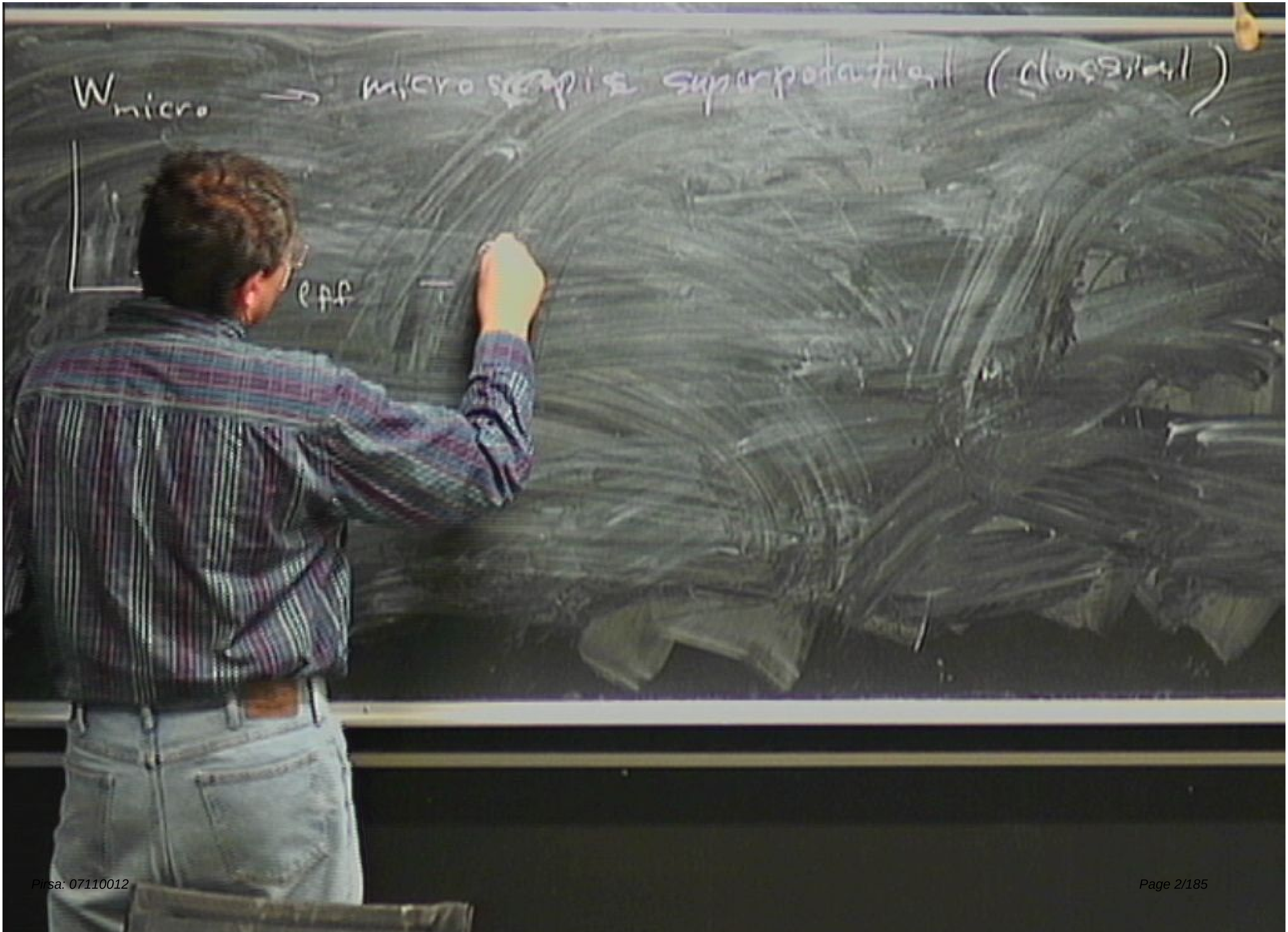
Title: Intro to Supersymmetry 16

Date: Nov 08, 2007 12:30 PM

URL: http://pirsa.org/07110012

Abstract:


W micro → microscopic superpotential (classical)
L eff =

$W_{micro} \rightarrow$ microscopic superpotential (classical)

$\hookrightarrow W_{eff}$ — ?

$W_{micro} \rightarrow$ microscopic superpotential (classical)

$\hookrightarrow W_{eff}$ — ?

$W_{micro}(\lambda)$

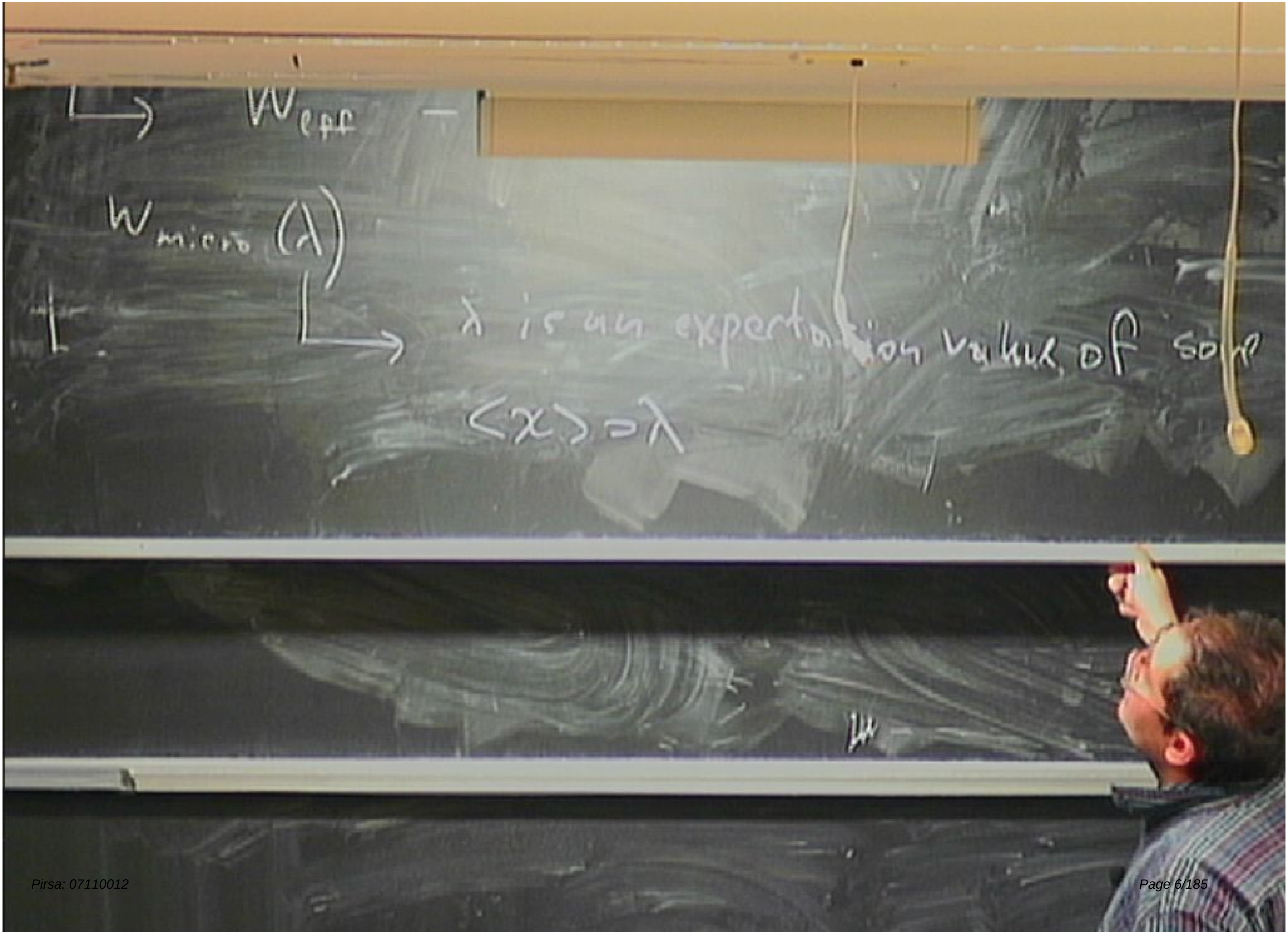
$\hookrightarrow$

$W_{micro} \rightarrow$ microscopic superpotential (classical)

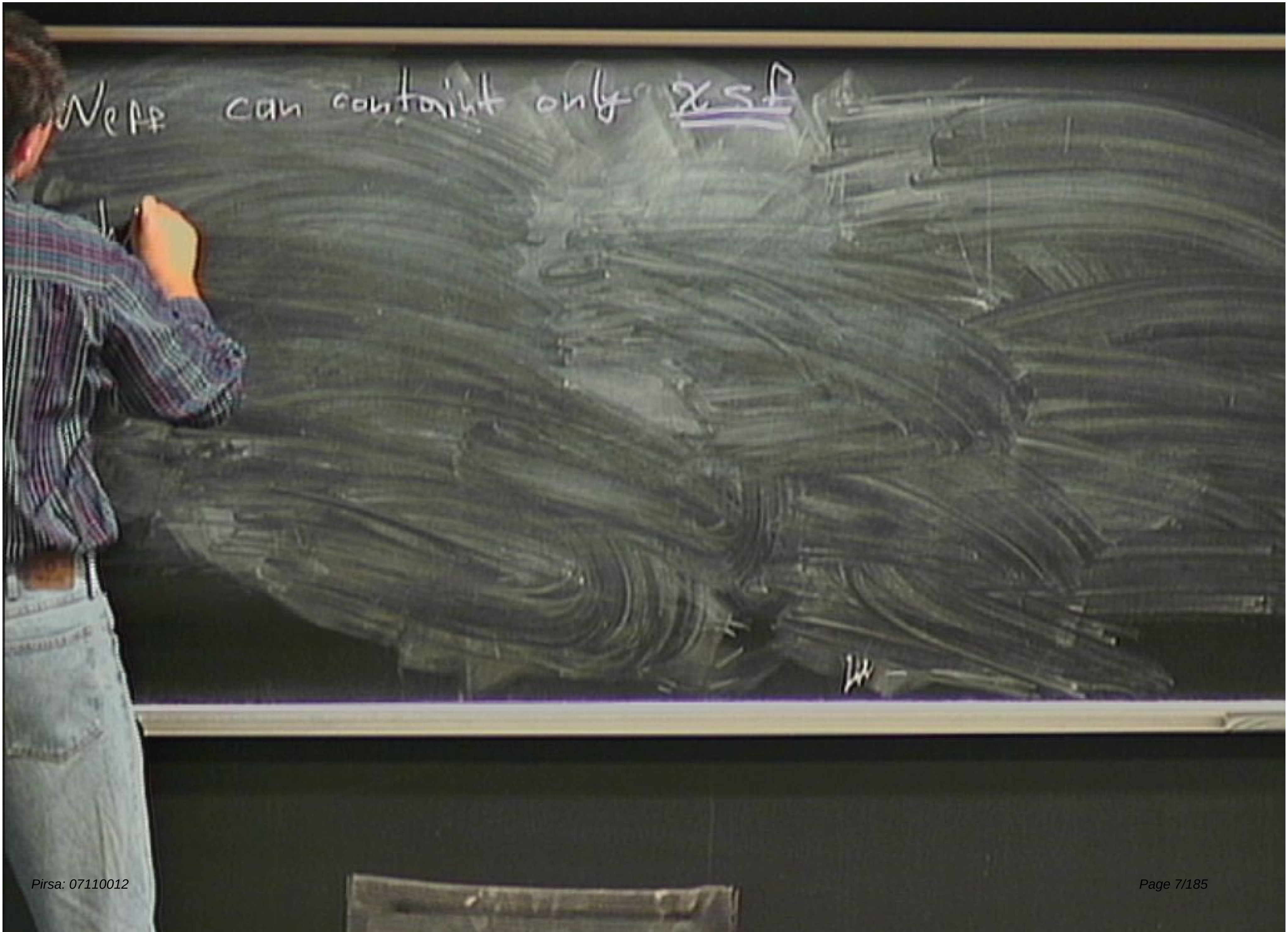
$\hookrightarrow W_{eff} = ?$

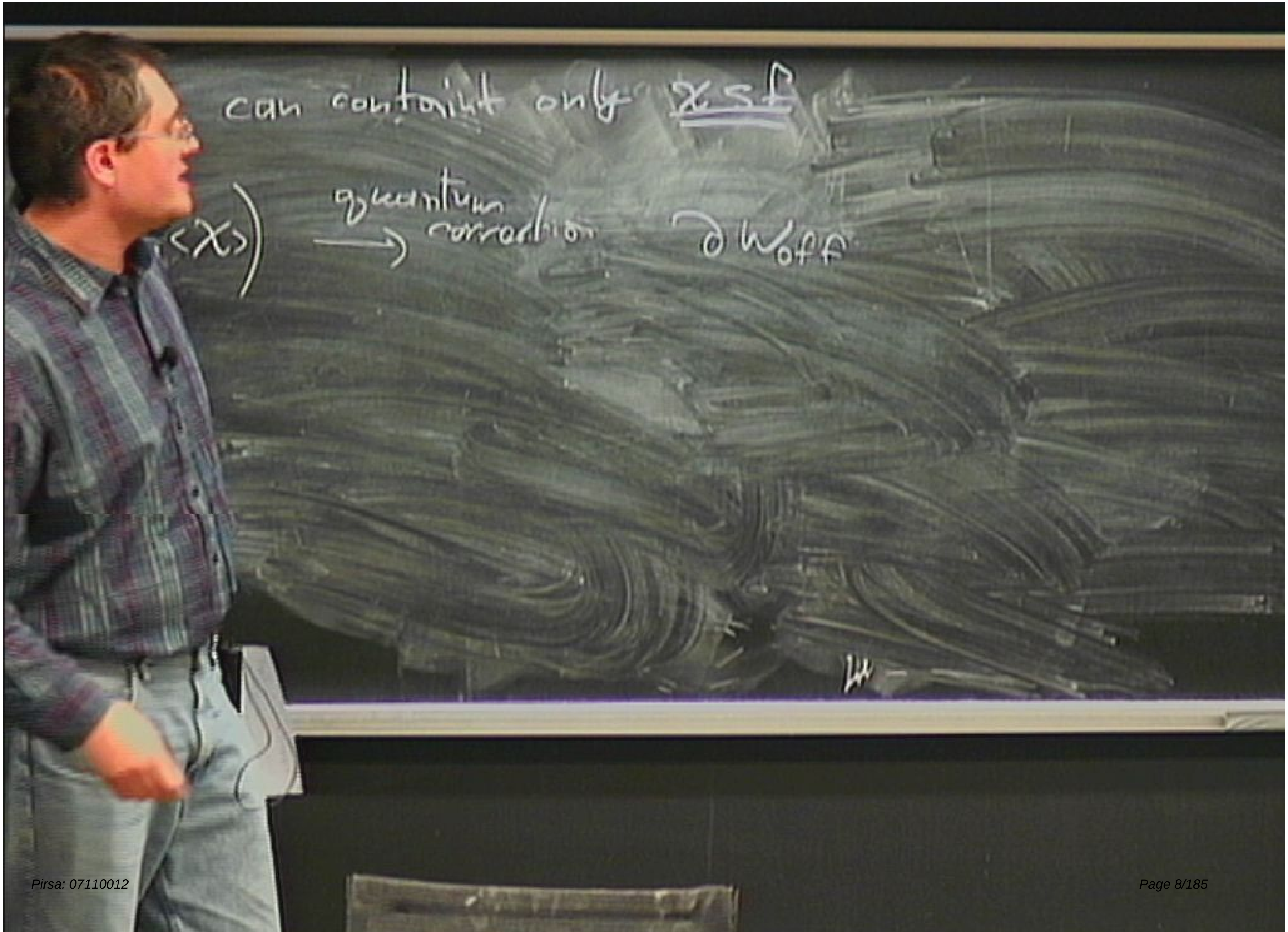
$W_{micro}(\lambda)$

$\hookrightarrow$ λ is an expectation value of



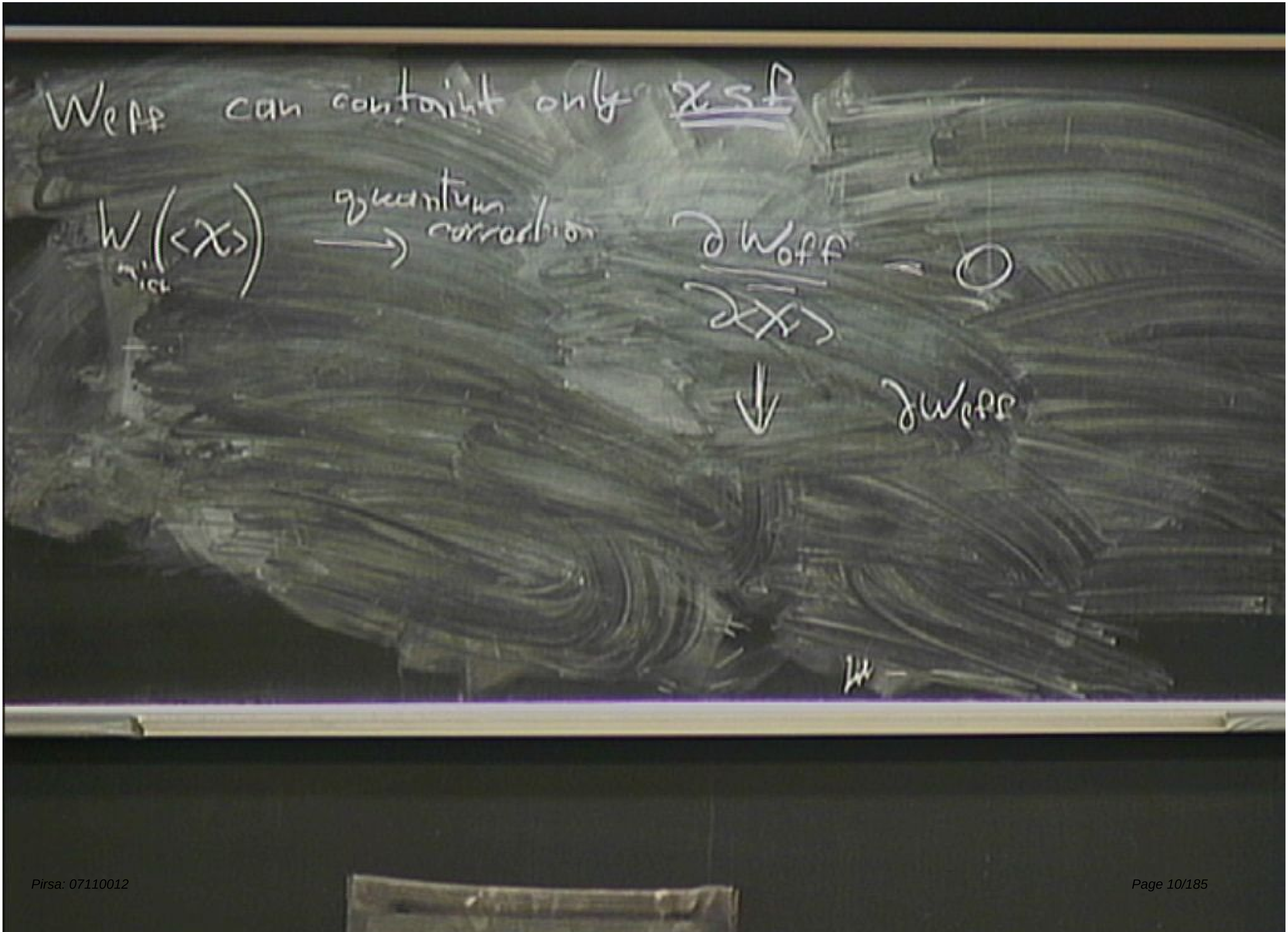
W eff
W micro (λ)
λ is an expectation value of some
<x> = λ


W_{eff} can contain only χSB


can contraint only
quantum
correction

W_{eff} can contain only χSF

$$W_{\text{mic}}(\langle \chi \rangle) \xrightarrow[\text{correction}]{\text{quantum}} \qquad \frac{\partial W_{\text{eff}}}{\partial \langle \chi \rangle} = 0$$


Weff can contain only
W(<X>)
quantum
correction
∂Weff
∂<X>
= 0
∂Weff

W_{eff} can contain only χSF

$$W_{tree}(\langle X \rangle) \xrightarrow[\text{correction}]{\text{quantum}} \quad \frac{\partial W_{eff}}{\partial \langle X \rangle} = 0$$

$$\Downarrow \quad \frac{\partial W_{eff}}{\partial \bar{X}} = 0$$

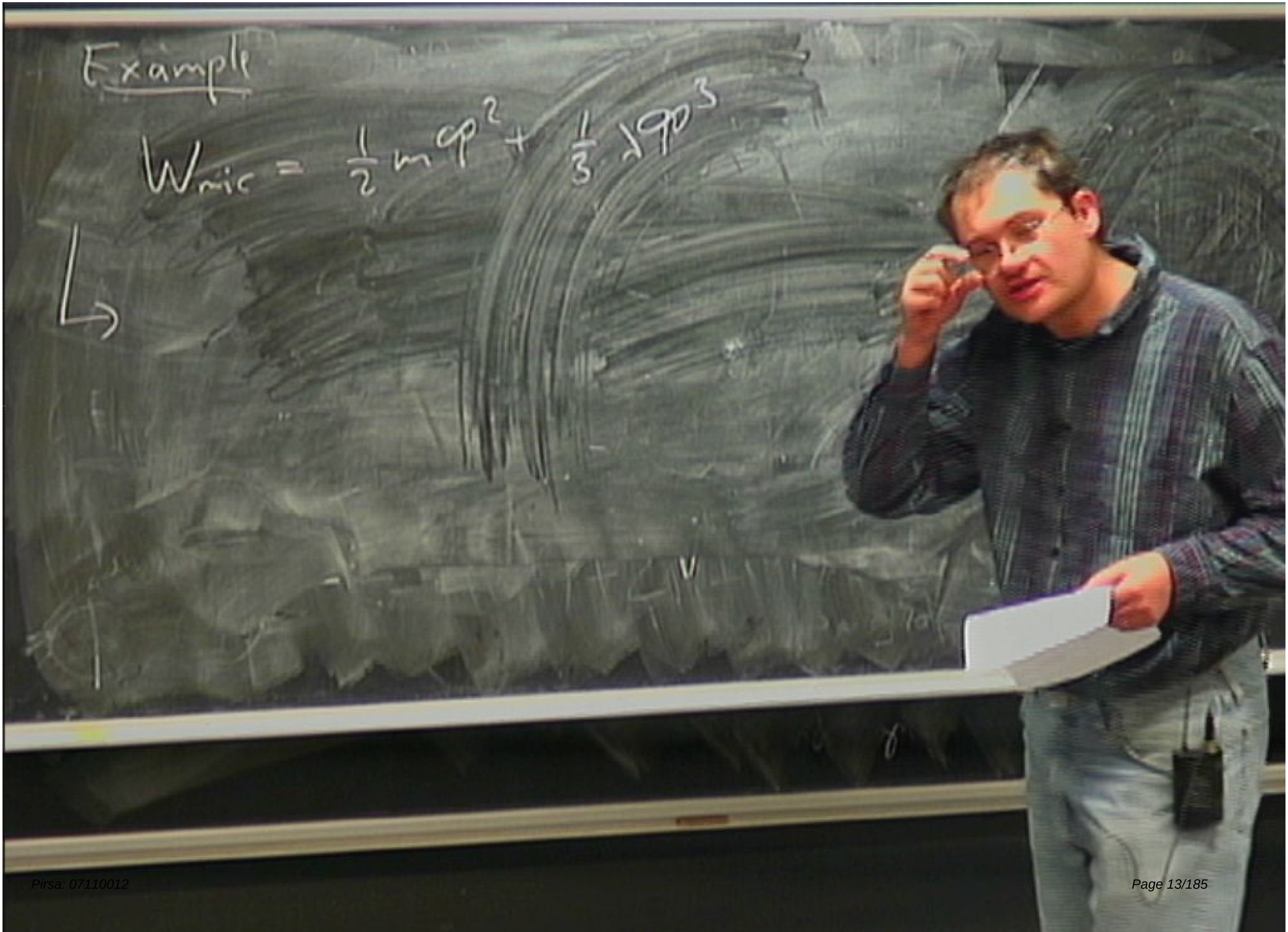
W_{eff} can contain only $\underline{\chi SF}$

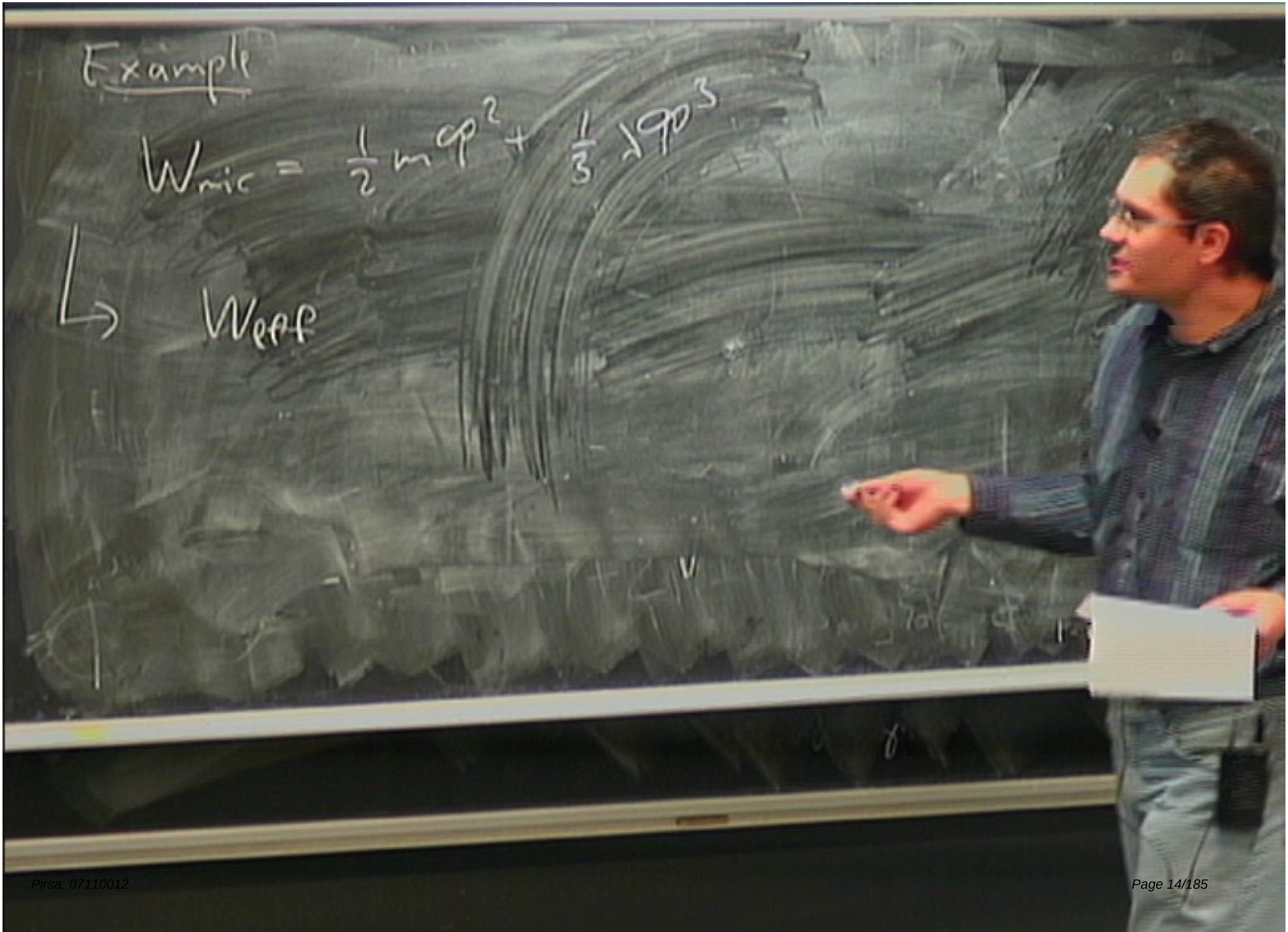
$$W_{\text{micro}}(\langle X \rangle) \xrightarrow[\text{correction}]{\text{quantum}}$$

$$\frac{\partial W_{eff}}{\partial \langle X \rangle} = 0$$

$$\Downarrow$$

$$\frac{\partial W_{eff}}{\partial \bar{X}} = 0$$


Example
$W_{mic} = \frac{1}{2} m\varphi^2 + \frac{1}{3}\lambda\varphi^3$


Example
$W_{mic} = \frac{1}{2} m\varphi^2 + \frac{1}{3}\lambda\varphi^3$
W_{eff}

Example

$$W_{mic} = \frac{1}{2} m \varphi^2 + \frac{1}{3} \lambda \varphi^3$$

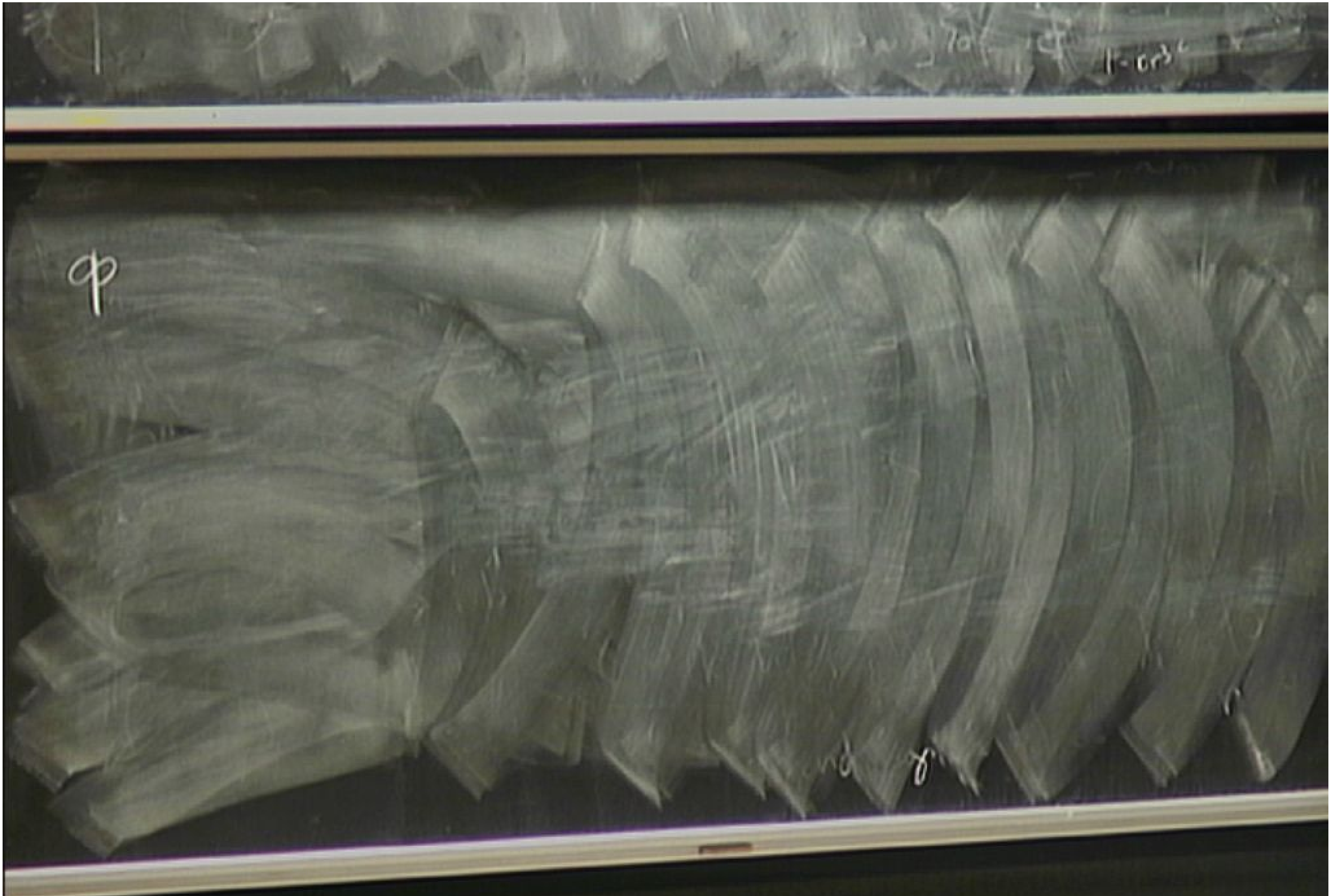
$$\hookrightarrow \quad W_{eff} = W_{eff}(\varphi,$$

Example

$$W_{mic} = \frac{1}{2} m \varphi^2 + \frac{1}{3} \lambda \varphi^3$$

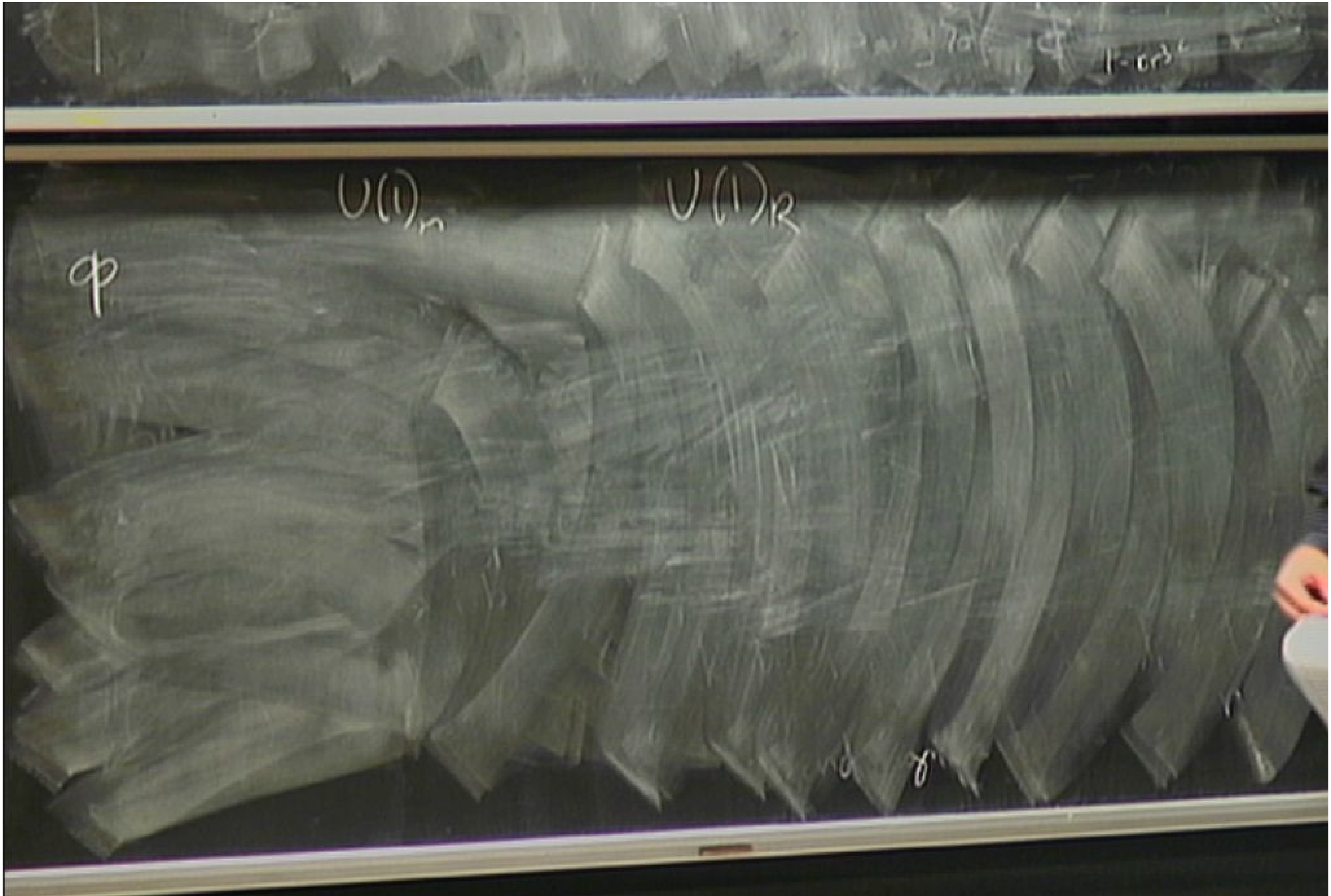
$$\hookrightarrow \quad W_{eff} = W_{eff}(\varphi, \lambda, m)$$

$$\frac{\partial W_{eff}}{\partial \lambda} = 0 \qquad \frac{\partial W_{eff}}{\partial m} = 0$$


φ

$U(1)$

φ


U(1)_A
U(1)_R
φ

	$U(1)_n$	$U(1)_R$
ϕ		$+1$
m		
λ		

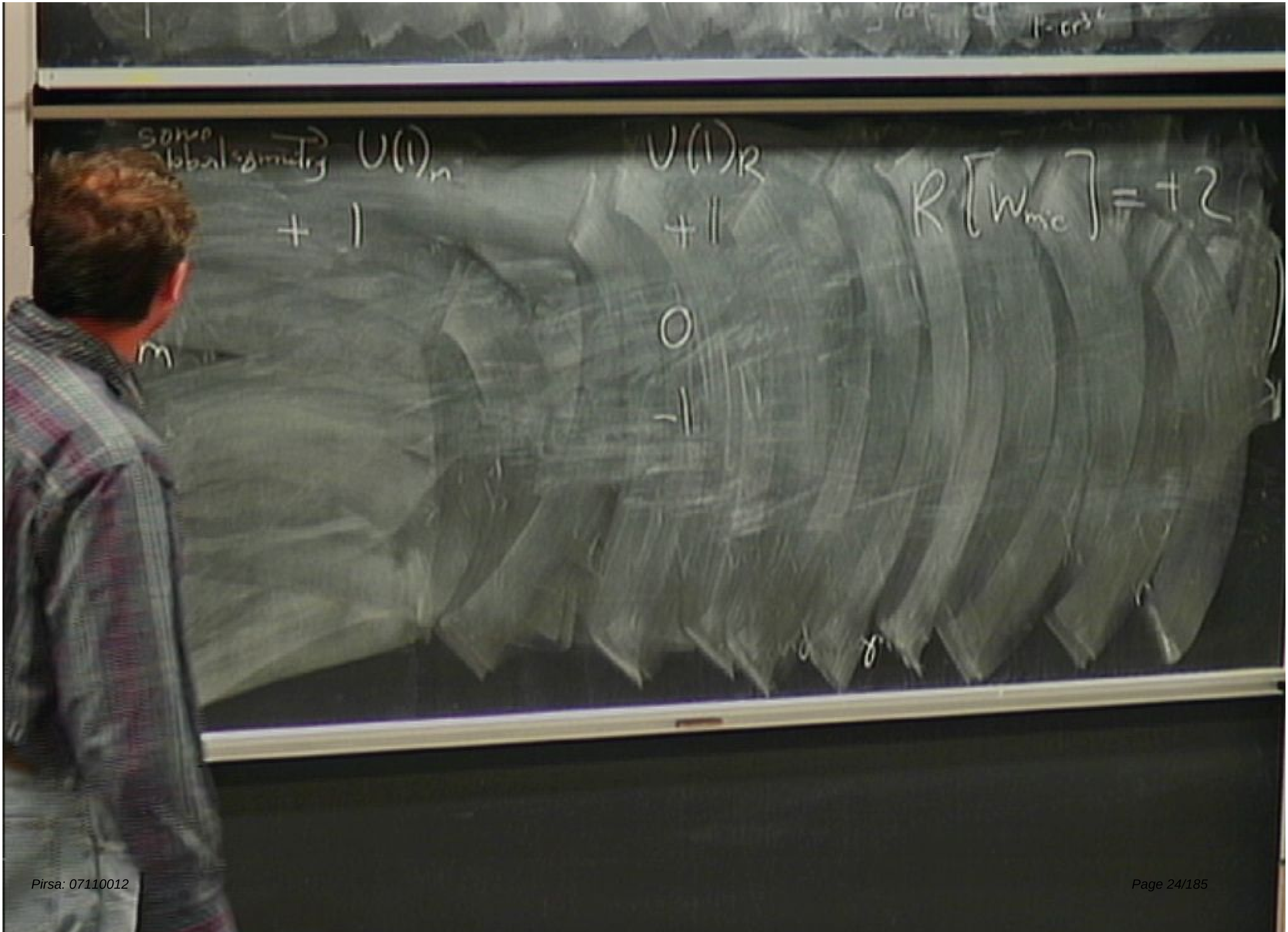
	$U(1)_n$	$U(1)_R$
ϕ		$+1$
m		0
λ		-1

	$U(1)_n$	$U(1)_R$
φ		$+1$
m		0
λ		-1

$R[W_{mic}] = +2$

some global symmetry	$U(1)_n$	$U(1)_R$
ϕ		$+1$
m		0
λ		-1

$R[W_{mic}] = +2$


some global symmetry
U(1)
U(1)R
+1
+1
0
-1
R[W] = +2

some global symmetry	$U(1)_n$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ		-1

$R[W_{mic}] = +2$

some global symmetry	$U(1)_B$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ		-1

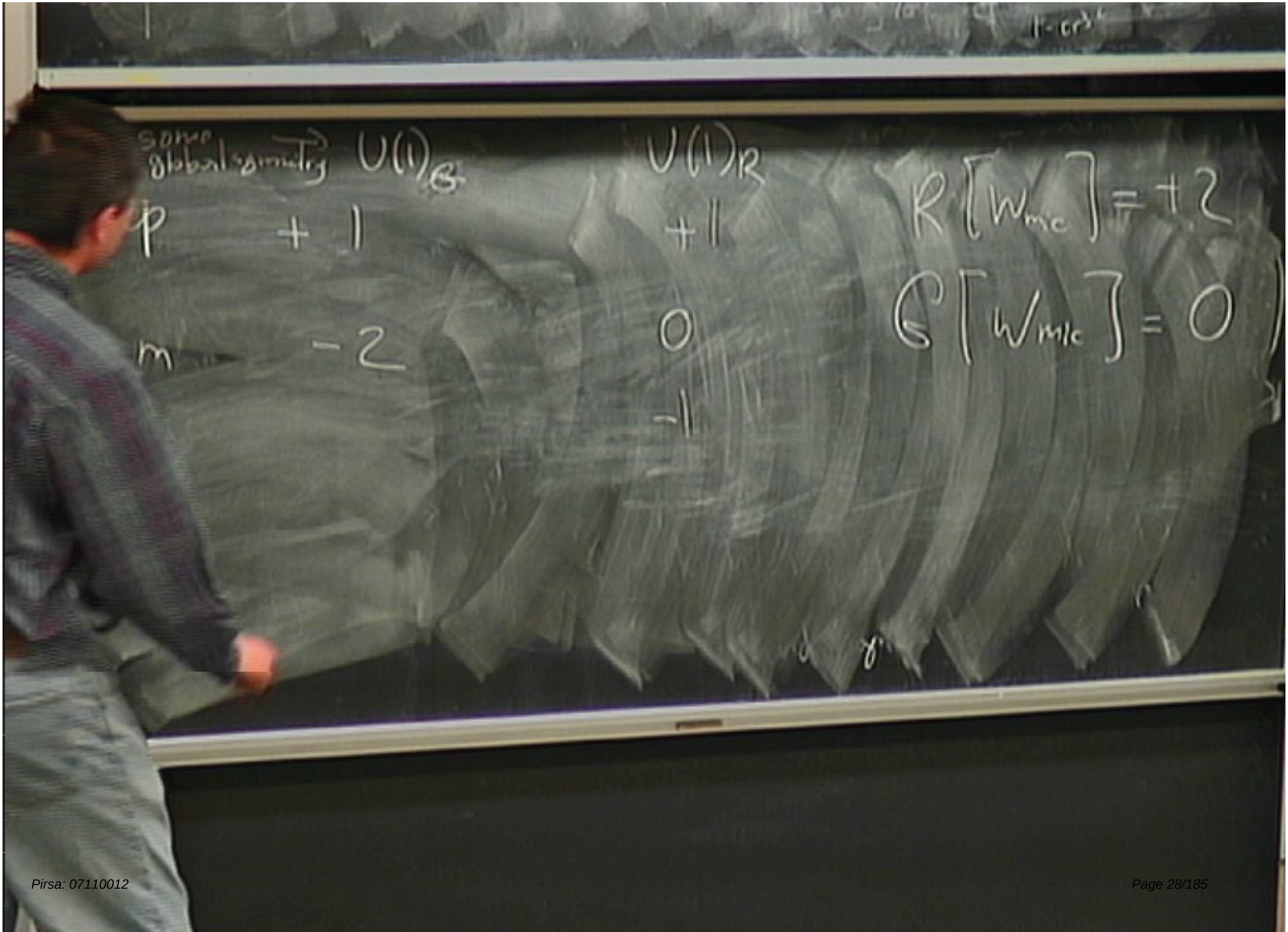
$$R[W_{m/c}] = +2$$

$$B[W_{m/c}] = 0$$

some global symmetry →	$U(1)_B$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ		-1

$$R[W_{mic}] = +2$$

$$B[W_{mic}] = 0$$


some global symmetry
$U(1)_B$
$U(1)_R$
p +1 +1
m −2 0
−1
$R[W_{mic}] = +2$
$B[W_{mic}] = 0$

some global symmetry	$U(1)_G$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ	-3	-1

$$R[W_{mic}] = +2$$

$$G[W_{mic}] = 0$$

some global symmetry	$U(1)_G$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ	-3	-1

$$R[W_{mic}] = +2$$

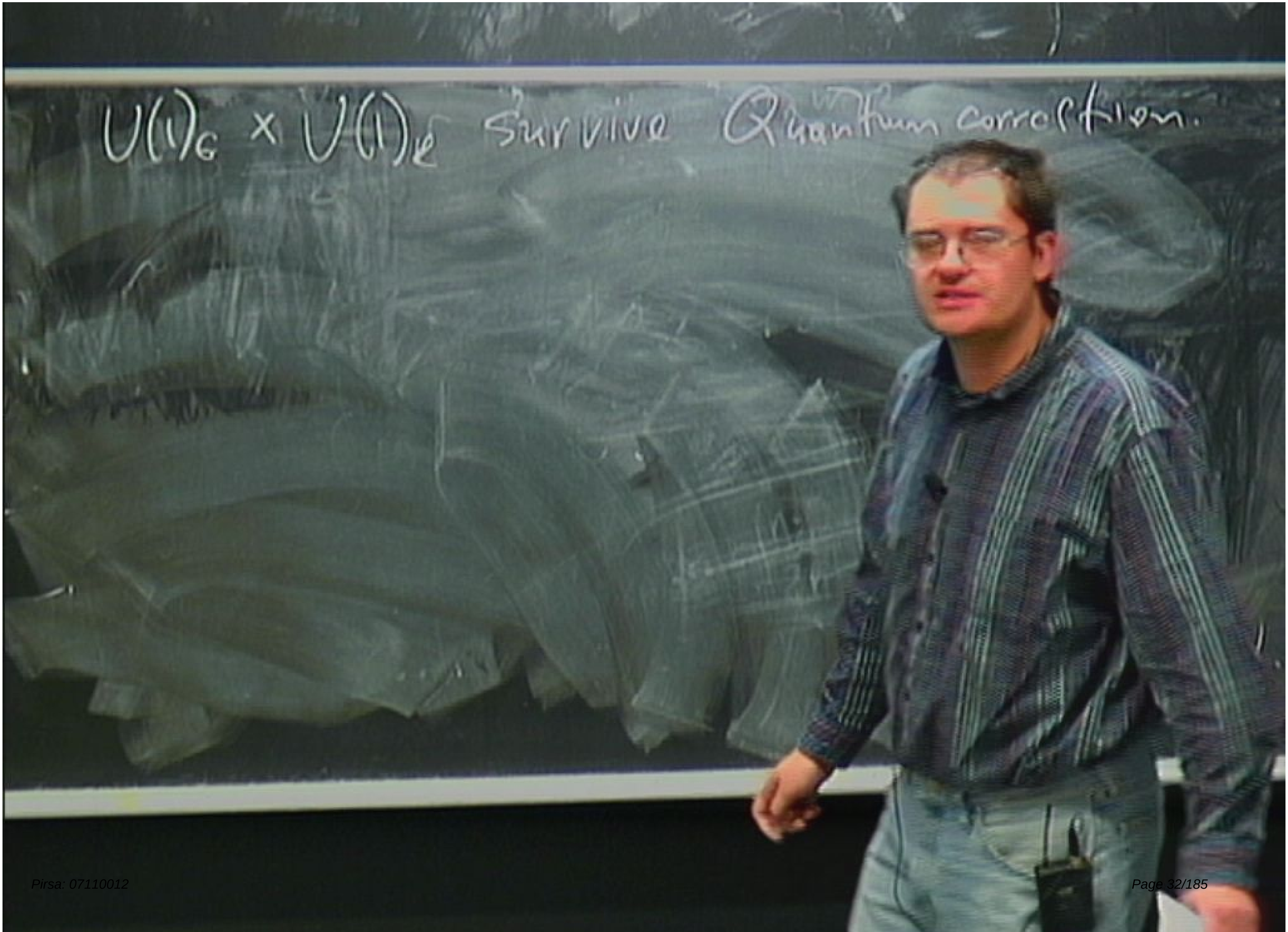
$$G[W_{mic}] = 0$$

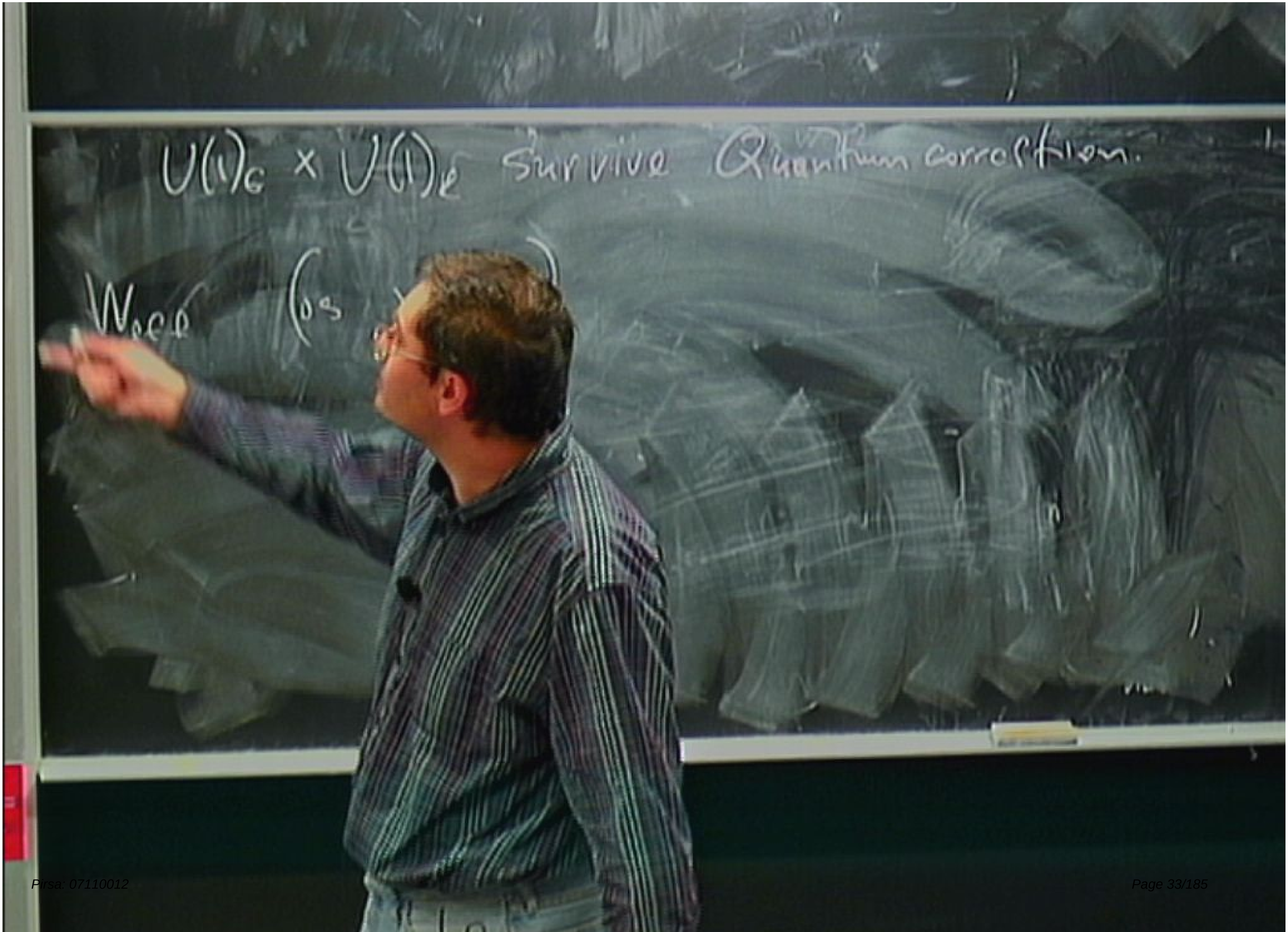
some global symmetry

	$U(1)_G$	$U(1)_R$
ϕ	$+1$	$+1$
m	-2	0
λ	-3	-1

$$R[W_{m/c}] = +2$$

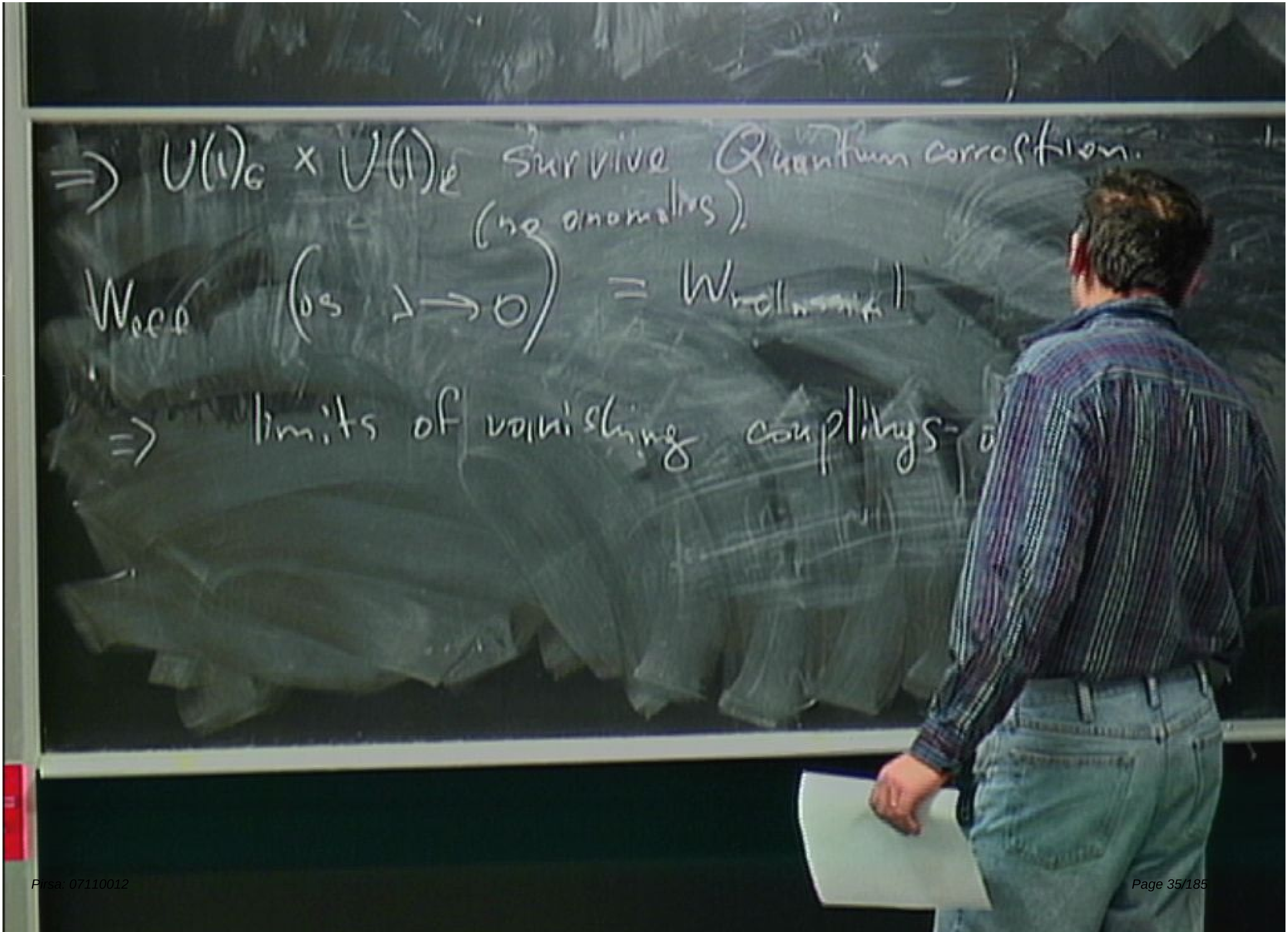
$$G[W_{m/c}] = 0$$


$U(1)_G \times U(1)_e$ survive Quantum correction.


U(1)_G × U(1)_ℓ survive Quantum correction.
W_eff

$U(1)_G \times U(1)_E$ survive Quantum correction.

W_{eff} (as $\lambda \to 0$) $= W_{\text{tree-level}}$


⇒ U(1)_G × U(1)_ℓ survive Quantum correction.
(no anomalies)
W_eff (as λ → 0) =
⇒ limits of vanishing couplings

$\Rightarrow U(1)_G \times U(1)_R$ survive Quantum correction. (no anomalies).

W_{eff} (as $\lambda \to 0$) $= W_{classical}$

$\Rightarrow$ limits of vanishing couplings are smooth

$\langle x \rangle = v$

$\Rightarrow$ Construct most general monomials from
φ, m, λ invariant under all global
symmetries,

$\Rightarrow$ Construct most general monomials from φ, m, λ invariant under all global symmetries,

$$\varphi^{n_1} m^{n_2} \lambda^{n_3}$$

on value of some

$\langle x \rangle = \lambda$

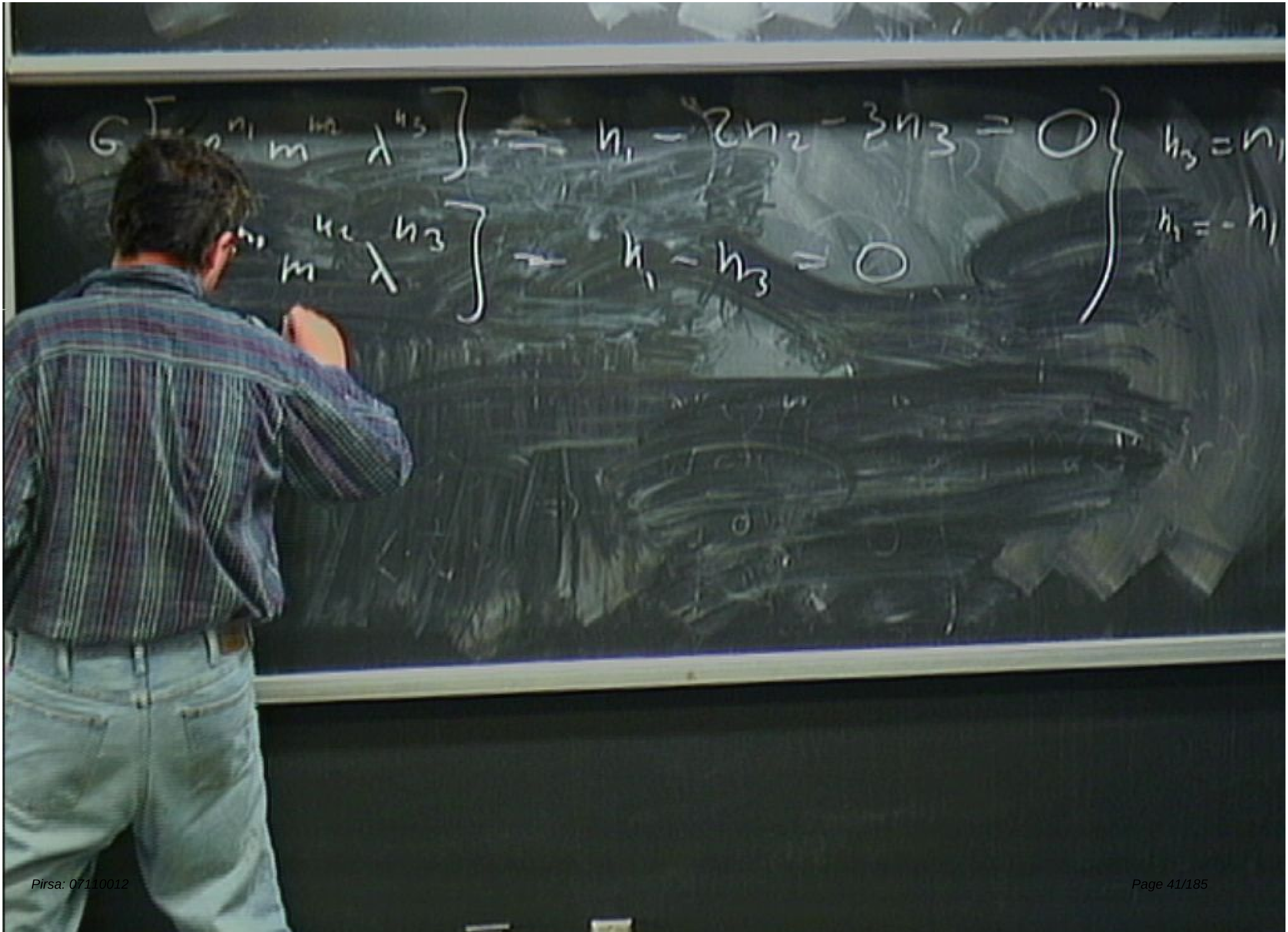
$\Rightarrow$ Construct most general monomials from φ, m, λ invariant under all global symmetries

$$R[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = 0$$

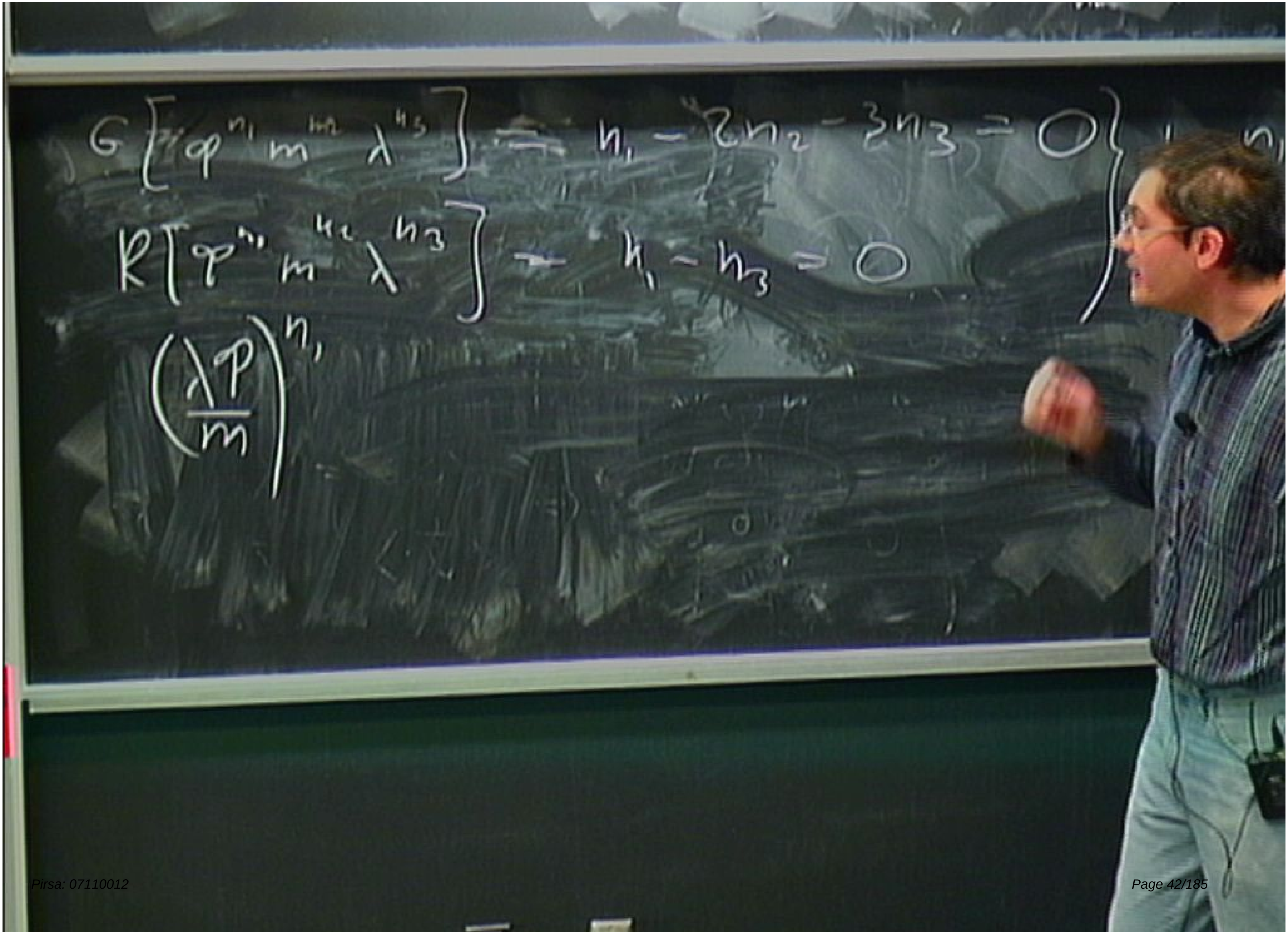
$$G[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = 0$$

$$G\left[\varphi^{n_1} m^{n_2} \lambda^{n_3}\right] = n_1 - 2n_2 - 3n_3 = 0$$

$$R\left[\varphi^{n_1} m^{n_2} \lambda^{n_3}\right] = n_1 - n_3 = 0$$



$G[\,\ldots\, m^{n_2}\, \lambda^{n_3}] = n_1 - 2n_2 - 3n_3 = 0$
$n_3 = n_1$
$m^{n_2}\, \lambda^{n_3}] = n_1 - n_3 = 0$


$G[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = n_1 - 2n_2 - 3n_3 = 0$
$R[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = n_1 - n_3 = 0$
$\left(\frac{\lambda\varphi}{m}\right)^{n_1}$

$$G[\varphi^{n_1} m^{n_2} \lambda^{n_3}] - n_1 - 2n_2 - 3n_3 = 0$$

$$R[\varphi^{n_1} m^{n_2} \lambda^{n_3}] - n_1 - n_3 = 0$$

$$n_3 = n_1 \qquad n_2 = -n_1$$

$$\left(\frac{\lambda\varphi}{m}\right)^{n_1} \quad \text{where } n_1 \text{ is any}$$

$$W_{eff} = m\varphi^2 \, f\left(\frac{\varphi\lambda}{m}\right)$$

$$W_{eff} = m\varphi^2 \, f\left(\frac{\varphi\lambda}{m}\right)$$

an arbitrary function

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an arbitrary function

$f(z)$ is that it is a holomorphic function.

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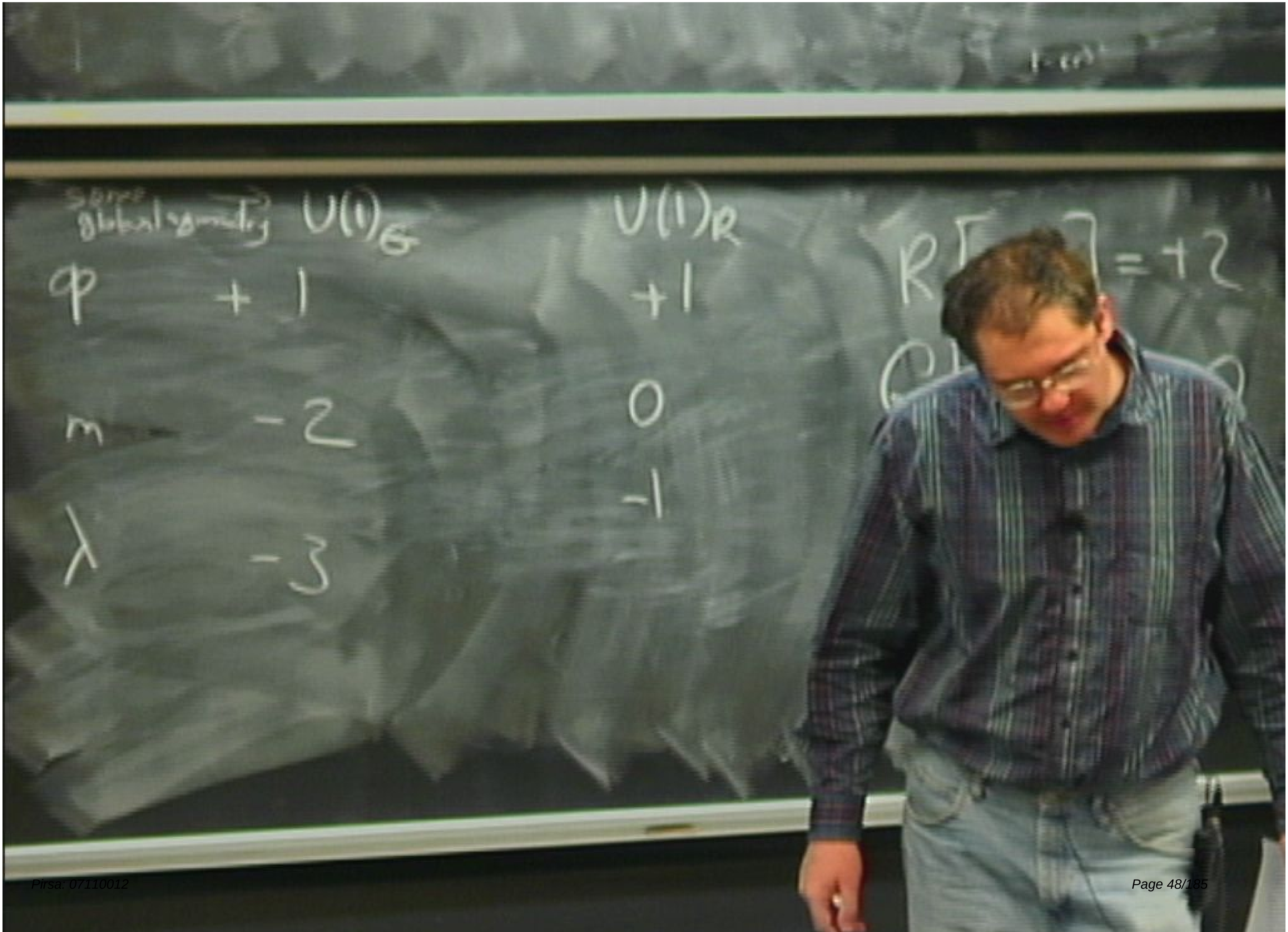
an arbitrary function

$f(z)$ is that it is a holomorphic function.


global symmetry
U(1)_G
U(1)_R
φ +1 +1
m -2 0
λ -3 -1
R[ ] = +2

$\Rightarrow$ poles

$\Rightarrow$ branch points

$\Rightarrow$

$\angle z$

$\Rightarrow$ poles

$\Rightarrow$ branch points

$\Rightarrow$ essential singularity.

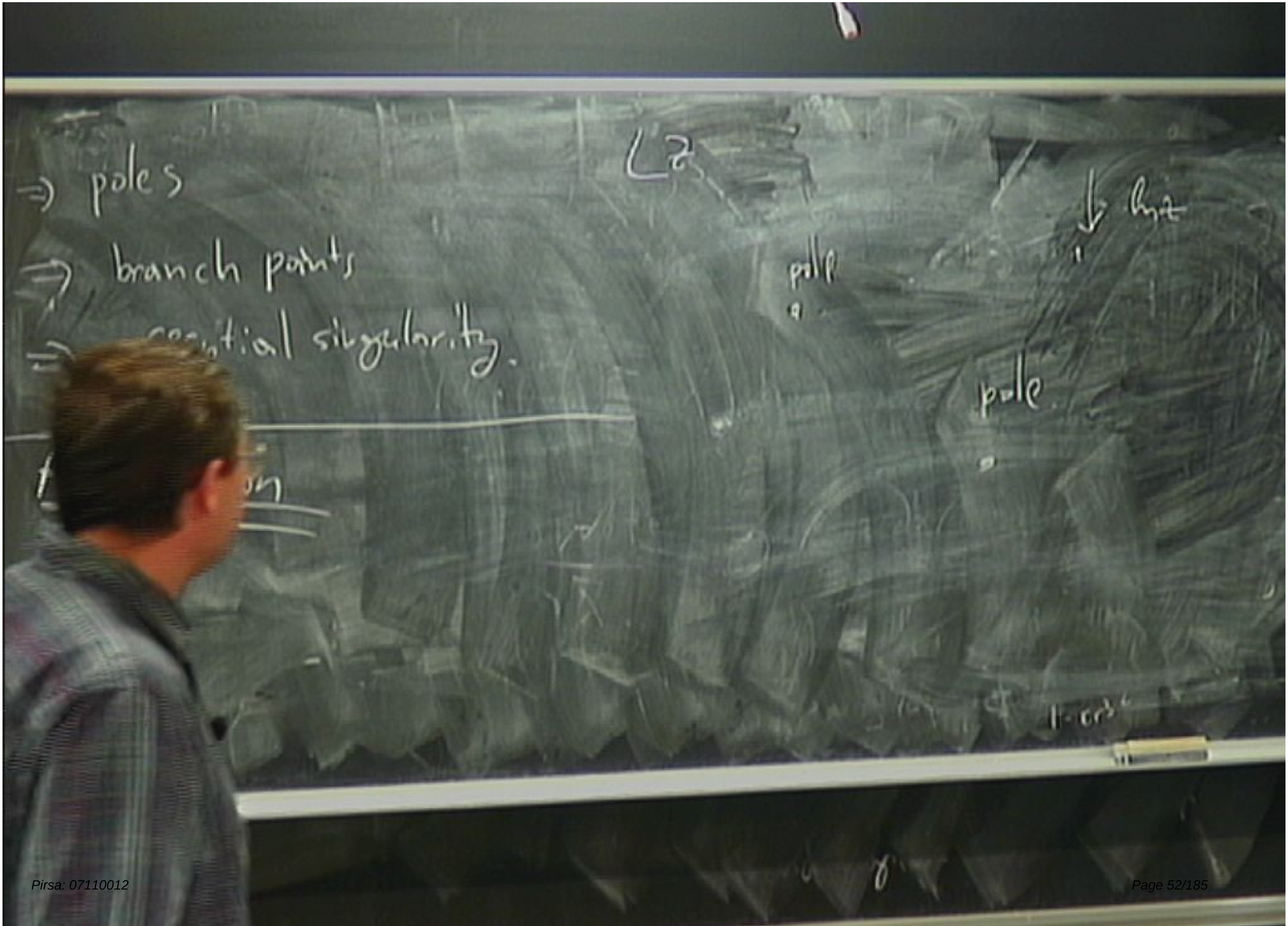
⇒ poles

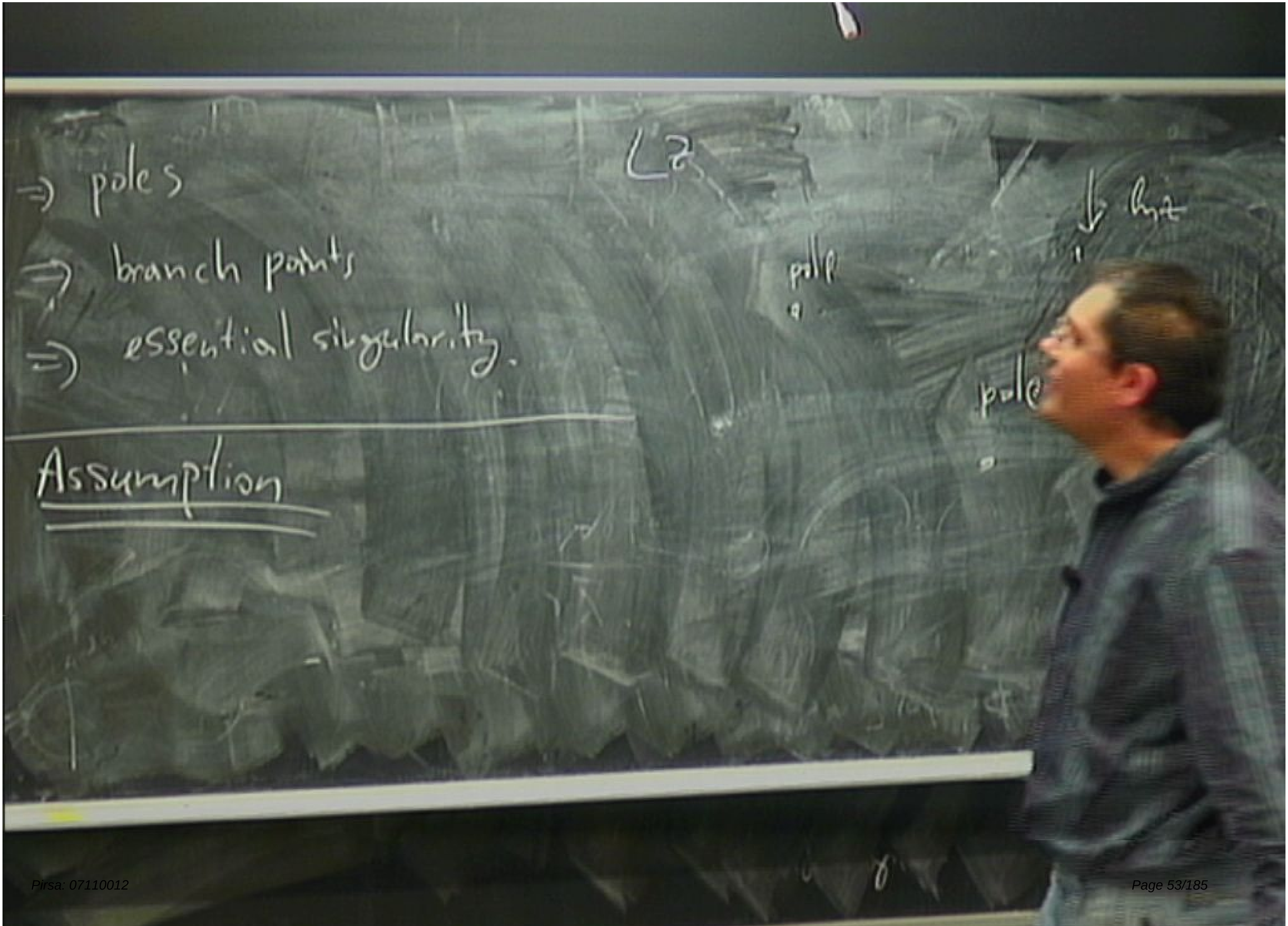
⇒ branch points

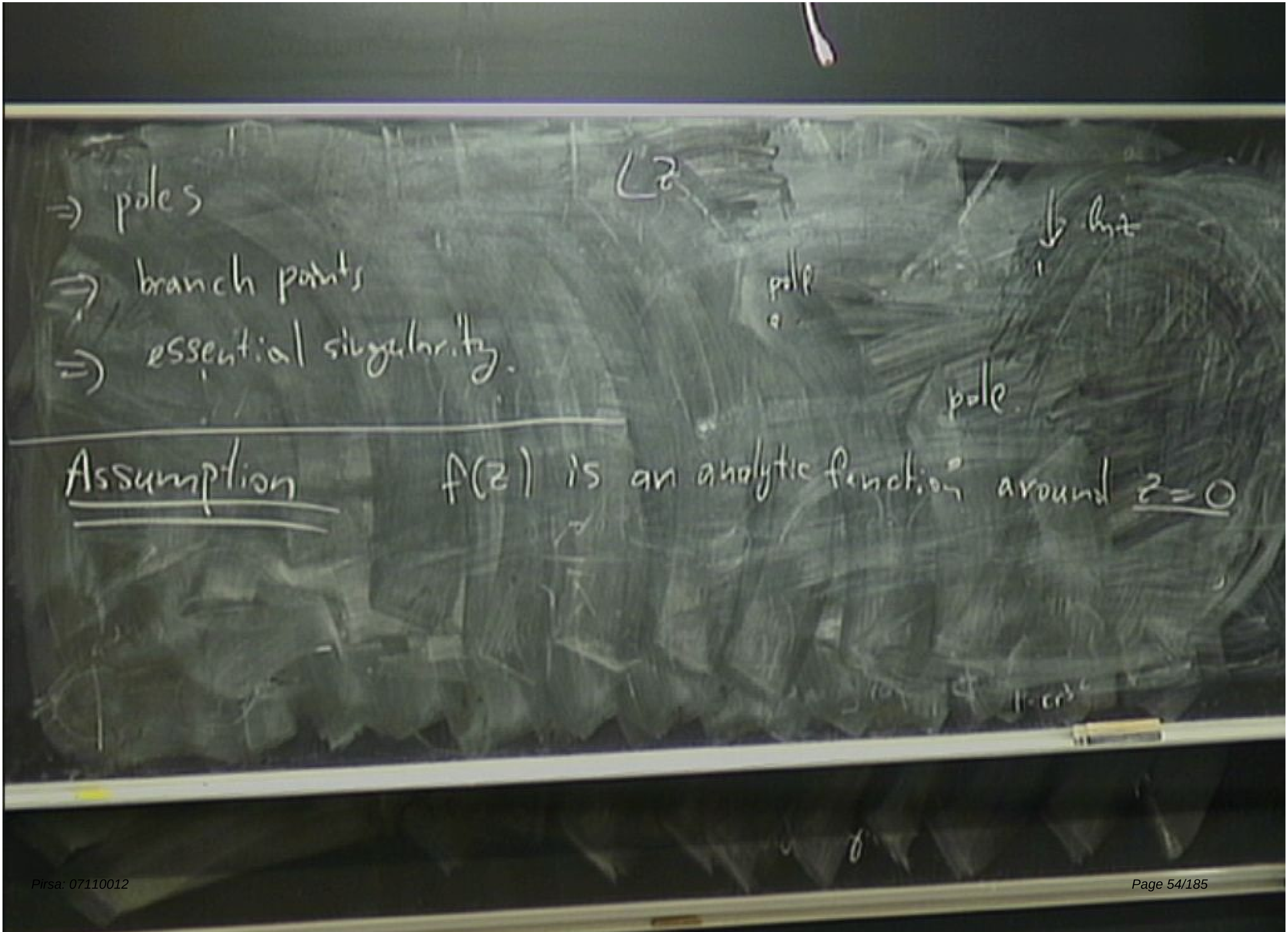
⇒ essential singularity.

pole

pole


poles
branch points
singularity.
pole
pole

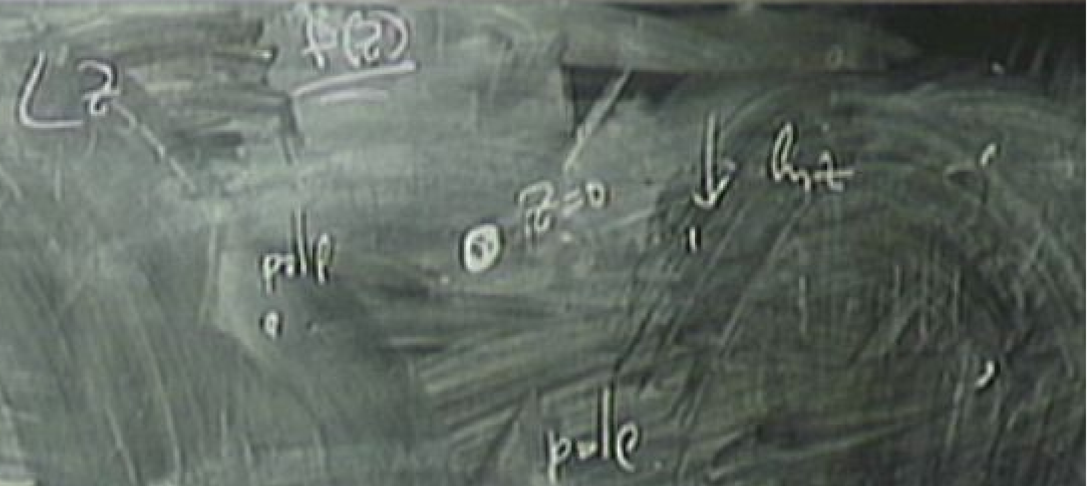

⇒ poles
⇒ branch points
⇒ essential singularity.
Assumption
pole
pole


⇒ poles
⇒ branch points
⇒ essential singularity.
pole
pole.
Assumption
f(z) is an analytic function around z=0

⇒ poles

⇒ branch points

⇒ essential singularity.



Assumption $f(z)$ is an analytic function around $\underline{z=0}$

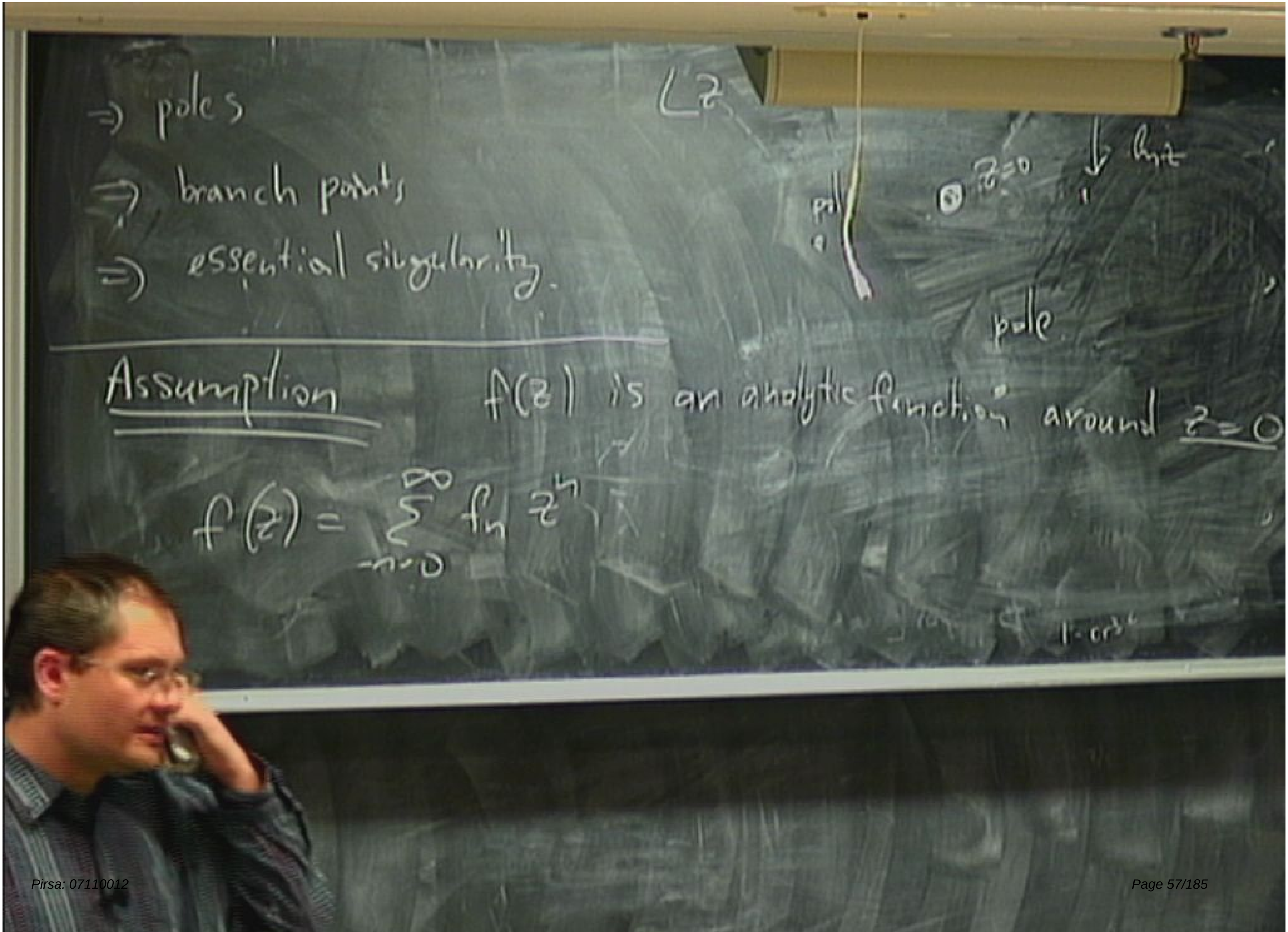
$$G[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = n_1 - 2n_2 - 3n_3 = 0$$

$$R[\varphi^{n_1} m^{n_2} \lambda^{n_3}] = n_1 - n_3 = 0$$

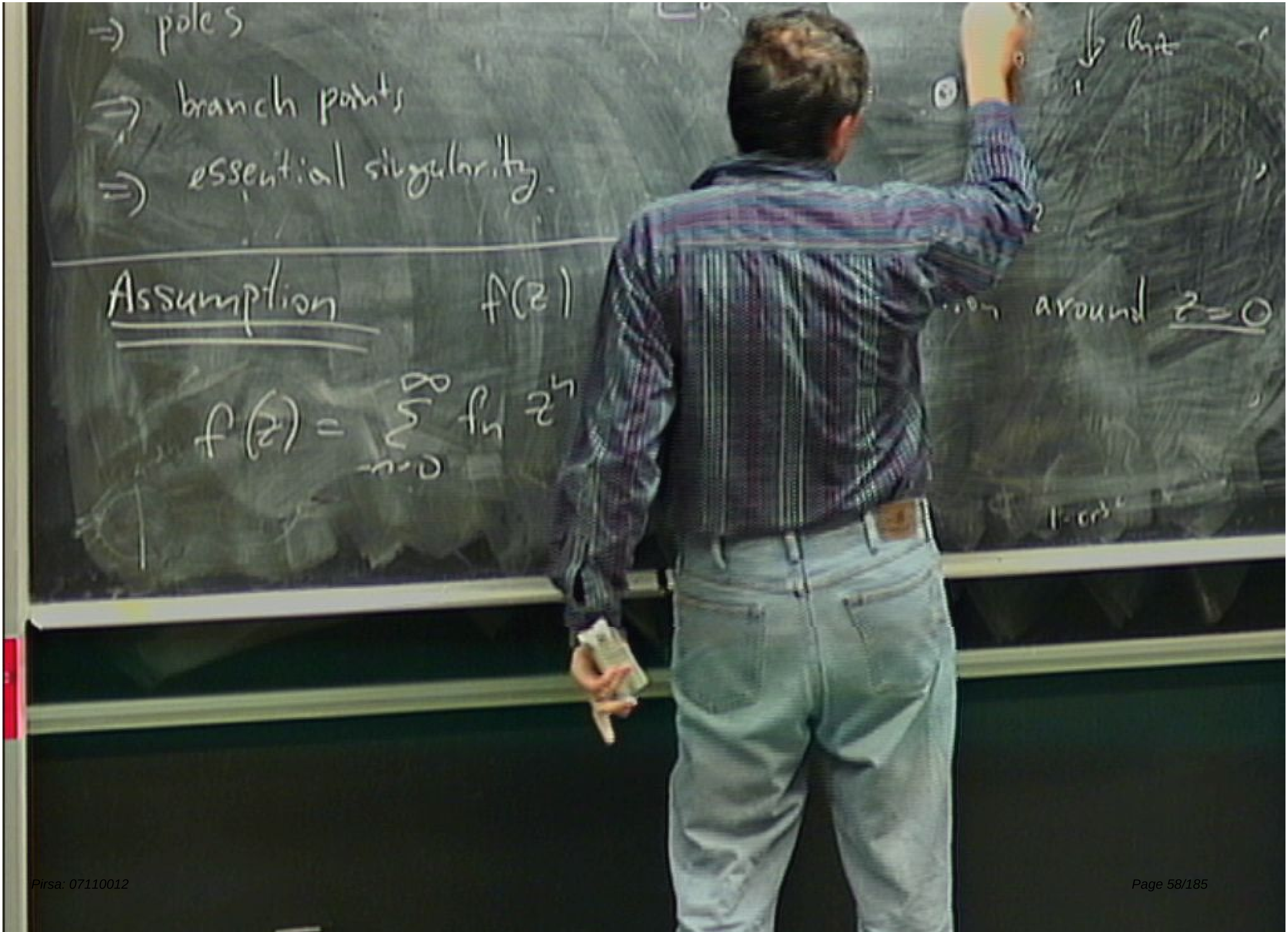
$n_3 = n_1$

$n_2 = -n_1$

$$\left(\frac{\lambda \varphi}{m}\right)^{n_1}$$ where n_1 is any



⇒ poles
⇒ branch points
⇒ essential singularity.
Assumption f(z) is an analytic function around z=0
$f(z) = \sum_{n=0}^{\infty} f_n z^n$
z=0
pole


⇒ poles
⇒ branch points
⇒ essential singularity.
Assumption
f(z)
around z=0
f(z) = Σ fn z^n

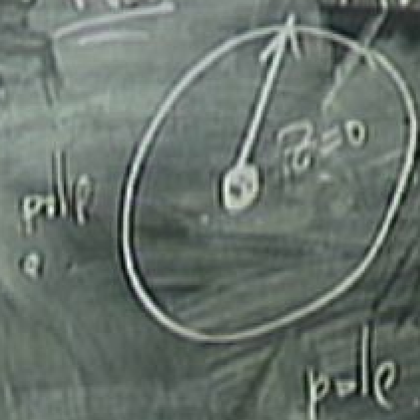
$f(z)$

Finite radius of conv

⇒ poles

⇒ branch points

⇒ essential singularity.



$\downarrow \lim$

Assumption $f(z)$ is an analytic function around $z=0$

$$f(z) = \sum_{n=0}^{\infty} f_n z^n \Rightarrow$$

$$W_{eff} = m_1 q^2$$

$$W_{eff} = m_1 \varphi^2 \sum_{n=0}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

$$W_{eff} = m_1 \varphi^2 \sum_{n=0}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

$$= \sum_{n=0}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n}$$

$\Rightarrow$ poles

$\Rightarrow$ branch points

$\Rightarrow$ essential singularity.

$f(z)$

Finite radius

Assumption $f(z)$ is an analytic function

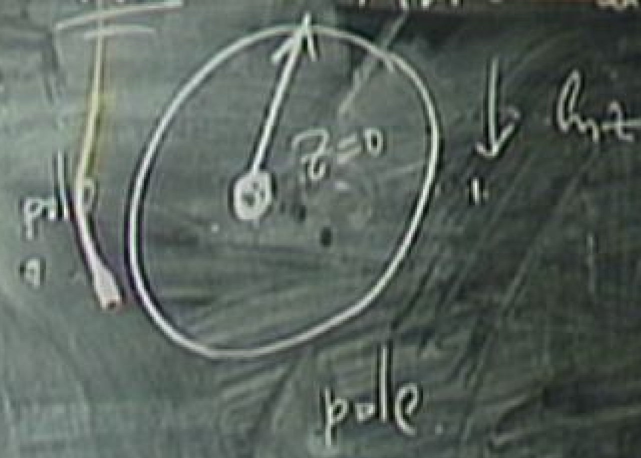
$$f(z) = \sum_{n=0}^{\infty} f_n z^n \Rightarrow$$

$$= \sum_{n=0} f_n \, \lambda^n$$

$\Rightarrow$ poles

$\Rightarrow$ branch points

$\Rightarrow$ essential singularity.



~~Assumption~~ $f(z)$ is an analytic function around $z=$

$$f(z) = \sum_{n=0}^{\infty} f_n z^n \Rightarrow$$

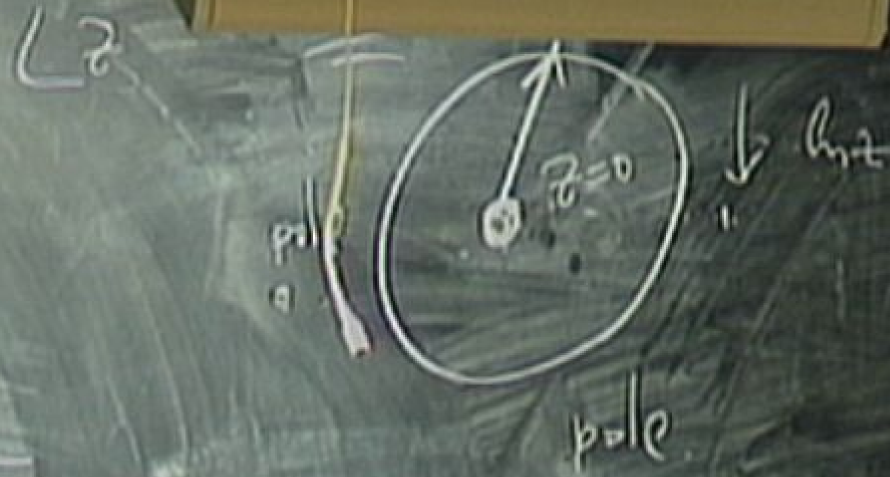
Smaller assumption

$$= \sum_{n=0} f_n \,\varphi\, \lambda^n \, h_n$$

$\Rightarrow$ poles

$\Rightarrow$ branch points

$\Rightarrow$ essential singularity.



~~Assumption~~ $f(z)$ is an analytic function around $z=$

$$f(z) = \sum_{n=0}^{\infty} f_n z^n \Rightarrow$$

Smaller assumption $\varphi = 0$ is not a singular point

$$= \sum_{n=0}^{\infty} f_n \varphi^{n+2} \lambda^n h^{1-n}$$

pole.

~~Assumption~~ $f(z)$ is an analytic function around $z=$

$$f(z) = \sum_{-\infty}^{\infty} f_n z^n \Rightarrow$$

Smaller assumption $\varphi = 0$ is not a singular point

$$= \sum_{n=0}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n}$$

Smaller assumption $\varphi = 0$ is not a singular point

$$W_{eff} = m\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n}$$

Smaller assumption $\varphi = 0$ is not a singular point

$$W_{eff} = m\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

f_n are some constants

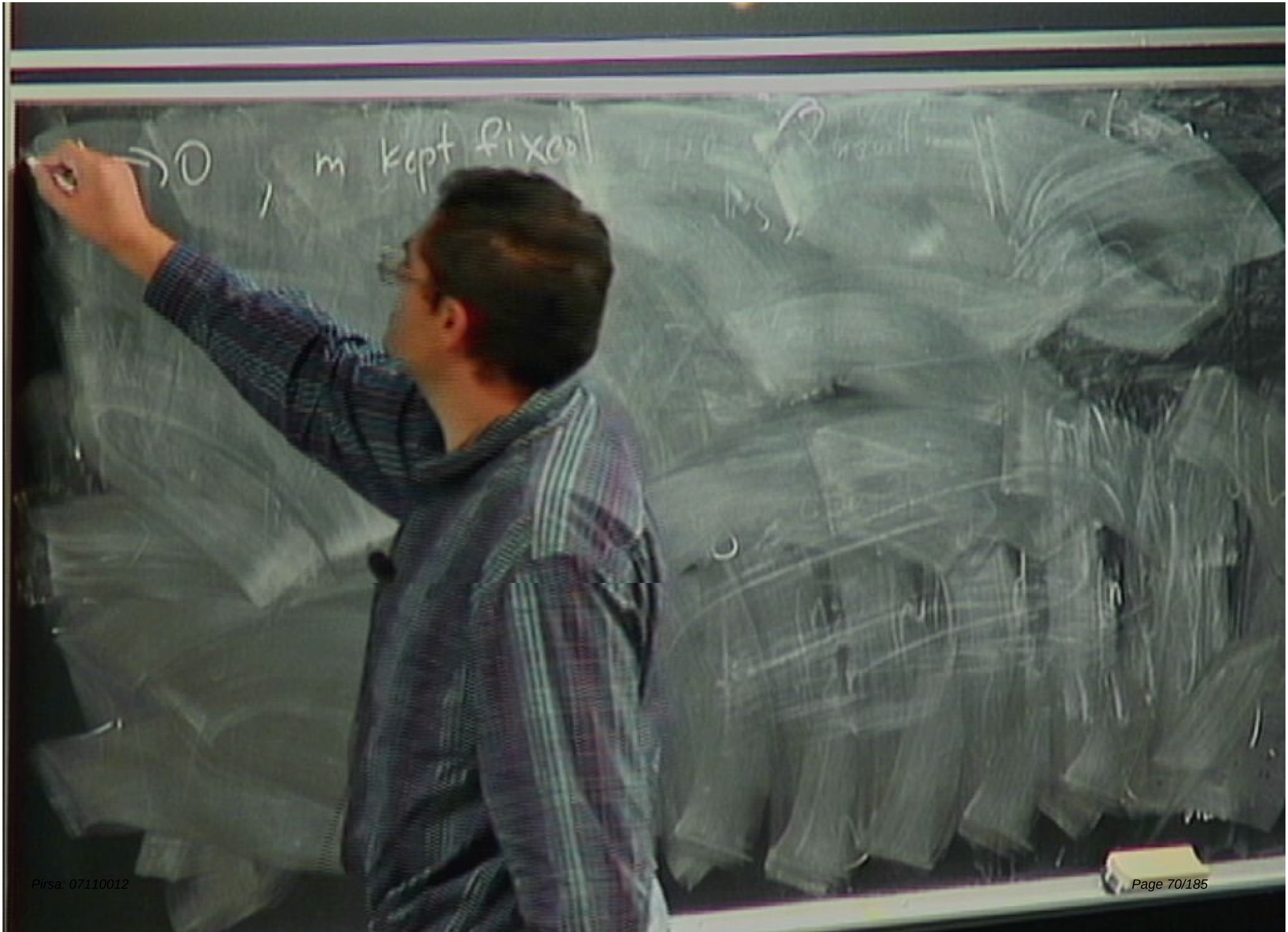
$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n}$$

Smaller assumption $\varphi = 0$ is not a singular point

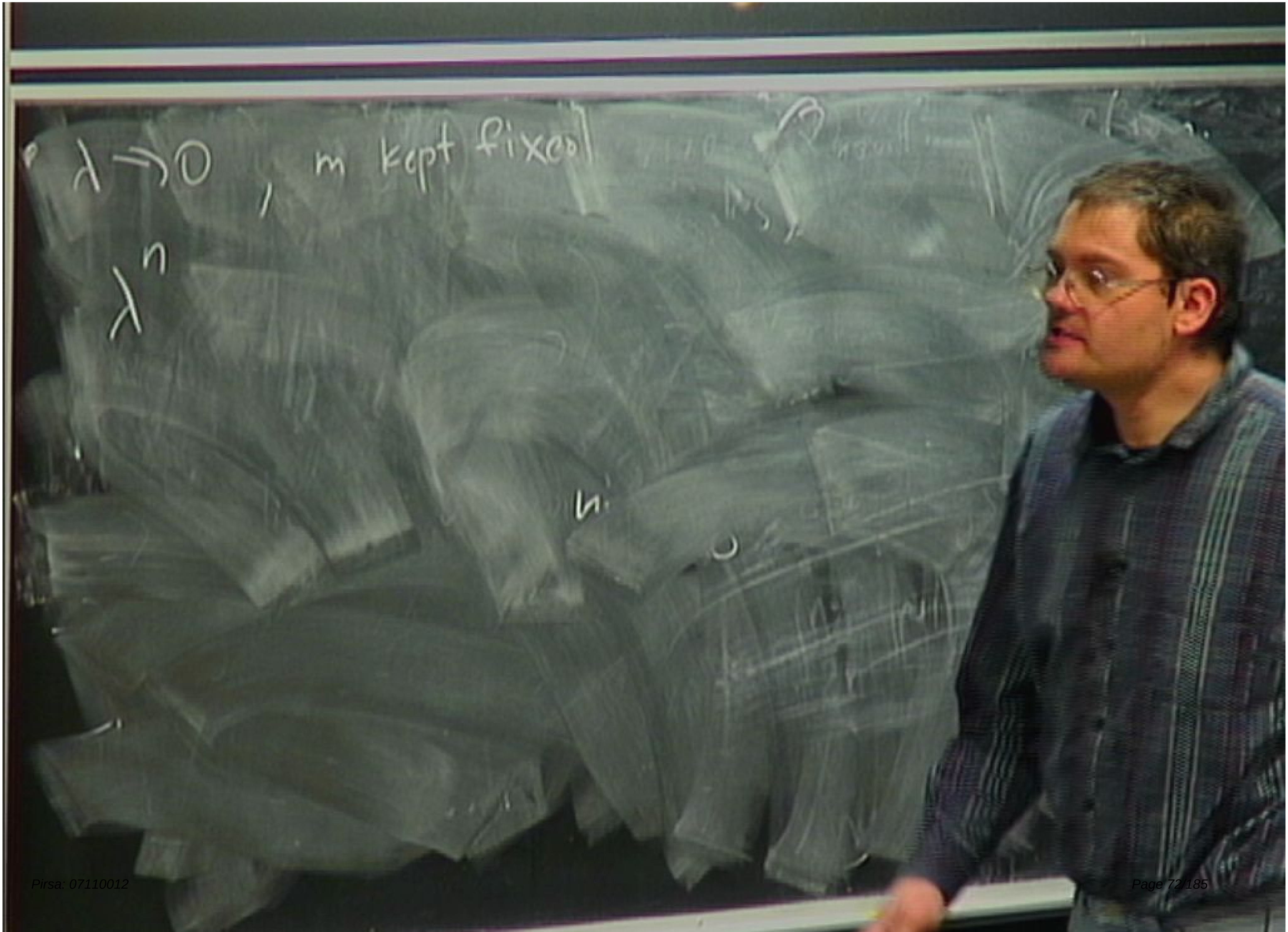
$$W_{eff} = m\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n} \qquad f_n \text{ are some constants}$$

$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n}$$

$\Rightarrow$ $\lambda \to 0$, $m \to 0$ smooth


m kept fixed

$\lambda \to 0$, m kept fixed


λ → 0 , m kept fixed
λ^n

$\lambda \to 0$, m kept fixed

$\lambda^n \Rightarrow \boxed{n \geq 0}$

- $\lambda \to 0$, m kept fixed

$$\lambda^n \Rightarrow \boxed{n \geq 0}$$

- $m \to 0$, λ kept fixed

- $\lambda \to 0$, m kept fixed

$$\lambda^n \implies \boxed{n \geq 0}$$

- $m \to 0$, λ kept fixed

$$m^{1-n}$$

• $\lambda \to 0$, m kept fixed

$$\lambda^n \Rightarrow \boxed{n \geq 0}$$

• $\underline{m \to 0}$, λ kept fixed

$$m^{1-n} \Rightarrow 1-n \geq 0 \qquad \boxed{n \leq 1}$$

$$\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

f_n are some const

$$\sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{-n} =$$

$m \to 0$ smooth

$$\mathcal{L}_{eff} = m\,\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

f_n are some constants

$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n} =$$

only surviving term $n=0$, $n=1$

$\Rightarrow$ $\lambda \to 0$, $m \to 0$ smooth

$$\mathcal{L}_{eff} = m\,\varphi^2 \sum_{-\infty}^{\infty} f_n\, \varphi^{n}\, \lambda^{n}\, m^{-n}$$

f_n are some constants

$$= \sum_{-\infty}^{\infty} f_n\, \varphi^{n+2}\, \lambda^{n}\, m^{1-n} = f_0\, \varphi^2\, m$$

only surviving term $n=0$

$n=1$

$\Rightarrow$ $\lambda \to 0$, $m \to 0$ smooth

$$N_{eff} = m_1 \varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

f_n are some constants

$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n} = f_0 \varphi^2 m + f_1 \varphi^3 \lambda$$

only surviving term $n=0$, $n=1$

$\Rightarrow$ $\lambda \to 0$, $m \to 0$ smooth

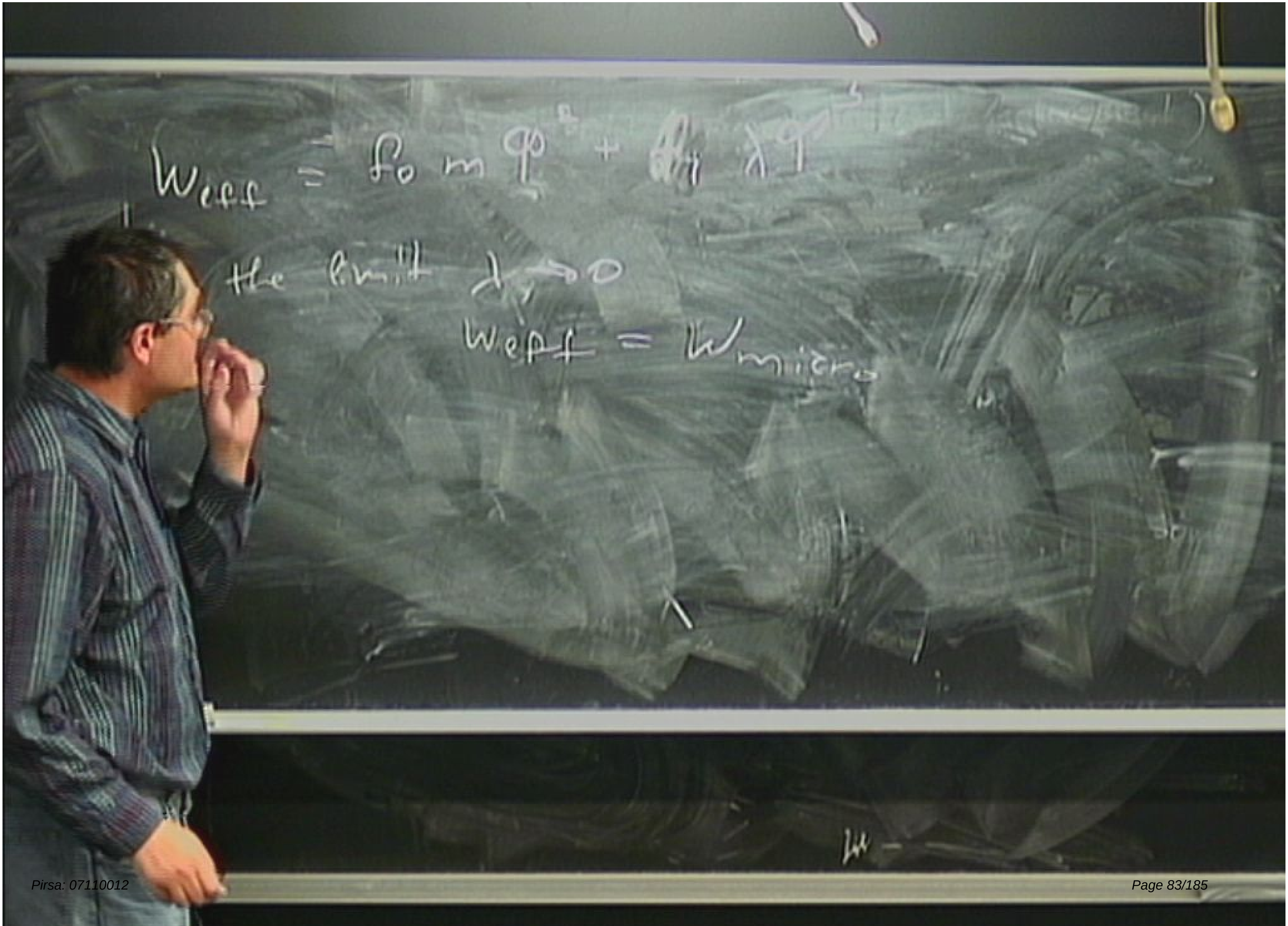
If Quantum corrections do not break

$U(1)_B \times U(1)_K$

If Quantum corrections do not break

$U(1)_B \times U(1)_R$ (SUSY is unbroken)

+ $\boxed{\varphi = 0}$ is a nonsingular point in a field space.



Weff = fo m φ + f1 λ φ
the limit λ → 0
Weff = Wmicro

$$W_{eff} = f_0 \, m \, \varphi^2 + f_1 \, \lambda \, \varphi^3$$

$\Rightarrow$ In the limit $\lambda \to 0$

$$W_{eff} = W_{micro}$$

$$f_0 = \frac{1}{2} \qquad f_1 = \frac{1}{3}$$

$$W_{\underline{eff}} = f_0\, m\, \varphi^2 + f_1\, \lambda\, \varphi^3$$

$\Rightarrow$ In the limit $\lambda \to 0$

$$W_{eff} = W_{micro}$$

$$f_0 = \frac{1}{2}\,, \quad f_1 = \frac{1}{3}$$

$$W_{micro} = \mu_1 \varphi^2 + \mu_2 \varphi^2 + \dots + \mu_n \varphi^n$$

$$W_{micro} = \mu_1 \varphi^2 + \mu_2 \varphi^2 + \dots + \mu_n \varphi^n$$

	$U(1)_a$	$U_E(1)$
φ	$+1$	$+1$
μ_n	$-n$	$2-n$

$$W_{micro} = \mu_1 \varphi + \mu_2 \varphi^2 + \dots + \mu_n \varphi^n$$

	$U(1)_a$	$U_R(1)$
φ	$+1$	$+1$
μ_n	$-n$	$2-n$

$$W_{eff} \equiv W_{micro}$$

$$W_{micro} = \mu_1 \varphi^{?} + \mu_2 \varphi^{?} + \cdots + \mu_n \varphi^{n}$$

	$U(1)_a$	$U_R(1)$
φ_i	$+1$	$+1$
μ_n	$-n$	$2-n$

$\boxed{W_{eff} \equiv W \ldots}$

Smaller assumption $\varphi = 0$ is not a singular point

$$W_{eff} = m\varphi^2 \sum_{-\infty}^{\infty} f_n \varphi^n \lambda^n m^{-n}$$

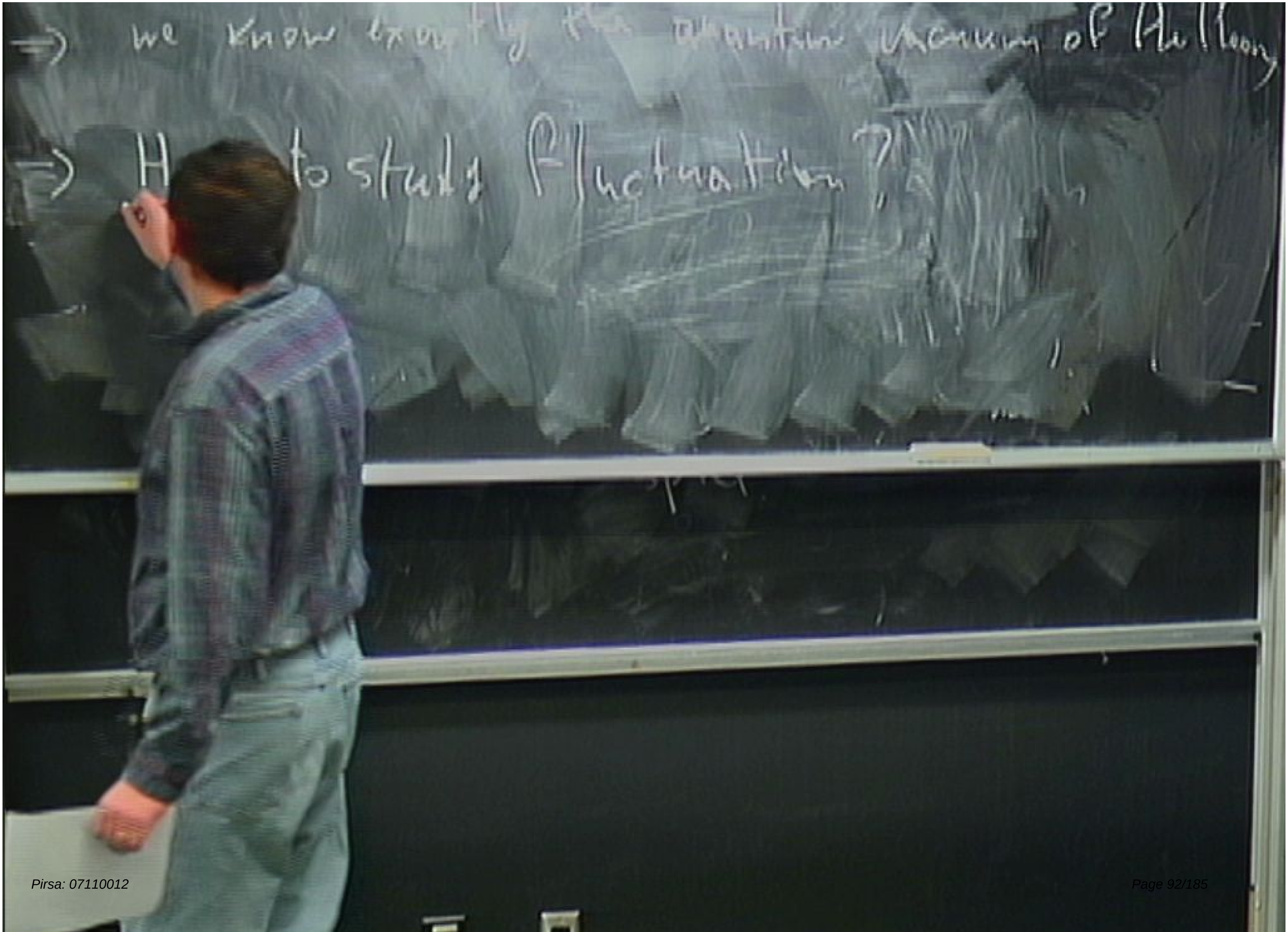
f_n are some constan[ts]

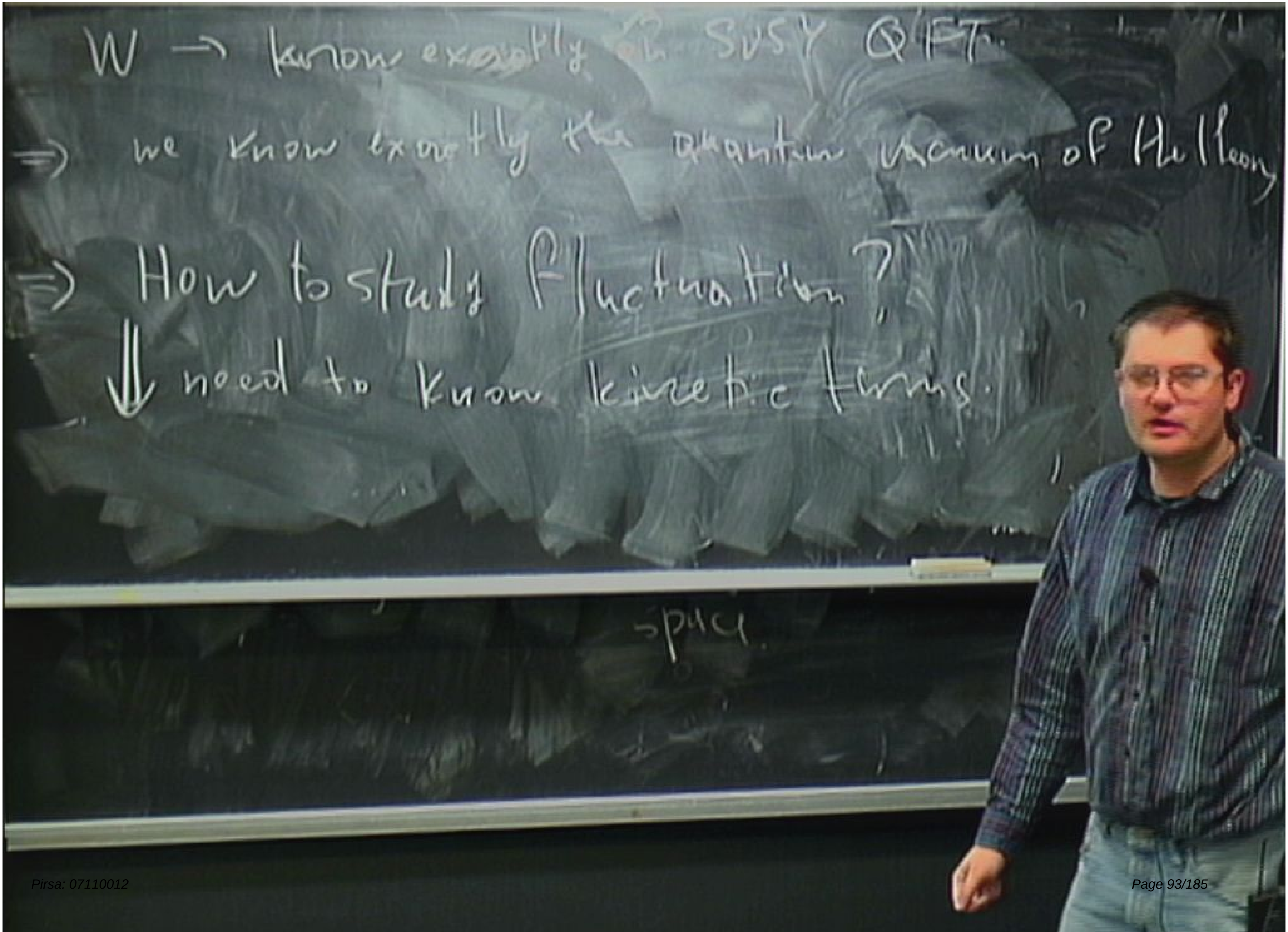
$$= \sum_{-\infty}^{\infty} f_n \varphi^{n+2} \lambda^n m^{1-n} = f_0 \varphi^2 m + f_1 \varphi^3 \ldots$$

only surviving term $n=0$, $n=1$

$\Rightarrow$ $\lambda \to 0$, $m \to 0$ smooth

$W \to$ know exactly in SUSY QFT.


⇒ we know exactly the quantum vacuum of the theory
⇒ H to study fluctuation?

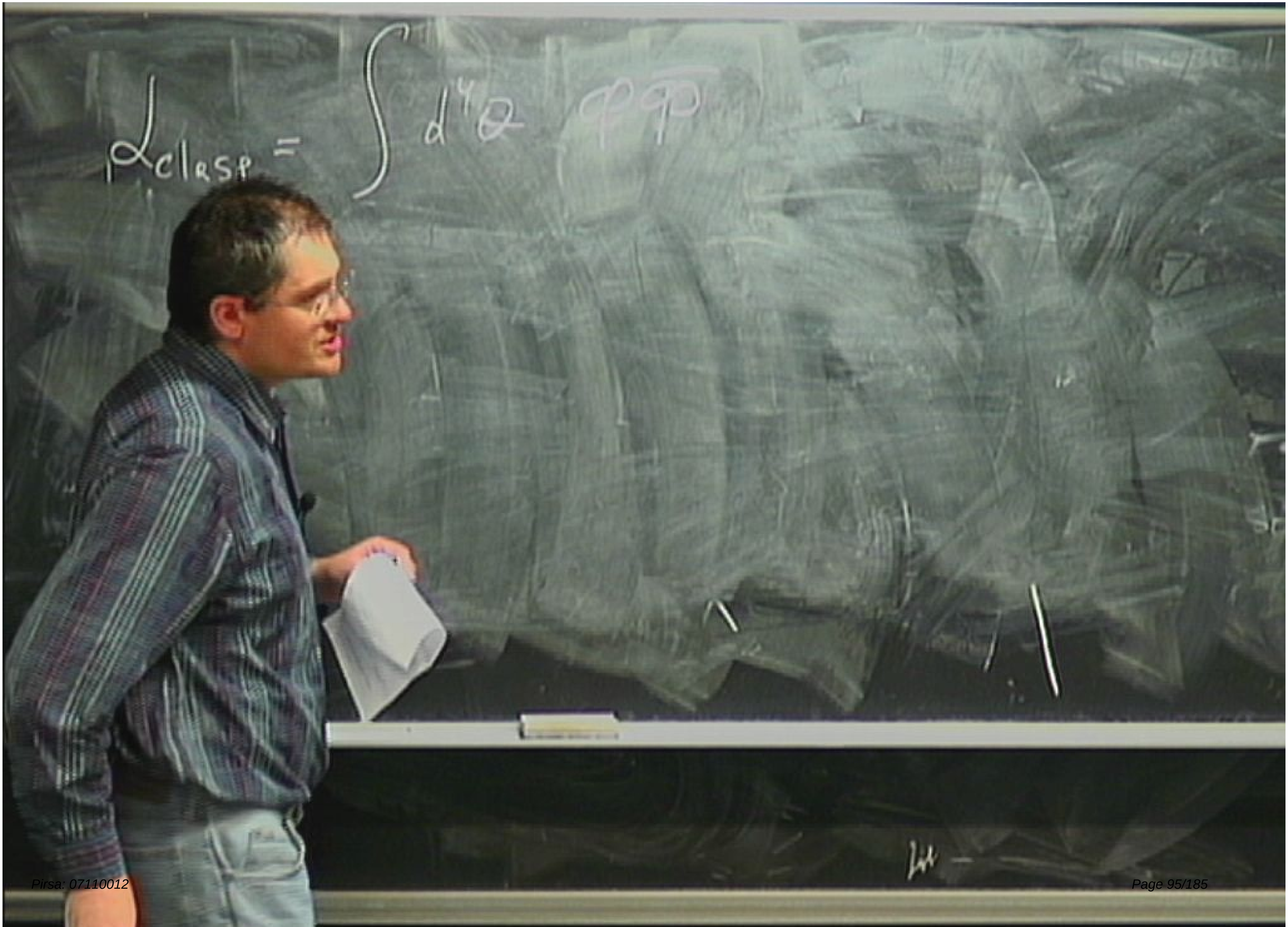

W → know exactly SUSY QFT.
⇒ we know exactly the quantum vacuum of the theory
⇒ How to study fluctuation?
⇓ need to know kinetic terms.
space

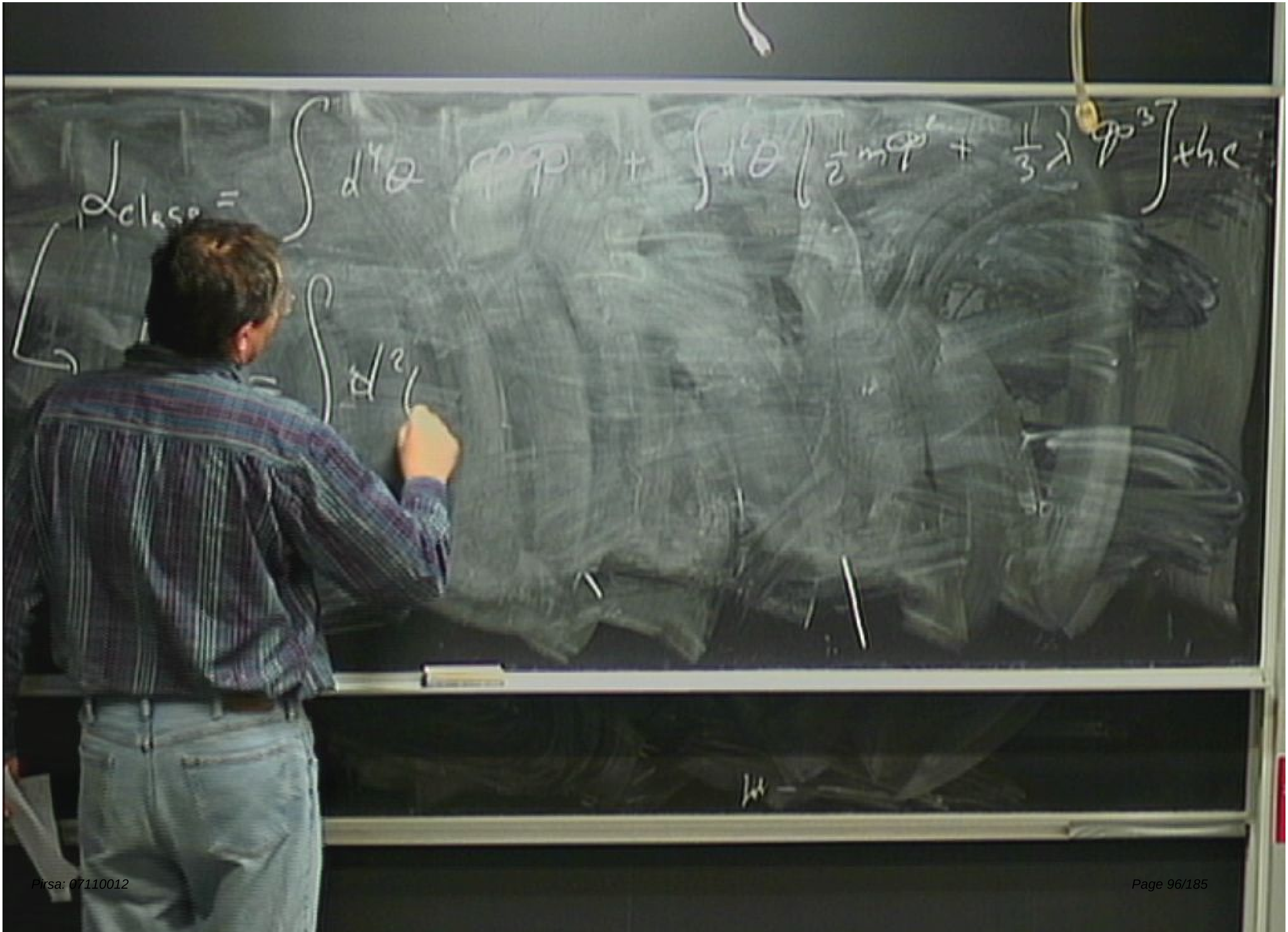
$\Rightarrow$ How to study fluctuation?

$\Downarrow$ need to know kinetic terms.

$K(\varphi, \bar{\varphi}) \to$ can not rely on holomorphicity

space


$\mathcal{L}_{clasp} = \int d^4\theta \, \Phi \bar{\Phi}$


$\mathcal{L}_{close} = \int d^4\theta \, \bar{\varphi}\varphi + \int d^2\theta \left[\frac{1}{2} m \varphi^2 + \frac{1}{3}\lambda \varphi^3\right] + h.c.$
$= \int d^2($

$$\mathcal{L}_{class} = \int d^4\theta\ \Phi\bar{\Phi} + \int d^2\theta \left[\frac{1}{2}m\Phi^2 + \frac{1}{3}\lambda\Phi^3\right] + h.c$$

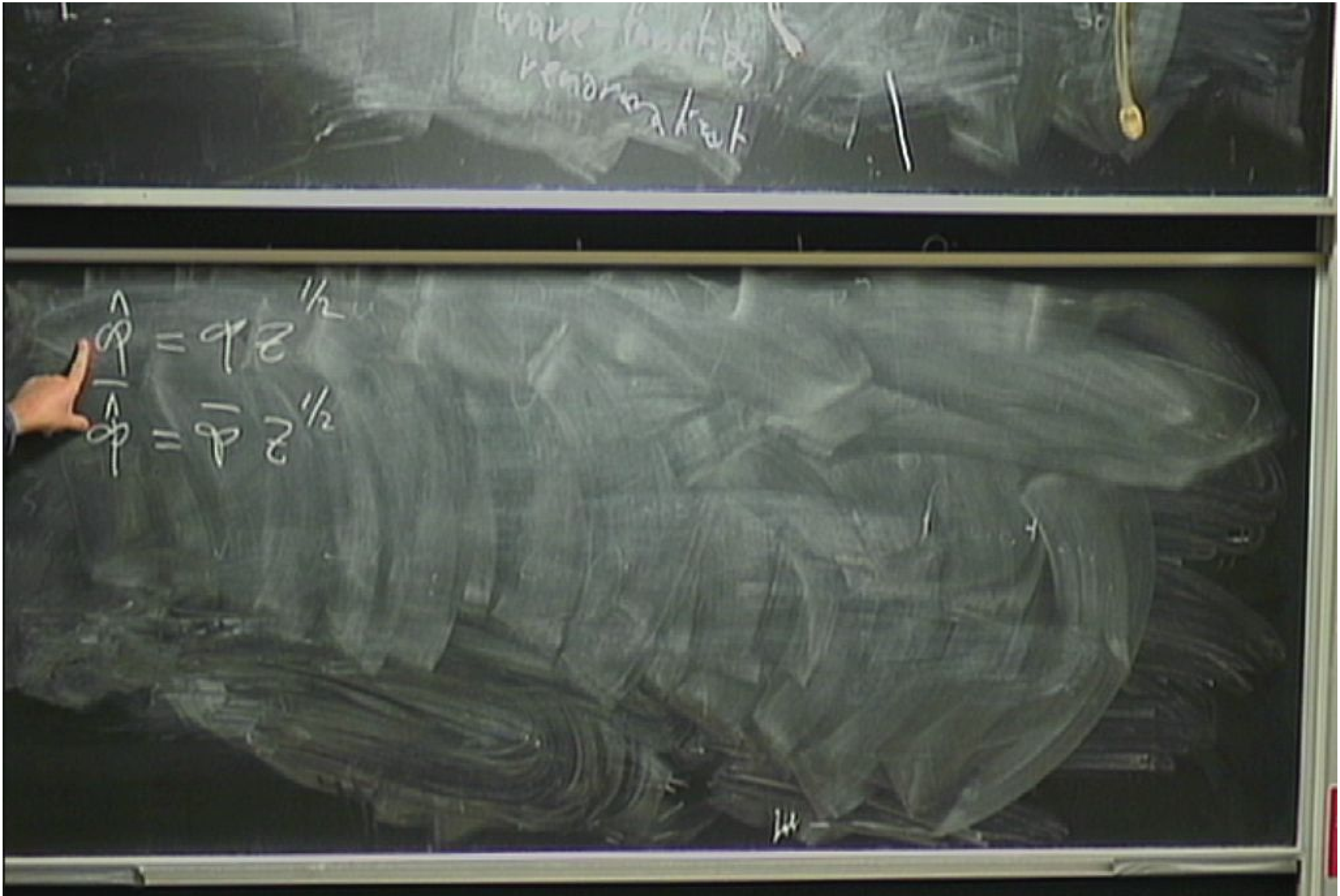
$$\mathcal{L}_{eff} = \int d^4\theta\ \Phi\bar{\Phi}\, Z(m,\bar{m},\lambda,\bar{\lambda}) + \int d^2\theta \left[\frac{1}{2}m\Phi^2 + \frac{1}{3}\lambda\Phi^3\right] + h.c$$

wave-function renormalization

$$\mathcal{L}_{class} = \int d^4\theta\, \Phi\bar{\Phi} + \int d^2\theta \left[\frac{1}{2} m\Phi^2 + \frac{1}{3}\lambda\Phi^3\right] + h.c.$$

$$\mathcal{L}_{eff} = \int d^4\theta\, \Phi\bar{\Phi}\, Z(m, \bar{m}, \lambda, \bar{\lambda}) + \int d^2\theta \left[\frac{1}{2} m\Phi^2 + \frac{1}{3}\lambda\Phi^3\right] + h.c.$$

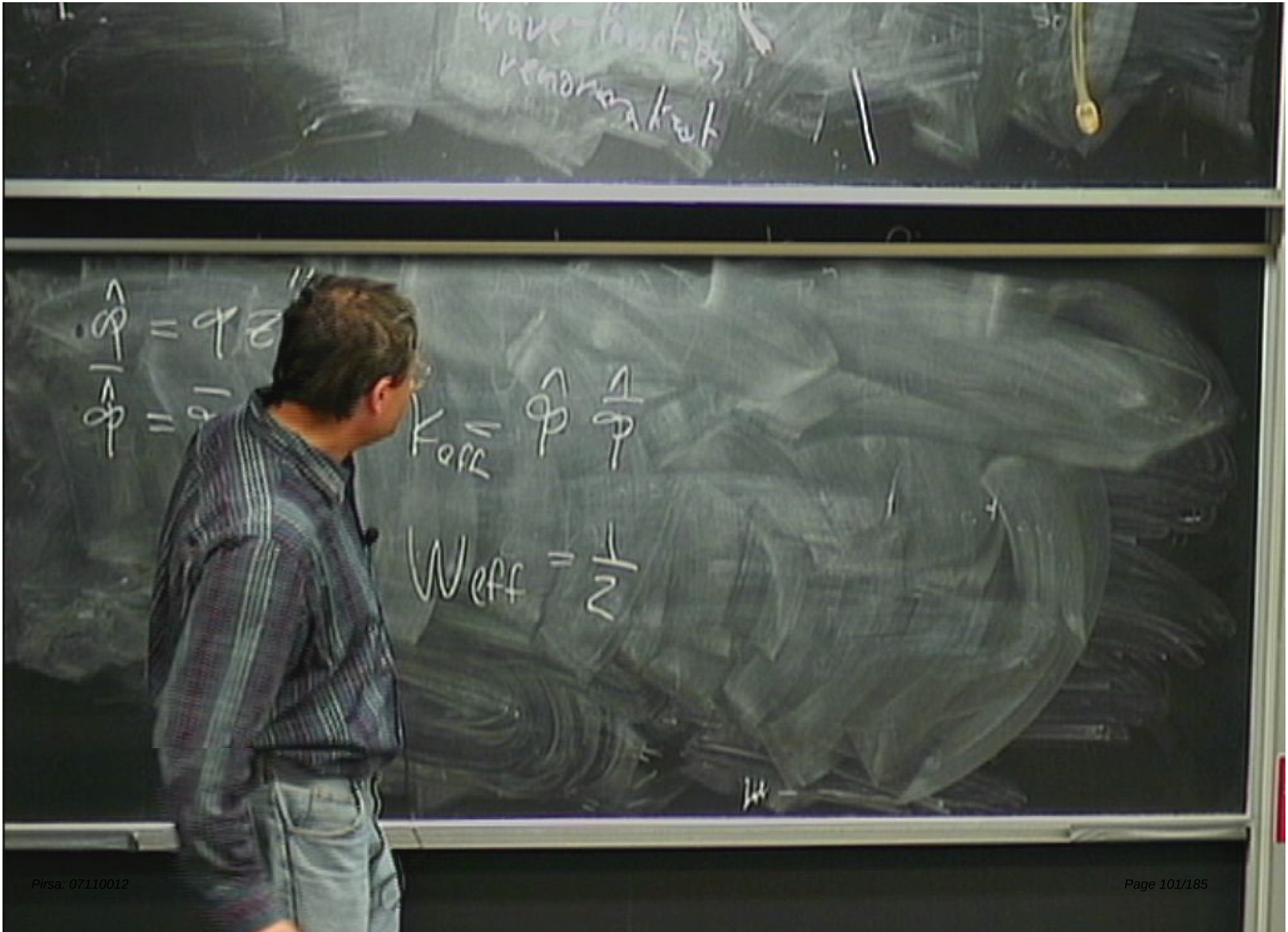
wave-function renormalization


$\hat{\varphi} = \varphi Z^{1/2}$
$\hat{\bar{\varphi}} = \bar{\varphi} Z^{1/2}$

wave-function
renormalization

$$\hat{\varphi} = \varphi Z^{1/2}$$

$$\hat{\bar{\varphi}} = \bar{\varphi} Z^{1/2} \qquad K_{eff} = \hat{\varphi}\,\frac{1}{\varphi}$$


Keff = φ̂ 1/φ̄
Weff = 1/2

wave function renormalization

$$\hat{\varphi} = \varphi Z^{1/2}$$

$$\hat{\bar{\varphi}} = \bar{\varphi} Z^{1/2}$$

$$K_{eff} = \hat{\varphi} \hat{\bar{\varphi}}$$

$$W_{eff} = \frac{1}{2} \frac{m \hat{\varphi}^2}{Z} + \frac{\lambda}{3 Z^{3/2}} \hat{\varphi}^3$$

$\Rightarrow$ certain ratios of coupling can be protected against Quantum corrections in k

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$$W_{eff} = f_0 \hat{\Phi}^2 + f_1 \hat{\Phi}^3$$

$\Rightarrow$ certain ratios of coupling can be protected against Quantum corrections in k

$$W_{eff} = f_0 \, \hat{\phi}^2 + f_1 \, \hat{\phi}^3$$

$$\frac{f_0^3}{f_1^2}$$

$\Rightarrow$ certain ratios of coupling can be protected against Quantum correction in K

$\frac{1}{2} m \phi^2 + \frac{1}{3} \lambda \phi^3$

$$W_{eff} = f_0 \, \Phi^2 + f_1 \, \Phi^3$$

$$\left. \frac{f_0^3}{f_1^2} \right|_{\text{classically}} =$$

$\Rightarrow$ certain ratios of coupling can be protected against Quantum correction in K

$\frac{1}{2} m \varphi^2 + \frac{1}{3} \lambda \varphi^3$

$$W_{eff} = f_0 \hat{\varphi}^2 + f_1 \hat{\varphi}^3$$

$$\left.\frac{f_0^3}{f_1^2}\right|_{\text{classically}} = \frac{\left(\frac{1}{2} m\right)^3}{\left(\frac{1}{3}\lambda\right)^2} = \overline{\uparrow 2M}$$

Perturbative computation of Z

Perturbative computation of Z

$\Rightarrow$ There is Yukawa interaction

$$\lambda \, \psi^{\alpha} \psi_{\alpha} \varphi$$

Perturbative computation of Z

$\Rightarrow$ There is Yukawa interaction

$\lambda\, \psi^2 \psi_2 \varphi$

$\uparrow$ cubic coupling.

Perturbative computation of Z

→ There is Yukawa interaction

$\lambda \, \psi^{\alpha} \psi_{\alpha} \, \varphi$

↑ cubic coupling.

Perturbative computation of Z

→ There is Yukawa interaction

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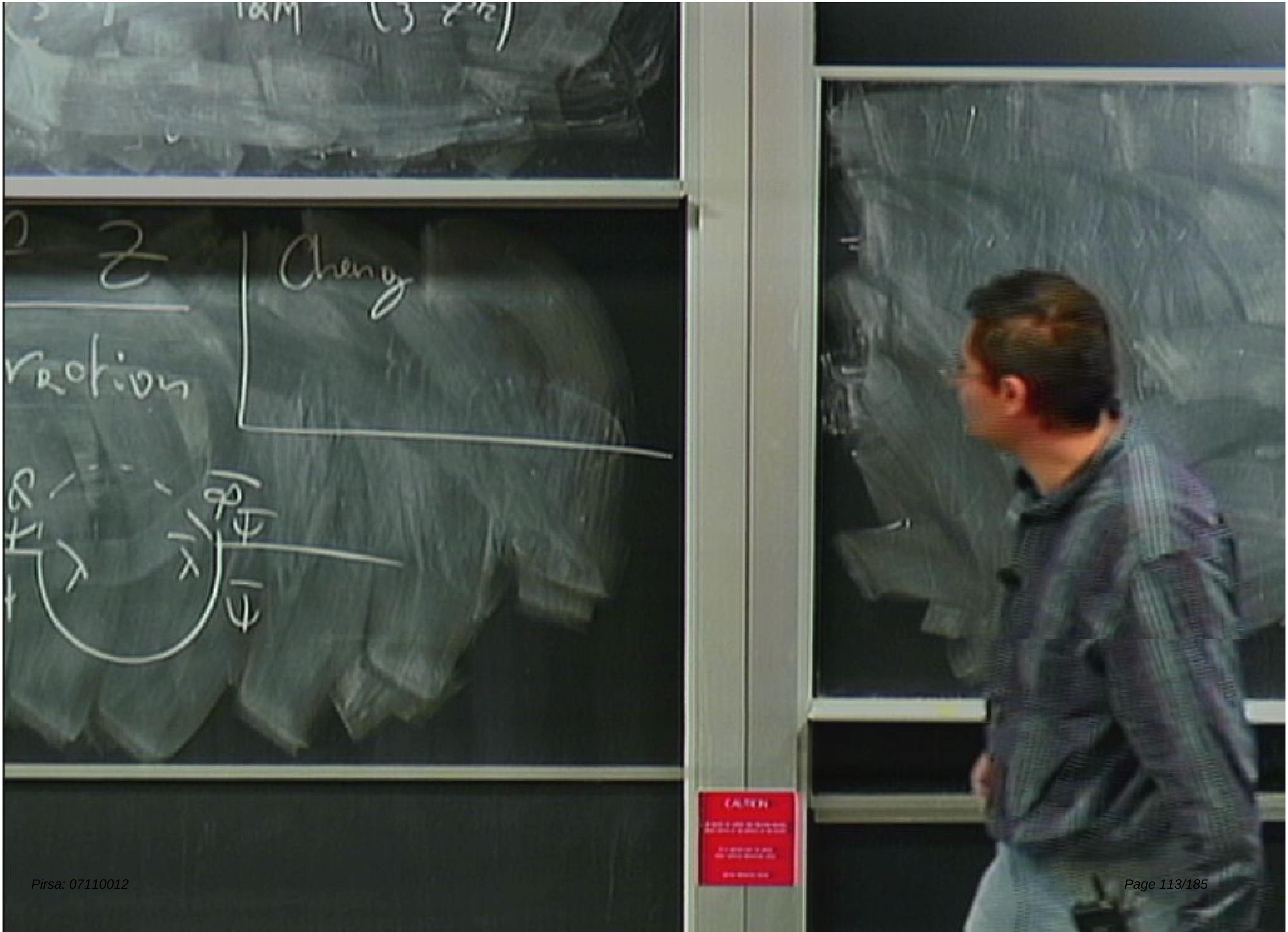
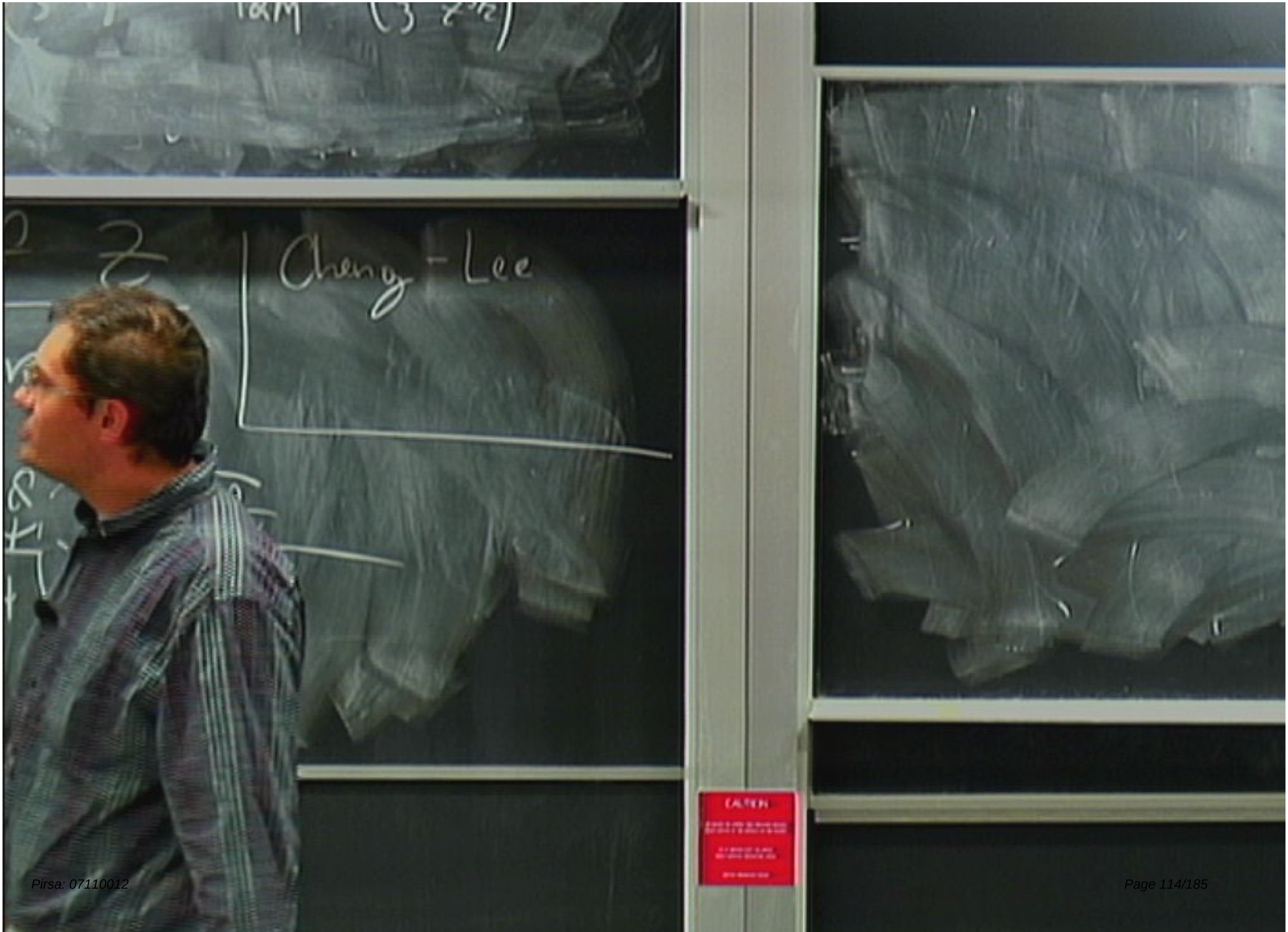
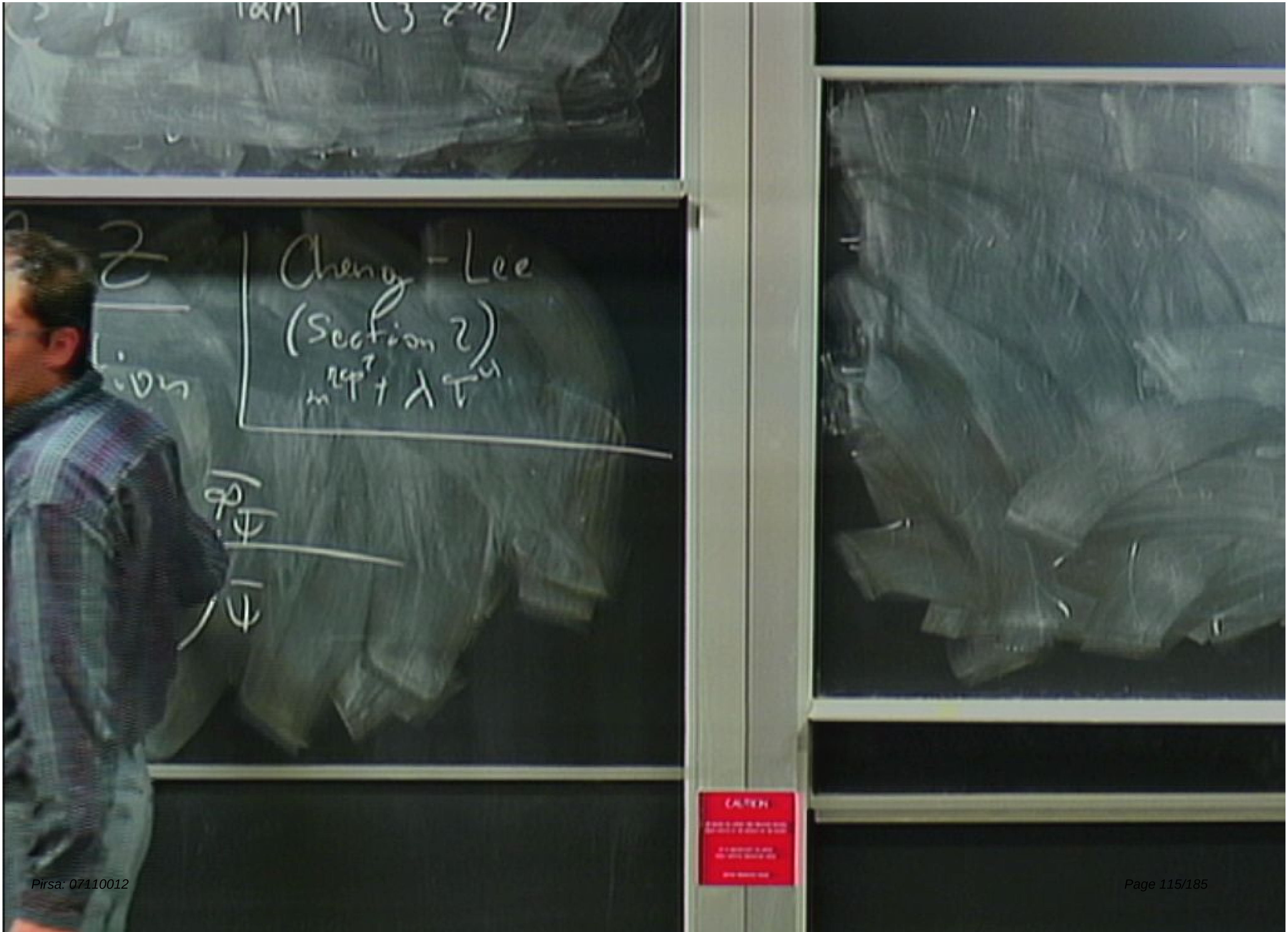
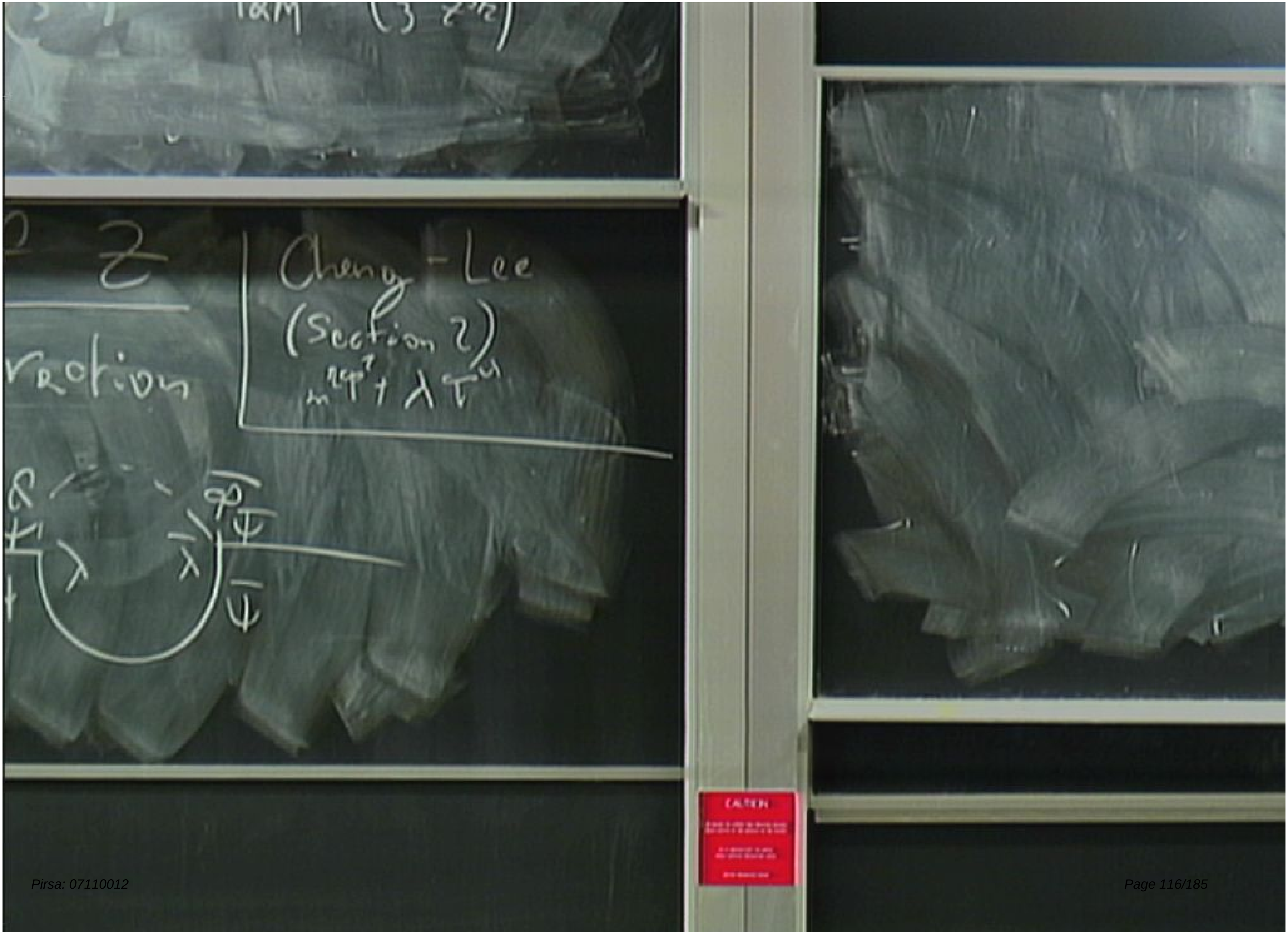
↑ cubic coupling.


Cheng
CAUTION


Cheng-Lee


Cheng-Lee
(Section 2)
CAUTION


Cheng-Lee
(Section 2)


$z^{1/2} =$

...rturbative computation of Z

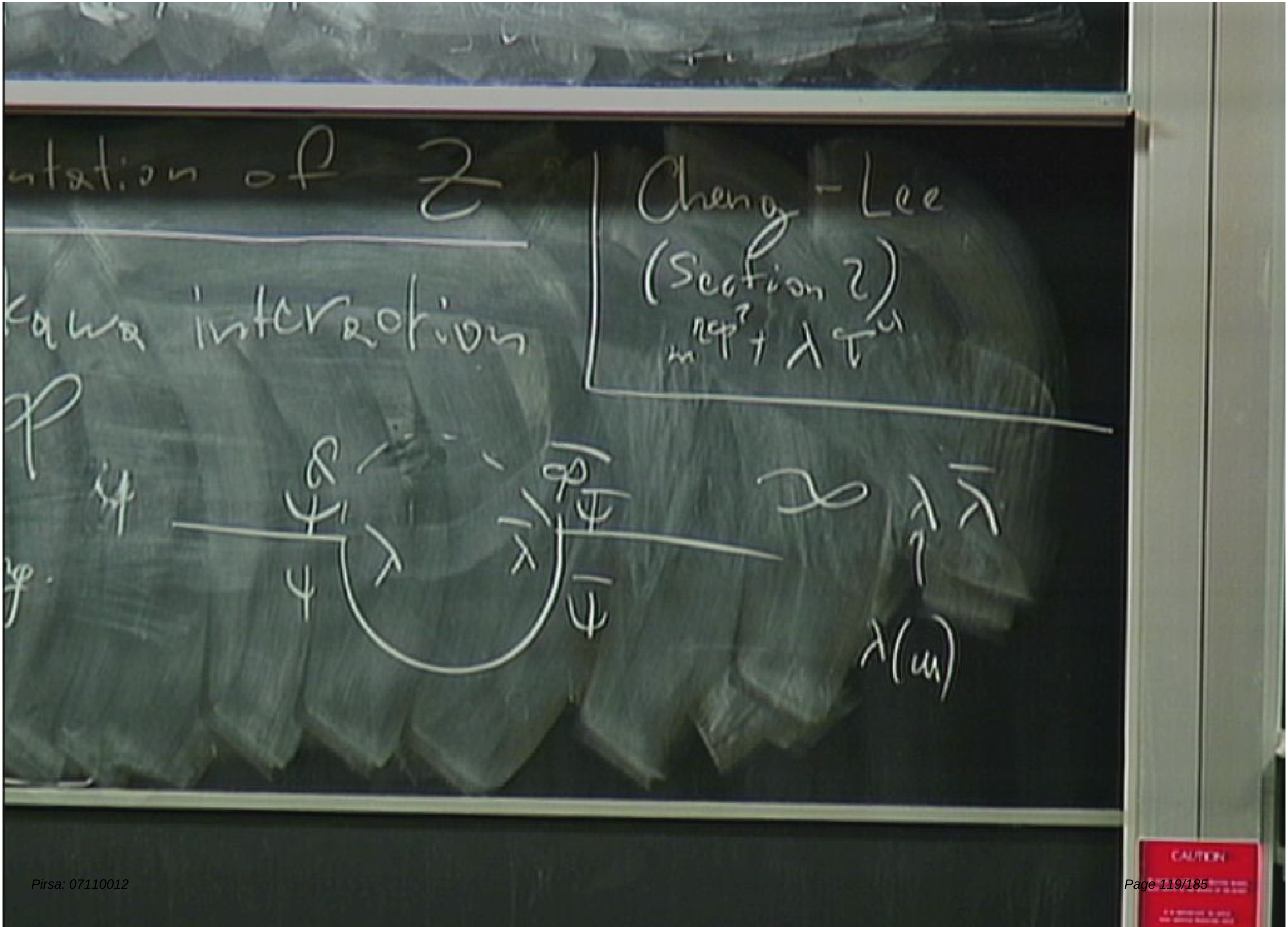
Cheng-Lee
(Section 2)
$m^2\varphi^2 + \lambda\varphi^4$

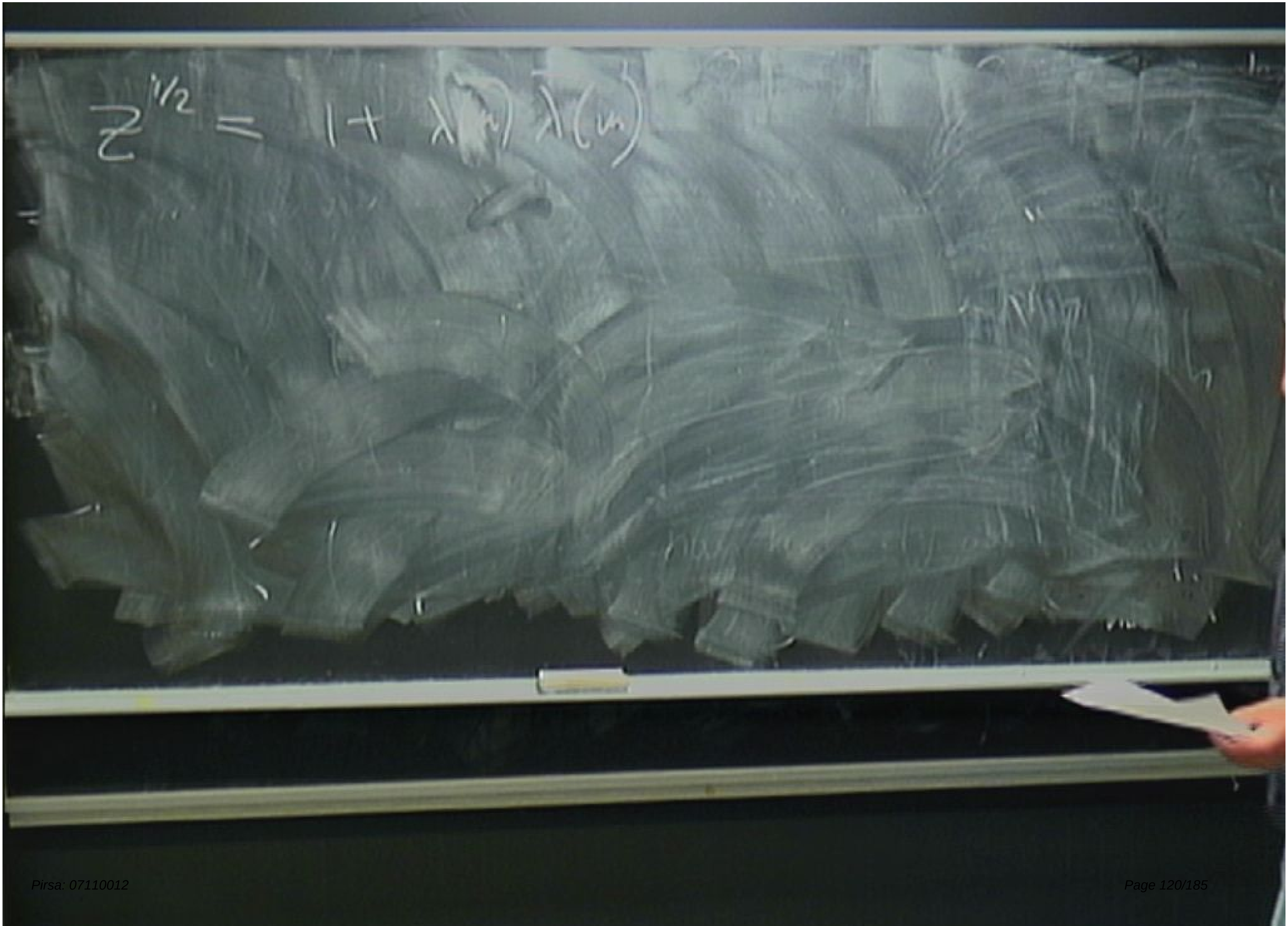
There is Yukawa interaction

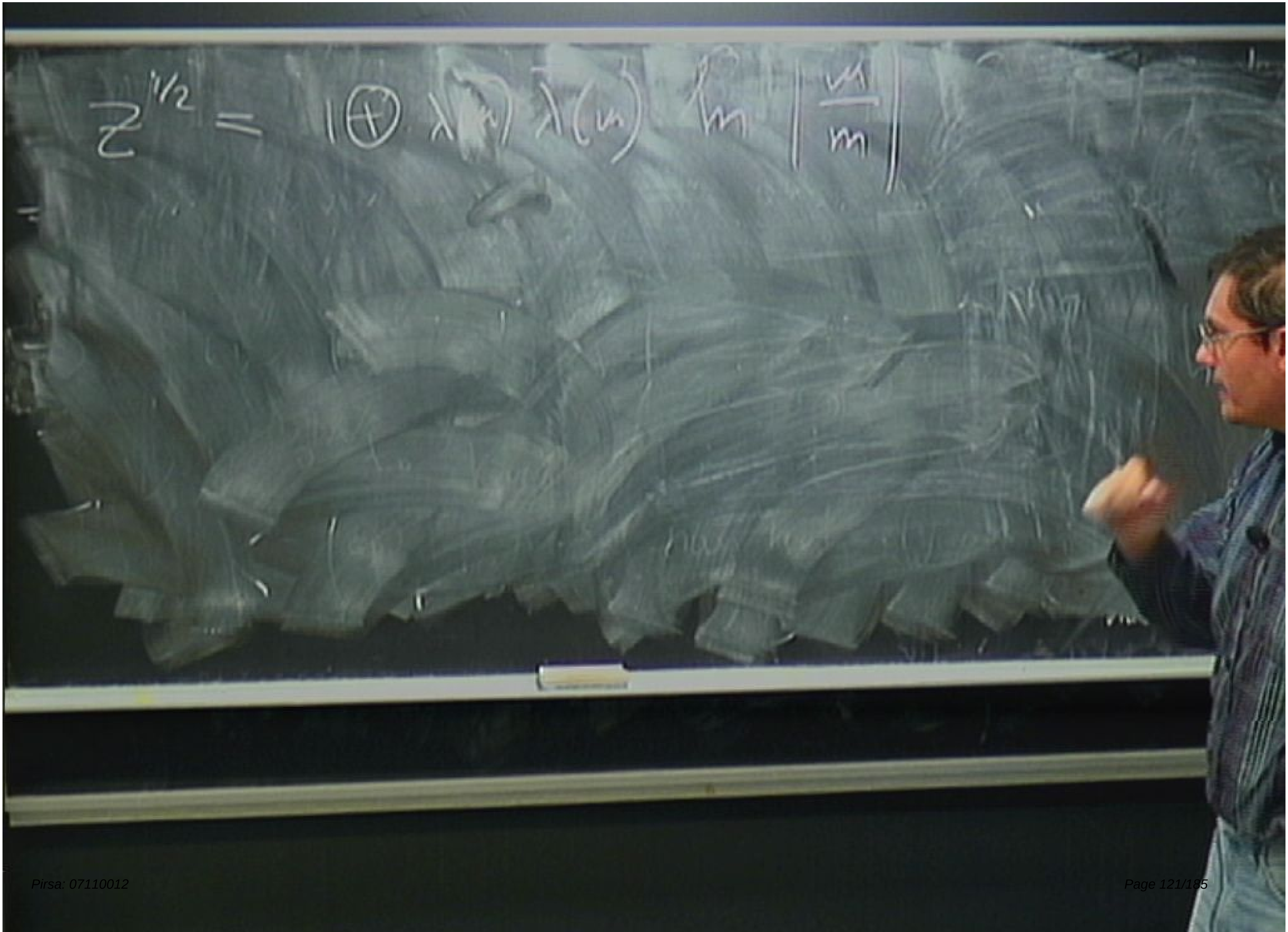
$\lambda\,\psi^\alpha \psi_\alpha \varphi$

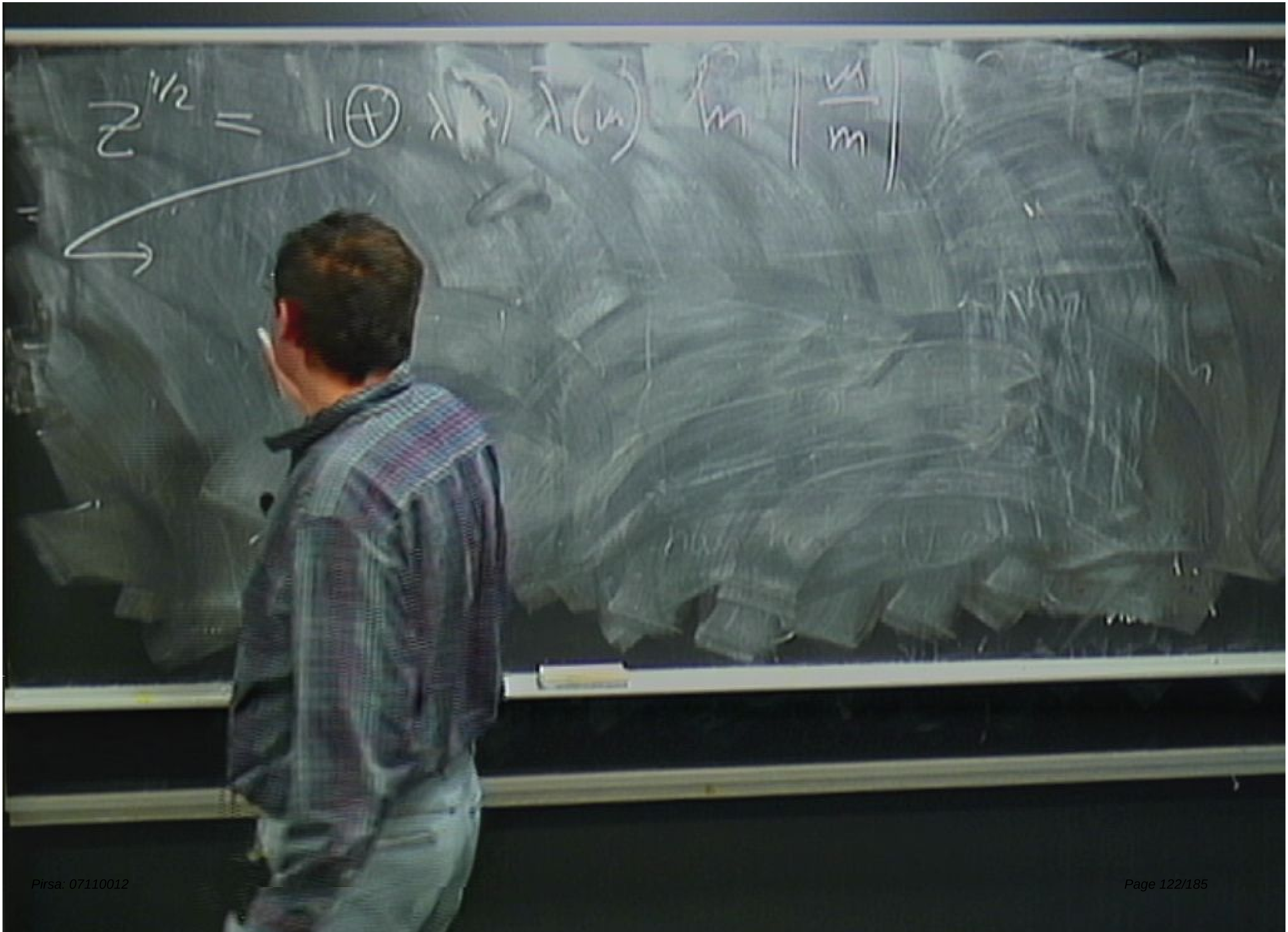
$\uparrow$ cubic coupling.

$\propto \lambda\bar{\lambda}$


ntation of Z
Cheng - Lee
(Section 2)
$m^2\varphi^2 + \lambda\varphi^4$
kawa interaction
$\infty \; \lambda\bar{\lambda}$
$\lambda(m)$
CAUTION


$Z^{1/2} = 1 + \lambda(m)\,\bar{\lambda}(m)$

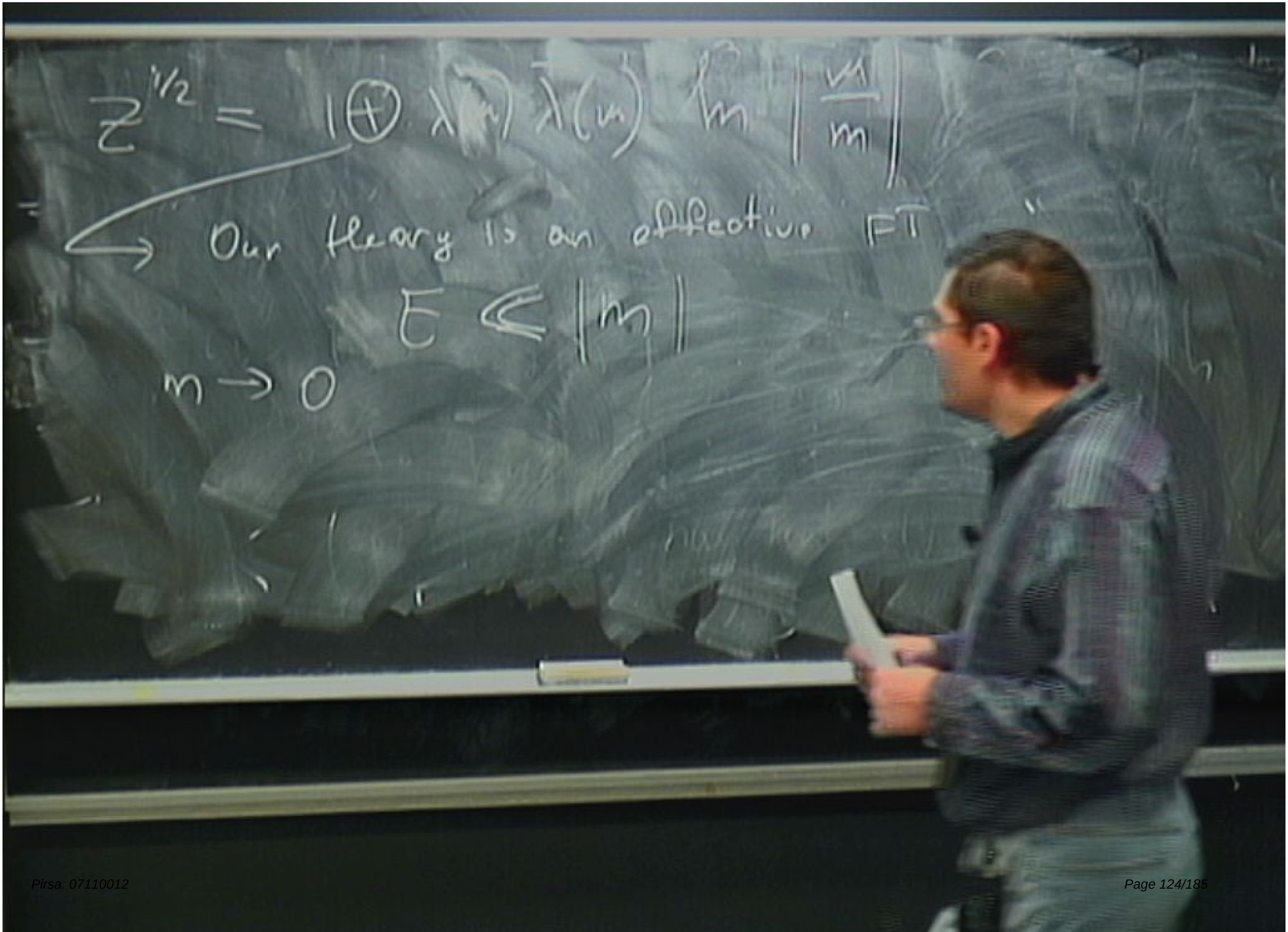

$Z^{1/2} =$



$$Z^{1/2} = 1 \oplus \lambda(m)\,\bar{\lambda}(m)\,\ln\left|\frac{\mu}{m}\right|$$

$\rightarrow$ Our theory is an effective FT

$$E \leq m$$

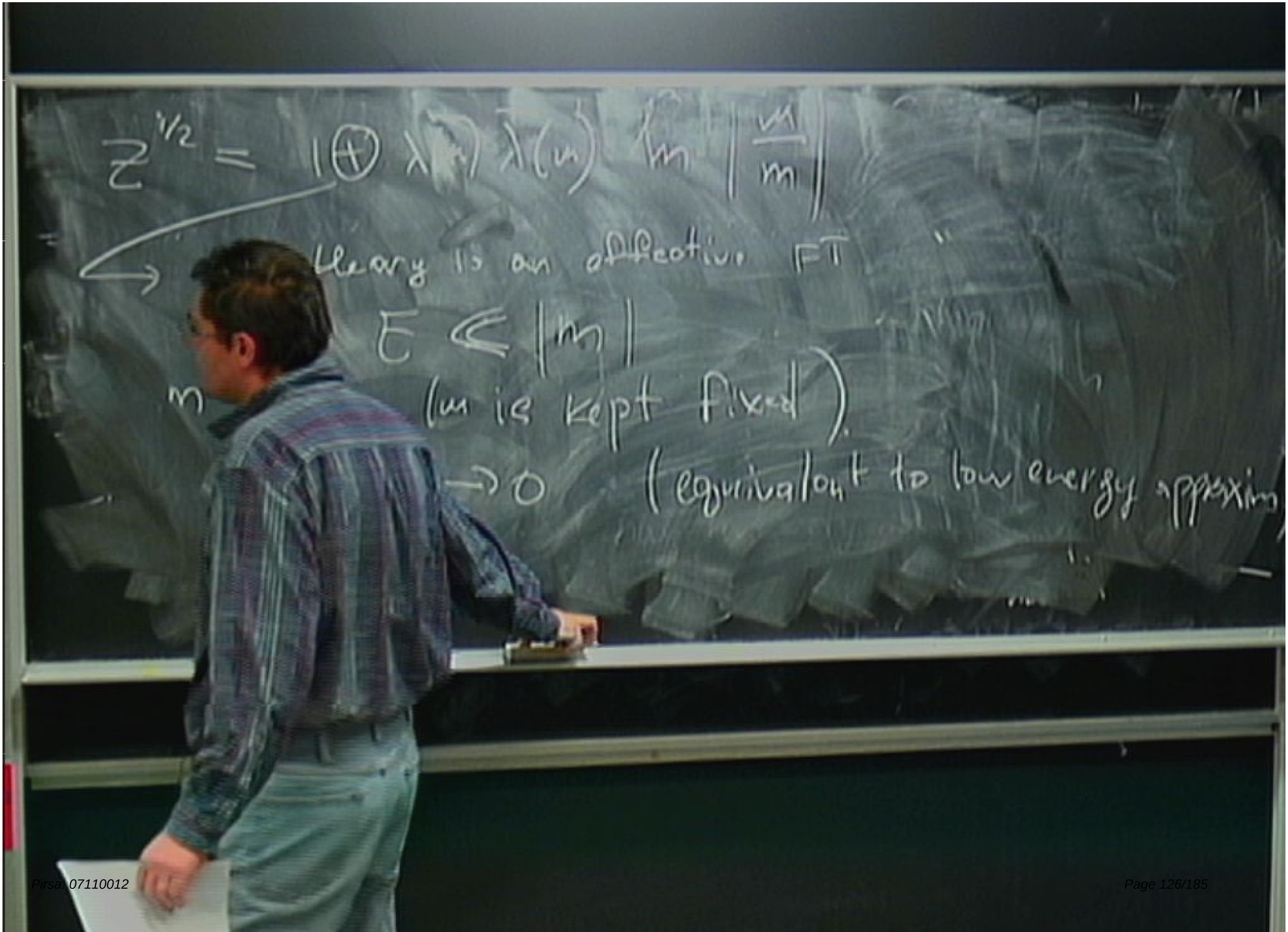

$Z^{1/2} = 1 \oplus \lambda(\mu)\,\bar{\lambda}(\mu)\,\hat{m}\left|\frac{\mu}{m}\right|$
Our theory is an effective FT
$E \leq |m|$
$m \to 0$

$$Z^{1/2} = 1 + \lambda(m)\,\bar{\lambda}(m)\,\hat{f}_m \left| \frac{\mu}{m} \right|$$

$\rightarrow$ Our theory is an effective FT

$$E \leq |m|$$

$m \to 0$ (μ is kept fixed).


$Z^{1/2} = 1 + \lambda(m)\,\bar{\lambda}(m)\,\ln\left|\frac{m}{m}\right|$
theory is an effective FT
$E \leq |m|$
(m is kept fixed)
(equivalent to low energy approxim

$$Z^{1/2} = 1 \oplus \lambda(\mu)\, \bar{\lambda}(\mu)\, \ln \left| \frac{\mu}{m} \right|$$

$\longrightarrow$ Our theory is an effective FT

$$E \leq |m|$$

$m \to 0$ (μ is kept fixed).

$\Downarrow$ $E \to 0$ (equivalent to low energy approxim

term $n=0$

The physical field is ...

term $n=0$

The physical field is φ

$\Rightarrow$ as $\varepsilon \to 0$ theory becomes weakly coupled in term of

term $n=0$

Thy physical field is $\hat{\varphi}$

$\Rightarrow$ as $\varepsilon \to 0$ theory becomes weakly coupled in term of $\hat{\varphi}$

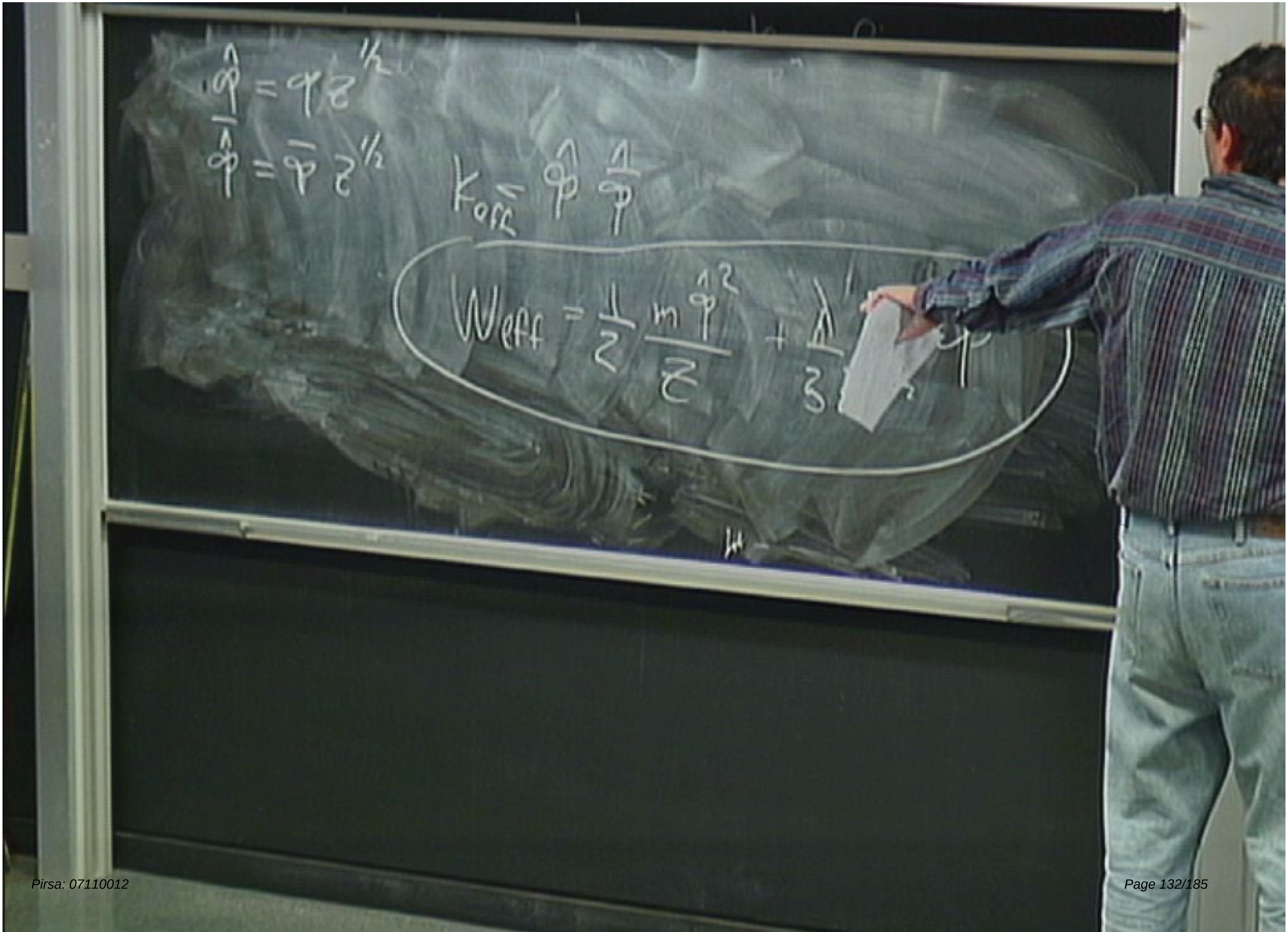
$m \to 0$ $\quad \varepsilon^{1/2} \longrightarrow +$

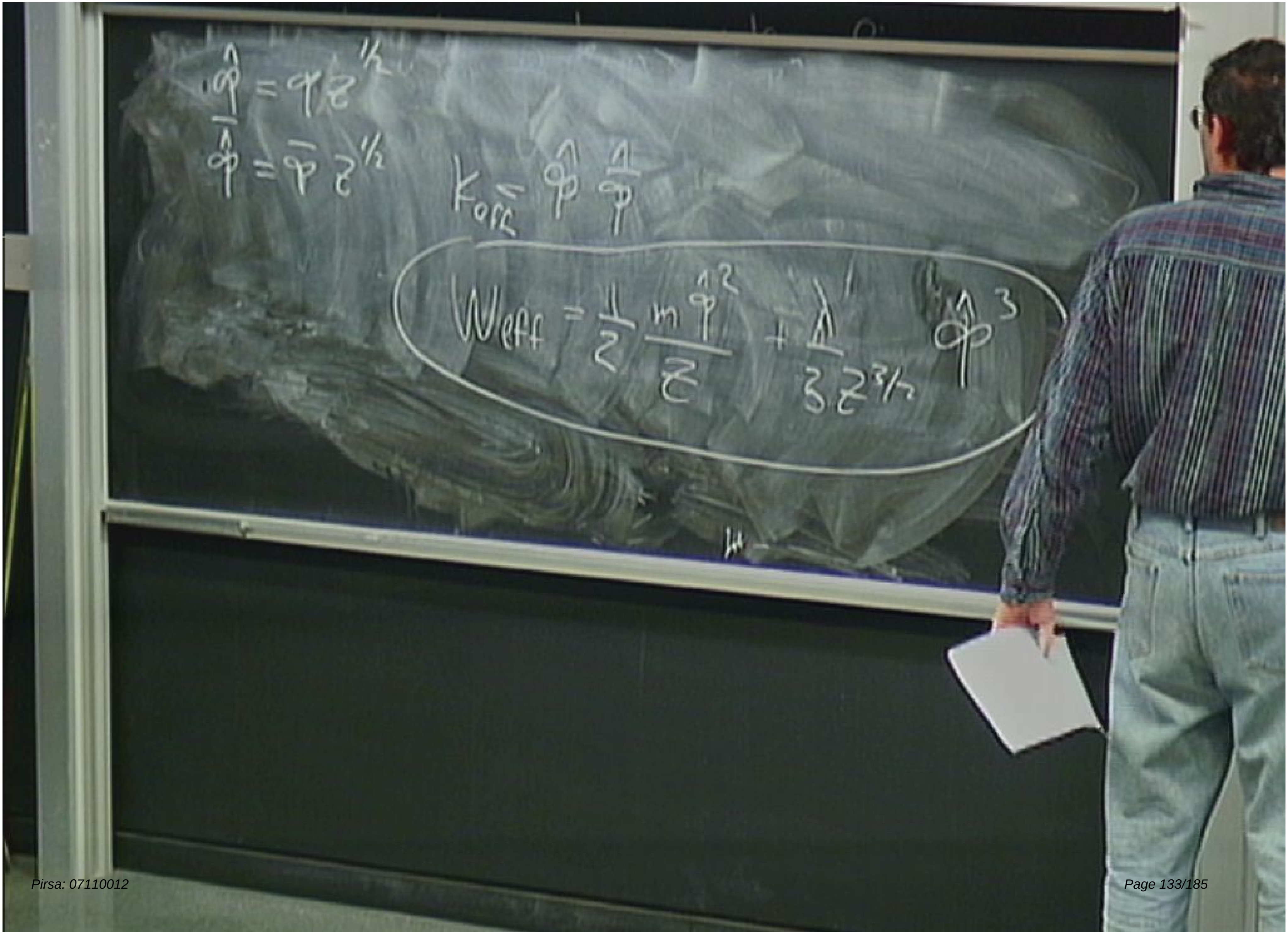
term $n=0$

The physical field is φ

$\Rightarrow$ as $\mathcal{E} \to 0$ theory becomes weakly coupled in term of $\hat{\varphi}$

$m \to 0$ $\quad Z^{1/2} \to + \, \|\lambda\|^2 \ln\left(\frac{M}{0}\right)$


$\hat{\varphi} = \varphi z^{1/2}$
$\hat{\bar{\varphi}} = \bar{\varphi} \bar{z}^{1/2}$
$K_{eff} = \hat{\varphi} \hat{\bar{\varphi}}$
$W_{eff} = \frac{1}{2} \frac{m \hat{\varphi}^2}{z} + \frac{\lambda}{3}$


$\hat{\varphi} = \varphi z^{1/2}$
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$W_{eff} = \frac{1}{2} \frac{m \hat{\varphi}^2}{z} + \frac{\lambda}{3 z^{3/2}} \hat{\varphi}^3$

The physical field is $\hat{\varphi}$

$\Rightarrow$ as $E \to 0$ theory becomes weakly coupled in term of $\hat{\varphi}$

$m \to 0$ $\quad Z^{1/2} \longrightarrow + \, \|\hat{\lambda}\|^2 \ln\left(\frac{\mu}{0}\right) \longrightarrow +\infty$

$W_{eff} \to 0$

surviving
term $n=0$
$n=1$

The physical field is $\hat{\phi}$

$\Rightarrow$ as $\epsilon \to 0$ theory becomes weakly coupled in term of $\hat{\phi}$

$m \to 0$ $\quad Z^{1/2} \to + \, |\lambda|^2 \ln\left(\frac{\mu}{0}\right) \to +\infty$

$W_{ef} \to 0$

$$G^{(n)} = \langle \varphi(x_1) \cdots \varphi(x_n) \rangle$$

$$G^{(n)} = G^{(n)}(\Lambda)$$

$$\Rightarrow \text{prove } \frac{\partial G^{(n)}}{\partial \lambda} =$$

$$G^{(n)} = \langle \varphi(x_1) \cdots \varphi(x_n) \rangle$$

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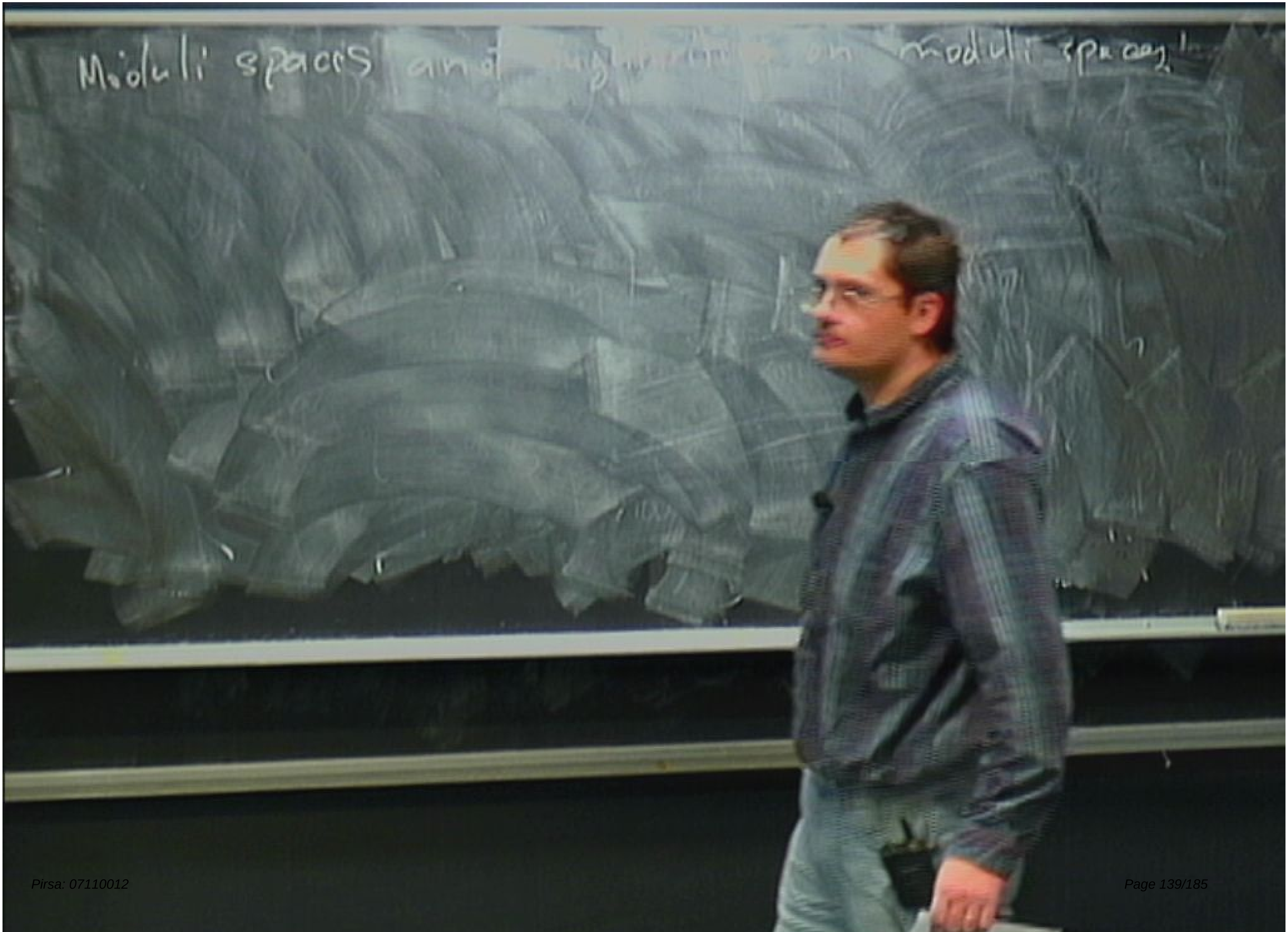
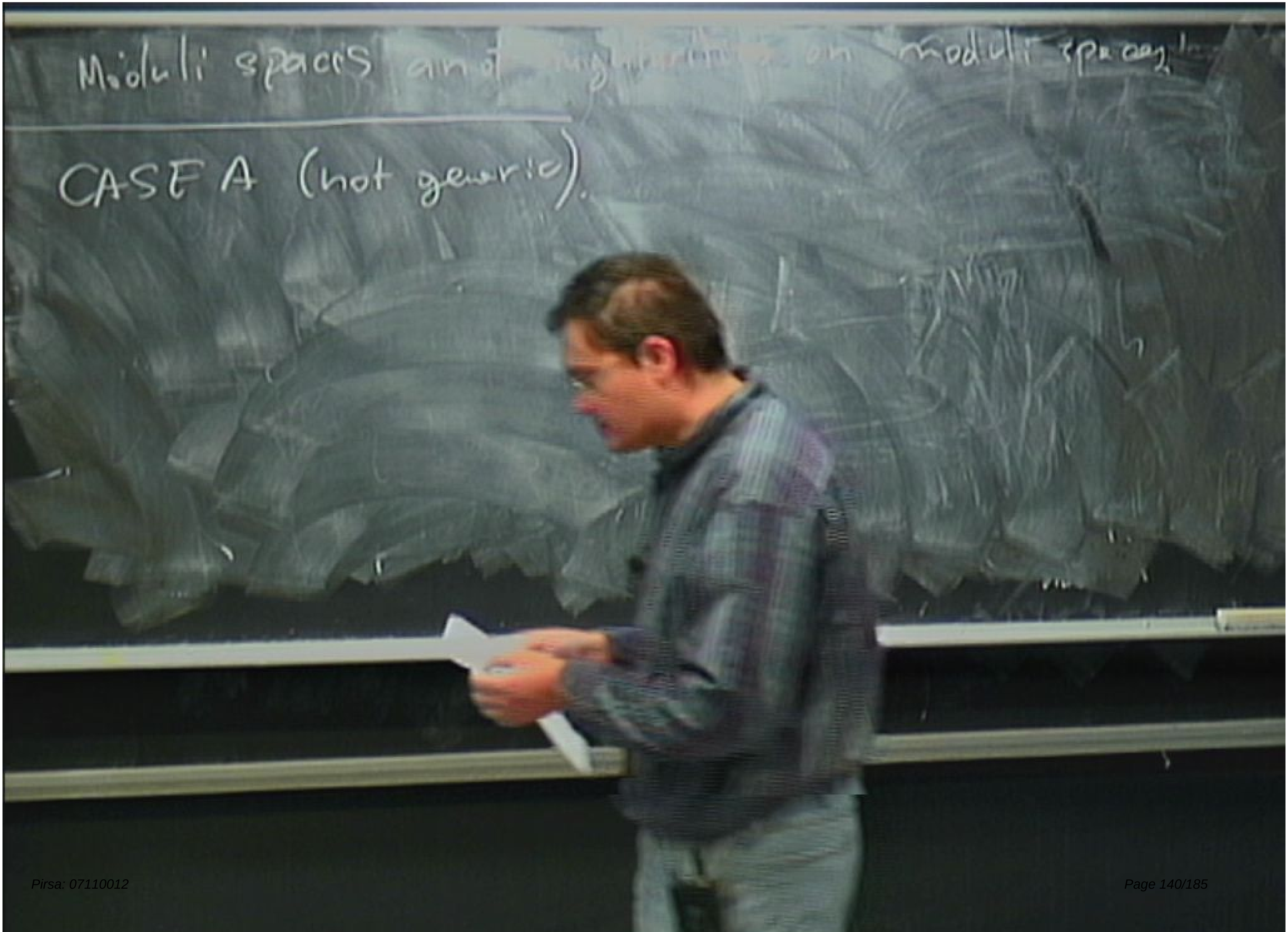
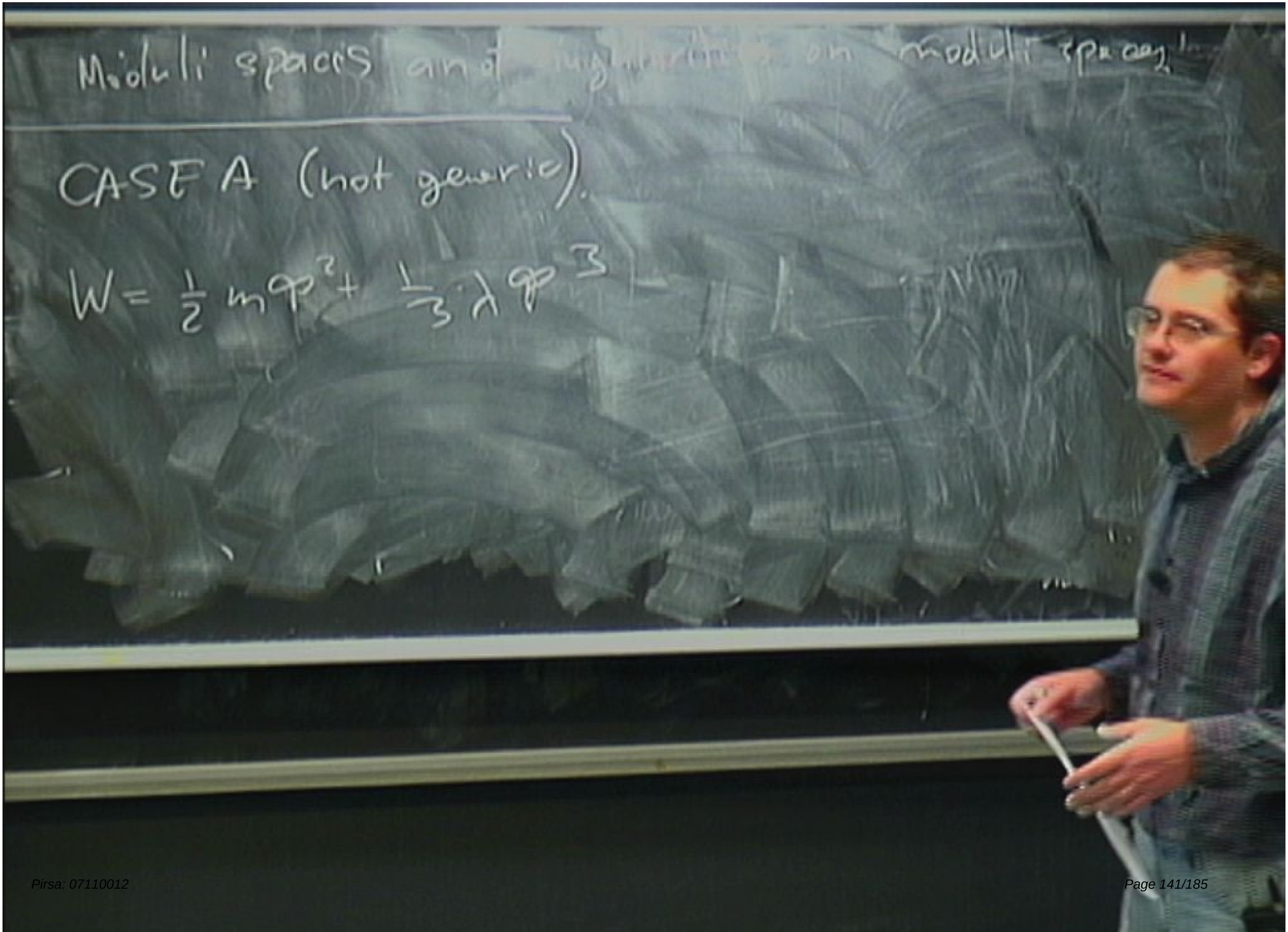
$$G^{(n)} = \langle \varphi(x_1) \cdots \varphi(x_n) \rangle$$ xsfls

$$G^{(n)} = G^{(n)}(\Lambda)$$

$$\Rightarrow \text{prove } \frac{\partial G^{(n)}}{\partial \lambda} = 0$$


Moduli spaces and
on moduli spaces


CASE A (not generic).

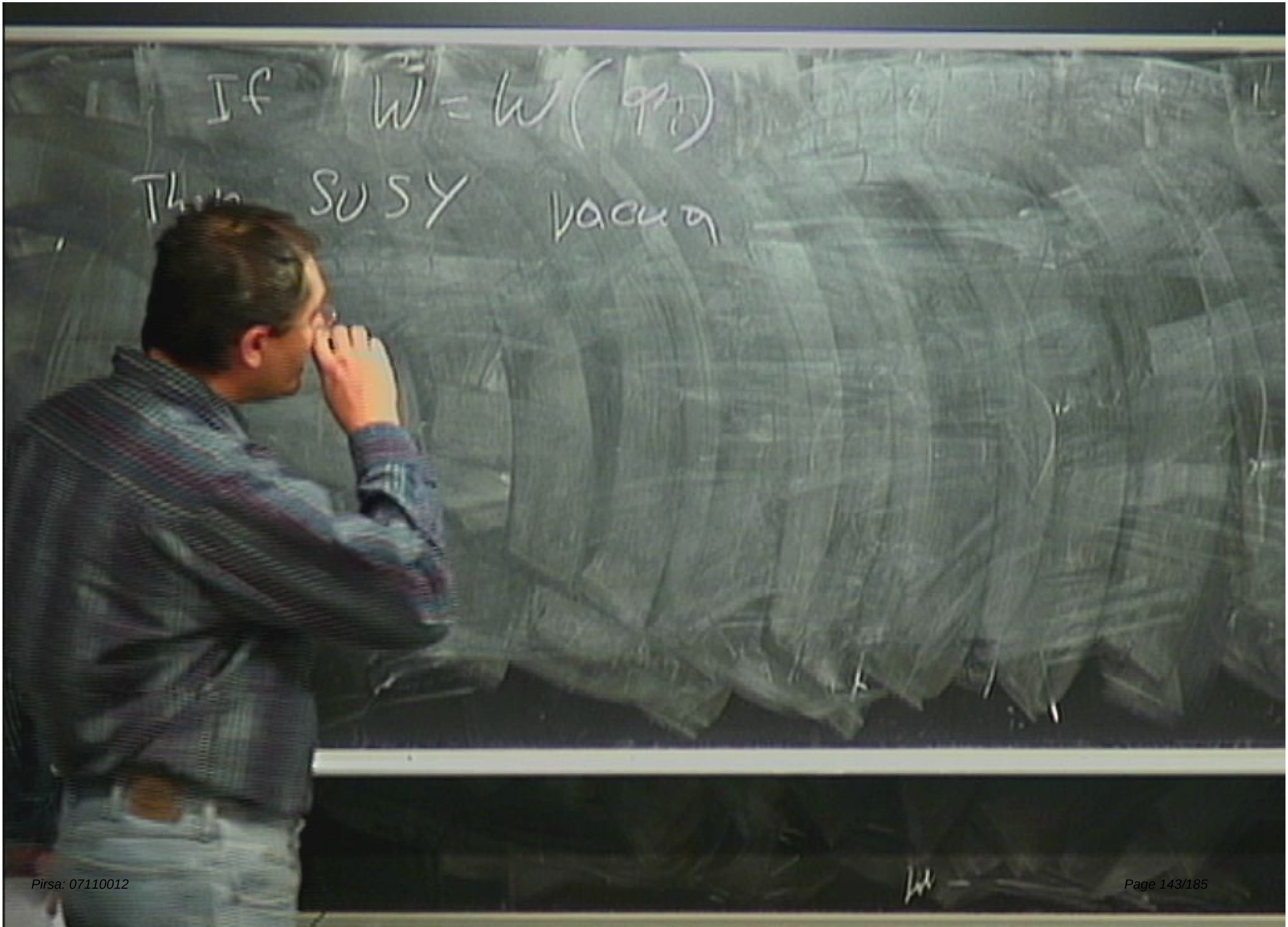

Moduli spaces and
on moduli spaces
CASE A (not generic).
$W = \frac{1}{2} m \varphi^2 + \frac{1}{3} \lambda \varphi^3$

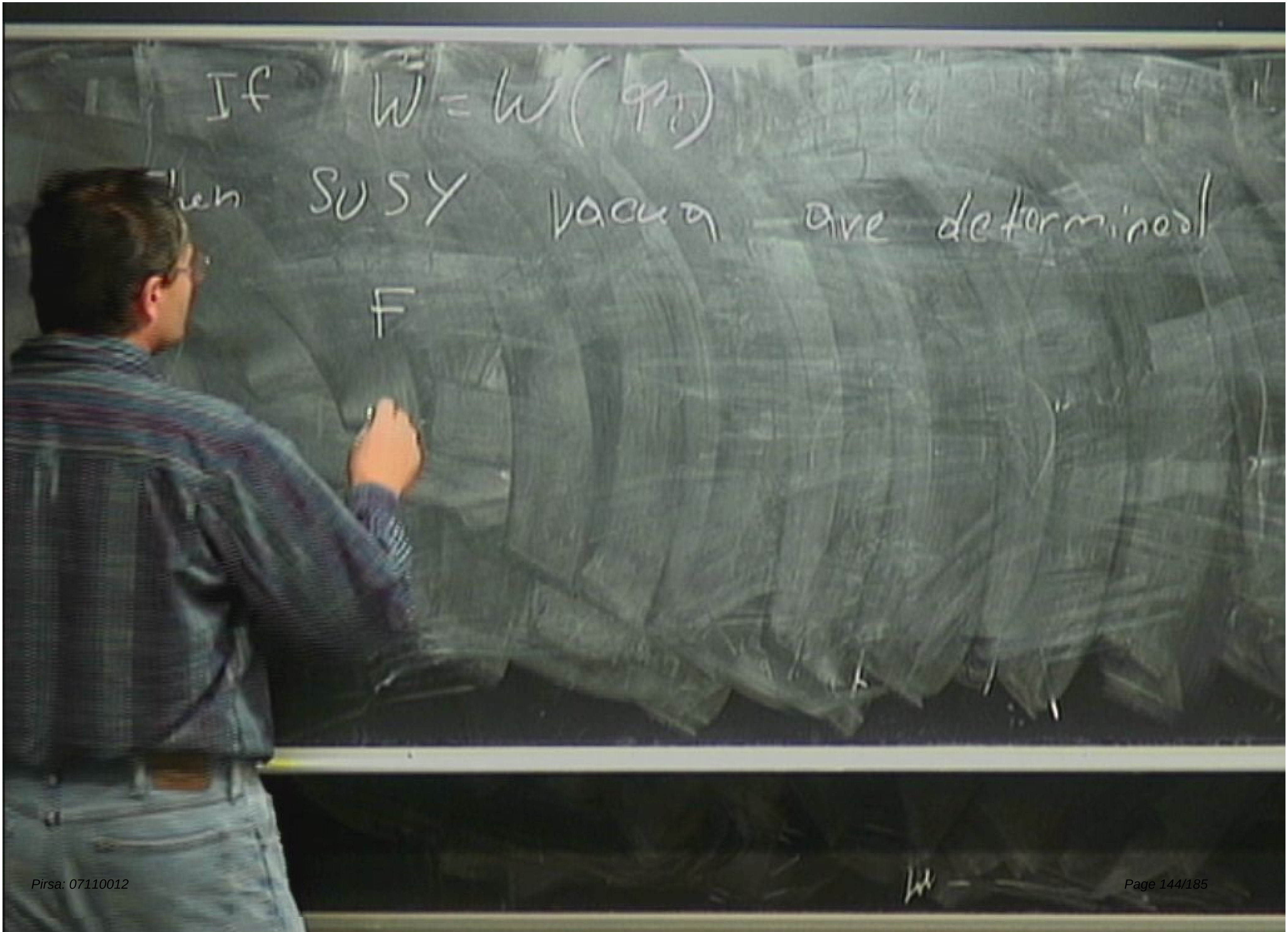
Moduli spaces and [illegible] on moduli spaces

CASE A (not generic).

$$W = \frac{1}{2} m \varphi^2 + \frac{1}{3} \lambda \varphi^3$$

$\Rightarrow$ Find the space of SUSY vacua


If $\vec{W} = W(\varphi_i)$
Then SUSY vacua


If $W = W(\varphi_i)$
hen SUSY vacua are determined
F

If $W = W(\varphi_i)$

Then SUSY vacua are determined

$$F_i = \frac{\partial W}{\partial \varphi_i} = 0 \;, \quad \text{for any } i$$

$$\frac{\partial W}{\partial \phi}$$

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda\varphi^2 \Rightarrow$$

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda\varphi^2 \Rightarrow \varphi_v = \left\{0, -\frac{\lambda}{m}\right\}$$

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda\varphi^2 \Rightarrow \varphi_v = \left\{0, -\frac{\lambda}{m}\right\}$$

$\Rightarrow$ discrete vacua

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda \varphi^2 \Rightarrow \varphi_v = \left\{ 0, -\frac{m}{\lambda} \right\}$$

$\Rightarrow$ discrete vacua $\Rightarrow$ usually arise from breaking of some discrete symmetry

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda\varphi^2 \Rightarrow \varphi_v = \left\{0, -\frac{\lambda}{m}\right\}$$

$\Rightarrow$ discrete vacua $\Rightarrow$ usually arise from breaking of some discrete symmetry

$\exists$ some hidden Z_2 symmetry in the model

$$0 = \frac{\partial W}{\partial \varphi} = m\varphi + \lambda\varphi^2 \Rightarrow \varphi_v = \left\{ 0, -\frac{\lambda}{m} \right\}$$

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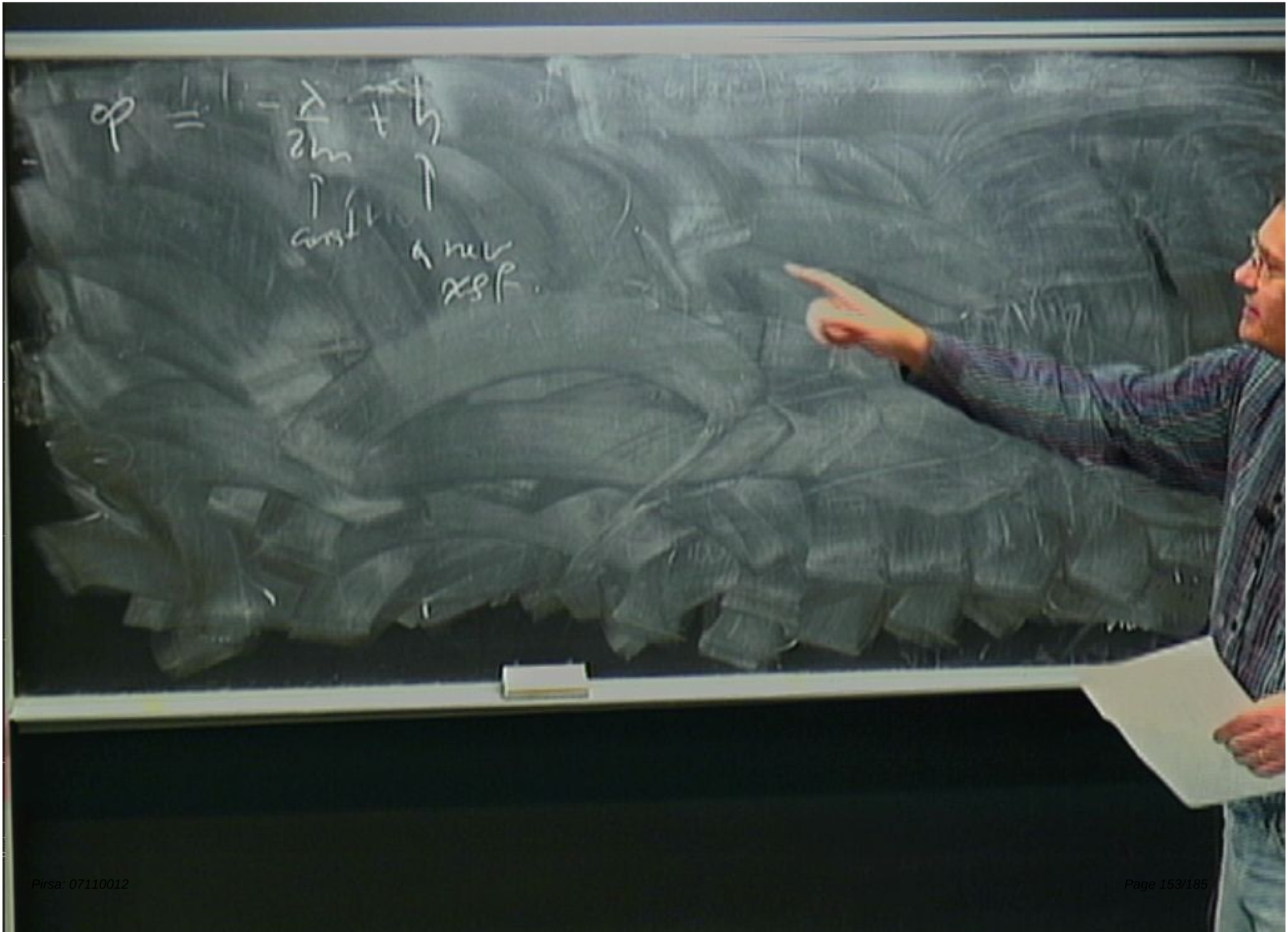

a new

$$\varphi = 1 - \frac{\lambda}{2m} + h$$

const

a new exp.

$$h_\pm = \pm \frac{\lambda}{2m}$$

$$h \leftrightarrow -h$$

$$\varphi = -\frac{\lambda}{2m} + h$$

const   a new expt.

$$h_\pm = \pm\frac{\lambda}{2m}$$

$$h \leftrightarrow -h$$

$$W(h) = \frac{m^3}{12\lambda^2} - \frac{m^2}{4\lambda} h + \frac{1}{3}\lambda h^3$$

$\varphi = -\frac{\lambda}{2m} + h$

const   a new

$h_\pm = \pm \frac{\lambda}{2m}$

$h \leftrightarrow -h$

$W(h) = \cancel{\frac{m^3}{12\lambda^2}} - \frac{m^2}{4\lambda} h + \frac{1}{3}\lambda h^3 \simeq -\frac{m^2}{4\lambda} h + \frac{1}{3}$

$\int d^2\theta\, W$

$$\varphi = -\frac{\lambda}{2m} + h$$

const

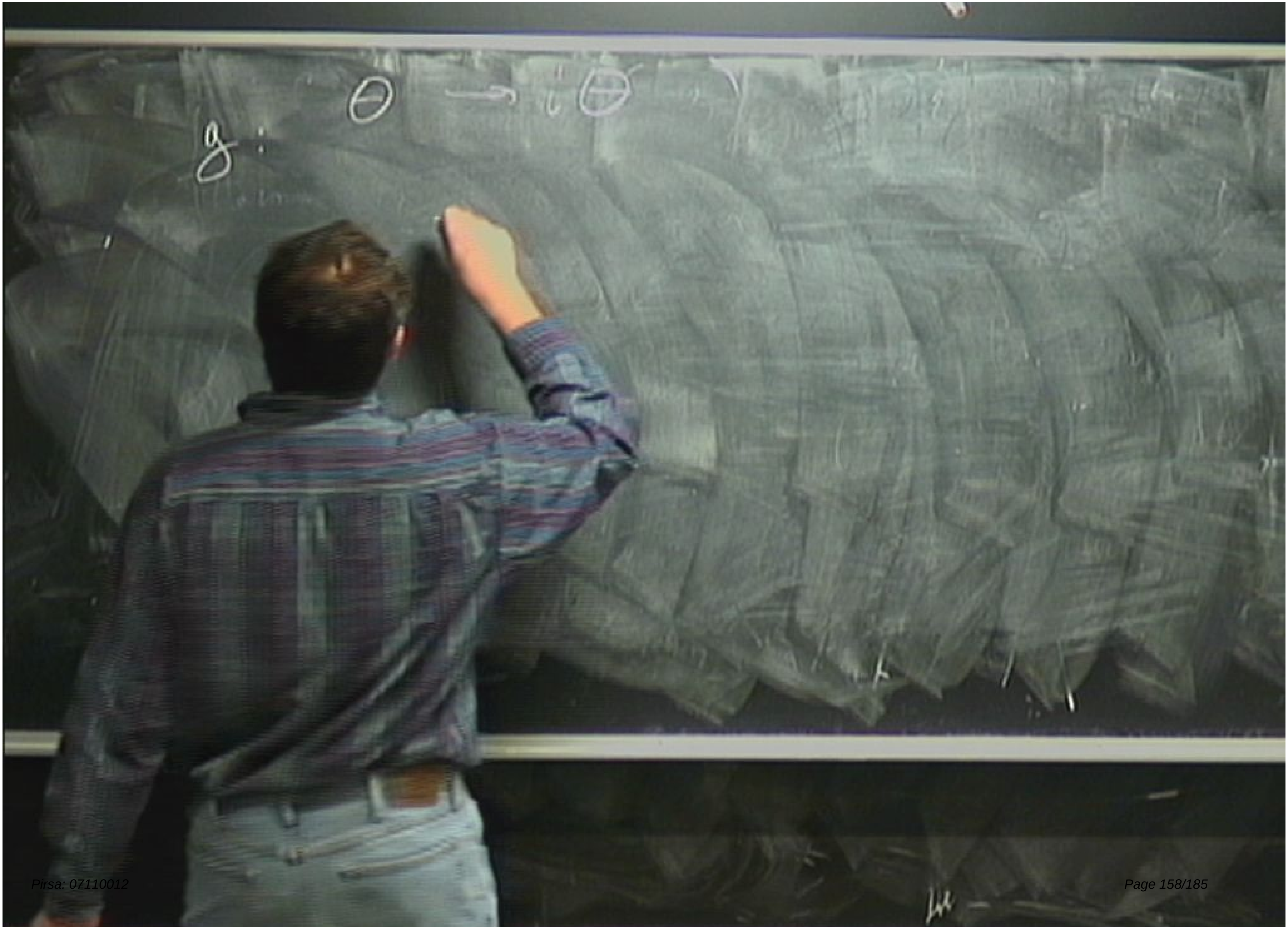
a new xgf.

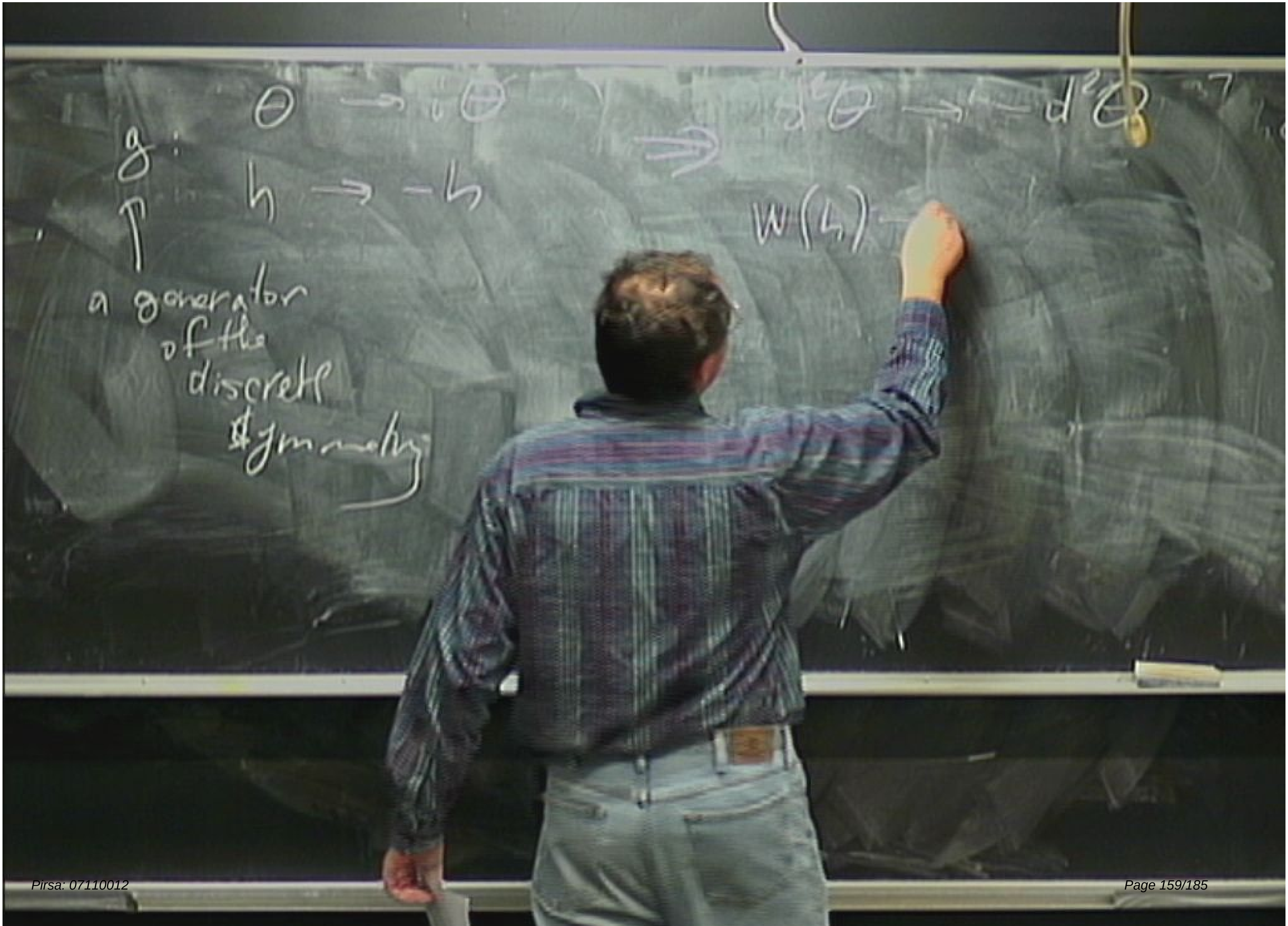
$$h_\pm = \pm\frac{\lambda}{2m}$$

$$h \leftrightarrow -h$$

$$W(h) = \cancel{\frac{m^3}{12\lambda^2}} - \frac{m^2}{4\lambda}h + \frac{1}{3}\lambda h^3 \simeq -\frac{m^2}{4\lambda}h + \frac{1}{3}\lambda h^3$$

$$\int d^2\theta\, W$$


g: Θ → iΘ

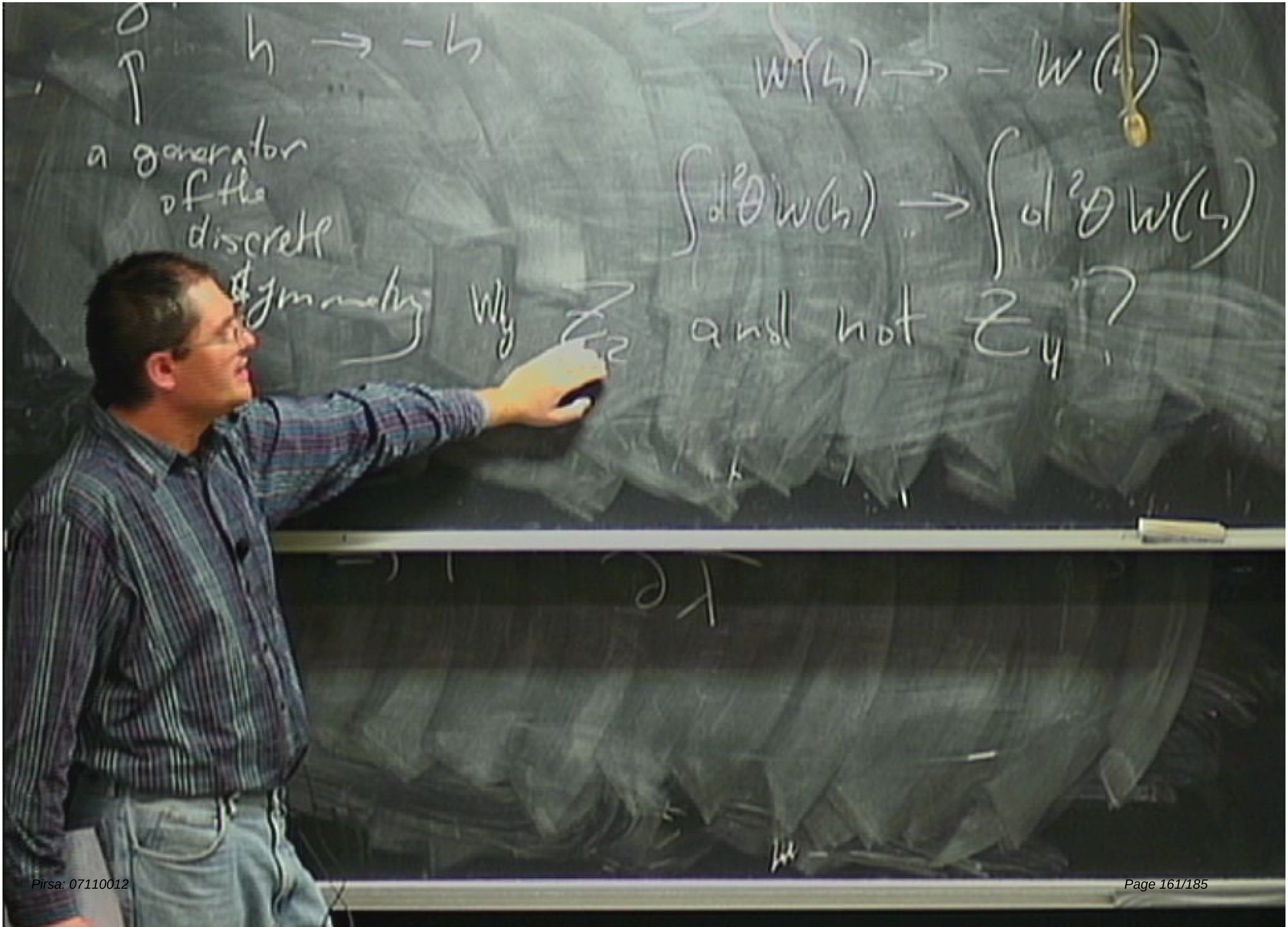

g:
θ → iθ
⇒ d²θ → −d²θ
h → −h
w(h) →
a generator of the discrete symmetry

$g: \quad \theta \to i\theta \qquad \Rightarrow \quad d^2\theta \to -d^2\theta$

$\quad\; h \to -h \qquad\qquad W(h) \to -W(h)$

a generator of the discrete symmetry

$$\int d^2\theta\, W(h) \to \int d^2\theta\, W(h)$$


h → -h
W(h) → - W(h)
a generator
of the
discrete
symmetry
Why Z2 and not Z4?

$$g: \quad \theta \to i\theta \qquad \Rightarrow \quad d^2\theta \to -d^2\theta$$

$$h \to -h \qquad W(h) \to -W(h)$$

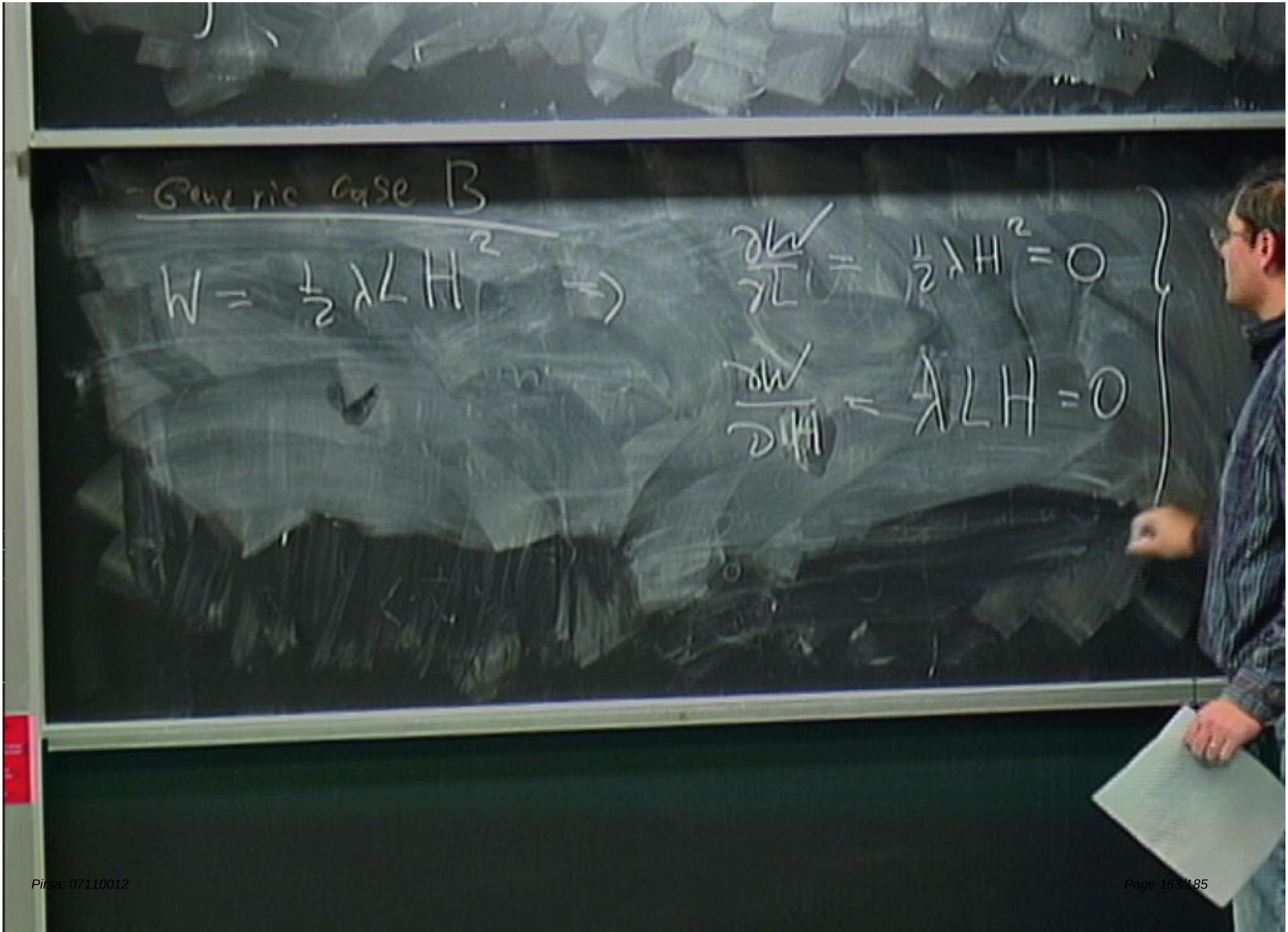
a generator of the discrete symmetry

$$\int d^2\theta\, W(h) \to \int d^2\theta\, W(h)$$

Why Z_2 and not Z_4?

$$g^2: \quad \theta \to -\theta, \quad h \to h$$

$$g^4: \quad \theta \to \theta, \quad h \to h$$


Generic case B
$W = \frac{1}{2}\lambda L H^2 \Rightarrow$
$\frac{\partial W}{\partial L} = \frac{1}{2}\lambda H^2 = 0$
$\frac{\partial W}{\partial H} = \lambda L H = 0$

Generic case B

$$W = \tfrac{1}{2}\lambda L H^2 \Rightarrow \left\{ \begin{array}{l} \dfrac{\partial W}{\partial L} = \tfrac{1}{2}\lambda H^2 = 0 \\[2ex] \dfrac{\partial W}{\partial H} = \lambda L H = 0 \end{array} \right.$$

$$\Rightarrow \frac{H = 0}{L}$$

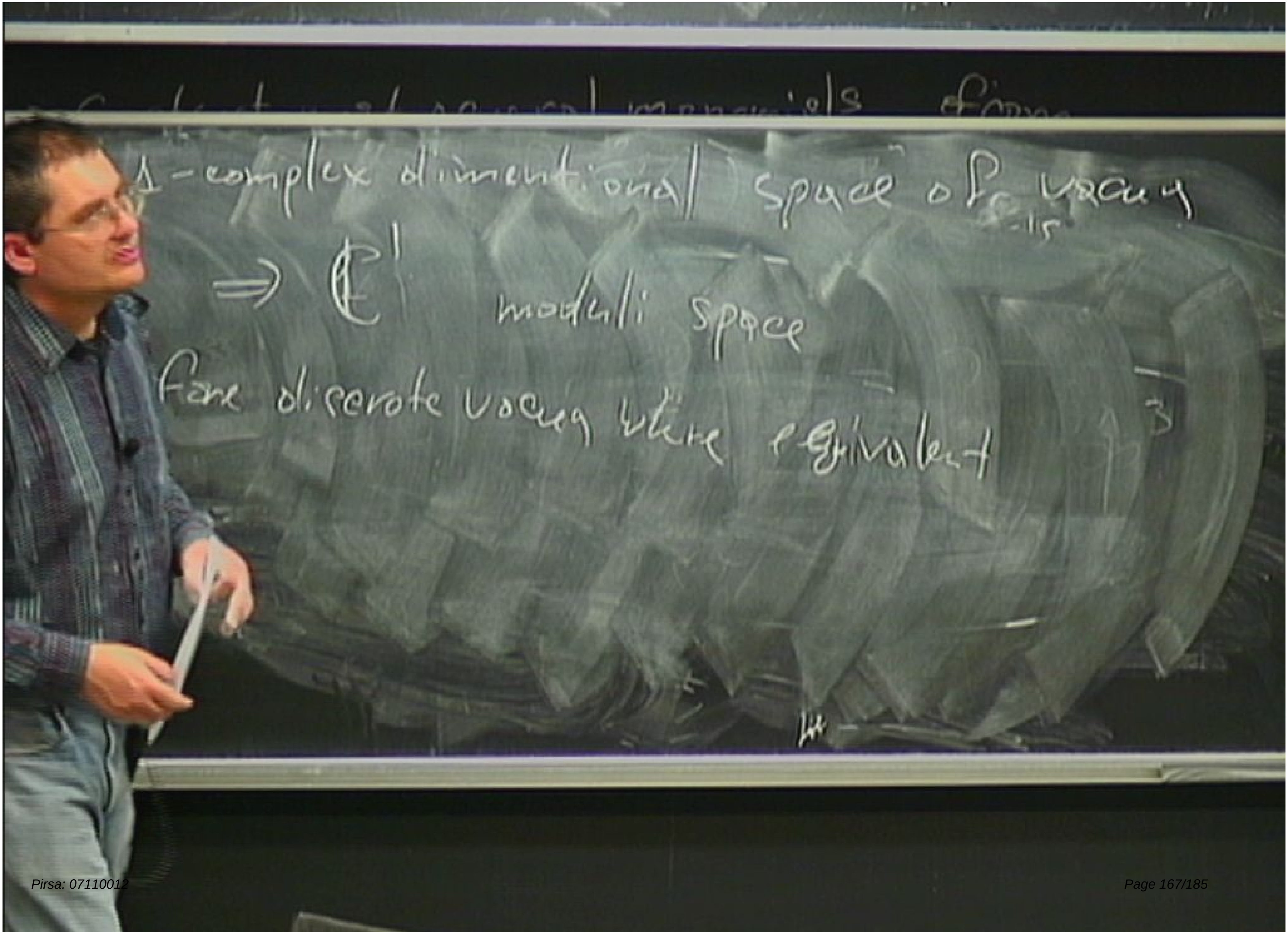
- Generic case B

$$W = \tfrac{1}{2}\lambda L H^2 \Rightarrow \left\{ \begin{aligned} \frac{\partial W}{\partial L} &= \tfrac{1}{2}\lambda H^2 = 0 \\ \frac{\partial W}{\partial H} &= \lambda L H = 0 \end{aligned} \right.$$

$$\Rightarrow \begin{aligned} &\langle H \rangle = 0 \\ &\langle L \rangle - \text{anything} \end{aligned}$$

$\Rightarrow$ a 1-complex dimensional space of vacua

$\Rightarrow \mathbb{C}^1$ moduli space


1-complex dimentional space of vacua
⇒ ℂ¹ moduli space
discrete vacua
equivalent

⇒ a 1-complex dimensional space of vacua

⇒ $\mathbb{C}^1$ moduli space

⇒ before discrete vacua were equivalent

⇒ Construct most general monomials of form

⇒ a 1-complex dimensional space of vacua

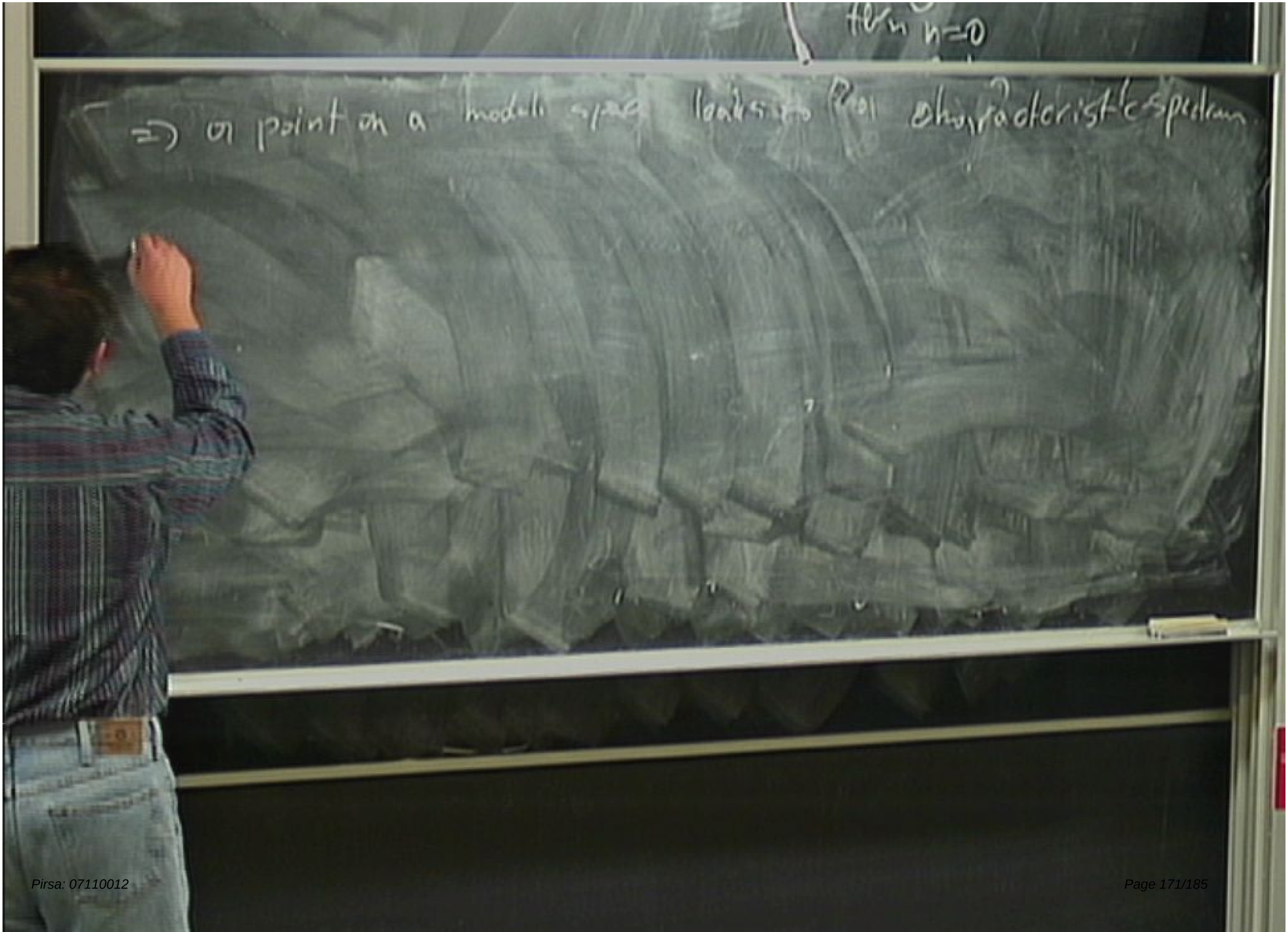
⇒ $\mathbb{C}^1$ moduli space

⇒ before discrete vacua were equivalent

⇒ has is equivalent vacua

$n=0$

$\Rightarrow$ a point on a moduli space leads to ?


⇒ a point on a moduli space leads to a characteristic spectrum.

$n=0$

$\Rightarrow$ a point on a moduli space leads to a characteristic spectrum.

$$H = \langle H \rangle + y$$

$$L = \langle L \rangle + X$$

$\Rightarrow$ a point on a moduli space leads to a characteristic spectrum

$$H = \langle H_i \rangle + y = y$$

$$L = \langle L \rangle + X = \langle L \rangle + X$$

then $n=0$

$\Rightarrow$ a point on a moduli space looks like Ross characteristic spectrum

$$W_{eff}(x,y) = \frac{\lambda}{2}\left[\langle L\rangle + x\right] y^2$$

$$H = \langle H\rangle + y = y$$

$$L = \langle L\rangle + X = \langle L\rangle + X$$

$\Rightarrow$ a point on a moduli space leads to a characteristic spectrum

$n=0$

$$H = \langle H \rangle + y = y$$

$$W_{pot}(x,y) = \frac{\lambda}{2}\left[\langle L \rangle + x\right] y^2$$

$$L = \langle L \rangle + X = \langle L \rangle + X$$

$\Rightarrow$ a point on a moduli space leads to a characteristic spectrum

$$H = \langle H \rangle + y = y$$

$$L = \langle L \rangle + X = \langle L \rangle + X$$

$$W_{eff}(x,y) = \frac{\lambda}{2}\left[\langle L \rangle + x\right] y^2$$

$$= \frac{\lambda \langle L \rangle}{2} y^2 + \frac{\lambda}{2} x y^2$$

$\Rightarrow$ a point on a moduli space leads to a characteristic spectrum

$$H = \langle H_i \rangle + y = y$$

$$L = \langle L \rangle + x = \langle L \rangle + x$$

$$W_{eff}(x,y) = \frac{\lambda}{2}\left[\langle L \rangle + x\right] y^2$$

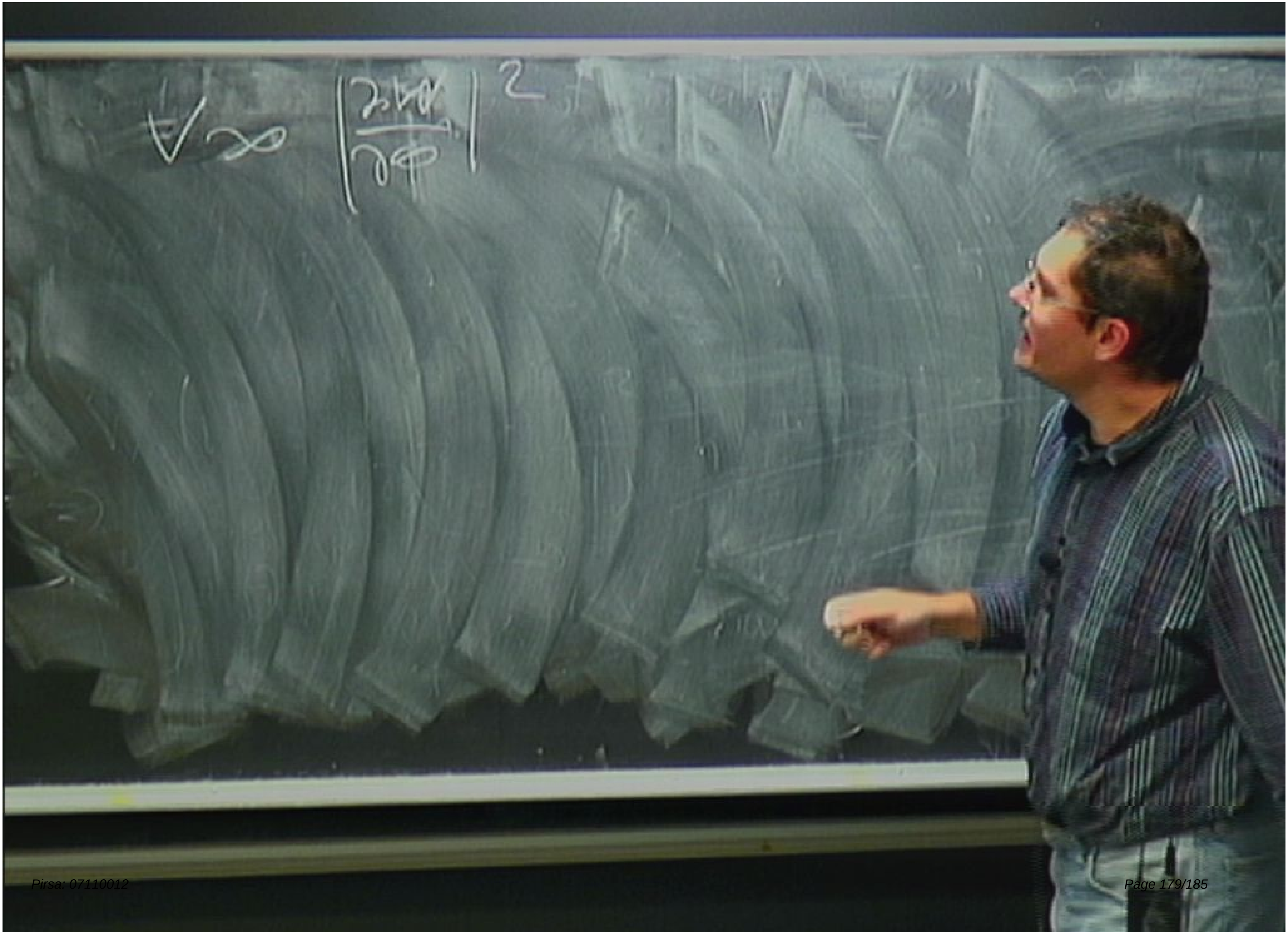
$$= \frac{\lambda \langle L \rangle}{2} y^2 + \frac{\lambda}{2} x y^2$$

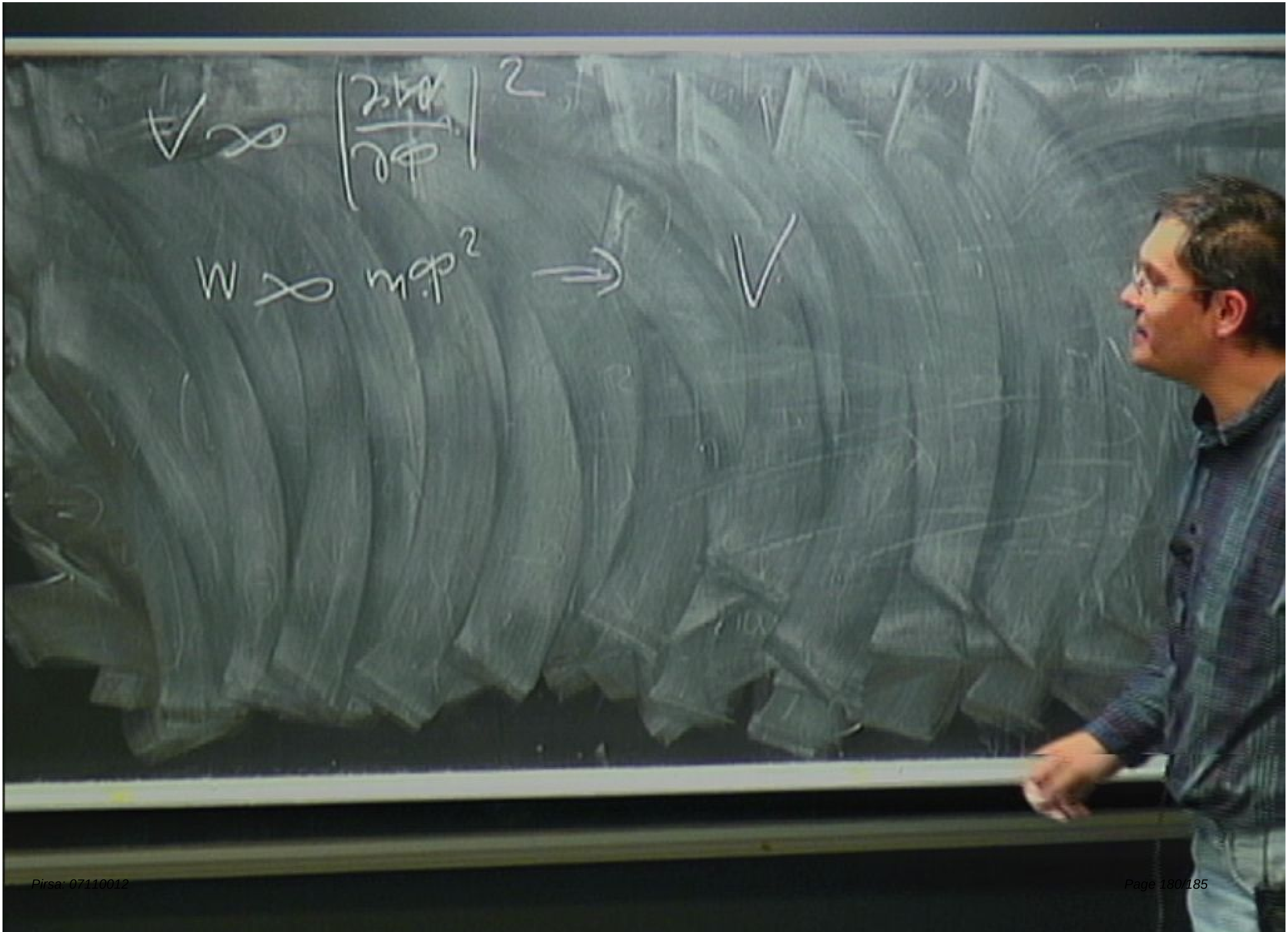
$$W_{eff}(x,y) = \frac{\lambda}{2}\left(\langle L\rangle + x\right)y^2$$

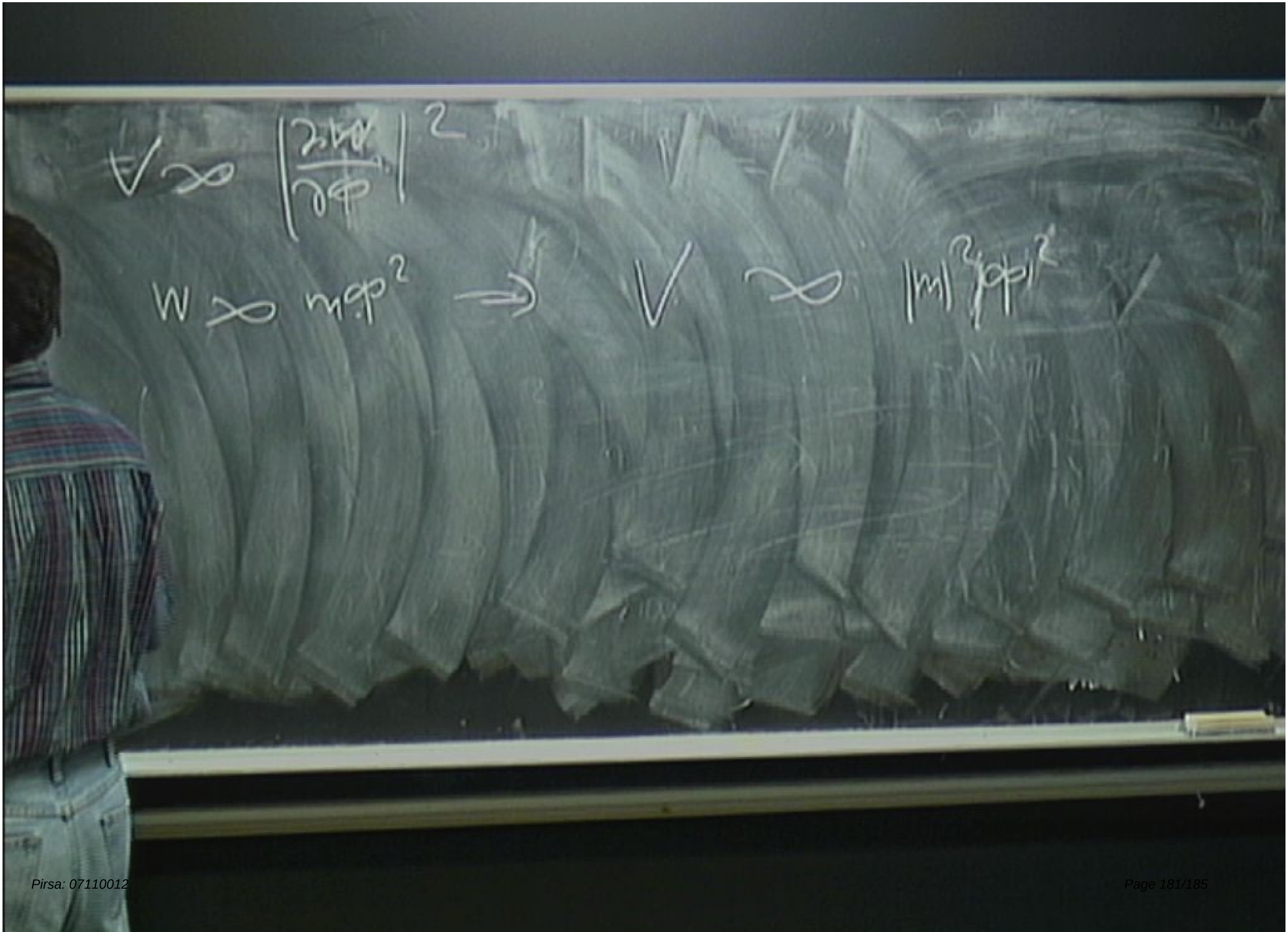
$$+\,x$$

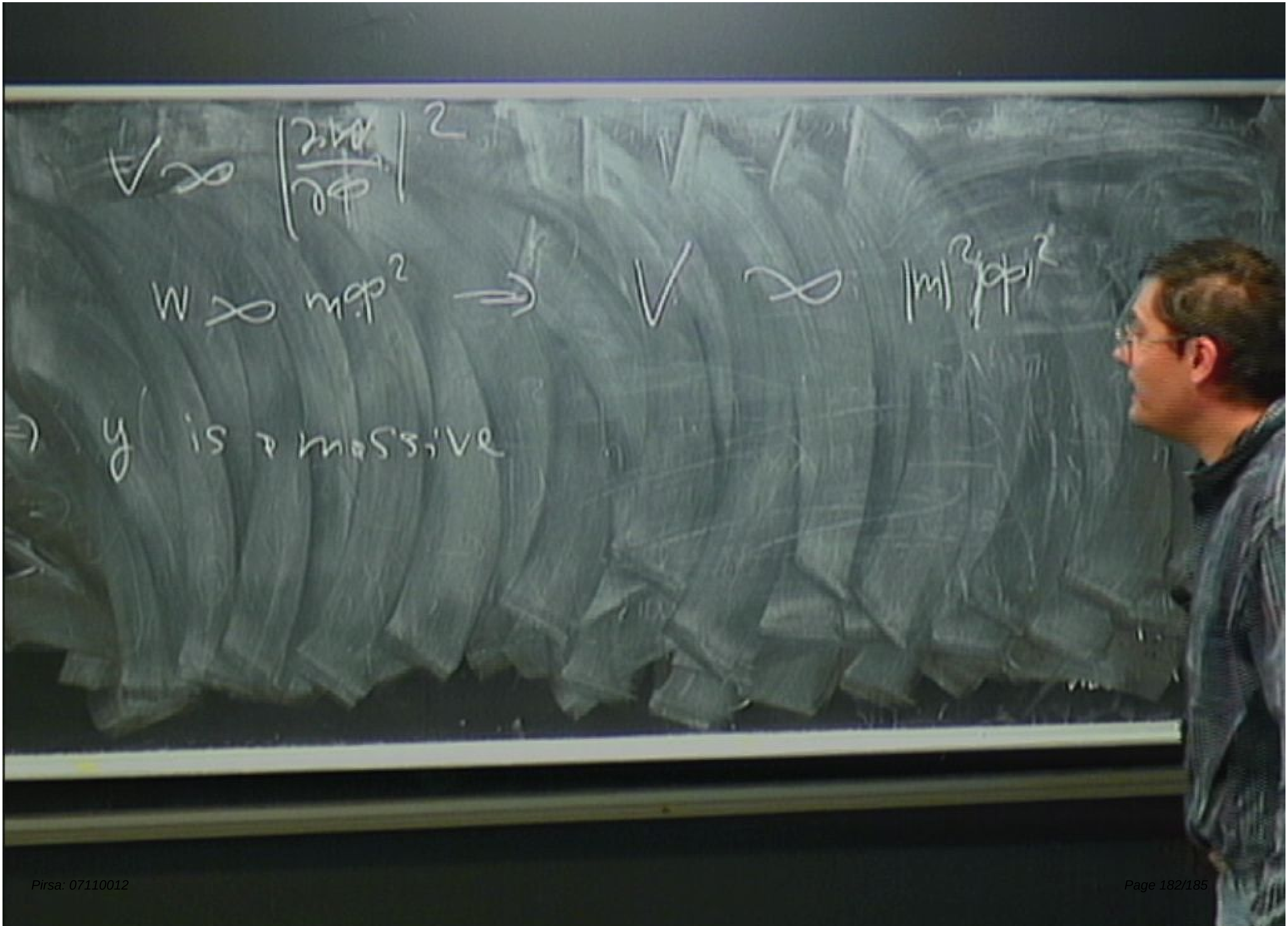
$$= \frac{\lambda\langle L\rangle}{2}y^2 + \frac{\lambda}{2}xy^2$$

"mass" term.




$W \propto m\phi^2 \Rightarrow V$

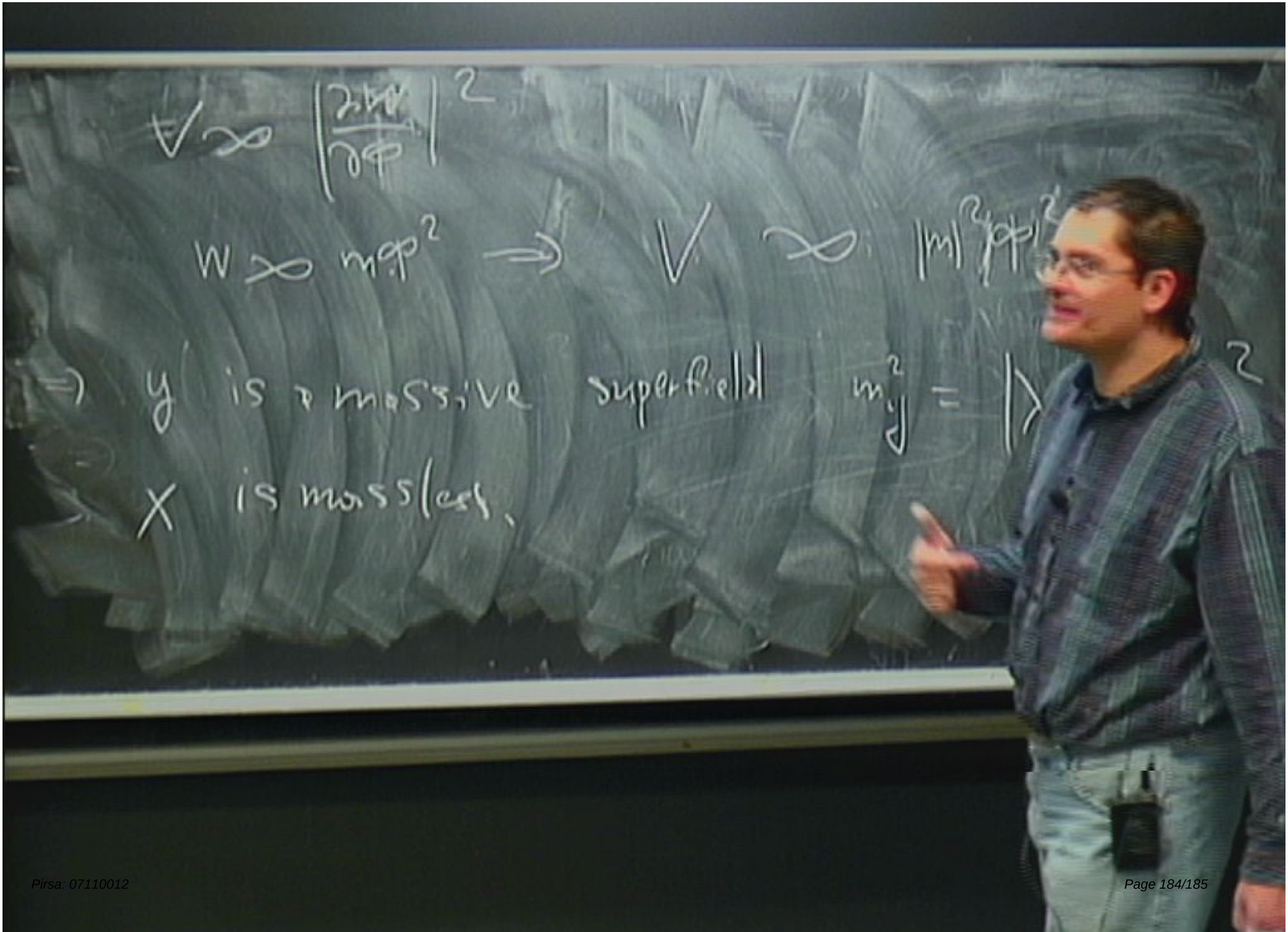

$V \propto \left|\frac{\partial W}{\partial \varphi}\right|^2$
$W \propto m\varphi^2 \Longrightarrow V \propto |m|^2|\varphi|^2$


$V \propto \left|\frac{\partial W}{\partial \phi}\right|^2$
$W \propto m\phi^2 \Longrightarrow V \propto |m|^2|\phi|^2$
$\Rightarrow$ y is a massive

$$V \propto \left|\frac{\partial W}{\partial \phi}\right|^2$$

$$W \propto m\phi^2 \Rightarrow V \propto |m|^2|\phi|^2$$

$\Rightarrow$ y is a massive superfield $m_y^2 = |\lambda \langle L \rangle|^2$


V ∝ |∂W/∂φ|²
W ∝ mφ² ⟹ V ∝ |m|²|φ|²
y is a massive superfield m_y² =
X is massless.

$$V \propto \left|\frac{\partial W}{\partial \phi}\right|^2$$

$$W \propto m\phi^2 \Rightarrow V \propto |m|^2|\phi|^2$$

$\Rightarrow$ y is a massive superfield $\quad m_y^2 = |\lambda \langle L \rangle|^2$

X is massless. (no term X^2 #)