

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$\Rightarrow$ SUSY in unbroken $U(1)_R$

$\Rightarrow$ global symmetries are not anomalous

$\Rightarrow$ $\lambda = \langle x \rangle$

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$\bar{\lambda} =$

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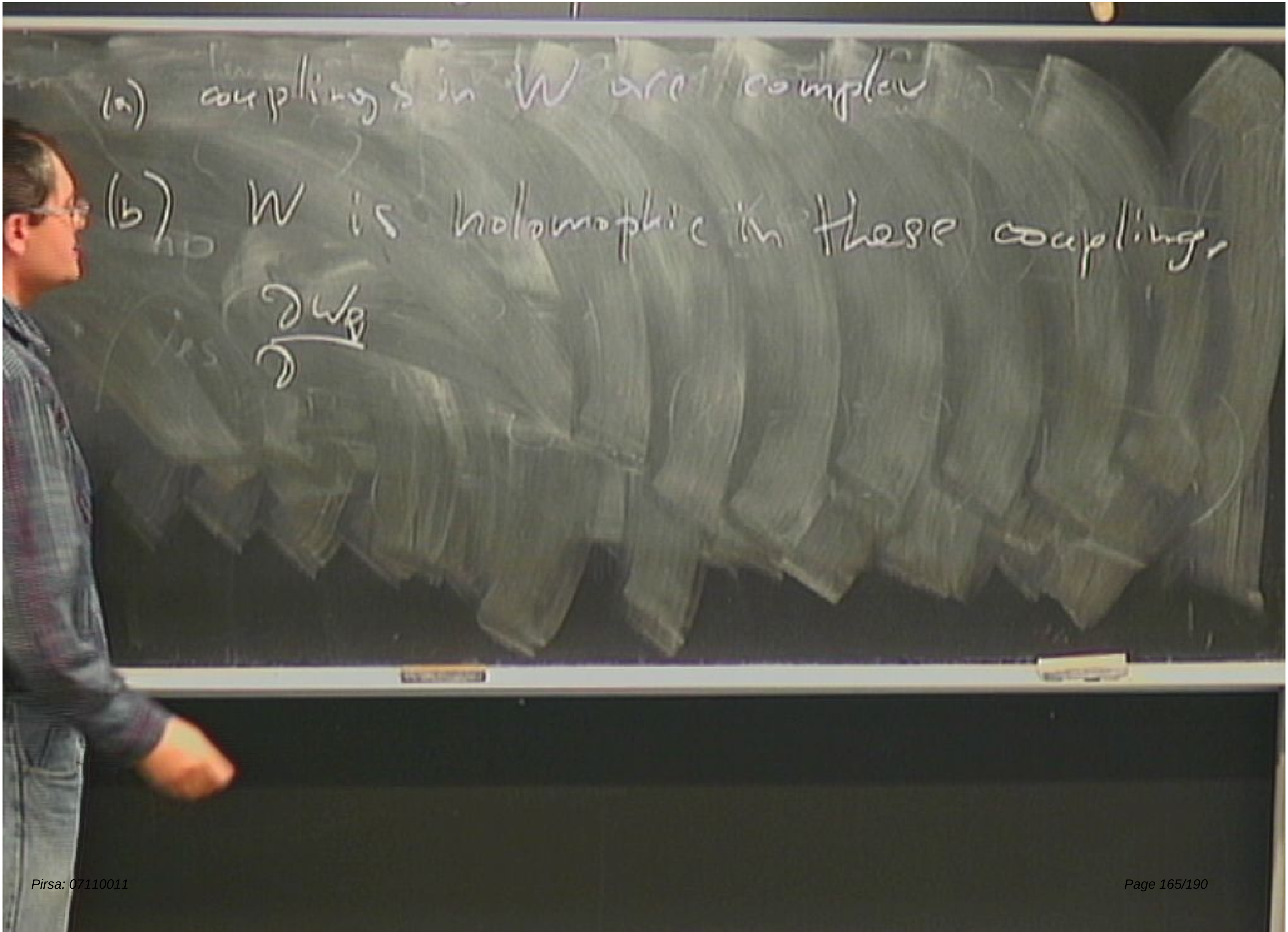

(a) couplings in W are complex
(b) W is holomorphic in these couplings,
∂W/∂

(a) couplings in W are complex

(b) W is holomorphic in these couplings,

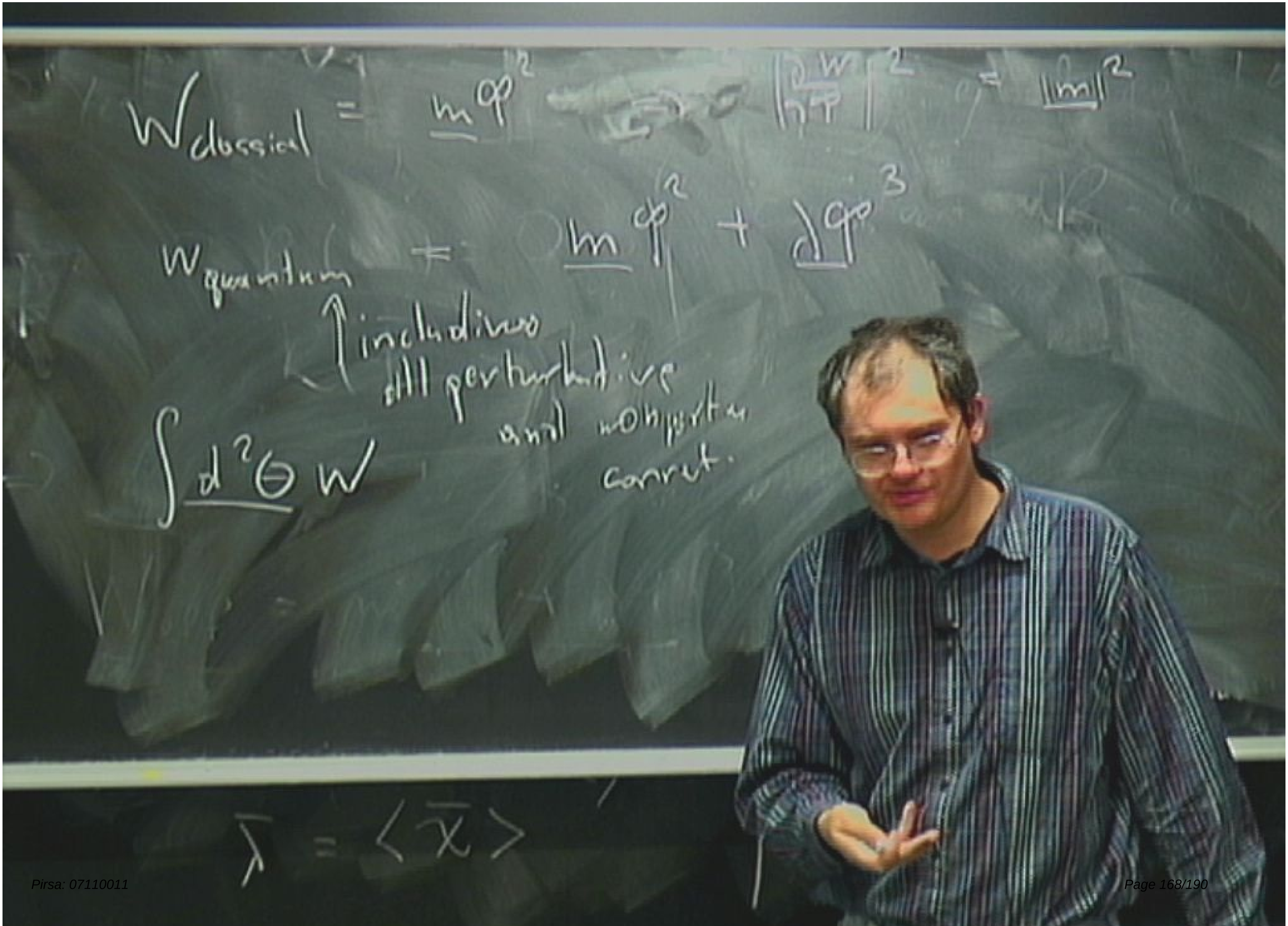
$$\frac{\partial W_g}{\partial \bar{m}} = 0 \qquad \frac{\partial W_g}{\partial \bar{\lambda}} = 0$$

$$W_{classical} = \underline{m}\,\varphi^2 \qquad \left|\frac{\partial W}{\partial \varphi}\right|^2 = |\underline{m}|^2$$

$$W_{quantum} = \underline{m}\,\varphi^2 + \underline{\lambda}\,\varphi^3$$

including all perturbative and nonpert. correct.

$$\bar{\lambda} = \langle \bar{x} \rangle \qquad \frac{\partial W_1}{\partial \bar{\lambda}} = 0$$


W classical = m φ²
W quantum = m φ² + λ φ³
including all perturbative and nonpert corrct.
∫ d²θ W

$$W_{classical} = \underline{m}\,\varphi^2 \qquad \left|\frac{\partial W}{\partial \varphi}\right|^2 = |\underline{m}|^2$$

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$\uparrow$ including all perturbative and nonpert. correct.

$$\int \underline{d^2\theta}\, W$$

$$\bar{\lambda} = \langle \bar{x} \rangle \qquad \left(\frac{\partial W_1}{\partial \bar{\lambda}} = 0 \right)$$

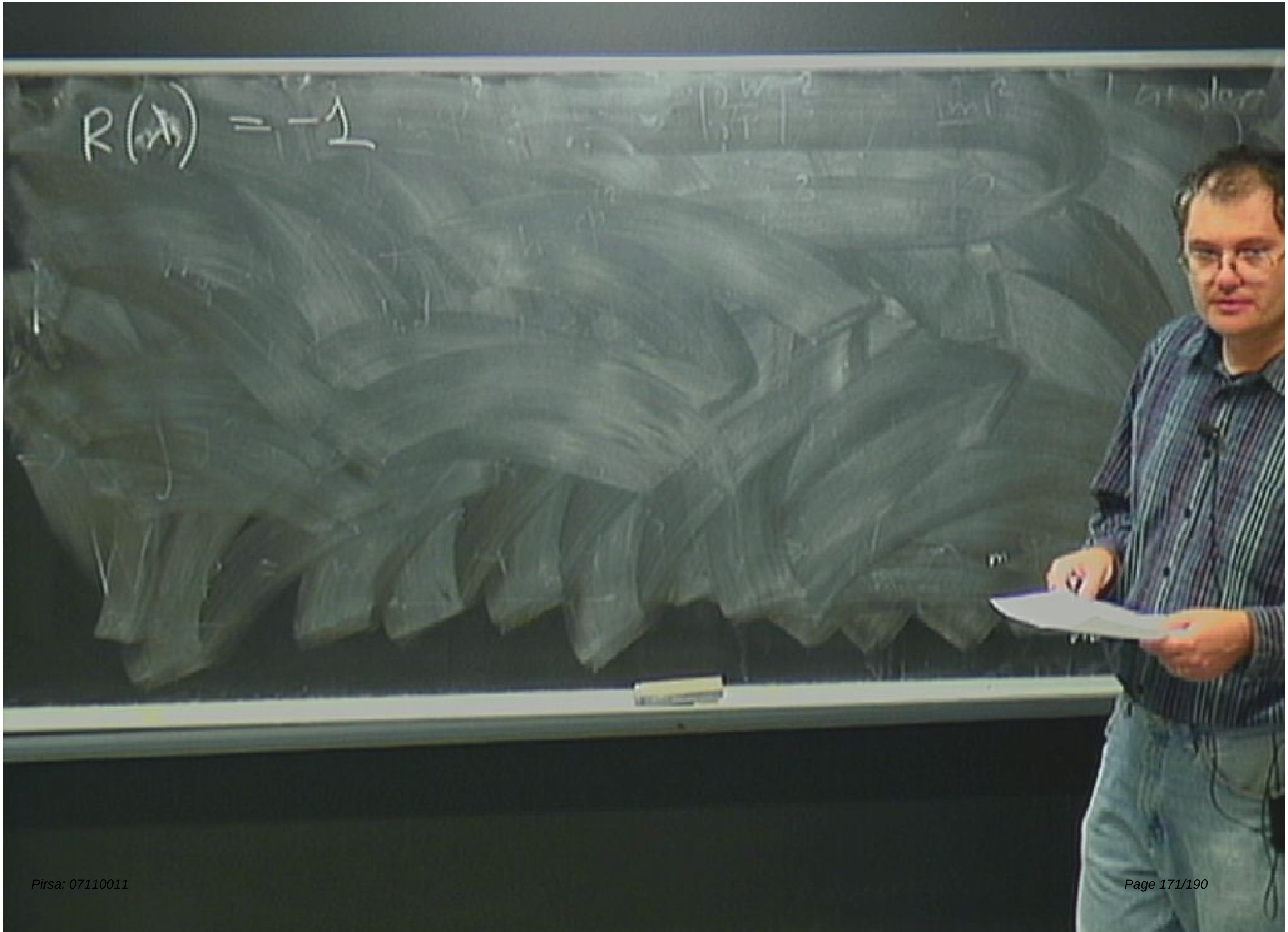
(a) couplings in W are complex

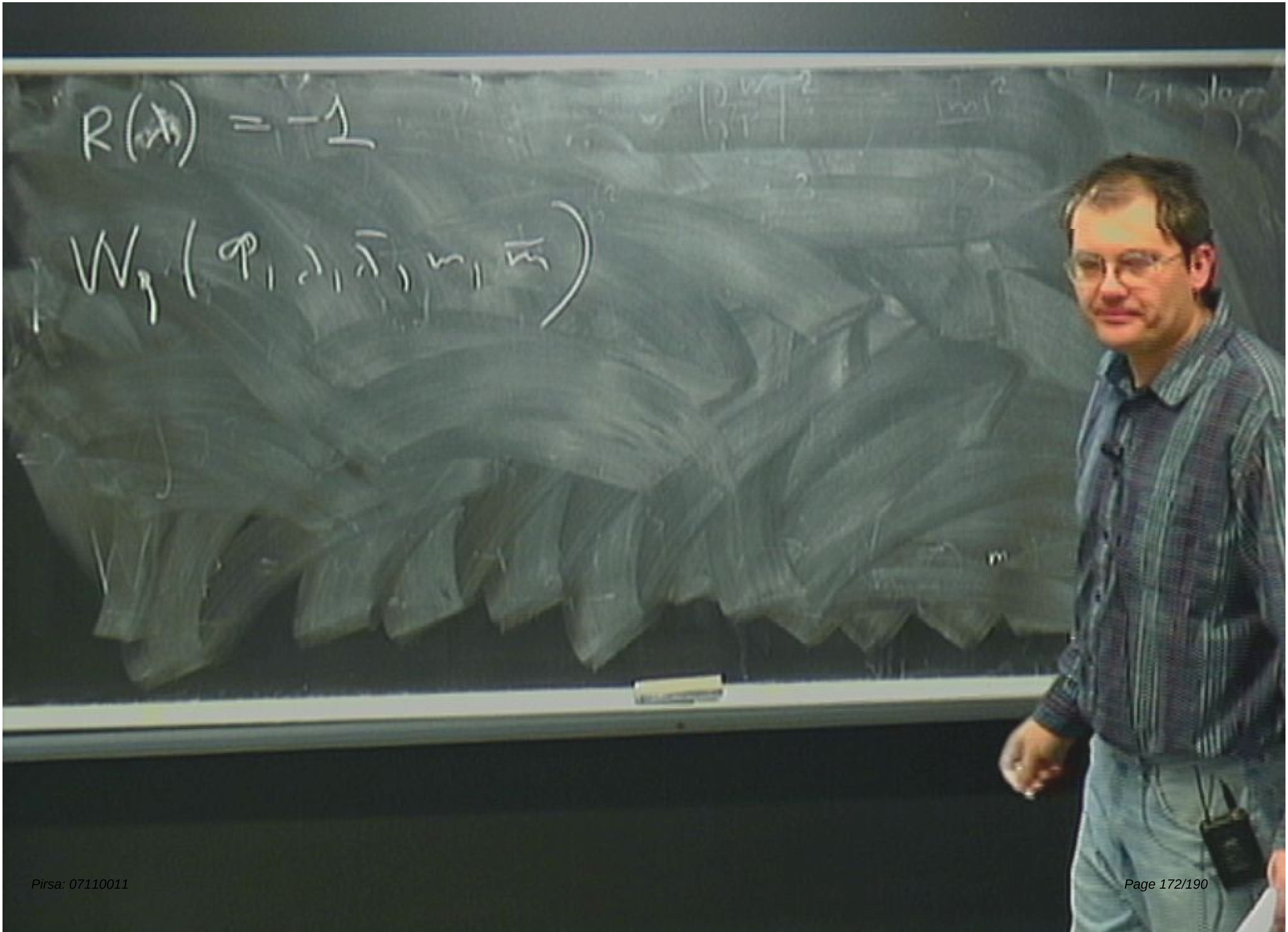
(b) W is holomorphic in these couplings

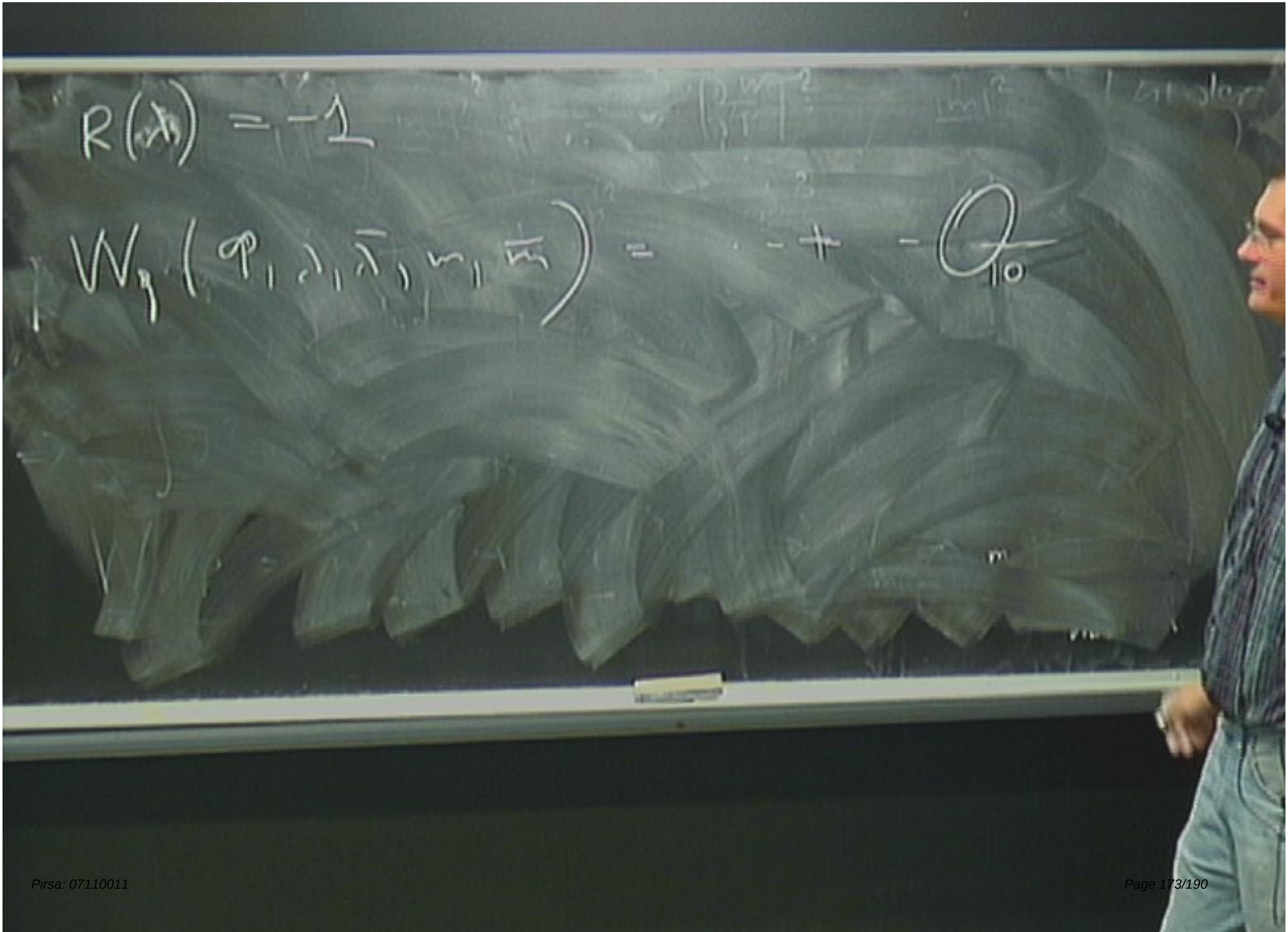
$$\frac{\partial W_g}{\partial \bar{m}} = 0 \qquad \frac{\partial W_g}{\partial \bar{\lambda}} = 0$$

chiral $\Leftrightarrow$ holomorphic

antichiral $\Leftrightarrow$ anti hol


R(λ) = −1


R(λ) = −1
W_g (φ, λ, λ̄, m, m̄)


R(λ) = −1
W_g(φ, λ, λ̄, m, m̄) = · − + − ⊘_10

$$R(\lambda) = -1$$

$$W_g(\varphi, \lambda, \bar{\lambda}, m, \bar{m}) = \cdots + \cdots \mathcal{O}_{10}\, f(\lambda, \bar{\lambda}) + \cdots$$

$$R(\mathcal{O}_{10}) =$$

$$R(\lambda) = -1$$

$$W_\eta(\varphi, \lambda, \bar{\lambda}, m, \bar{m}) = \cdots + \cdots \left[O_{10} \, f(\lambda, \bar{\lambda}) + \right.$$

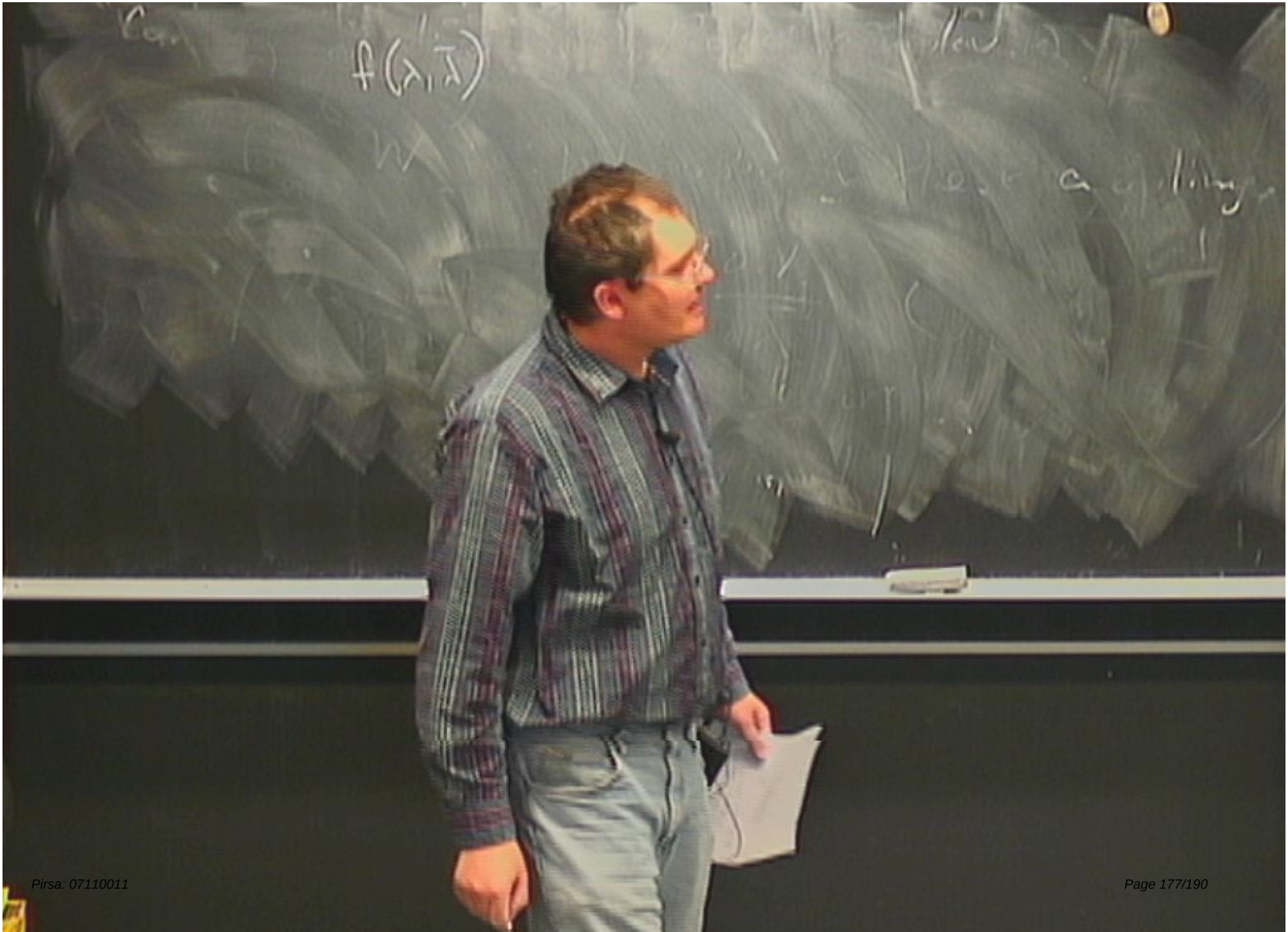
$$R(O_{10}) = +10$$

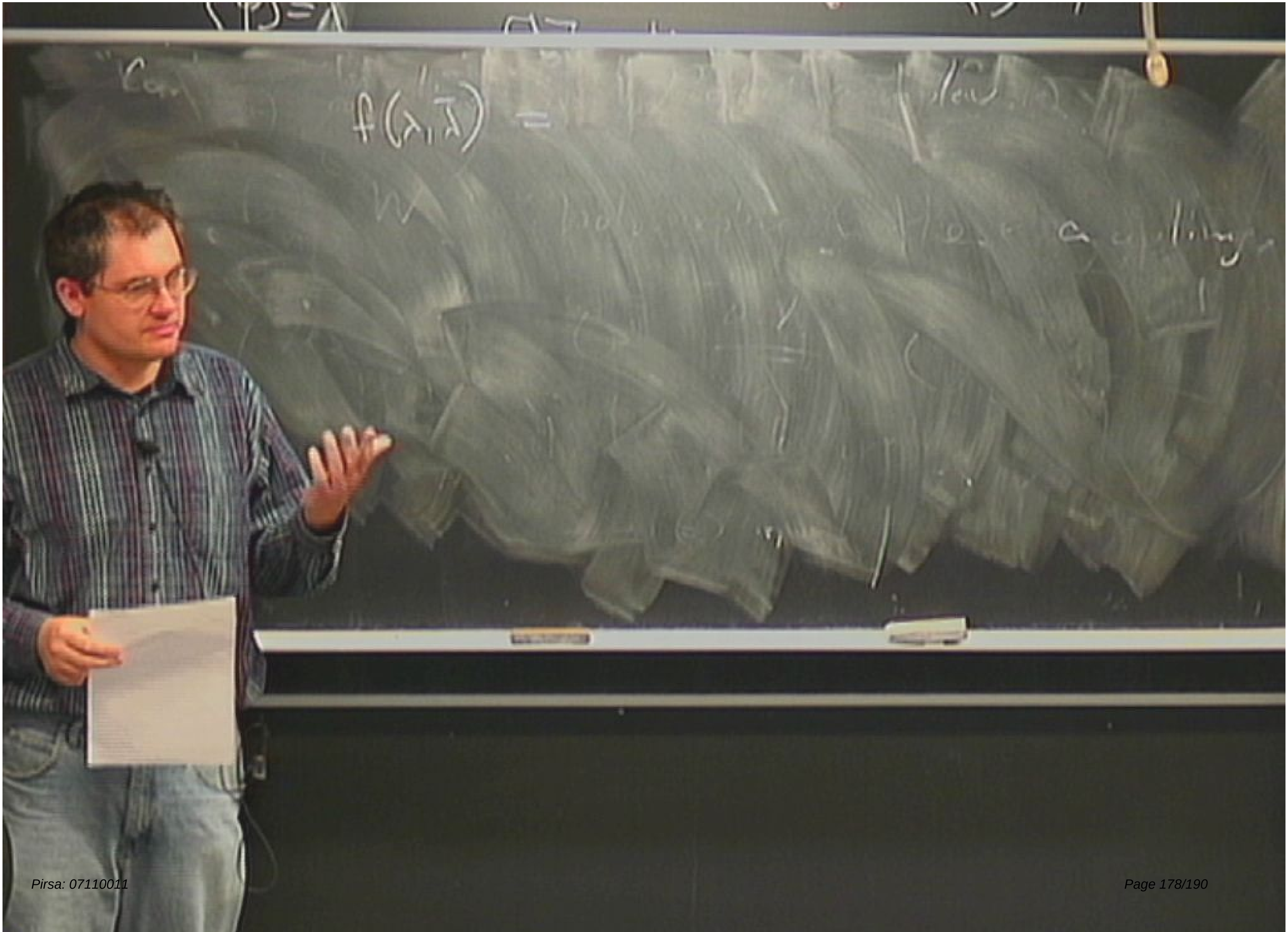
$R(\lambda) = -1$

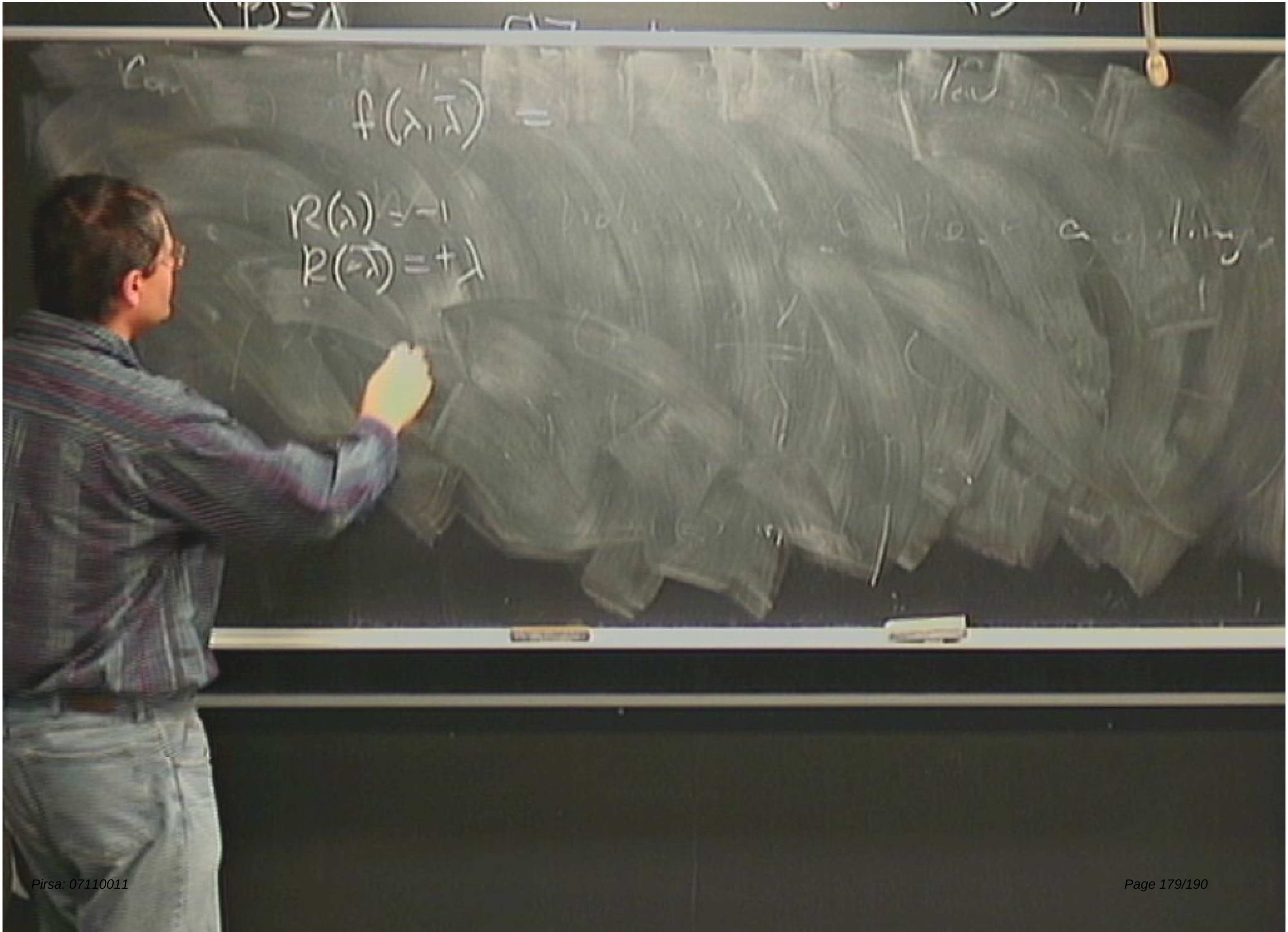
$W_\eta(\varphi, \lambda, \bar{\lambda}, m, \bar{m}) = \cdots + \cdots \mathcal{O}_{10} f(\lambda, \bar{\lambda}) +$

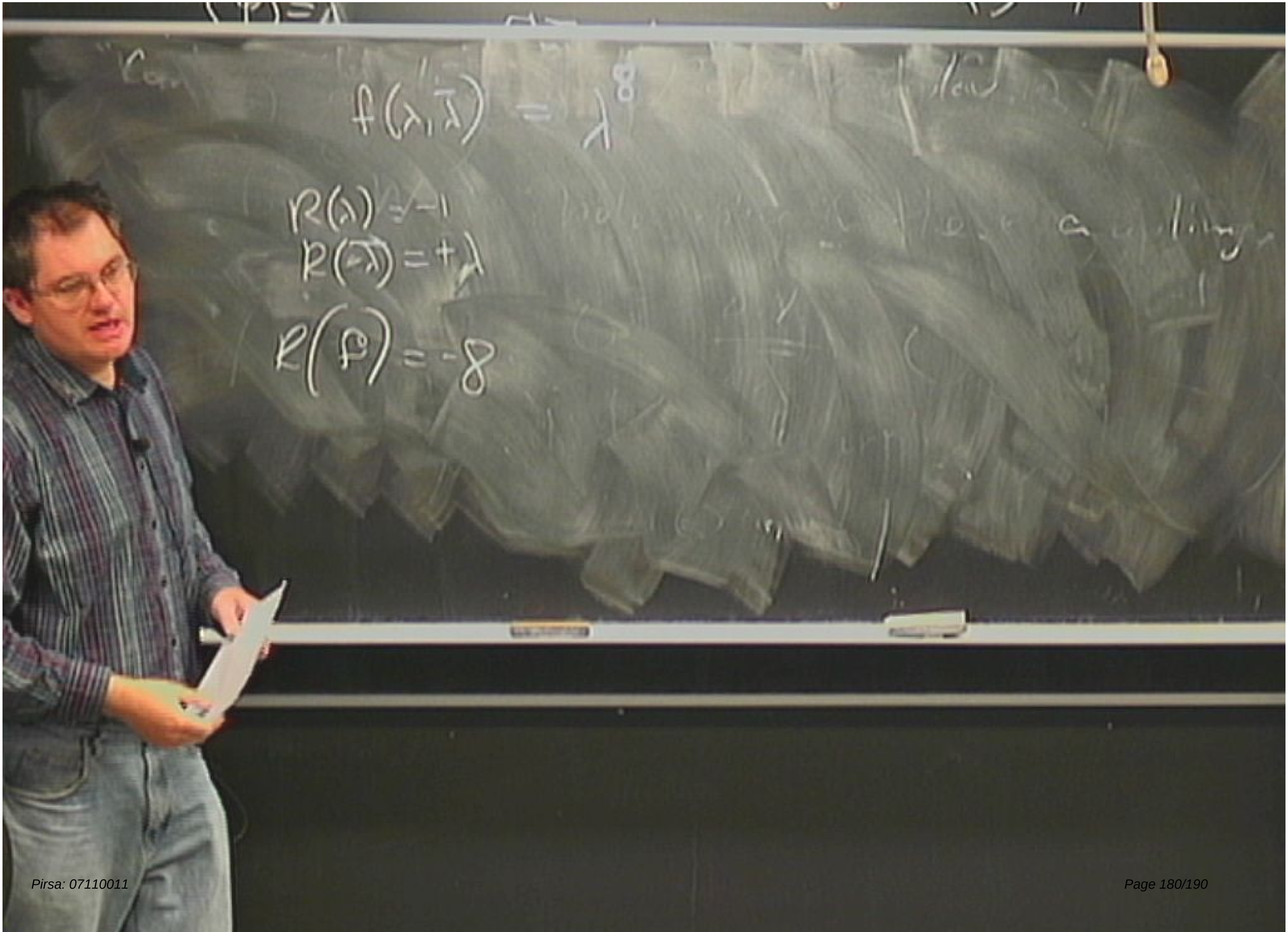
$R(\mathcal{O}_{10}) = +10$

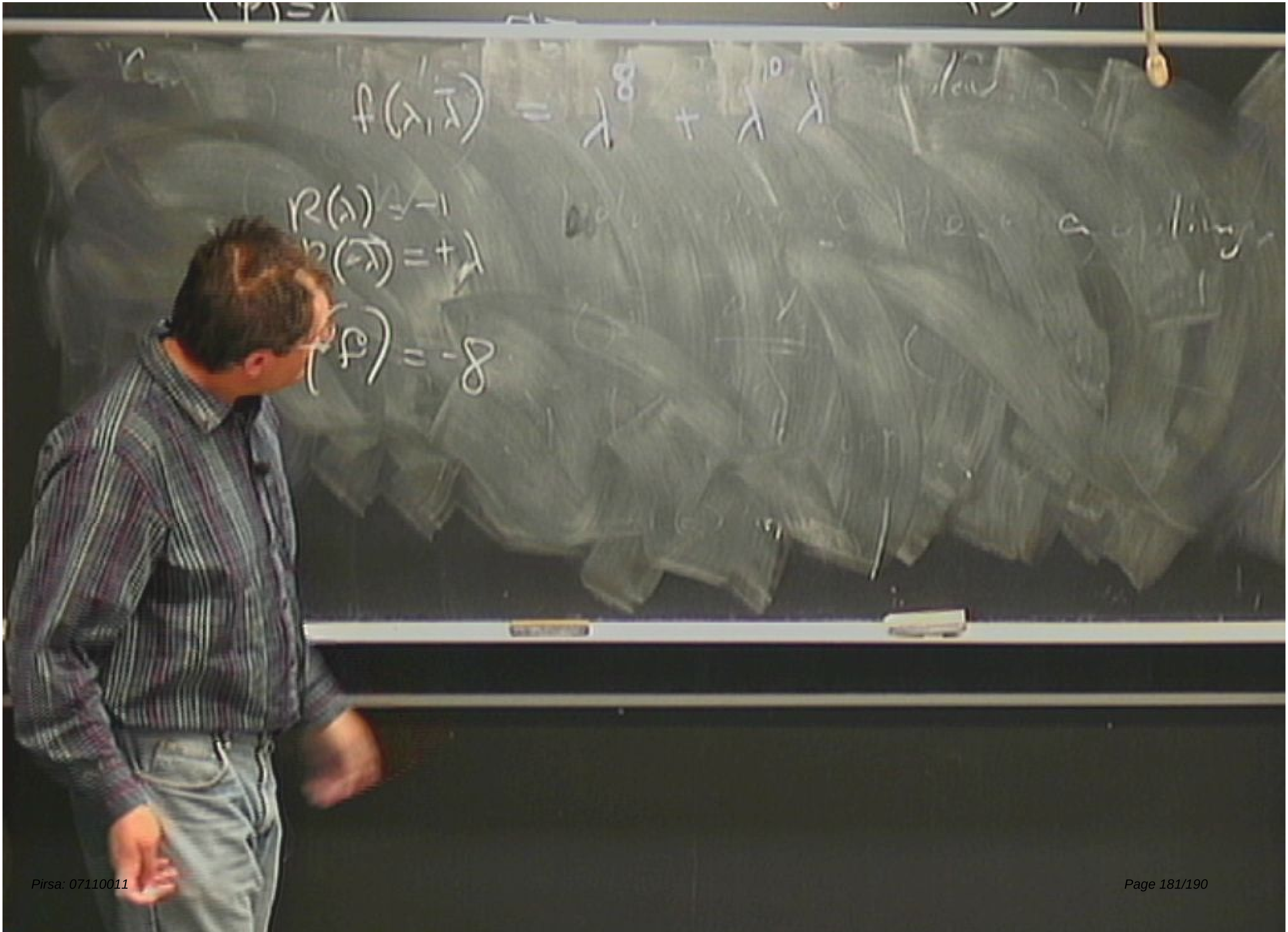
$R(f(\lambda, \bar{\lambda})) = -8$

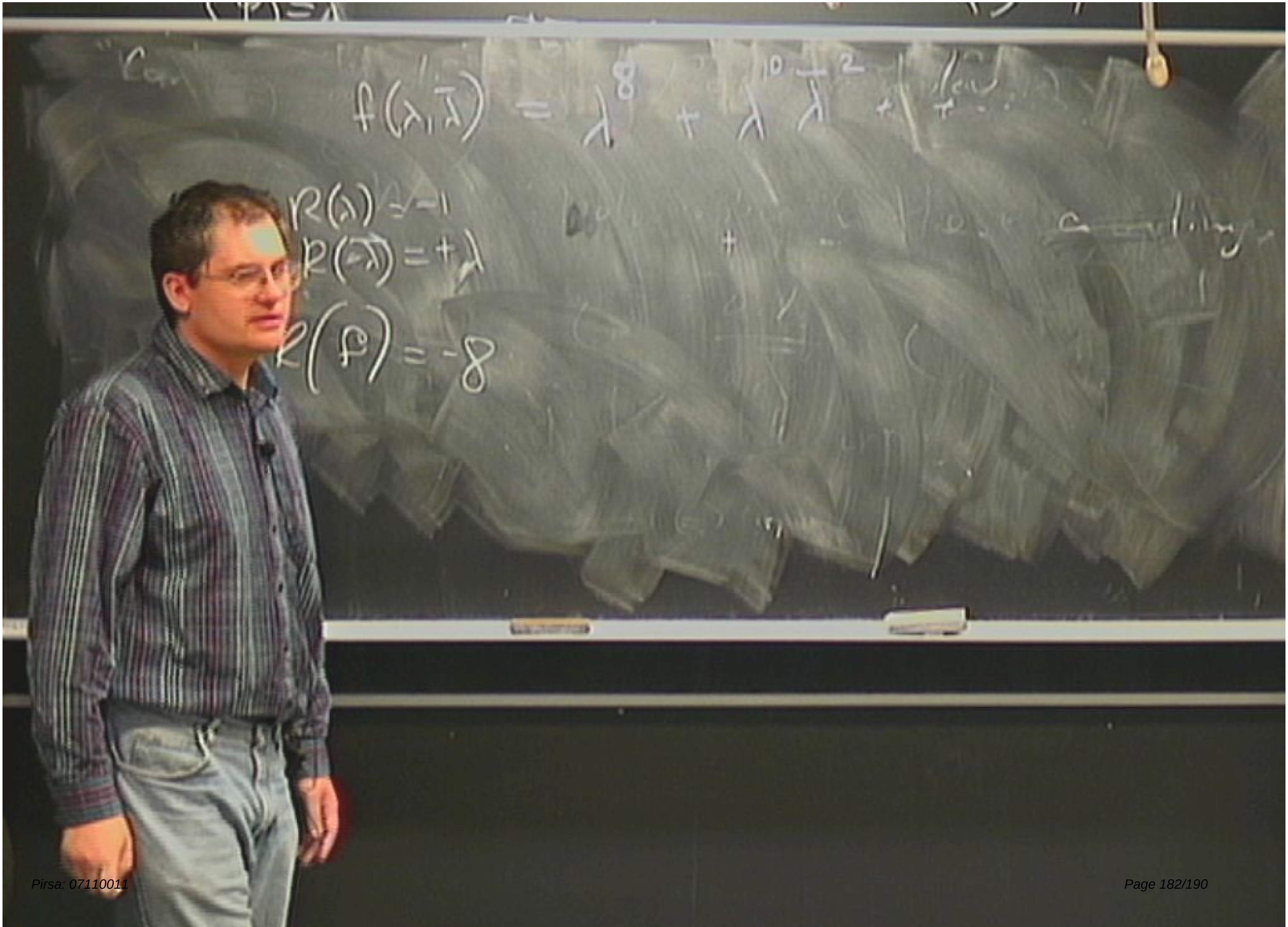

f(λ, λ̄)

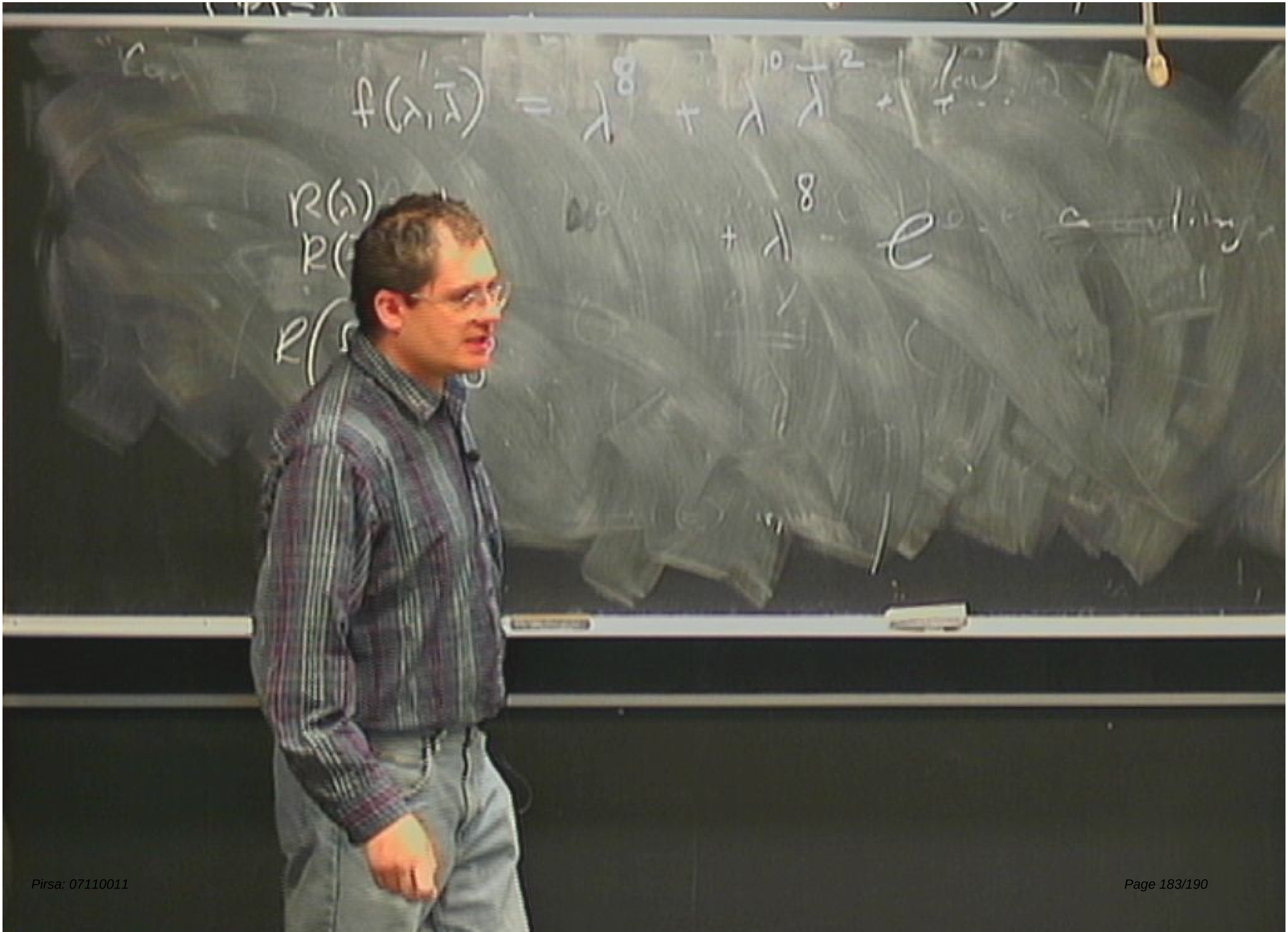


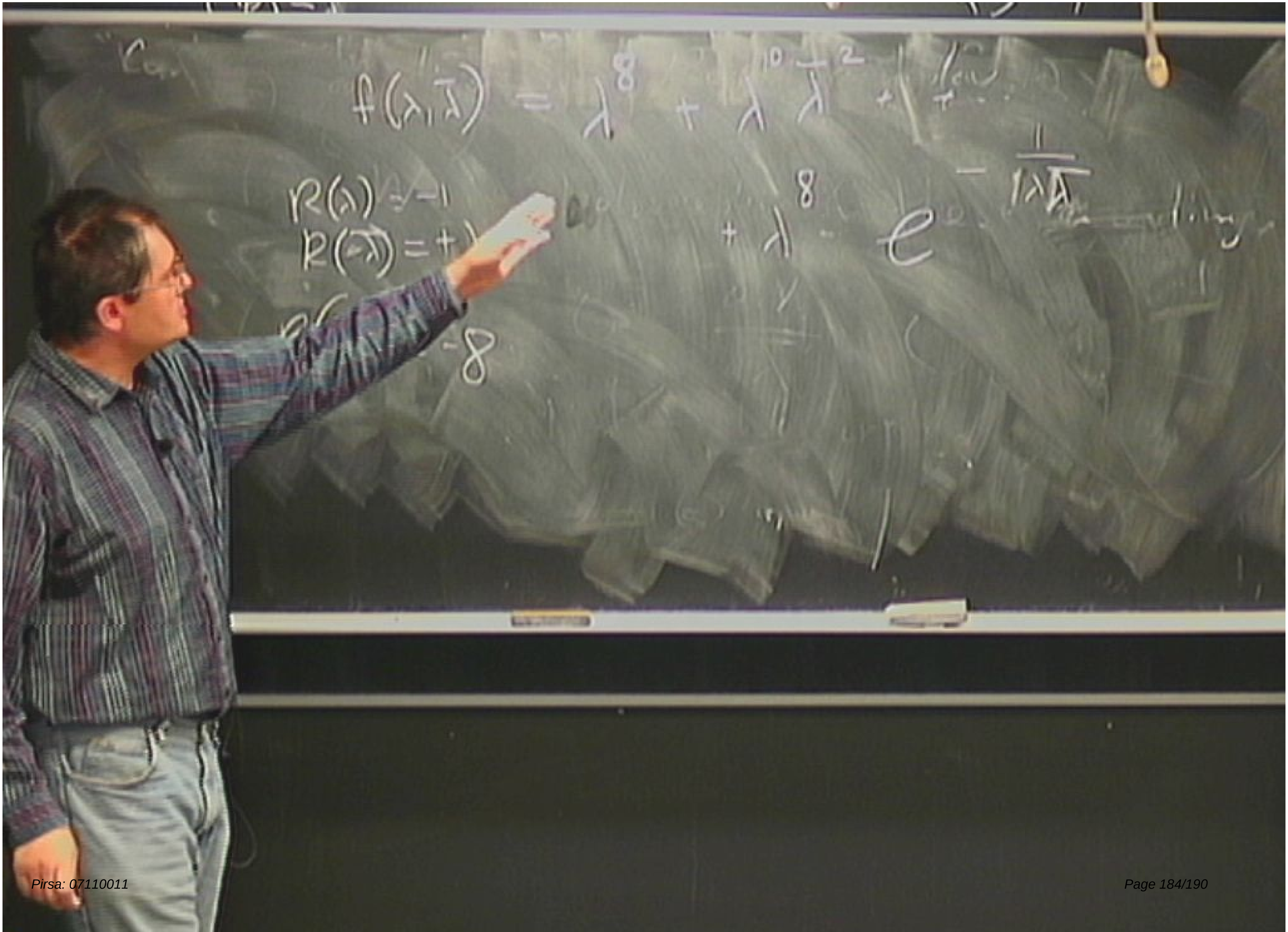


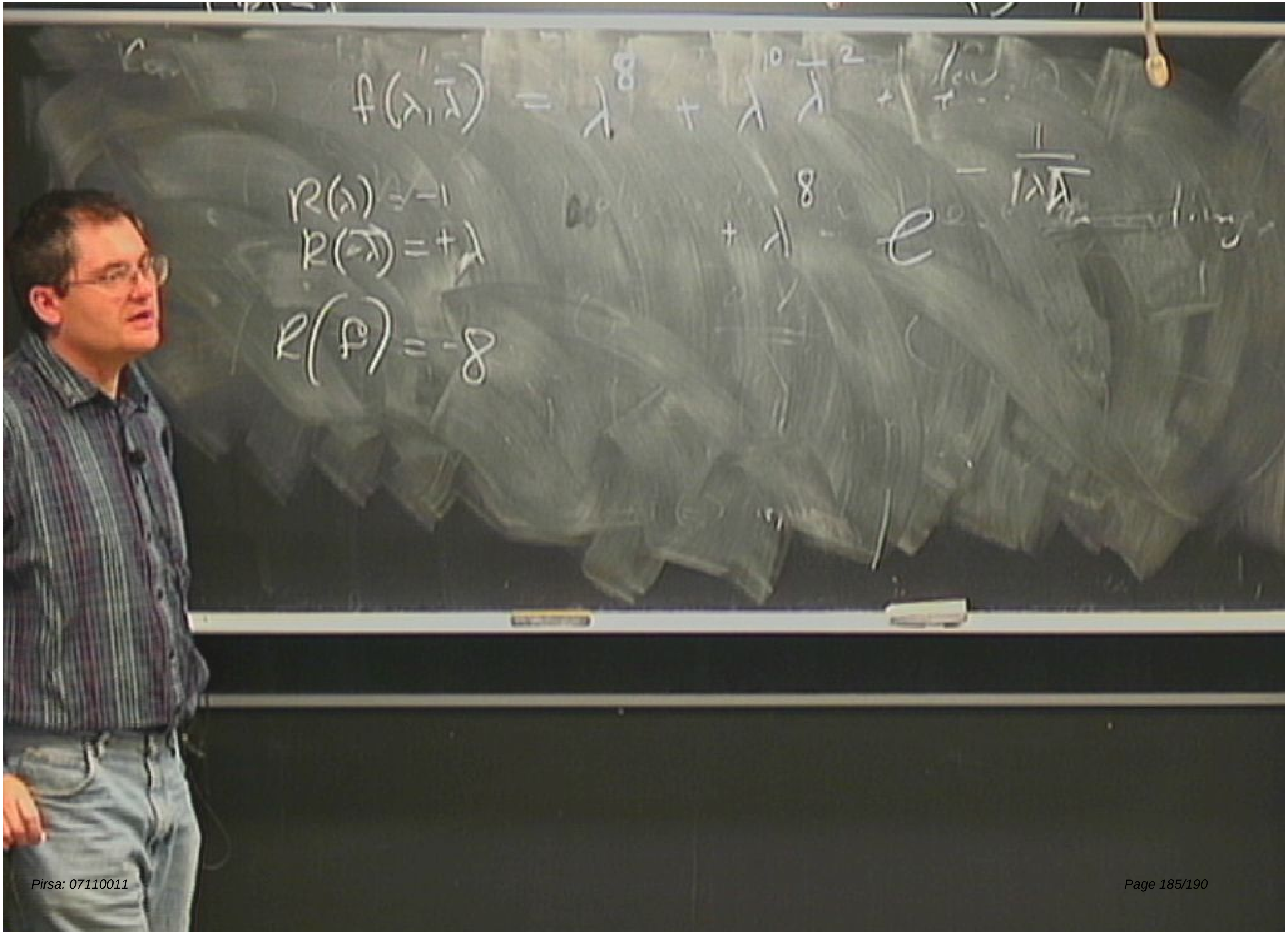

$f(\lambda,\bar\lambda) = \lambda^8$
$R(\lambda) = -1$
$R(\bar\lambda) = +1$
$R(\beta) = -8$

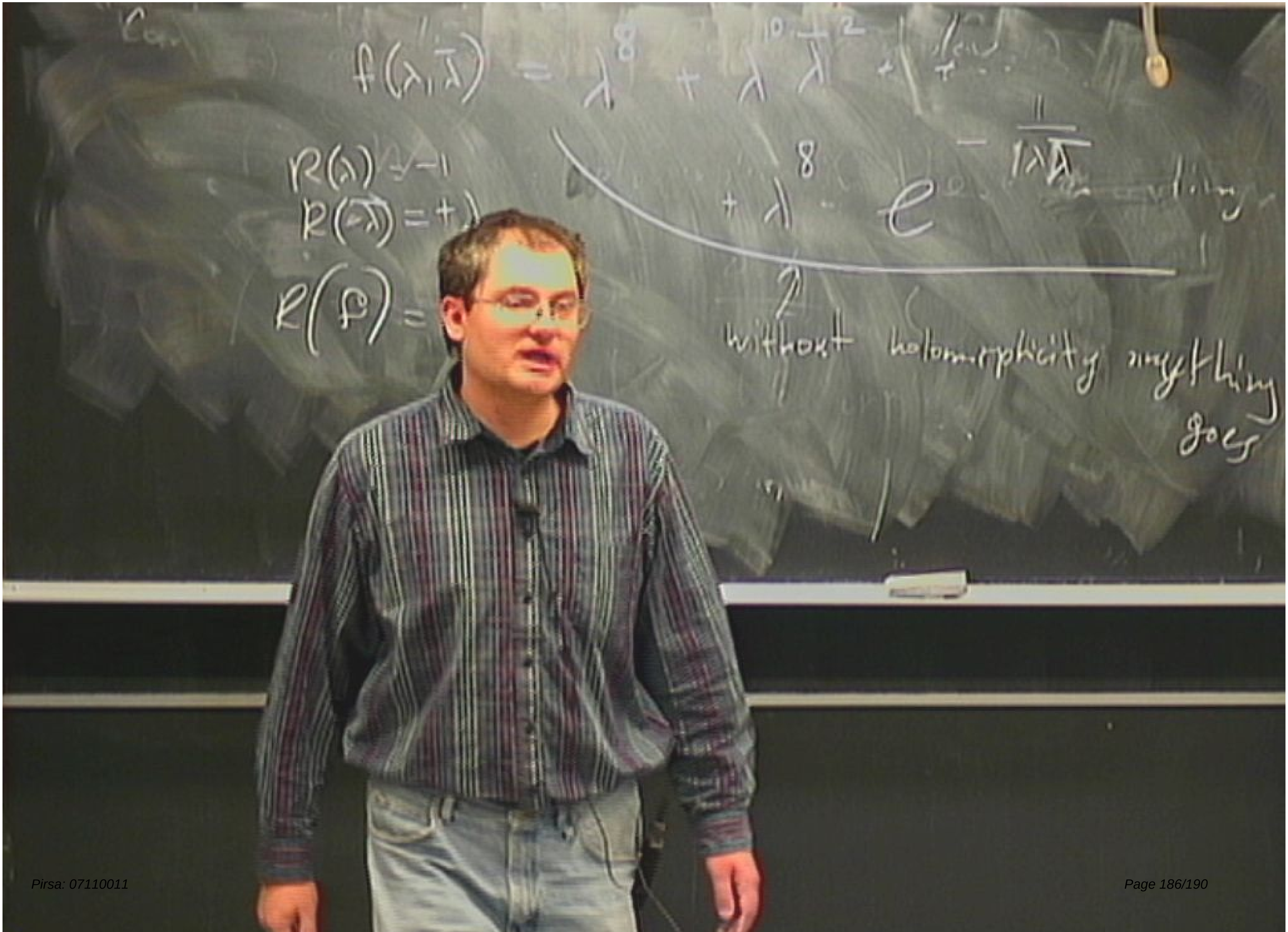

f(λ, λ̄) = λ^8 + λ^10 λ
R(λ) = -1
= -8

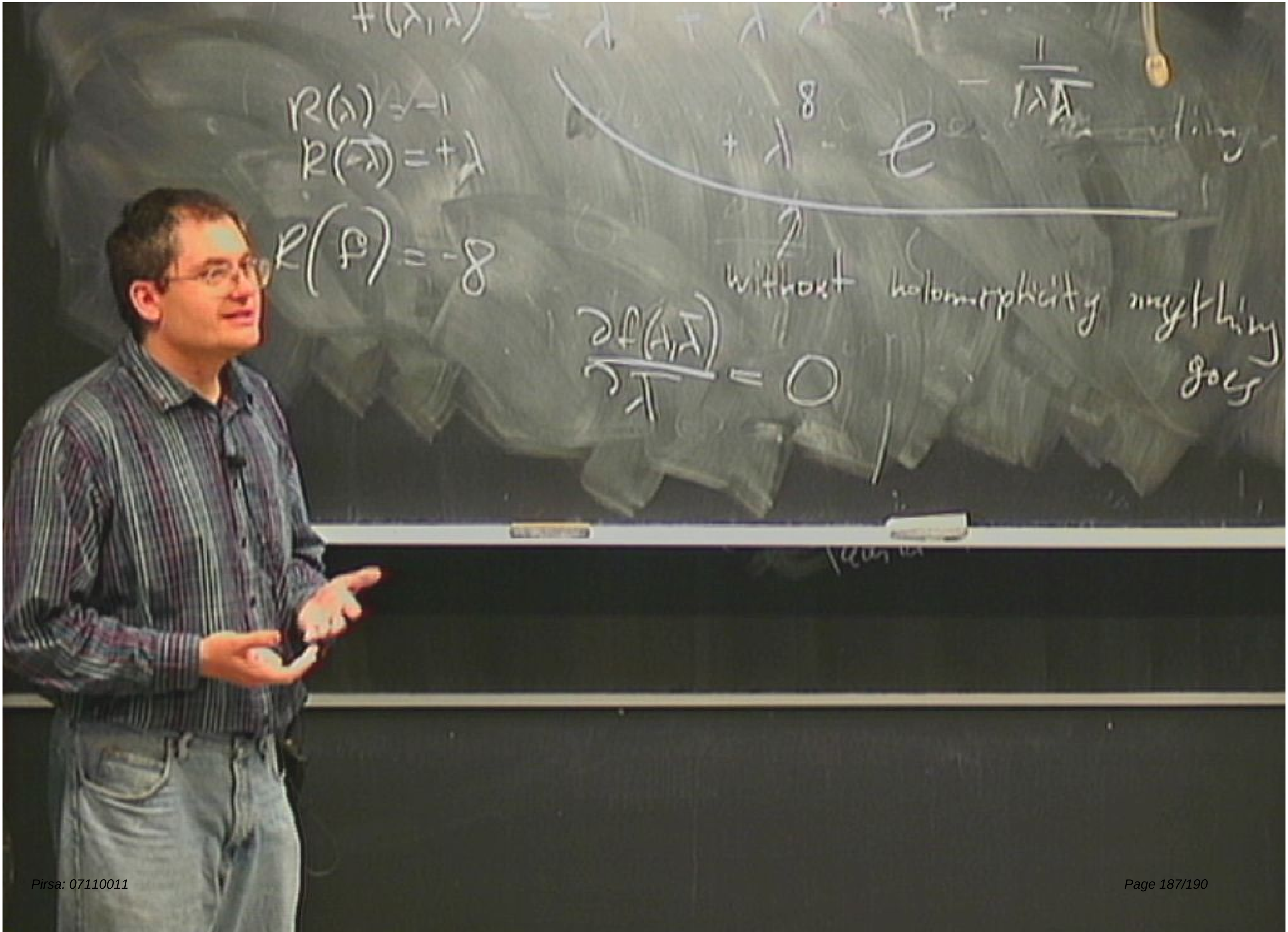

f(λ,λ̄) = λ^8 + λ^10 λ̄^2 + ...
R(λ) = -1
R(f) = -8

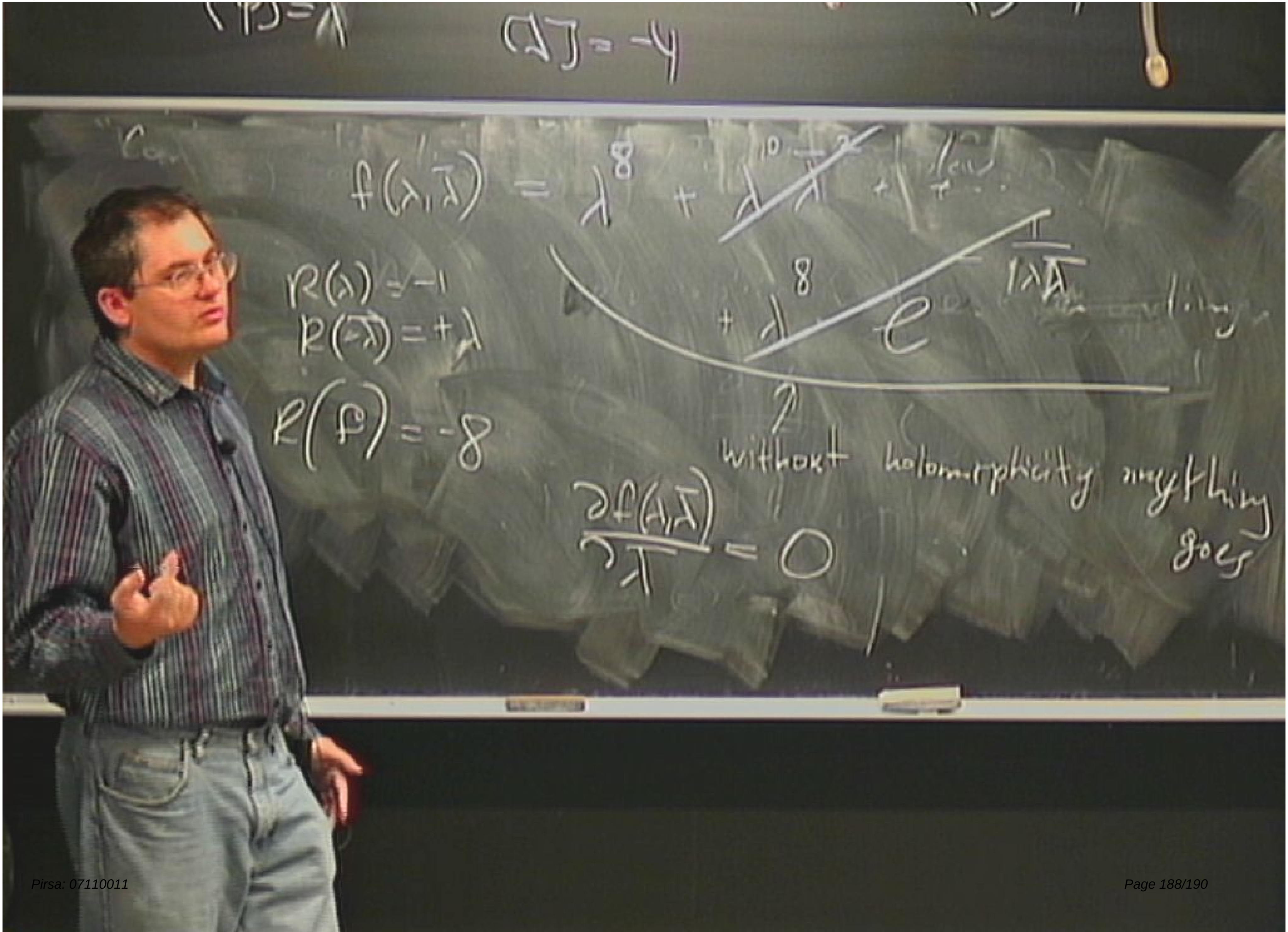

f(λ, λ̄) = λ8 + λ10 λ̄2 +
R(λ)

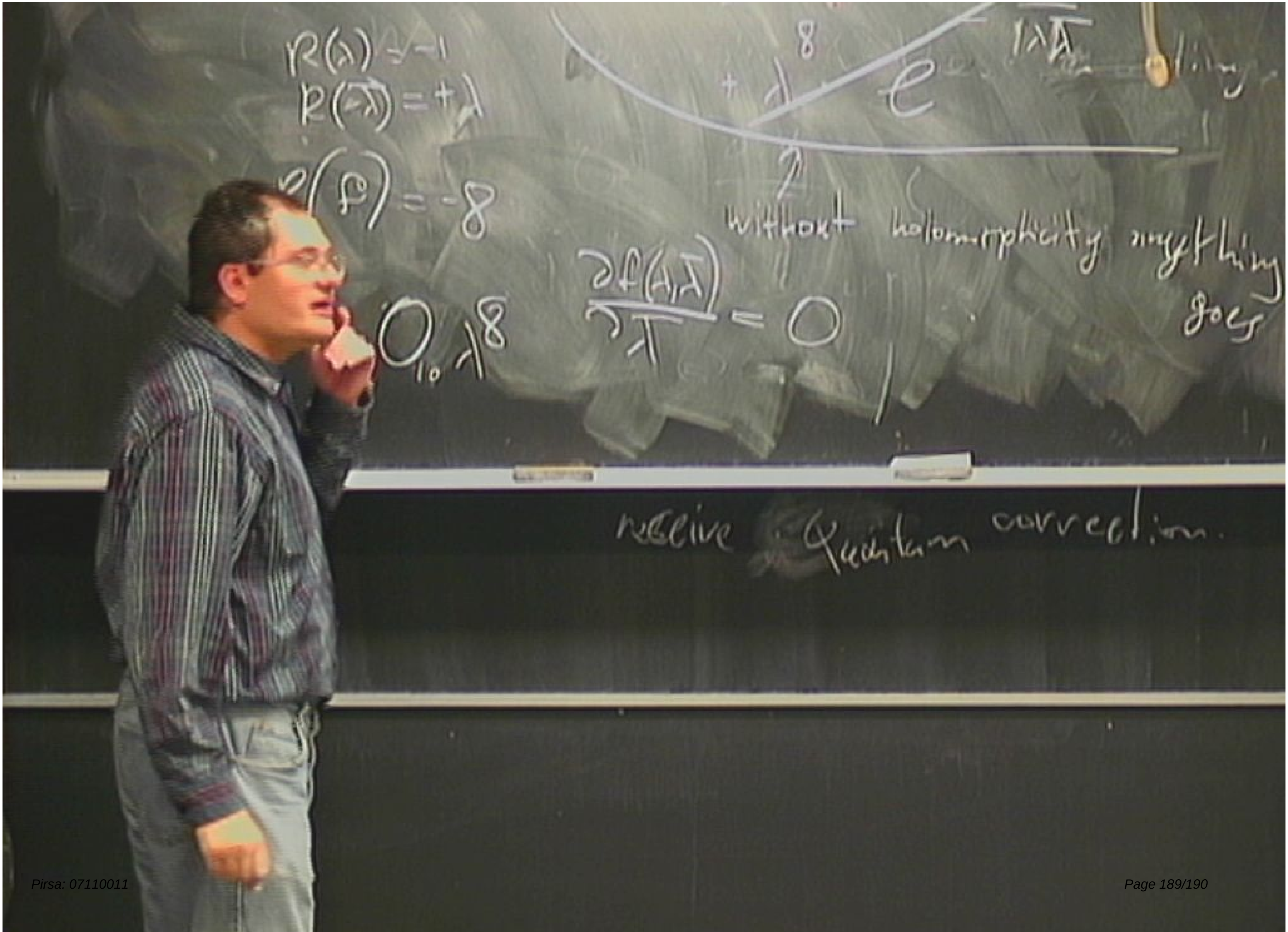

f(λ, λ̄) = λ^8 + λ^10 λ̄^2 +
R(λ) = −1
R(λ̄) = +1
−8


R(λ) = -1
R(λ̄) = +1
R(f) = -8


without holomorphicity anything goes


without holomorphicity anything goes


f(λ, λ̄) = λ^8 + λ^8 e^(−1/|λλ̄|)
R(λ) = −1
R(λ̄) = +1
R(β) = −8
without holomorphicity anything goes
∂f(λ, λ̄)/∂λ̄ = 0


without holomorphicity anything goes
receive Quantum correction.

$R(\lambda) = -1$

$R(\bar{\lambda}) = +1$

$R(\theta) = -8$

without holomorphicity anything goes

$\Rightarrow \quad O_{10}\,\lambda^{8} \qquad \frac{\partial f(\lambda,\bar{\lambda})}{\partial \bar{\lambda}} = 0$

$\Rightarrow$ W does not receive Quantum correction.