Title: Intro to Supersymmetry 14

Date: Nov 01, 2007 12:30 PM

URL: http://pirsa.org/07110010

Abstract:

$\Rightarrow$ S_{eff} is a Legendre transform w.r.t. a source

$\Rightarrow$ S_{eff} is a Legendre transform w.r.t. a source of a generating functional for the connected corr. function

$$: W[J] = \ln Z[J]$$

$\Rightarrow$ S_{eff} is a Legendre transform wrt a source of a generating functional for the connected corr. function

$$: W[J] = \ln Z[J]$$

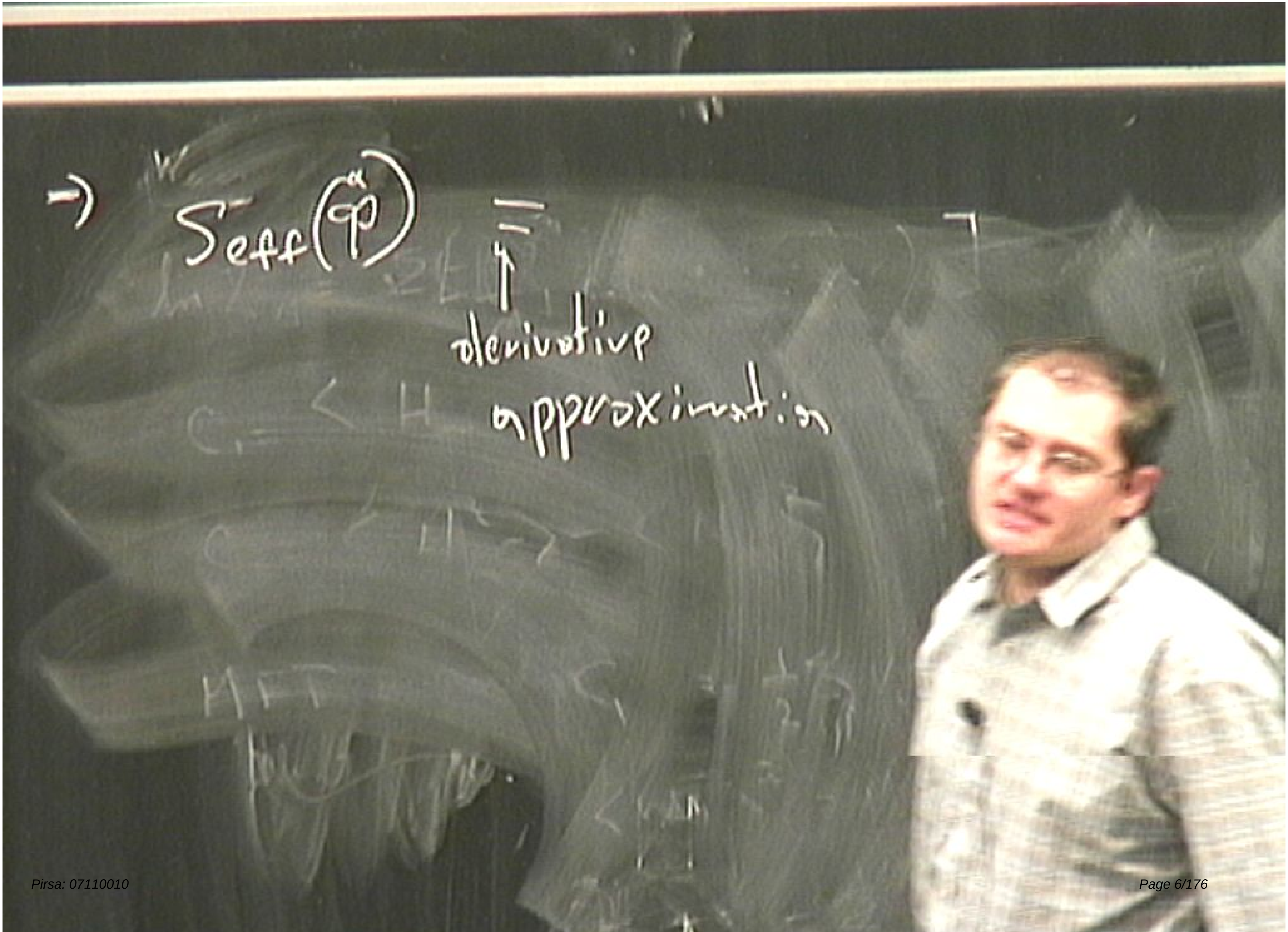
$$S_{eff}(\hat{\varphi}) = W[J] - \int d^n x\, J(x)\hat{\varphi}(x)$$

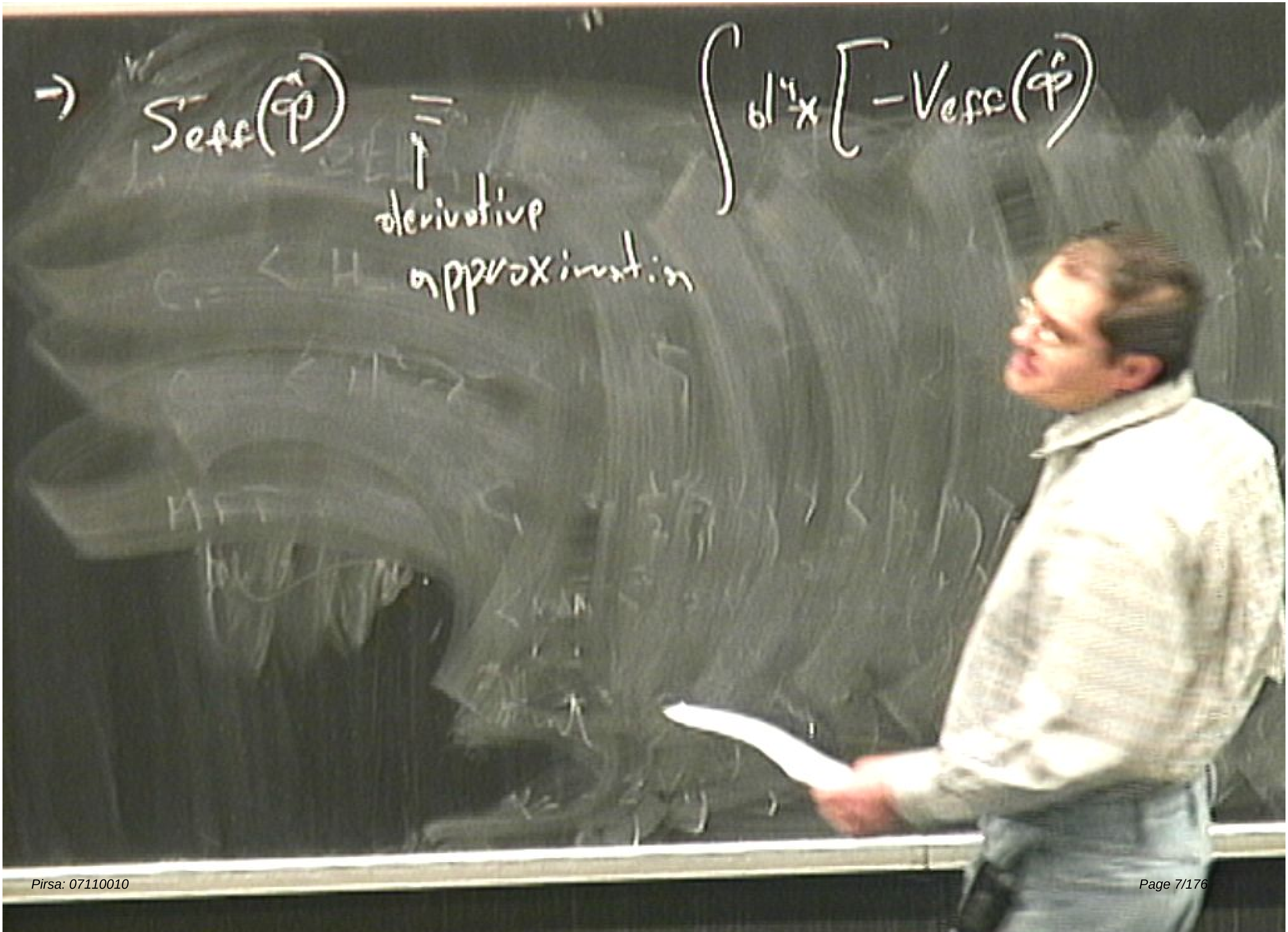
$\Rightarrow$ S_{eff} is a Legendre transform wrt a source of a generating functional for the connected corr. function

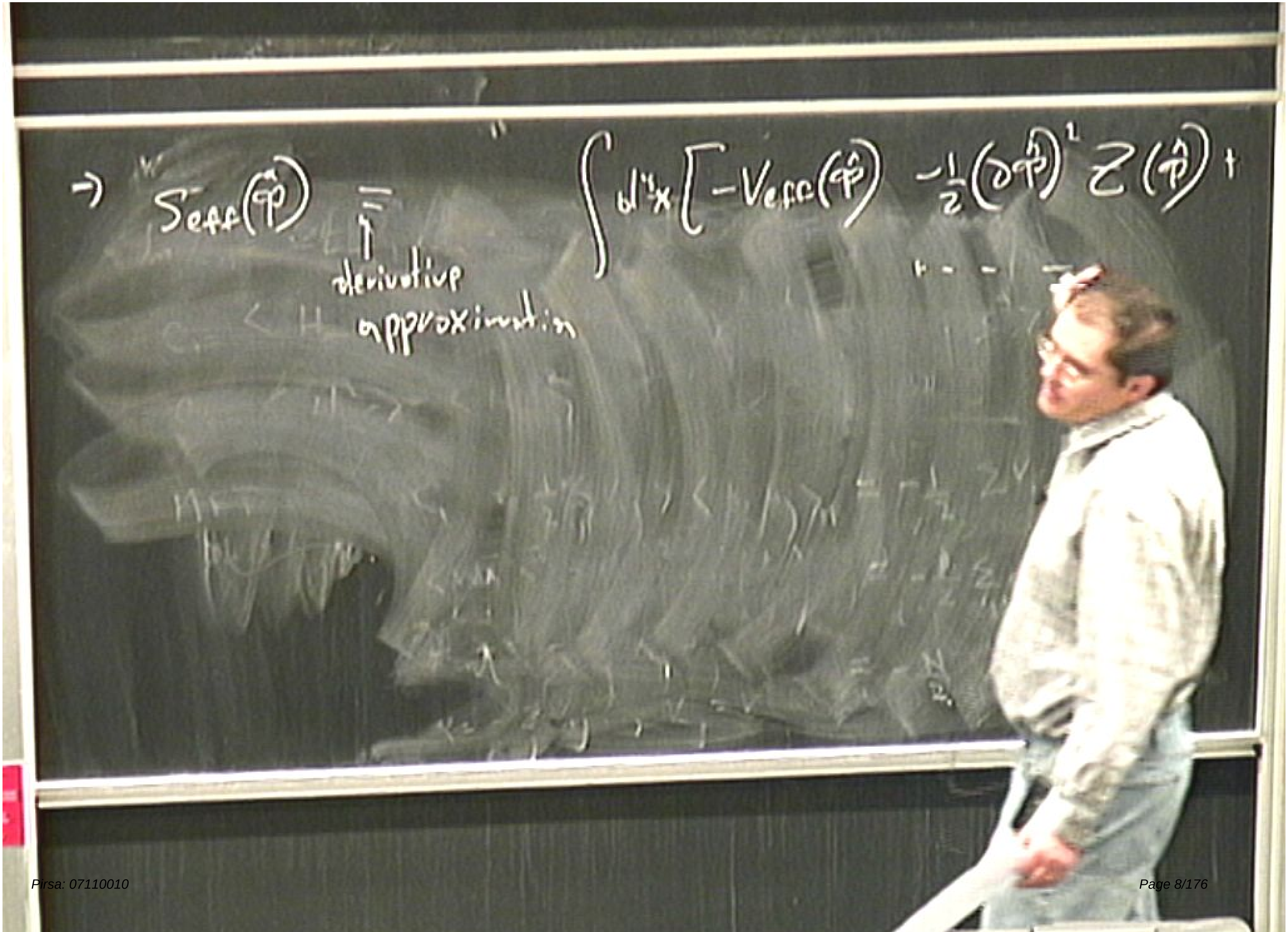
$$: W[J] = \ln Z[J]$$

$$S_{eff}(\hat{\varphi}) = W[J] - \int d^n x\, J(x)\hat{\varphi}(x)$$

$$\hat{\varphi}(x) = \frac{\delta W[J]}{\delta J(x)}$$


$S_{eff}(\varphi^{\alpha}) \equiv$
derivative
approximation


$\rightarrow \; S_{eff}(\hat{\varphi}) \;=\; \int d^4x \, [-V_{eff}(\hat{\varphi})$
derivative
approximation


→ Seff(φ̂) = ∫d⁴x [−Veff(φ̂) − ½(∂φ̂)² Z(φ̂) + . . .
derivative
approximation

$$\rightarrow \; S_{eff}(\hat{\varphi}) \underset{\substack{\uparrow \\ \text{derivative} \\ \text{approximation}}}{=} \int d^4x \left[-V_{eff}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 Z(\hat{\varphi}) + \cdots \right]$$

$\Rightarrow$ $S_{\text{eff}}(\hat{\varphi}) \underset{\substack{\uparrow \\ \text{derivative} \\ \text{approximation}}}{=} \int d^4x \left[-V_{\text{eff}}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 Z(\hat{\varphi}) + \dots \right]$

$\Rightarrow$ we do not quantize eff actions.

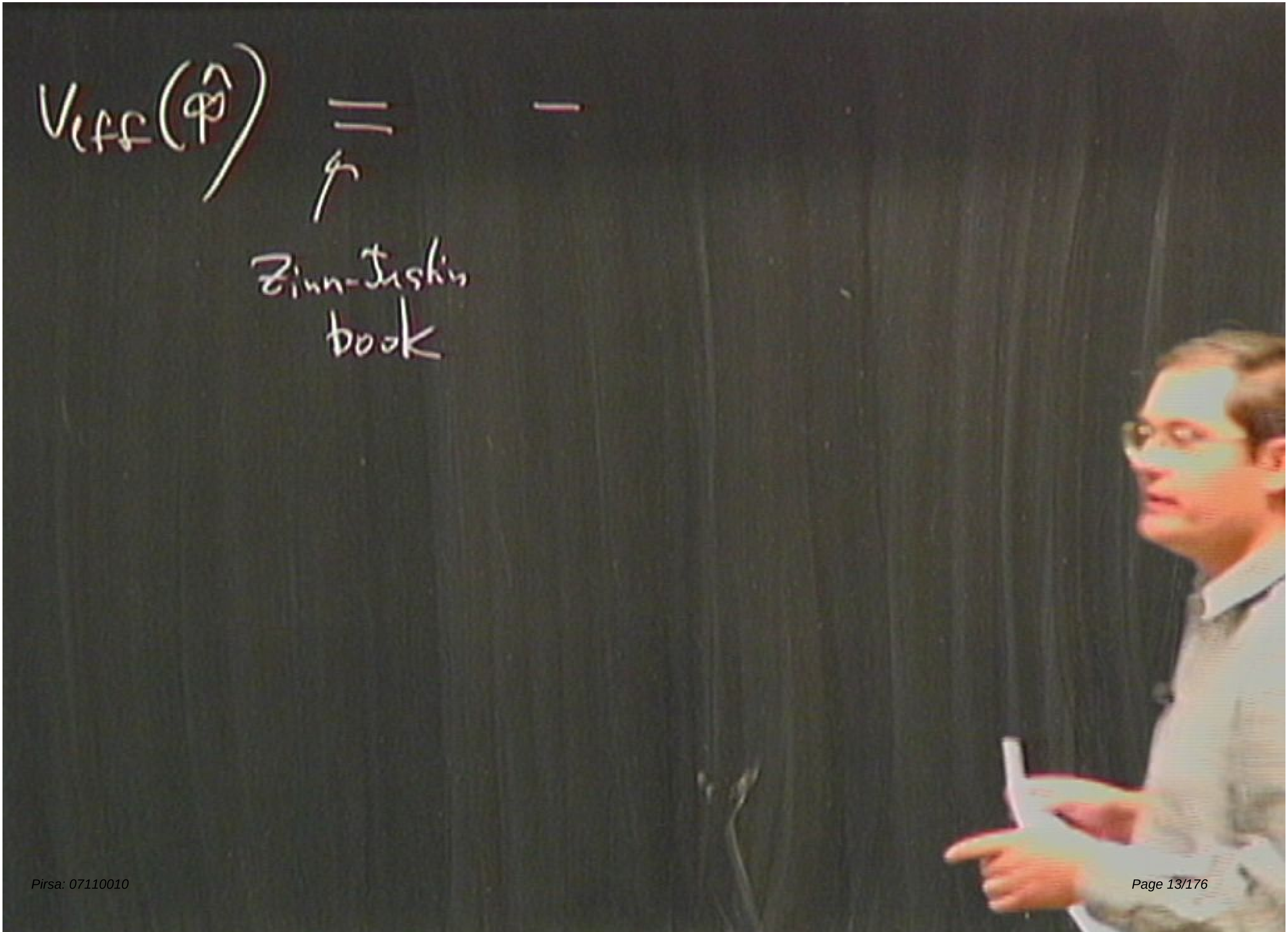
$\Rightarrow$ $S_{eff}(\hat{\varphi}) \underset{\substack{\uparrow \\ \text{derivative} \\ \text{approximation}}}{=} \int d^4x \left[-V_{eff}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 Z(\hat{\varphi}) + \dots \right]$

$\Rightarrow$ we do not quantize eff actions.

$\Rightarrow$ Remember in QFT observables are time-ordered correlation functions.

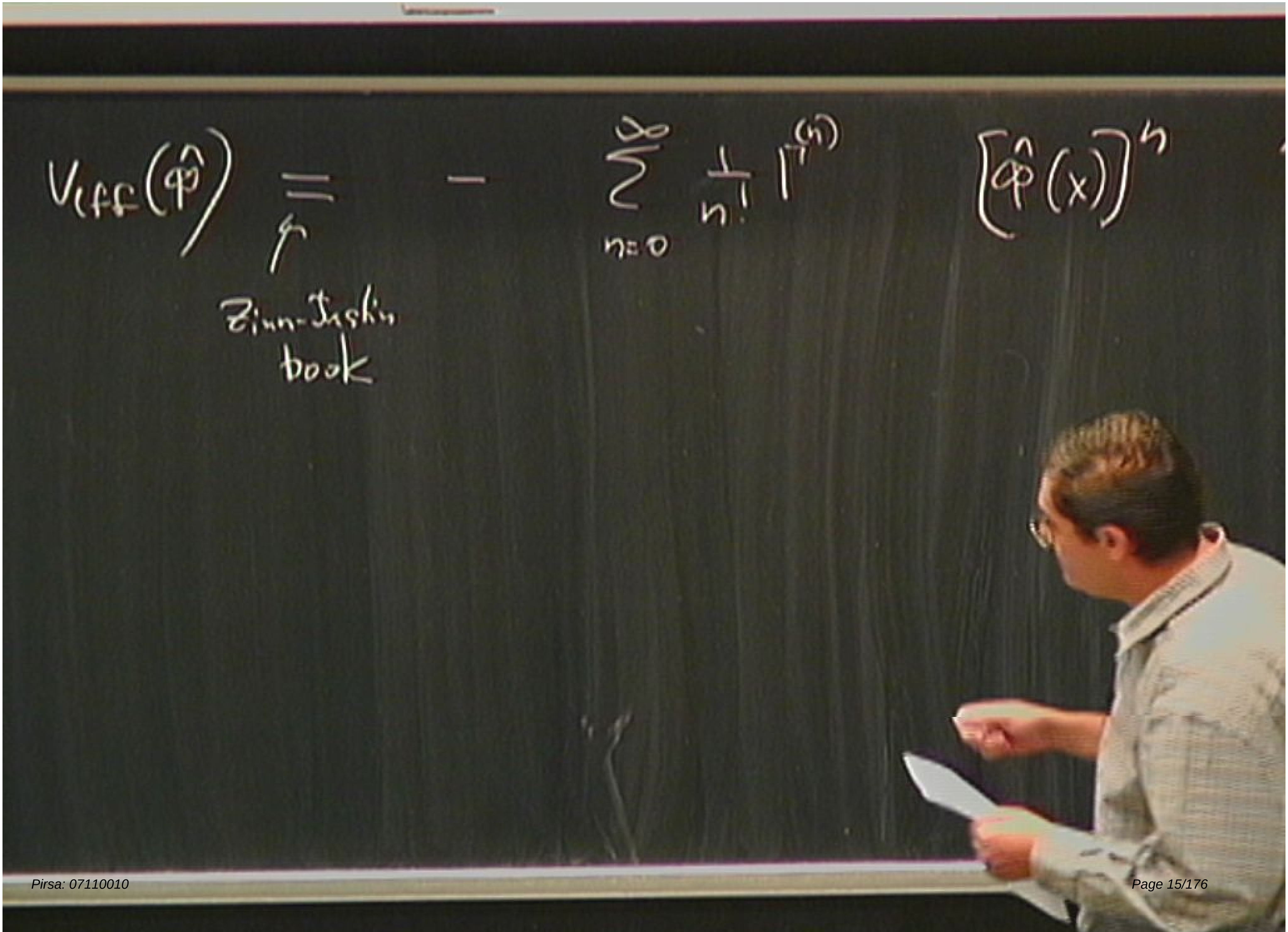
$V_{eff}(\hat{\varphi}) =$

Zinn-Justin book


$V_{eff}(\hat{\varphi}) = \quad -$
φ
Zinn-Justin
book

$$V_{\text{eff}}(\hat{\varphi}) \underset{\uparrow}{=} - \sum_{n=0}^{\infty} \frac{1}{n!} \qquad \left[\hat{\varphi}(x)\right]^n$$

Zinn-Justin book


$V_{eff}(\hat{\varphi}) = - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)} [\hat{\varphi}(x)]^n$
Zinn-Justin book

$$V_{eff}(\hat{\varphi}) \underset{\uparrow}{=} - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)}\underbrace{(0,0,0.0)}_{n\text{-zeros}} \left[\hat{\varphi}(x)\right]^n$$

Zinn-Justin book

$$V_{eff}(\hat{\varphi}) = - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)}\underbrace{(0,0,0,0)}_{n \text{ zeros}} \left[\hat{\varphi}(x)\right]^n$$

Zinn-Justin book

$\Gamma^{(n)}$ are the amputated correlation functions of our QFT at zero momenta

$$\underline{\underline{V_{eff}(\hat{\varphi})}} = - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)}\underbrace{(0,0,0..0)}_{n-\text{zeros}} [\hat{\varphi}$$

Zinn-Justin book

$\Gamma^{(n)}$ are the amputated correlation fu

of our QFT at zero mom

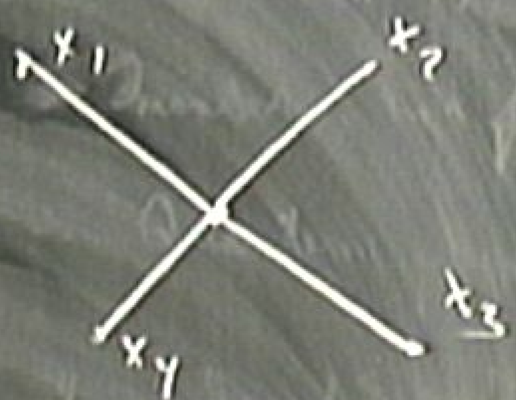
$$V_{eff}(\hat{\varphi}) \underset{\uparrow}{=} - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)}\underbrace{(0,0,0..0)}_{n\text{-zeros}} \left[\hat{\varphi}(x)\right]^n$$

Zinn-Justin book

$\Gamma^{(n)}$ are the amputated correlation functions of our QFT at zero momenta

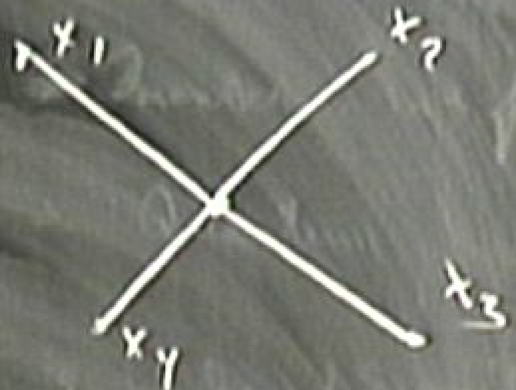
$$\langle T(\varphi(x), \varphi(0))\rangle = G^{(2)}(x)$$

$$\langle T(\varphi(x), \varphi(0)) \rangle = G^{(2)}(x)$$



$$G^{(4)}(x_1, x_2, x_3, x_4) = \langle T(\varphi(x_1) \cdots \varphi(x_4)) \rangle$$

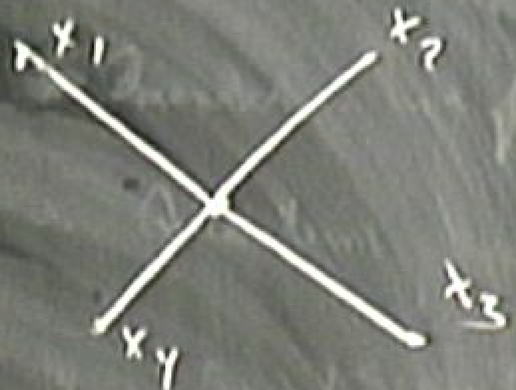
$$\langle T(\varphi(x),\varphi(0))\rangle = G^{(2)}(x)$$



$$G^{(4)}(x_1,x_2,x_3,x_4) = \langle T(\varphi_1(x_1)\cdots\varphi(x_4))\rangle$$

$$\Gamma^{(4)}(x_1\cdots x_4) =$$

$$\langle T(\varphi(x), \varphi(0))\rangle = G^{(2)}(x)$$



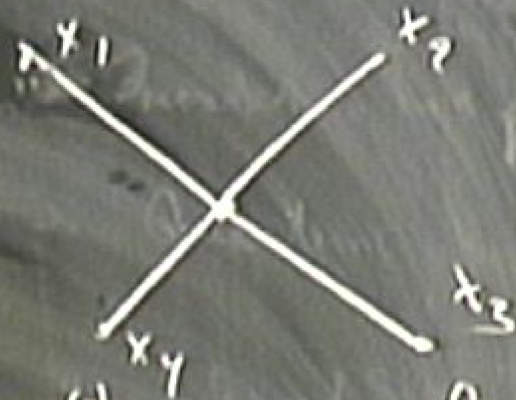
$$G^{(4)}(x_1, x_2, x_3, x_4) = \langle T(\varphi(x_1) \cdots \varphi(x_4))\rangle$$

$$\Gamma^{(4)}(x_1 \cdots x_4) = \frac{G^{(4)}(x_1 \cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$$

$$\ldots^{(4)}(x_1, x_2, x_3, x_4) = \langle T(\varphi_1(x_1) \cdots \varphi(x_4)) \ldots$$

$$\ldots(x_1 \cdots x_4) = \frac{G^{(4)}(x_1 \cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$$

$$\langle T(\varphi(x),\varphi(0))\rangle = G^{(2)}(x)$$

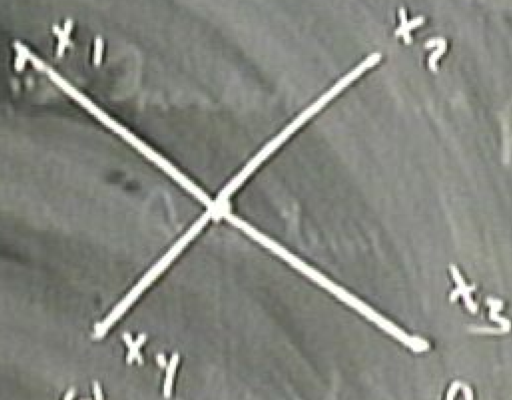


$$G^{(4)}(x_1,x_2,x_3,x_4) = \langle T(\varphi(x_1)\cdots\varphi(x_4))\rangle$$

$$\Gamma^{(4)}(x_1\cdots x_4) = \frac{G^{(4)}(x_1\cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$$

$$G^{(n)}(k_1,\cdots k_n) = \int \prod \frac{d^4 x_i}{(2\pi)^4}\, e^{+ik_i x_i}$$

$$\langle T(\varphi(x)\,\varphi(0))\rangle = G^{(2)}(x)$$

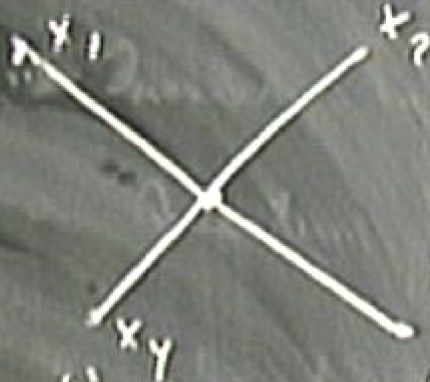


$$G^{(4)}(x_1, x_2, x_3, x_4) = \langle T(\varphi(x_1) \cdots \varphi(x_4))\rangle$$

$$\Gamma^{(4)}(x_1 \cdots x_4) = \frac{G^{(4)}(x_1 \cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$$

$$G^{(n)}(k_1 \cdots k_n) = \int \prod \frac{d^4 x_i}{(2\pi)^4}\, e^{+ik_i x_i}\, G^{(n)}(x_1 \cdots x_n)$$

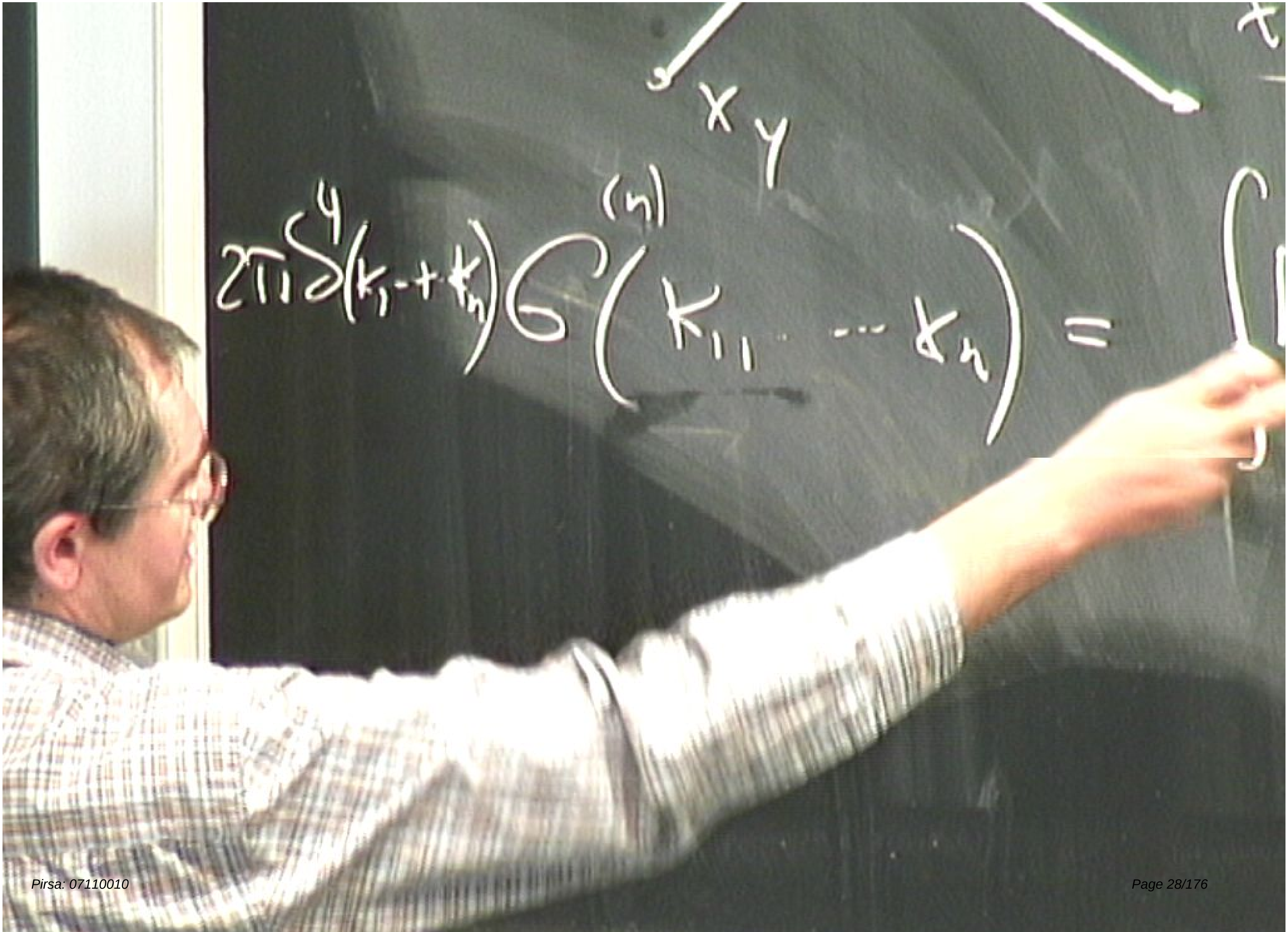
$$\langle T(\varphi(x),\varphi(0))\rangle = G^{(2)}(x)$$

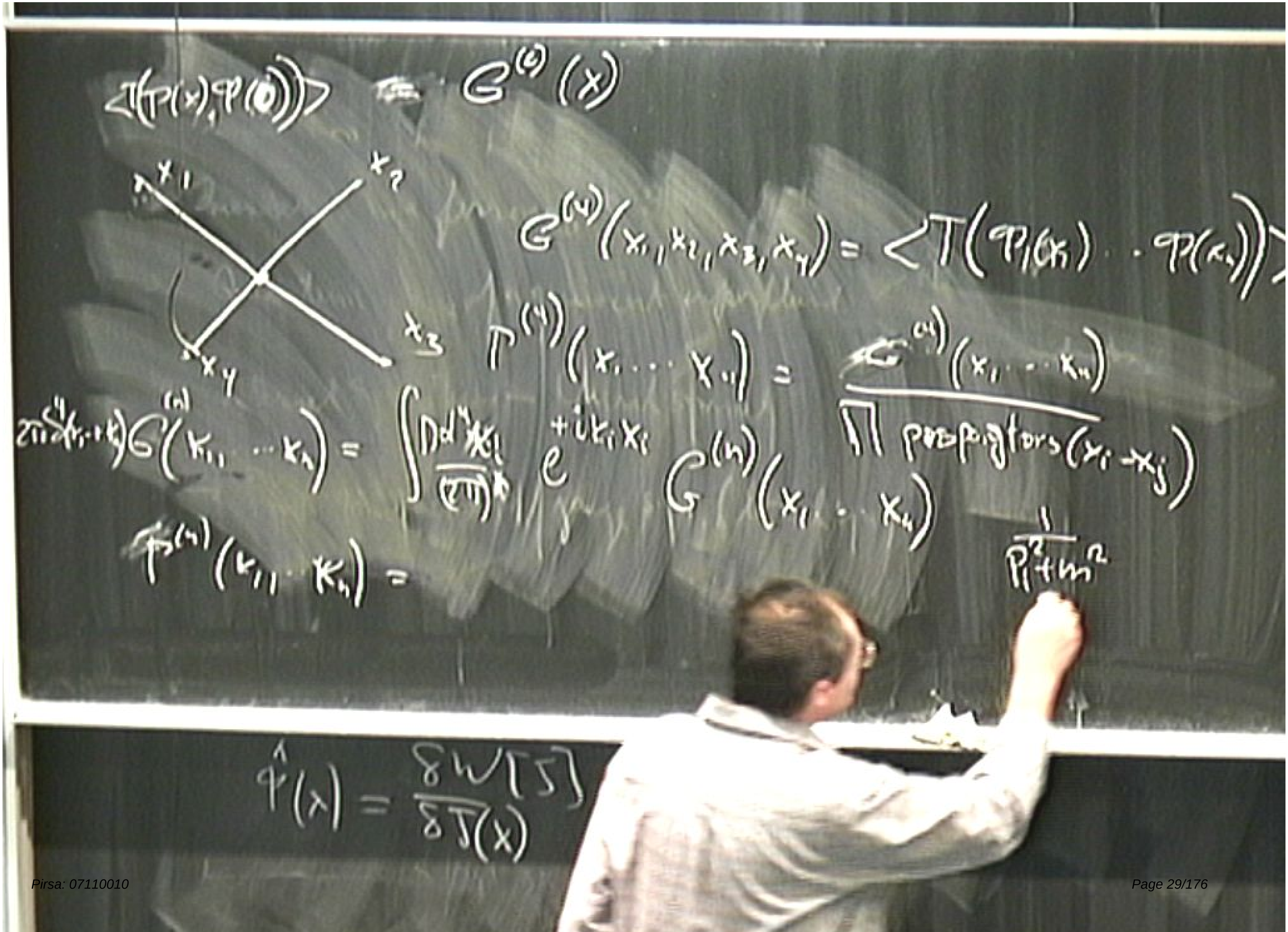


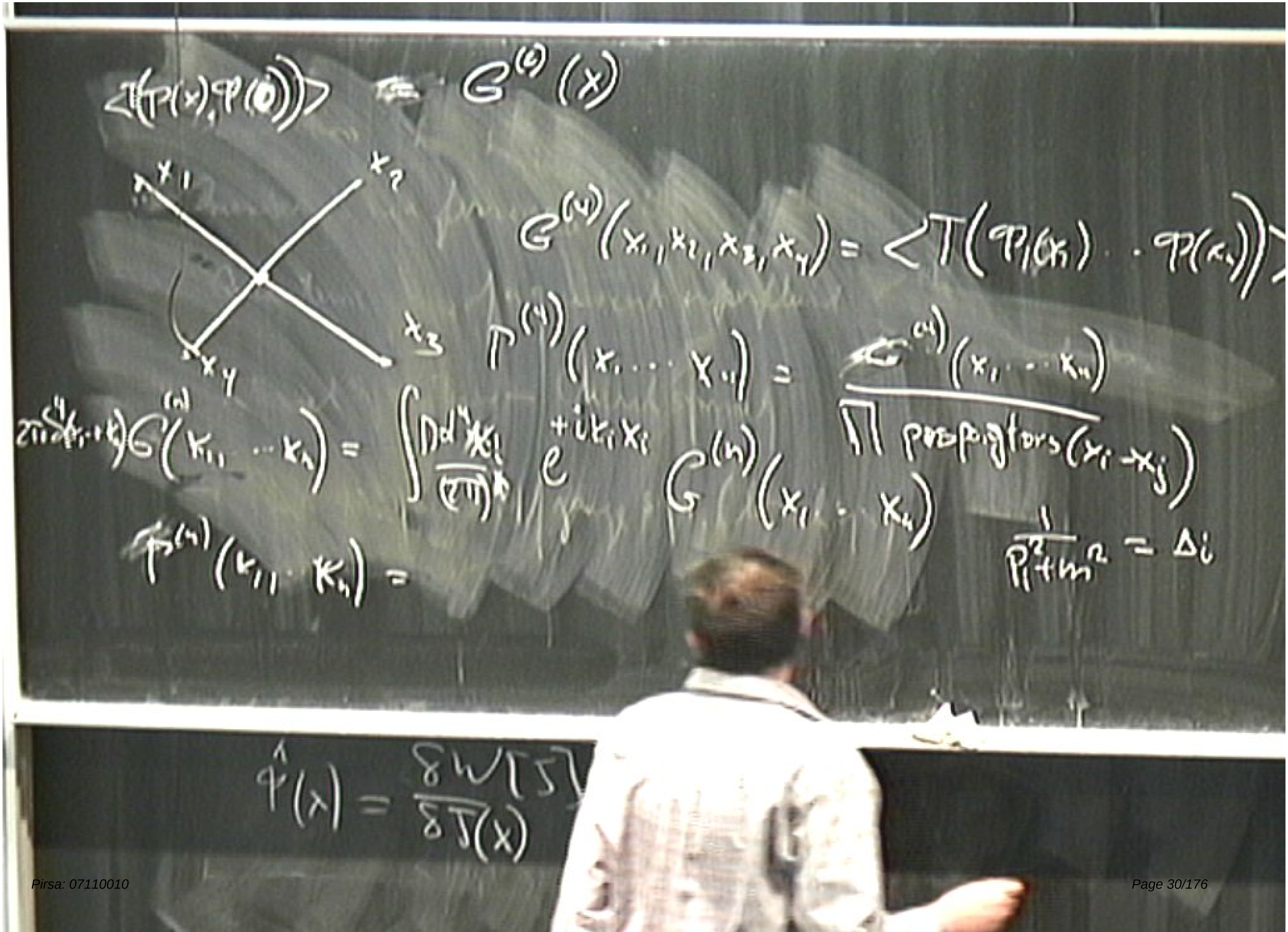
$$G^{(4)}(x_1,x_2,x_3,x_4) = \langle T(\varphi(x_1)\cdots\varphi(x_4))\rangle$$

$$\Gamma^{(4)}(x_1\cdots x_4) = \frac{G^{(4)}(x_1\cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$$

$$(2\pi)^4\delta(k_1+\cdots+k_4)\, G^{(n)}(k_1\cdots k_n) = \int \prod \frac{d^4x_i}{(2\pi)^4}\, e^{+ik_i x_i}\, G^{(n)}(x_1\cdots x_n)$$


x y
$(2\pi)^4\delta^4(k_1+\dots+k_n)\,G^{(n)}(k_1,\dots,k_n) =$


$\langle T(\varphi(x), \varphi(0))\rangle = G^{(2)}(x)$
x_1
x_2
x_3
x_4
$G^{(4)}(x_1, x_2, x_3, x_4) = \langle T(\varphi(x_1) \cdots \varphi(x_4))\rangle$
$\Gamma^{(4)}(x_1 \cdots x_4) = \dfrac{G^{(4)}(x_1 \cdots x_4)}{\prod \text{propagators}(x_i - x_j)}$
$(2\pi)^4\delta^4(k_1+\cdots+k_n)\, G^{(n)}(k_1 \cdots k_n) = \int \prod \dfrac{d^4x_i}{(2\pi)^4} e^{+ik_i x_i} G^{(n)}(x_1 \cdots x_n)$
$\Gamma^{(n)}(k_1 \cdots k_n) =$
$\dfrac{1}{p_i^2+m^2}$
$\hat{\varphi}(x) = \dfrac{\delta W[J]}{\delta J(x)}$

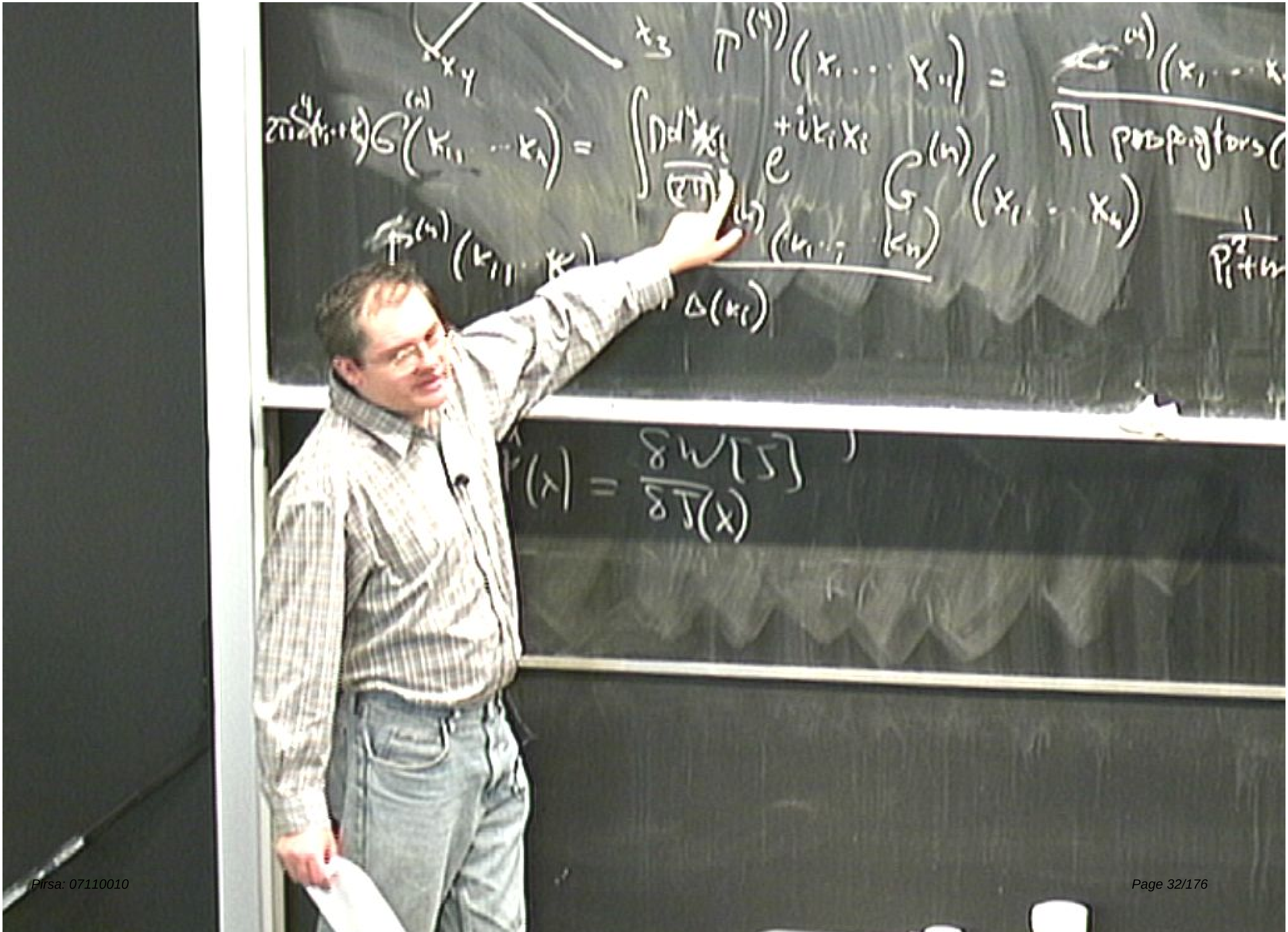

<T(φ(x) φ(0))> = G(2)(x)
x1 x2 x3 x4
G(4)(x1, x2, x3, x4) = <T(φ(x1) ... φ(xn))>
Γ(4)(x1 ... x4) = G(4)(x1 ... x4) / ∏ propagators(xi - xj)
G(n)(k1, ... kn) = ∫ ∏ d4xi / (2π)4 e+ikixi G(n)(x1 ... x4)
1 / (pi2 + m2) = Δi
Γ(n)(k1, ... kn) =
φ̂(x) = δW[J] / δJ(x)

$$\Gamma^{(n)}(x_1 \cdots x_n) =$$

$$(\cdots + k_n)\, G^{(n)}(k_1, \cdots k_n) = \int \prod \frac{d^4 x_i}{(2\pi)^4}\, e^{+i k_i x_i}\, G^{(n)}(x_1 \cdots$$

$$\Gamma^{(n)}(k_1 \cdots k_n) = \frac{G^{(n)}(k_1 \cdots k_n)}{\prod \Delta(k_i)}$$

$$\hat{\varphi}(x) = \frac{\delta W[J]}{\delta J(x)}$$



Order by order in perturbation theory.

$V = \underline{m^2}$

Order by order in perturbation theory.

$$V = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

Order by order in perturbation theory.

$$V = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

Order by order in perturbation theory.

$$V_{\text{class.}} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

$(-i\lambda)$

Order by order in perturbation theory.

$$V_{clas.} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

$(-i\lambda)$ + loop correction

Order by order in perturbation theory.

$$V_{\text{clas.}} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

 $(-i\lambda)$ + loop correction 

Order by order in perturbation theory.

$$V_{class} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

 $(-i\lambda)$ + loop correction  +

+

Order by order in perturbation theory

$$V_{\text{clas.}} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

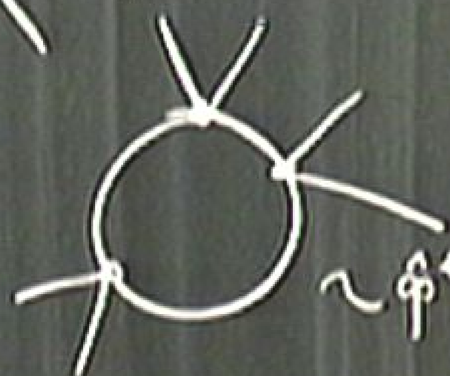
 $(-i\lambda)$ + loop correction $\Big\{$  +

\+ 

Order by order in perturbation theory.

$$V_{\text{cla.}} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

 $(-i\lambda)$ + loop correction $\Big\{$  +

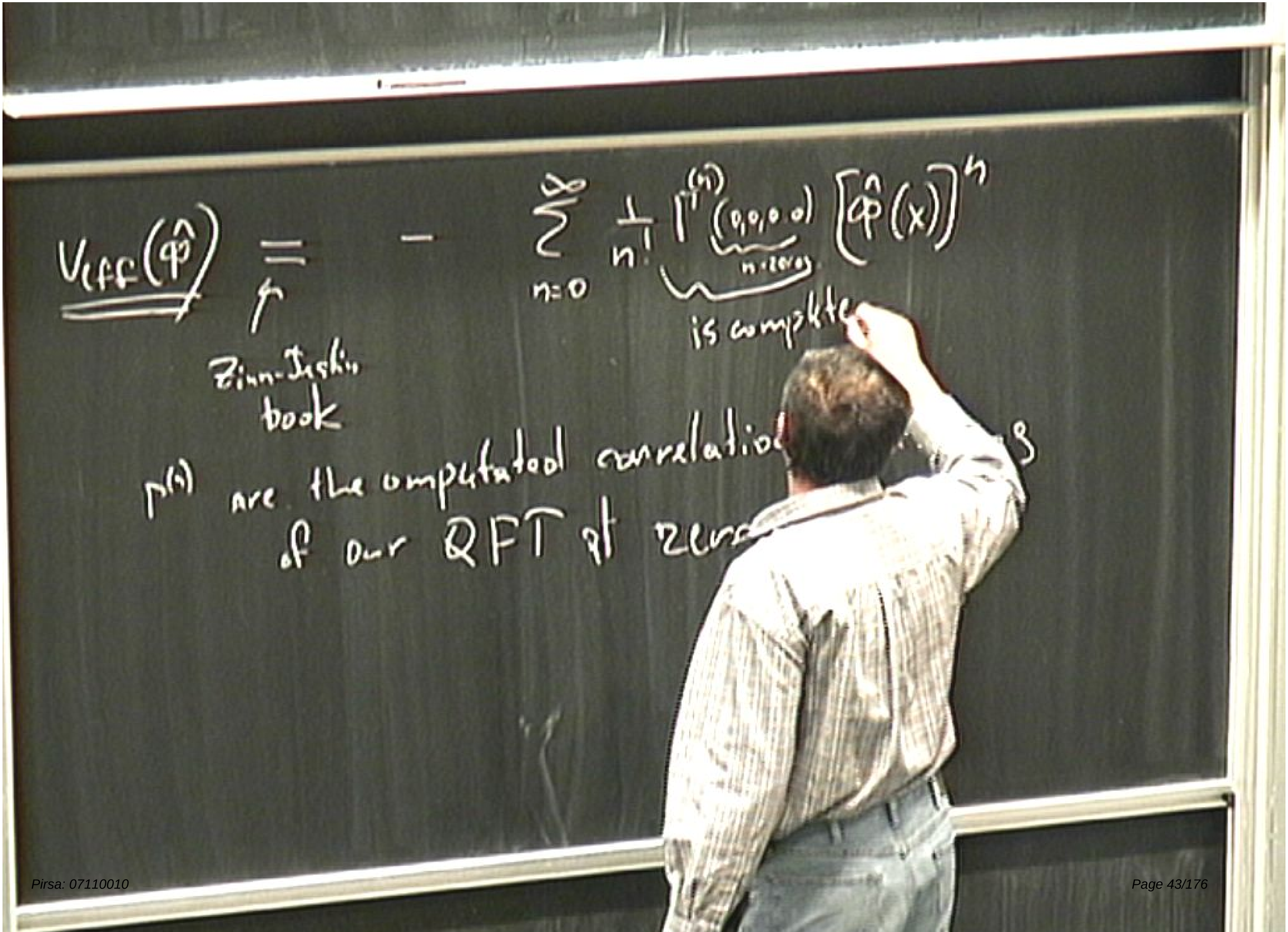
+  $\sim \varphi^6$

Order by order in perturbation theory.

$$V_{\text{clas.}} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

 $(-i\lambda)$ + loop correction $\Big\{$  +

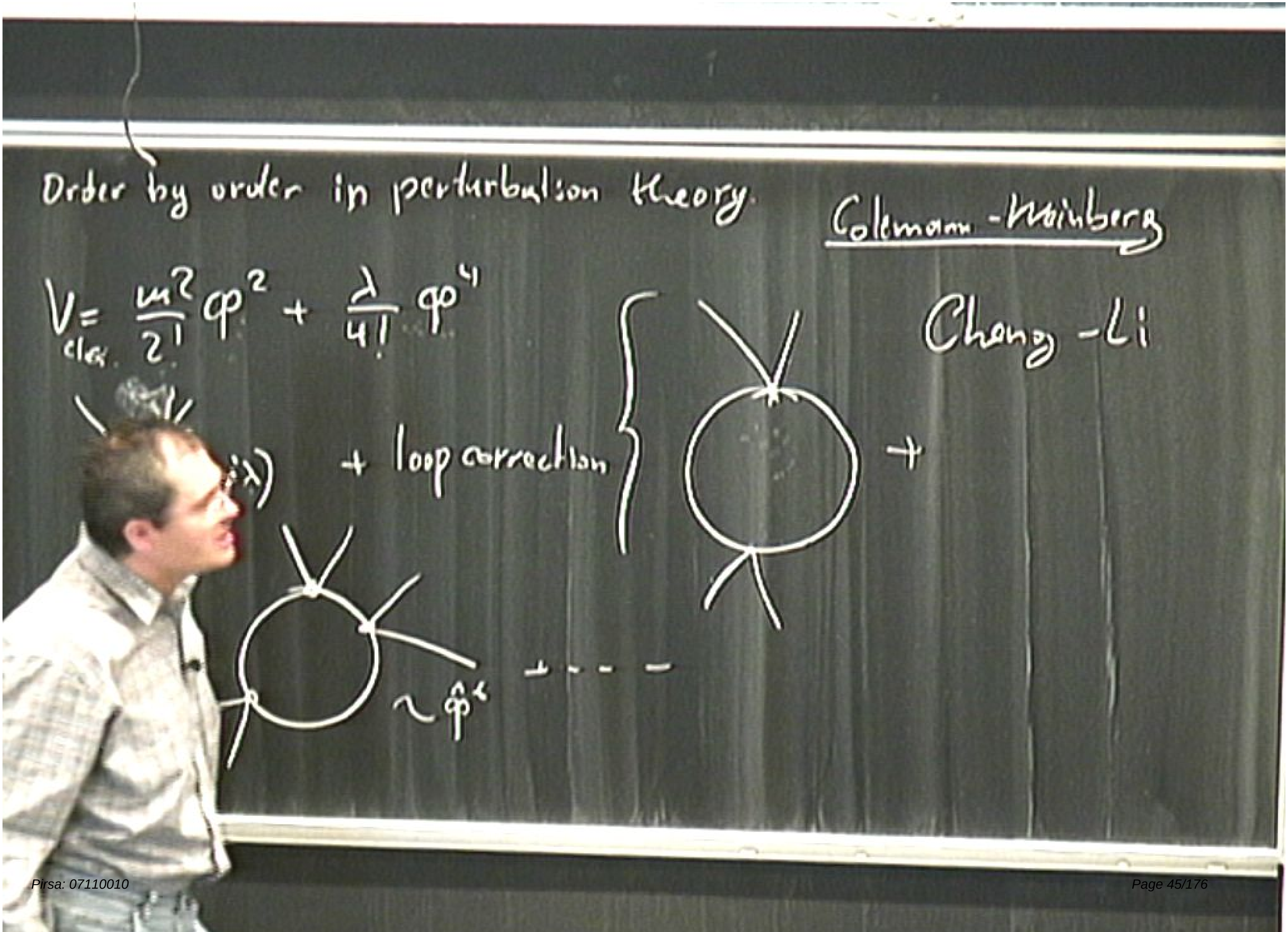
+  $\sim \varphi^6$ + - - - -

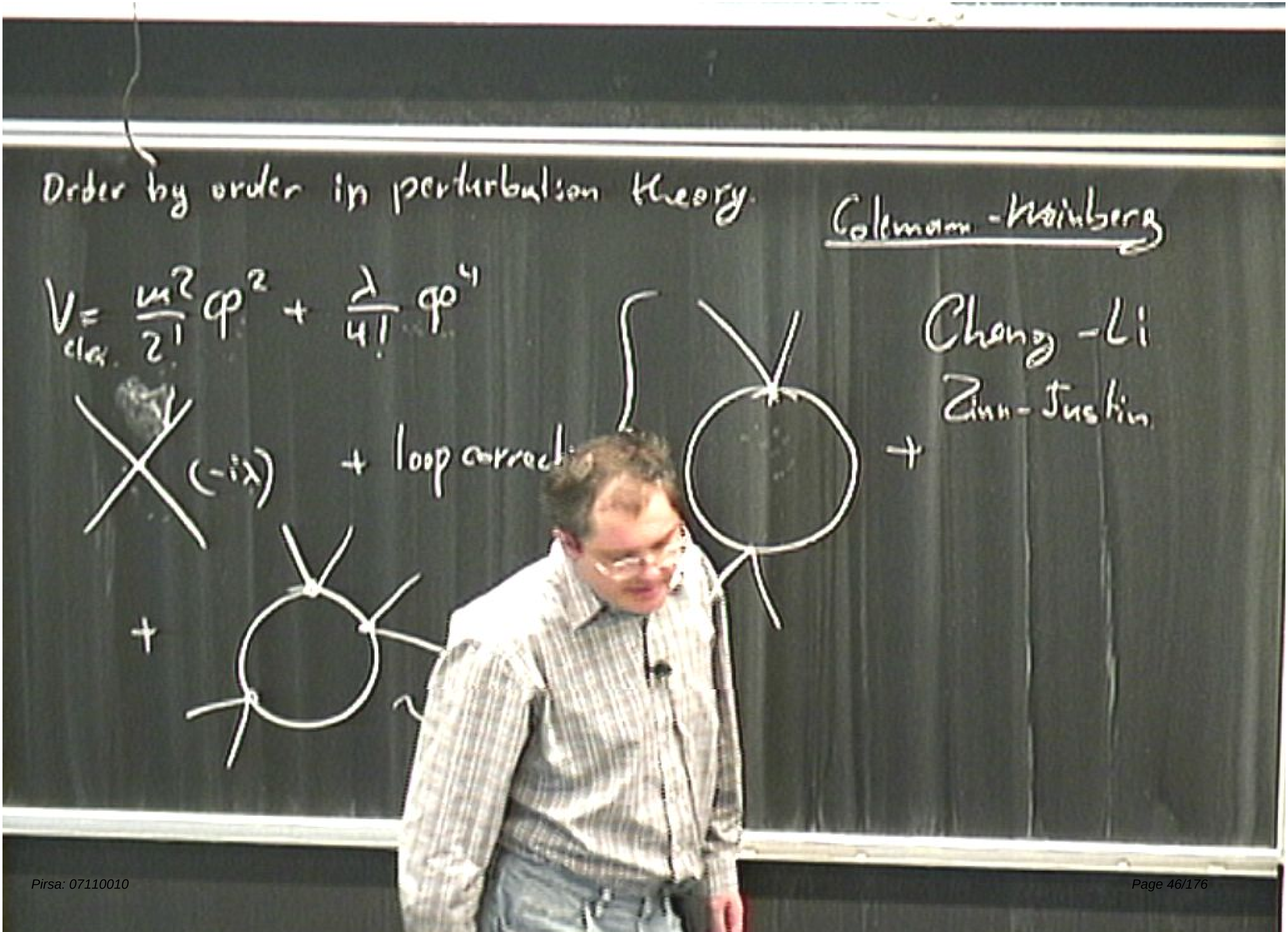

$V_{eff}(\hat{\varphi}) = - \sum_{n=0}^{\infty} \frac{1}{n!} \Gamma^{(n)}(\underbrace{0,0,0..0}_{n\ zeros}) \left[\hat{\varphi}(x)\right]^n$
is complete
Zinn-Justin book
$\Gamma^{(n)}$ are the amputated correlation
of our QFT at zero

$$\underline{\underline{V_{eff}(\hat{\varphi})}} \underset{\uparrow}{=} - \sum_{n=0}^{\infty} \frac{1}{n!} \underbrace{\Gamma^{(n)}\underbrace{(0,0,0..0)}_{n\text{ zeros}}}_{\text{is completed to 1-loop order}} \left[\hat{\varphi}(x)\right]^n$$

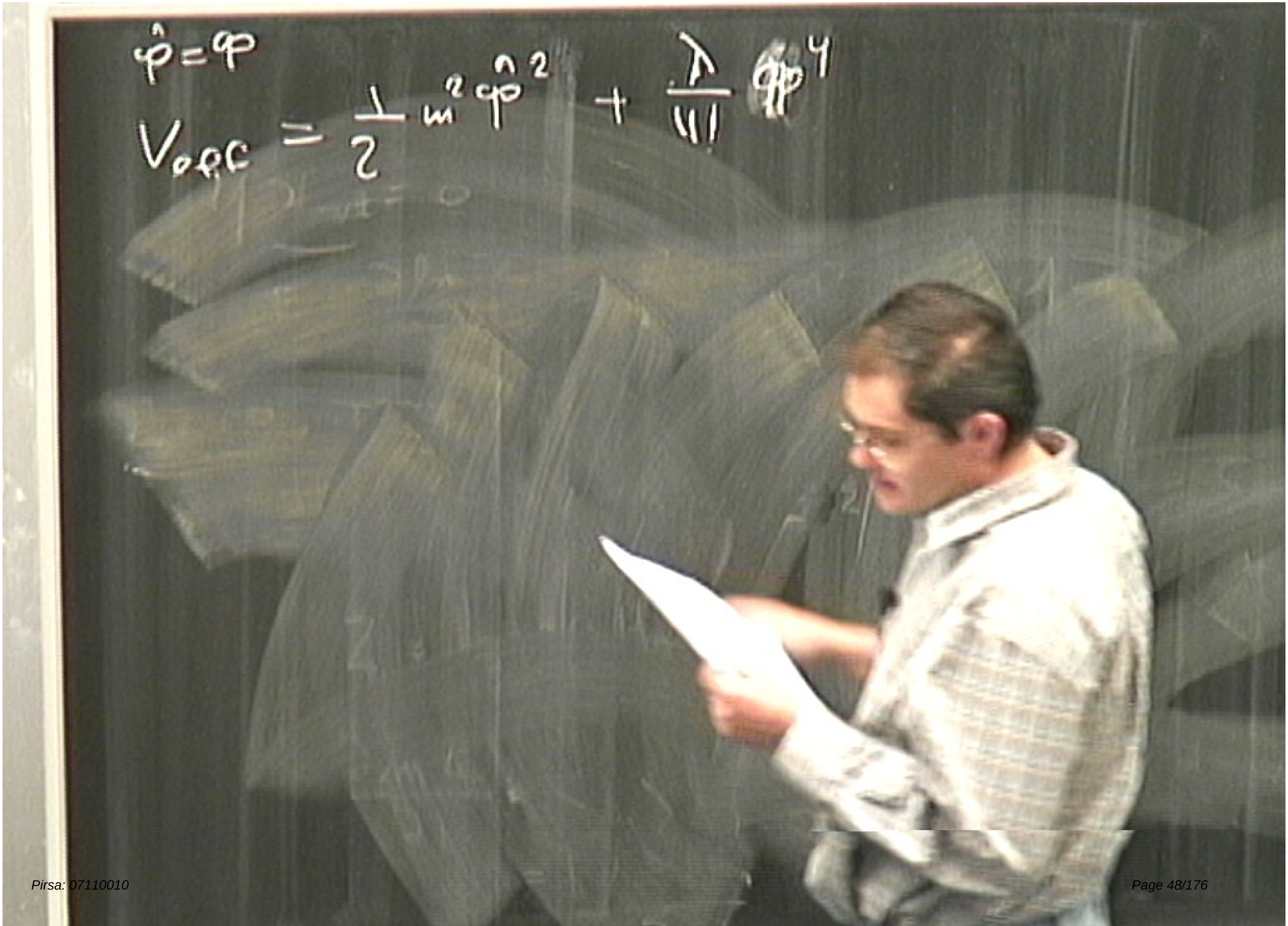
Zinn-Justin book

$\Gamma^{(n)}$ are the computed correlation functions of our QFT at zero momenta.


Order by order in perturbation theory.
Coleman-Weinberg
$V_{clas} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$
Chang-Li
+ loop correction
+
$\sim \hat{\varphi}^6$
+ - - -


Order by order in perturbation theory.
Coleman-Weinberg
$V_{clas.} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$
Chang-Li
Zinn-Justin
$(-i\lambda)$
+ loop correcti
+
+

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2$$


$\hat{\varphi} = \varphi$
$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!} \varphi^4$

$\hat{\varphi} = \varphi$

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!} \hat{\varphi}^4 + \frac{m^4_{eff}(\varphi)}{64\pi^2} \left[\ln \frac{m^2_{eff}(\varphi)}{m^2} + \cdots \right]$$

$$\hat{\varphi} = \varphi$$

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!} \hat{\varphi}^4 + \frac{m_{eff}^4(\varphi)}{64\pi^2} \left[\ln \frac{m_{eff}^2(\varphi)}{m^2} + \cdots \right]$$

$$m_{eff}^2(\varphi) = m^2 + \frac{\lambda}{2} \hat{\varphi}^2$$

$\rightarrow \quad S_{eff}(\hat{\varphi}) = \int d^4x \left[-V_{eff}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 Z(\hat{\varphi}) \right]$

$\hat{\varphi} = \varphi$

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!} \hat{\varphi}^4 + \frac{m^4_{eff}(\hat{\varphi})}{64\pi^2} \left[\ln \frac{m^2_{eff}(\hat{\varphi})}{\mu^2} + \cdots \right]$$

$$m^2_{eff}(\hat{\varphi}) = m^2 + \frac{\lambda}{2} \hat{\varphi}^2$$

arbitrary scale μ

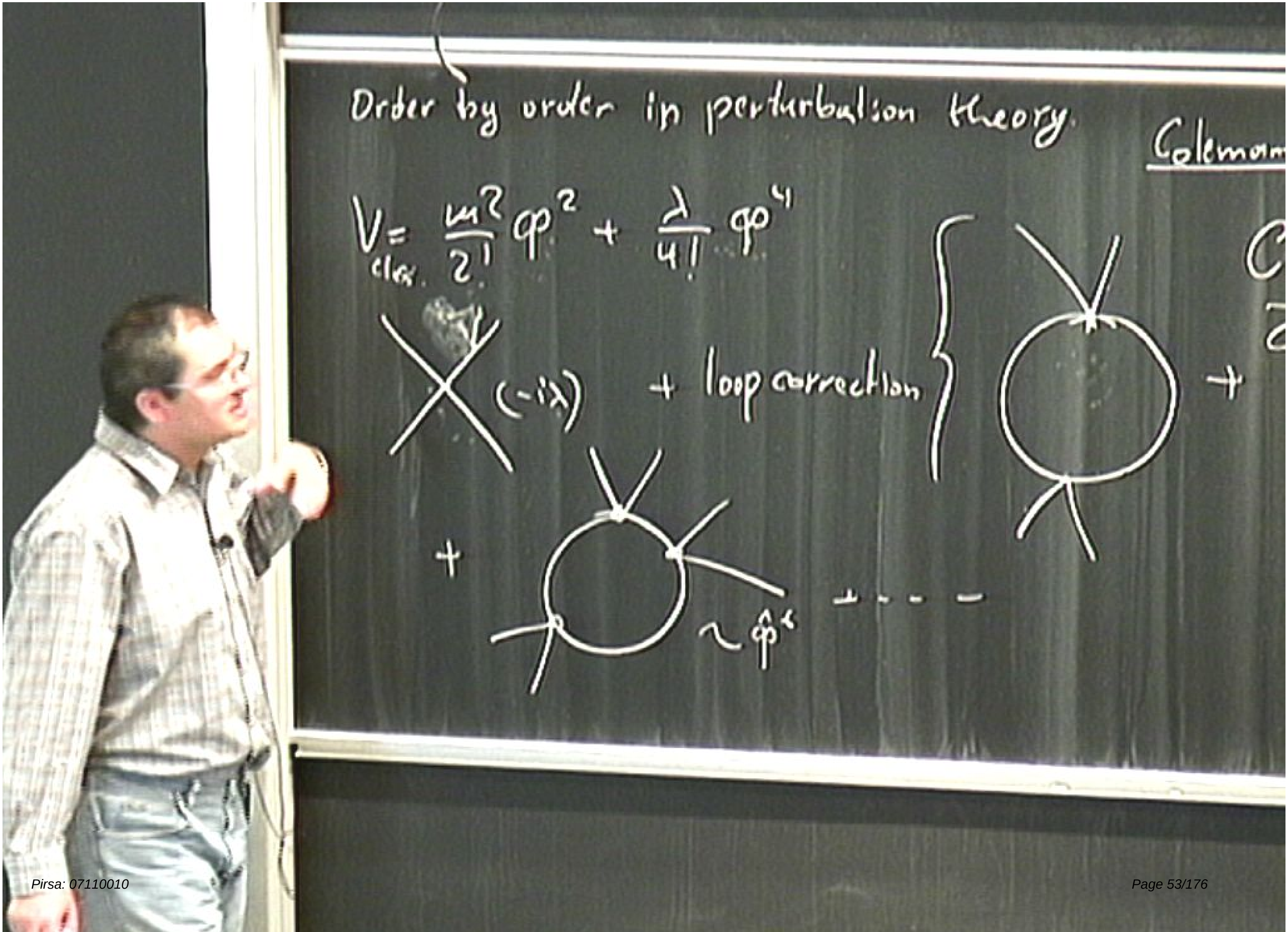
$$\rightarrow \quad S_{eff}(\hat{\varphi}) = \int d^4x \left[-V_{eff}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 Z(\hat{\varphi}) \right]$$

$\hat{\varphi} = \varphi$

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!}\hat{\varphi}^4 + \frac{m_{eff}^4(\hat{\varphi})}{64\pi^2}\left[\ln \frac{m_{eff}^2(\hat{\varphi})}{\mu^2} + \cdots \right]$$

$$m_{eff}^2(\hat{\varphi}) = m^2 + \frac{\lambda}{2}\hat{\varphi}^2$$

arbitrary scale μ


Order by order in perturbation theory.
$V_{clas.} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$
$(-i\lambda)$
+ loop correction
$\sim \hat{\varphi}^6$

$$\to \quad S_{eff}(\hat{\varphi}) = \int d^4x \left[-V_{eff}(\hat{\varphi}) - \frac{1}{2}(\partial\hat{\varphi})^2 \ldots \right.$$

$\hat{\varphi} = \varphi$

$$V_{eff} = \frac{1}{2} m^2 \hat{\varphi}^2 + \frac{\lambda}{4!} \hat{\varphi}^4 +$$

$$+ \frac{m^4_{eff}(\hat{\varphi})}{64\pi^2} \left[\ln \frac{m^2_{eff}(\hat{\varphi})}{\mu^2} + \cdots \right]$$

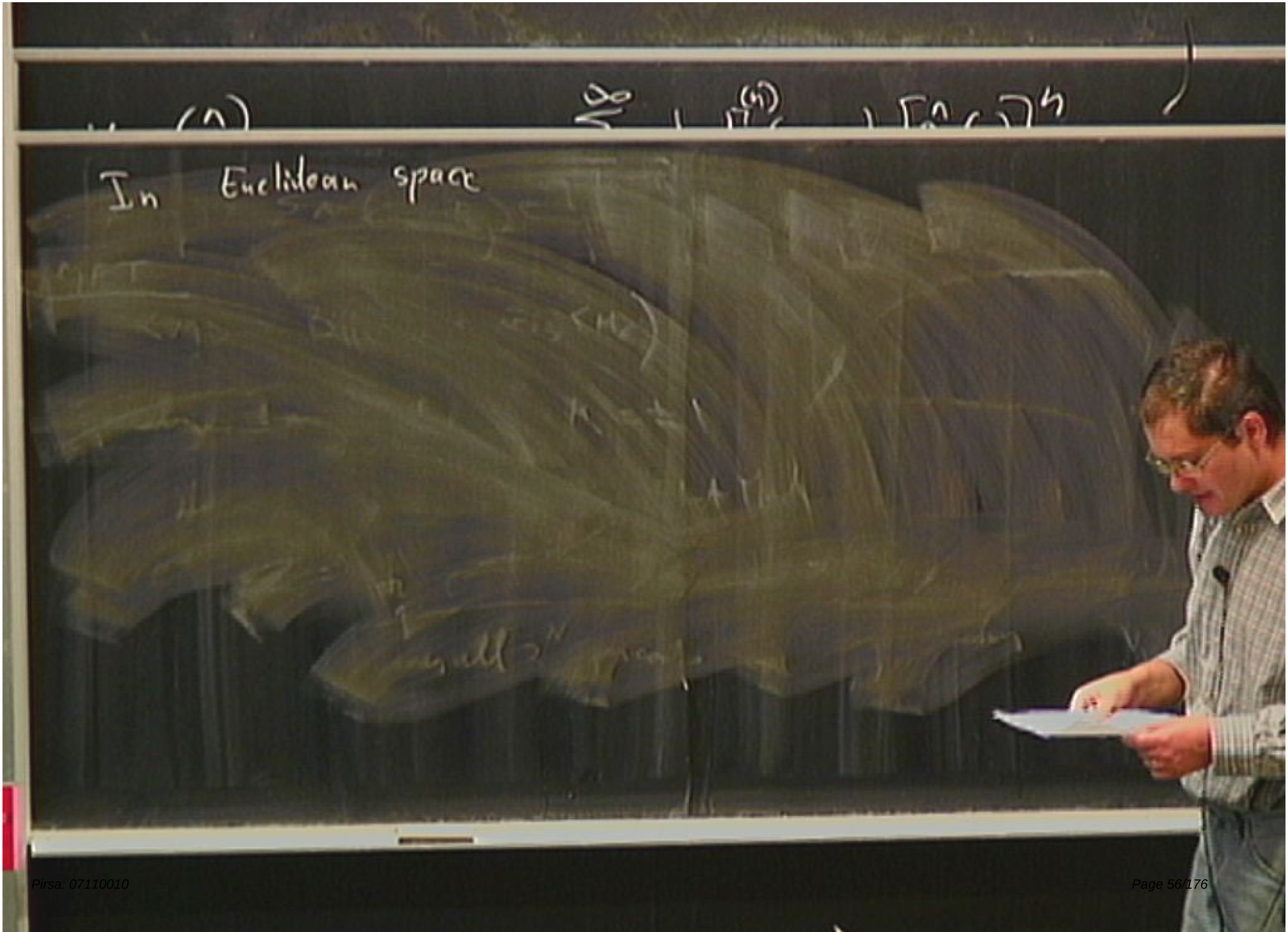
$$m^2_{eff}(\hat{\varphi}) = m^2 + \frac{\lambda}{2} \hat{\varphi}^2$$

$$V_{eff} = \frac{1}{2} m^2 \varphi^2 + \frac{\lambda}{4!} \varphi^4 +$$

$$+ \frac{m_{eff}^4(\varphi)}{64\pi^2} \left[\ln \frac{m_{eff}^2(\varphi)}{\mu^2} + \cdots \right]$$

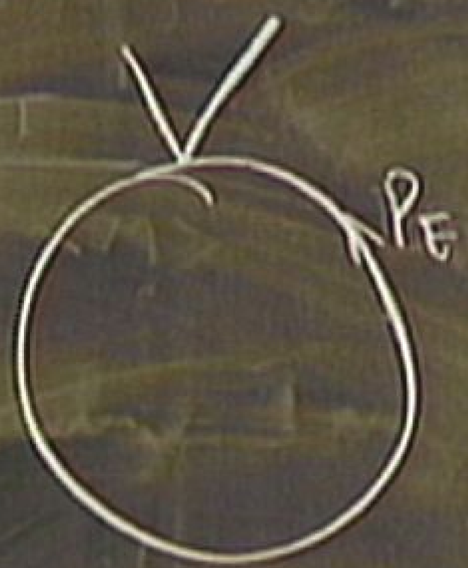
$$m_{eff}^2(\varphi) = m^2 + \frac{\lambda}{2} \hat{\varphi}^2$$

arbitrary scale μ


In Euclidean space

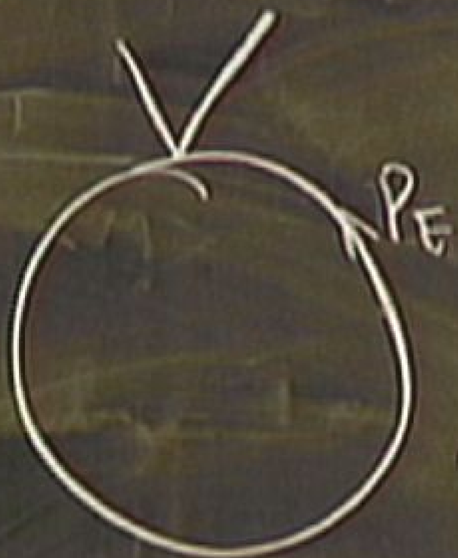
In Euclidean space

In Euclidean space



$|p_E|$

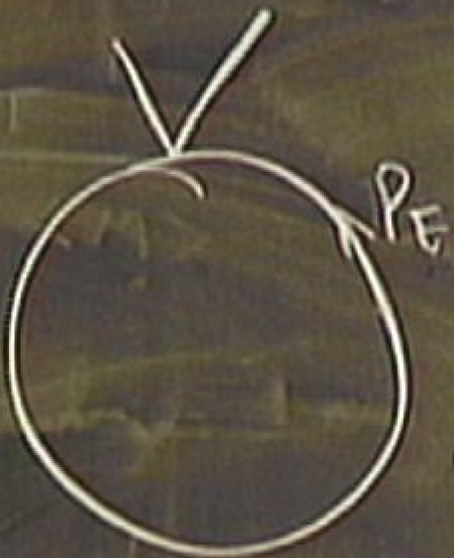
In Euclidean space



$|p_E| < \Lambda$

$\sim \Lambda^2$

In Euclidean space



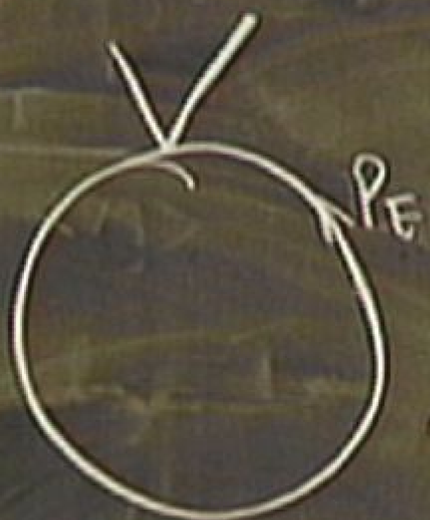
$|p_E| < \Lambda$

$\sim \Lambda^2$

Λ is a cutoff

(

In Euclidean space



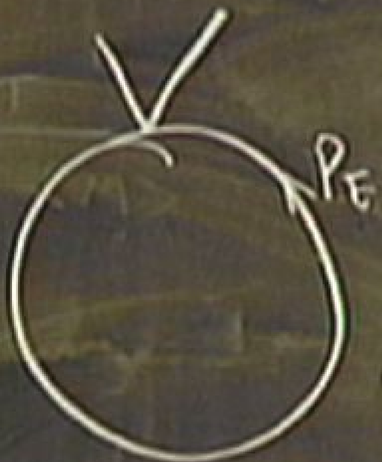
$|P_E| < \Lambda$

$\sim \Lambda^2$

Λ is a cutoff

(regularization)

In Euclidean space

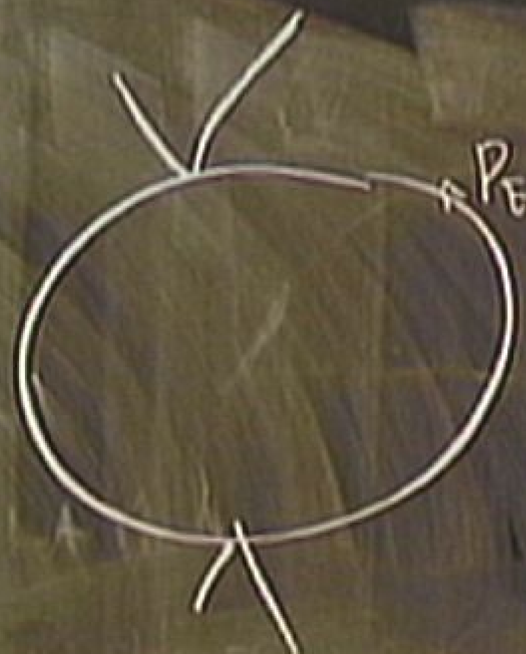


$|p_E| < \Lambda$

$\sim \Lambda^2$

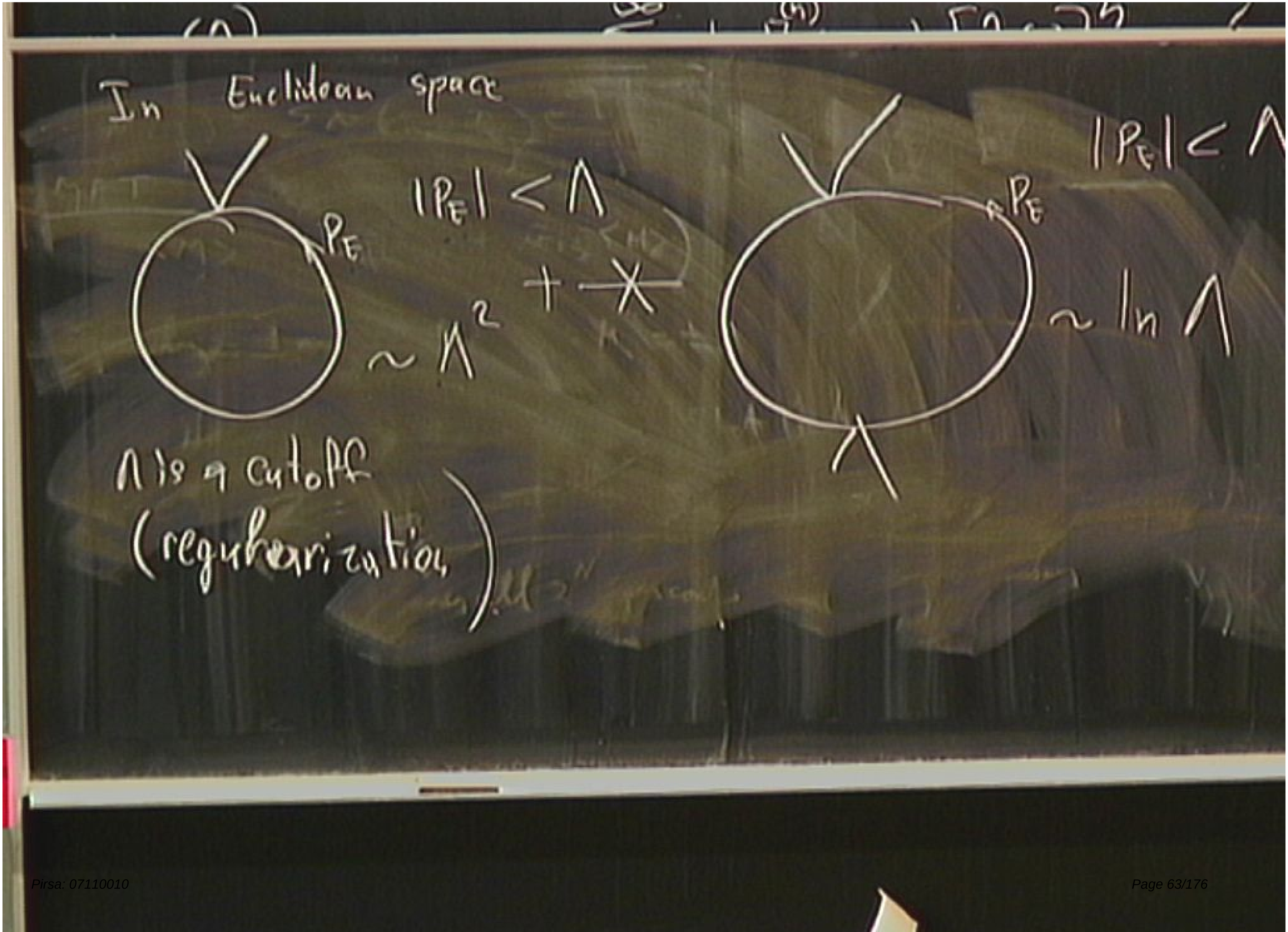
Λ is a cutoff

(regularization)

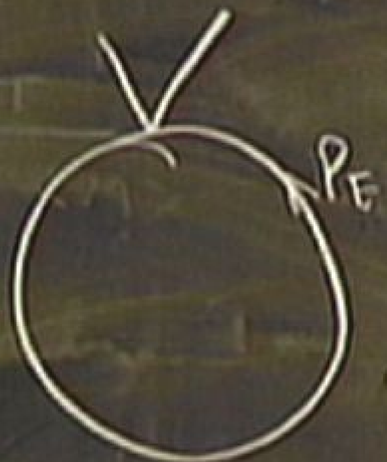


$|p_E| < \Lambda$

$\sim \ln \Lambda$


In Euclidean space
|p_E| < Λ
p_E
~ Λ^2 +
|p_E| < Λ
p_E
~ ln Λ
Λ is a cutoff
(regularization)

In Euclidean space

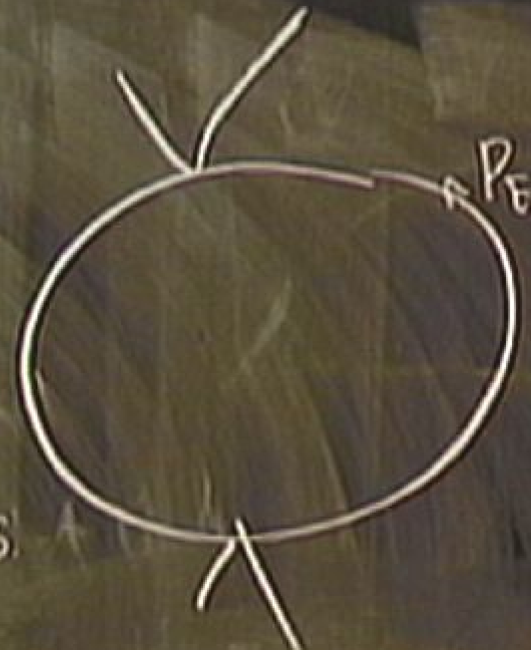


$|p_E| < \Lambda$

$\sim \Lambda^2 +$ 

Renorm counterterms

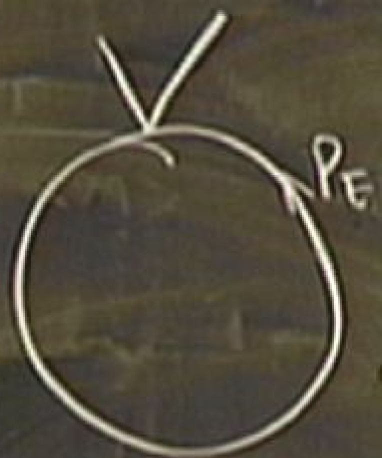
Λ is a cutoff (regularization)



$|p_E| < \Lambda$

$\sim \ln \Lambda$

In Euclidean space



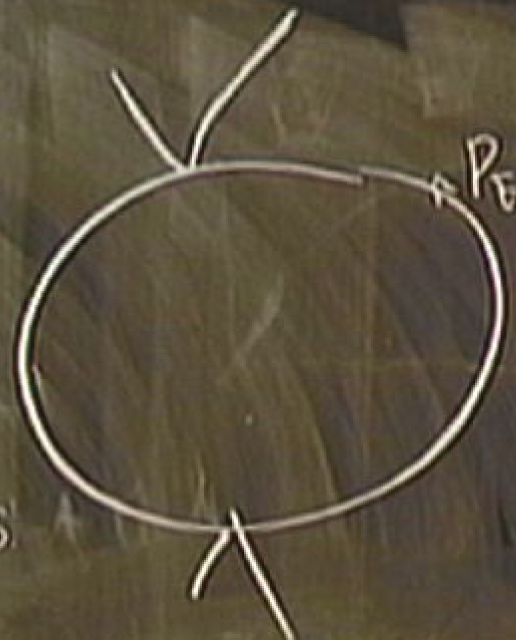
$|P_E| < \Lambda$

$\sim \Lambda^2 \; +$

Prov counterms

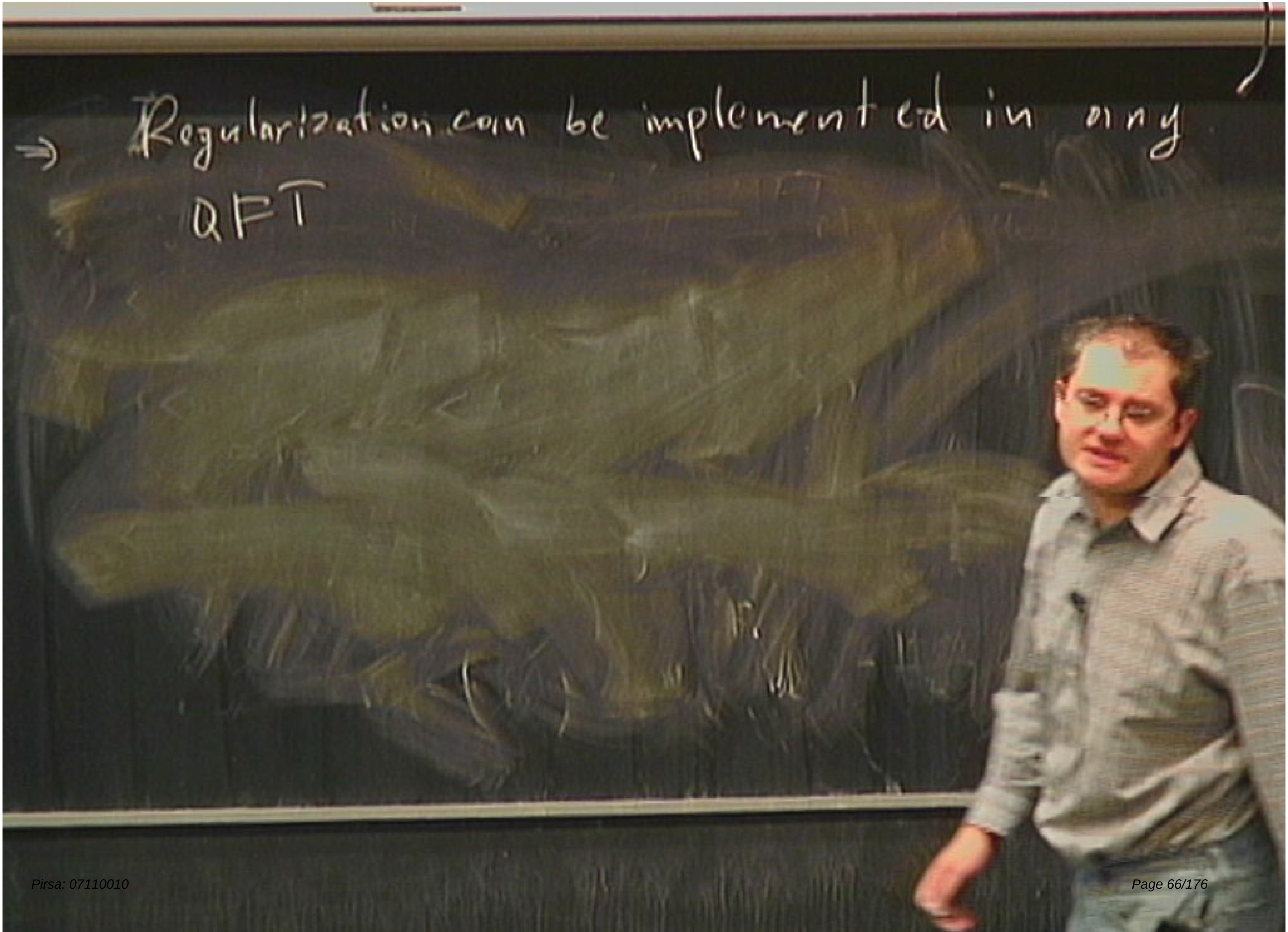
Λ is a cutoff

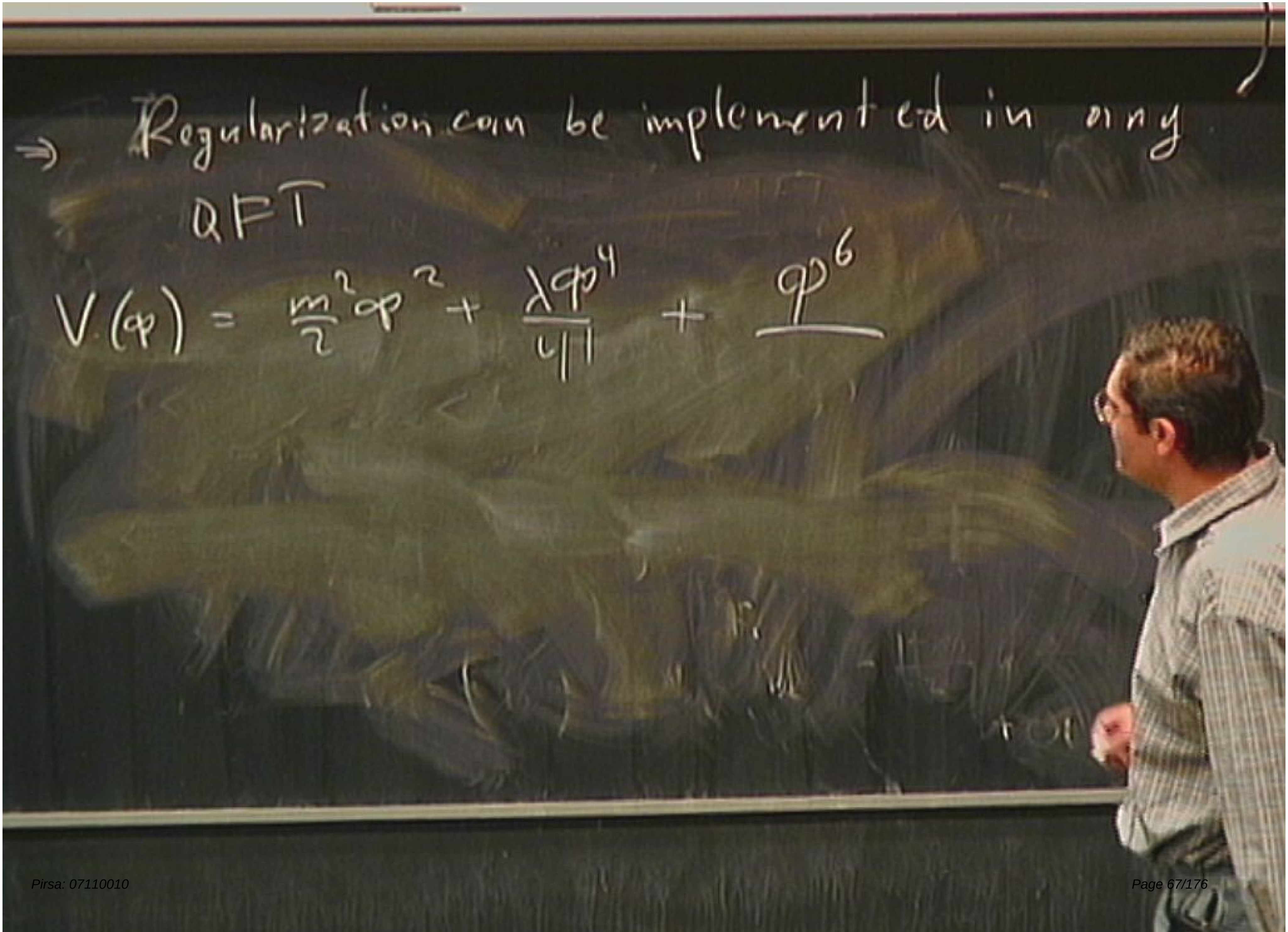
(regularization)



$|P_E| < \Lambda$

$\sim \ln \Lambda$


⇒ Regularization can be implemented in any
QFT

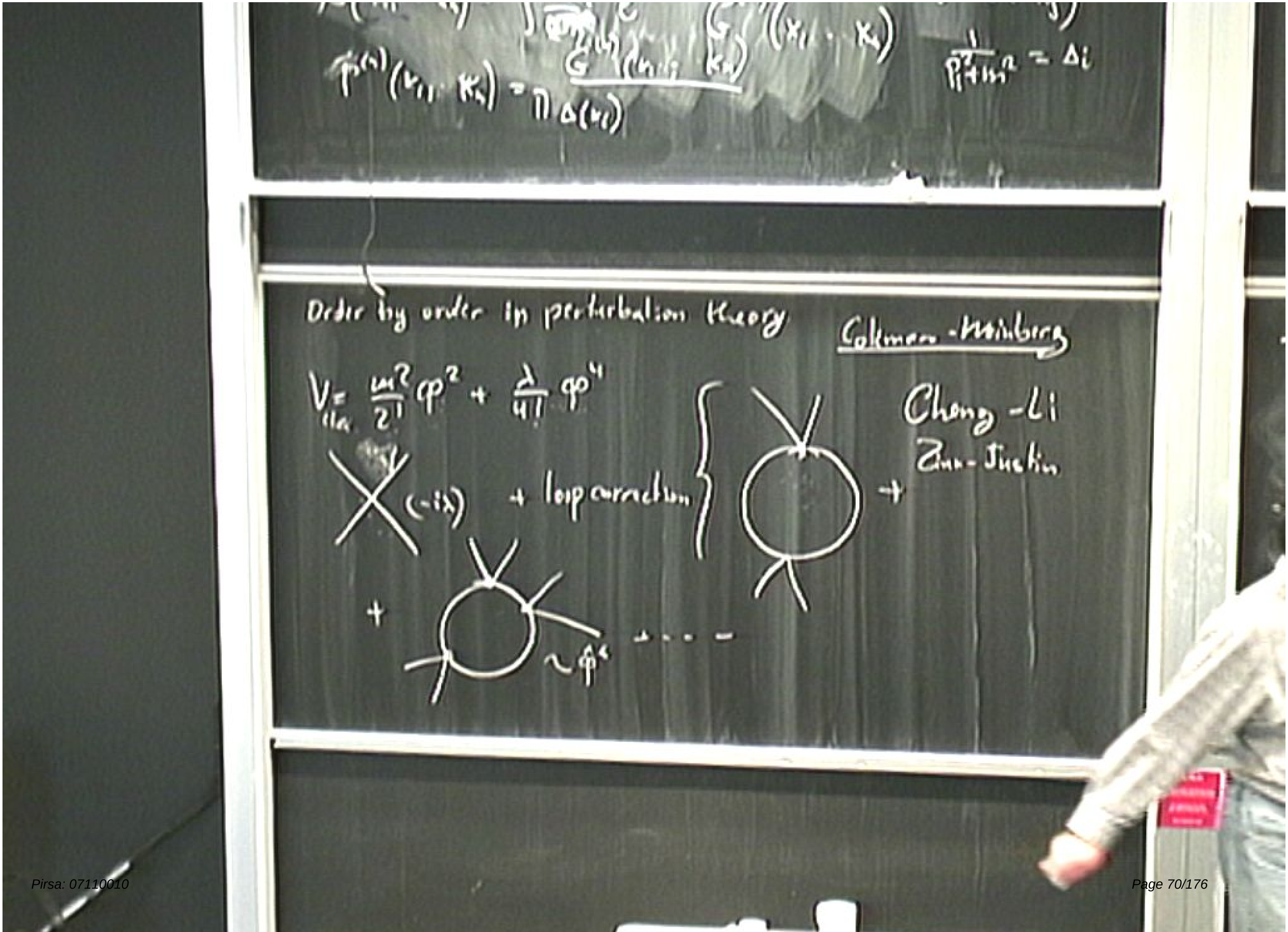

⇒ Regularization can be implemented in any QFT
$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{\quad}$

$\Rightarrow$ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{\Lambda^2}$$

⇒ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{[illegible]}$$


$\Gamma^{(n)}(k_1 \dots k_n) = \frac{G^{(n)}(k_1 \dots k_n)}{\prod \Delta(k_i)}$
$\frac{1}{p_i^2+m^2} = \Delta_i$
Order by order in perturbation theory
Coleman-Weinberg
$V_{int} = \frac{m^2}{2!}\varphi^2 + \frac{\lambda}{4!}\varphi^4$
Cheng-Li
Zinn-Justin
$(-i\lambda)$
+ loop correction
$\sim \varphi^6$

$${}^{4} + \frac{\varphi^{6}}{M^{2}}$$

⇒ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{[illegible]}$$

$$\Rightarrow \quad V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \varphi$$

⇒ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{[illegible]}$$

⇒ $$V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum$$

$$|P_{\text{loop}}| < \Lambda$$

$\Rightarrow$ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{}$$

$$\Rightarrow V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n \geq 4} \frac{\varphi^{2n}}{}$$

$|P_{\text{loop}}| < \Lambda$

⇒ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{\;}$$

$$\Rightarrow \quad V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^{n}}{\;}$$

$|P_{\text{loop}}| < \Lambda$

QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{M^2}$$

$$V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{\substack{n>4 \\ n \text{ even}}} \frac{\varphi^n}{\Lambda^n}$$

$|P_{\text{loop}}| < \Lambda$

⇒ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{}$$

$$\Rightarrow \quad V(\varphi)_{\text{regularized}} = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{\substack{n>4 \\ n\ \text{even}}} \frac{\varphi^n}{\Lambda^{n-4}}\, C_n$$

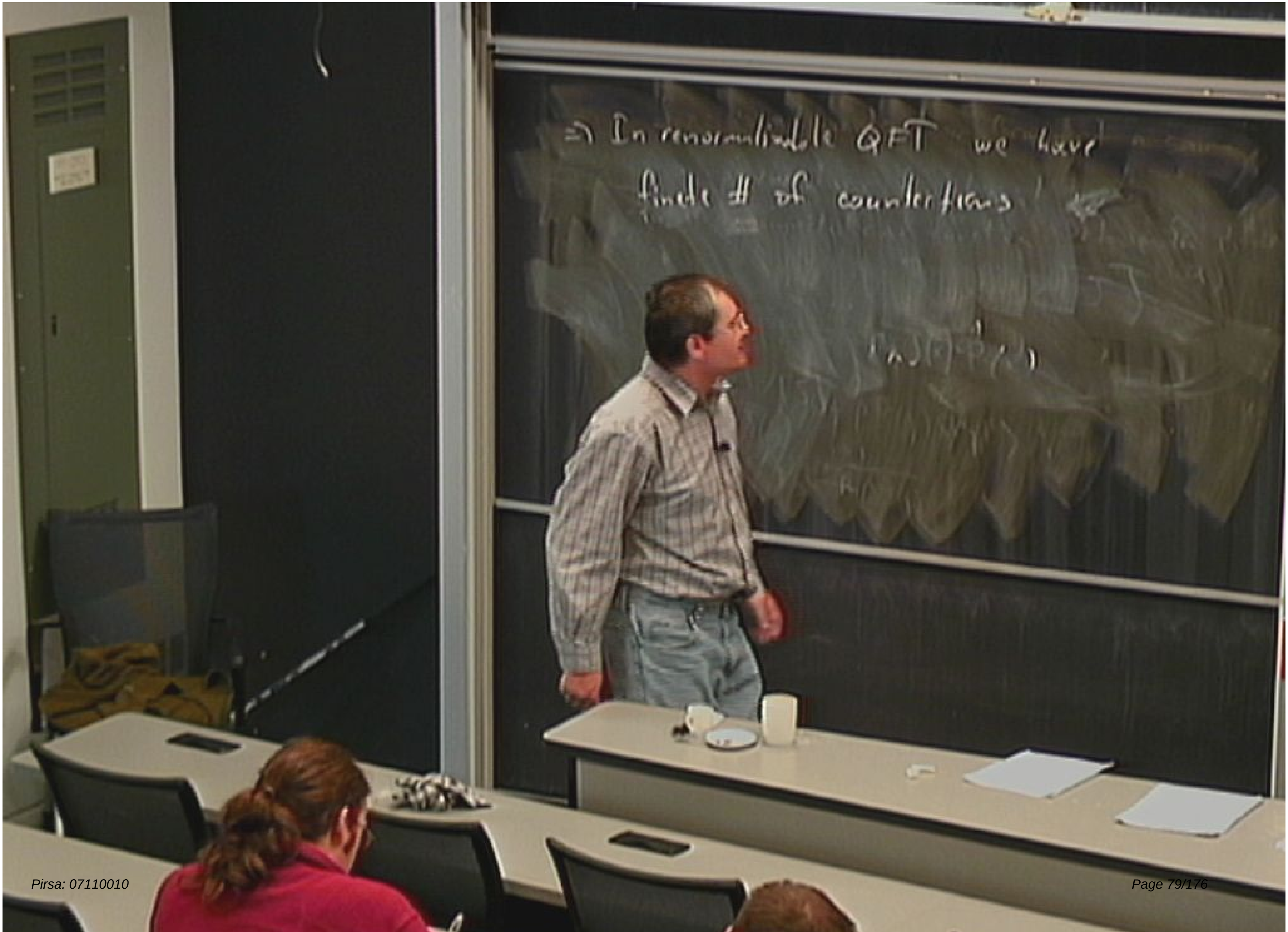
$$|P_{\text{loop}}| < \Lambda$$

$\Rightarrow$ Regularization can be implemented in any QFT

$$V(\varphi) = \frac{m^2}{2}\varphi^2 + \frac{\lambda\varphi^4}{4!} + \frac{\varphi^6}{[illegible]}$$

$$\Rightarrow \quad V_{\text{regularized}}(\varphi) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{\substack{n>4 \\ n \text{ even}}} \frac{\varphi^n}{\Lambda^{n-4}} \, c_n(m, \lambda, m)$$

$|P_{\text{loop}}| < \Lambda$


⇒ In renormalizable QFT we have
finite # of counterterms

$\Rightarrow$ In renormalizable QFT we have finite # of counterterms such that

V_{eff}

$\int_x J(x)\,\hat{\phi}(x)$

⇒ In renormalizable QFT we have finite # of counterterms such that

$$V_{eff} = V_{eff}^{(bare)}$$

$\Rightarrow$ In renormalizable QFT we have finite # of counterterms such that

$$V_{eff} = V_{eff}^{(bare)} + V_{eff}^{(counterterms)}$$

$\Rightarrow$ In renormalizable QFT we have finite # of counterterms such that

$$V_{\text{eff}} = \underbrace{V_{\text{eff}}^{(\text{bare})} + V_{\text{eff}}^{(\text{counterterms})}}$$

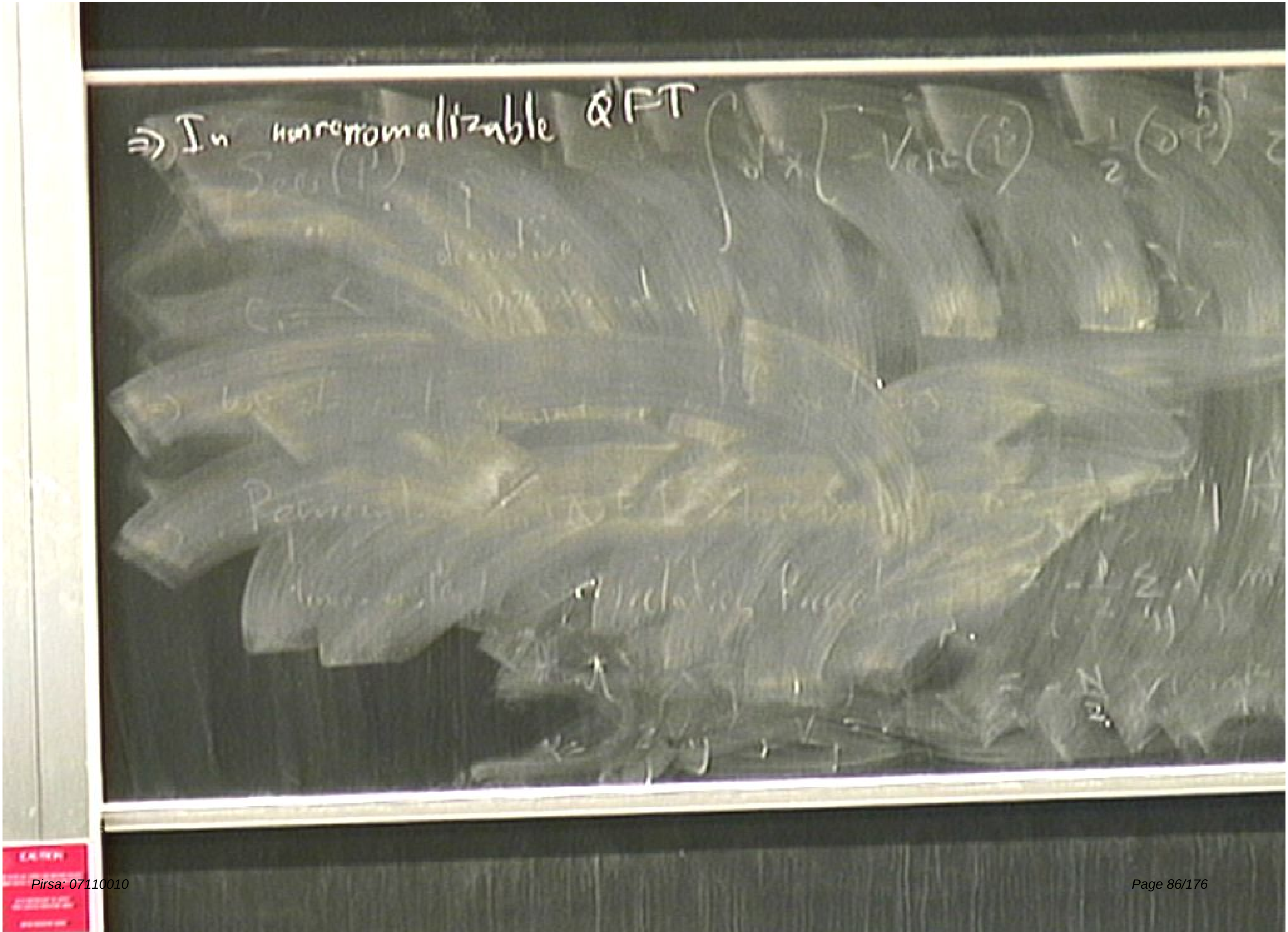
$\Rightarrow$ In renormalizable QFT we have finite # of counterterms such that

$$V_{eff} = \underbrace{V_{eff}^{(bare)} + V_{eff}^{(counterterms)}}_{\Lambda \text{ independent}}$$

$\Rightarrow$ In renormalizable QFT we have finite # of counterterms such that

$$V_{eff} = \underbrace{V_{eff}^{(bare)} + V_{eff}^{(counterterms)}}_{\Lambda \text{ independent}}$$

$\Lambda \to \infty \Rightarrow V_{eff}^{physical}$


⇒ In nonrenormalizable QFT

$\Rightarrow$ In unrenormalizable QFT
IS not possible to remove Λ-dependence.

$\Rightarrow$ In unrenormalizable QFT
IS not possible to remove Λ-dependence.

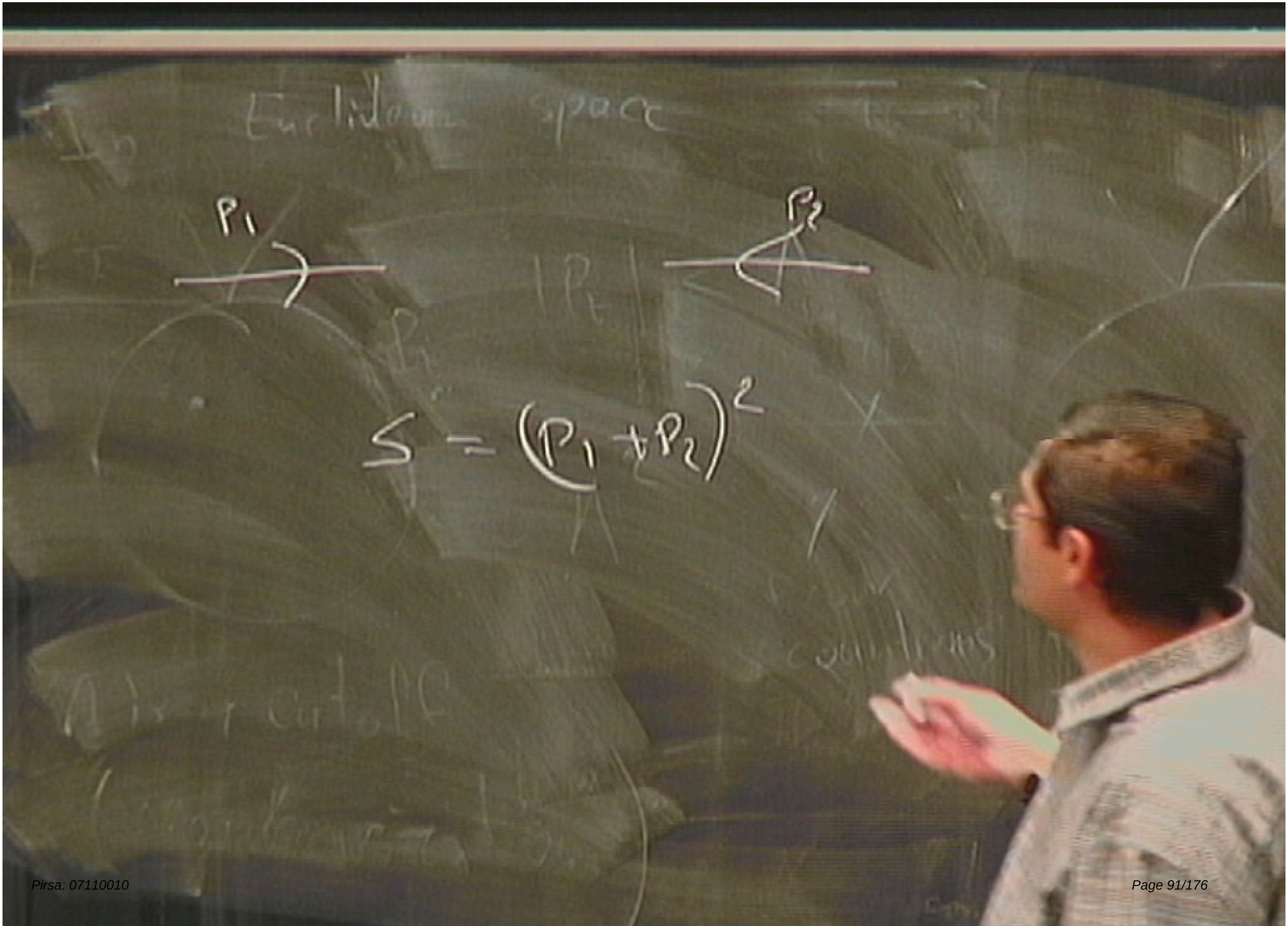
$\Rightarrow$

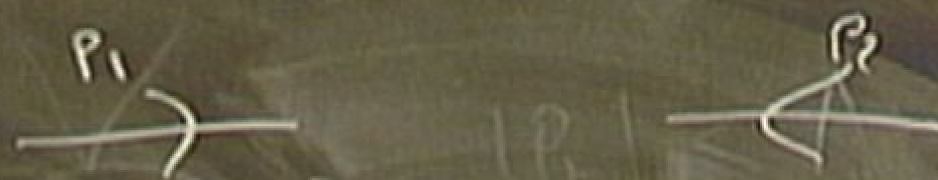
⇒ In nonrenormalizable QFT
IS not possible to remove Λ-dependence.

⇒ V_{eff} in nonrenorm QFT.

⇒ In nonrenormalizable QFT
IS not possible to remove Λ-dependence.

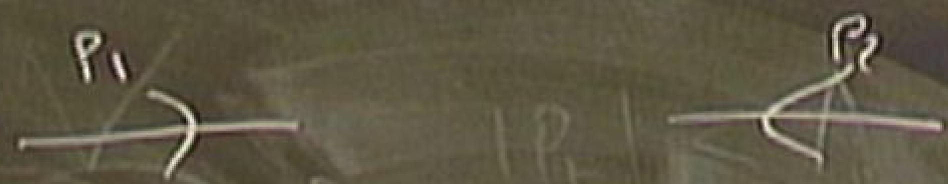
⇒ V_{eff} in nonrenorm QFT will crucially
depend on a particular way
In which you regularize divergent integrals


Euclidean space
p_1
p_2
$s = (p_1 + p_2)^2$



$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda$$



$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda^2$$

$$V_{eff}\left(p_1\ s \ll \Lambda^2\right)$$

$|p_E| < \Lambda$

p_1 p_2

$$s = (p_1 + p_2)^2$$

$$s << \Lambda^2$$

$$V_{eff}\left(\varphi,\ s << \Lambda^2\right) = \frac{m^2 \varphi^2}{2} + \frac{\lambda \varphi^4}{4!} + \sum_{n > 4} \frac{\varphi^n}{\Lambda^{4-n}}.$$

Euclidean space

$|p_i| < \Lambda$

$p_1 \quad p_2$

$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda^2$$

$$V_{\text{eff}}\left(\varphi,\ s \ll \Lambda^2\right) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{n-4}}$$

$|P_i| < \Lambda$

$p_1 \rightarrow \quad \leftarrow p_2$

$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda^2$$

$$V_{eff}\left(\varphi,\ s \ll \Lambda^2\right) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{4-n}}.$$

In nonrenormalizable QFT

IS not possible to remove Λ-dependence

V_{eff} in nonrenorm QFT will crucially depend on a particular way In which you regularize divergent integrals

p_1 $\quad$ p_2

$|P_E| < \Lambda$

$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda^2$$

$$V_{\text{eff}}\left(\varphi,\ s \ll \Lambda^2\right) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{4-n}}$$

In nonrenormalizable QFT
IS not possible to remove Λ-dependence

V_{eff} in nonrenorm QFT will crucially depend on a particular way in which you regularize divergent integrals

p_1 $\quad$ p_2

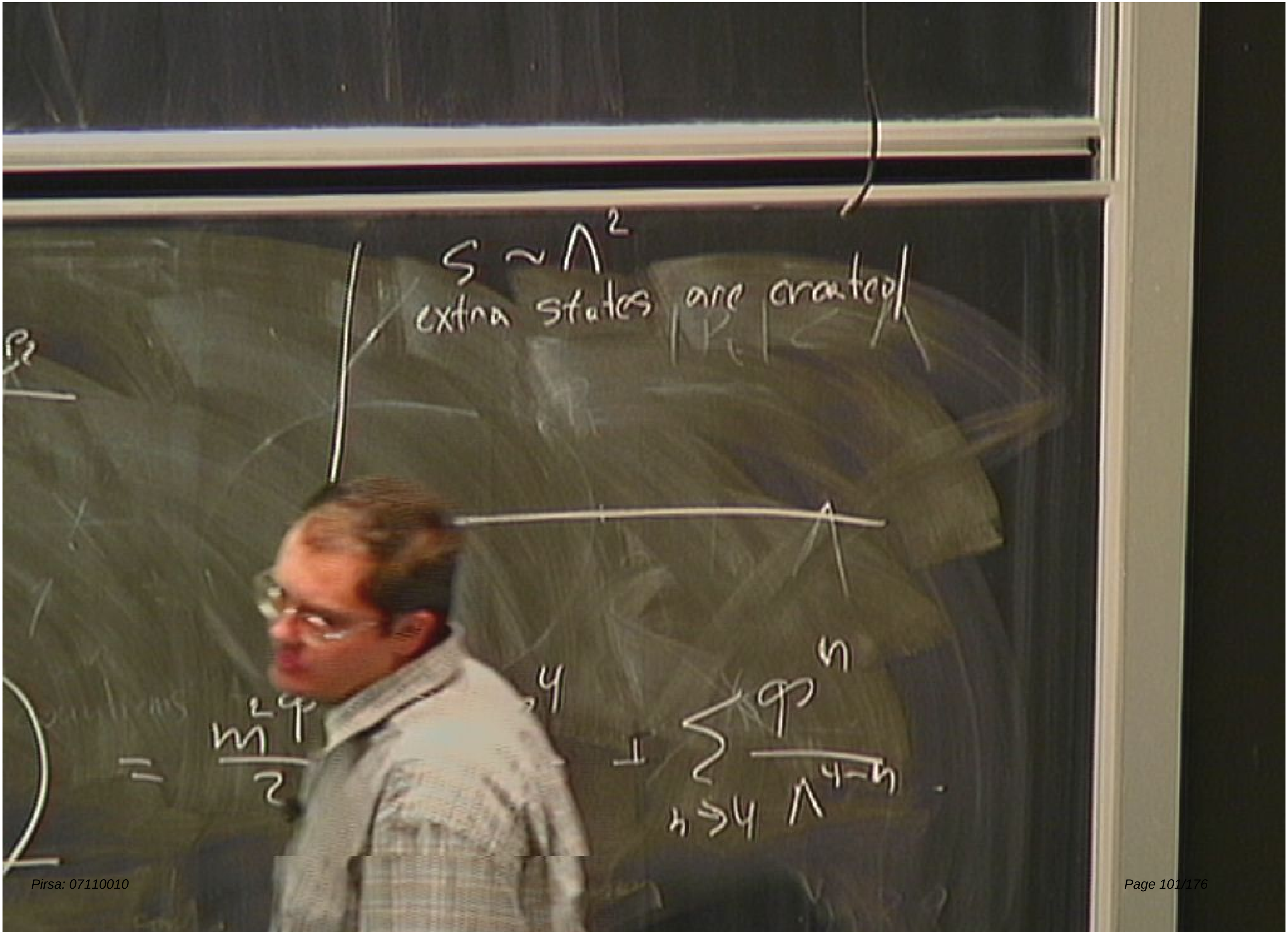
$s \sim \Lambda^2$

$|P_E| < \Lambda$

$$s = (p_1 + p_2)^2$$

$$s \ll \Lambda^2$$

$$V_{\text{eff}}\left(\varphi,\ s \ll \Lambda^2\right) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{n-4}}$$



S ~ Λ²
extra states are created
= m²φ²/2
Σ φⁿ / Λ⁴⁻ⁿ
n>4

$\delta \sim \Lambda^2$

extra states are created

Λ

$$= \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{4-n}}.$$

$m^2 \sim \Lambda^2$

p_1 $\qquad$ p_2

$s = (p_1 + p_2)^2$

$s \ll \Lambda^2$

$$V_{eff}\left(\varphi,\ s \ll \Lambda^2\right) = \frac{m^2\varphi^2}{2} + \frac{\lambda\varphi^4}{4!} + \sum_{n>4} \frac{\varphi^n}{\Lambda^{4-n}}.$$

$s \sim \Lambda^2$

extra states are created

nonrenorm QFT require a UV completion

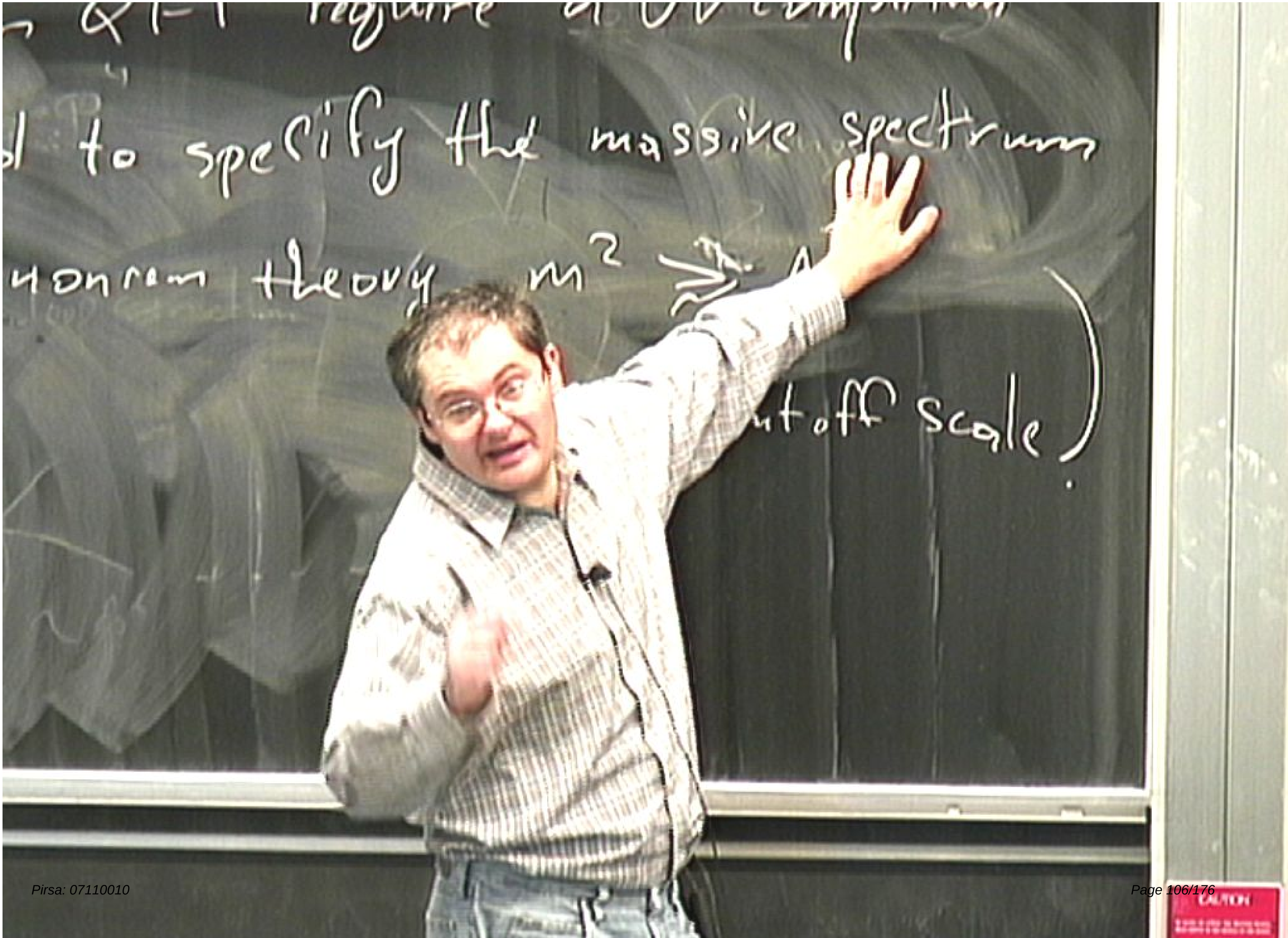
(we

nonrenorm QFT require a UV complition

(we need to specify the massive spectrum

of nonrenorm theory $m^2 \gtrsim \Lambda^2$

cutoff scale).



to specify the massive spectrum
nonren theory m^2
off scale

In gravity

$$\sqrt{-g}\,R \longrightarrow \sqrt{-g}\left(R + \# \frac{R^2}{m_{pl}^2} + \# \frac{R^3}{m_{pl}^4} + \right)$$

In gravity

$$\sqrt{-g}\,R \longrightarrow \sqrt{-g}\left[R + \#\frac{R^2}{m_{pl}^2} + \frac{\#R^3}{m_{pl}^4} + \cdots\right.$$

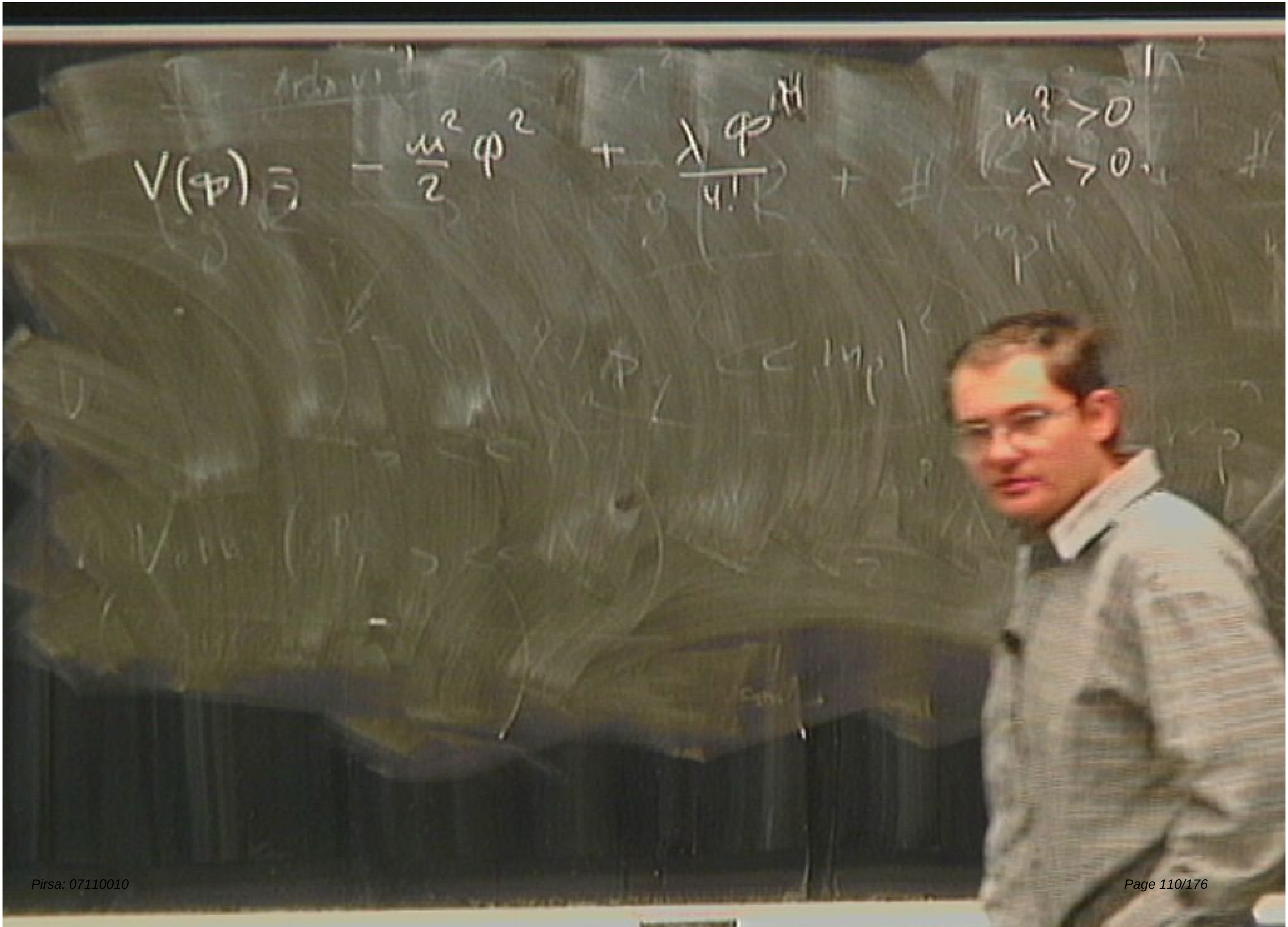
$$\partial^2 \ll m_{pl}^2$$

In gravity

$$\sqrt{g}\,R \longrightarrow \sqrt{-g}\left[R + \# \frac{R^2}{m_{pl}^2} + \frac{\# R^3}{m_{pl}^4} + \cdots \right.$$

$$\mathcal{R} \ll m_{pl}^2$$

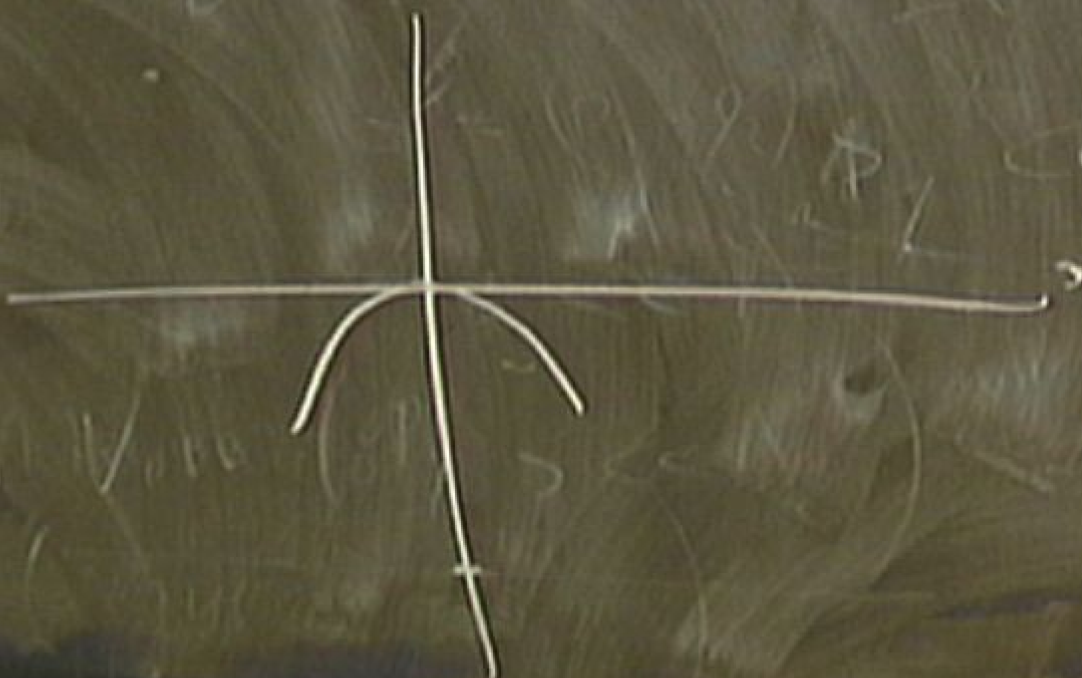
$$S \sim m_p^n$$

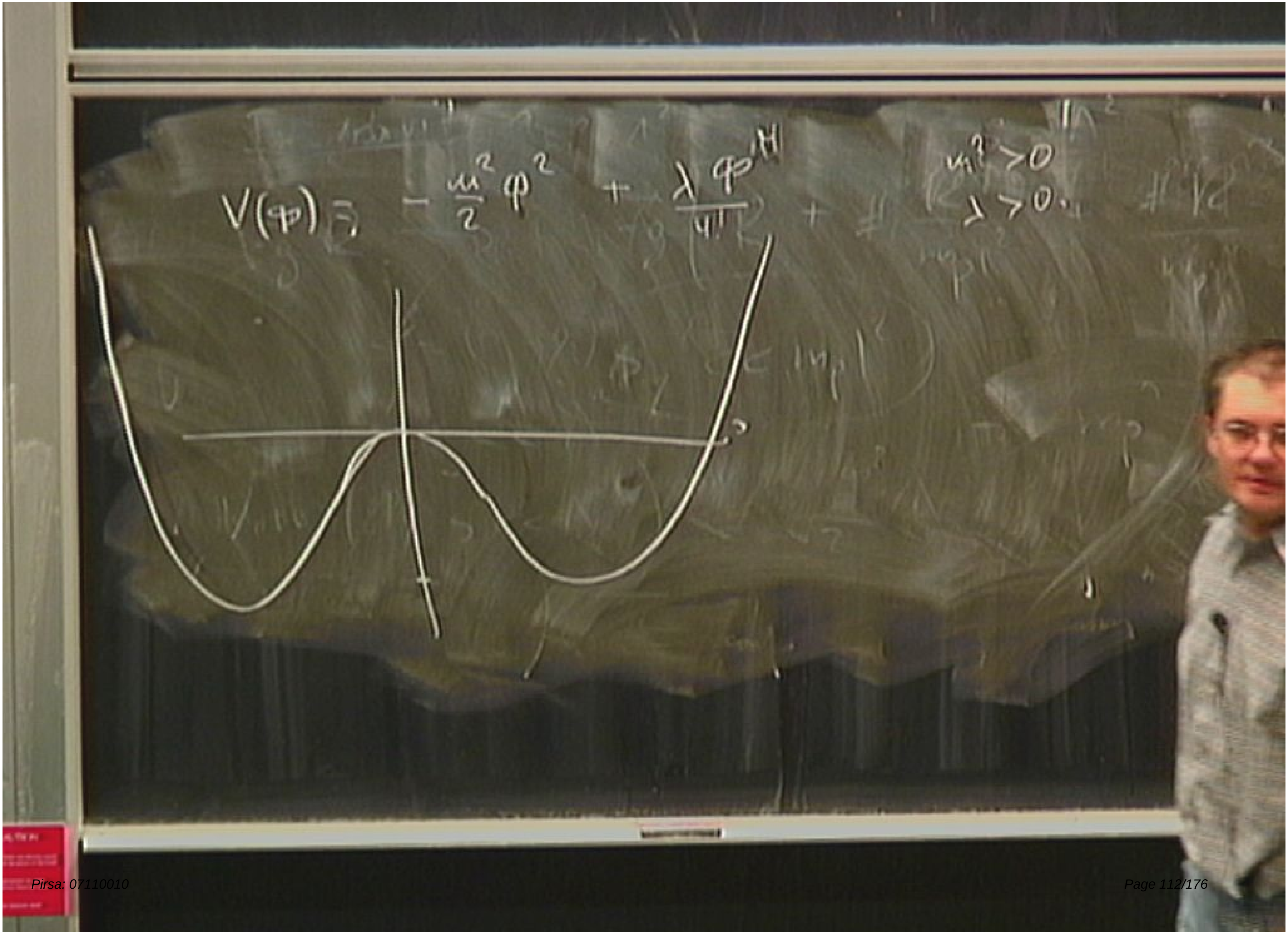

V(φ) = − m²/2 φ² + λ φ⁴/4!
m² > 0
λ > 0.

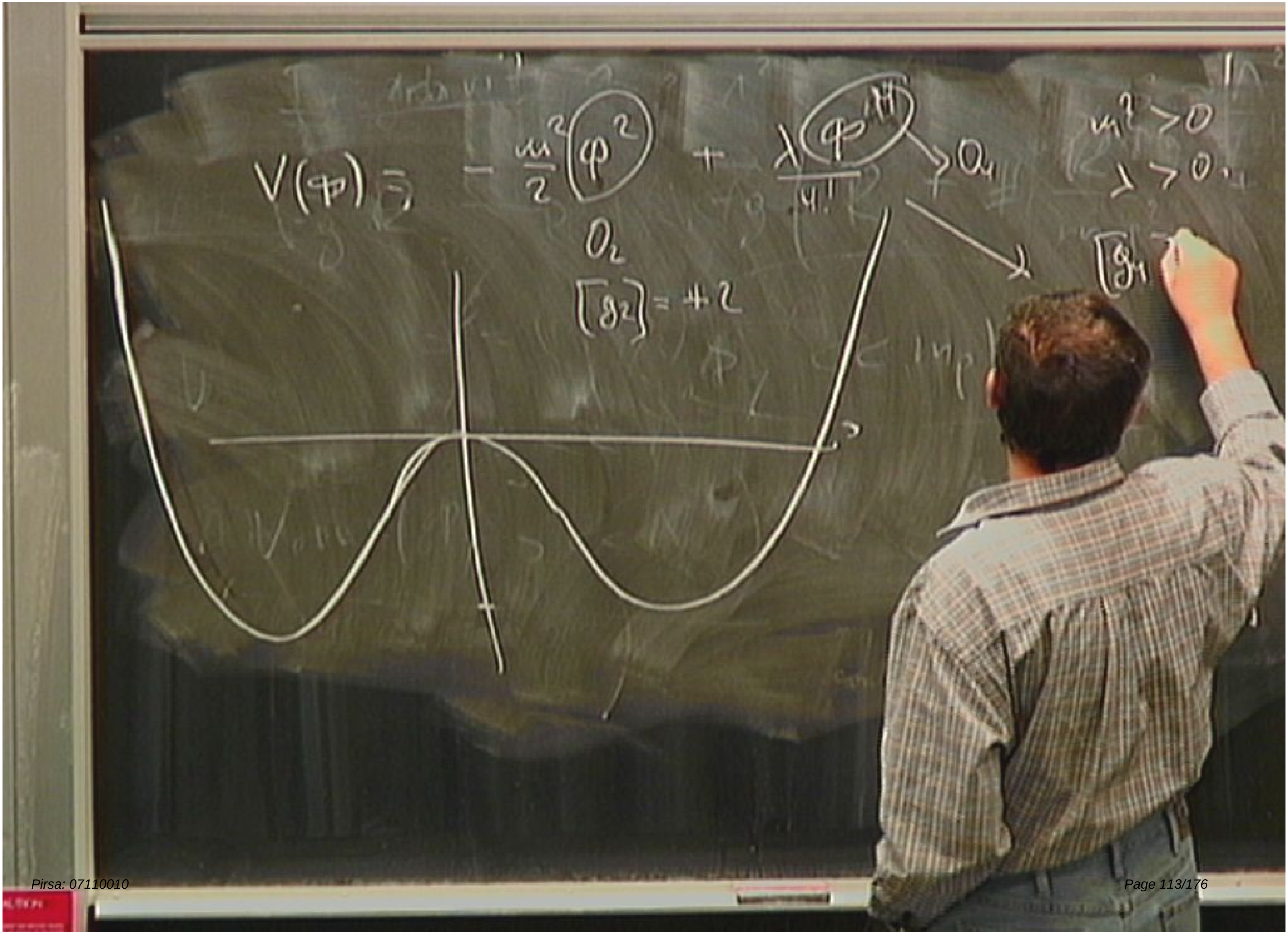
$$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \frac{\lambda\,\varphi^4}{4!}$$

$m^2 > 0$

$\lambda > 0.$




$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \frac{\lambda\,\varphi^4}{4!}$
$m^2 > 0$
$\lambda > 0.$



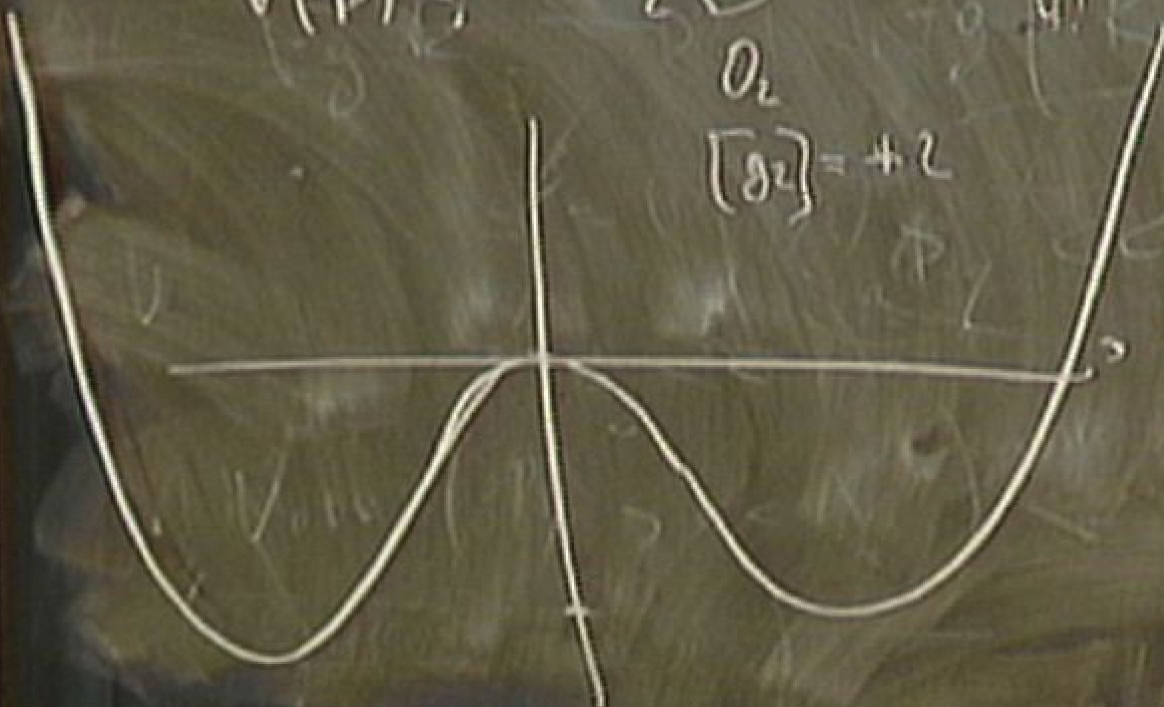
V(φ) = − m²/2 φ² + λ/4! φ⁴
O₄
m² > 0
λ > 0
O₂
[g₂] = +2

$$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \frac{\lambda}{4!}\varphi^4 \to O_4 \qquad m^2 > 0, \quad \lambda > 0$$

O_2

$[g_2] = +2$

$\to \lambda \qquad [g_4] \simeq 0$



$$V(\varphi) = -\frac{m^2}{2}\varphi^2 + \frac{\lambda}{4!}\varphi^4$$

$\varphi^4 \to O_4$

O_2

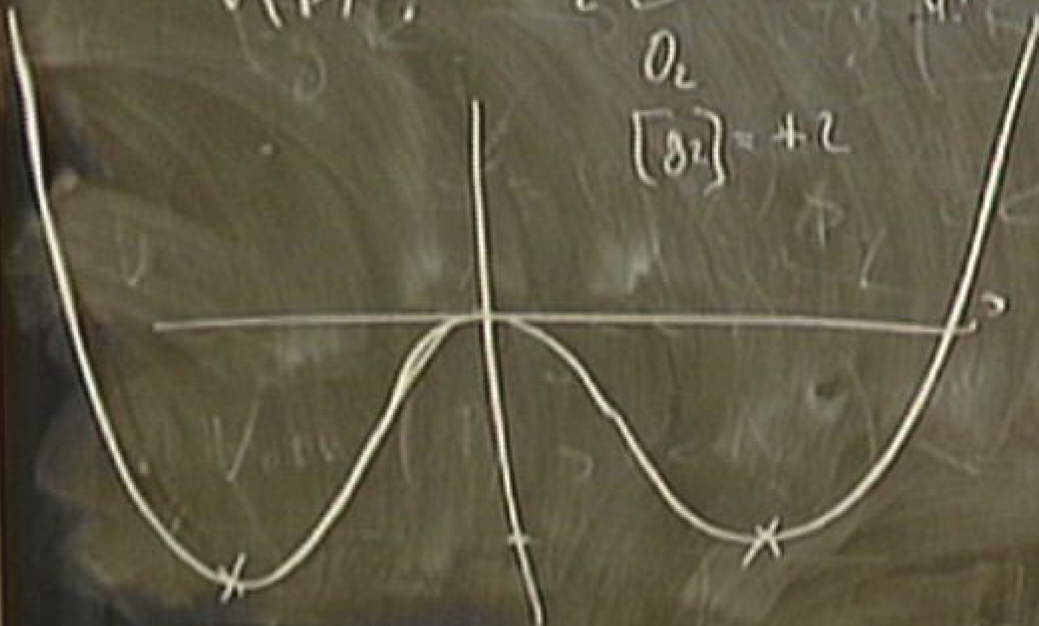
$[g_2] = +2$

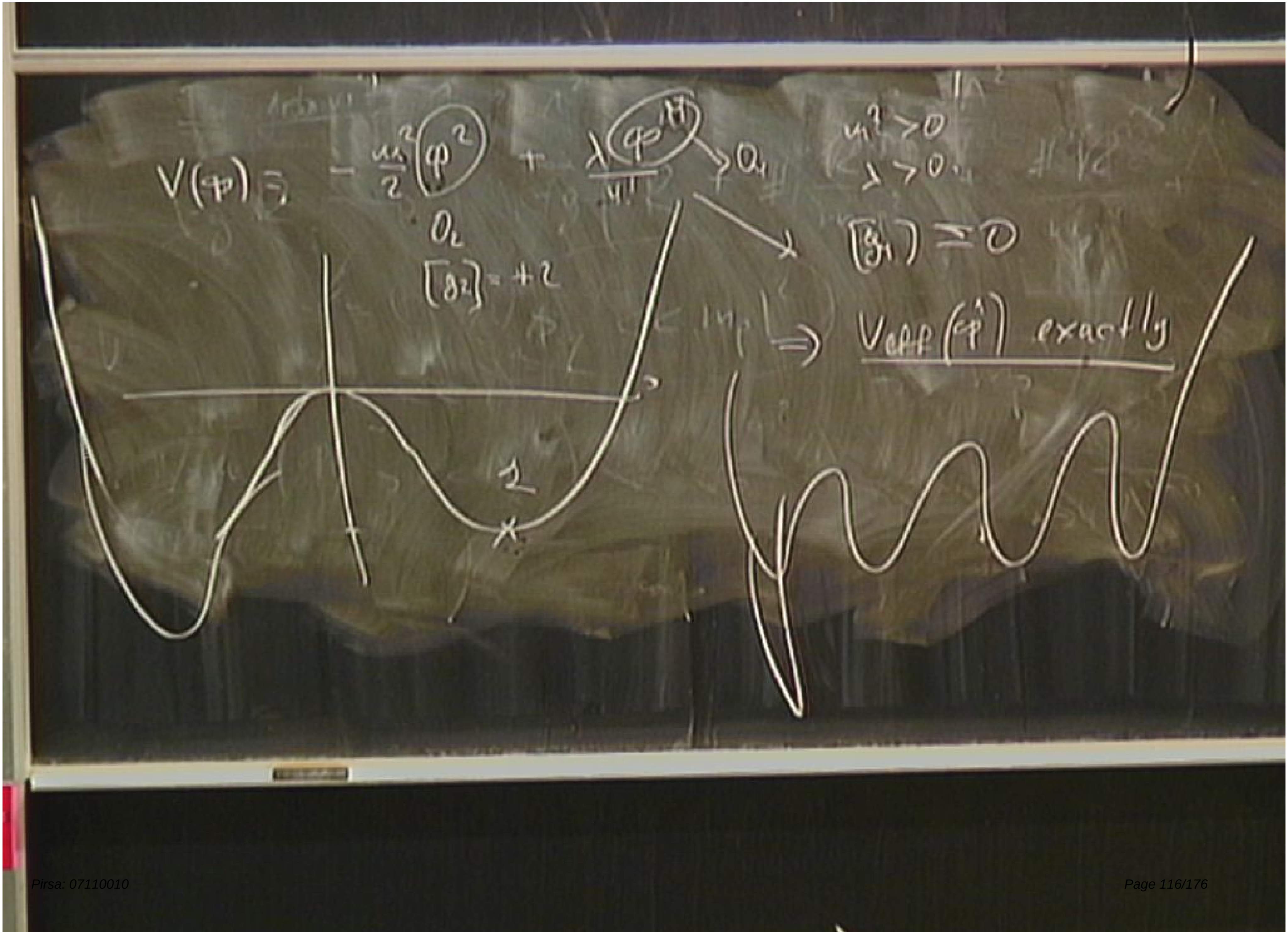
$m^2 > 0$

$\lambda > 0$

$[g_4] = 0$

$\ll M_p \Rightarrow$ $\underline{V_{eff}(\varphi) \text{ exactly}}$




V(φ) = - m²/2 φ² + λ/M⁴ φ⁴
O_4
O_2
[g_2] = +2
m² > 0
λ > 0.
[g_4] = 0
V_eff(φ̂) exactly

⇒ Consider power counting renormalizability of SUSY QFT

⇒ Consider power counting renormalizability of SUSY QFT

$$\mathcal{L} = \int d^4\theta \; K(\Phi_i, \bar{\Phi}_i)$$

⇒ Consider power counting renormalizability of SUSY QFT

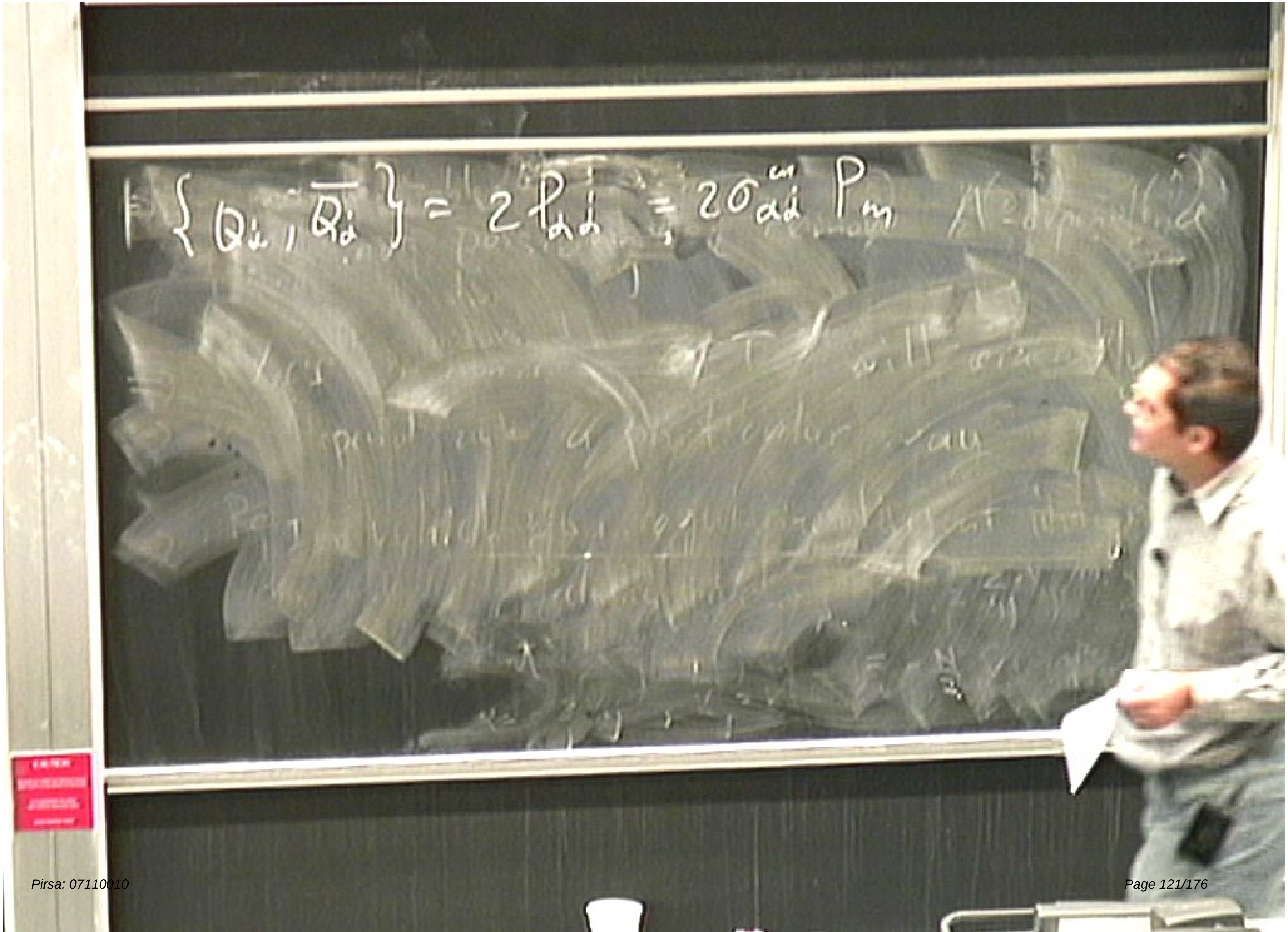
$$\mathcal{L} = \int d^4\theta \, K(\Phi_i, \bar{\Phi}_i) + \int d^2\theta \, W(\Phi$$

⇒ Consider power counting renormalizability of SUSY QFT

$$\mathcal{L} = \int d^4\theta \, K(\Phi_i, \bar{\Phi}_i) + \int d^2\theta \, W(\Phi_i) + h.c.$$

Kähler potential

superpotential


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

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

$$[P_m] = +1$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha} \qquad \bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial\bar\theta^{\dot\alpha}}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha} \qquad \bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial\bar\theta^{\dot\alpha}}$$

$$[Q_\alpha] = +\frac{1}{2}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot{\alpha}}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha} \qquad \bar{Q}_{\dot{\alpha}} \sim -\frac{\partial}{\partial\bar{\theta}^{\dot{\alpha}}}$$

$$[Q_\alpha] = +\frac{1}{2} \Rightarrow [\theta^\alpha] = [\bar{\theta}_{\dot{\alpha}}] = -\frac{1}{2}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha} \qquad \bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial\bar\theta^{\dot\alpha}} \qquad [d\theta] =$$

$$[Q_\alpha] = +\frac{1}{2} \Rightarrow [\theta^\alpha] = [\bar\theta_{\dot\alpha}] = -\frac{1}{2}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial\theta^\alpha} \qquad \bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial\bar\theta^{\dot\alpha}} \qquad [d\theta] = \left[\frac{\partial}{\partial\theta}\right] =$$

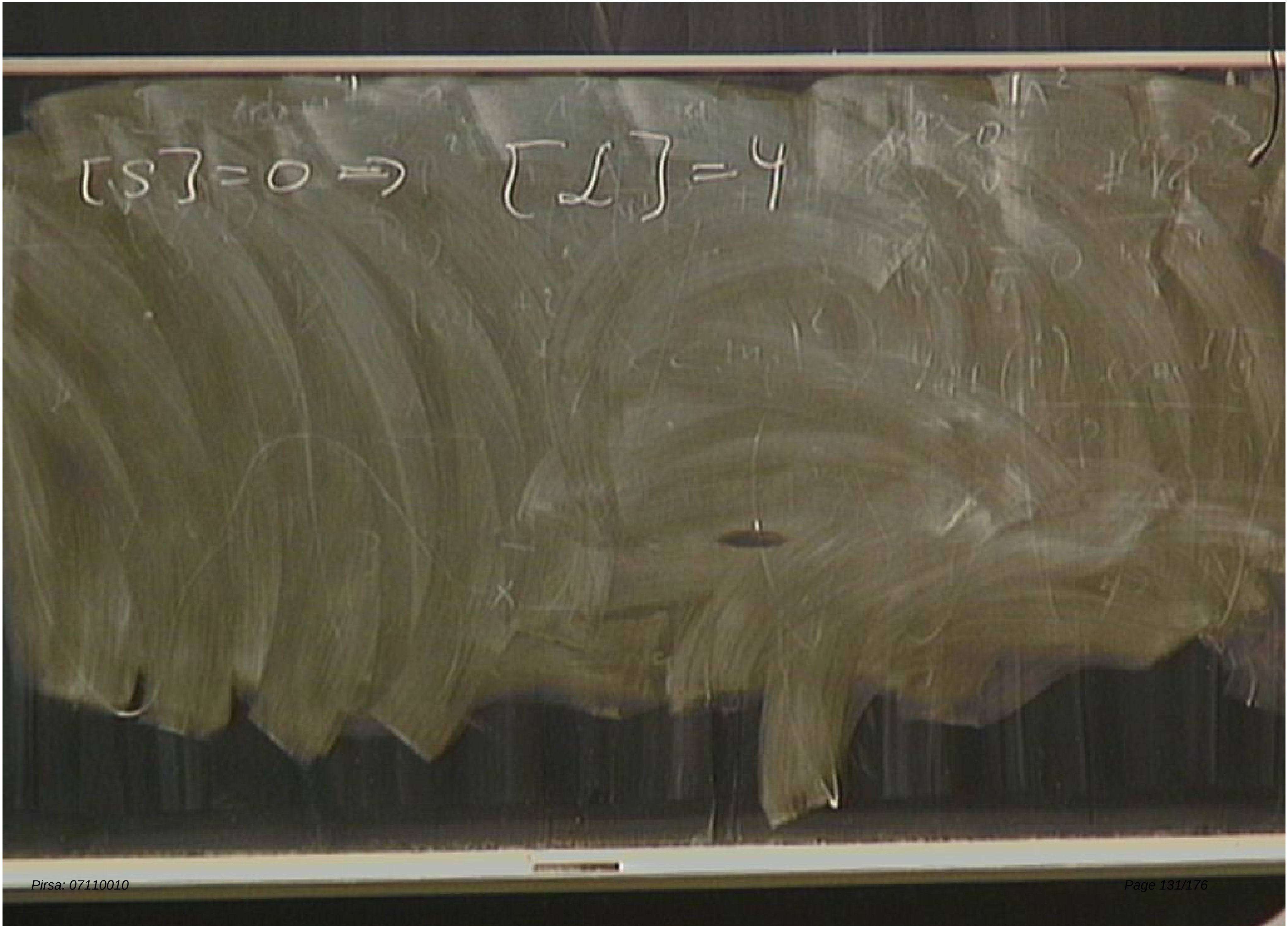
$$[Q_\alpha] = +\frac{1}{2} \Rightarrow [\theta^\alpha] = [\bar\theta_{\dot\alpha}] = -\frac{1}{2}$$

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

$$[P_m] = +1 \Rightarrow [Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$$

$$Q_\alpha \sim \frac{\partial}{\partial \theta^\alpha} \qquad \bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial \bar{\theta}^{\dot\alpha}} \qquad [d\theta] = \left[\frac{\partial}{\partial\theta}\right] = +\frac{1}{2}$$

$$[Q_\alpha] = +\frac{1}{2} \Rightarrow [\theta^\alpha] = [\bar{\theta}_{\dot\alpha}] = -\frac{1}{2}$$


$[S]=0 \Rightarrow [\mathcal{L}]=4$

$$[S] = 0 \Rightarrow [\mathcal{L}] = 4$$

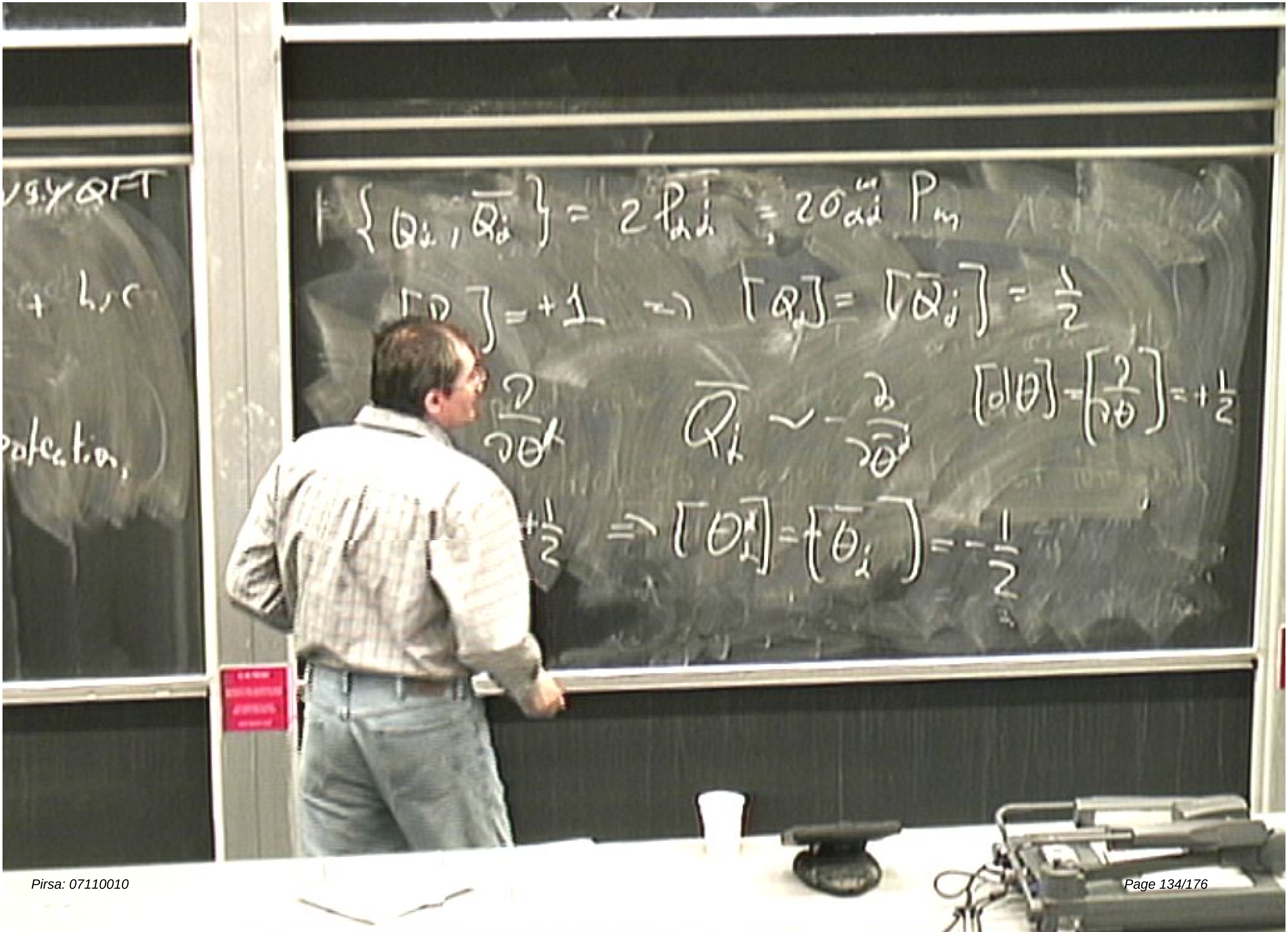
$$[d^4\theta] = 4 \cdot \tfrac{1}{2} = 2$$

$\Rightarrow$ Consider power counting renormalizability of SUSY QFT

$$\mathcal{L} = \int d^4\theta \, K(\Phi_i, \bar{\Phi}_i) + \int d^2\theta \, W(\Phi_i) + h.c.$$

Kähler potential

Superpotential



$\{Q_\alpha, \bar{Q}_{\dot\alpha}\} = 2P_{\alpha\dot\alpha} = 2\sigma^m_{\alpha\dot\alpha} P_m$
$[Q_\alpha] = [\bar{Q}_{\dot\alpha}] = \frac{1}{2}$
$\bar{Q}_{\dot\alpha} \sim -\frac{\partial}{\partial\bar\theta^{\dot\alpha}}$
$[d\theta] = [\frac{\partial}{\partial\theta}] = +\frac{1}{2}$
$[\theta_\alpha] = [\bar\theta_{\dot\alpha}] = -\frac{1}{2}$

$$[S] = 0 \Rightarrow [\mathcal{L}] = 4$$

$$[d^4\theta] = 4 \cdot \tfrac{1}{2} = 2 \Rightarrow [K] = +2$$

$$[d^2\theta] = 2 \cdot \tfrac{1}{2} = 1 \Rightarrow [W] = +3$$

$[S] = 0 \Rightarrow [\mathcal{L}] = 4$

$[d^4\theta] = 4 \cdot \frac{1}{2} = 2 \Rightarrow [K] = +2$

$[d^2\theta] = 2 \cdot \frac{1}{2} = 1 \Rightarrow [W] = +3$

$\Rightarrow$ WZ-model $\quad K = \varphi\bar{\varphi}$

$[S] = 0 \Rightarrow [\mathcal{L}] = 4$

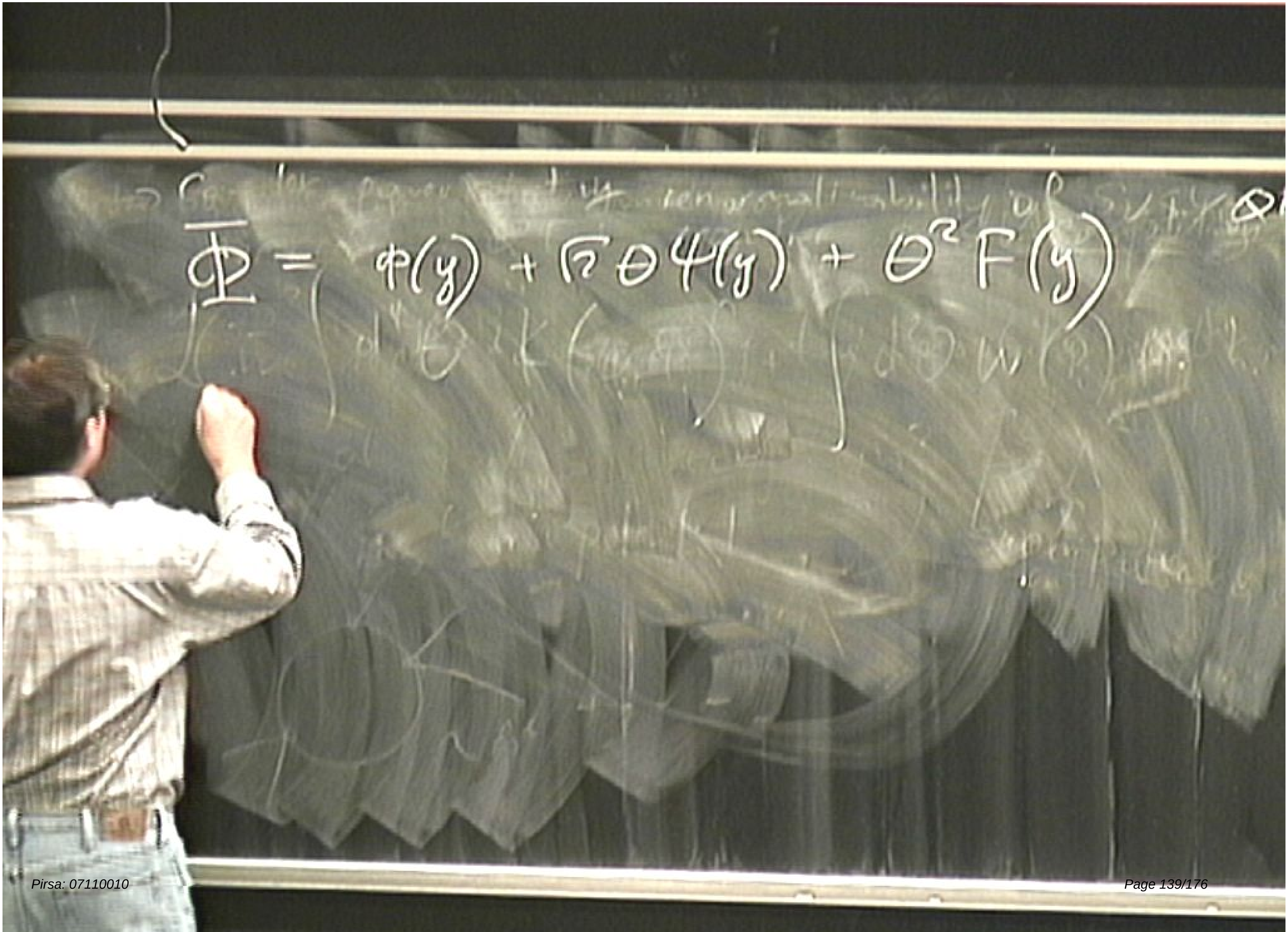
$[d^4\theta] = 4 \cdot \frac{1}{2} = 2 \Rightarrow [K] = +2$

$[d^2\theta] = 2 \cdot \frac{1}{2} = 1 \Rightarrow [W] = +3$

$\Rightarrow$ WZ-model $\quad K = \varphi\bar{\varphi}$

$[\varphi] = 1$

$$\bar{\Phi} = \varphi(y)$$


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

$$\Phi = \phi(y) + \sqrt{2}\,\theta\psi(y) + \theta^2 F(y)$$

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

$$\Phi = \phi(y) + \sqrt{2}\,\theta\,\psi(y) + \theta^2 F(y)$$

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

$$[\Phi] = +1$$

$$\bar{\Phi} = \phi(y) + \sqrt{2}\,\theta\,\psi(y) + \theta^2 F(y)$$

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

scalar

$$[\Phi] = +1 \qquad [\phi] = +1$$

$$\Phi = \phi(y) + \sqrt{2}\,\theta\psi(y) + \theta^2 F(y)$$

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

$$[\Phi] = +1 \qquad [\phi] = +1 \leftarrow \text{scalar}$$

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

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

$$[\Phi] = +1 \qquad [\varphi] = +1 \quad \text{scalar}$$

$$[\psi] = +\frac{3}{2}$$

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

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

$$[\Phi] = +1$$

$[\varphi] = +1$ scalar

$[\psi] = +\frac{3}{2}$ mass dimension of a free fermion

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

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

$$[\Phi] = +1$$

$[\varphi] = +1$ ← scalar

$[\psi] = +\frac{3}{2}$ ← mass dimension of a free fermion

$[F] = +2$

WZ model was identified

$$W(\varphi_i) = \underbrace{\underbrace{v_i \varphi_i + m_{ij} \varphi_i \varphi_j + \lambda_{ijk} \varphi^i \varphi^j \varphi^k}_{WZ} + \dots}_{\text{nlsm}}$$

WZ model was identified

$$W(\varphi_i) = \underbrace{\underbrace{v_i \varphi_i + m_{ij} \varphi_i \varphi_j + \lambda_{ijk} \varphi^i \varphi^k \varphi^j}_{WZ} + \cdots}_{\text{nlsm}}$$

$[W] = 3 \qquad [\Phi_i] = +1$

WZ model was identified

$$W(\Phi_i) = \underbrace{\underbrace{v_i \overset{1}{\Phi_i} + m_{ij} \overset{2}{\Phi_i \Phi_j} + \lambda_{ijk} \overset{3}{\varphi^i \varphi^j \varphi^k}}_{WZ} + \cdots}_{nlsm}$$

$$[W] = 3 \qquad [\Phi_i] = +1$$

$[\;]$

WZ model was identified

$$\overset{3}{W}(\varphi_i) = \underbrace{\underbrace{v_i \overset{1}{\varphi_i} + m_{ij} \overset{2}{\varphi_i \varphi_j} + \lambda_{ijk} \overset{3}{\varphi^i \varphi^j \varphi^k}}_{\text{WZ}} + \cdots}_{\text{nbm}}$$

$[W] = 3 \qquad [\Phi_i] = +1$

$[v_i] = +2 \qquad [m_{ij}] = 1 \qquad [\lambda_{ijk}] = 0$

$$W(\varphi_i) = \underbrace{v_i \varphi_i + m_{ij} \varphi_i \varphi_j + \lambda_{ijk} \varphi \varphi \varphi}_{W_2} + \cdots$$

nlsm

$$[W] = 3 \qquad [\Phi_i] = +1$$

$$[v_i] = +2 \qquad [m_{ij}] = 1 \qquad [\lambda_{ijk}] = 0$$

$$V \propto |\partial W|^2$$

WZ model was identified

$$\overset{3}{W}(\Phi_i) = \underbrace{\underbrace{v_i \overset{1}{\Phi_i} + m_{ij} \overset{2}{\Phi_i \Phi_j} + \lambda_{ijk} \overset{3}{\phi^i \phi^j \phi^k}}_{WZ} + \cdots}_{nlsm}$$

$$[W] = 3 \qquad [\Phi_i] = +1$$

$$[v_i] = +2 \qquad [m_{ij}] = 1 \qquad [\lambda_{ijk}] = 0$$

$$V \propto |\partial W|^2$$

In WZ model all couplings $\{g_n\} \geq 0$.

In WZ model all couplings $[g_n] \geq 0$.

$\Rightarrow$ WZ model picks up most general
susy renormalizable

In WZ model all couplings $\{g_n\} \geq 0$.

$\Rightarrow$ WZ model picks up most general susy renormalizable QFT for χSF's

WZ model was identified

$$W(\Phi_i) = \underbrace{\underbrace{\overset{3}{v_i \overset{1}{\Phi_i}} + m_{ij} \overset{2}{\Phi_i \Phi_j} + \lambda_{ijk} \overset{3}{\Phi^i \Phi^k \Phi^j}}_{WZ} + \cdots}_{nlsm}$$

$[W] = 3 \qquad [\Phi] = +1$

$[v_i] = +2 \qquad [m_{ij}] = 1 \qquad [\lambda_{ijk}] = 0$

$V \propto |\partial W|^2$

$\Rightarrow$ using Kähler potential to determine

$[\Phi] = +1$

⇒ using ~~K~~ Kähler potential to determine

$[\Phi] = +1$

⇒ "Kinetic scaling"

⇒ using Kähler potential to determine

$[\Phi] = +1$

⇒ "Kinetic scaling"

How do we deal with nlsm?

$K(\Phi_i, \bar{\Phi}_{\bar{v}})$ and $W(\Phi_i)$

arbitrary

$\Rightarrow$ using Kähler potential to determine

$[\Phi] = +1$

$\Rightarrow$ "Kinetic scaling"

How do we deal with nlsm?

$K = \varphi_i \bar{\varphi}_i$

$K(\varphi_i, \bar{\varphi}_i)$ and $W(\varphi_i)$

$[\varphi_i] = +1$

arbitrary

$\Rightarrow$ h/gm must be an effective QFT

$\Rightarrow$ h/gm <u>must</u> be an effective QFT

$\Rightarrow$ n/gm <u>must</u> be an effective QFT

valid below some cut off scale Λ

$\Rightarrow$ n/sm <u>must</u> be an effective QFT valid below some cutoff scale Λ

$E < \Lambda$

$\Rightarrow$

$\Rightarrow$ n/sm must be an effective QFT

valid below some cutoff scale Λ

$\Rightarrow$ $\underbrace{E \ll \Lambda}_{\text{can be trivially satisfied if I choose } E=0}$

$\Rightarrow$ n/gm <u>must</u> be an effective QFT
valid below some cutoff scale Λ

$$\Rightarrow \underbrace{E \ll \Lambda}_{\text{can be trivially satisfied if I choose } E=0}$$

$\Rightarrow$ SUSY effective field theories are useful

$\Rightarrow$ n/sm must be an effective QFT valid below some cutoff scale Λ

$\Rightarrow$ $\underbrace{E \ll \Lambda}$ $(0 \ll \Lambda)$

can be trivially satisfied if I choose $E = 0$

$\Rightarrow$ s/sy effective field theories are useful

⇒ n/sm <u>must</u> be an effective QFT

valid below some cutoff scale Λ

$\underbrace{E \ll \Lambda}$ $\quad (0 \ll \Lambda)$

can be trivially satisfied if I choose $E = 0$

⇒ susy effective field theories are useful and valid to study vacuum properties of the theory

$\Rightarrow$ n/sm must be an effective QFT valid below some cut off scale Λ

$\Rightarrow$ $\underbrace{E \ll \Lambda}$ $\quad (0 \ll \Lambda)$

can be trivially satisfied if I choose $E=0$

$\Rightarrow$ SUSY effective field theories are useful and valid to study vacuum properties of the theory

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\rho) + (\partial\rho)^2 Z(\rho) \right]$$

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + (\partial\varphi)^2 Z(\varphi) \right]$$

??

$\Rightarrow$ vacuua . .

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + (\partial\varphi)^2 Z(\varphi) \right]$$

??
$\Rightarrow$ vacua . .

$\Rightarrow$ with constant (or slowly varie

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + (\partial\varphi)^2 Z(\varphi) \right]$$

??

$\Rightarrow$ vacua . .

$\Rightarrow$ with constant (or slowly varying fields)

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + \cancel{(\partial\varphi)^2 \, Z(\varphi)} \right]$$

derivative terms are not important

??

$\Rightarrow$ vacua . .

$\Rightarrow$ with constant (or slowly varying fields)

$\Rightarrow$

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + (\partial\varphi)^2 \, Z(\varphi) \right]$$

derivative terms are not important

⇒ vacua ?? . .

⇒ with constant (or slowly varying fields)

⇒ Kähler potential in at φm wrt scaling must be irrelevant

WZ model was identified

$$S_{eff} = \int d^4x \left[-V_{eff}(\varphi) + (\partial\varphi)^2 \mathcal{K}(\varphi) \right]$$

derivative terms are not important

$\Rightarrow$ vacuua ??

$\Rightarrow$ with constant (or slowly varying fields)

$\Rightarrow$ Kähler potential in n[illegible] wrt scaling must be irrelevant