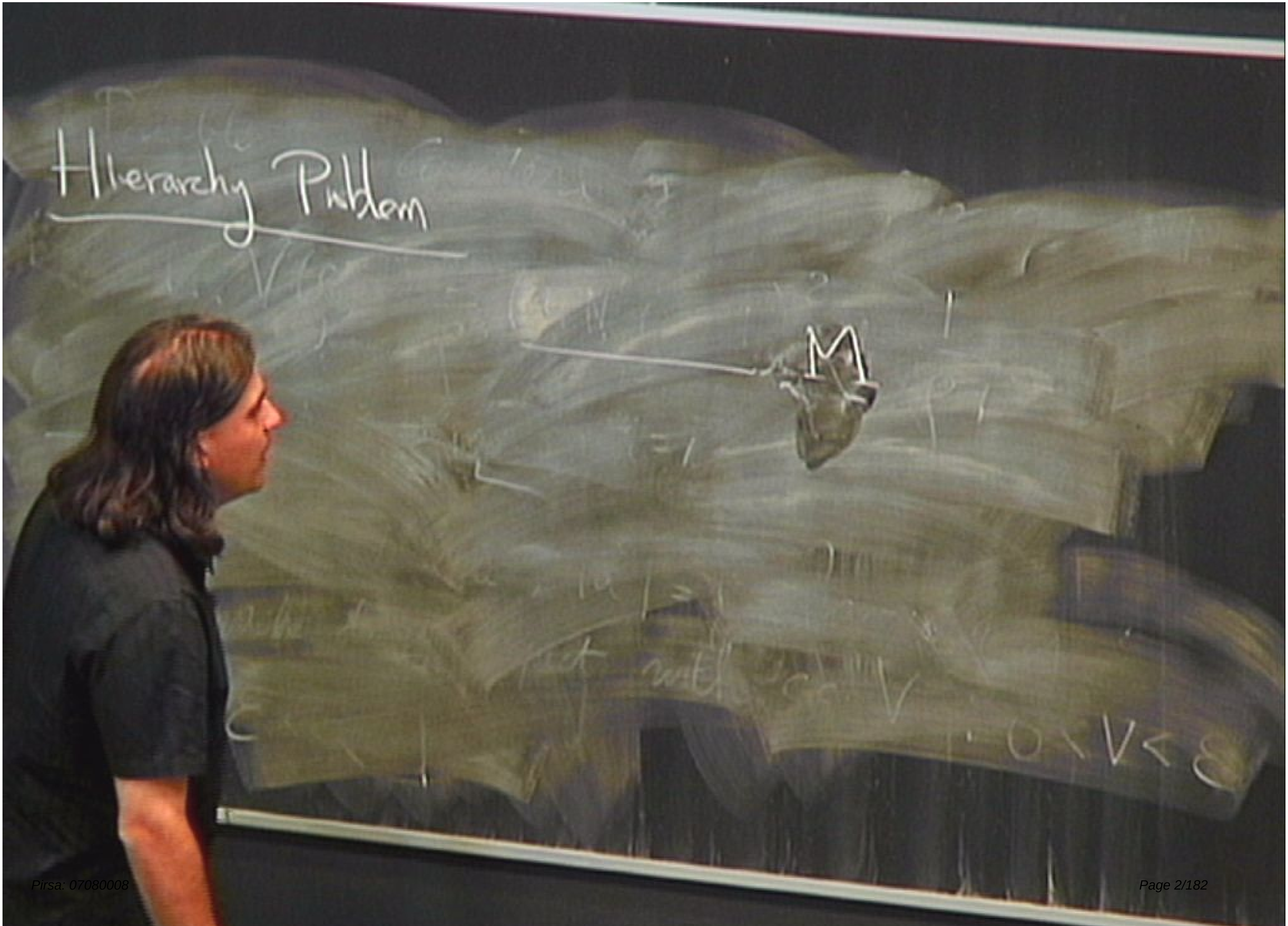
Title: Introduction to Low Energy Supersymmetry 2

Date: Aug 08, 2007 02:00 PM

URL: http://pirsa.org/07080008

Abstract:


Hierarchy Problem
M

Hierarchy Problem

$$\Lambda + m_h^2 h^\dagger h$$

M

Hierarchy Problem

$$\Lambda + m_h^2 h^\dagger h$$

M

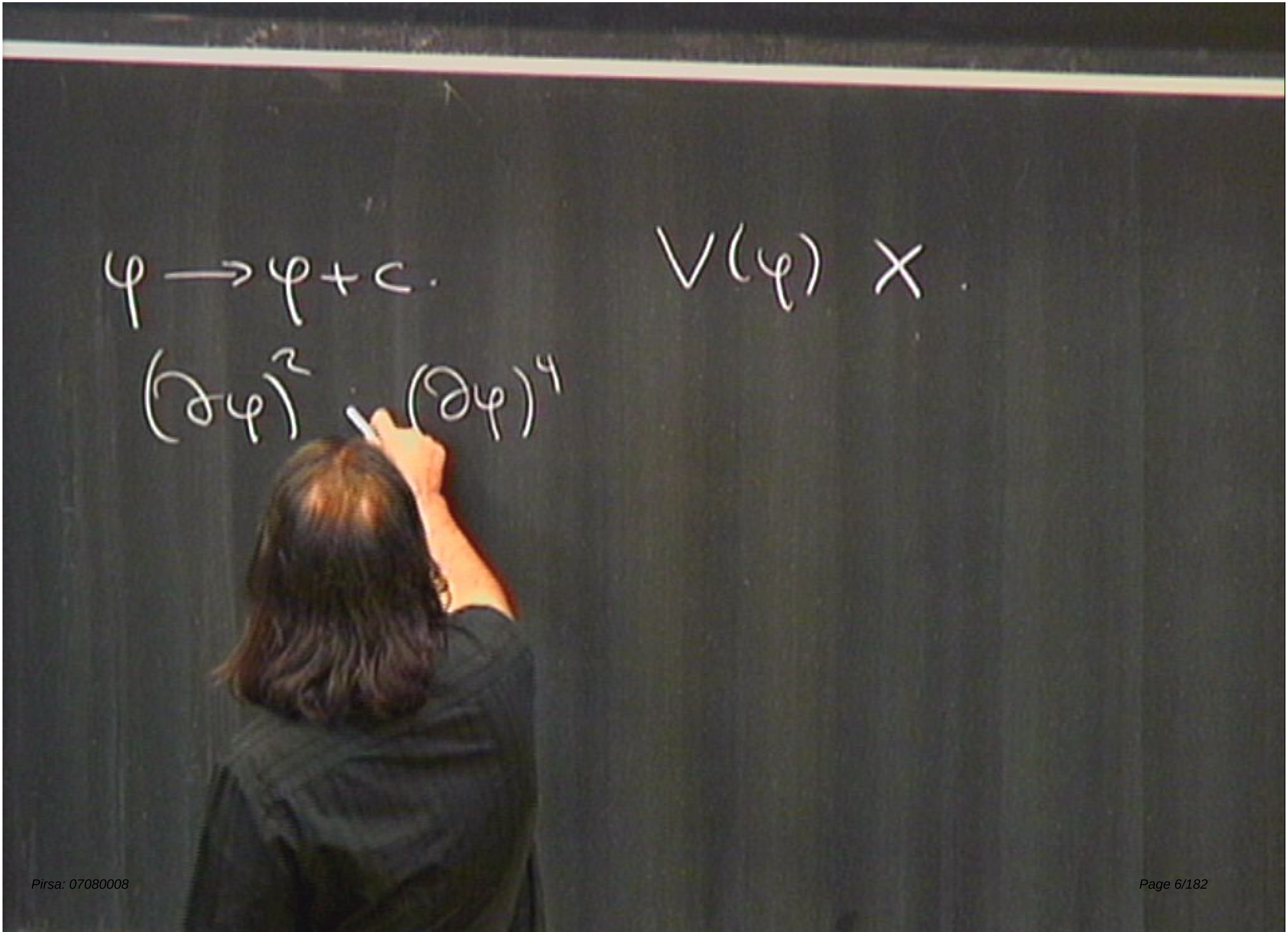
$$\Lambda \sim M^4, \quad m_h^2 \sim M^2$$

Hierarchy Problem

M

$$\Lambda + m_h^2 h^\dagger h$$

$$\Lambda \sim M^4 , \; m_h^2 \sim M^2$$


$\varphi \longrightarrow \varphi + c$.
$(\partial\varphi)^2$, $(\partial\varphi)^4$
$V(\varphi)$ X.

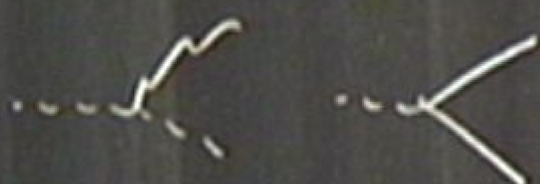
$\varphi \longrightarrow \varphi + c.$ $\qquad V(\varphi)$ X.

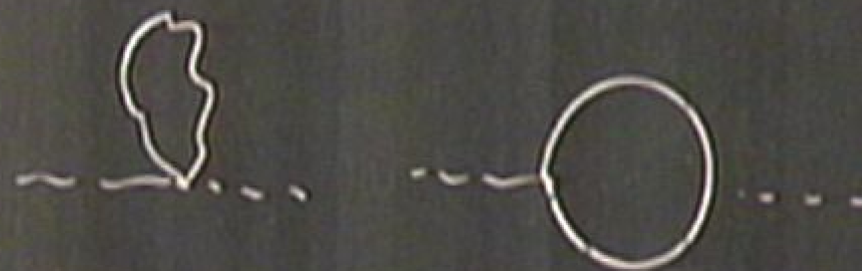
$(\partial\varphi)^2 + (\partial\varphi)^4 + \ldots$

$\varphi \longrightarrow \varphi + c.$

$V(\varphi)$ ✗.

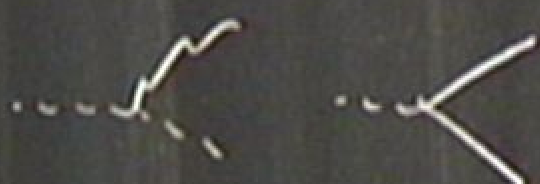
$(\partial\varphi)^2 + (\partial\varphi)^4 + \dots$



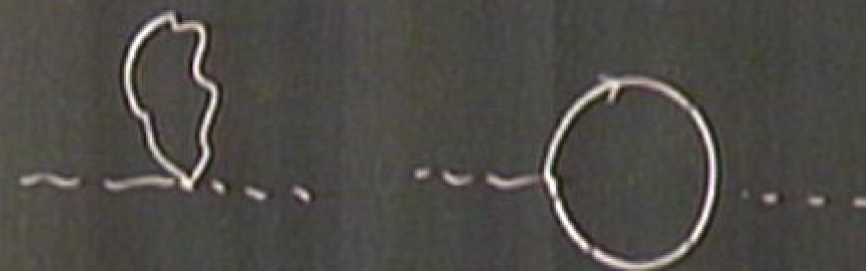


$\varphi \longrightarrow \varphi + c.$

$(\partial\varphi)^2 + (\partial\varphi)^4 + \dots$



$V(\varphi)\ \times$



$\frac{g^2 M^2}{16\pi^2}$ $\qquad$ $\frac{3\lambda_t^2}{8\pi^2} M^2$

$\sim (0.3 M)^2$

$\varphi \longrightarrow \varphi + c$.

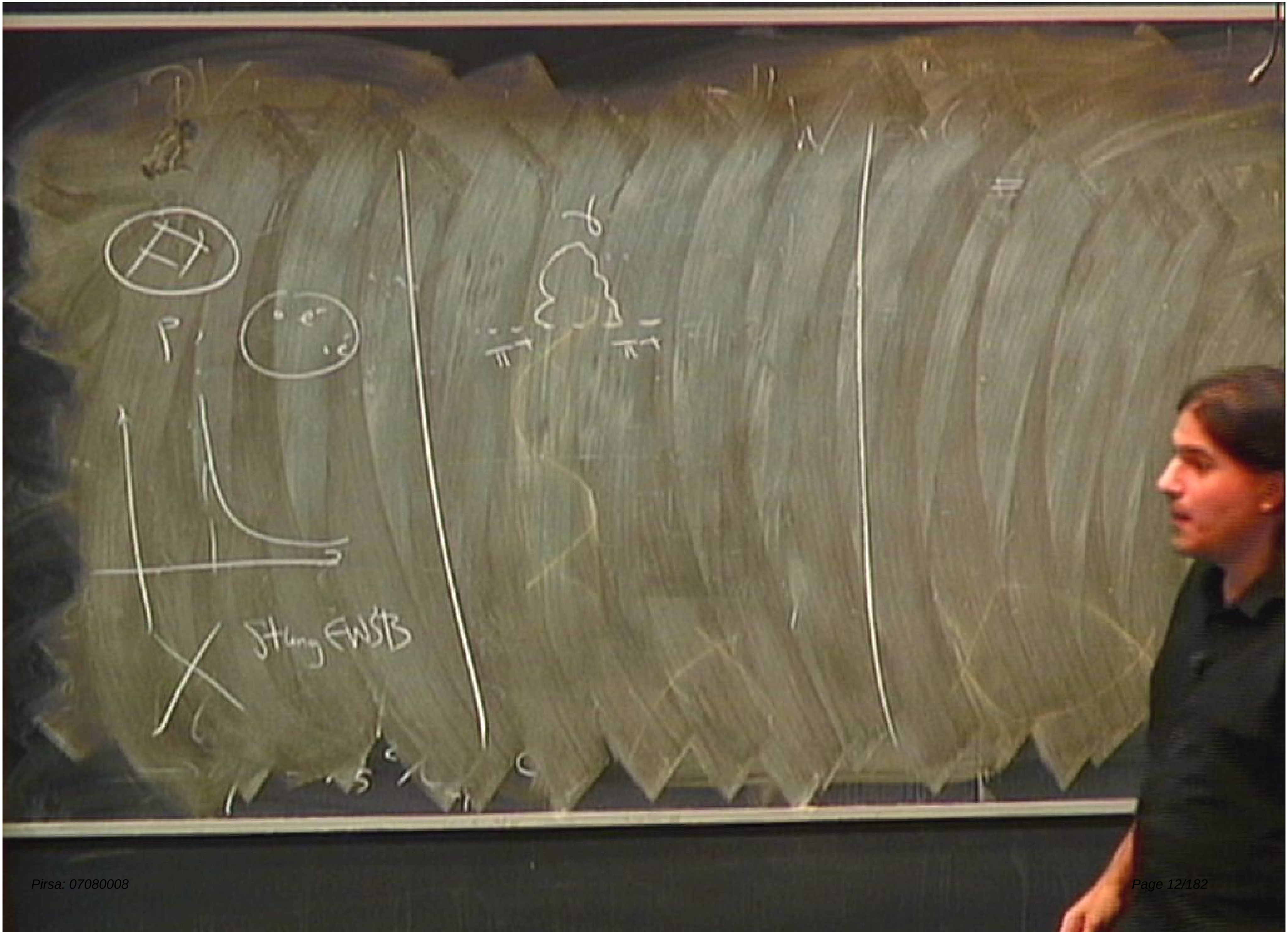
$(\partial\varphi)^2 + (\partial\varphi)^4 + \dots$

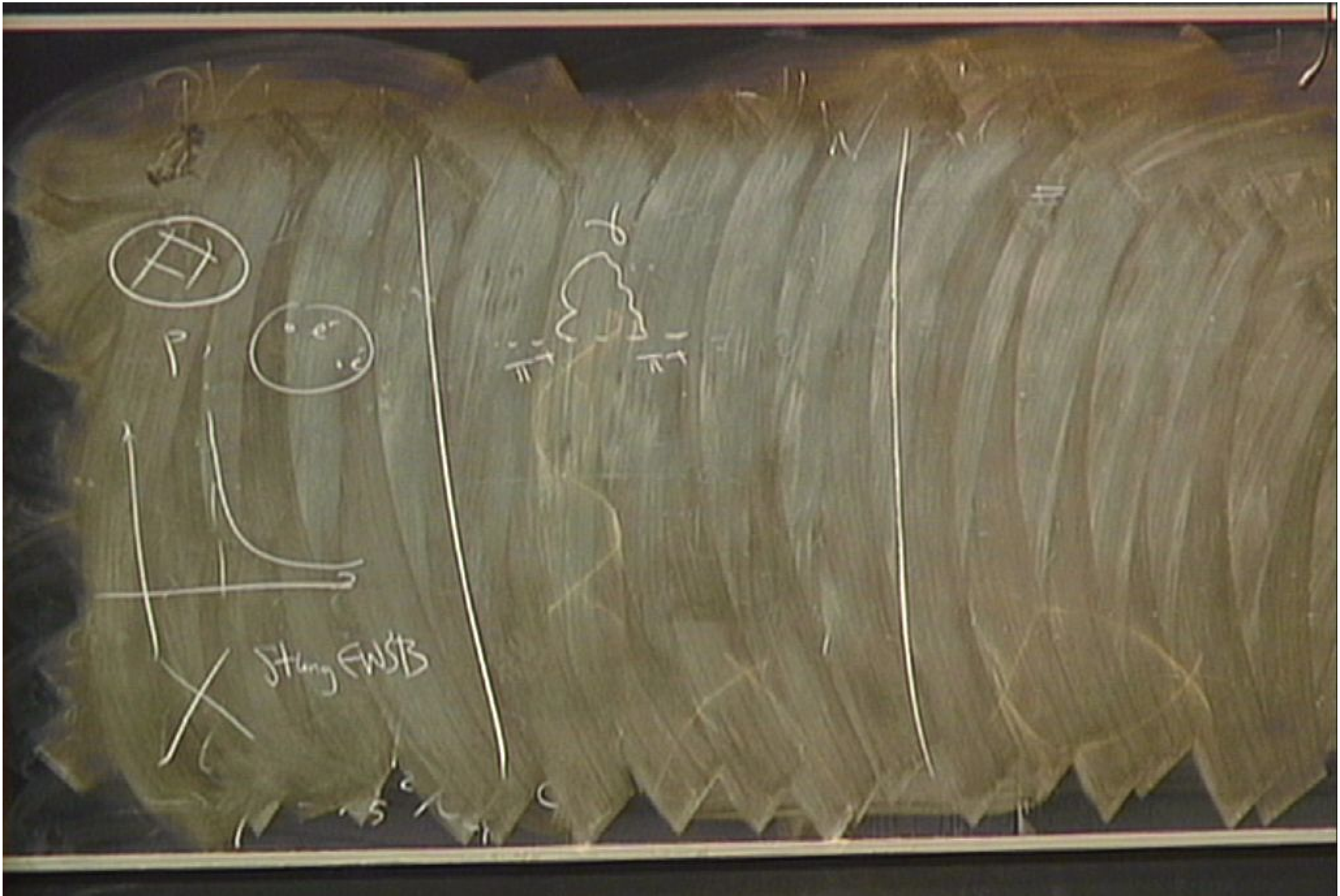
$V(\varphi)$ ×.

$\frac{g^2 M^2}{16\pi^2}$

$\frac{3\lambda_t^2}{8\pi^2} M^2$

$\sim (0.3M)^2$


Strong EWSB


Strong EWSB

$\varphi \to \varphi + c.$ $\quad V(\varphi)$ ✗.

$(\partial\varphi)^2 + (\partial\varphi)^4 + \dots$

$(.3M)^2 \gg (100\,\text{GeV})^2$

$M \lesssim \text{TeV}$

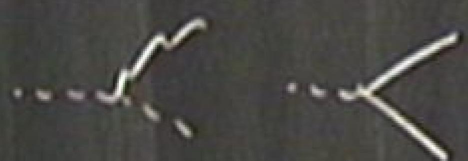
$\frac{g^2 \Lambda^2}{16\pi^2}$

$\frac{3\lambda_t^2}{8\pi^2}\Lambda^2$

$\sim (.3\Lambda)^2$

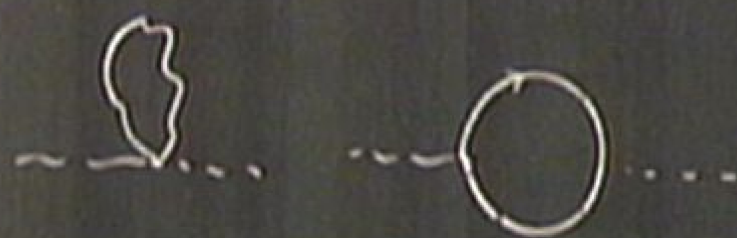
$\varphi \to \varphi + c.$ $\qquad V(\varphi)\ \times.$

$(\partial\varphi)^2 + (\partial\varphi)^4 + \cdots$

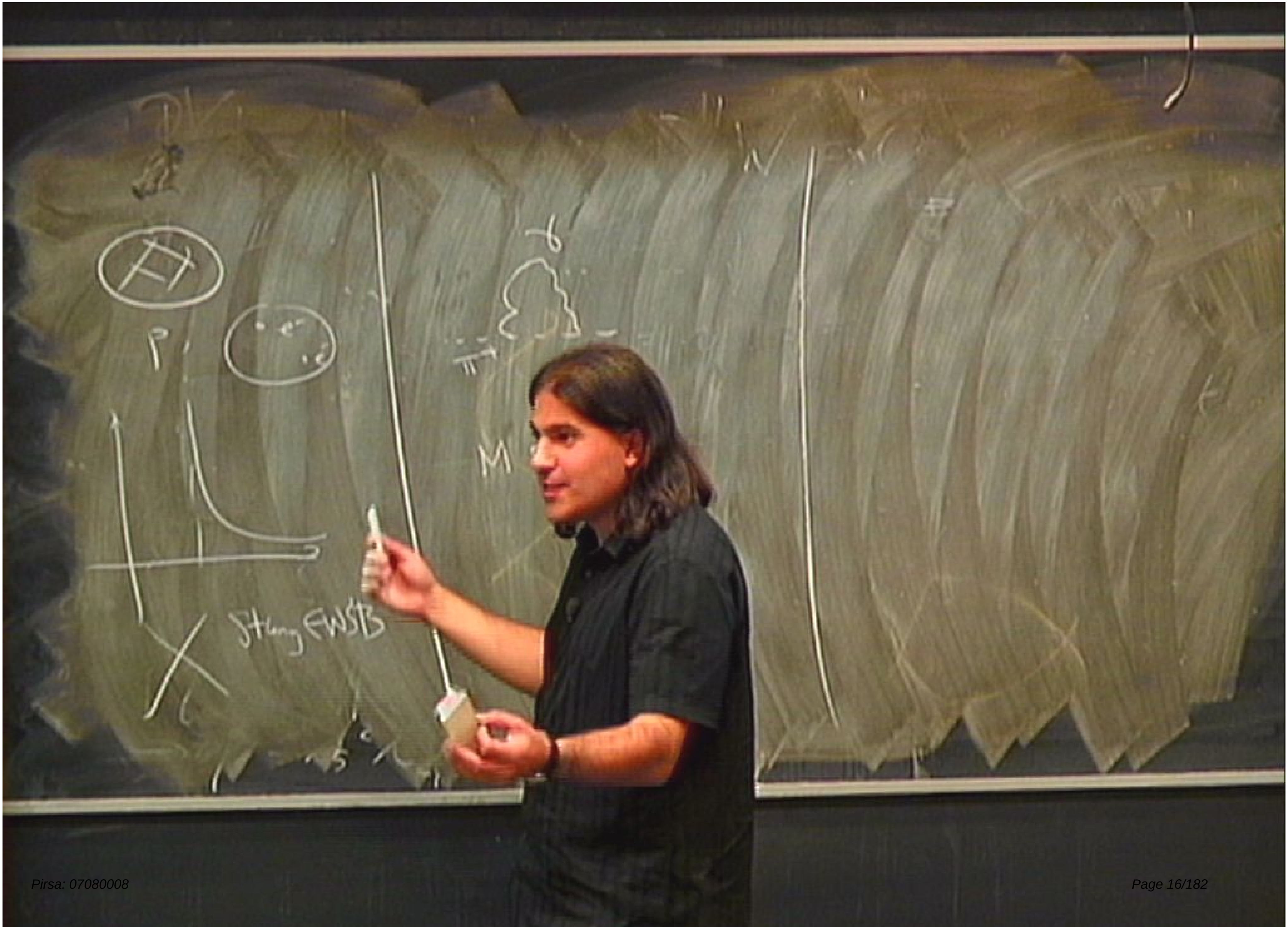


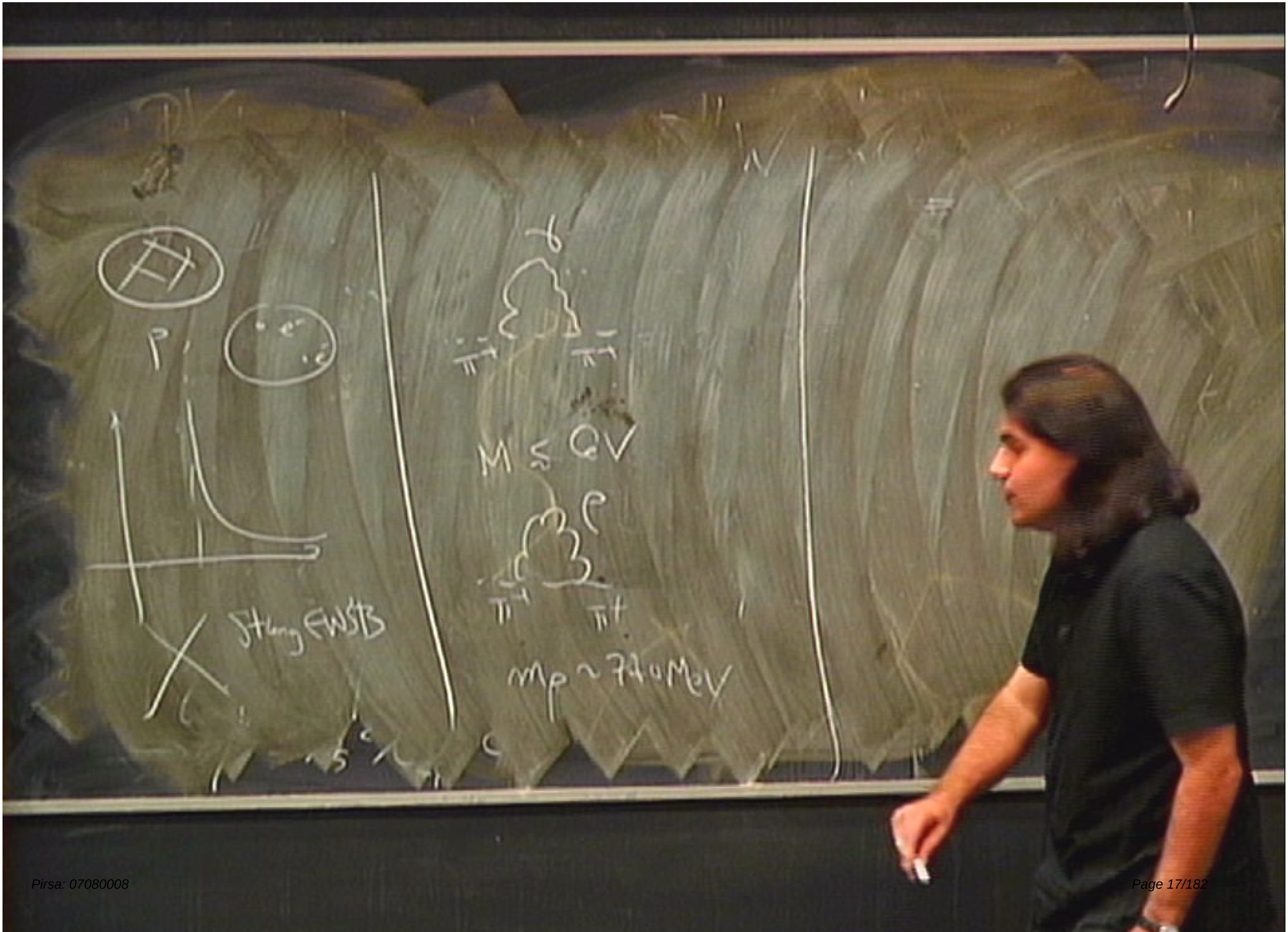
$(.3M)^2 \gg (100\,\mathrm{GeV})^2$

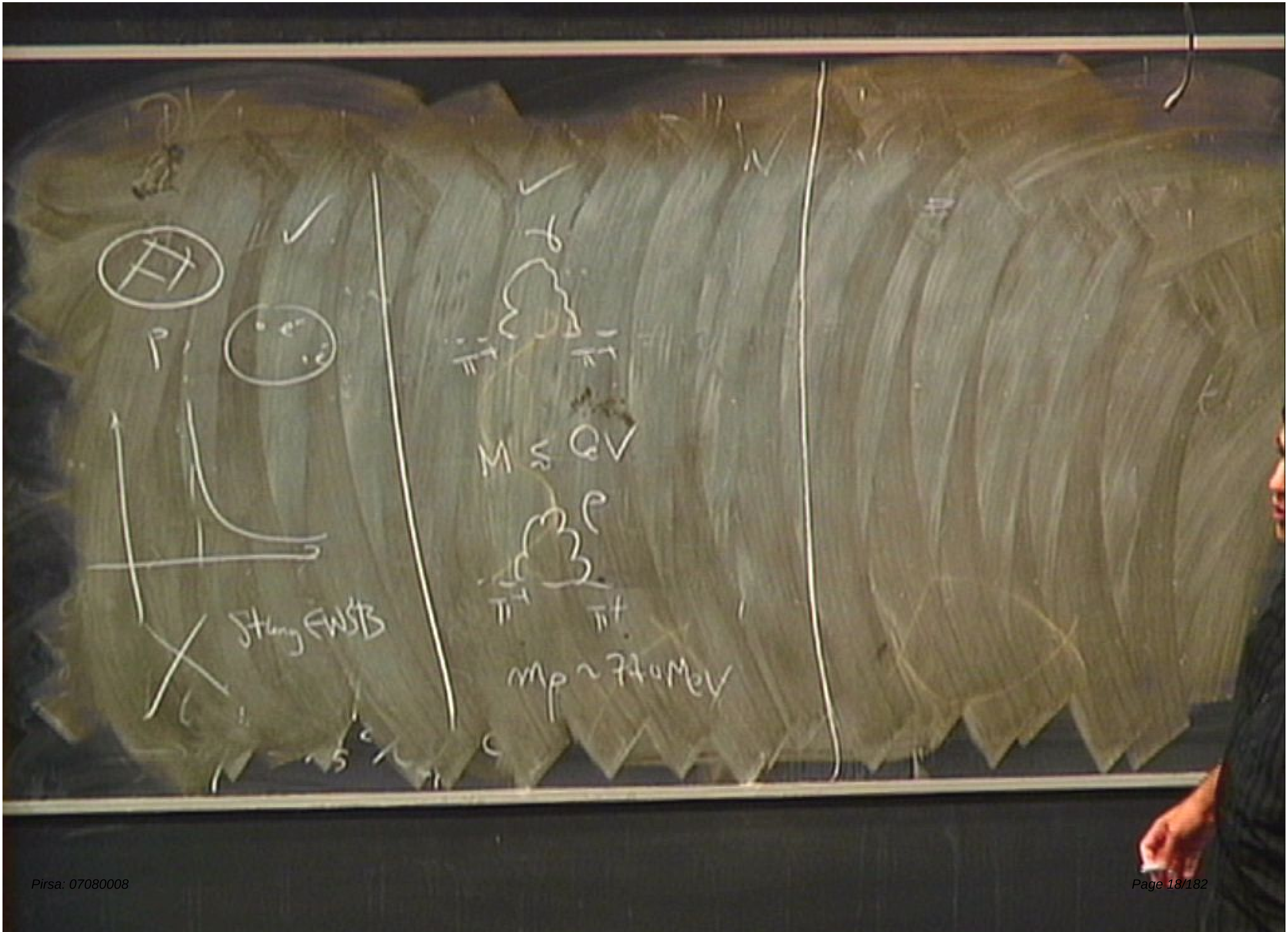
$M \lesssim \mathrm{TeV}$

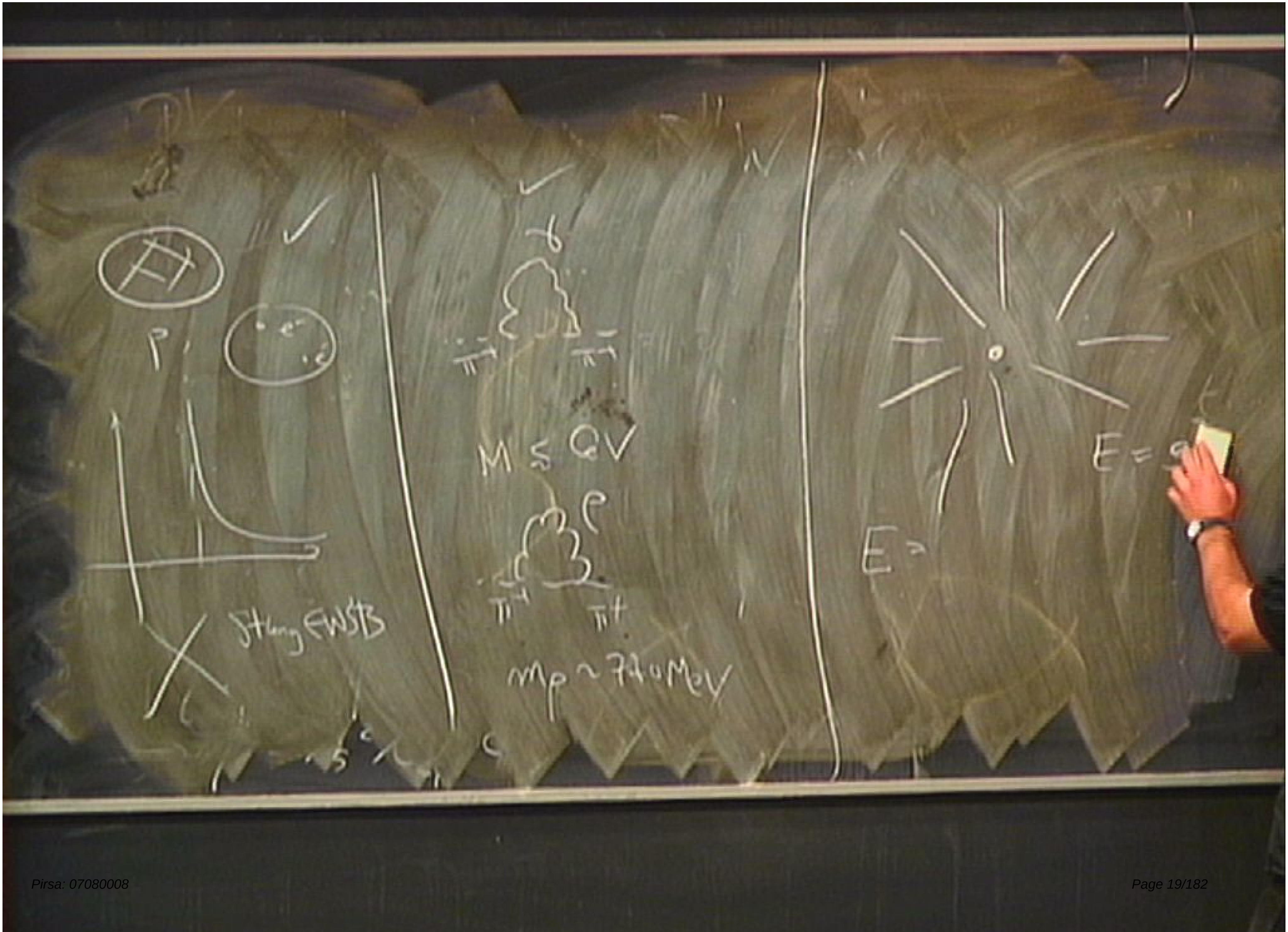


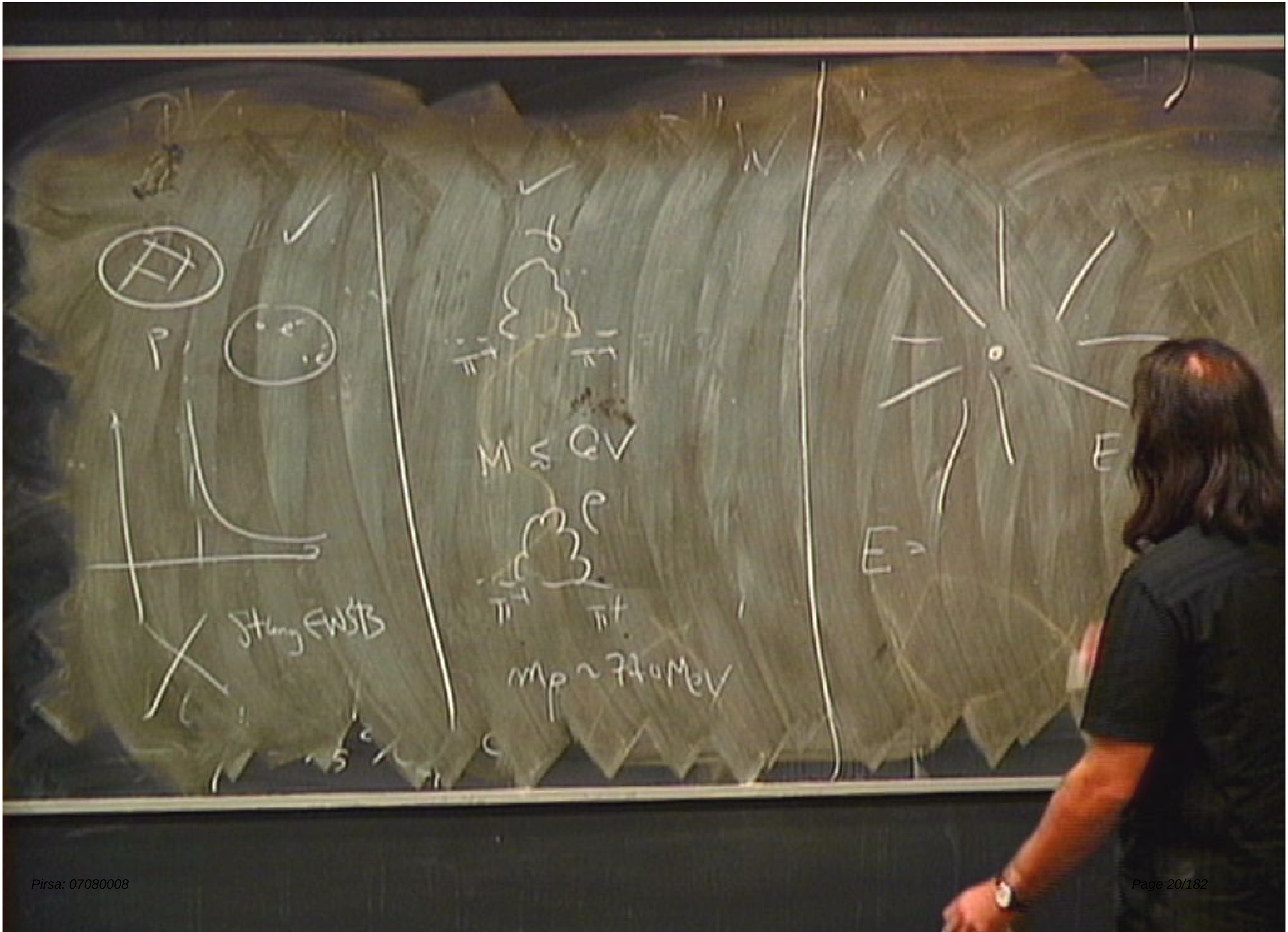
$\frac{g^2 M^2}{16\pi^2}$ $\qquad \frac{3\lambda_t^2}{8\pi^2} M^2 \sim (.3M)^2$

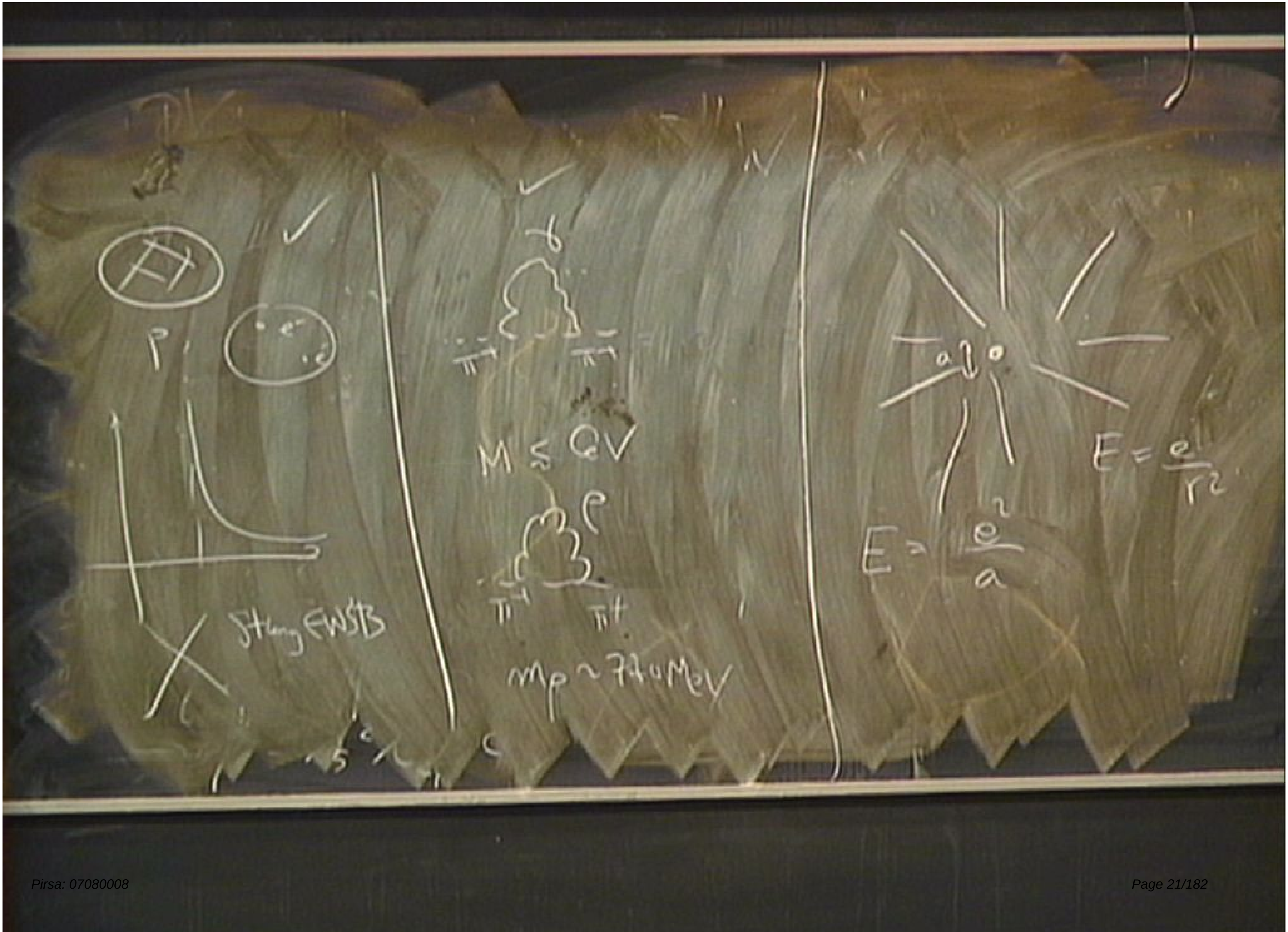

Strong EWSB
M

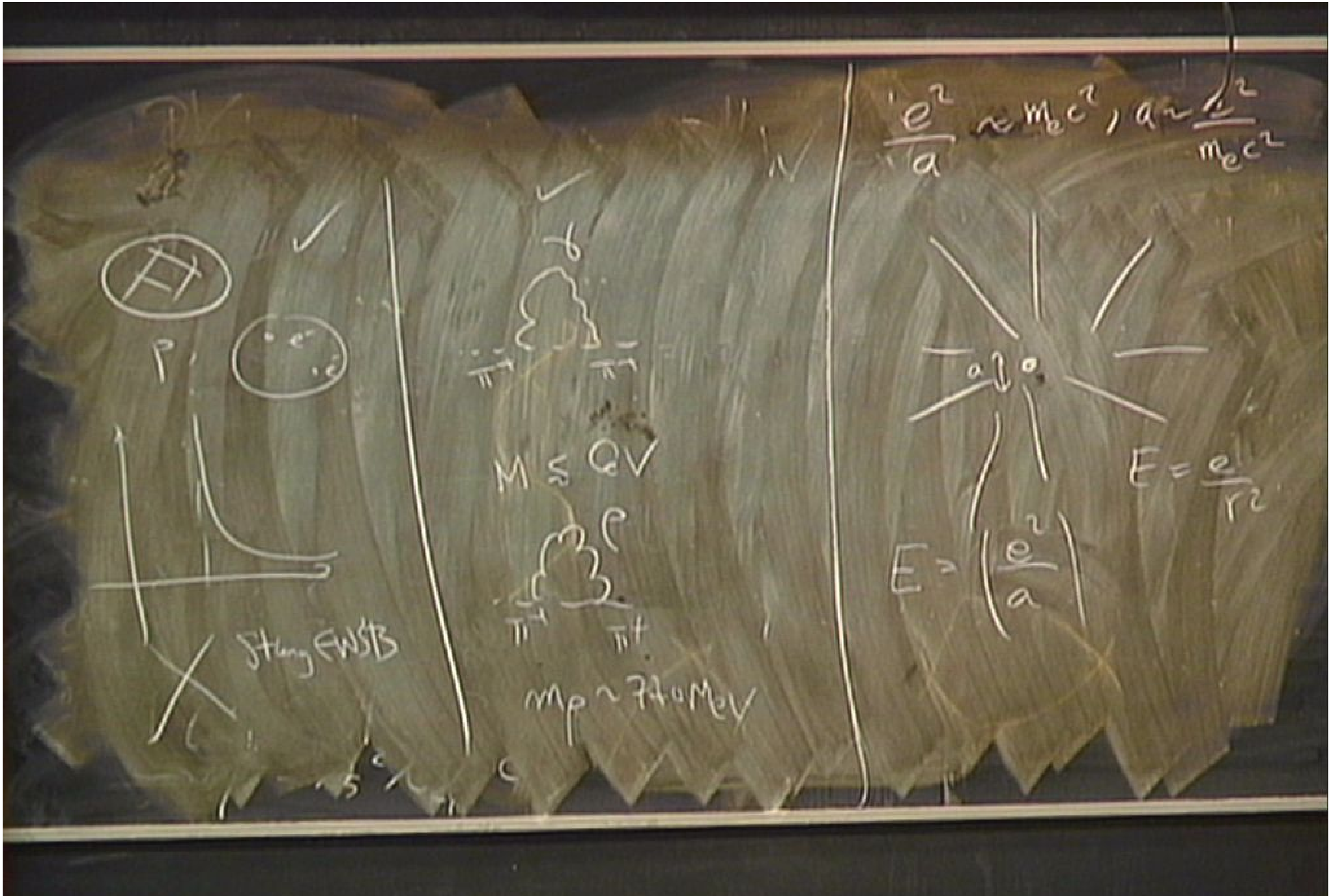

Strong EWSB
M ≲ GeV
mρ ~ 770 MeV


Strong EWSB
M ≲ GeV
mρ ~ 770 MeV

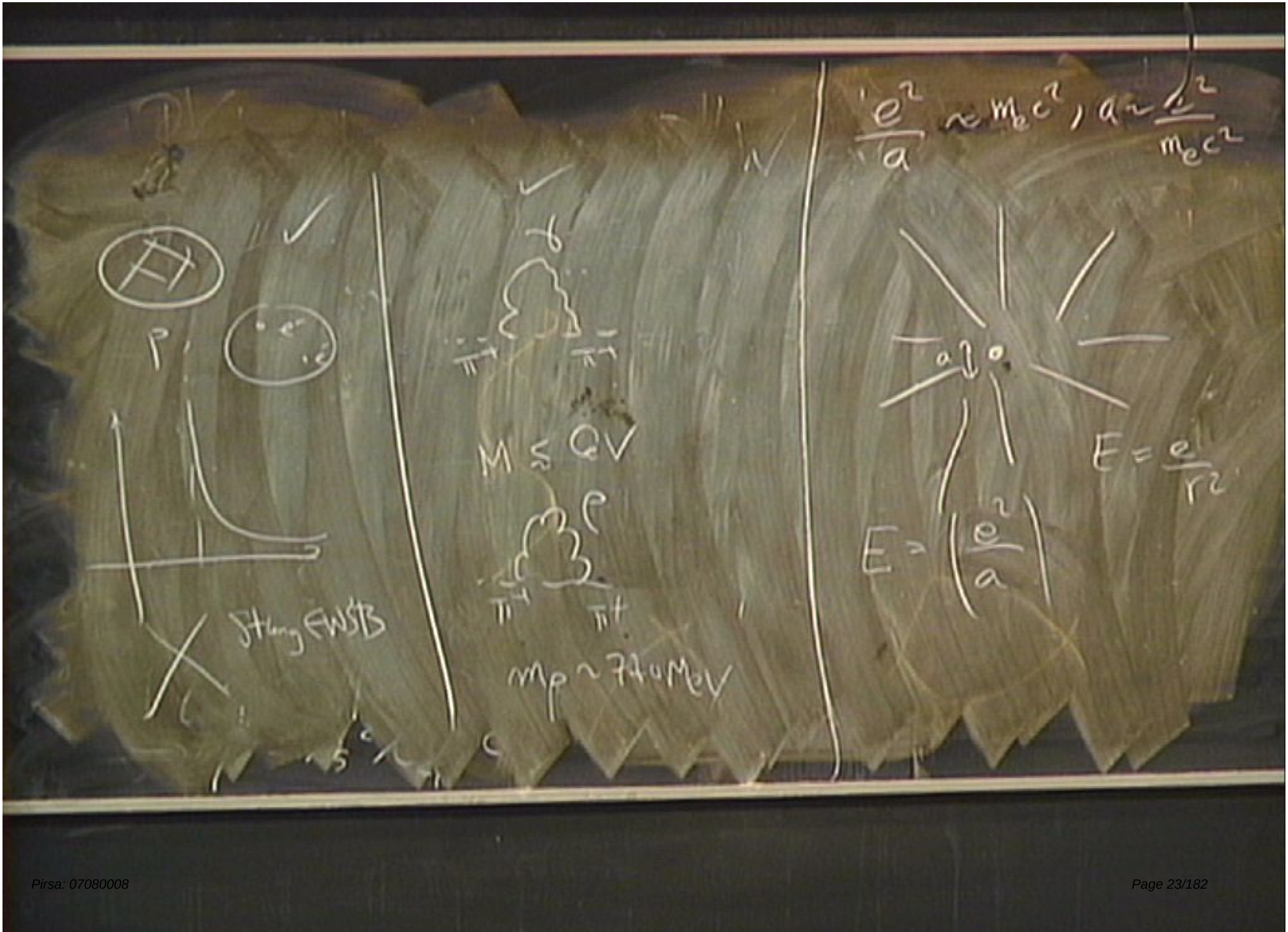

Strong EWSB
M ≲ QV
mρ ~ 770 MeV
E =

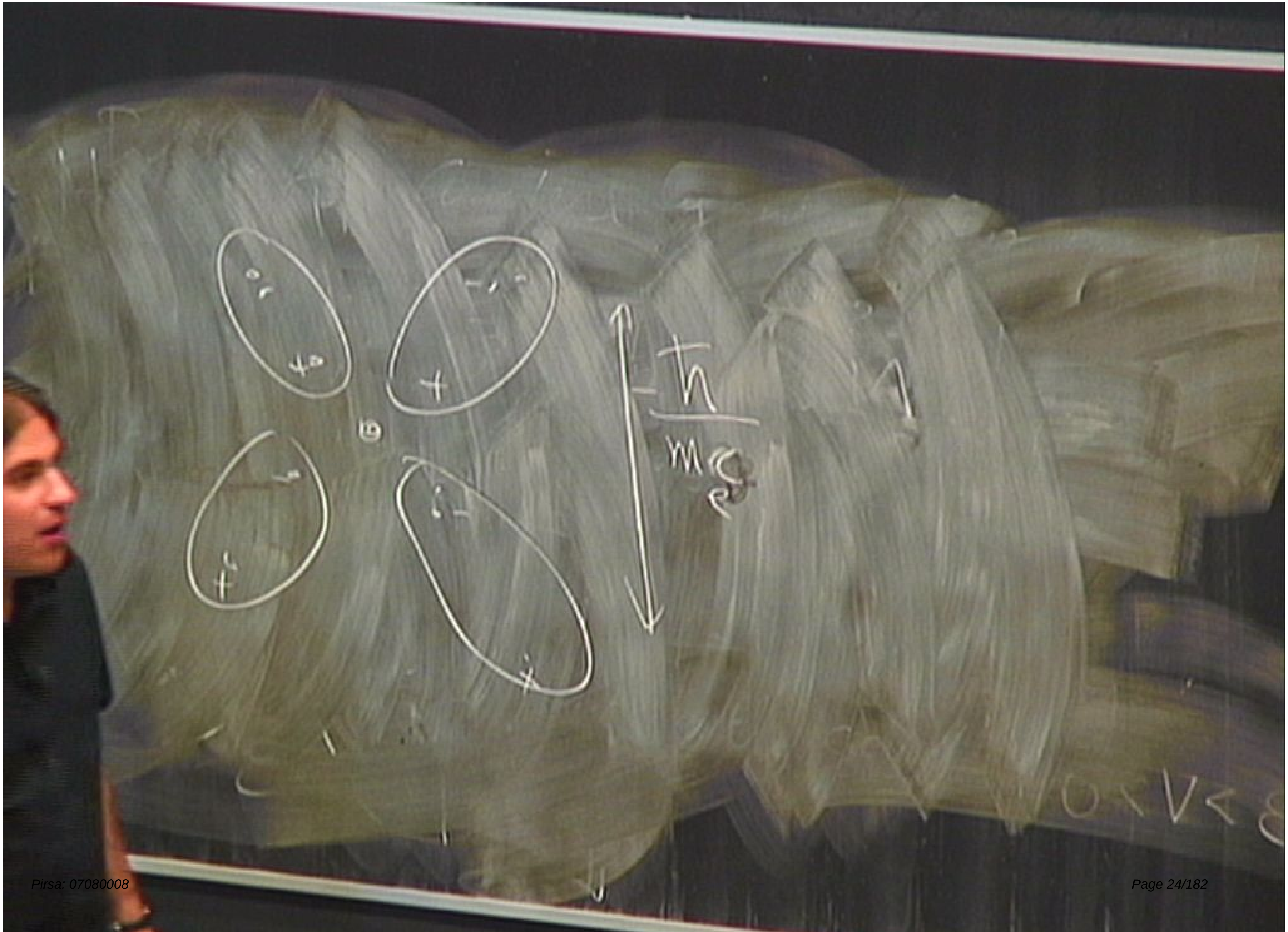

Strong EWSB
mρ ~ 770 MeV

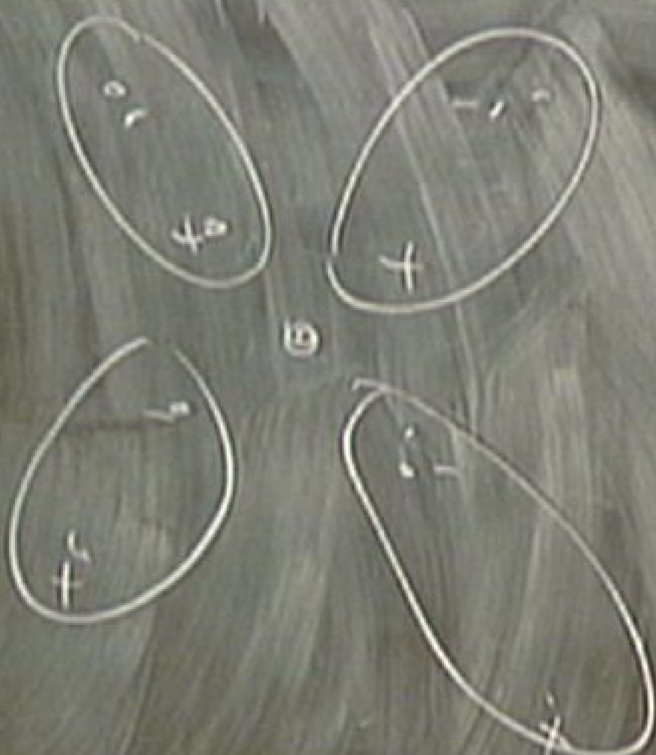

Strong EWSB
M ≲ GeV
mρ ~ 770 MeV
E = e/r²
E ~ e²/a



$\frac{e^2}{a} \sim m_e c^2$, $a \sim \frac{e^2}{m_e c^2}$
$E = \frac{e}{r^2}$
$E \sim \left(\frac{e^2}{a}\right)$
$M \lesssim QV$
$m_\rho \sim 770$ MeV
Strong EWSB

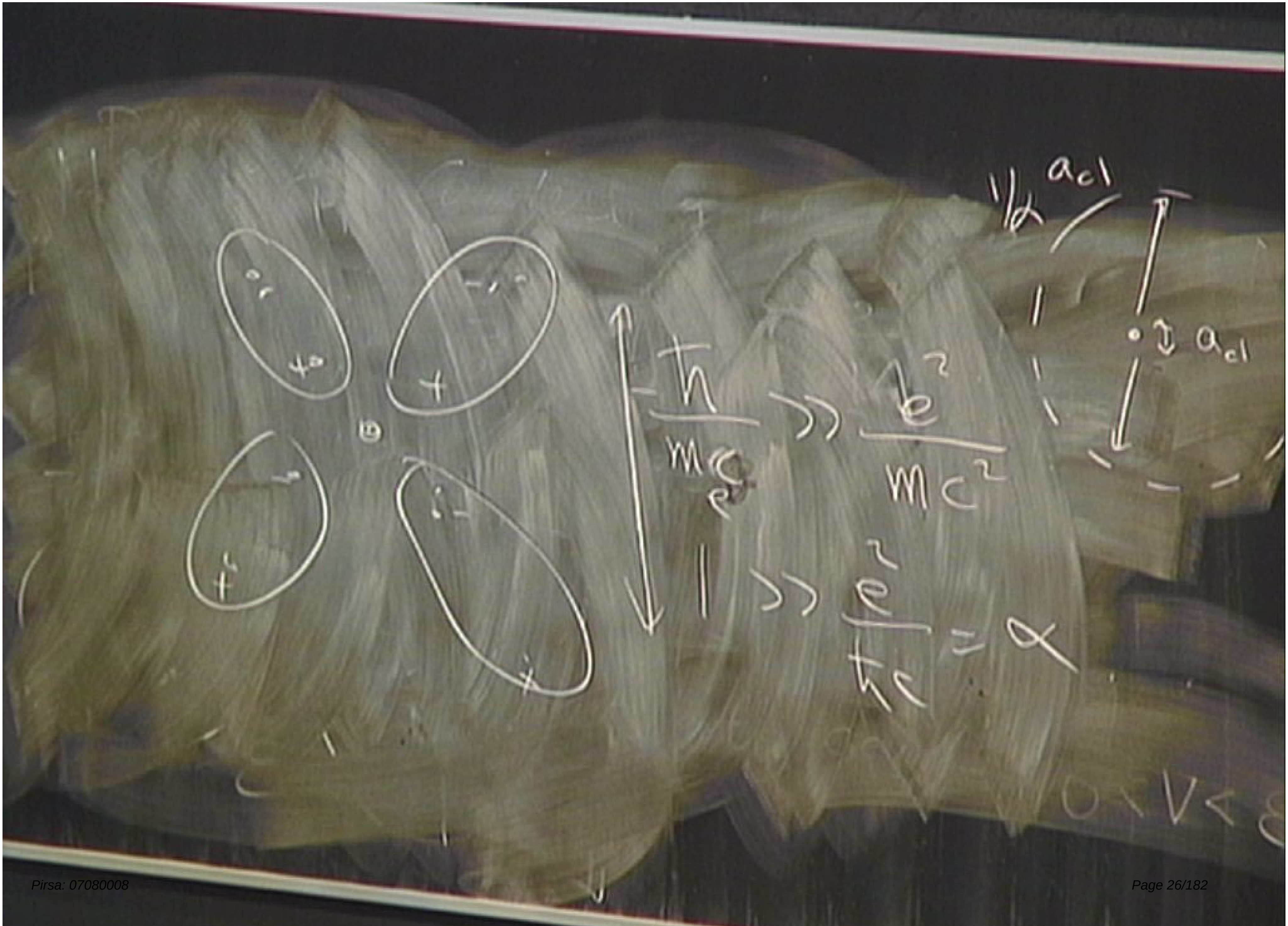

Strong EWSB
M ≲ QV
mρ ~ 770 MeV
e²/a ~ mₑc², a ~ e²/mₑc²
E = e/r²
E ~ (e²/a)

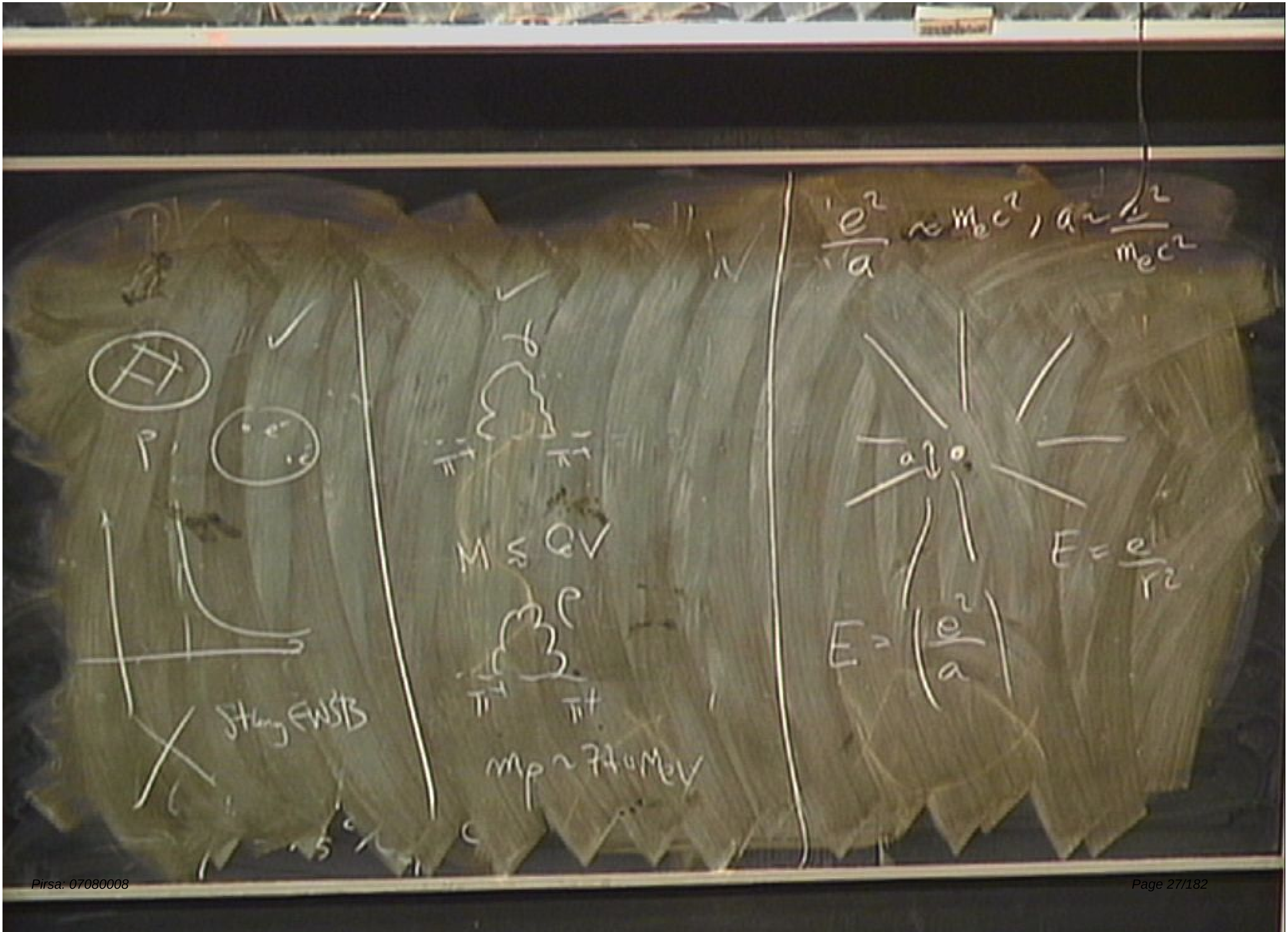


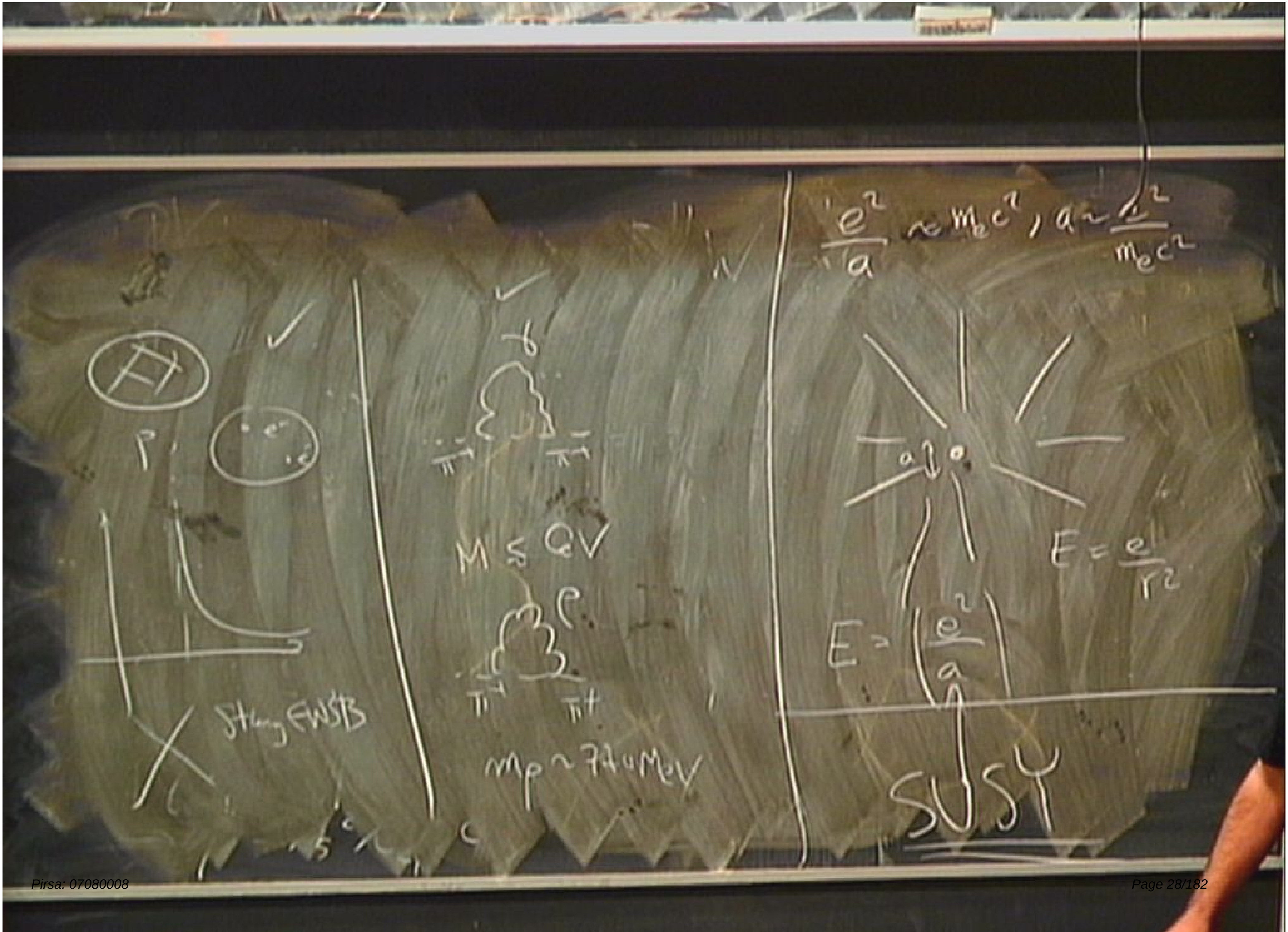


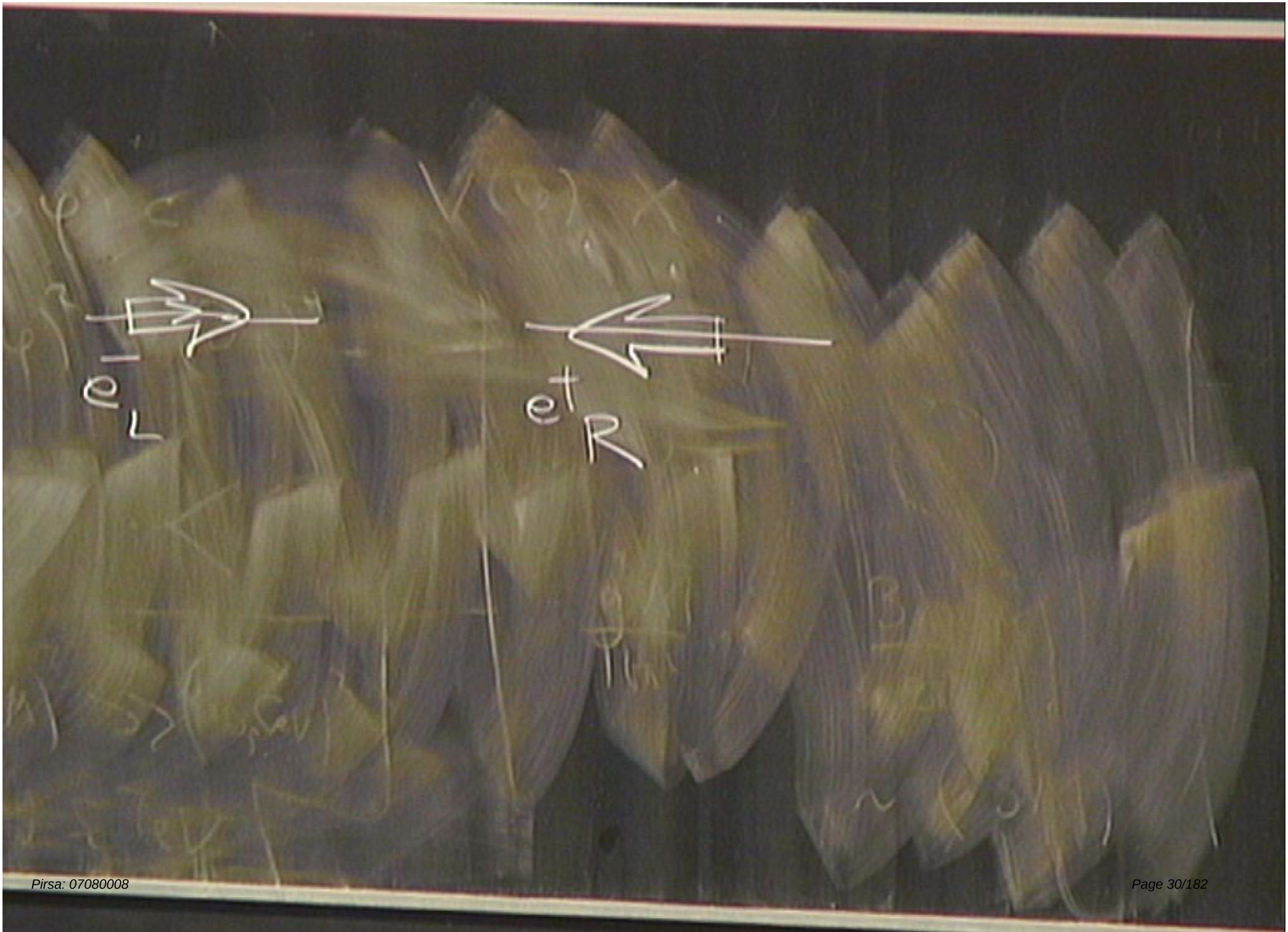
$$\frac{\hbar}{mc} \gg \frac{e^2}{mc^2}$$

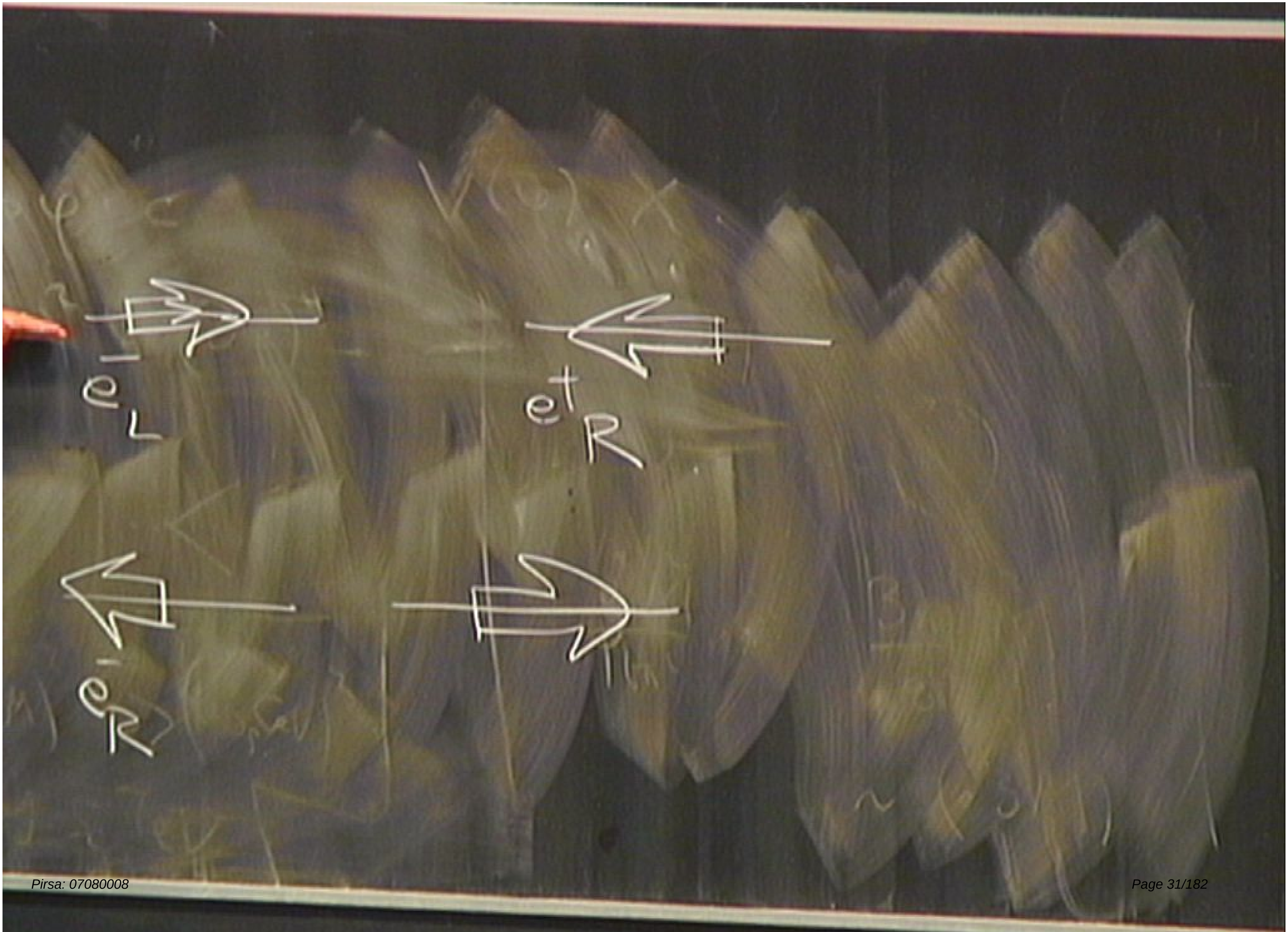
$$1 \gg \frac{e^2}{\hbar c} = \alpha$$

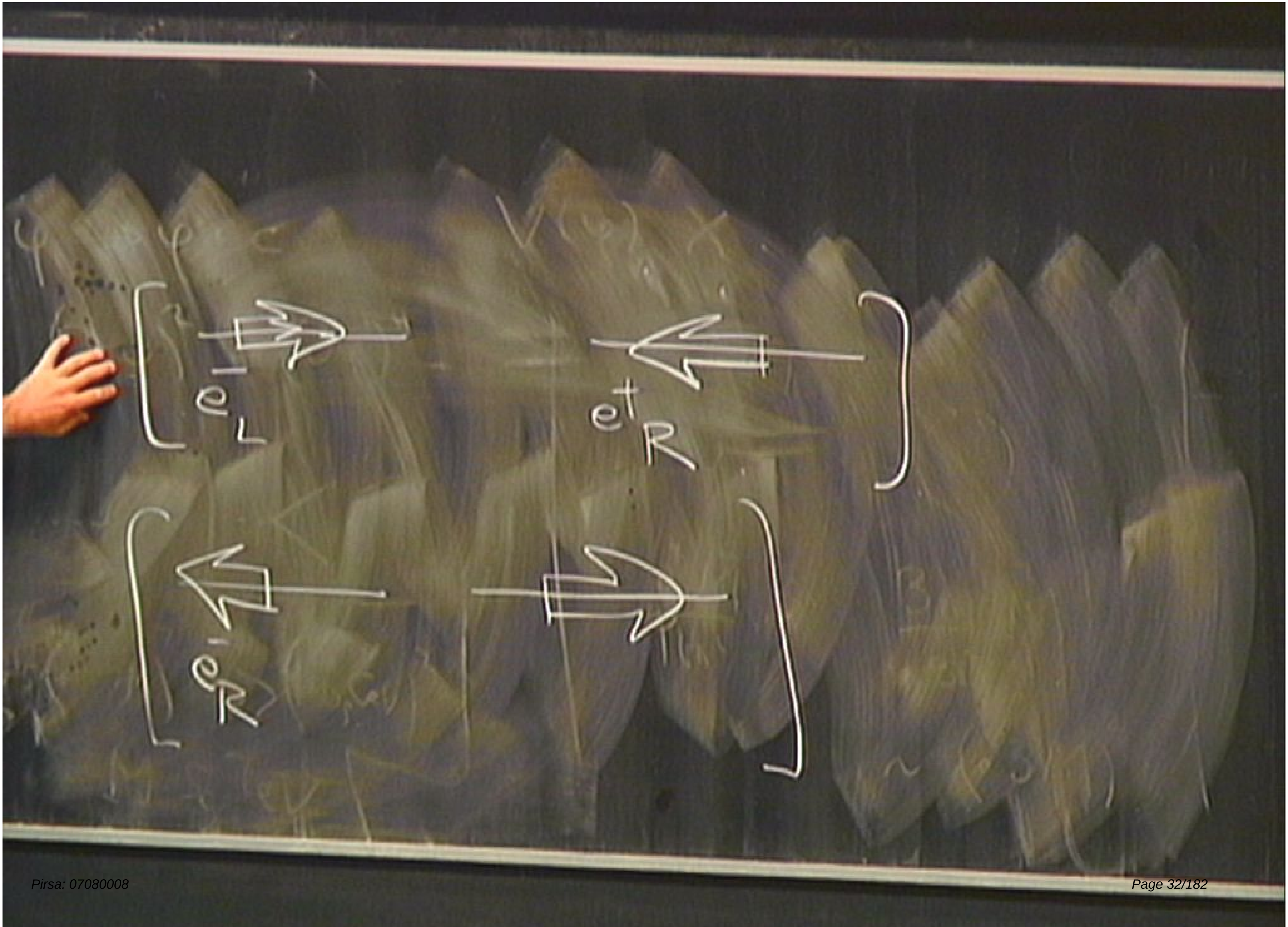

$1/\alpha \; a_{cl}$
a_{cl}
$\frac{\hbar}{mc} \gg \frac{e^2}{mc^2}$
$1 \gg \frac{e^2}{\hbar c} = \alpha$

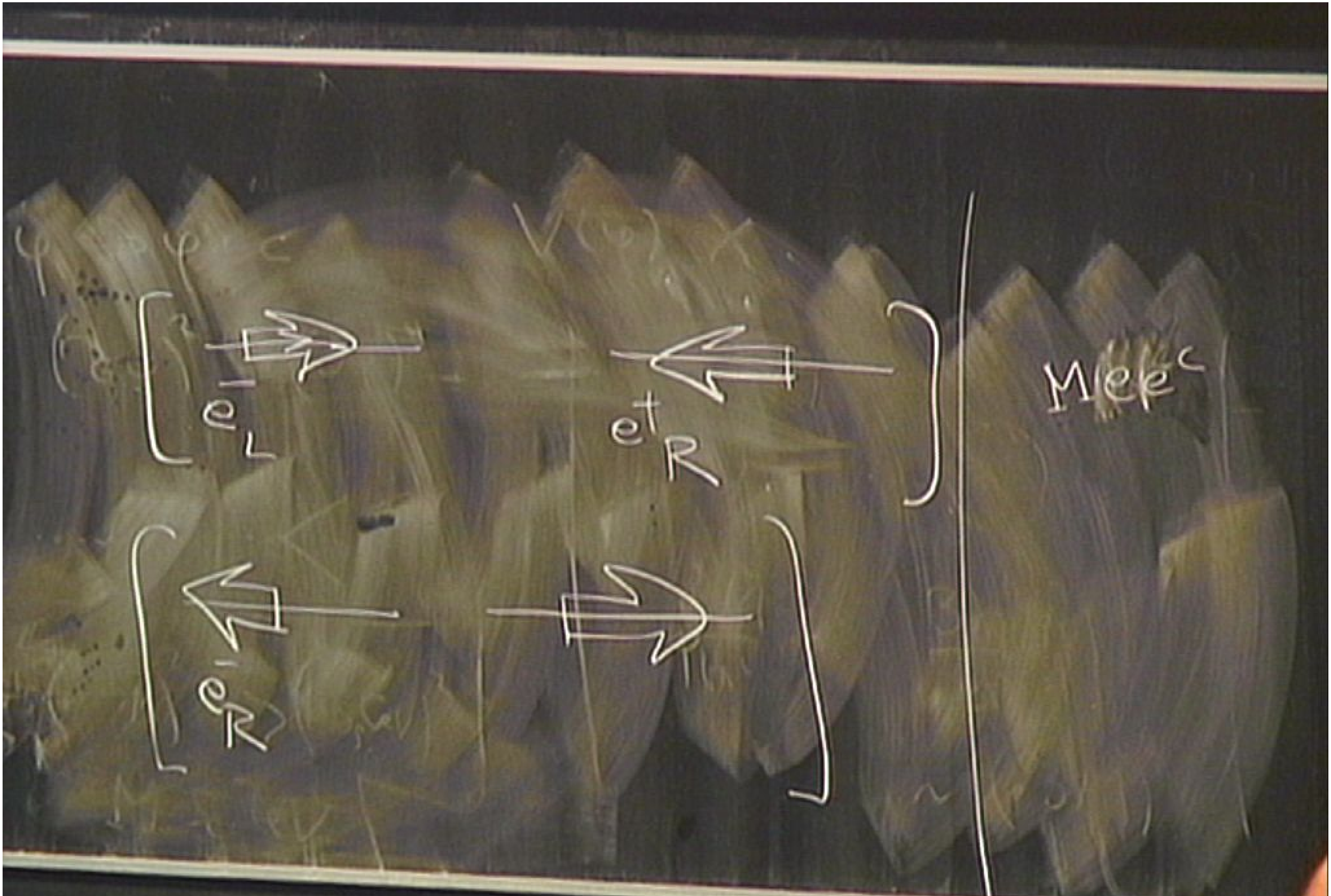

e²/a ~ m_e c², a ~ e²/(m_e c²)
p
e⁻
Strong EWSB
γ
π⁺
M ≲ QV
ρ
m_ρ ~ 770 MeV
E = e/r²
E ~ (e²/a)

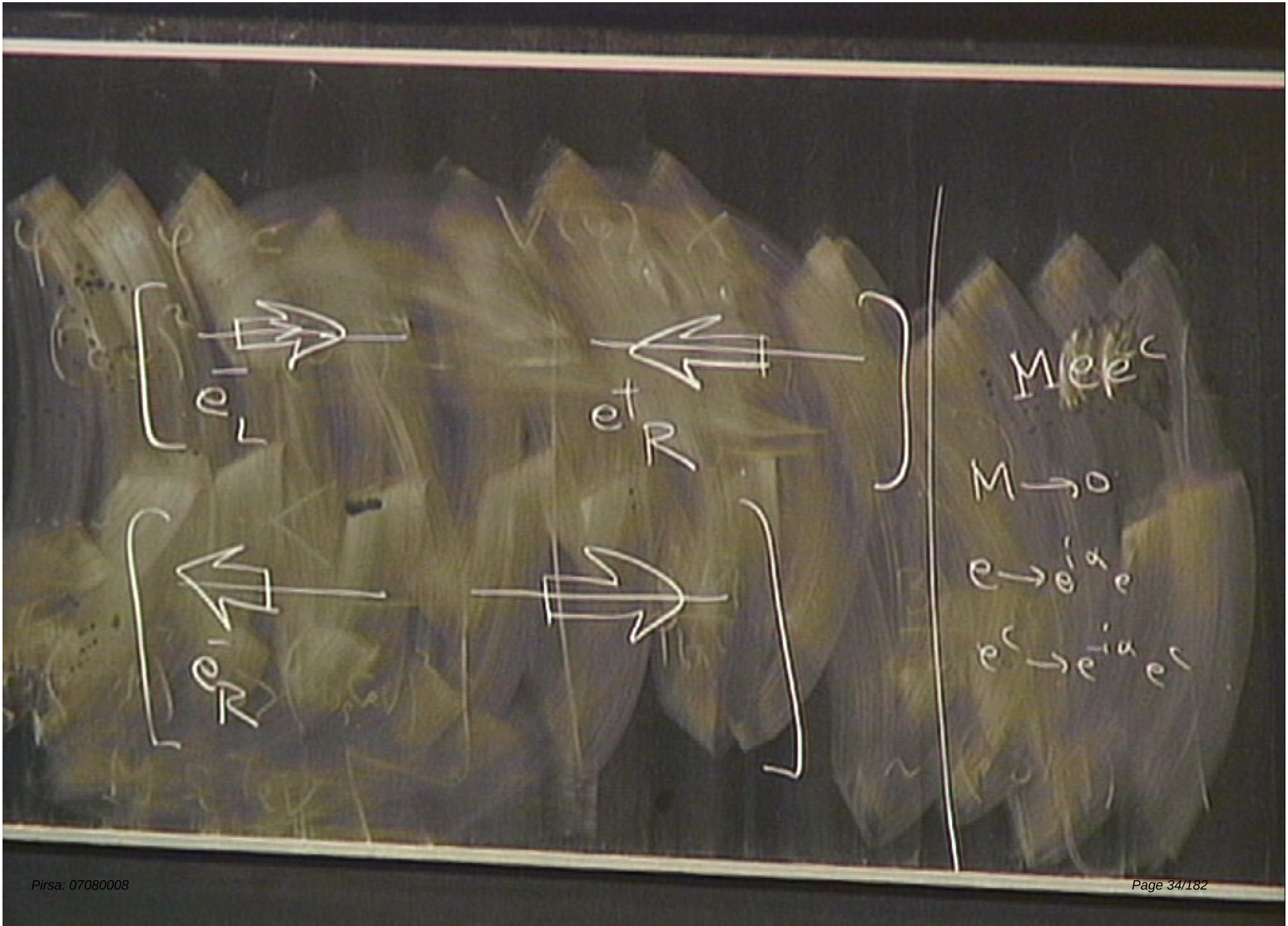

Strong EWSB
M ≲ QV
mρ ~ 770 MeV
e²/a ~ mₑc², a ~ e²/mₑc²
E = e/r²
E ~ (e²/a)
SUSY

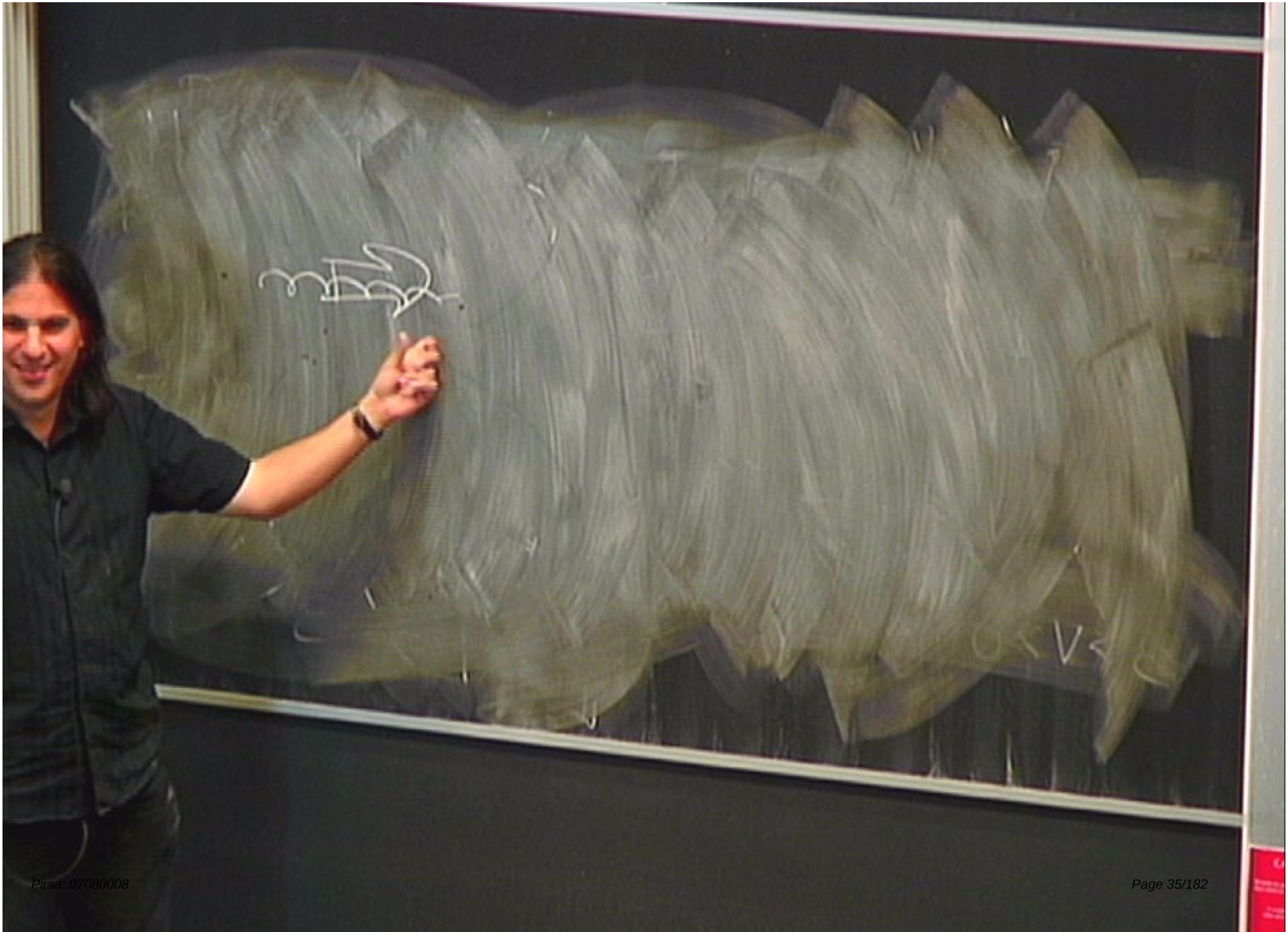

e_L^-
e_R^+

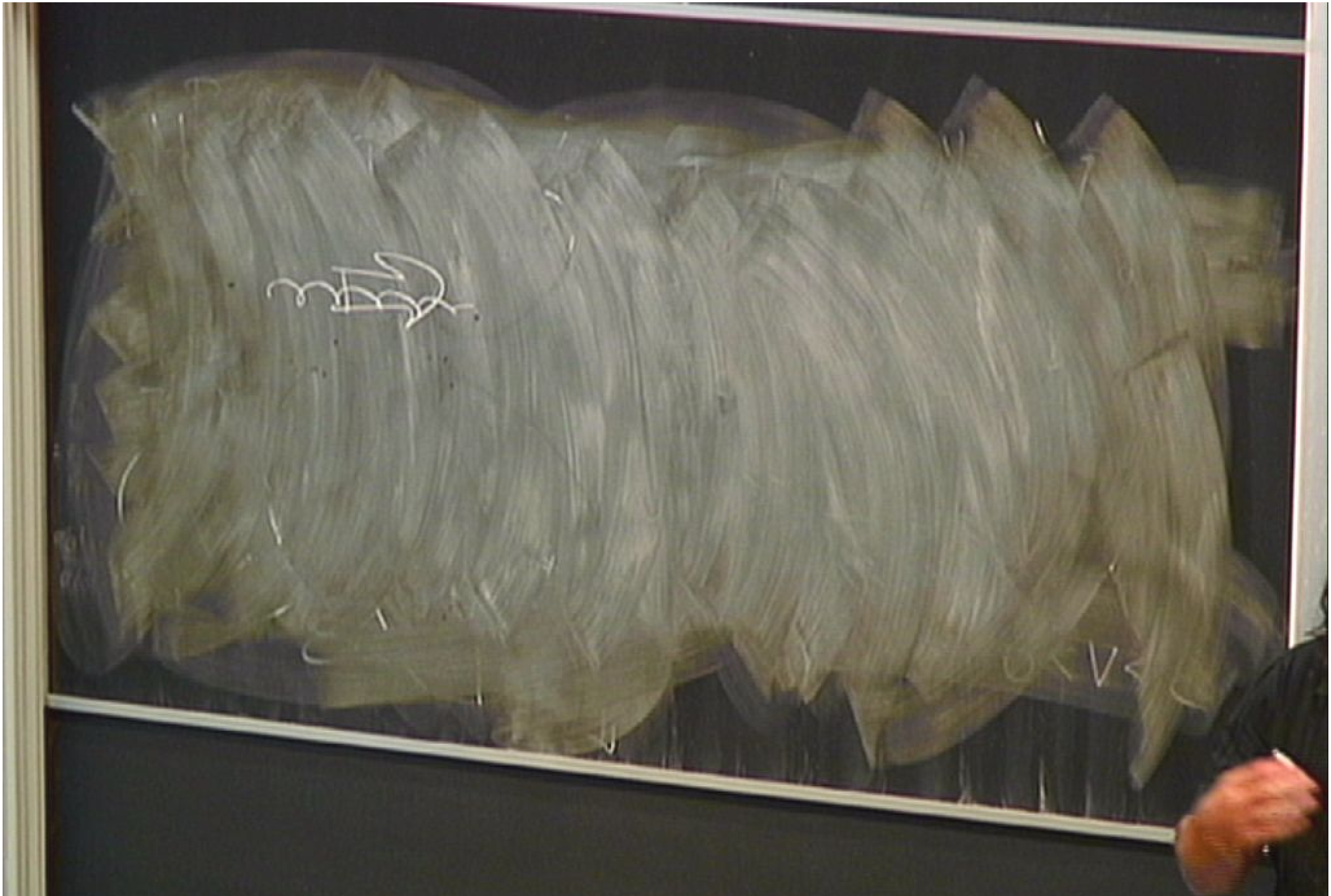

e^-_L
e^+_R
e^-_R

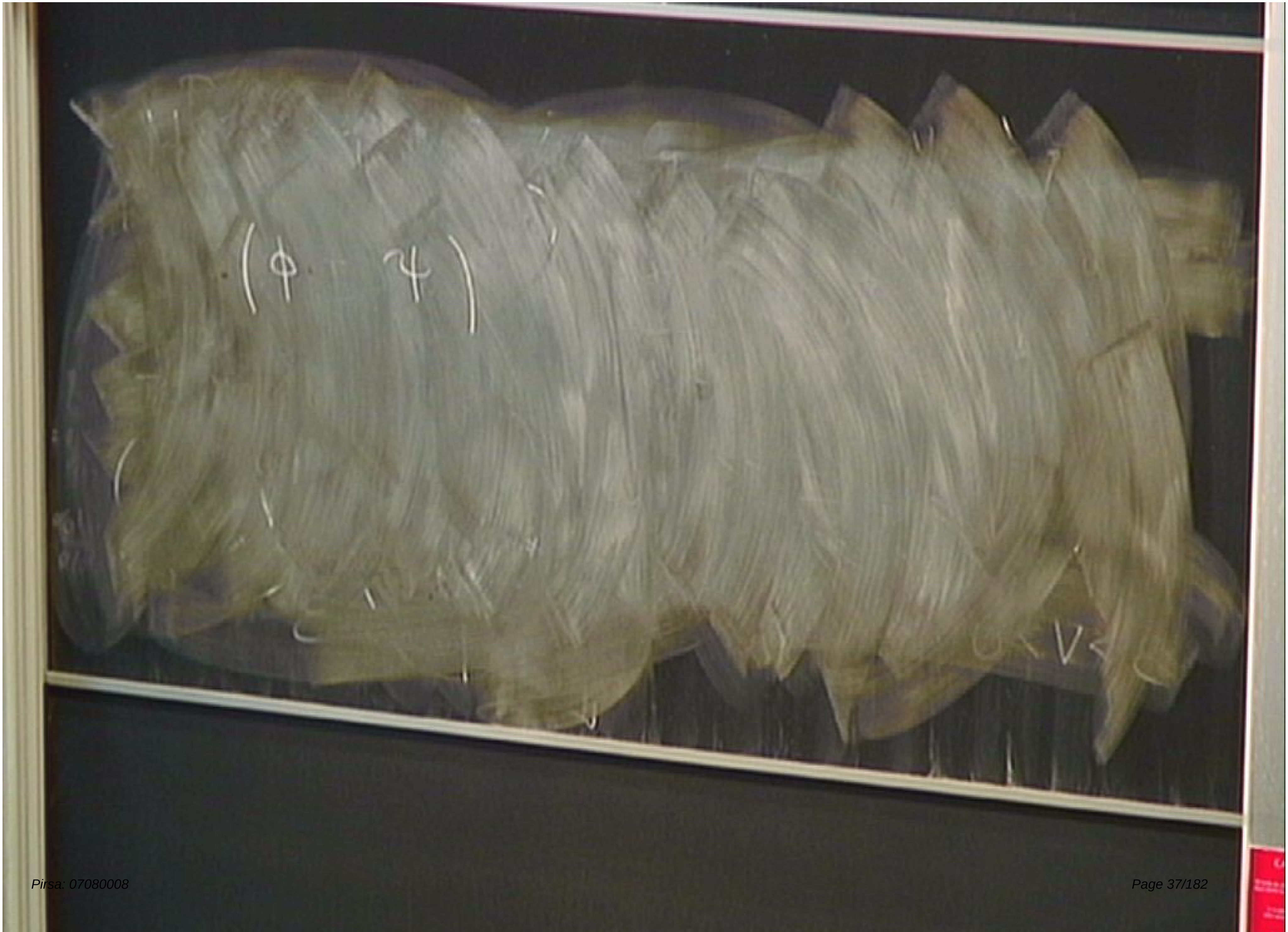

e^-_L
e^+_R
e^-_R

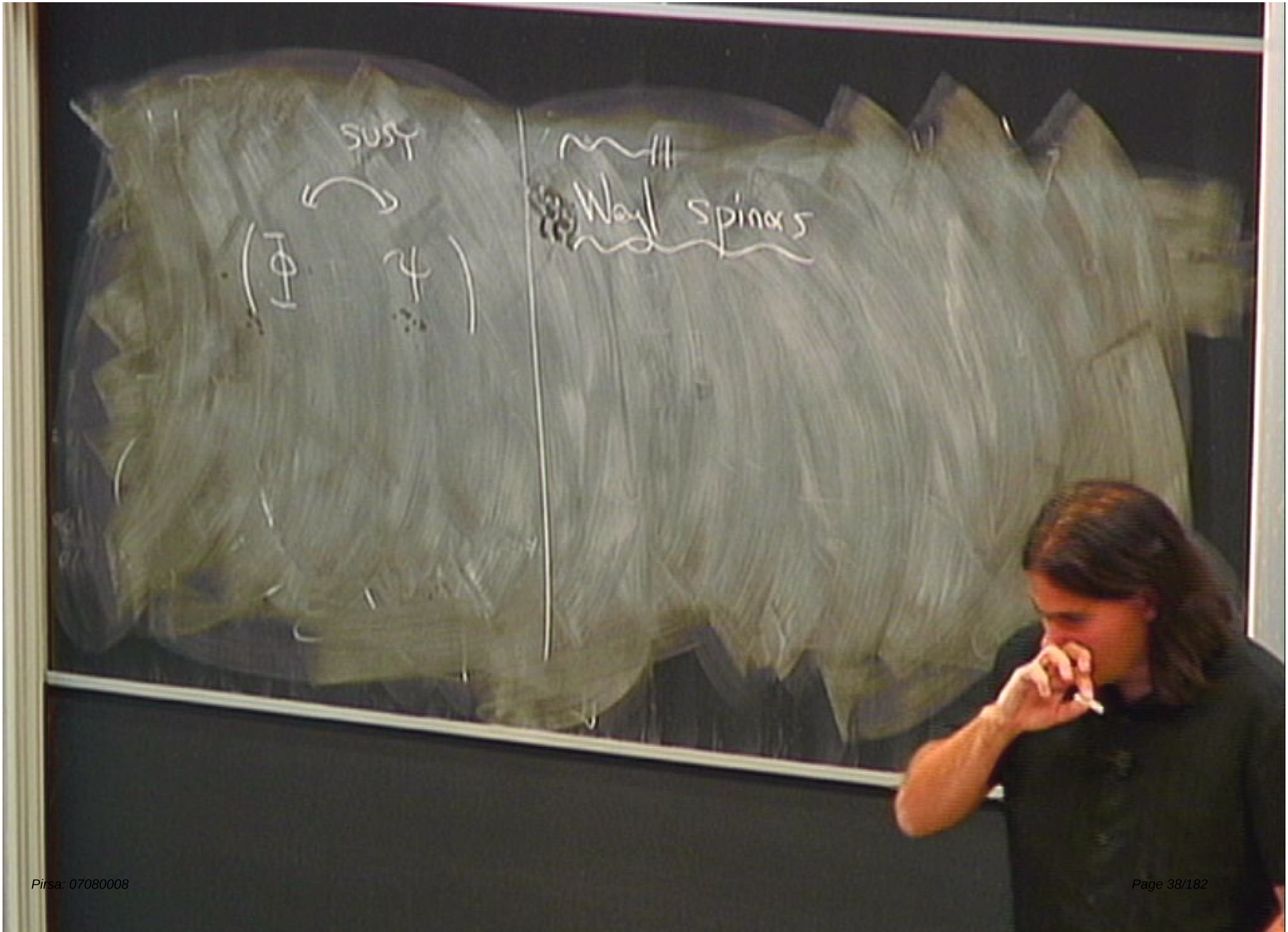

e^-_L
e^+_R
e^-_R
$M e e^c$

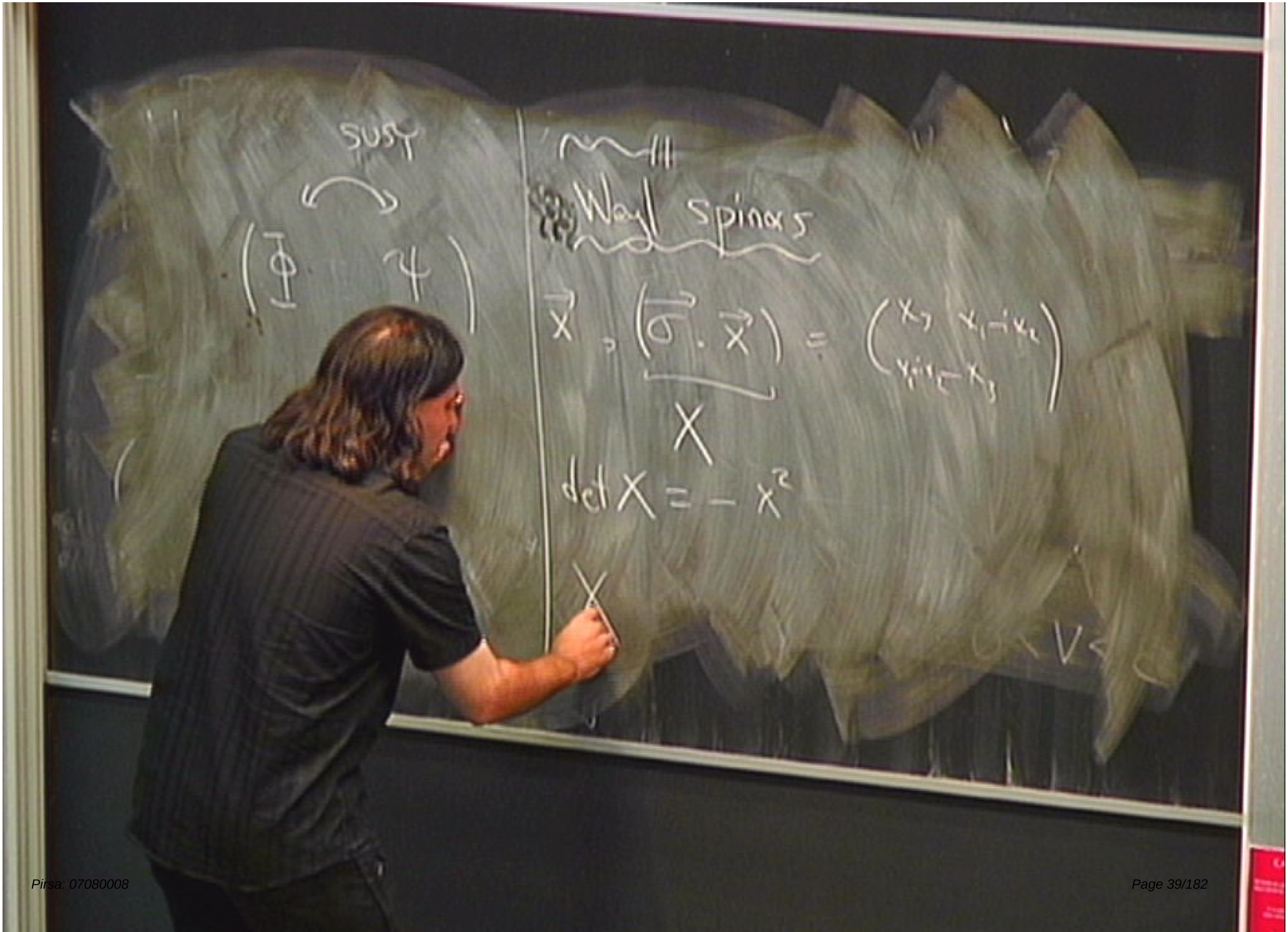

e^-_L
e^+_R
e^-_R
$M e e^c$
$M \to 0$
$e \to e^{i\alpha} e$
$e^c \to e^{-i\alpha} e^c$

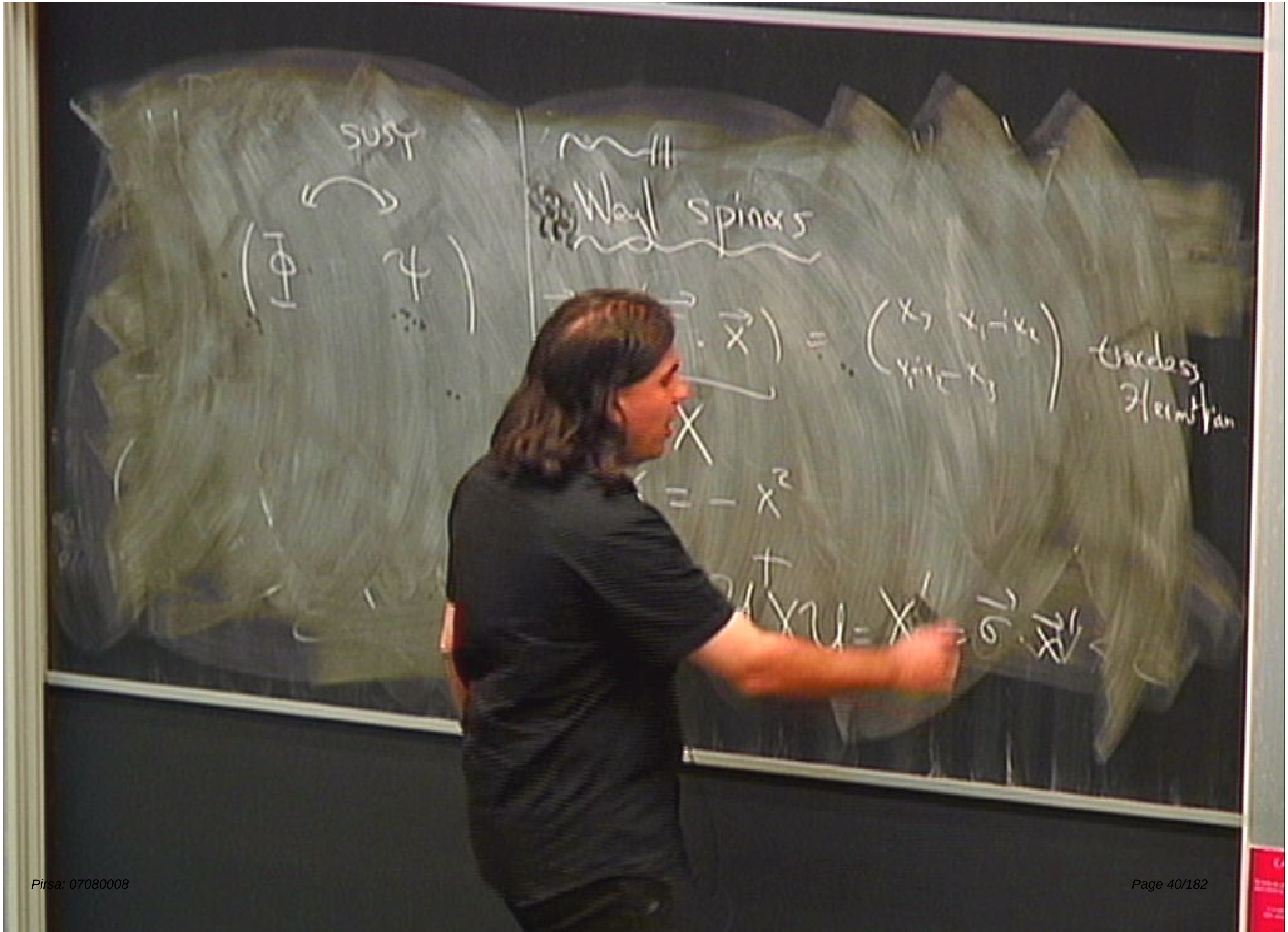


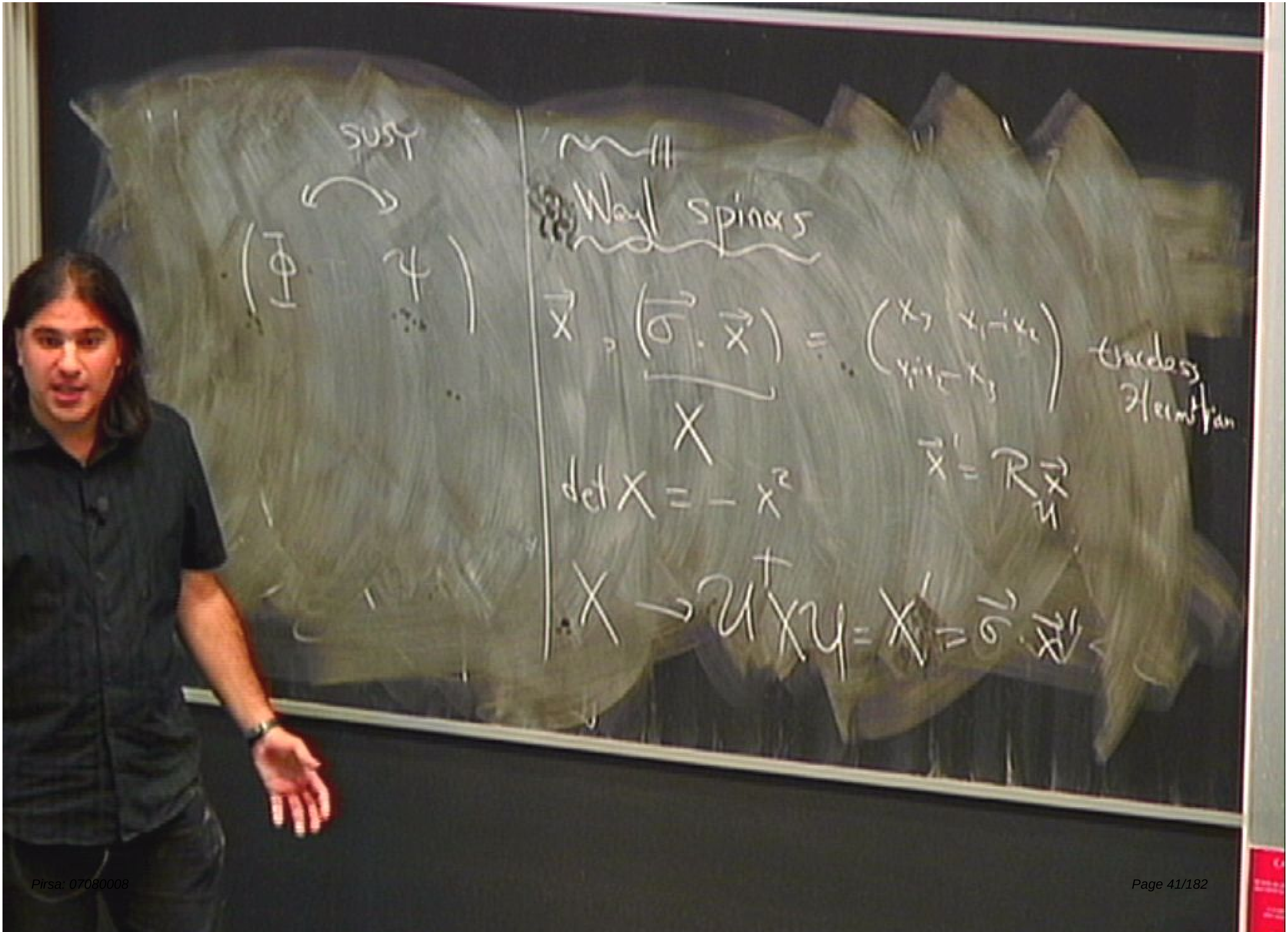



(ϕ ψ)


SUSY
Weyl spinors


susy
Weyl spinors
$\vec{x}$, $(\vec{\sigma}\cdot\vec{x}) = \begin{pmatrix} x_3 & x_1 - ix_2 \\ x_1 + ix_2 & -x_3 \end{pmatrix}$
X
$\det X = -x^2$


SUSY
Weyl spinors
traceless
Hermitian


susy
Weyl spinors
traceless
Hermitian

SUSY

$$\left(\Phi \quad \psi \right)$$

Weyl spinors

$$\vec{x}, \quad \underbrace{(\vec{\sigma}\cdot\vec{x})}_{X} = \begin{pmatrix} x_3 & x_1 - i x_2 \\ x_1 + i x_2 & -x_3 \end{pmatrix} \quad \text{traceless Hermitian}$$

$$\det X = -x^2 \qquad \vec{x}' = R_U \vec{x}$$

$$X \to U^\dagger X U = X' = \vec{\sigma}\cdot\vec{x}'$$

$$\psi \to U\psi$$

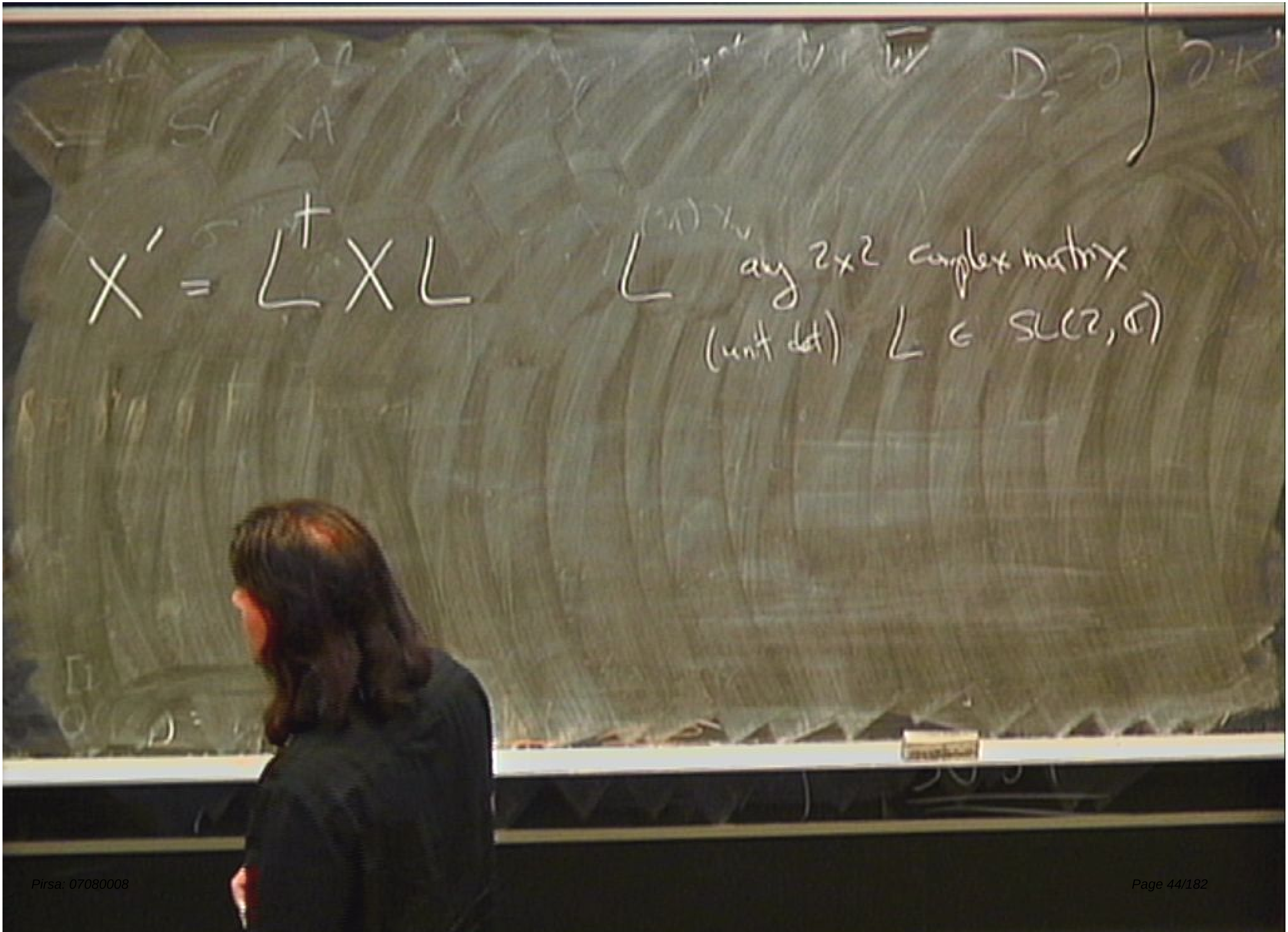
$$(1, \vec{\sigma}) = \sigma^\mu$$

$$x^\mu \; ; \quad \sigma^\mu x_\mu = \begin{pmatrix} x^0 + x^3 & x^1 - i x^2 \\ x^1 + i x^2 & x^0 - x^3 \end{pmatrix}$$

$$\| $$

$$X$$

$$\det X = x^{0\,2} - \vec{x}^{\,2} = x^\mu x_\mu \, .$$


$X' = L^{\dagger} X L$
L any 2x2 complex matrix
(unit det) $L \in SL(2,\mathbb{C})$

$$X' = L^{\dagger} X L$$

L any 2×2 complex matrix

(unit det) $L \in SL(2,\mathbb{C})$

$$\det X' = \det X$$

$$X'^{\mu} = \Lambda^{\mu}{}_{\nu}(L)\, X^{\nu}$$

$$\psi_{\alpha} \to L_{\alpha}{}^{\beta}\, \psi_{\beta}$$

$$\bar{\psi}_{\dot{\alpha}}$$

$$X' = L^\dagger X L$$

L any 2×2 complex matrix

(unit det) $L \in SL(2,\mathbb{C})$

$$\det X' = \det X$$

$$X'^\mu = \Lambda^\mu{}_\nu(L)\, X^\nu$$

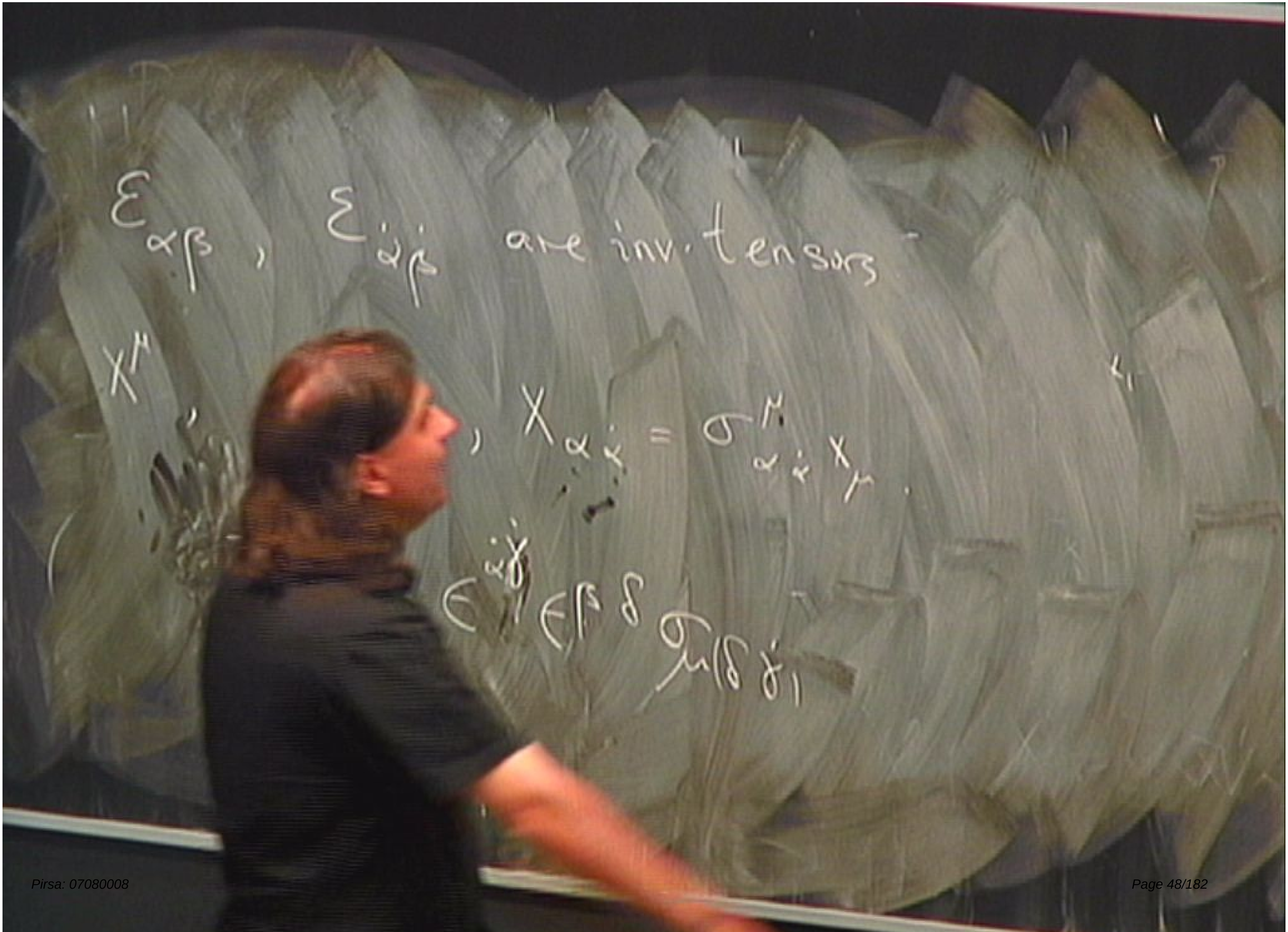
$$\psi_\alpha \to L_\alpha{}^\beta\, \psi_\beta$$

$$\bar\psi_{\dot\alpha} \to L^*{}_{\dot\alpha}{}^{\dot\beta}\, \bar\psi_{\dot\beta}$$

SUSY

$\epsilon_{\alpha\beta}$, $\epsilon_{\dot\alpha\dot\beta}$ are inv. tensors

x^μ , $\sigma^\mu_{\alpha\dot\alpha}$



$\varepsilon_{\alpha\beta}$, $\varepsilon_{\dot\alpha\dot\beta}$ are inv. tensors
X^μ
$X_{\alpha\dot\alpha} = \sigma^\mu_{\alpha\dot\alpha} X_\mu$
$\epsilon^{\dot\alpha\dot\gamma} \epsilon^{\beta\delta} \sigma_{\mu\beta\delta\dot\gamma}$

$\epsilon_{\alpha\beta}$, $\epsilon_{\dot\alpha\dot\beta}$ are inv. tensors

$X^\mu = \frac{1}{2}\bar\sigma^{\mu\dot\alpha\alpha}$

X^μ , $\sigma^\mu_{\alpha\dot\alpha}$, $X_{\alpha\dot\alpha} = \sigma^\mu_{\alpha\dot\alpha} X_\mu$.

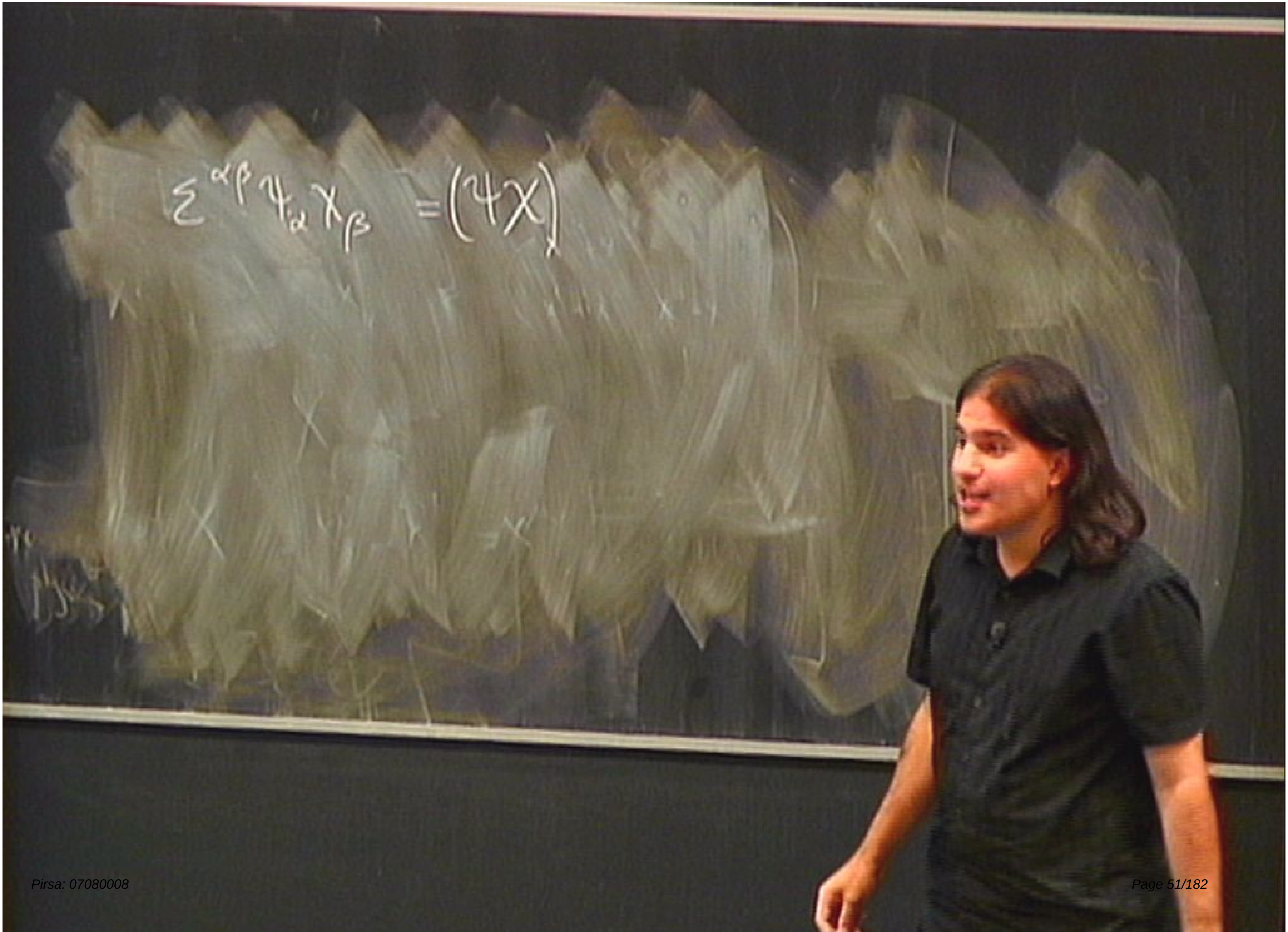
$$\bar\sigma_\mu^{\dot\alpha\beta} = \epsilon^{\dot\alpha\dot\gamma}\epsilon^{\beta\delta}\sigma_{\mu(\delta\dot\gamma)}$$

$\epsilon_{\alpha\beta}$, $\epsilon_{\dot\alpha\dot\beta}$ are inv. tensors

$$X^\mu = \frac{1}{2}\bar\sigma^{\mu\dot\alpha\alpha} X_{\alpha\dot\alpha}$$

X^μ , $\sigma^\mu_{\alpha\dot\alpha}$, $X_{\alpha\dot\alpha} = \sigma^\mu_{\alpha\dot\alpha} X_\mu$

$$\bar\sigma_\mu^{\dot\alpha\beta} = \epsilon^{\dot\alpha\dot\gamma}\epsilon^{\beta\delta}\sigma_{\mu\delta\dot\gamma}$$


$\epsilon^{\alpha\beta}\psi_\alpha\chi_\beta = (\psi\chi)$

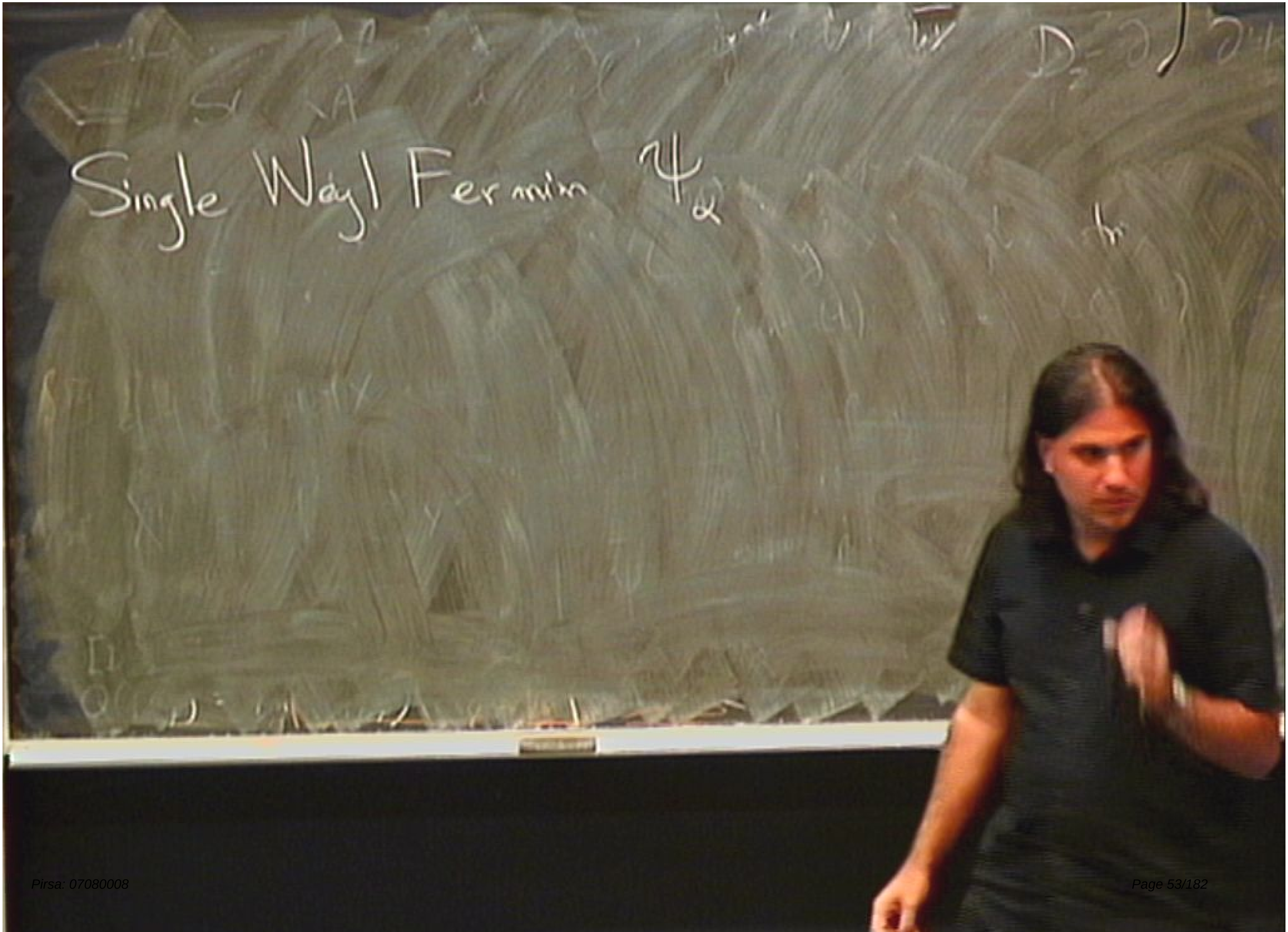
Grassman ψ, χ

$$\varepsilon^{\alpha\beta}\psi_\alpha\chi_\beta = (\psi\chi) = (\chi\psi)$$

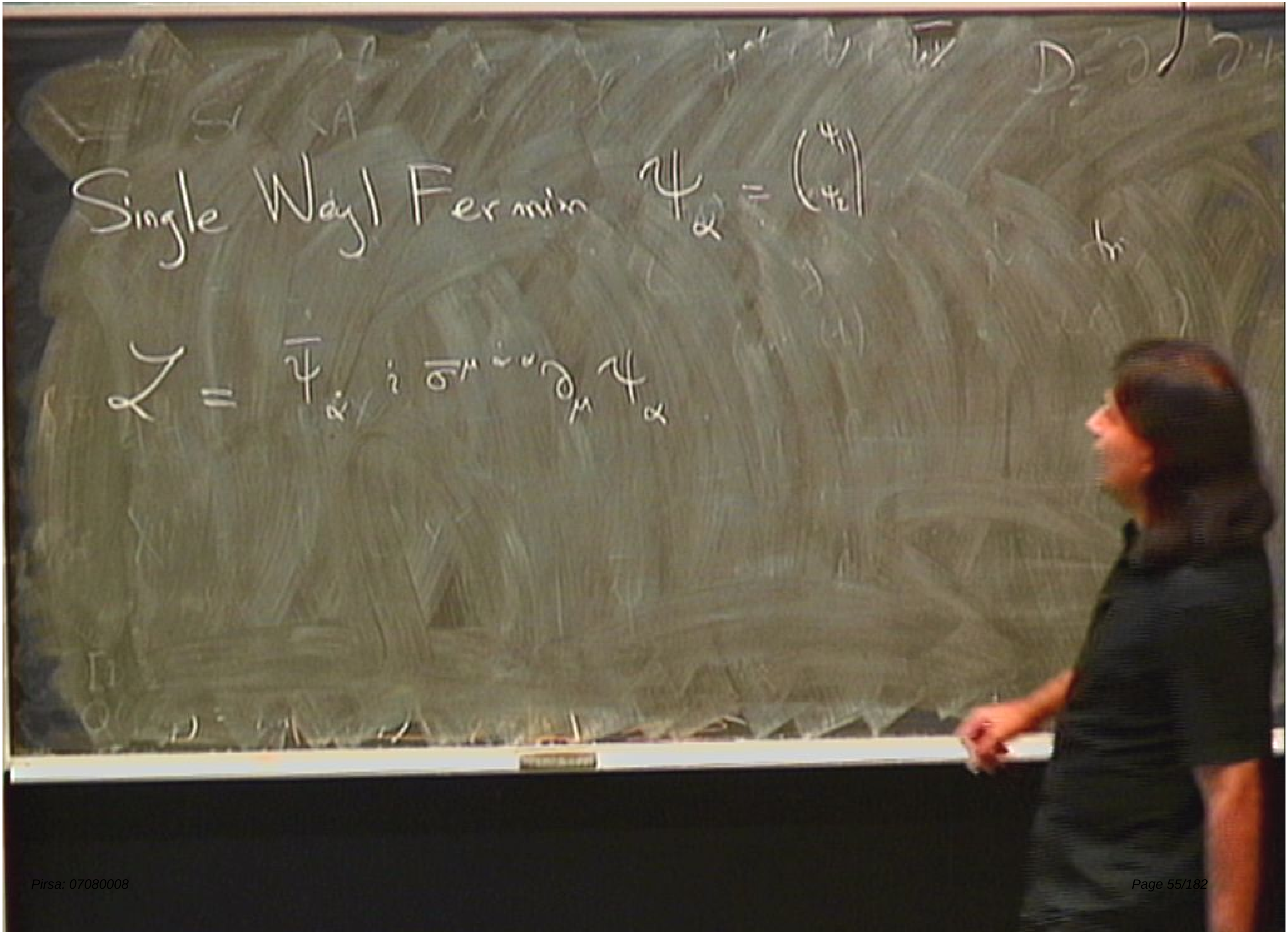
$$= -\varepsilon^{\alpha\beta}\chi_\alpha\psi_\beta$$

c-numbers

$$(\bar\psi\bar\chi) = (\bar\chi\bar\psi)$$


Single Weyl Fermion ψ_α

Single Weyl Fermion $\psi_\alpha = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix}$


Single Weyl Fermion $\psi_\alpha = \begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix}$
$\mathcal{L} = \bar{\psi}_{\dot\alpha}\, i\, \bar{\sigma}^{\mu\dot\alpha\alpha} \partial_\mu \psi_\alpha$

Single Weyl Fermion $\psi_\alpha = \begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix}$

$$\mathcal{L} = \bar{\psi}_{\dot{\alpha}}\, i\, \bar{\sigma}^{\mu\dot{\alpha}\alpha} \partial_\mu \psi_\alpha = \bar{\psi}\, i\, \bar{\sigma}^{\mu} \partial_\mu \psi$$

$$= \bar{\psi}_{\dot{\alpha}}\, i\, \partial^{\dot{\alpha}\alpha} \psi_\alpha$$

Single Weyl Fermion $\psi_\alpha = \begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix}$

$$\mathcal{L} = \bar{\psi}_{\dot\alpha}\, i\, \bar{\sigma}^{\mu\,\dot\alpha\alpha}\partial_\mu \psi_\alpha = \bar{\psi}\, i\, \bar{\sigma}^{\mu}\partial_\mu \psi$$

$$= \left(\bar{\psi}_{\dot\alpha}\, i\, \partial^{\dot\alpha\alpha}\, \psi_\alpha\right)$$

Single Weyl Fermion $\psi_\alpha = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix}$

$$\mathcal{L} = \bar\psi_{\dot\alpha}\, i\, \bar\sigma^{\mu\,\dot\alpha\alpha} \partial_\mu \psi_\alpha = \bar\psi\, i\, \bar\sigma^\mu \partial_\mu \psi$$

$$= \left(\bar\psi_{\dot\alpha}\, i\, \partial^{\dot\alpha\alpha} \psi_\alpha \right)$$

$$\bar\sigma\, p\, \psi_p = 0$$

$$\begin{pmatrix} p^0+p^3 & 0 \\ 0 & p^0-p^3 \end{pmatrix} \psi = 0$$

Single Weyl Fermion $\psi_\alpha = \begin{pmatrix} \psi_1 \\ \psi_2 \end{pmatrix}$

$$\mathcal{L} = \bar{\psi}_{\dot\alpha}\, i\, \bar{\sigma}^{\mu\dot\alpha\alpha} \partial_\mu \psi_\alpha = \bar{\psi}\, i\, \bar{\sigma}^\mu \partial_\mu \psi$$

$$= \left(\bar{\psi}_{\dot\alpha}\, i\, \partial^{\dot\alpha\alpha} \psi_\alpha\right)$$

$$\bar{\sigma}\, p\, \psi_p = 0$$

$$\begin{pmatrix} p^0+p^3 & 0 \\ 0 & p^0-p^3 \end{pmatrix} \psi = 0$$

$p^0 = |\vec p|$

$\vec{\sigma} \cdot \hat{p}\, \psi = +\psi$

$\vec{\sigma} \cdot \hat{p}\, \psi = -\psi$

$p^0 = -|\vec p|$

Massive Fermion

Massive Fermion

$$\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + \frac{1}{2}M\psi\psi + h.c.$$

Massive Fermion

$$\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + \frac{1}{2}M\psi\psi + h.c.$$

$$\psi \to e^{i\alpha}\psi \quad \times$$

Massive Fermion

1) $\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + \frac{1}{2}M\psi\psi + h.c.$

$\psi \to e^{i\alpha}\psi$ X

2) $\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + i\bar{\psi}^c\bar{\sigma}\partial\psi^c$

Massive Fermion

1) $\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + \frac{1}{2}M\psi\psi + h.c.$

$\psi \to e^{i\alpha}\psi$ ✗

2) $\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + i\bar{\psi}^c\bar{\sigma}\partial\psi^c + M\psi\psi^c$

$\psi \to e^{i\alpha}\psi$

$\psi^c \to e^{-i\alpha}\psi^c$

Massive Fermion

1) $$\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + \frac{1}{2}M\psi\psi + h.c.$$

$$\psi \to e^{i\alpha}\psi$$

2) $$\mathcal{L} = i\bar{\psi}\bar{\sigma}\partial\psi + i\bar{\psi^c}\bar{\sigma}\partial\psi^c + M\psi\psi^c$$

$$\psi \to e^{i\alpha}\psi$$
$$\psi^c \to e^{-i\alpha}\psi^c$$

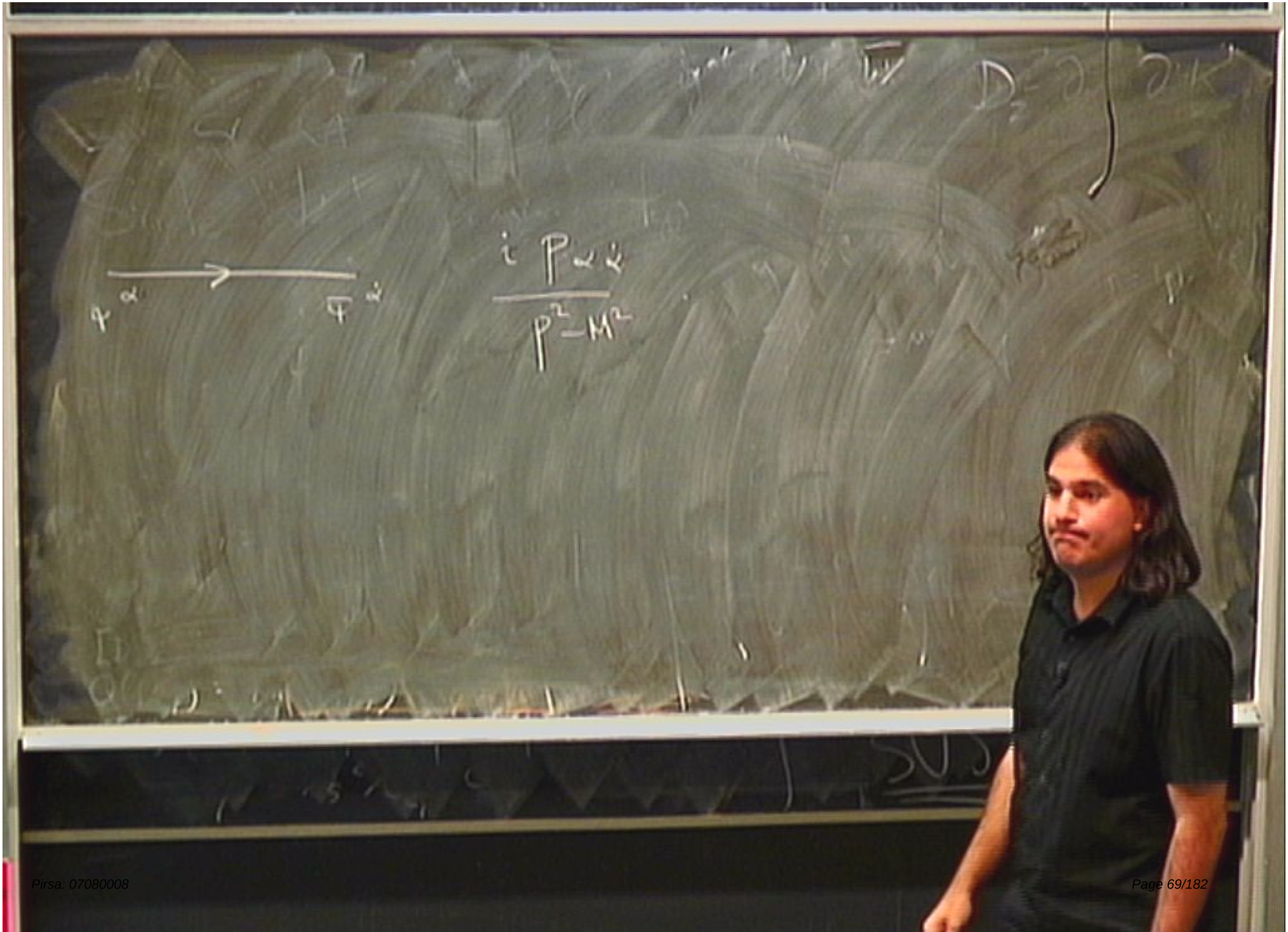
$$\mathcal{L} = \overline{\Psi}_D \left(i \gamma^\mu \partial_\mu - M \right) \Psi_D \qquad \Psi_D = \begin{pmatrix} \psi_\alpha \\ \overline{\psi}^{c\dot{\alpha}} \end{pmatrix}$$

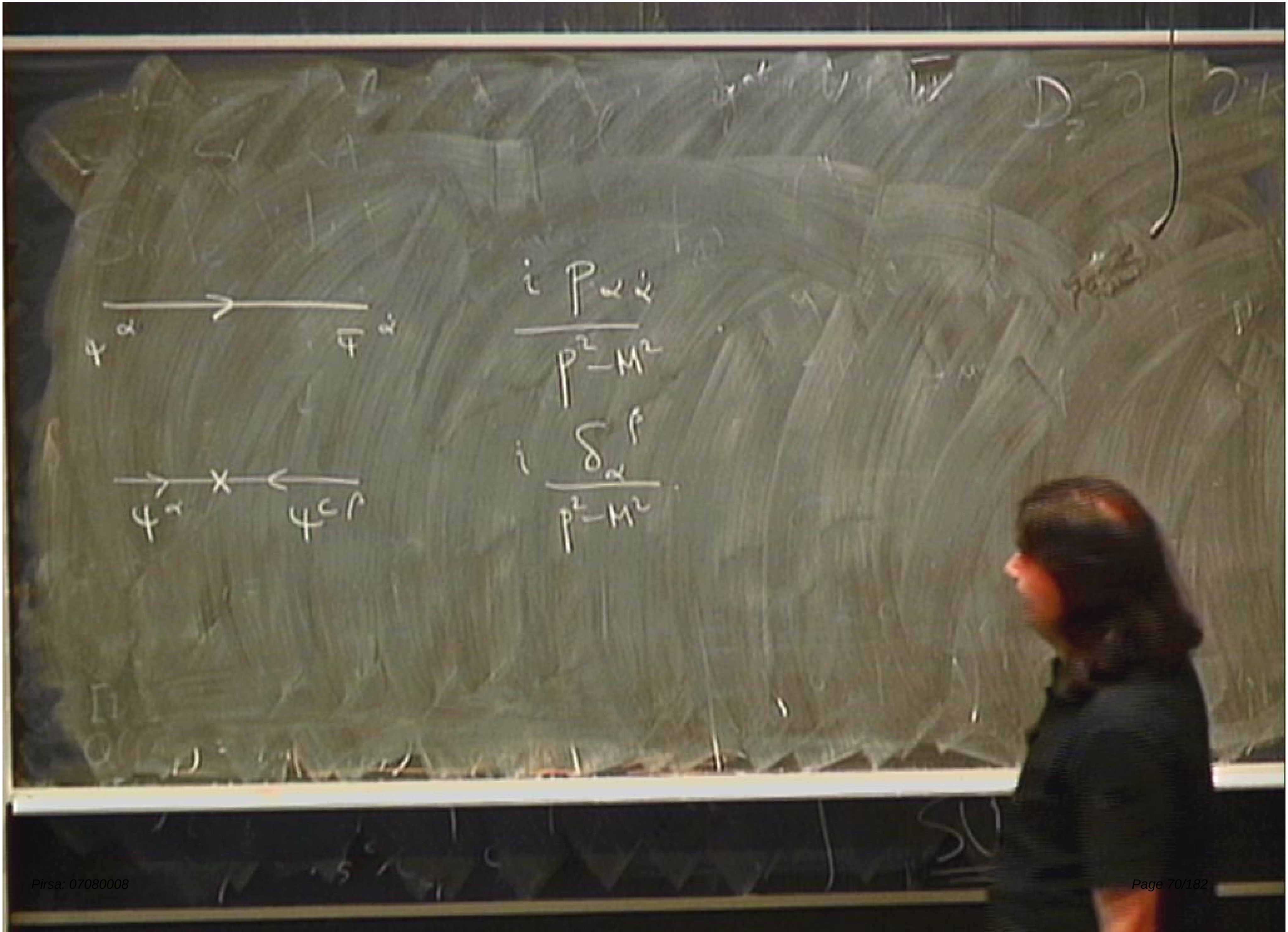
$$\mathcal{L} = \bar{\Psi}_D \left(i \gamma^\mu \partial_\mu - M \right) \Psi_D \qquad \Psi_D = \begin{pmatrix} \psi_\alpha \\ \bar{\psi}^{\dot{\alpha}} \end{pmatrix}$$

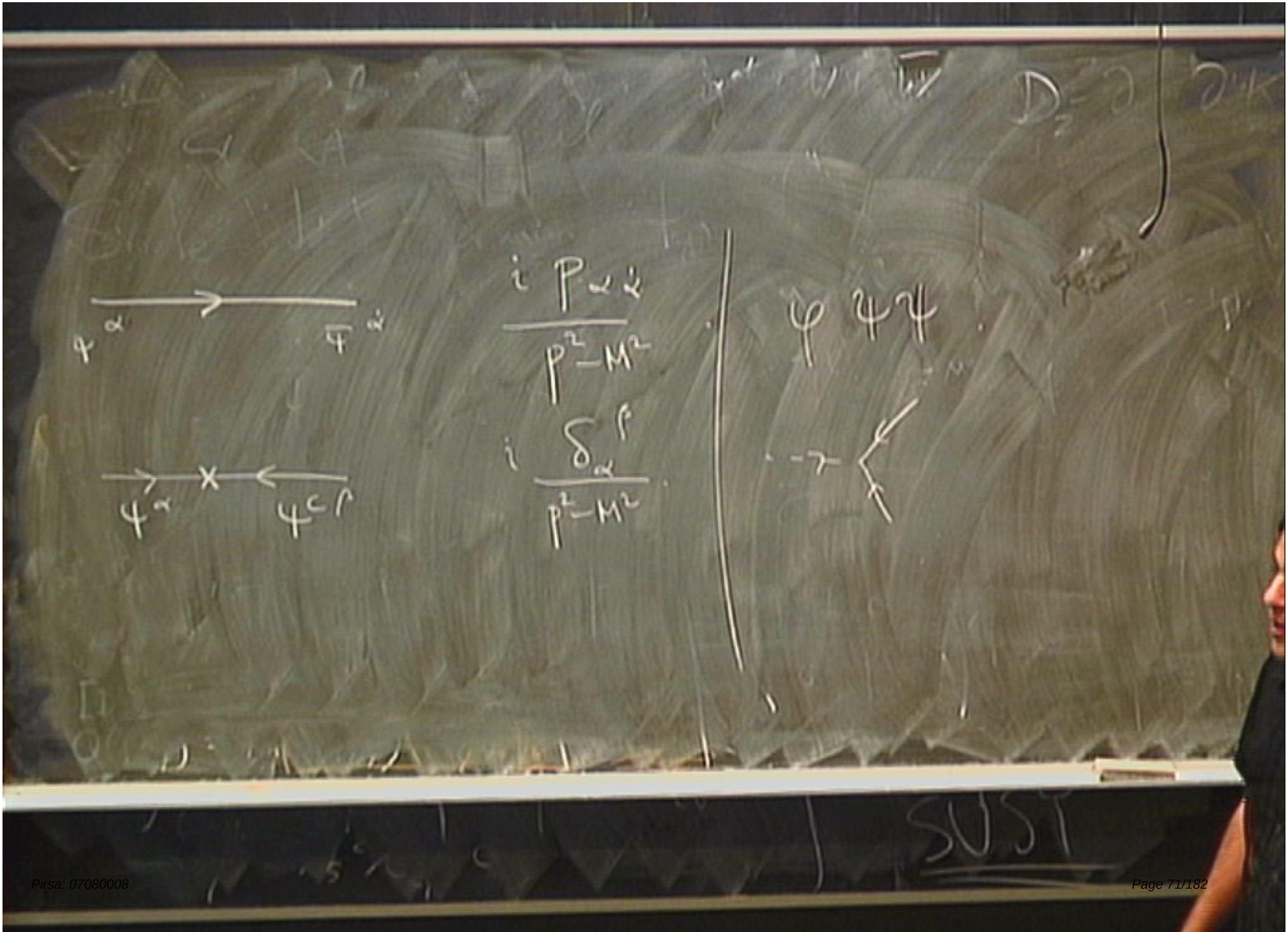
$$\gamma^\mu = \begin{pmatrix} 0 & \sigma^\mu \\ \bar{\sigma}^\mu & 0 \end{pmatrix}$$

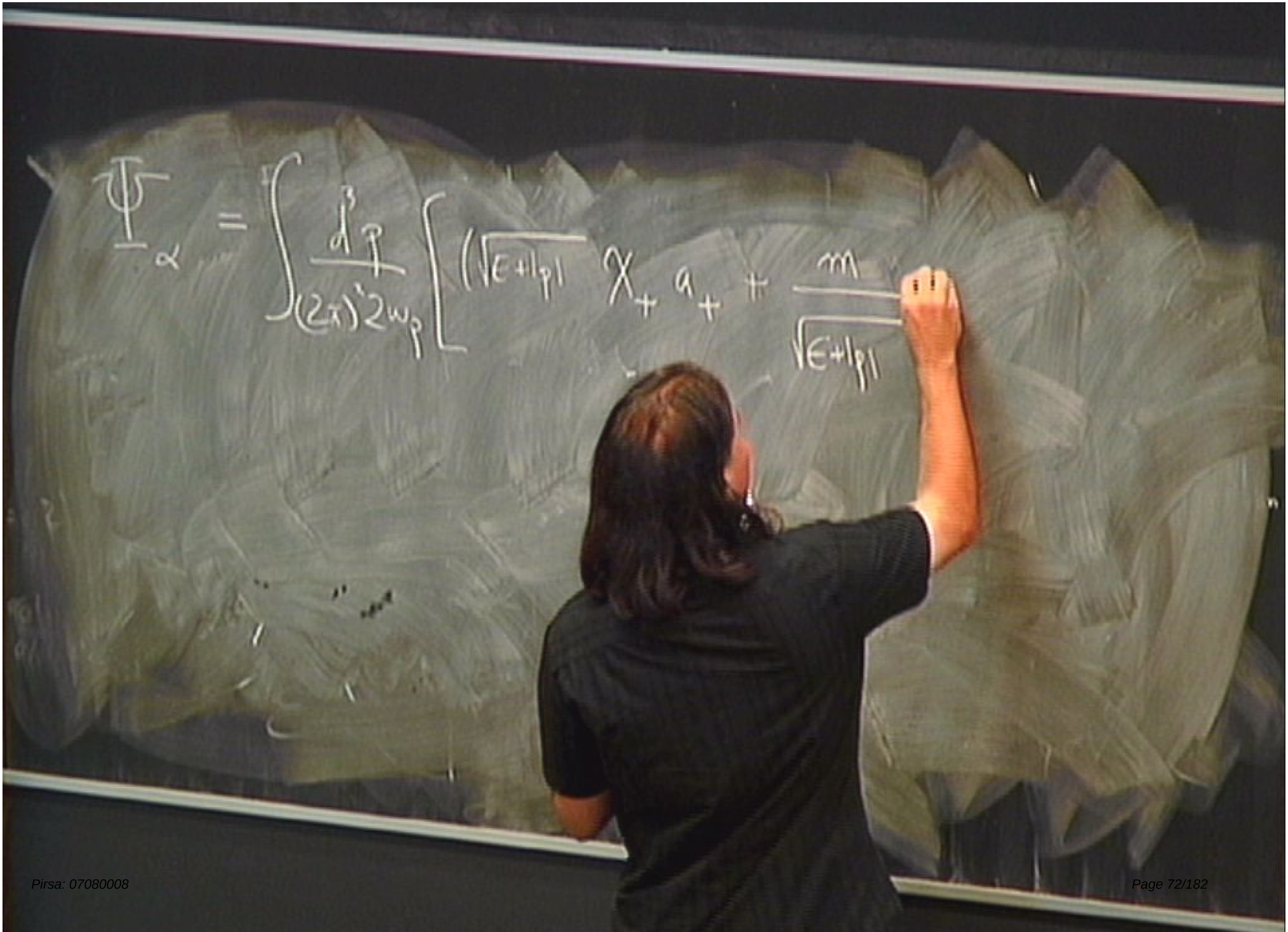
$$\mathcal{L} = \overline{\Psi}_D (i\gamma^\mu \partial_\mu - M)\Psi_D \qquad \Psi_D = \begin{pmatrix} \psi_\alpha \\ \overline{\psi}^{c\dot\alpha} \end{pmatrix}$$

$$\gamma^\mu = \begin{pmatrix} 0 & \sigma^\mu \\ \bar\sigma^\mu & 0 \end{pmatrix}$$


ψ^{α} $\bar{\psi}^{\dot{\alpha}}$
$\frac{i\, p_{\alpha\dot{\alpha}}}{p^2 - M^2}$


ψ^{α}
$\bar{\psi}^{\dot{\alpha}}$
$\dfrac{i\, p_{\alpha\dot{\alpha}}}{p^2-M^2}$
ψ^{α}
$\psi^{c\beta}$
$\dfrac{i\, \delta_{\alpha}^{\ \beta}}{p^2-M^2}$


φ^α φ̄^α̇
i p_{αα̇} / (p² − M²)
i δ_α^β / (p² − M²)
φ^α φ^{cβ}
φ ψ ψ
SUSY


$\Psi_\alpha = \int \frac{d^3p}{(2\pi)^3 2\omega_p} \Big[\Big(\sqrt{E+|p|}\ \chi_+ a_+ + \frac{m}{\sqrt{E+|p|}}$

$$\Psi_\alpha = \int \frac{d^3p}{(2\pi)^3 2\omega_p} \Big[\Big(\sqrt{E+|p|}\, \chi_+ a_+ + \frac{m}{\sqrt{E+|p|}} \chi_- a_- \Big) e^{-ipx}$$

$$+ \Big(\sqrt{E+|p|}\, \chi_+ a_-^{c\dagger} - \frac{m}{\sqrt{E+|p|}} \chi_- a_+^{c\dagger} \Big) e^{ipx} \Big]$$

$$\Psi_\alpha = \int \frac{d^3p}{(2\pi)^3\, 2\omega_p}\Big[\Big(\sqrt{E+|p|}\;\chi_+ a_+ + \frac{m}{\sqrt{E+|p|}}\,\chi_- a_-\Big)e^{-ipx}$$

$$+\Big(\sqrt{E+|p|}\;\chi_+ a_-^{c\dagger} - \frac{m}{\sqrt{E+|p|}}\,\chi_- a_+^{c\dagger}\Big)e^{ipx}\Big]$$

ψ^c_α same, $a \leftrightarrow a^c$

ψ_M same, $a = a^c$

$$\Psi_\alpha = \int \frac{d^3p}{(2\pi)^3\, 2\omega_p}\Big[\Big(\sqrt{E+|p|}\,\chi_+ a_+ + \frac{m}{\sqrt{E+|p|}}\,\chi_- a_-\Big)e^{-ipx} + \Big(\sqrt{E+|p|}\,\chi_+ a_-^{c\dagger} - \frac{m}{\sqrt{E+|p|}}\,\chi_- a_+^{c\dagger}\Big)e^{ipx}\Big]$$

ψ^c_α same, $a \longleftrightarrow a^c$

ψ_M same, $a = a^c$

$$\vec{\sigma}\cdot\hat{p}\,\chi_\pm = \pm\chi_\pm$$

$\psi \qquad \varphi$

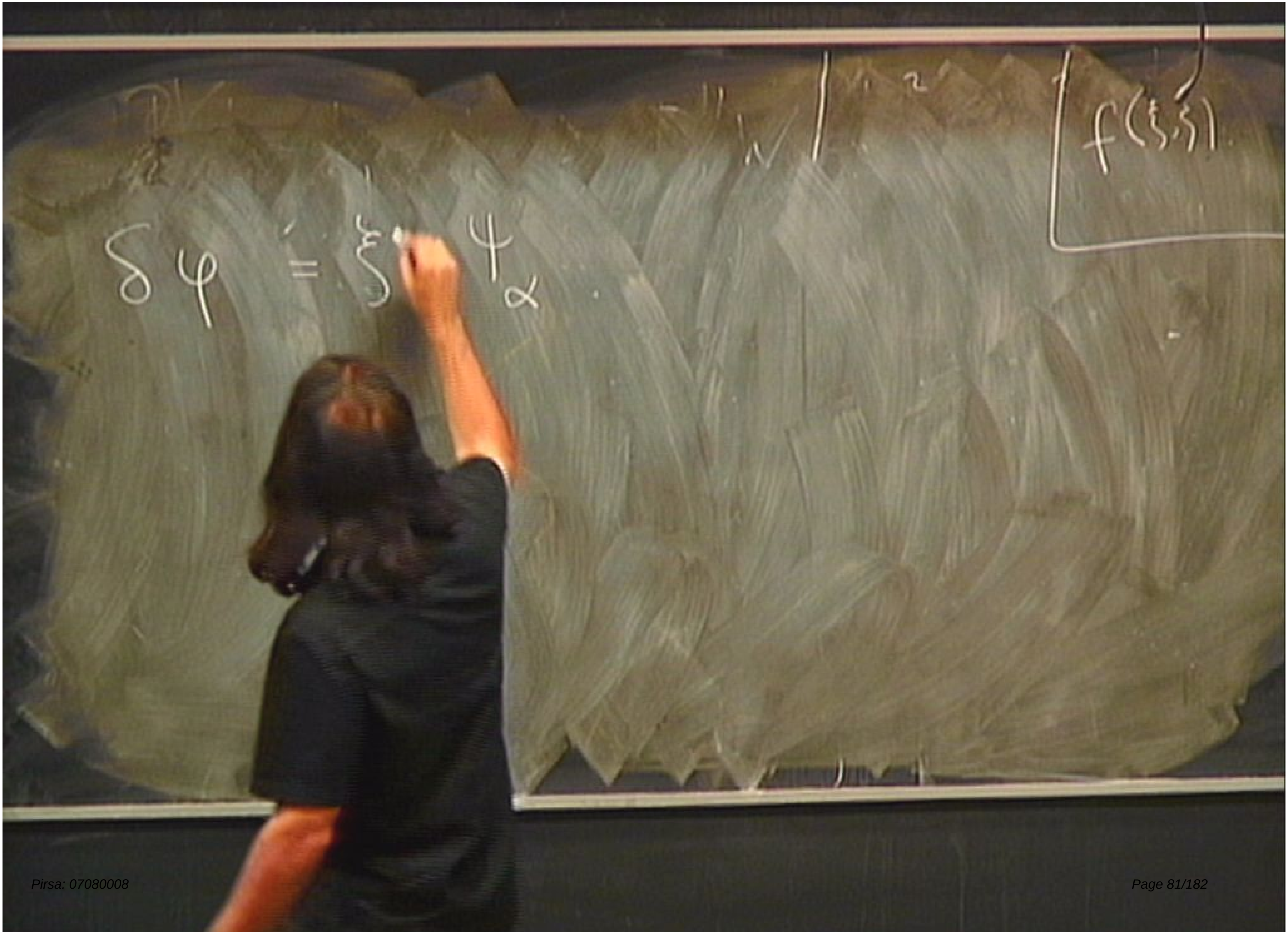
$$\mathcal{L} = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi} i \bar{\sigma} \partial \psi$$

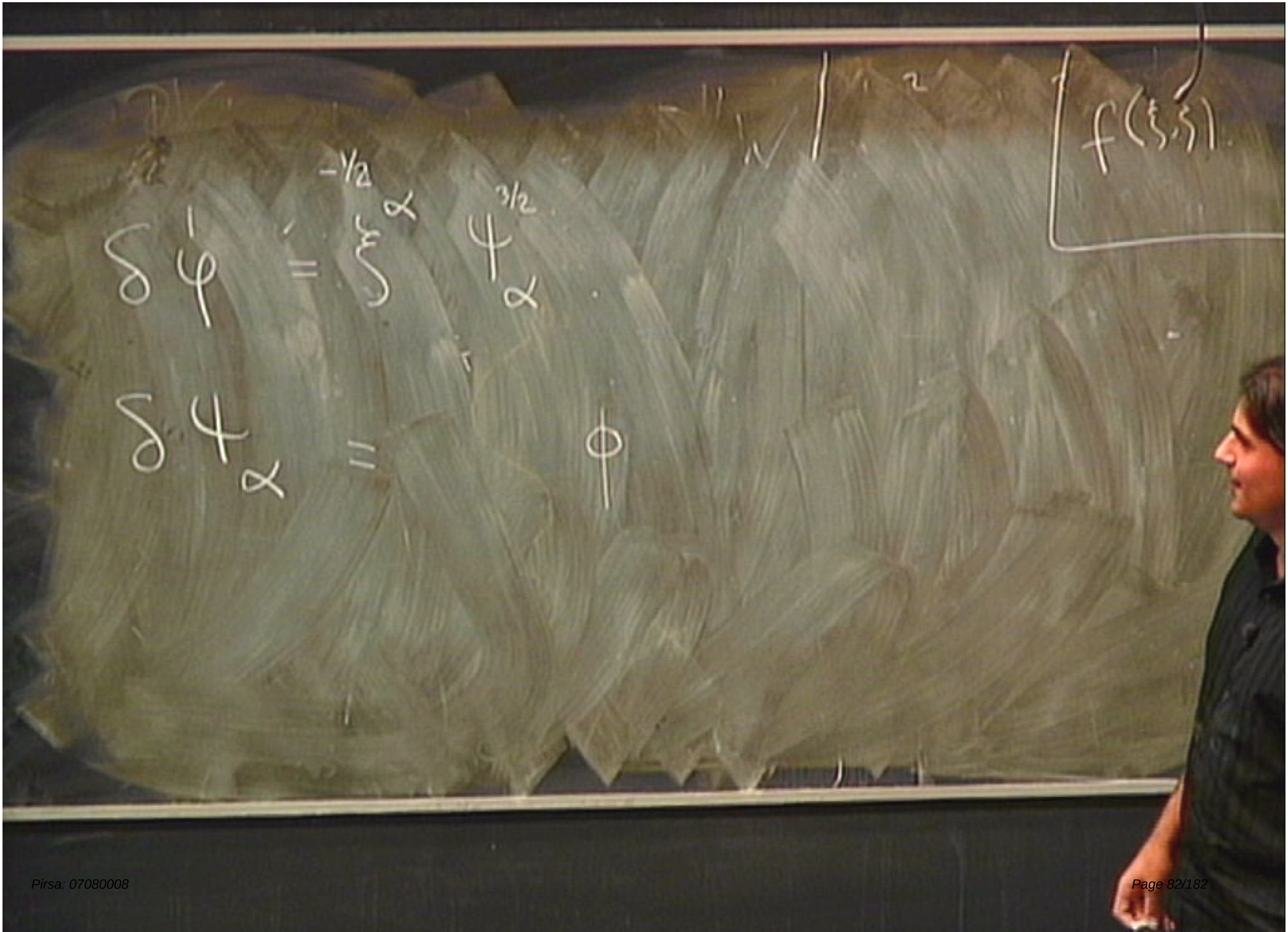
$\psi \qquad \varphi$

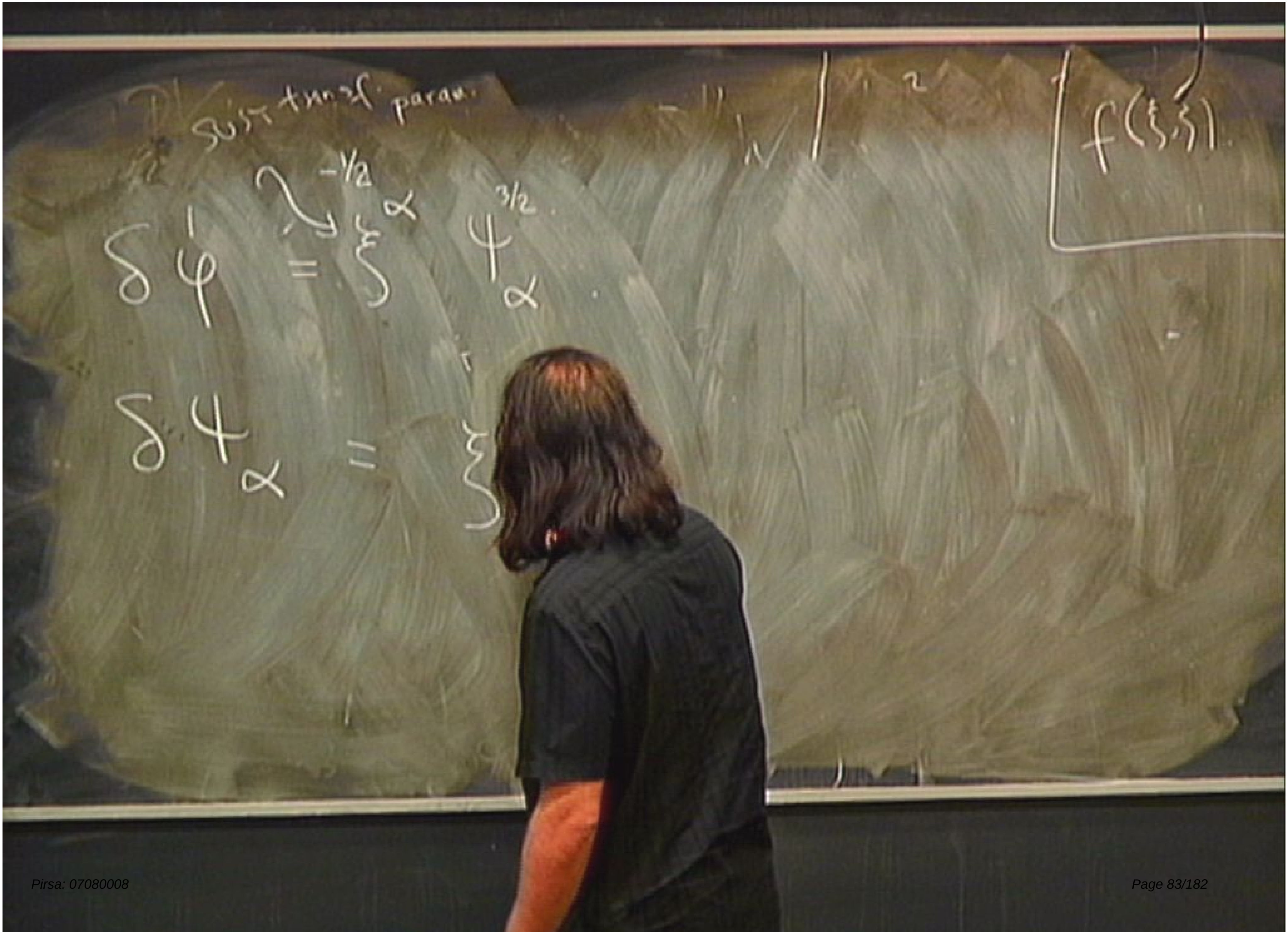
$$\mathcal{L} = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi}\, i\, \bar{\sigma}\, \partial \psi$$

$$\mathcal{L}_2 = -\frac{1}{4} F_{\mu\nu}^2 + \bar{\lambda} i \bar{\sigma}^\mu \partial_\mu \lambda$$

$$\delta\varphi = \psi_\alpha$$


$\delta\varphi = \xi \psi_\alpha$
$f(\xi,\xi)$


$\delta \varphi^{1} = \xi^{-1/2}_{\alpha} \psi^{3/2}_{\alpha}$
$\delta \psi_{\alpha} = \phi$
$f(\xi, \bar{\xi})$


SUSY transf. param.

susy transf. param.

$$\delta \overset{1}{\varphi} = \overset{-1/2}{\xi^{\alpha}} \overset{3/2}{\psi_{\alpha}}$$

$$\delta \psi_{\alpha} = \xi_{\alpha} \phi$$

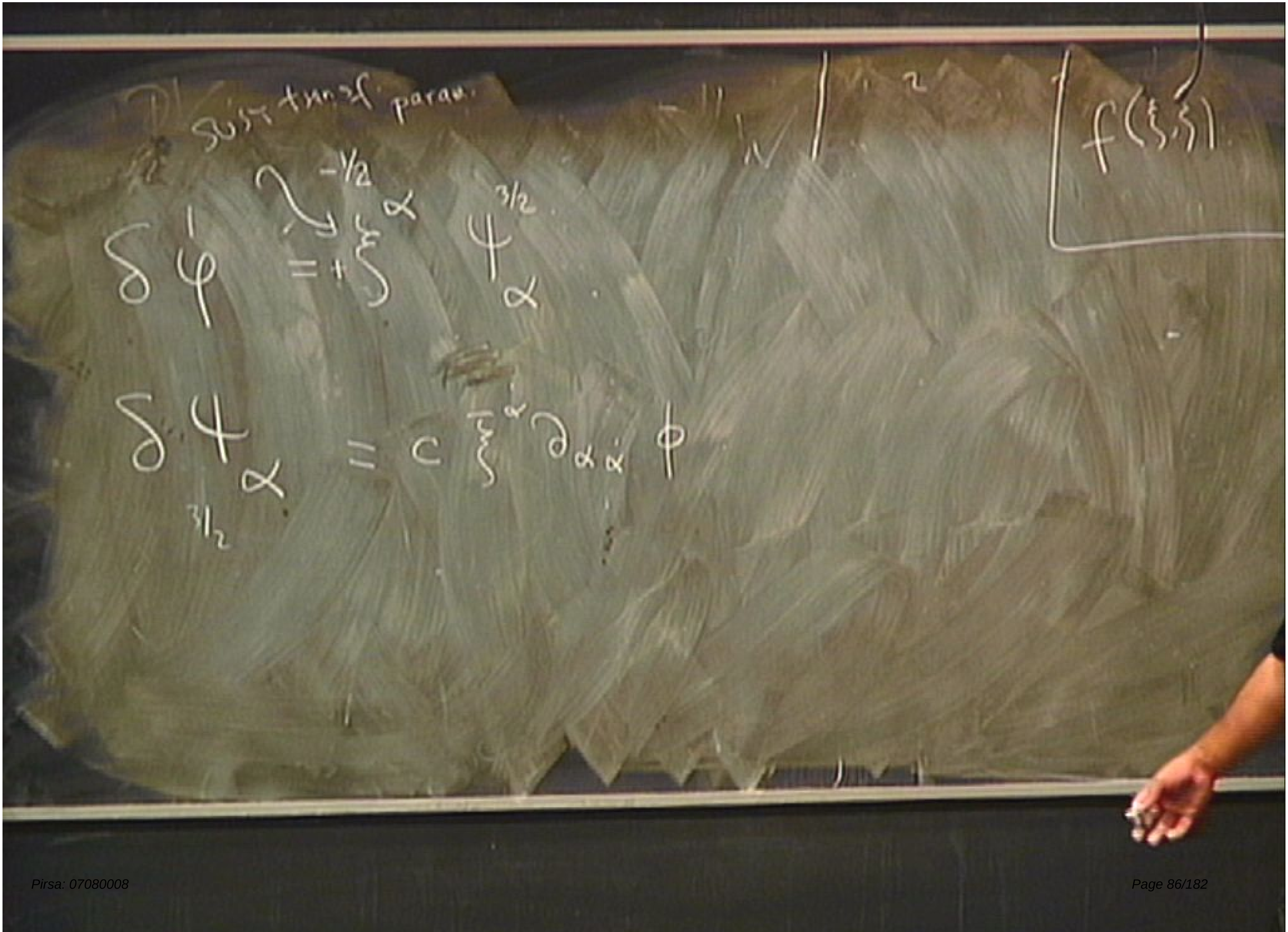
$$f(\xi, \bar{\xi})$$

susy transf. param.

$$\overset{1}{\delta\varphi} = \overset{-1/2}{\xi^\alpha}\ \overset{3/2}{\psi_\alpha}$$

$$\underset{3/2}{\delta\psi_\alpha} = \underset{-1/2}{\xi_\alpha}\,\partial_\mu \phi$$

$$\boxed{f(\xi,\bar{\xi})}$$


susy transf. param.
$-1/2$
$3/2$
$\delta \varphi = + \xi^{\alpha} \psi_{\alpha}$
$\delta \psi_{\alpha} = c\, \bar{\xi}^{\dot\alpha} \partial_{\alpha\dot\alpha} \phi$
$3/2$
$f(\xi, \bar\xi)$

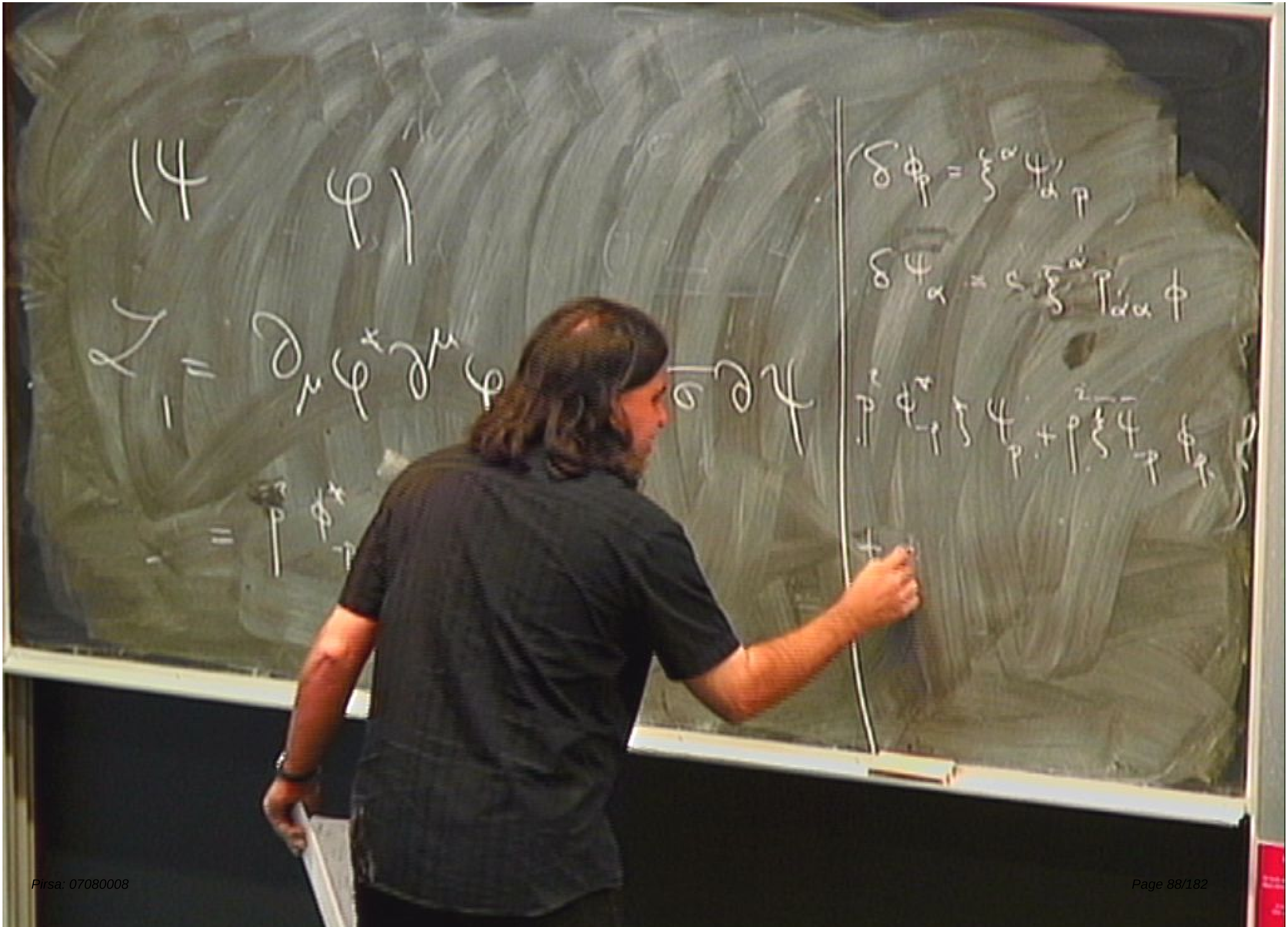
$|\psi \quad \varphi)$

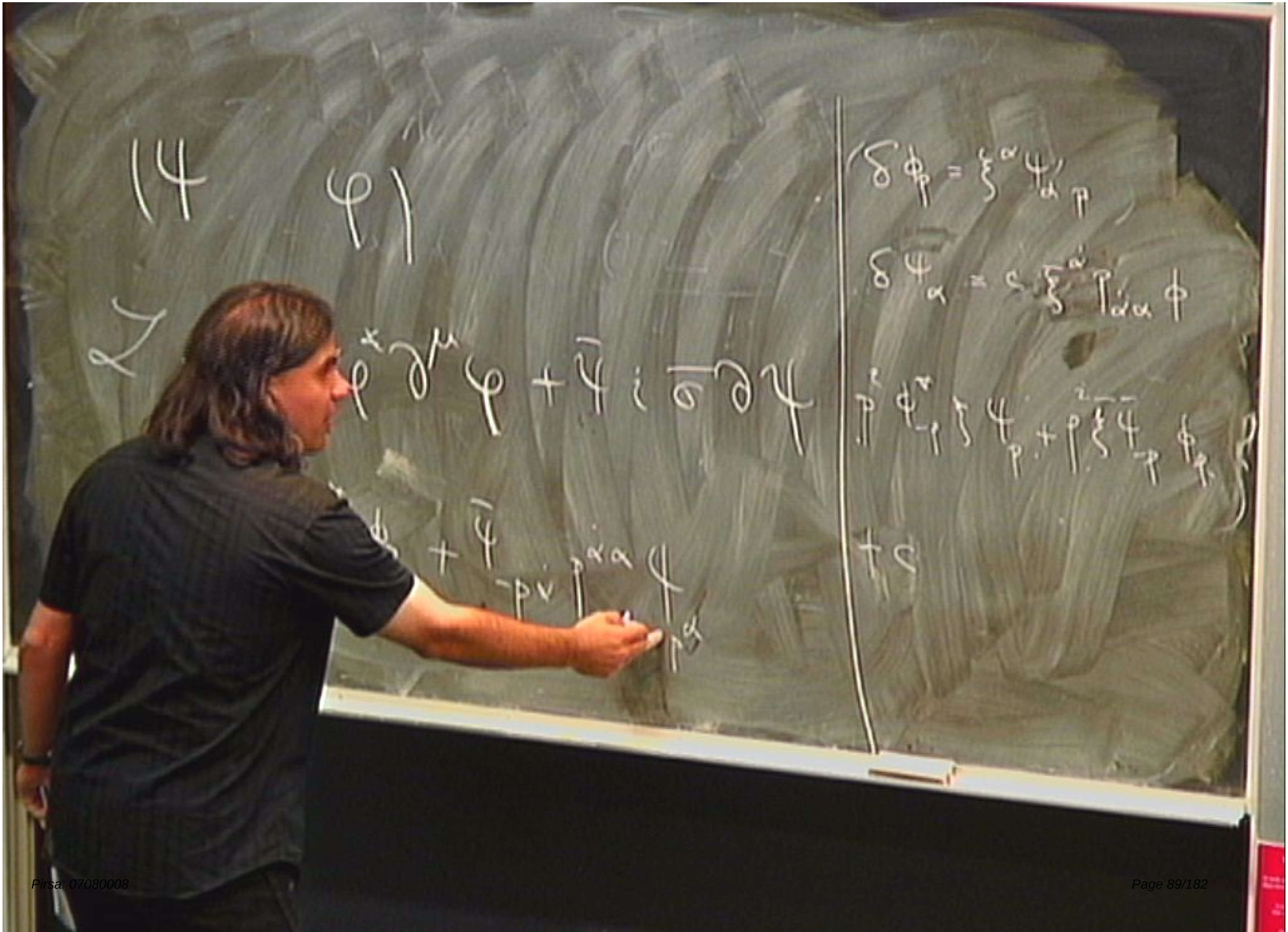
$$\mathcal{L}_1 = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi} i \bar{\sigma} \partial \psi$$

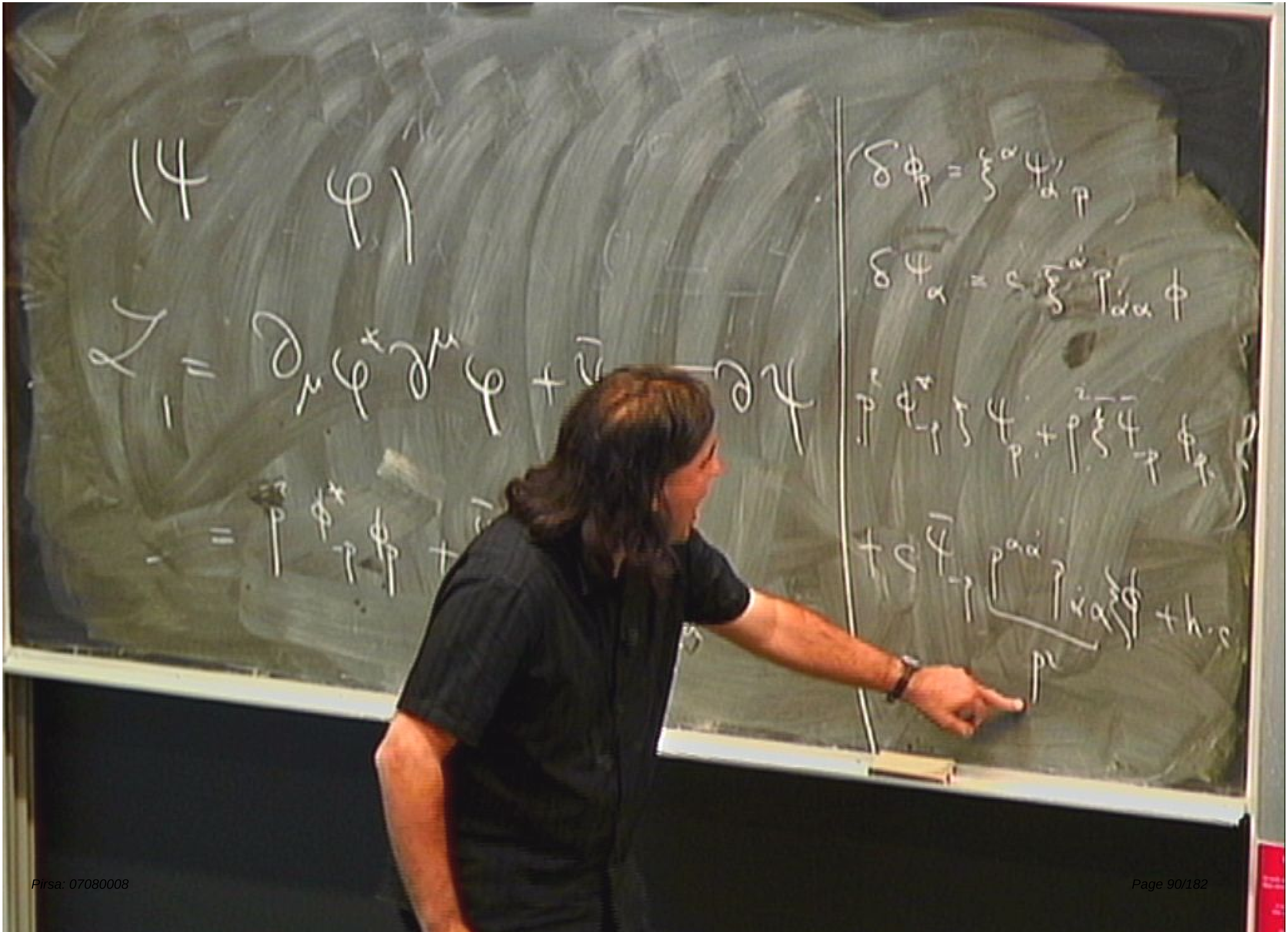
$$= p^2 \phi^*_{-p} \phi_p + \bar{\psi}_{-p\dot{\alpha}} p^{\dot{\alpha}\alpha} \psi_{p\alpha}$$

$$\delta \phi_p = \xi^\alpha \psi_{\alpha p}$$

$$\delta \bar{\psi}_{\dot\alpha} = c\, \xi^\alpha p_{\dot\alpha\alpha} \phi$$







$$|\psi \quad \varphi|$$

$$\mathcal{L}_1 = \partial_\mu \varphi^* \partial^\mu \varphi + \bar\psi\, i\, \bar\sigma \partial \psi$$

$$= p^2 \phi^*_{-p} \phi_p + \bar\psi_{-p\dot\alpha}\, p^{\dot\alpha\alpha}\, \psi_{p\alpha}$$

$$\delta \phi_p = \xi^\alpha \psi_{\alpha p}$$

$$\delta \bar\psi_{\dot\alpha} = c\, \bar\xi^{\alpha}\, p_{\dot\alpha\alpha}\, \phi$$

$$p^2 \phi^*_{-p}\, \xi \psi_p + p^2 \bar\xi \bar\psi_{-p}\, \phi_p$$

$$+ c\, \bar\psi_{-p}\, \underbrace{p^{\dot\alpha\alpha}\, p_{\dot\alpha\alpha}}_{p^2}\, \xi \phi + h.c.$$

$$\Rightarrow \boxed{c = -1}$$

$$\delta\phi = \sqrt{2}\,\xi^{\alpha}\psi_{\alpha}$$

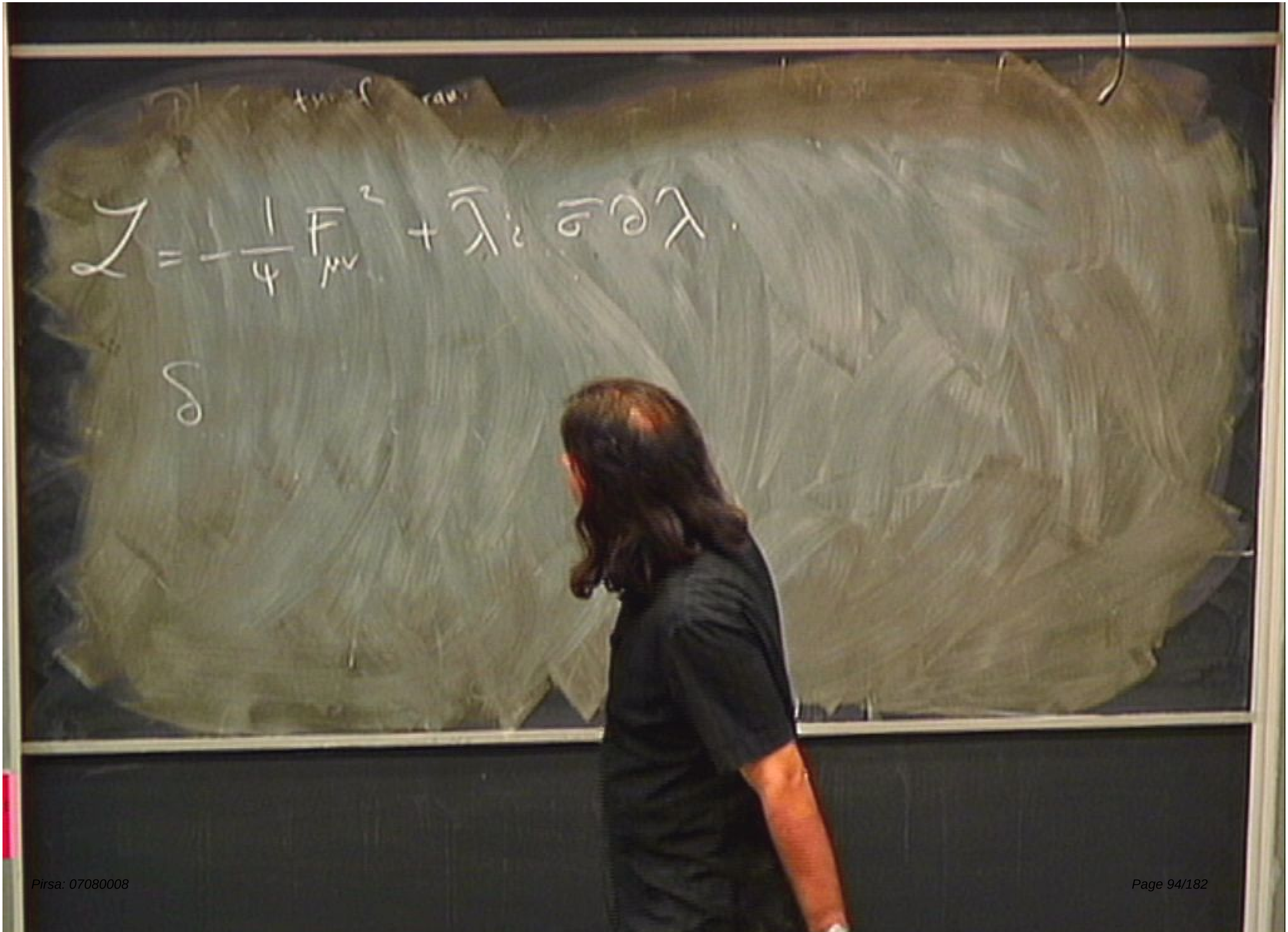
$$\delta\psi_{\alpha} = i\sqrt{2}\,\bar{\xi}^{\dot\alpha}\bar{\sigma}^{\mu}_{\dot\alpha\alpha}\,\partial_{\mu}\varphi$$

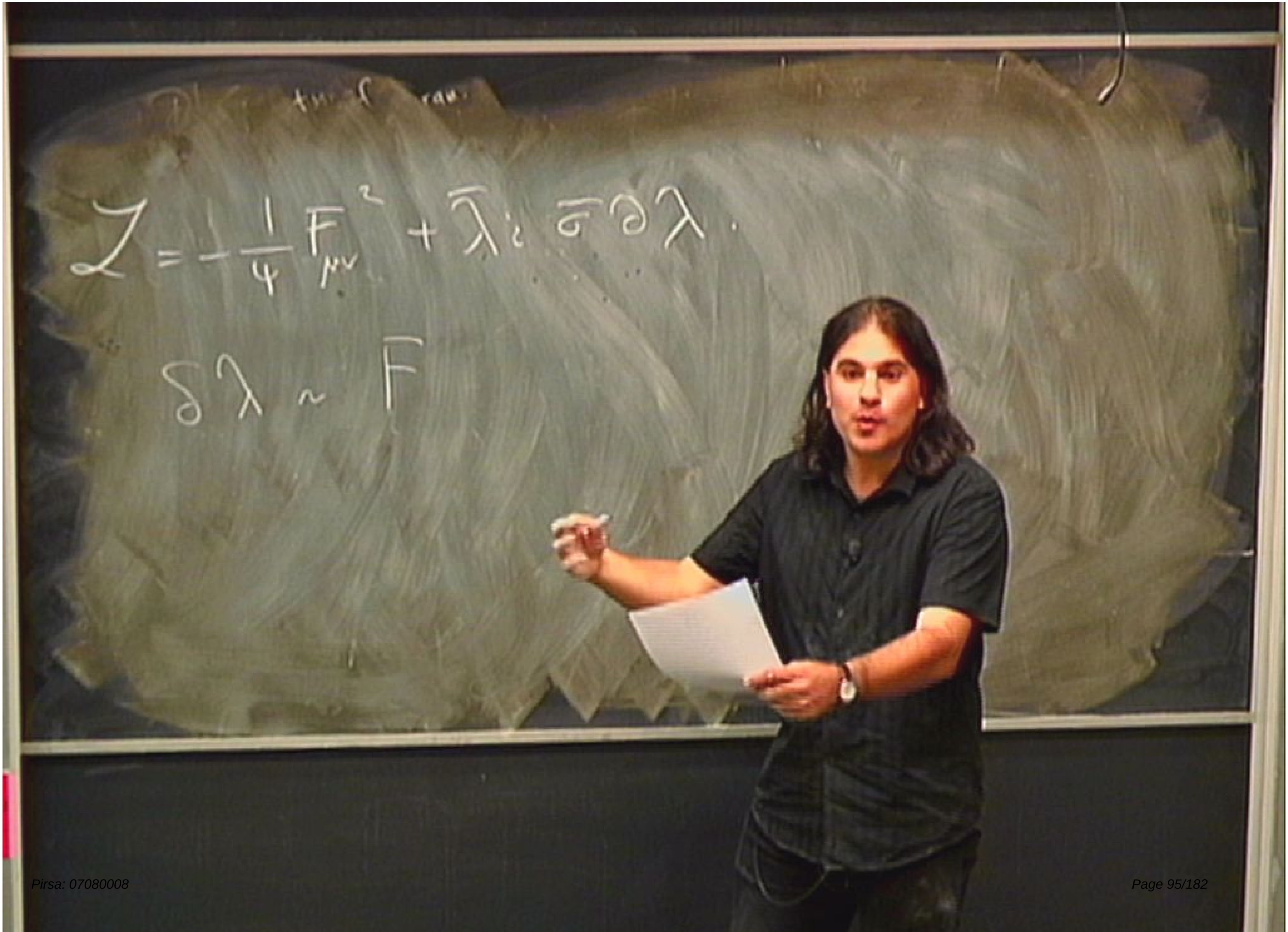
$$\delta\phi = \sqrt{2}\,\xi^{\alpha}\psi_{\alpha}$$

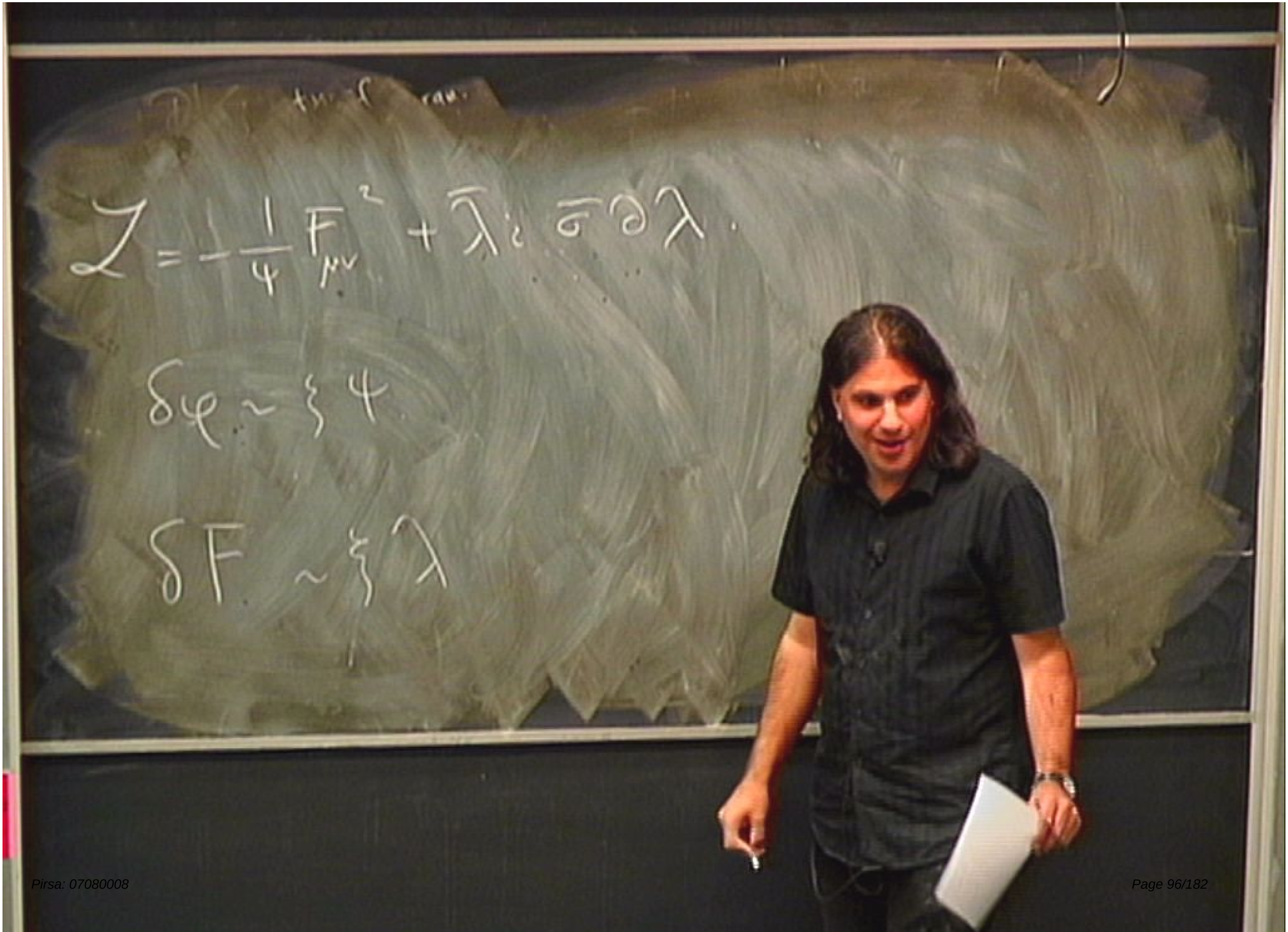
$$\delta\psi_{\alpha} = i\sqrt{2}\,\bar{\xi}^{\dot\alpha}\bar{\sigma}^{\mu}{}_{\dot\alpha\alpha}\,\partial_{\mu}\varphi$$

$$\delta\varphi \sim \xi\psi$$

$$\delta\psi \sim \bar{\xi}\,\partial\varphi$$


$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 + \bar{\lambda} i \bar{\sigma} \partial \lambda$
δ


$\mathcal{L} = -\frac{1}{4} F_{\mu\nu}^2 + \bar{\lambda}_i \bar{\sigma} \partial \lambda$
$\delta\lambda \sim F$


$\mathcal{L} = -\frac{1}{4} F_{\mu\nu}^2 + \bar{\lambda}_i \bar{\sigma} \partial \lambda$
$\delta \varphi \sim \xi \psi$
$\delta F \sim \xi \lambda$

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu}^2 + \bar{\lambda}_i \bar{\sigma} \partial \lambda$$

$$\delta\varphi \sim \xi \psi$$

$$\underset{\partial}{\delta F} \sim \underset{-1/2}{\xi} \underset{3/2}{\lambda} \chi$$

$$\underset{3/2}{\delta\lambda} \sim \underset{-1/2}{\xi} \underset{2}{F}$$

$$\delta F \sim \xi \partial \lambda$$

$$\delta\lambda_\alpha = \xi \qquad F_{\mu\nu}$$

$$\delta\phi_p = \xi^\alpha \psi_{\alpha\, p}$$

$$\delta\psi_\alpha = c\,\bar\xi^{\dot\alpha}\,\Gamma_{\dot\alpha\alpha}\,\phi$$

$$\rho^2\,\phi^*_{-p}\,\xi\,\psi_p + \rho^2\,\bar\xi\,\bar\psi_{-p}\,\phi_p$$

$$+\,c\,\bar\psi_{-p}\,\underbrace{\rho^{\alpha\dot\alpha}\,\Gamma_{\dot\alpha\alpha}}_{}\,\bar\xi\,\phi + h.c.$$

$$\Rightarrow \boxed{c = -1}^{\rho^2}$$

$$\delta \lambda_\alpha = \xi_\beta \, \sigma^{\mu\nu\beta}{}_{\alpha} F_{\mu\nu} .$$

$$(\sigma^\mu \bar{\sigma}^\nu)_\alpha{}^\beta$$

$$\delta \phi_p = \xi^\alpha \psi_{\alpha\, p}$$

$$\delta \bar{\psi}_{\dot\alpha} = i \, \xi^{\alpha} \, \Gamma_{\dot\alpha \alpha} \, \phi$$

$$p^2 \phi^*_{-p} \, \xi \, \psi_p + p^2 \bar{\xi} \bar{\psi}_{-p} \, \phi_p$$

$$+ \, i \, \bar{\psi}_{-p} \, \underbrace{p^{\alpha\dot\alpha} \, \Gamma_{\dot\alpha\alpha}}_{} \xi \phi + h.c.$$

$$\Rightarrow \boxed{\Gamma = -\frac{1}{p^2}}$$

$$\delta\lambda_\alpha = \xi_\beta\, \sigma^{\mu\nu\beta}{}_{\alpha}\, F_{\mu\nu}$$

$$(\sigma^\mu \bar\sigma^\nu)_\alpha{}^\beta \qquad \sigma^\mu \bar\sigma^\nu + \mu\leftrightarrow\nu = 2\eta^{\mu\nu}$$

$$\left(\sigma^\mu_{\alpha\dot\beta}\, \bar\sigma^{\dot\beta\gamma}\right)$$

$$\delta\phi_p = \xi^\alpha \psi_{\alpha\, p}$$

$$\delta\psi_\alpha = i\,\bar\xi^{\dot\alpha}\, \partial_{\dot\alpha\alpha}\phi$$

$$p^2\phi^*_{-p}\,\xi\,\psi_p + p^2\,\bar\xi\,\bar\psi_{-p}\,\phi_p$$

$$+\, i\,\bar\psi_{-p}\, p^{\alpha\dot\alpha}\, \partial_{\dot\alpha\alpha}\,\xi\phi + h.c.$$

$$\Rightarrow \boxed{k=-1}\; p^2$$

$$\delta\lambda_\alpha = \xi_\beta \, \sigma^{\mu\nu\beta}{}_\alpha F_{\mu\nu}$$

$$(\sigma^\mu \bar{\sigma}^\nu)_\alpha{}^\beta \qquad \sigma^\mu \bar{\sigma}^\nu + \mu \leftrightarrow \nu = 2\eta^{\mu\nu}$$

$$(\sigma^\mu_{\alpha\dot\beta} \bar{\sigma}^{\dot\beta\gamma}) \qquad \sigma^\mu \bar{\sigma}^\nu - \sigma^\nu \bar{\sigma}^\mu = \sigma^{\mu\nu}$$

$$\delta\phi_p = \xi^\alpha \psi_{\alpha p}$$

$$\delta\bar{\psi}_{\dot\alpha} = c\,\xi^\alpha P_{\alpha\dot\alpha}\phi$$

$$p^2 \phi^*_{-p} \xi \psi_p + p^2 \bar{\xi} \bar{\psi}_{-p} \phi_p$$

$$+ c\bar{\psi}_{-p} \underbrace{p^{\dot\alpha\alpha} P_{\dot\alpha\alpha}}_{p^2} \xi\phi + h.c.$$

$$\Rightarrow \boxed{c = -1}$$

$$\delta\lambda_\alpha = \xi_\beta \, \sigma^{\mu\nu\beta}{}_{\alpha} \, F_{\mu\nu} \qquad \delta F_{\mu\nu} = \left(\xi \sigma_\nu \partial_\mu \bar{\lambda} + h.c.\right) - (\mu \leftrightarrow \nu)$$

$$(\sigma^\mu \bar{\sigma}^\nu)_\alpha{}^\beta \qquad \sigma^\mu \bar{\sigma}^\nu + \mu \leftrightarrow \nu = 2\eta^{\mu\nu}$$

$$\left(\sigma^\mu_{\alpha\dot{\beta}} \, \bar{\sigma}^{\dot{\beta}\gamma}\right) \qquad \sigma^\mu \bar{\sigma}^\nu - \sigma^\nu \bar{\sigma}^\mu = \sigma^{\mu\nu}$$

$$\boxed{\delta\lambda_\alpha = \xi_\beta \, \sigma^{\mu\nu\beta}{}_\alpha \, F_{\mu\nu}} \quad \boxed{\delta F_{\mu\nu} = \left(\xi \sigma_\nu \partial_\mu \bar\lambda + \text{h.c.} \right) - (\mu \leftrightarrow \nu)}$$

$$\left(\sigma^\mu \bar\sigma^\nu\right)_\alpha{}^\beta \qquad \sigma^\mu \bar\sigma^\nu + \mu \leftrightarrow \nu = 2\eta^{\mu\nu}$$

$$\left(\sigma^\mu_{\alpha\dot\beta} \, \bar\sigma^{\dot\beta\gamma}\right) \qquad \sigma^\mu \bar\sigma^\nu - \sigma^\nu \bar\sigma^\mu = \sigma^{\mu\nu}$$

$$\boxed{\delta\lambda_\alpha = \xi_\beta\, \sigma^{\mu\nu\beta}{}_\alpha\, F_{\mu\nu}} \quad \boxed{\delta F_{\mu\nu} = \left(\xi\sigma_\nu \partial_\mu \bar{\lambda} + h.c.\right) - (\mu \leftrightarrow \nu)}$$

$$(\sigma^\mu \bar{\sigma}^\nu)_\alpha{}^\beta \qquad \sigma^\mu \bar{\sigma}^\nu + \mu \leftrightarrow \nu = 2\eta^{\mu\nu}$$

$$\left(\sigma^\mu_{\alpha\dot{\beta}}\, \bar{\sigma}^{\dot{\beta}\gamma}\right) \qquad \sigma^\mu \bar{\sigma}^\nu - \sigma^\nu \bar{\sigma}^\mu = \sigma^{\mu\nu}$$

Interacting theories

Interacting theories

$$\mathcal{L} = \partial\varphi^{*}\partial\varphi + \bar{\psi}\, i\, \bar{\sigma}\, \partial\psi$$

Interacting theories

$$\mathcal{L} = \partial\varphi^* \partial\varphi + \bar{\psi}\, i\, \bar{\sigma}\, \partial\psi$$

$$+ \tfrac{1}{2} h \psi\psi \phi - \frac{\lambda}{2} \phi^2 \phi^{*2}$$

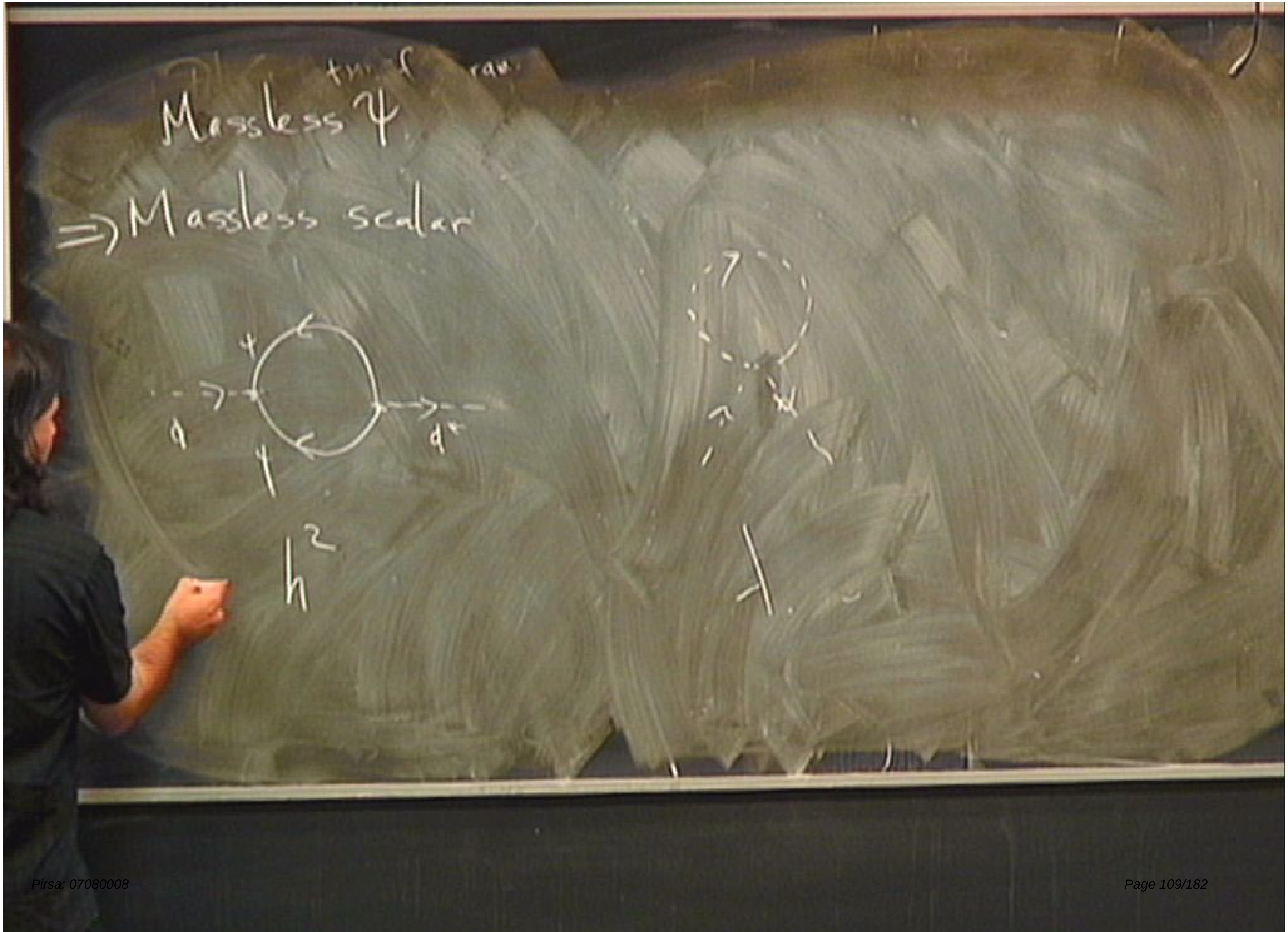
Interacting theories

$$\mathcal{L} = \partial\varphi^* \partial\varphi + \bar{\psi}\, i\, \bar{\sigma}\, \partial\psi$$

$$+ \tfrac{1}{2} h \psi\psi\, \phi - \frac{\lambda}{2} \phi^2 \phi^{*2}$$

$\psi \to e^{i\alpha}\psi$

$\phi \to e^{-2i\alpha}\phi$


Massless ψ
$\Rightarrow$ Massless scalar
h^2

Massless ψ

$\Rightarrow$ Massless scalar

$-h^2\Lambda^2$ $\quad$ $+\lambda\Lambda^2$

$\lambda = \frac{1}{2}h^2$ (ex

Massless ψ

$\Rightarrow$ Massless scalar

$-\,h^2\Lambda^2$

$+\,\lambda\Lambda^2$

$\lambda = \frac{1}{2}h^2$ (ex)

cancels!

Massless ψ

$\Rightarrow$ Massless scalar

$-h^2\Lambda^2$

$+\lambda\Lambda^2$

$\lambda = \frac{1}{2}h^2$ (ex)

cancels!

Massless ψ

$\Rightarrow$ Massless scalar

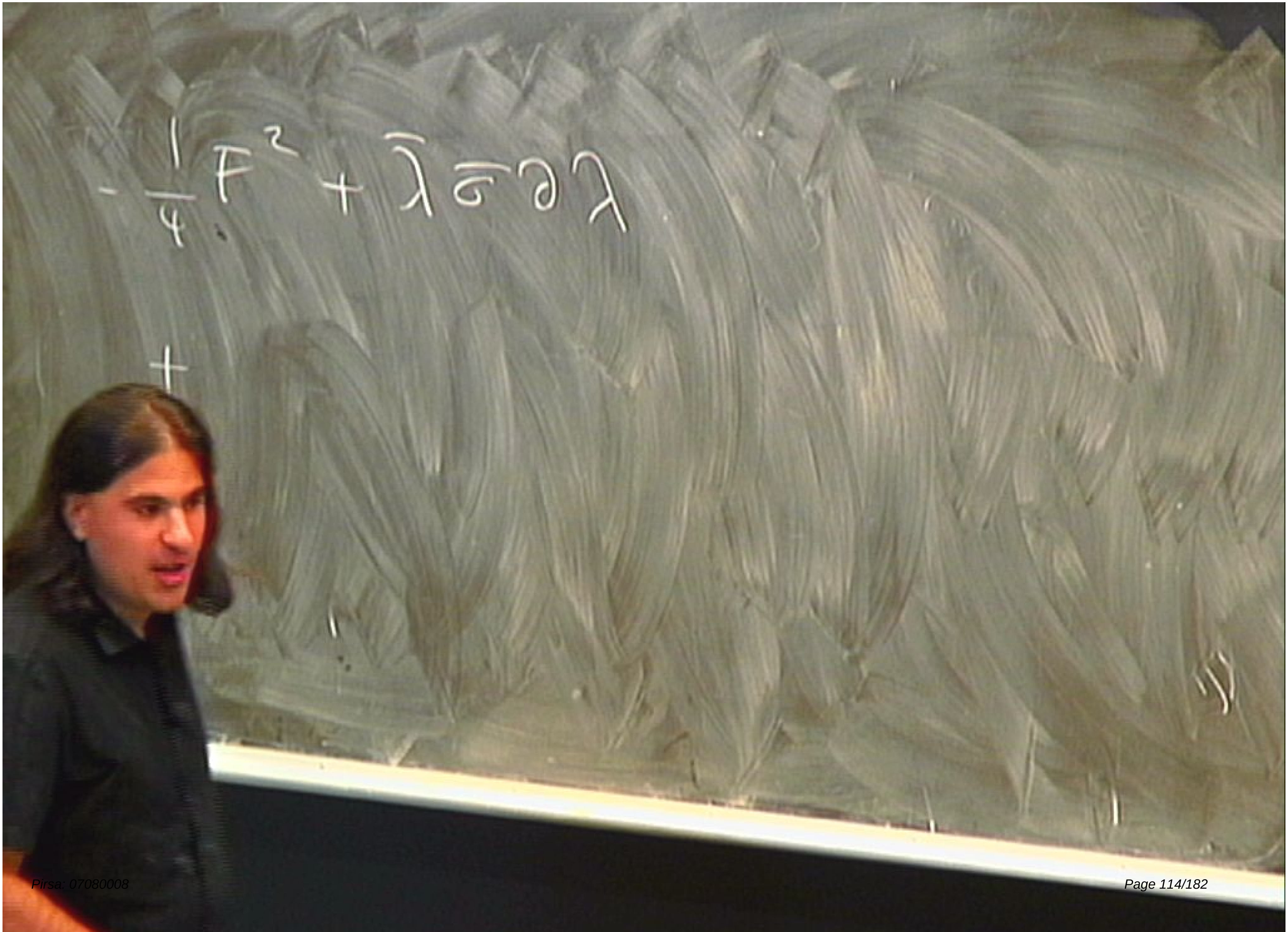
$-\ h^2 \Lambda^2$

$+\lambda \Lambda^2$

$\lambda = \frac{1}{2} h^2$ (ex)

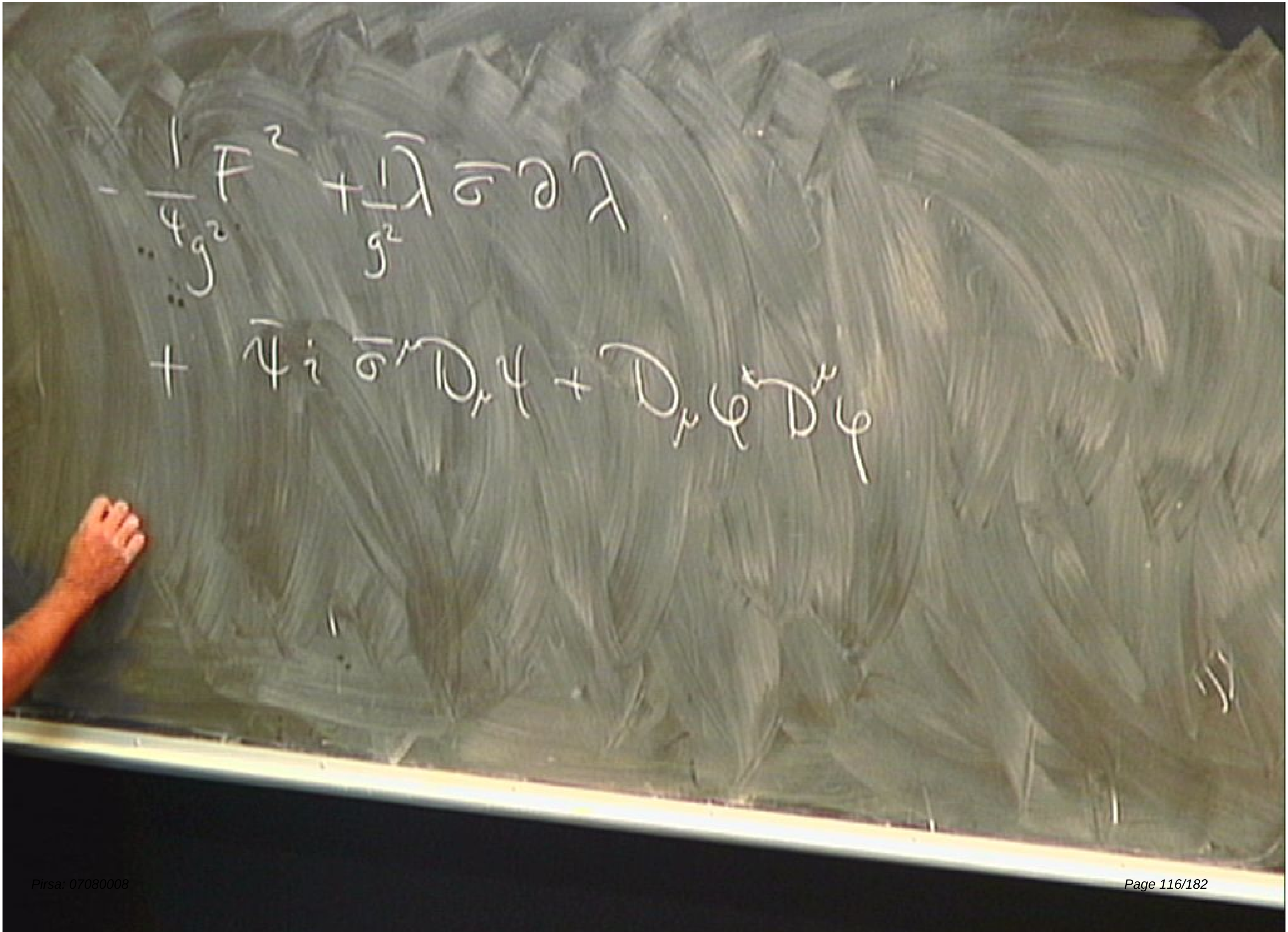
cancels!

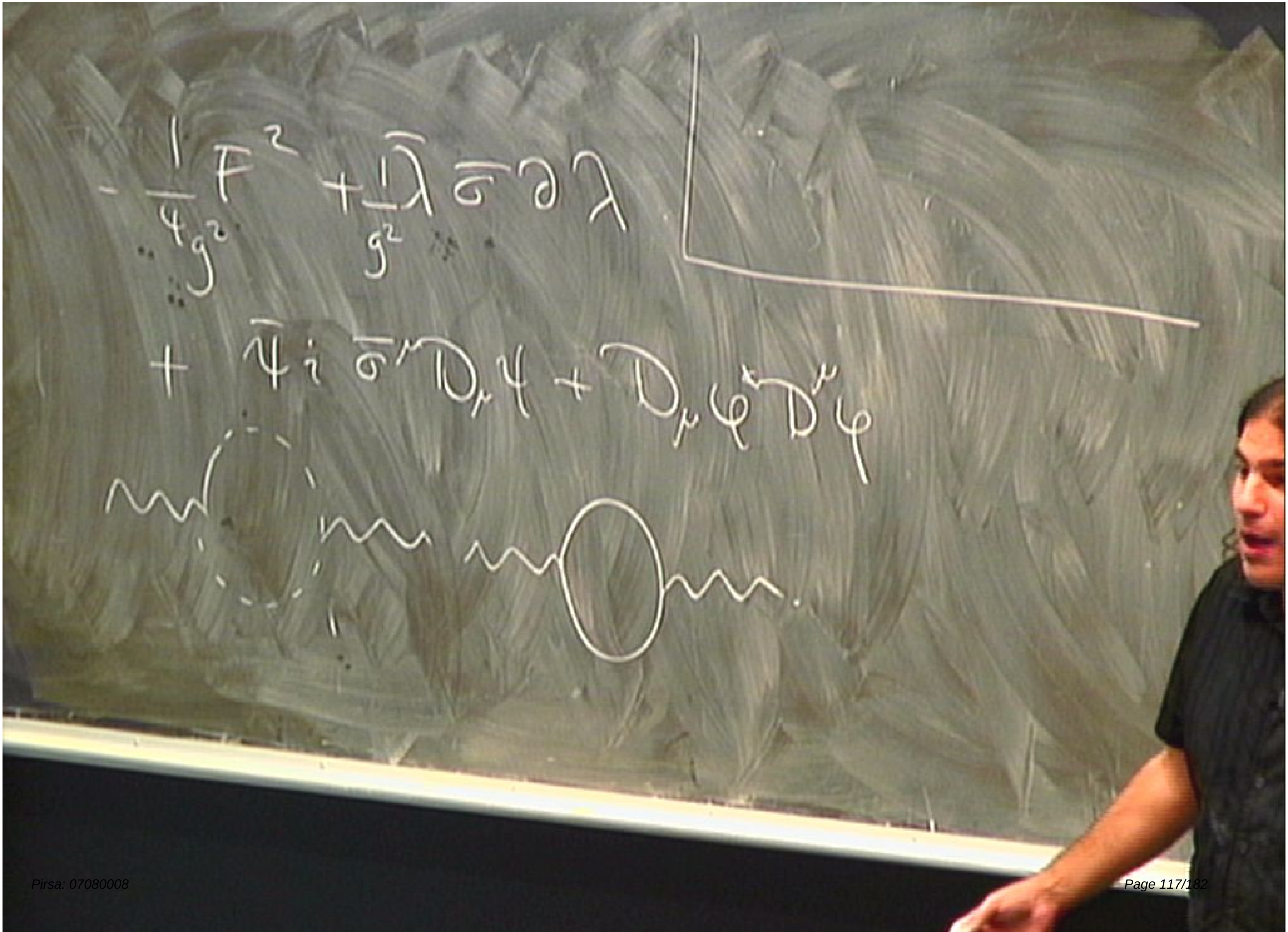
SUSY(?)


$-\frac{1}{4}F^2 + \bar{\lambda}\bar{\sigma}\partial\lambda$
$+$

$$-\frac{1}{4}F^2 + \bar{\lambda}\bar{\sigma}\partial\lambda$$

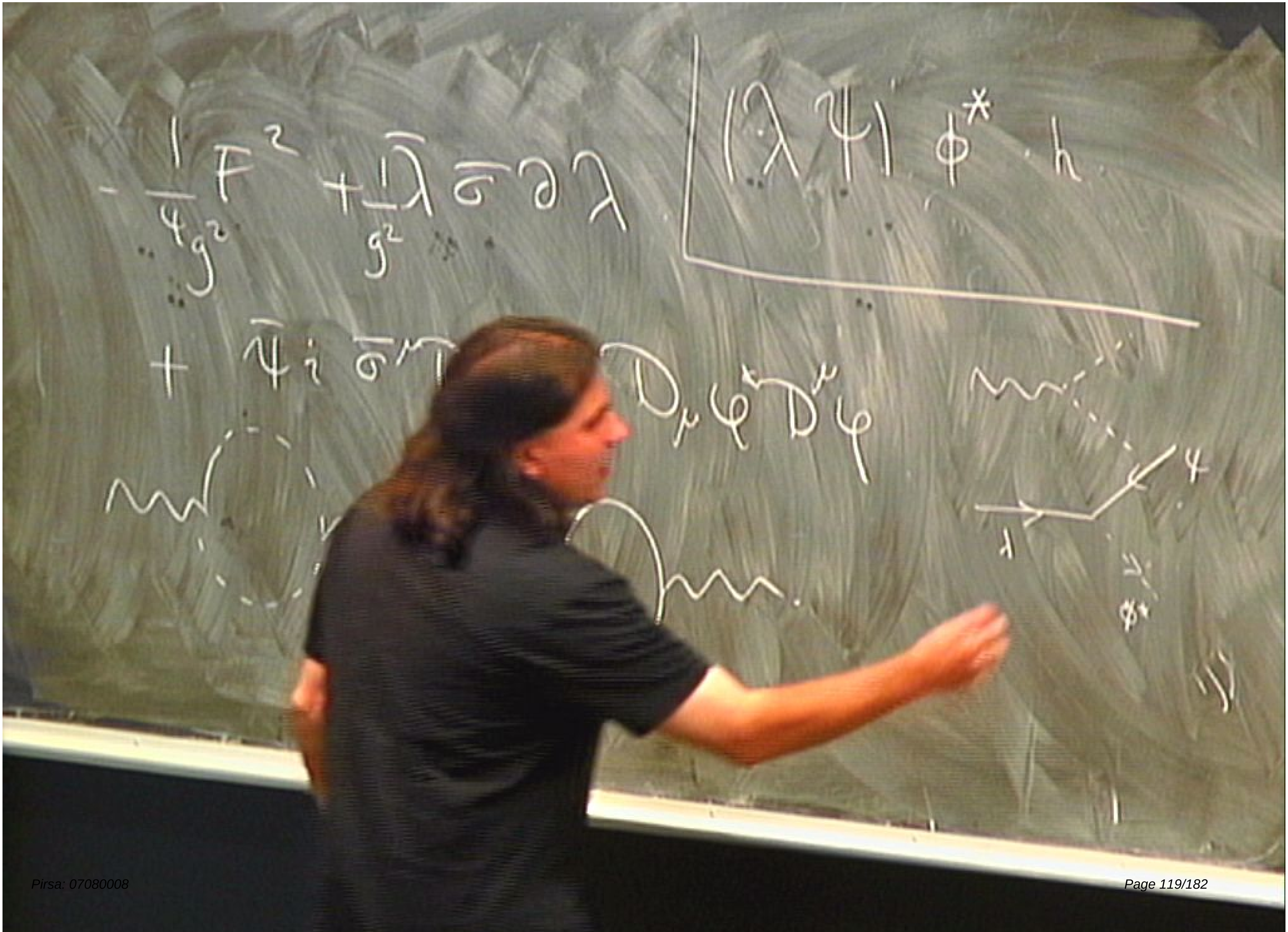
$$+ \bar{\psi} i \bar{\sigma}^\mu D_\mu \psi + D_\mu \varphi^* D^\mu \varphi$$


$-\frac{1}{4g^2}F^2 + \frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda$
$+ \bar{\psi} i \bar{\sigma}^\mu D_\mu \psi + D_\mu \varphi^\dagger D^\mu \varphi$


$-\frac{1}{4g^2}F^2 + \frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda$
$+ \bar{\psi} i \bar{\sigma}^\mu D_\mu \psi + D_\mu \varphi^\dagger D^\mu \varphi$

$$-\frac{1}{4g^2}F^2 + \frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda \qquad (\lambda\psi)\,\phi^*\cdot h$$

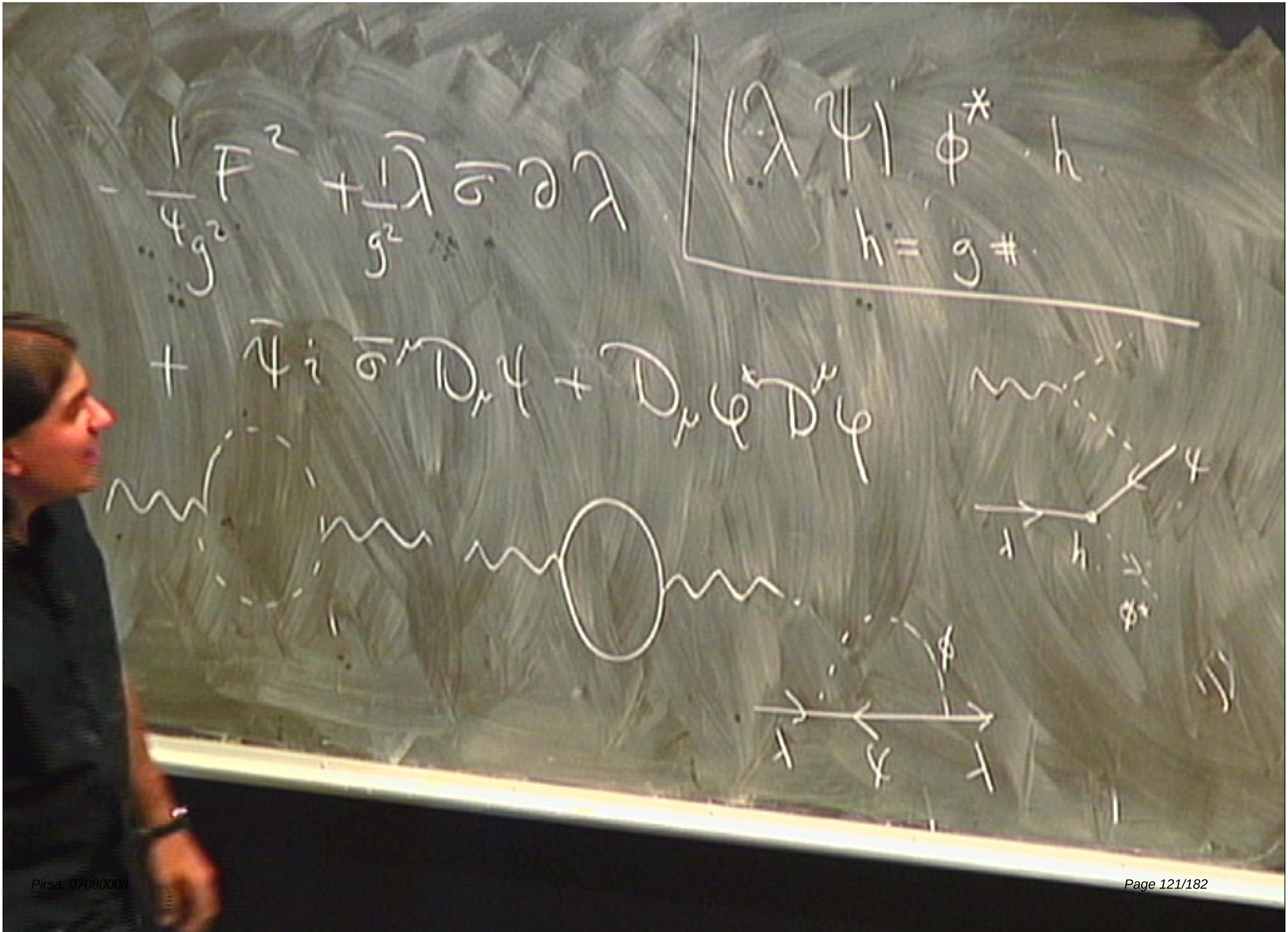
$$+\ \bar{\psi}\, i\,\bar{\sigma}^\mu D_\mu \psi + D_\mu\varphi^* D^\mu \varphi$$


-1/4g² F² + 1/g² λ̄ σ̄ ∂ λ
(λ ψ) φ* h
+ ψ̄ i σ̄
D_μ φ* D^μ φ
ψ
λ
φ*

$$-\frac{1}{4g^2}F^2+\frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda$$

$$(\lambda\psi)\,\phi^*\,h$$

$$+\bar{\psi}\,i\,\bar{\sigma}^\mu D_\mu\psi+D_\mu\varphi^* D^\mu\varphi$$

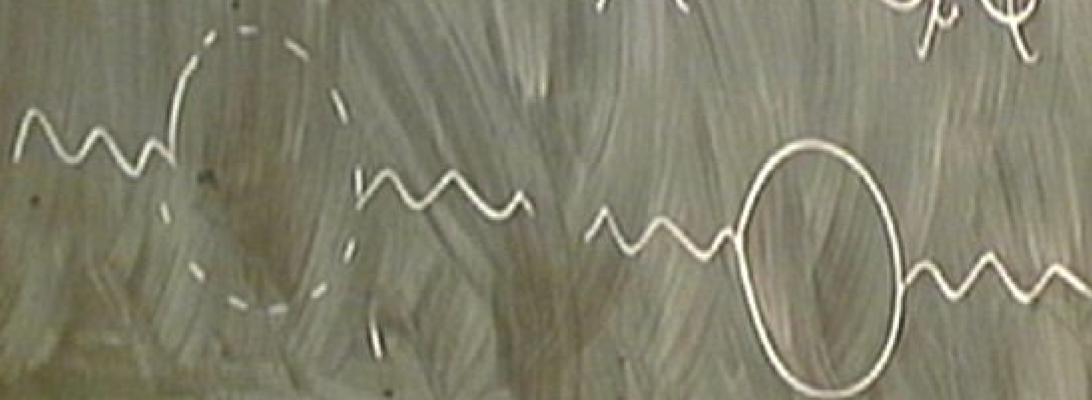

$-\frac{1}{4g^2}F^2 + \frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda$
$(\lambda\psi)\,\phi^*\,h$
$h = g\,\#$
$+\bar{\psi}\, i\,\bar{\sigma}^\mu D_\mu \psi + D_\mu \varphi^* D^\mu \varphi$
ψ
λ
h
ϕ^*
ϕ
λ
ψ
λ

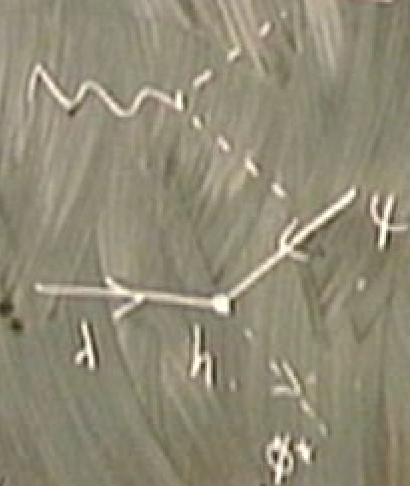
$$-\frac{1}{4g^2}F^2+\frac{1}{g^2}\bar{\lambda}\bar{\sigma}\partial\lambda$$

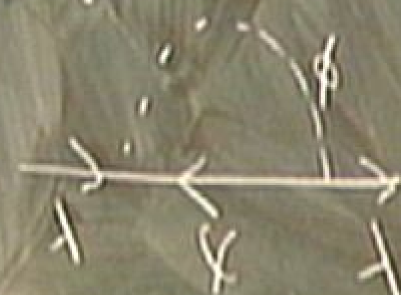
$$(\lambda\psi)\,\phi^*\cdot h$$

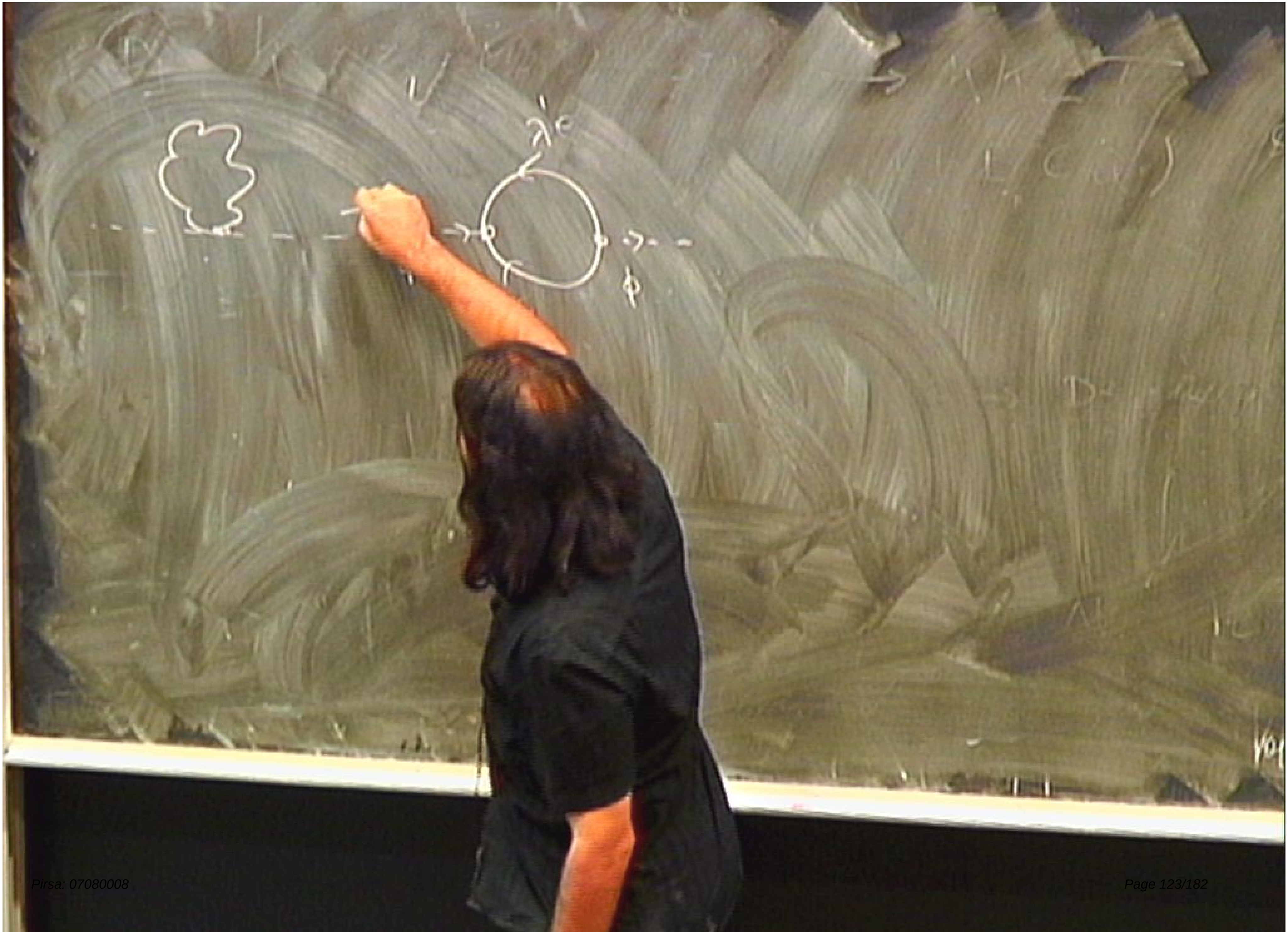
$$h = g\,\#$$

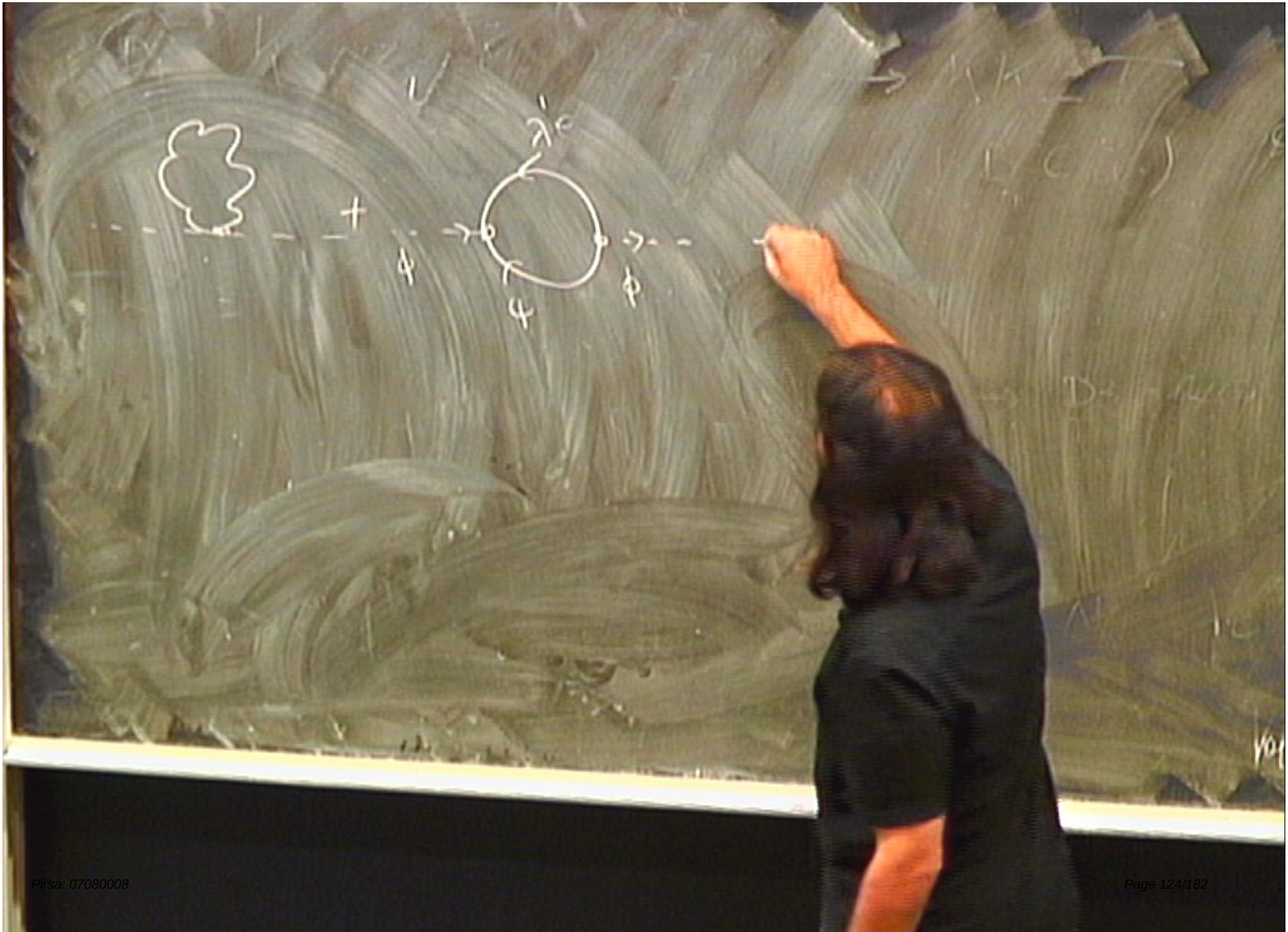
$$+\bar{\psi}\, i\,\bar{\sigma}^\mu D_\mu\psi + D_\mu\varphi^* D^\mu\varphi$$

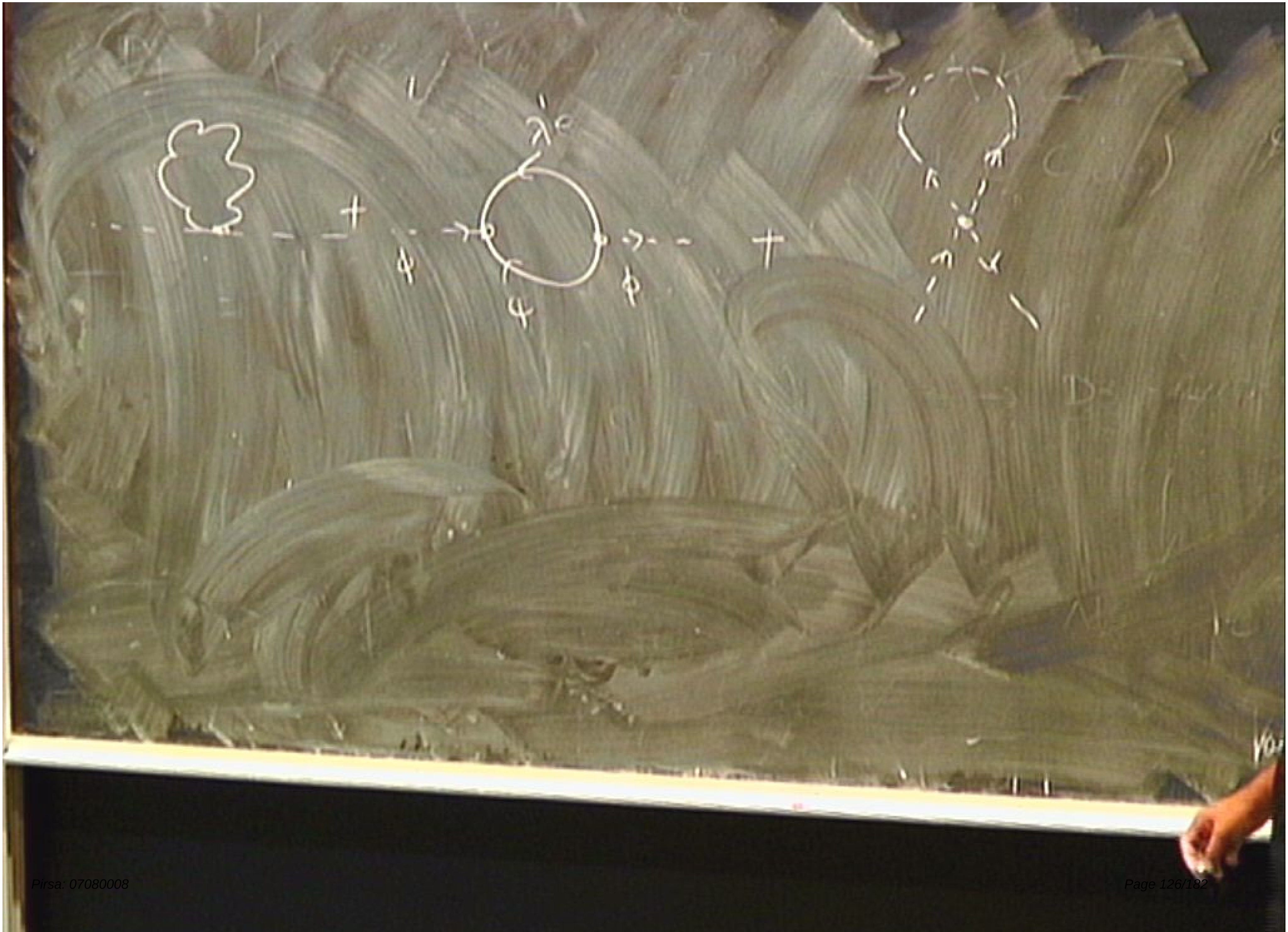


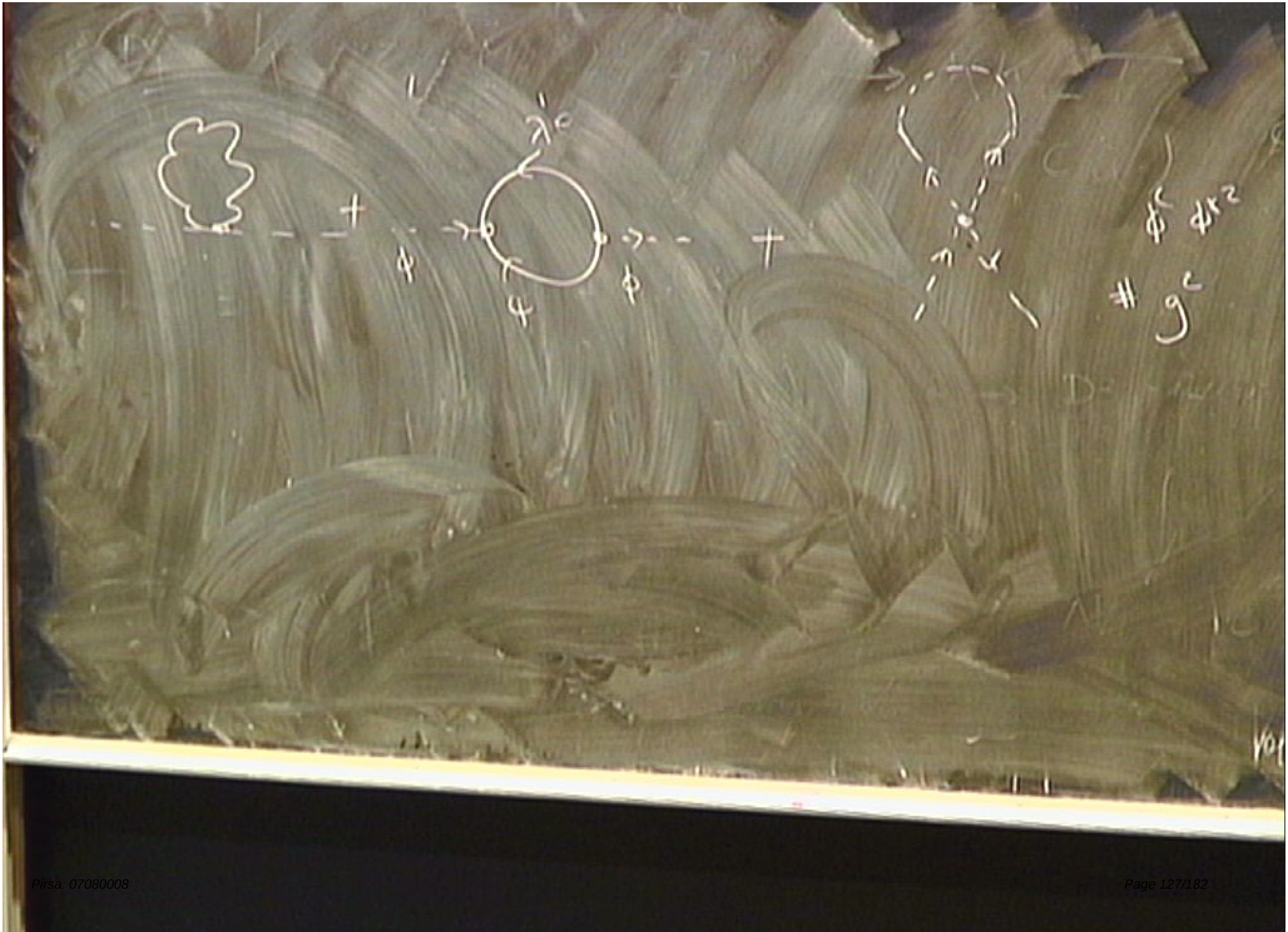


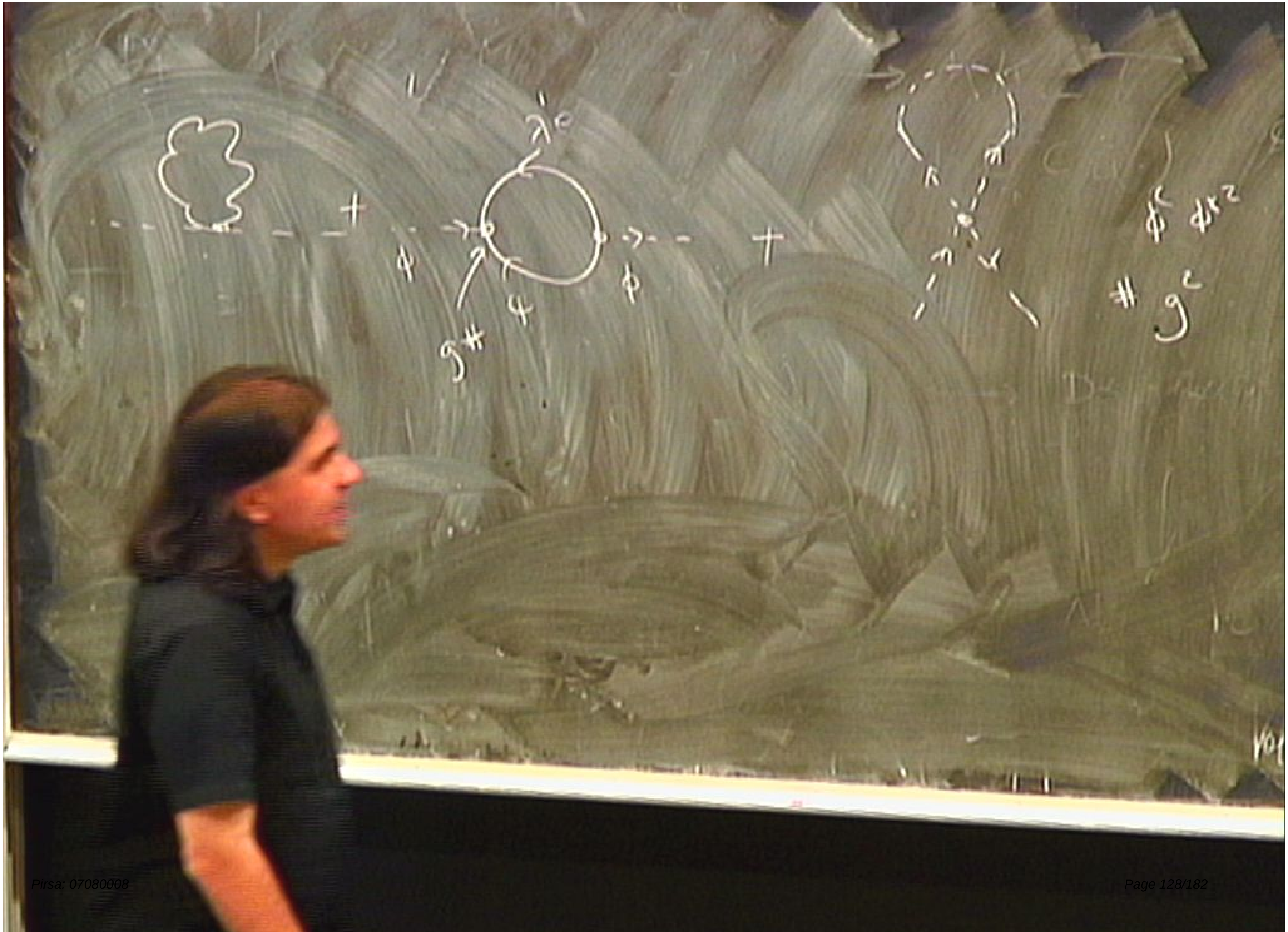


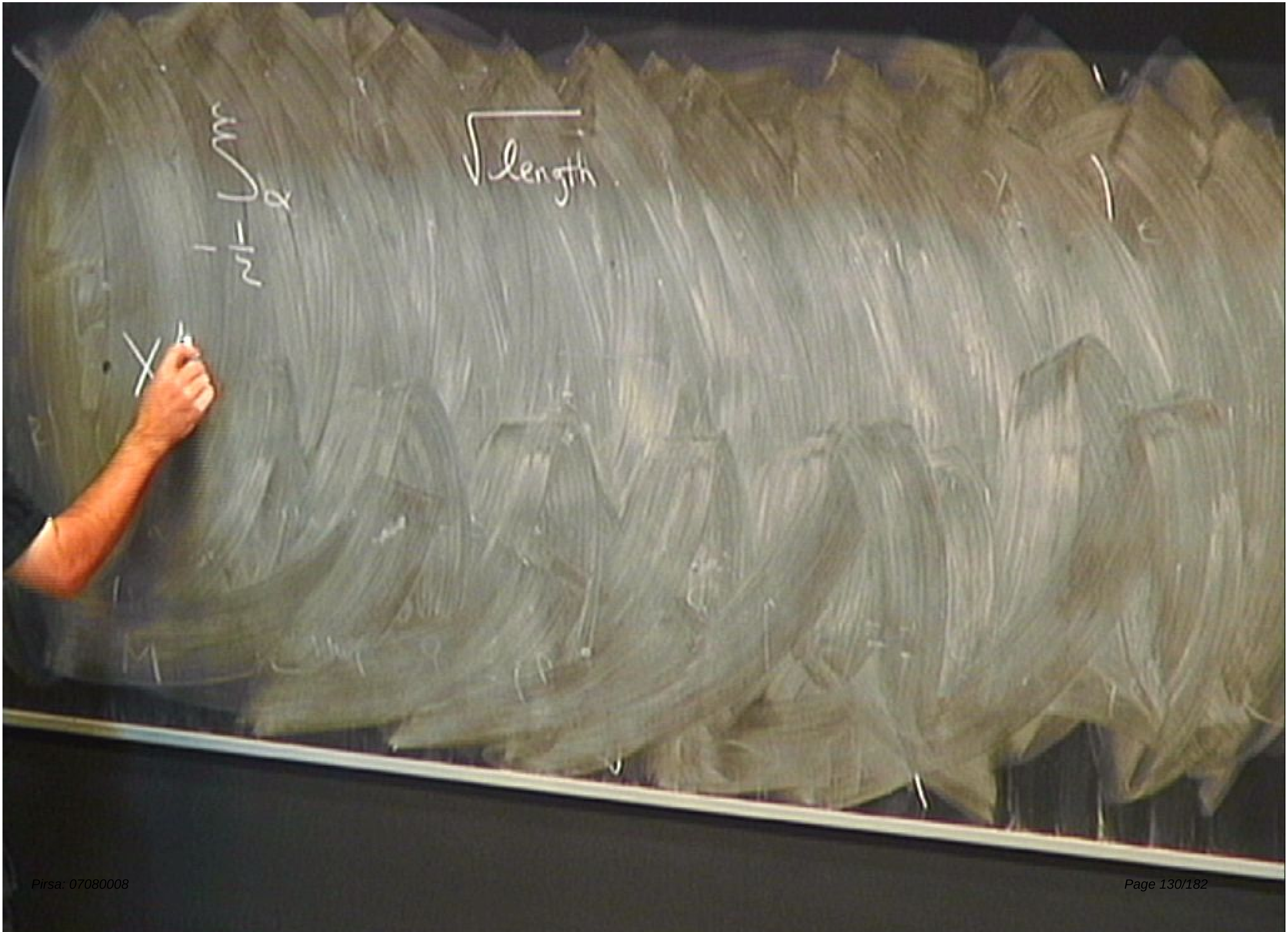

λ
φ

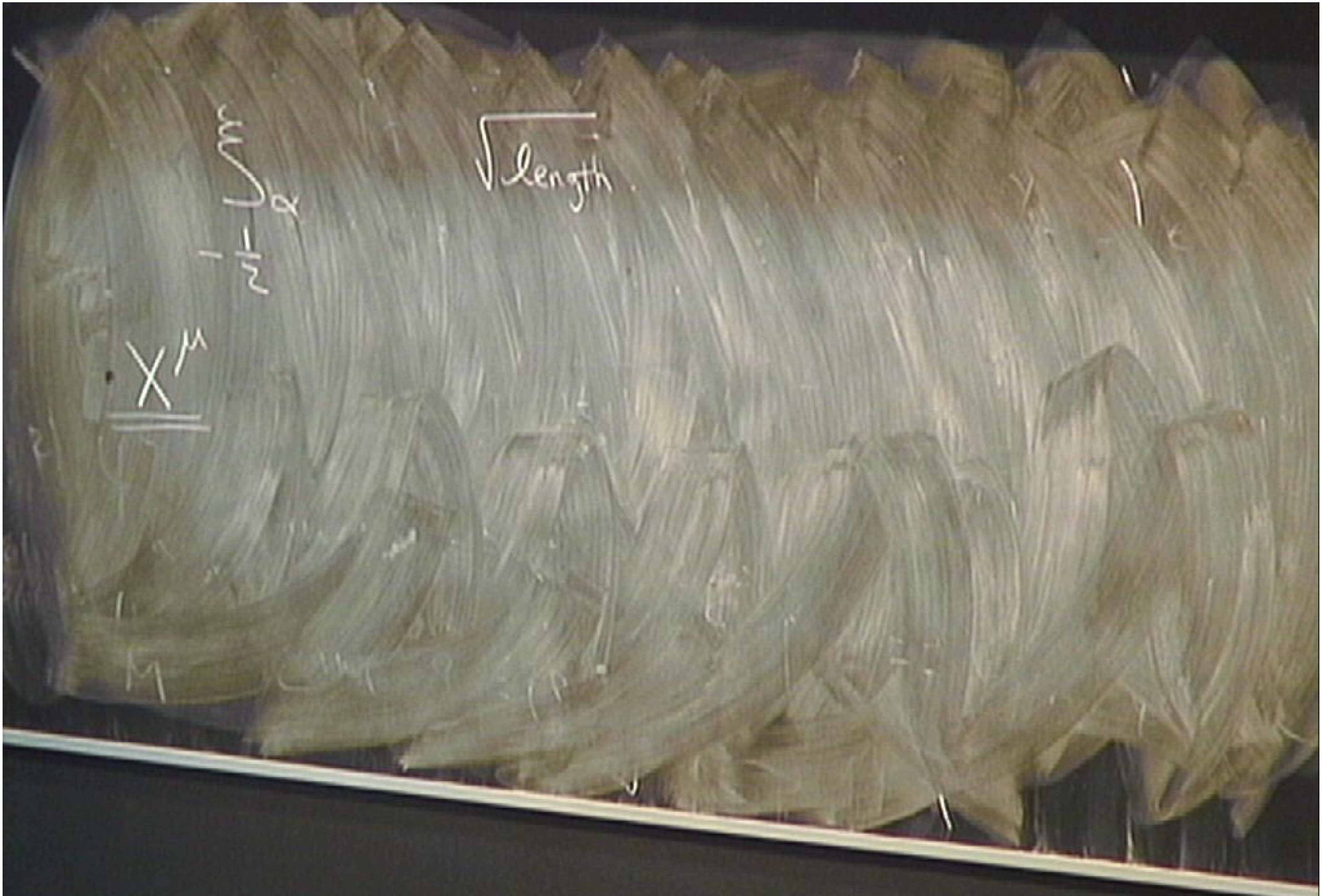

+
φ
ψ
φ

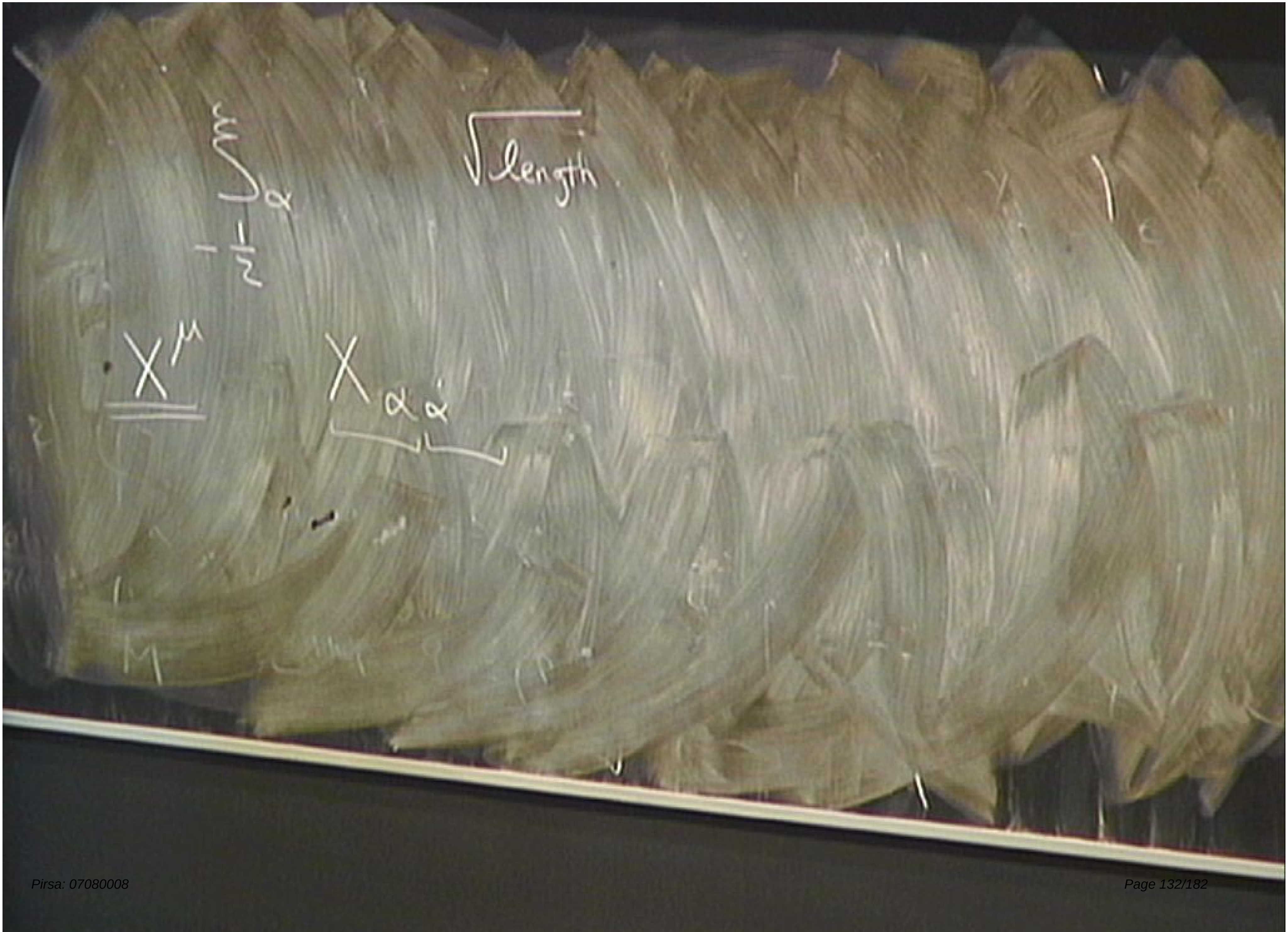



ϕ
ψ
ϕ
g^c




√length


$\sqrt{\text{length}}$
$-\frac{1}{2}$
X^{μ}


$\sqrt{\text{length}}$
X^μ
$X_{\alpha\alpha'}$

ξ_α $\quad \sqrt{\text{length}}$

$-\frac{1}{2}$

$\underline{\underline{X^\mu}} \qquad X_{\alpha\dot\alpha}$

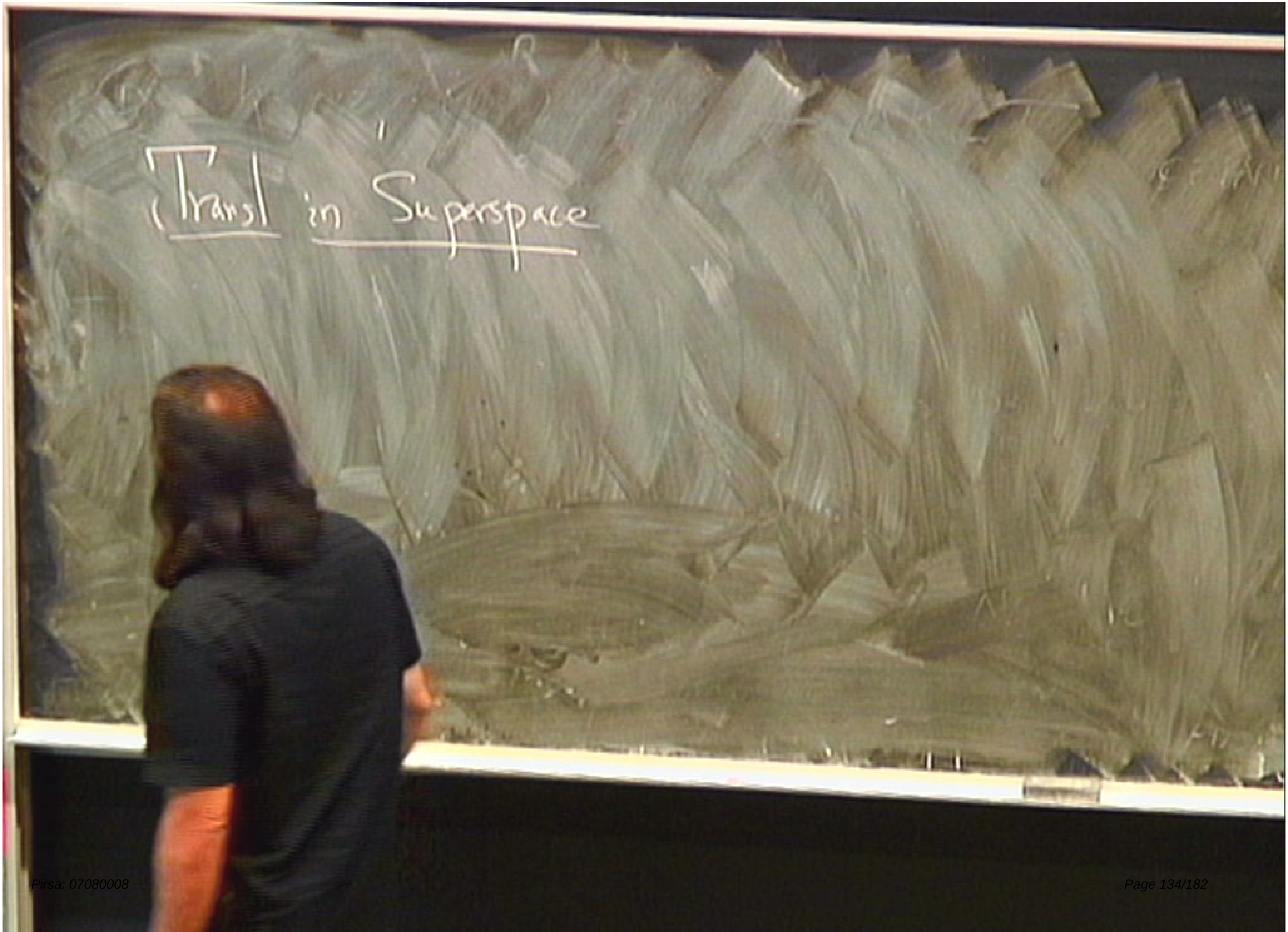
Superspace

$X^\mu \qquad \theta_\alpha \qquad \bar\theta_{\dot\alpha}$

$(X_{\alpha\dot\alpha})$

$(X^\mu, \theta_\alpha, \bar\theta_{\dot\alpha})$

$(X_{\alpha\dot\alpha}, \theta_\alpha, \bar\theta_{\dot\alpha})$


[Transl] in Superspace

Transl in Superspace

$$\Theta_\alpha \to \Theta_\alpha + \xi_\alpha$$

$$\bar{\Theta}_{\dot{\alpha}} \to \bar{\Theta}_{\dot{\alpha}} + \bar{\xi}_{\dot{\alpha}}$$

Transl in Superspace

$$\theta_\alpha \to \theta_\alpha + \xi_\alpha$$

$$\bar\theta_{\dot\alpha} \to \bar\theta_{\dot\alpha} + \bar\xi_{\dot\alpha}$$

$$x_{\alpha\dot\alpha} \to x_{\alpha\dot\alpha} + i\bar\xi_{\dot\alpha}\theta_\alpha - i\bar\theta_{\dot\alpha}\xi_\alpha$$

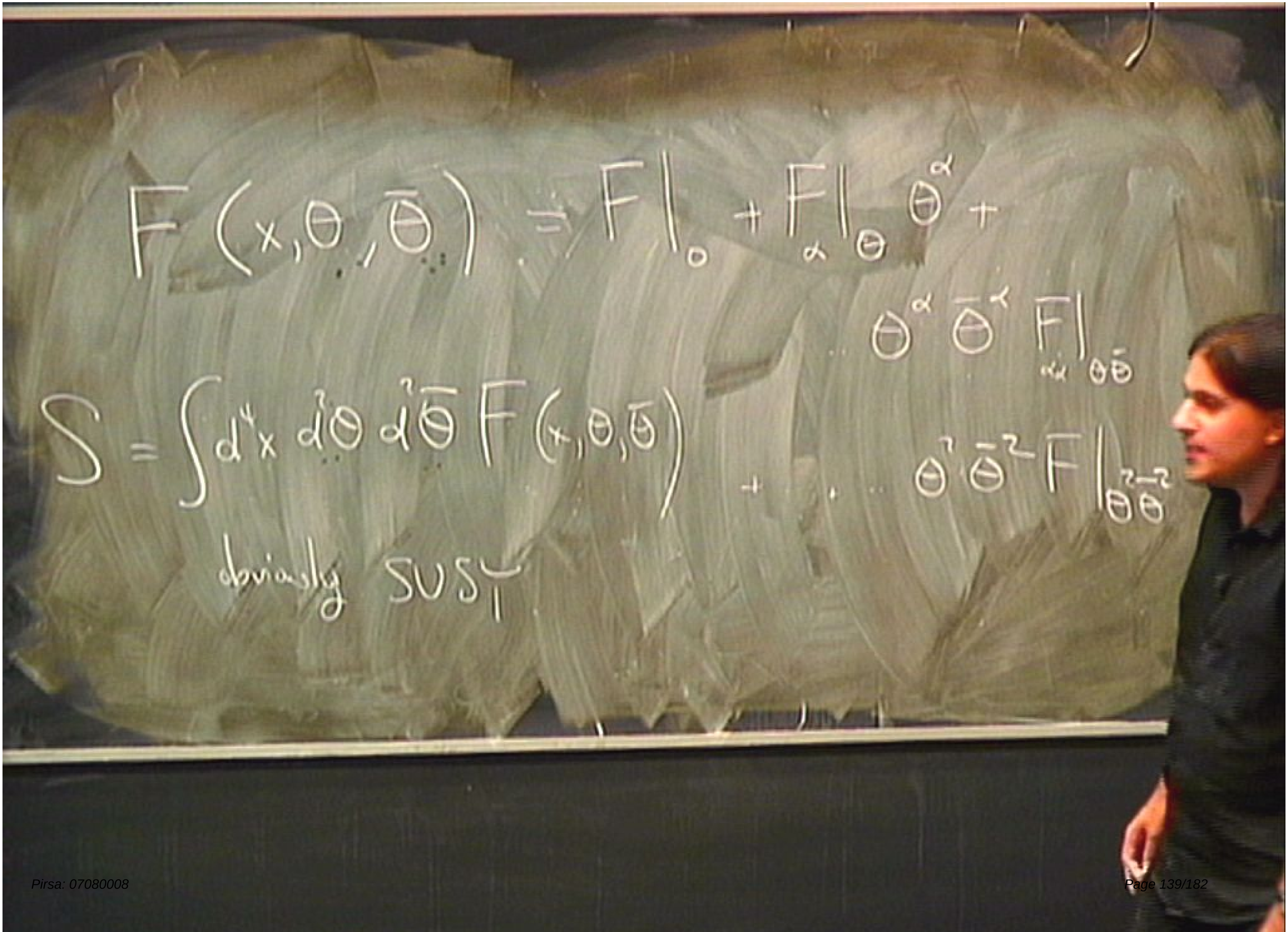
Transl in Superspace $\neq$ SUSY

$$\theta_\alpha \to \theta_\alpha + \xi_\alpha$$

$$\bar\theta_{\dot\alpha} \to \bar\theta_{\dot\alpha} + \bar\xi_{\dot\alpha}$$

$$X_{\alpha\dot\alpha} \to X_{\alpha\dot\alpha} + i\bar\xi_{\dot\alpha}\theta_\alpha - i\bar\theta_{\dot\alpha}\xi_\alpha$$

$$F(x,\theta,\bar{\theta}) = F|_0 + F_\alpha|_\theta \, \theta^\alpha + \theta^\alpha \bar{\theta}^{\dot\alpha} F_{\alpha\dot\alpha}|_{\theta\bar\theta} + \ldots \theta^2 \bar{\theta}^2 F|_{\theta^2\bar\theta^2}$$


$F(x,\theta,\bar\theta) = F|_0 + F_\alpha|_\theta \theta^\alpha +$
$\theta^\alpha \bar\theta^{\dot\alpha} F_{\alpha\dot\alpha}|_{\theta\bar\theta}$
$S = \int d^4x\, d^2\theta\, d^2\bar\theta\, F(x,\theta,\bar\theta)$
$+ \ldots \theta^2 \bar\theta^2 F|_{\theta^2\bar\theta^2}$
obviously SUSY

$$F(x,\theta,\bar{\theta}) = F|_0 + F_\alpha|_\theta \, \theta^\alpha + \theta^\alpha \bar{\theta}^{\dot{\alpha}} F_{\alpha\dot{\alpha}}|_{\theta\bar{\theta}} + \ldots \theta^2 \bar{\theta}^2 F|_{\theta^2\bar{\theta}^2}$$

$$S = \int d^4x \, d^2\theta \, d^2\bar{\theta} \, F(x,\theta,\bar{\theta})$$

obviously SUSY $= \int d^4x \, F|_{\theta^2\bar{\theta}^2}$.

$$F(x,\theta,\bar\theta) = F|_0 + F_\alpha|_\theta\,\theta^\alpha + \dots\ \theta^\alpha\bar\theta^{\dot\alpha} F_{\alpha\dot\alpha}|_{\theta\bar\theta} + \dots\ \theta^2\bar\theta^2 F|_{\theta^2\bar\theta^2}$$

$$S = \int d^4x\, d^2\theta\, d^2\bar\theta\, F(x,\theta,\bar\theta)$$

obviously SUSY $= \int d^4x\, F|_{\theta^2\bar\theta^2}$.

Subspace of Superspace

$$y_{\alpha\dot{\alpha}} = x_{\alpha\dot{\alpha}} + i\theta_\alpha \bar{\theta}_{\dot{\alpha}}$$

$$\hat{y}_{\alpha\dot{\alpha}} = \longrightarrow$$

Subspace of Superspace

$$y_{\alpha\dot\alpha} = x_{\alpha\dot\alpha} + i\theta_\alpha\bar\theta_{\dot\alpha}$$

$$\delta y_{\alpha\dot\alpha} = -i\bar\xi_{\dot\alpha}\theta_\alpha + i\xi_\alpha\bar\theta_{\dot\alpha} + i\xi_\alpha\bar\theta_{\dot\alpha} - i\theta_\alpha\bar\xi_{\dot\alpha}$$

Subspace of Superspace

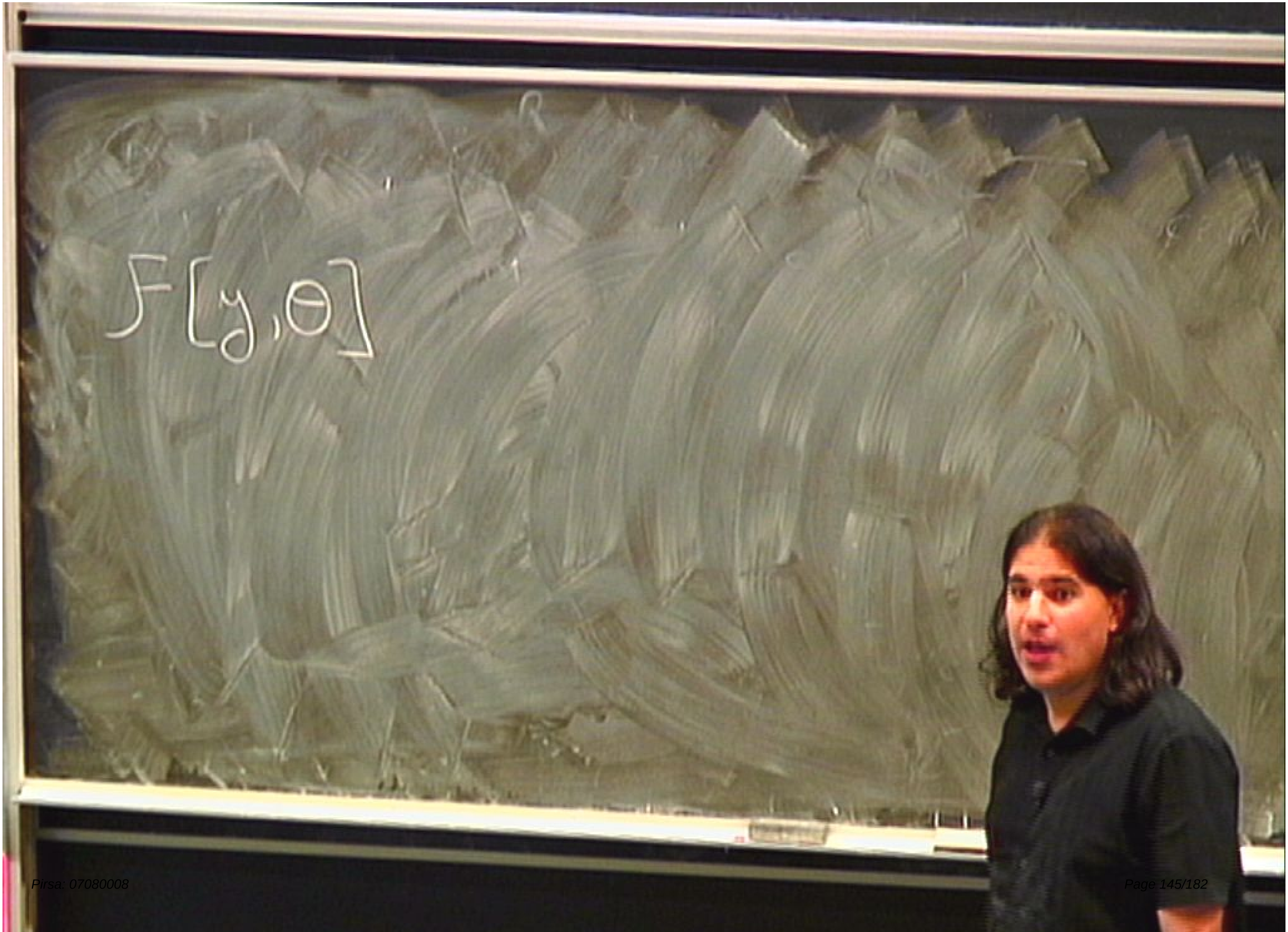
$$y_{\alpha\dot\alpha} = x_{\alpha\dot\alpha} + i\theta_\alpha\bar\theta_{\dot\alpha}$$

$$\delta y_{\alpha\dot\alpha} = \cancel{-i\bar\xi_{\dot\alpha}\theta_\alpha} + i\xi_\alpha\bar\theta_{\dot\alpha} + i\xi_\alpha\bar\theta_{\dot\alpha} \cancel{- i\theta_\alpha\bar\xi_{\dot\alpha}}$$

$$= 2i\xi_\alpha\bar\theta_{\dot\alpha} \quad \text{no } \bar\xi!$$

$y_{\alpha\dot\alpha} = x_{\alpha\dot\alpha} + i\theta_\alpha\bar\theta_{\dot\alpha}$ shifts under

$y^*_{\alpha\dot\alpha} = x_{\alpha\dot\alpha} - i\theta_\alpha\bar\theta_{\dot\alpha}$ shifts under $\bar\xi$


F[y,θ]

$$F[y, \theta] \longrightarrow F[y + \cdots, \theta + \xi]$$

$$F[y,\theta] \longrightarrow F[y+\cdots,\theta+\xi]$$

$$F^{\dagger}[y^{*},\bar{\theta}]$$

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

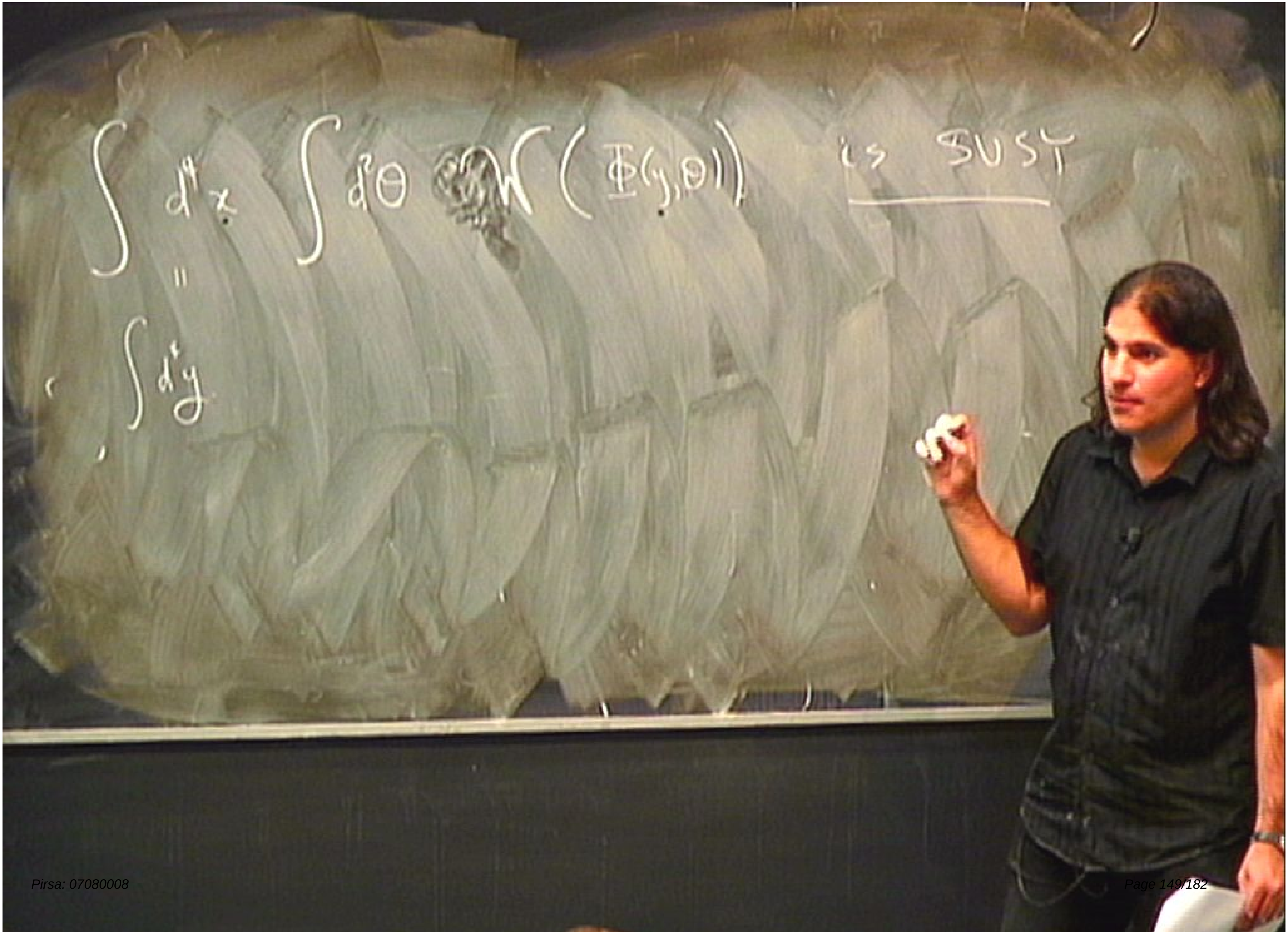
$$F[y,\theta] \longrightarrow F[y+\cdots,\ \theta+\xi]$$

$$F^{\dagger}[y^{*},\bar{\theta}]$$

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

$$\Big(\Phi(x,\theta,\bar{\theta})$$

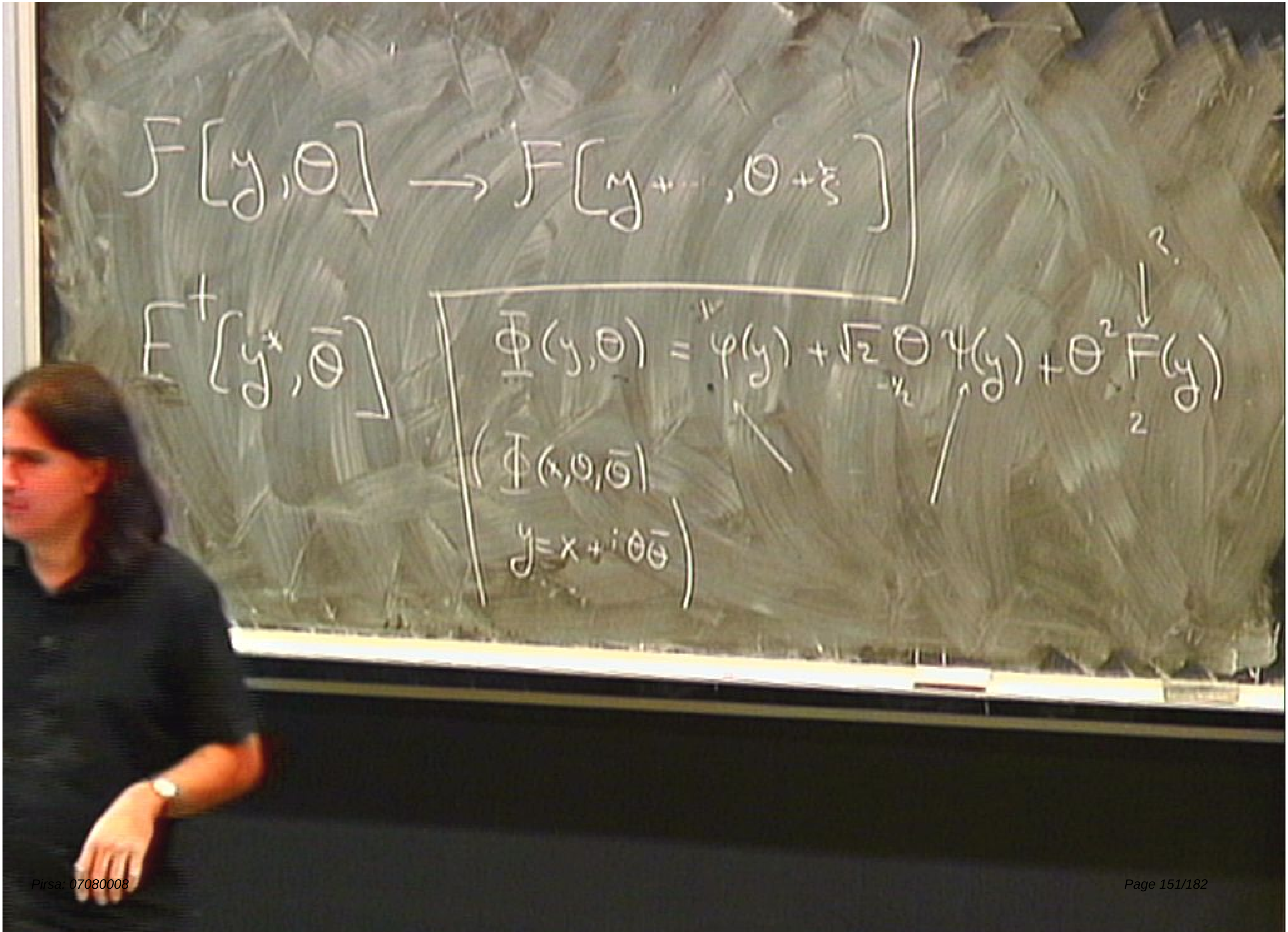
$$y = x + i\theta\bar{\theta}\Big)$$


$\int d^4x \int d^2\theta \, W(\Phi(y,\theta))$ is SUSY
$=$
$\int d^4y$

$$\int d^4x \int d^2\theta \, \mathcal{W}(\Phi(y,\theta)) \quad \text{is } \underline{\text{SUSY}}$$

$$\parallel$$

$$\int d^4y \quad = \quad \int d^4x \, \mathcal{W}\Big|_{\theta^2}$$


$F[y,\theta] \longrightarrow F[y+\cdots,\theta+\xi]$
$F^\dagger[y^*,\bar\theta]$
?
$\Phi(y,\theta) = \varphi(y) + \sqrt{2}\,\theta\,\psi(y) + \theta^2 F(y)$
$-\frac{1}{2}$
2
$(\Phi(x,\theta,\bar\theta)$
$y = x + i\theta\bar\theta)$

$$F[y,\theta] \longrightarrow F[y+\cdots, \theta+\xi]$$

$$F^{\dagger}[y^{*}, \bar{\theta}]$$

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

$$\left(\begin{array}{l}\Phi(x,\theta,\bar{\theta}) \\ y = x + i\theta\bar{\theta}\end{array}\right)$$

$$F[y,\theta] \longrightarrow F[y+\cdots,\theta+\xi]$$

$$F^{+}[y^{*},\bar{\theta}]$$

(Auxiliary)

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

$$\left(\Phi(x,\theta,\bar{\theta})\right.$$

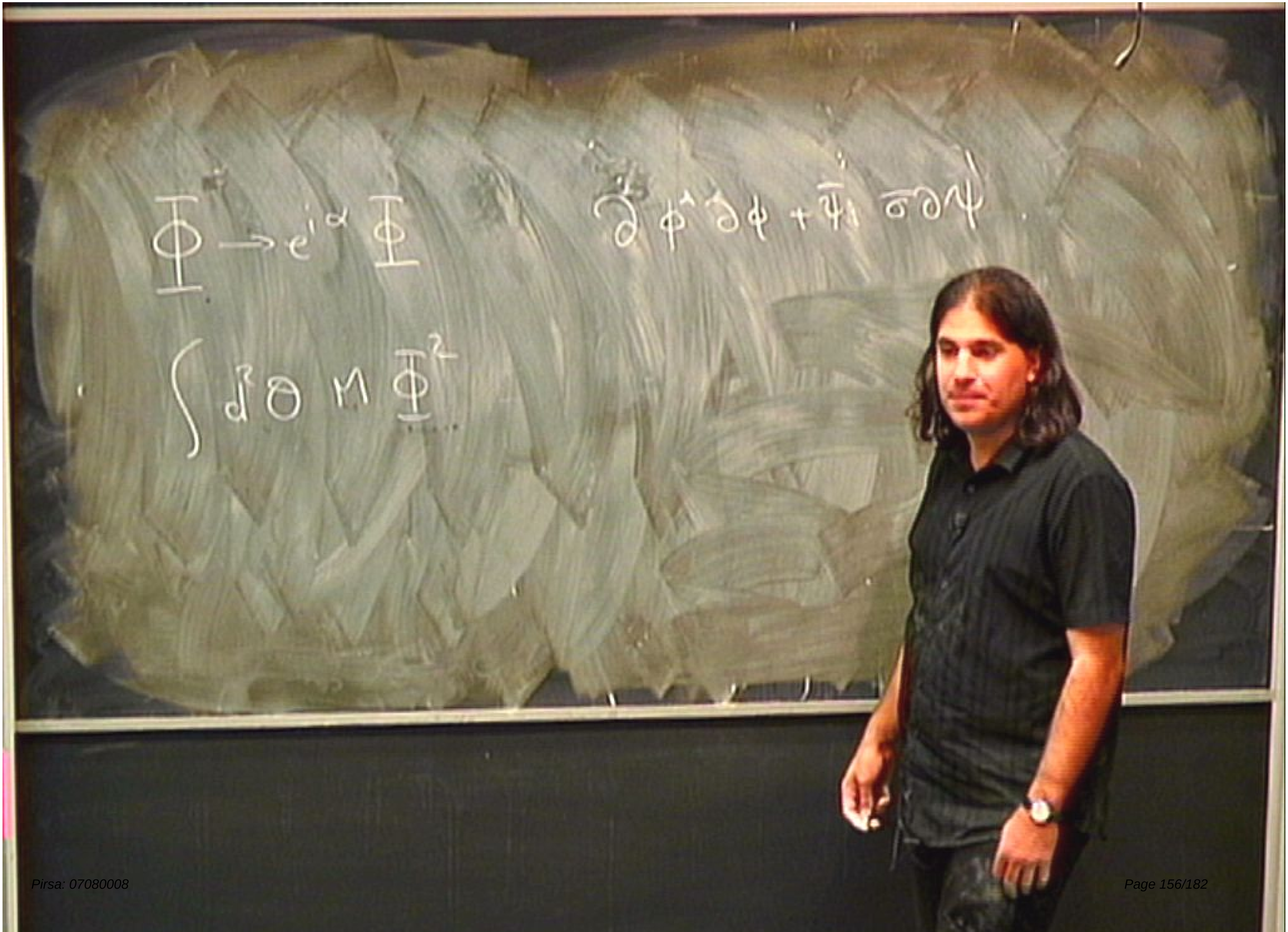
$$\left. y = x + i\theta\bar{\theta}\right)$$

Φ

$\partial \phi^\dagger \partial \phi + \bar{\psi} \, \sigma \partial \psi$

$$\Phi \to e^{i\alpha}\Phi$$

$$\partial\phi^*\partial\phi + \bar{\psi} i \bar{\sigma}\partial\psi$$


$\Phi \to e^{i\alpha}\Phi$
$\partial\phi^\dagger\partial\phi + \bar{\psi}\,\bar{\sigma}\partial\psi$
$\int d^2\theta\, M\, \Phi^2$

$$\Phi \to e^{i\alpha}\,\Phi$$

$$\partial\phi^{*}\partial\phi + \bar{\psi}\,\bar{\sigma}\,\partial\psi$$

$$\int d^2\theta \left[M\,\Phi^2 + \lambda\,\Phi^3 + \cdots \right]$$

$$\Phi \to e^{i\alpha} \Phi \qquad \partial\phi^* \partial\phi + \bar{\psi}_1 \, \bar{\sigma} \partial \psi$$

$$\int d^2\theta \left[M \Phi^2 + \lambda \Phi^3 + \cdots \right] \qquad \phi^\dagger \quad \phi$$

$$2$$

$$\Phi \to e^{i\alpha}\Phi$$

$$\partial\phi^\dagger\partial\phi + \bar\psi\,\bar\sigma\partial\psi$$

$$\int d^2\theta\left[M\Phi^2 + \lambda\Phi^3 + \cdots\right]$$

$$\int d^2\theta\, d^2\bar\theta\; \Phi^\dagger\,\Phi$$

$$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$$

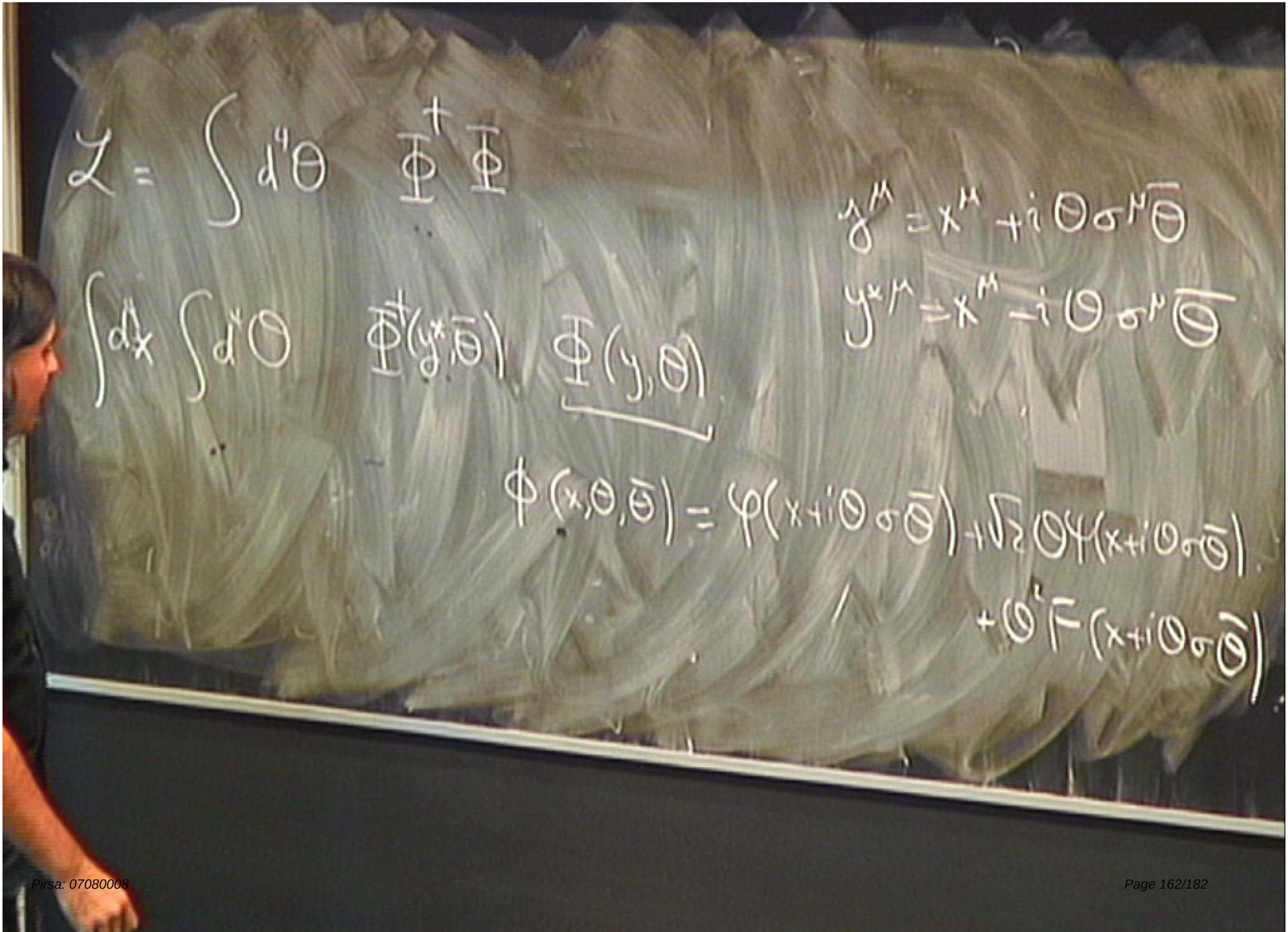
$$= \int d^4\theta \; \Phi^\dagger(y^*, \bar{\theta}) \; \Phi(y, \theta)$$

$$\mathcal{L} = \int d^4\theta \;\; \Phi^\dagger \Phi$$

$$\int d^4x \int d^4\theta \;\; \Phi^\dagger(y^*, \bar{\theta}) \;\; \Phi(y, \theta)$$

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

$$y^{*\mu} = x^\mu - i\,\theta\sigma^\mu\bar{\theta}$$


$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$
$y^\mu = x^\mu + i\theta\sigma^\mu\bar{\theta}$
$y^{*\mu} = x^\mu - i\theta\sigma^\mu\bar{\theta}$
$\int d^4x \int d^4\theta \; \Phi^\dagger(y^*, \bar{\theta}) \; \underline{\Phi(y,\theta)}$
$\phi(x,\theta,\bar{\theta}) = \varphi(x + i\theta\sigma\bar{\theta}) + \sqrt{2}\,\theta\psi(x + i\theta\sigma\bar{\theta})$
$+ \theta^2 F(x + i\theta\sigma\bar{\theta})$

$$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$$

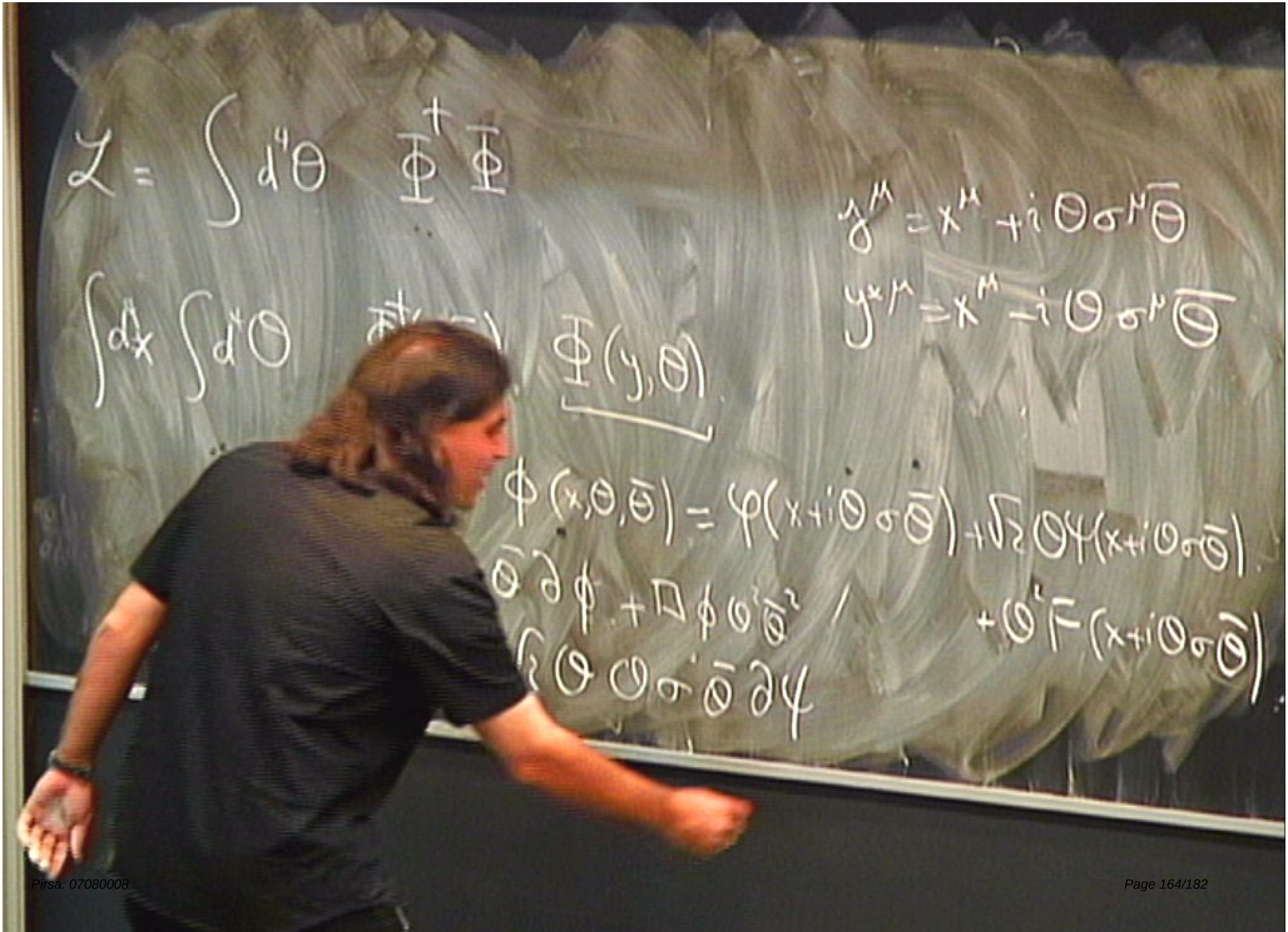
$$y^\mu = x^\mu + i\theta\sigma^\mu\bar\theta$$

$$y^{*\mu} = x^\mu - i\theta\sigma^\mu\bar\theta$$

$$\int d^4x \int d^4\theta \; \Phi^\dagger(y^*,\bar\theta) \; \underline{\Phi(y,\theta)}$$

$$\phi(x,\theta,\bar\theta) = \varphi(x+i\theta\sigma\bar\theta) + \sqrt{2}\,\theta\psi(x+i\theta\sigma\bar\theta) + \theta^2 F(x+i\theta\sigma\bar\theta)$$

$$= \varphi(x) + i\,\theta\sigma\bar\theta\,\partial\phi + \Box\phi\,\theta^2\bar\theta^2$$


$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$
$y^\mu = x^\mu + i\theta\sigma^\mu\bar\theta$
$y^{*\mu} = x^\mu - i\theta\sigma^\mu\bar\theta$
$\int d^4x \int d^4\theta \quad \Phi(y,\theta)$
$\phi(x,\theta,\bar\theta) = \varphi(x+i\theta\sigma\bar\theta) + \sqrt{2}\,\theta\psi(x+i\theta\sigma\bar\theta)$
$\bar\theta\,\partial\phi + \Box\phi\,\theta^2\bar\theta^2 \quad + \theta^2 F(x+i\theta\sigma\bar\theta)$
$\theta\,\theta\sigma\bar\theta\,\partial\psi$

$$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$$

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

$$y^{*\mu} = x^\mu - i\,\theta\sigma^\mu\bar{\theta}$$

$$\int d^4x \int d^4\theta \;\; \Phi^\dagger(y^*,\bar{\theta}) \;\; \underline{\Phi(y,\theta)}$$

$$\phi(x,\theta,\bar{\theta}) = \varphi(x+i\theta\sigma\bar{\theta}) + \sqrt{2}\,\theta\psi(x+i\theta\sigma\bar{\theta}) + \theta^2 F(x+i\theta\sigma\bar{\theta})$$

$$= \varphi(x) + i\,\theta\sigma\bar{\theta}\,\partial\phi + \Box\phi\,\theta^2\bar{\theta}^2 + \sqrt{2}\,\theta\psi(x) + \sqrt{2}\,\theta\,\theta\sigma\bar{\theta}\,\partial\psi + \theta^2 F(x)$$

$$\mathcal{L} = \int d^4\theta \; \Phi^\dagger \Phi$$

$$y^\mu = x^\mu + i\,\theta\sigma^\mu\bar\theta$$

$$y^{*\mu} = x^\mu - i\,\theta\sigma^\mu\bar\theta$$

$$\int d^4x \int d^4\theta \; \Phi^\dagger(y^*,\bar\theta)\; \underline{\Phi(y,\theta)}$$

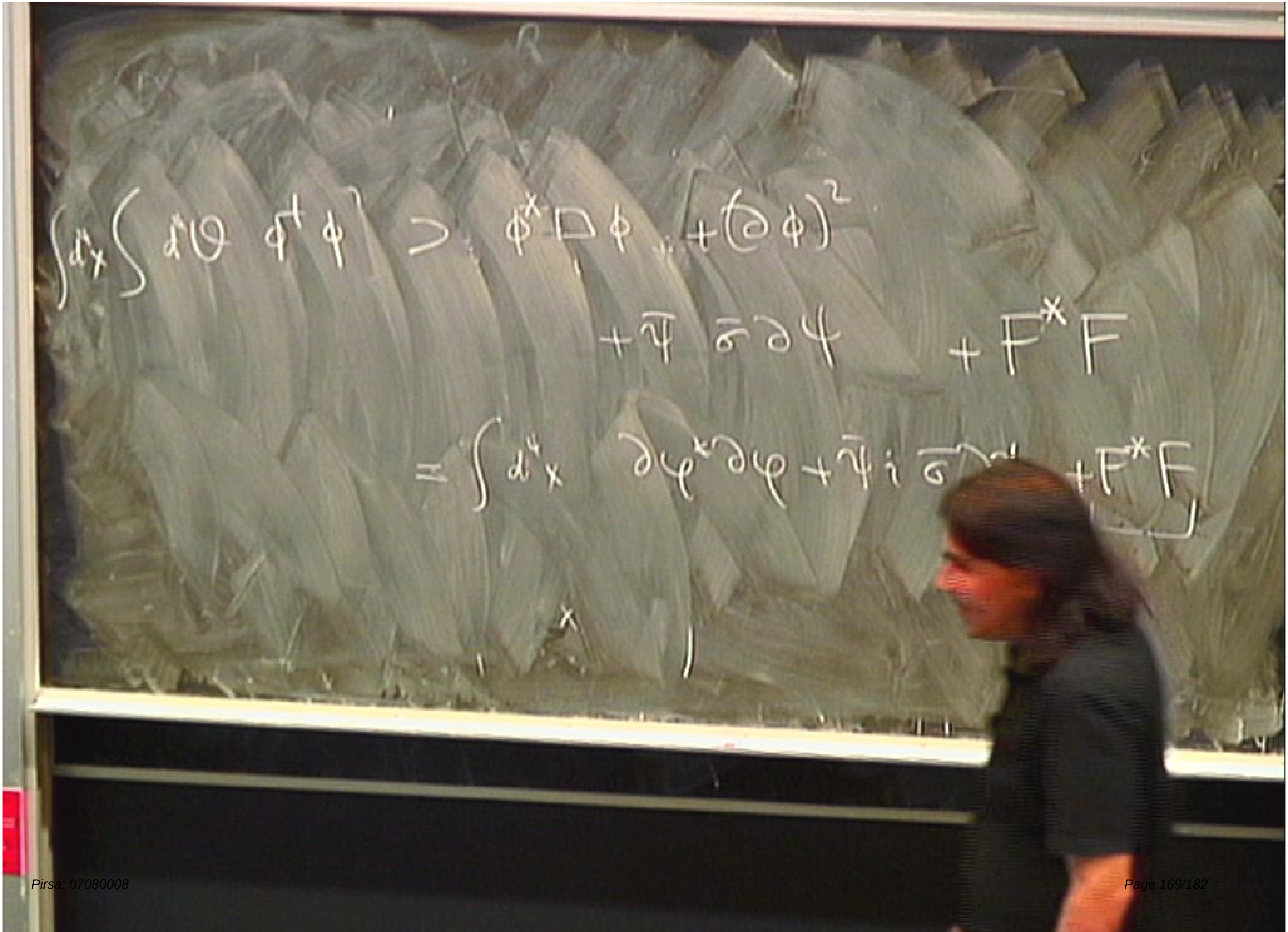
$$\phi(x,\theta,\bar\theta) = \varphi(x + i\theta\sigma\bar\theta) + \sqrt{2}\,\theta\psi(x + i\theta\sigma\bar\theta) + \theta^2 F(x + i\theta\sigma\bar\theta)$$

$$= \varphi(x) + i\,\theta\sigma\bar\theta\,\partial\phi + \Box\phi\,\theta^2\bar\theta^2 + \sqrt{2}\,\theta\psi(x) + \sqrt{2}\,\theta\,\theta\sigma\bar\theta\,\partial\psi + \theta^2 F(x)$$

$$\int d^4\theta \; \phi^\dagger \phi \supset \phi^* \Box \phi$$

$$\int d^4\theta \; \phi^\dagger \phi \supset \phi^* \Box \phi + (\partial \phi)^2$$

$$+ \bar{\psi} \, \bar{\sigma} \partial \psi \qquad + F^* F$$


$\int d^4x \int d^4\theta \; \Phi^\dagger \Phi \supset \phi^* \Box \phi + (\partial\phi)^2$
$+ \bar\psi \; \bar\sigma \partial \psi \qquad + F^* F$
$= \int d^4x \;\; \partial\varphi^* \partial\varphi + \bar\psi \, i \, \bar\sigma \qquad + F^* F$

$$\int d^4x \int d^4\theta \; \phi^\dagger \phi \supset \phi^* \Box \phi + (\partial\phi)^2$$

$$+ \bar\psi \, \bar\sigma \partial \psi \qquad + F^* F$$

$$= \int d^4x \;\; \partial\varphi^* \partial\varphi + \bar\psi \, i \, \bar\sigma \partial \psi \;\; + F^* F$$

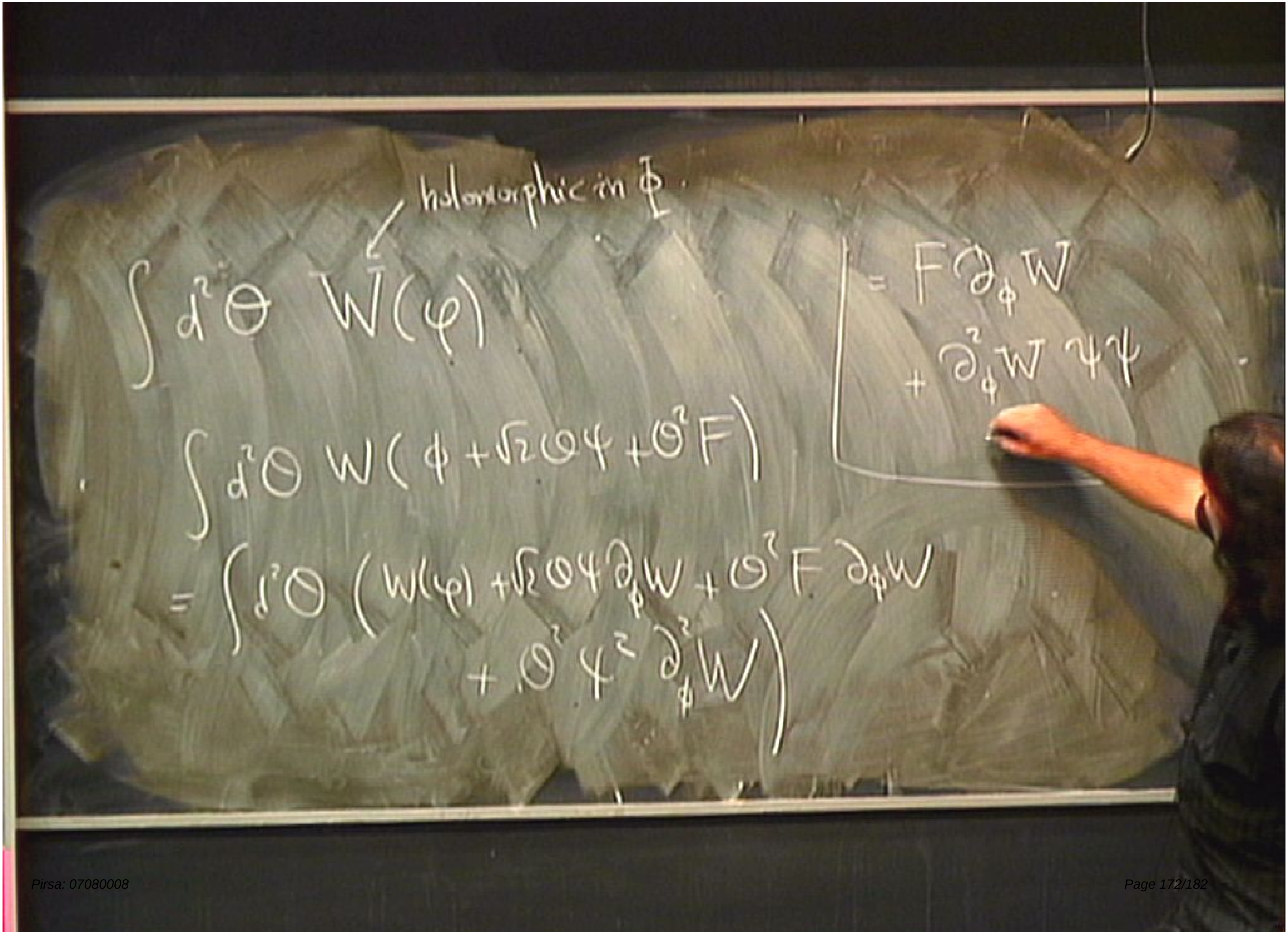
holomorphic in Φ

$$\int d^2\theta \; W(\varphi)$$

$$\int d^2\theta \; W(\phi + \sqrt{2}\,\theta\psi + \theta^2 F)$$

$$= \int d^2\theta \, \Big(W(\varphi) + \sqrt{2}\,\theta\psi\,\partial_\phi W + \theta^2 F\,\partial_\phi W$$

$$+ \, \theta^2 \psi^2 \, \partial_\phi^2 W$$


holomorphic in Φ
$\int d^2\theta \; W(\varphi)$
$= F \partial_\phi W$
$+ \partial_\phi^2 W \psi\psi$
$\int d^2\theta \; W(\phi + \sqrt{2}\theta\psi + \theta^2 F)$
$= \int d^2\theta \left(W(\varphi) + \sqrt{2}\theta\psi \partial_\phi W + \theta^2 F \partial_\phi W \right.$
$\left. + \theta^2 \psi^2 \partial_\phi^2 W \right)$

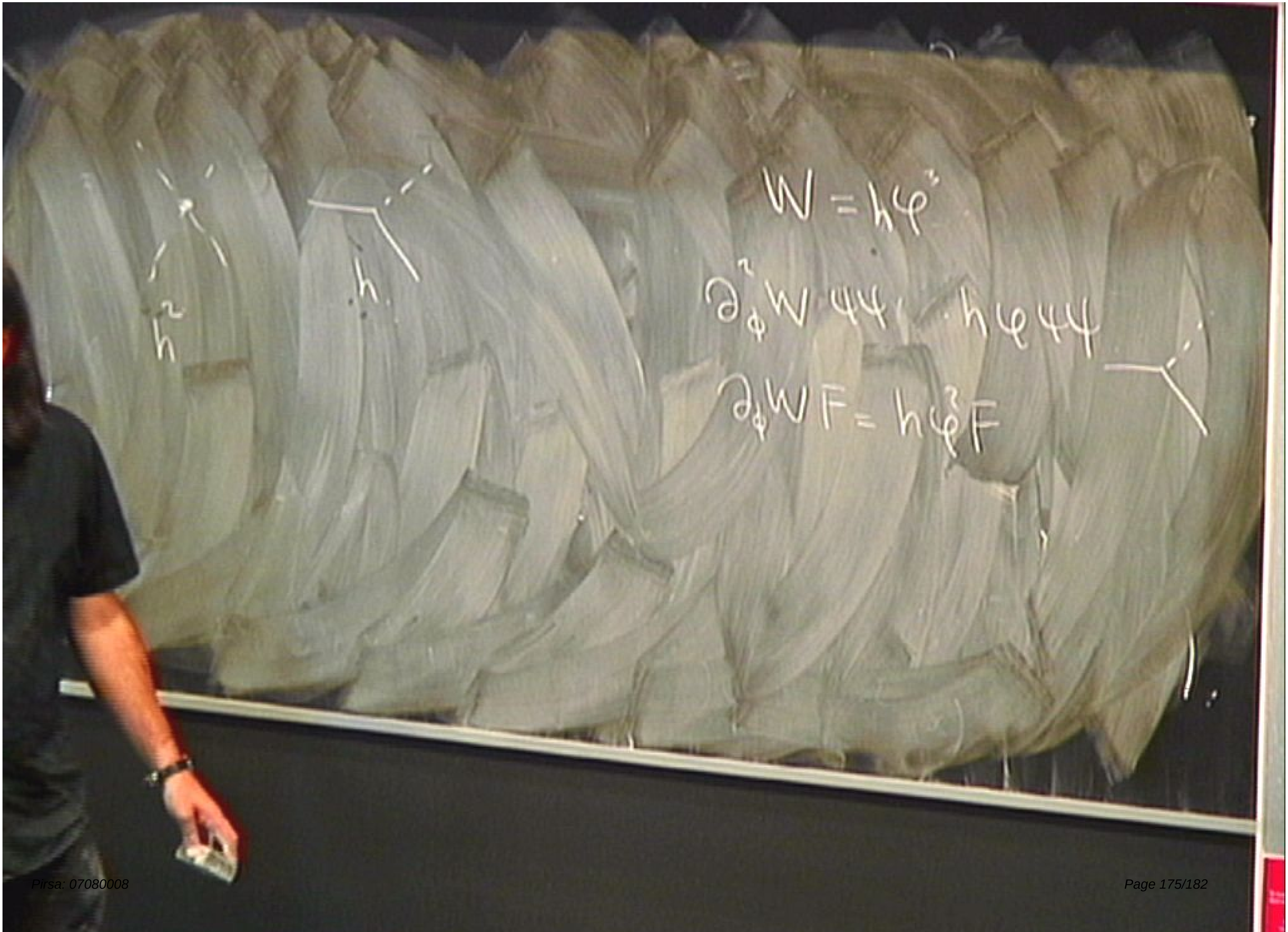
holomorphic in Φ

$$\int d^2\theta \; W(\varphi)$$

$$\int d^2\theta \; W(\phi + \sqrt{2}\,\theta\psi + \theta^2 F)$$

$$= \int d^2\theta \left(W(\varphi) + \sqrt{2}\,\theta\psi\,\partial_\phi W + \theta^2 F\,\partial_\phi W + \theta^2 \psi^2 \partial_\phi^2 W \right)$$

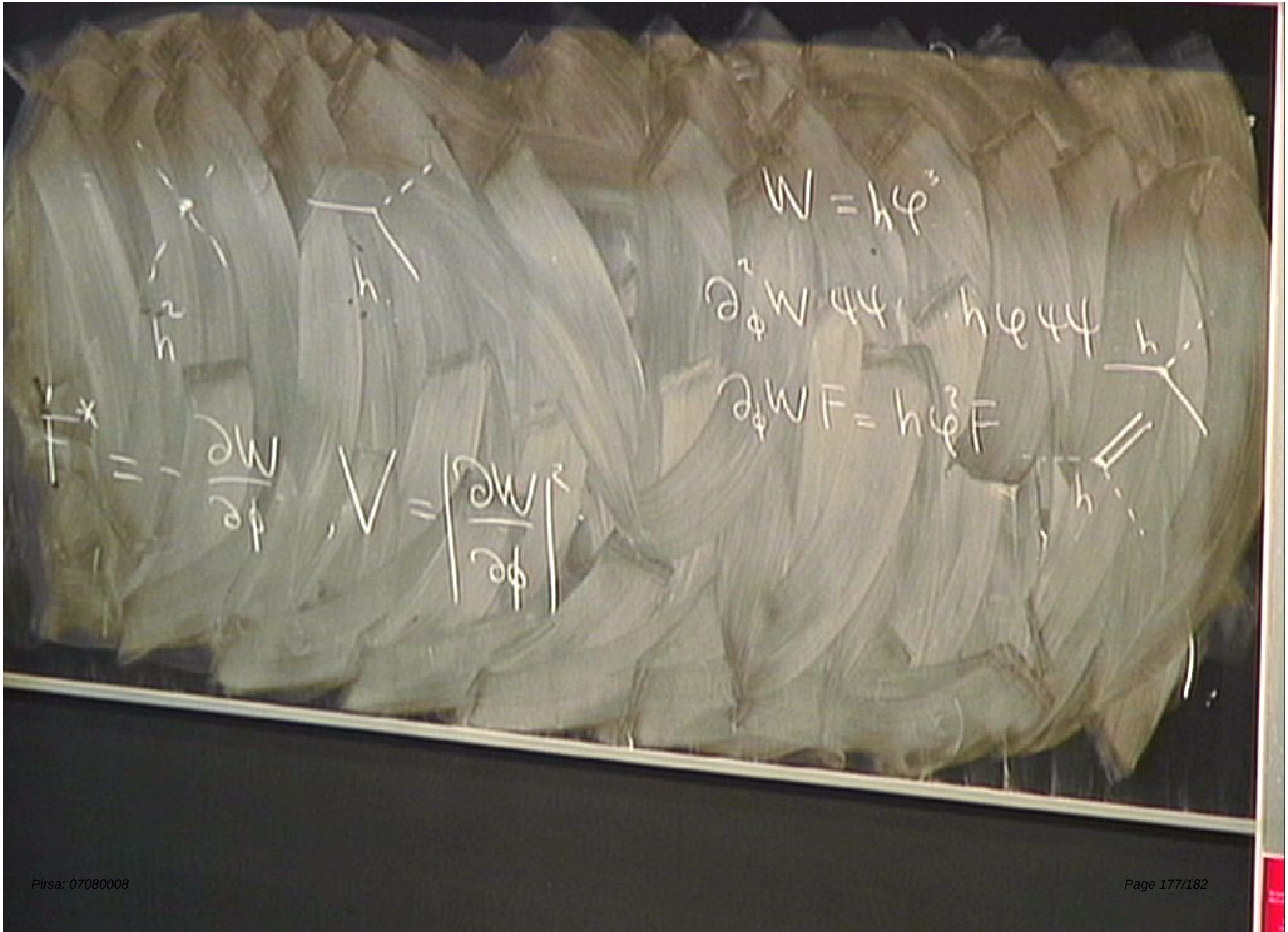
$$= F\partial_\phi W + \partial_\phi^2 W \,\psi\psi$$

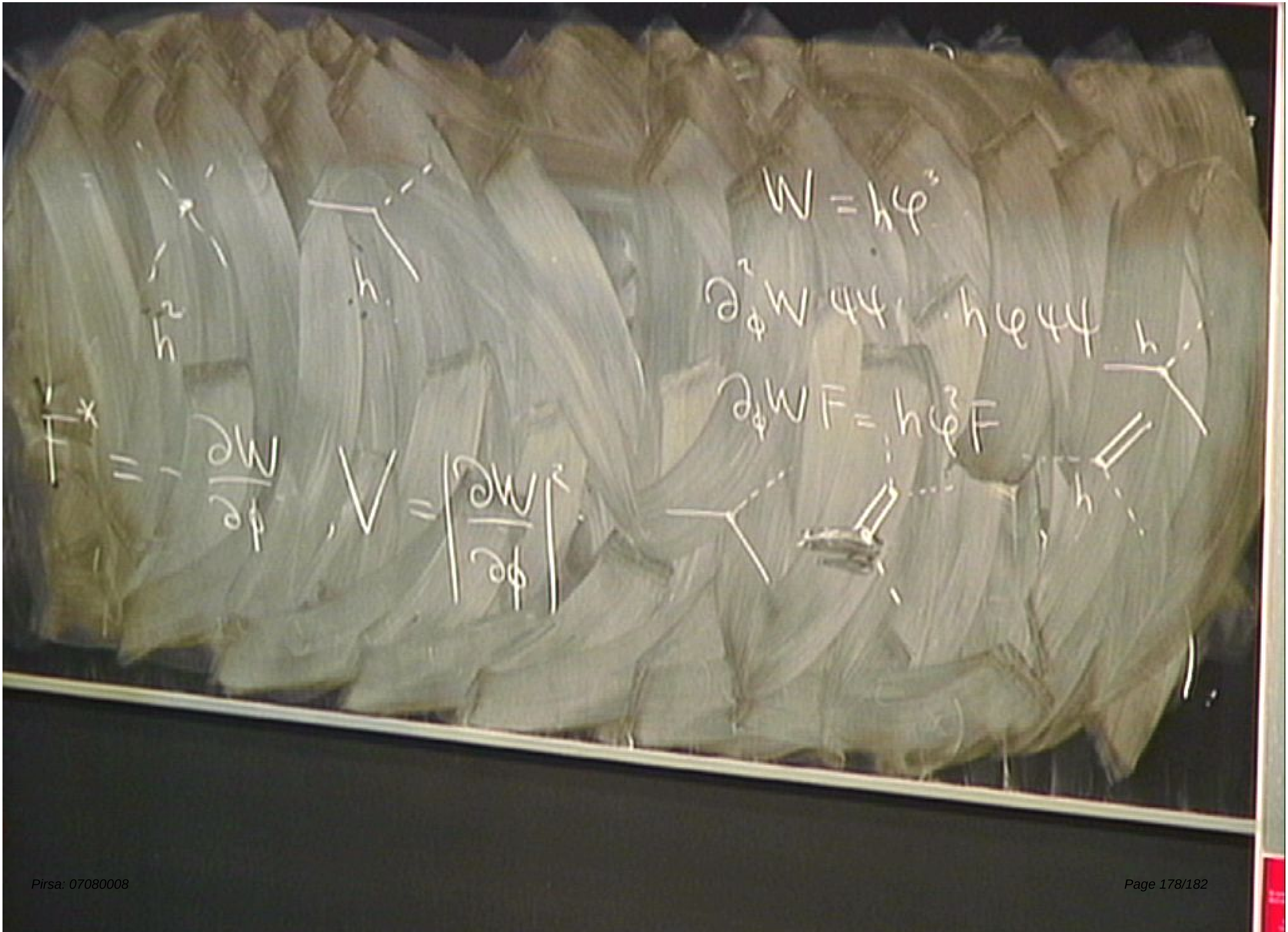

h²
h
W = hφ³
∂²φ W ψψ · hφψψ
∂φ W F = hφ² F

$$W = h\varphi^3$$

$$\partial_\phi^2 W \psi\psi = h\varphi\psi\psi$$

$$\partial_\phi W F = h\varphi^2 F$$


$W = h\varphi^3$
$\partial_\phi^2 W \psi\psi = h\varphi\psi\psi$
$\partial_\phi W F = h\varphi^2 F$
$F^* = -\frac{\partial W}{\partial \phi}$
$V = \left|\frac{\partial W}{\partial \phi}\right|^2$
h^2
h



W = hφ³
∂²_φ W ψψ = hφψψ
∂_φ W F = hφ² F
F* = − ∂W/∂φ
V = |∂W/∂φ|²
h
h²

$$F^* = -\frac{\partial W}{\partial \phi}$$

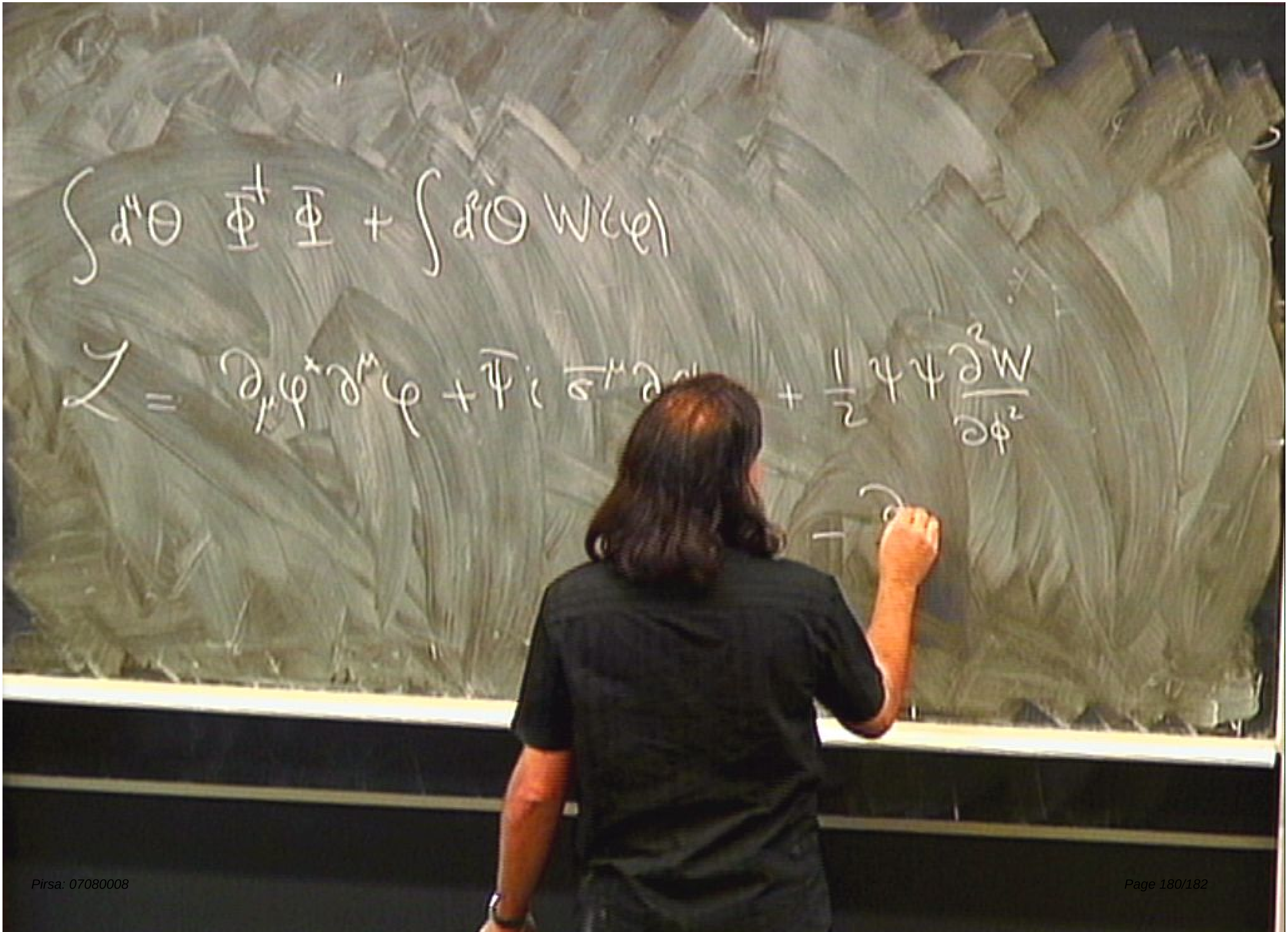
$$V = \left|\frac{\partial W}{\partial \phi}\right|^2$$

$$W = h\varphi^3$$

$$\partial_\phi^2 W \psi\psi \quad h\varphi\psi\psi$$

$$\partial_\phi W F = h\varphi^2 F$$

h^2 h h h


$\int d^4\theta\ \Phi^\dagger \Phi + \int d^2\theta\ W(\varphi)$
$\mathcal{L} = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi} i \bar{\sigma}^\mu \partial$
$+ \frac{1}{2} \psi \psi \frac{\partial^2 W}{\partial \phi^2}$

$$\int d^4\theta \, \Phi^\dagger \Phi + \int d^2\theta \, W(\varphi)$$

$$\mathcal{L} = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi} i \bar{\sigma}^\mu \partial_\mu \psi + \frac{1}{2} \psi \psi \frac{\partial^2 W}{\partial \phi^2} - \left| \frac{\partial W}{\partial \phi} \right|^2$$

$$\int d^4\theta \, \Phi^\dagger \Phi + \int d^2\theta \, W(\varphi)$$

$$\mathcal{L} = \partial_\mu \varphi^* \partial^\mu \varphi + \bar{\psi} i \bar{\sigma}^\mu \partial_\mu \psi + \frac{1}{2} \psi \psi \frac{\partial^2 W}{\partial \phi^2} - \left| \frac{\partial W}{\partial \phi} \right|^2$$