Title: Superstring Cosmology Mini-course: Part 2

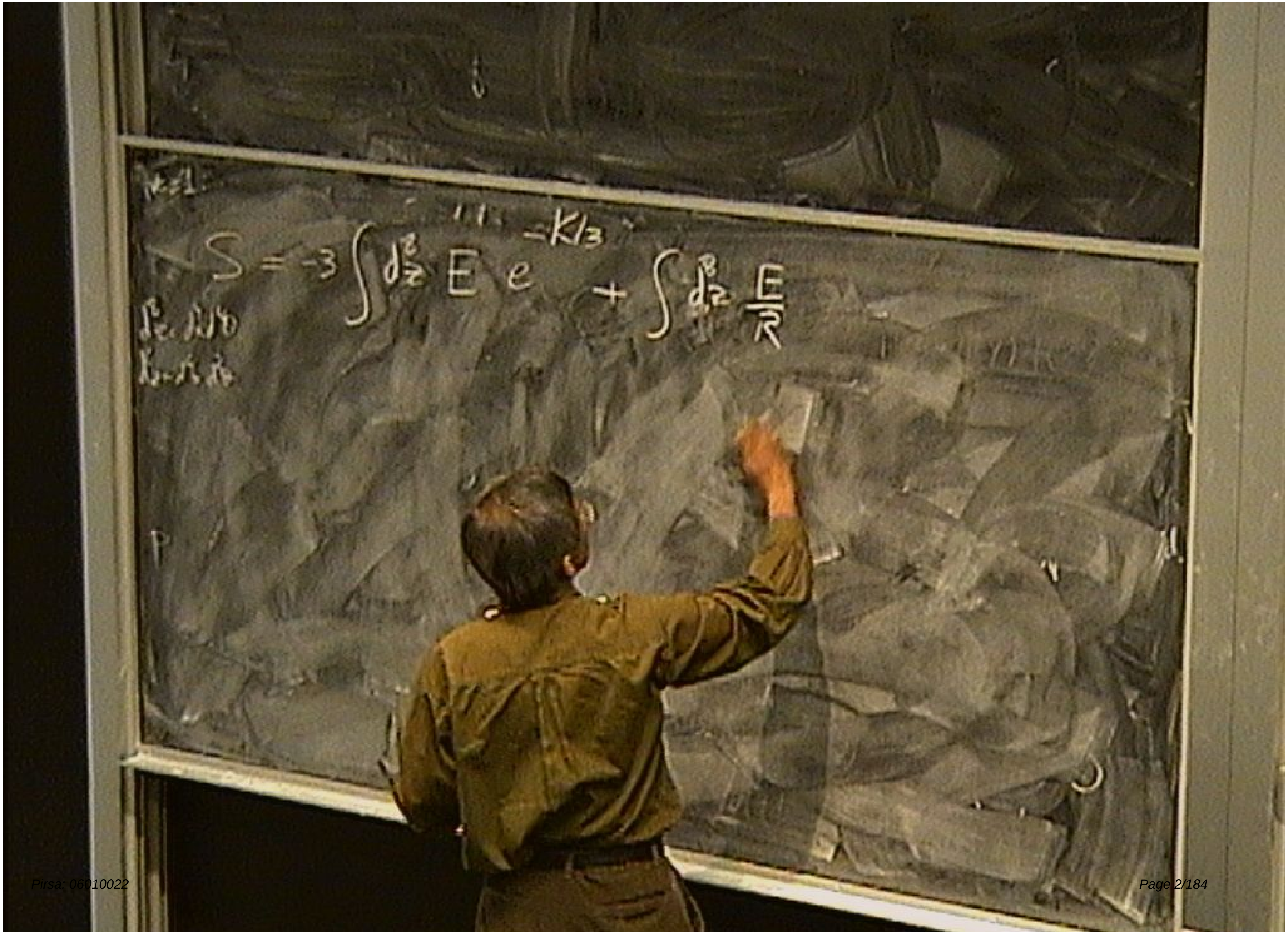
Date: Jan 31, 2006 11:00 AM

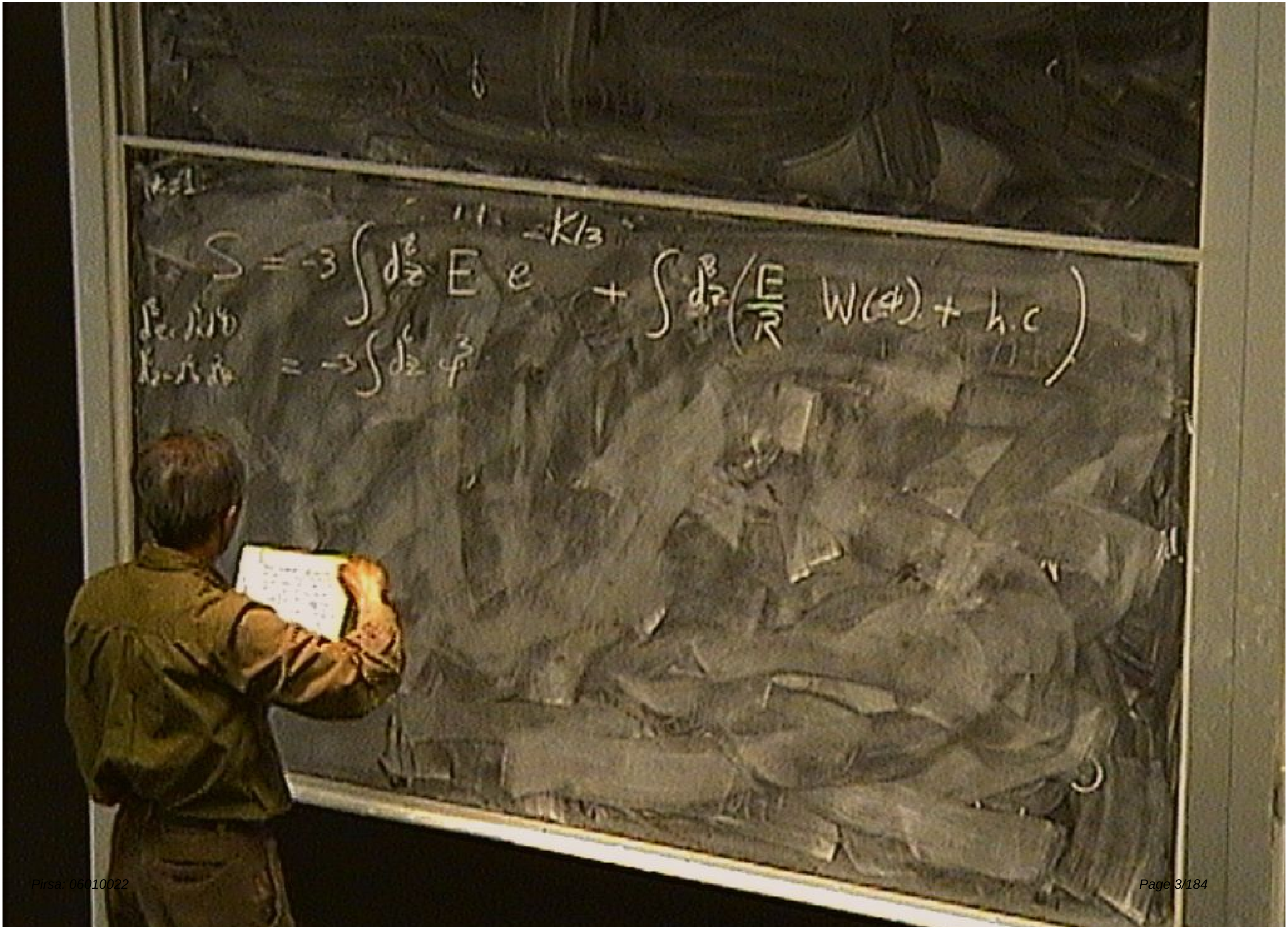
URL: http://pirsa.org/06010022

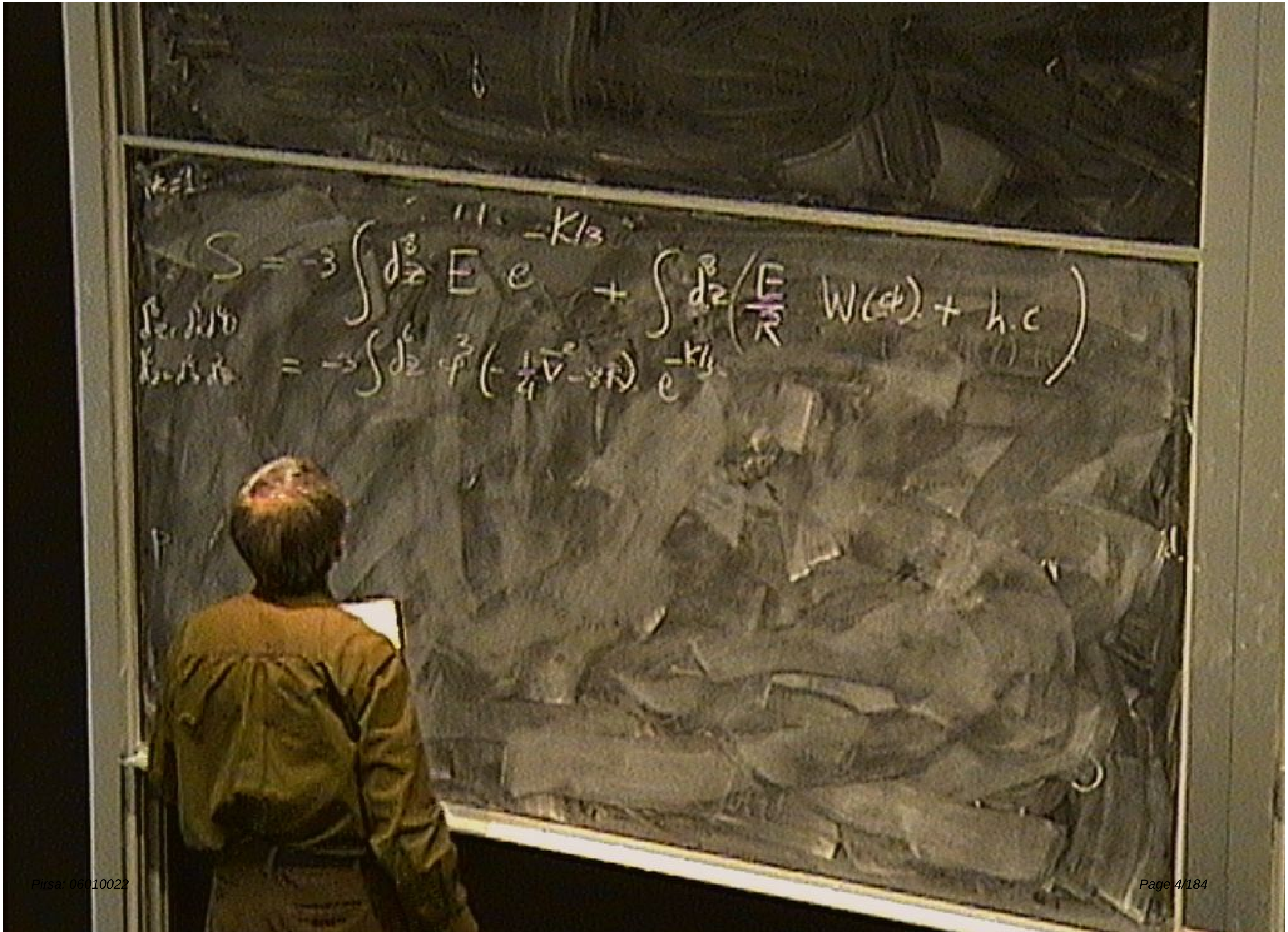
Abstract: From Monday, January 30th to Thursday, February 2nd, Senarath (Shanta) de Alwis will give a four lecture mini-course on `Potentials for light moduli in N=1 supergravity and string theory'. In these lectures, Shanta will be describing some of the technical ingredients used in recent constructions of inflation in string theory. The lectures will be given at a level appropriate for advanced graduate students and will be held in the Bob Room at 11:00am each day.

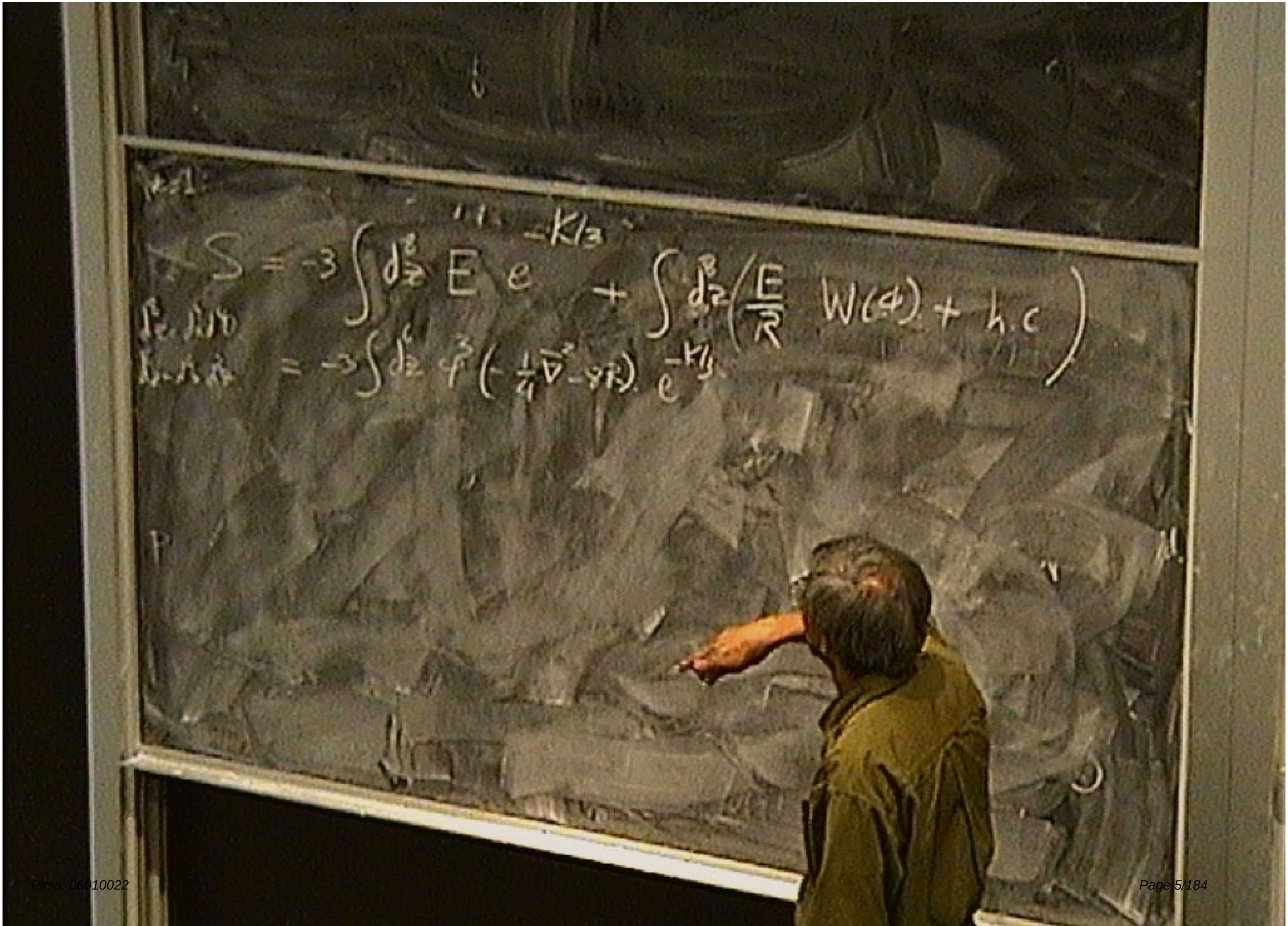
The topics to be covered include:
Derivation of the potential for chiral scalars in N=1 supergravity;
Weyl anomalies and the generation of non-perturbative terms in the superpotential;
Derivation of moduli potentials from fluxes in type IIB and heterotic string theory;
Derivation of potentials for light moduli by integrating out heavy moduli.

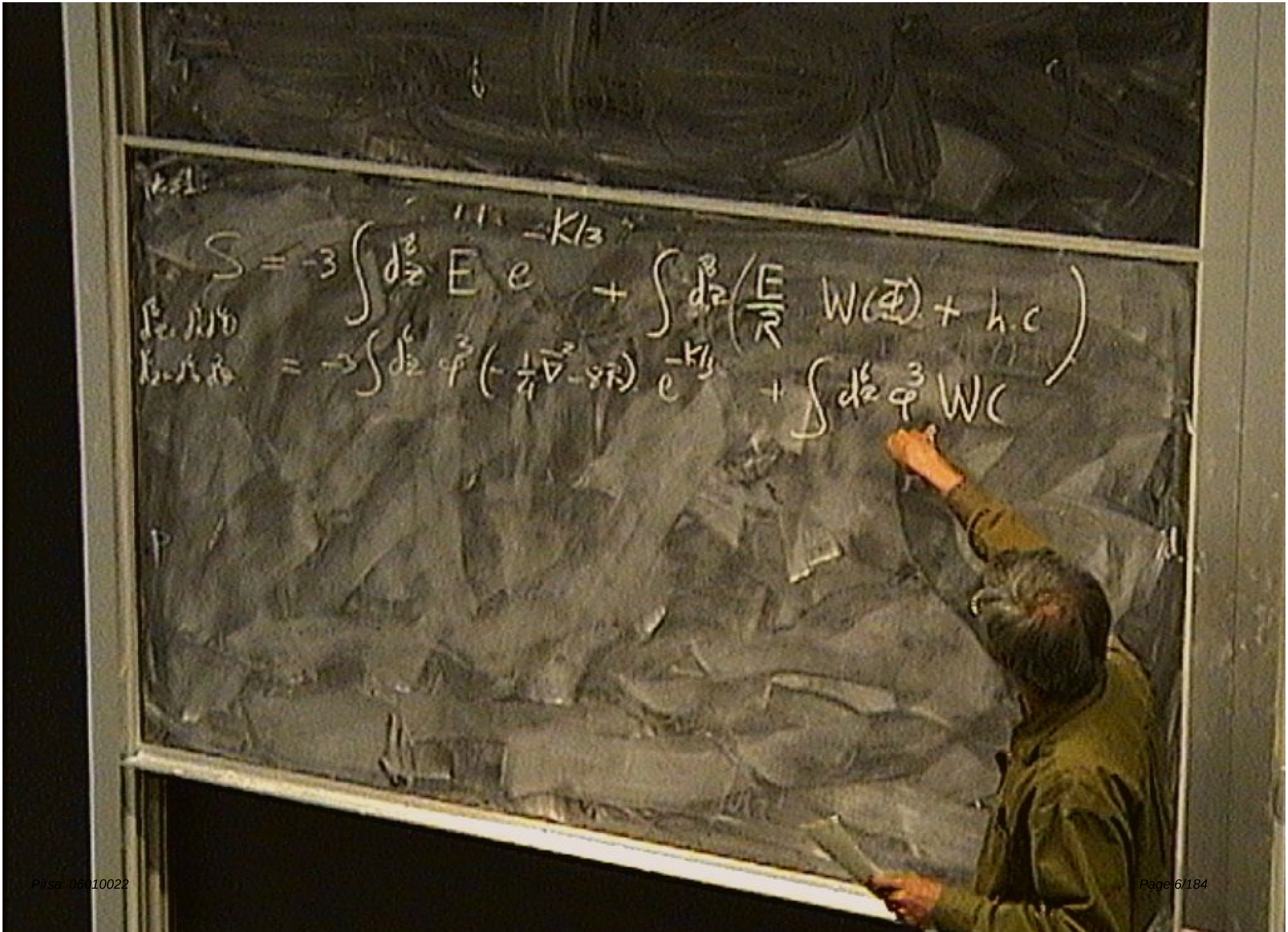
Shanta is a faculty member in the Physics Department at the University of Colorado, Boulder who is spending his sabbatical year here at Perimeter.


$S = -3\int d^3z\, E\, e^{-K/3} + \int d^3z\, \frac{E}{R}$


S = -3 ∫ d^8z E e^{-K/3} + ∫ d^6z (E/R W(φ) + h.c)
= -3 ∫ d^8z φ^3



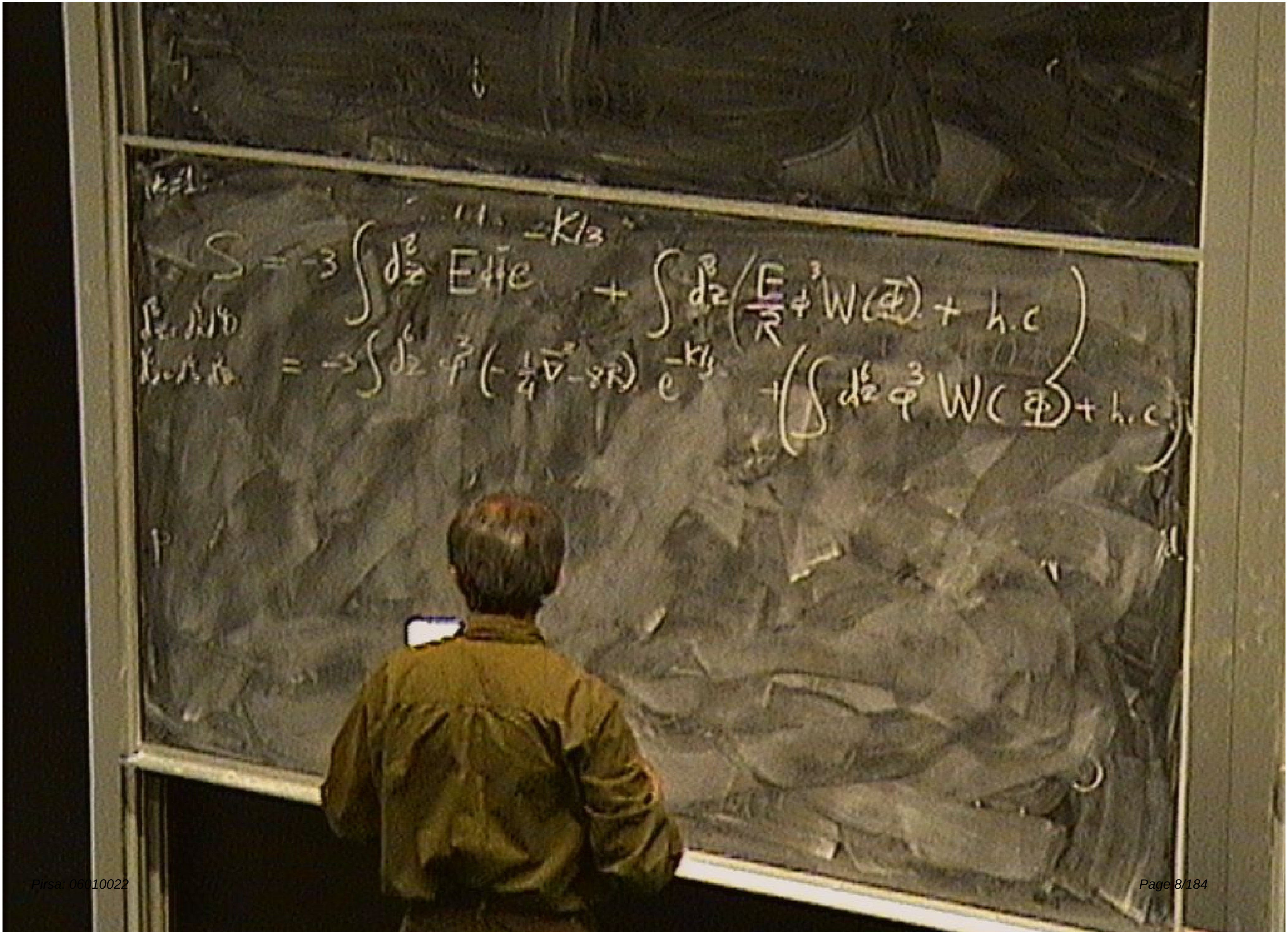


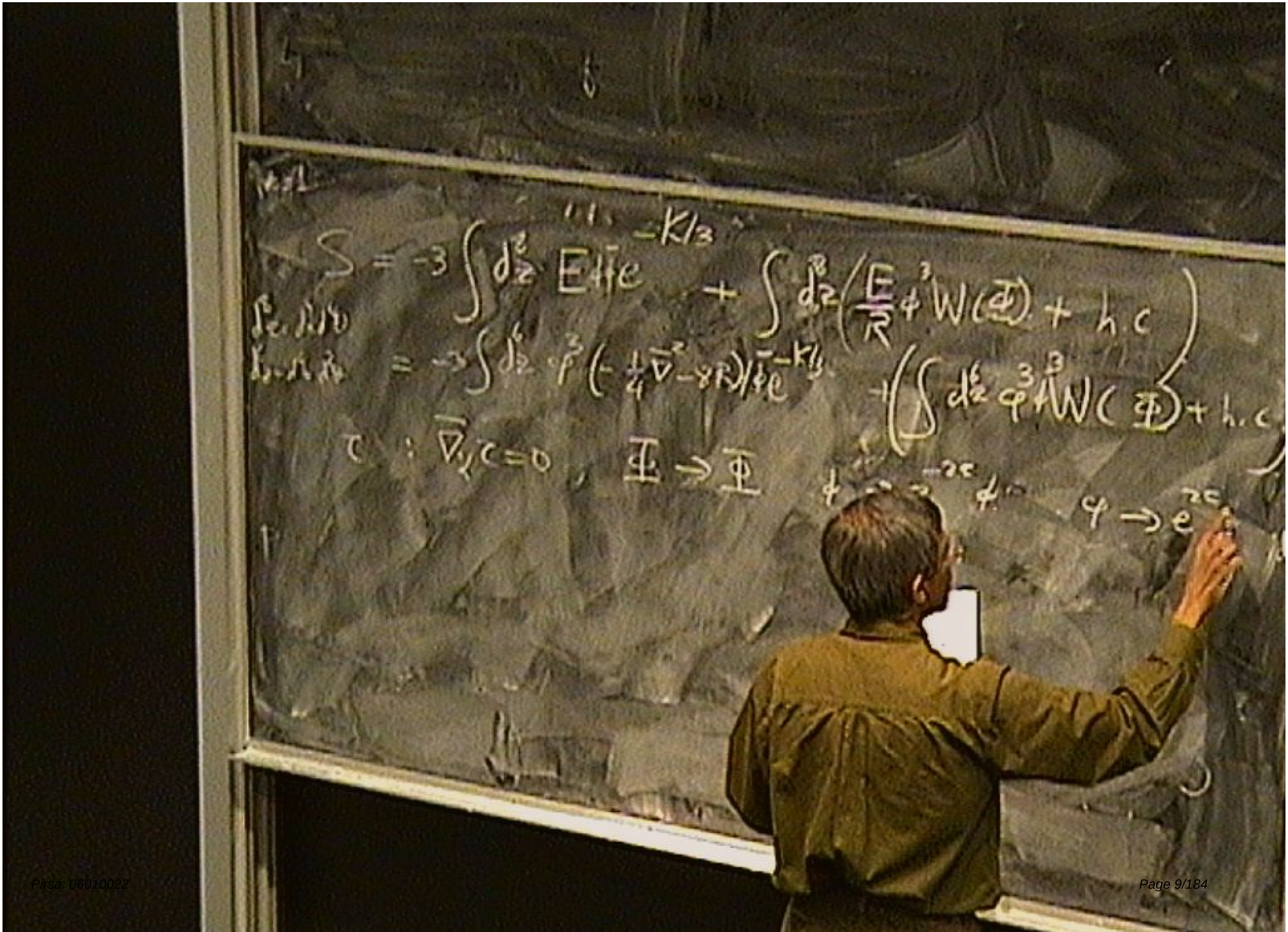


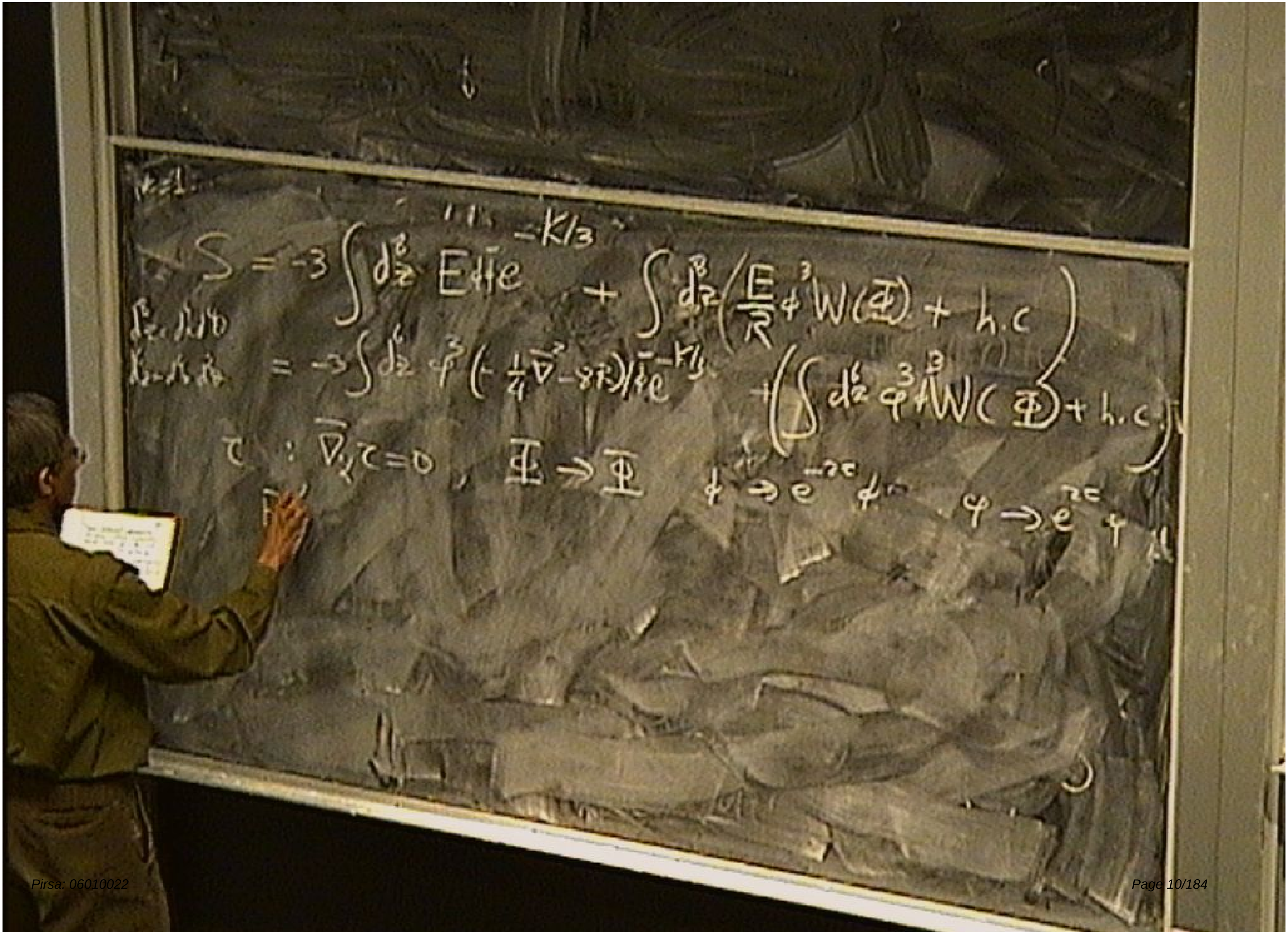
$S = -3\int d^8z\, E\, e^{-K/3} + \int d^6z \left(\frac{E}{R} W(\Phi) + h.c.\right)$
$= -3\int d^8z\, \bar{\varphi}^3 \left(-\frac{1}{4}\bar{\nabla}^2 - 8R\right) e^{-K/3} + \int d^6z\, \varphi^3 W($

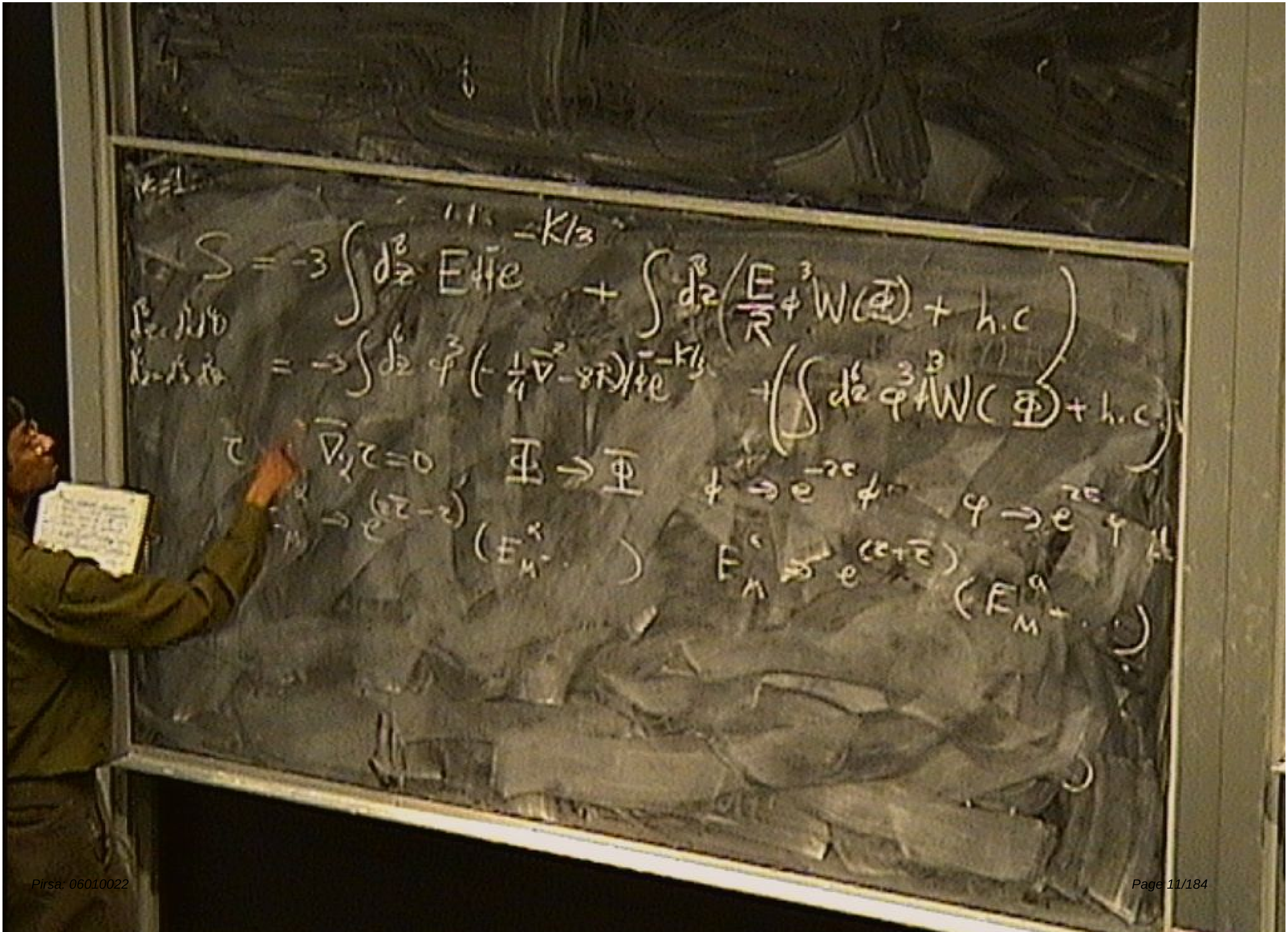
$$S = -3\int d^8z\, E\, e^{-K/3} + \int d^6z \left(\frac{E}{R}\, W(\Phi) + h.c. \right)$$

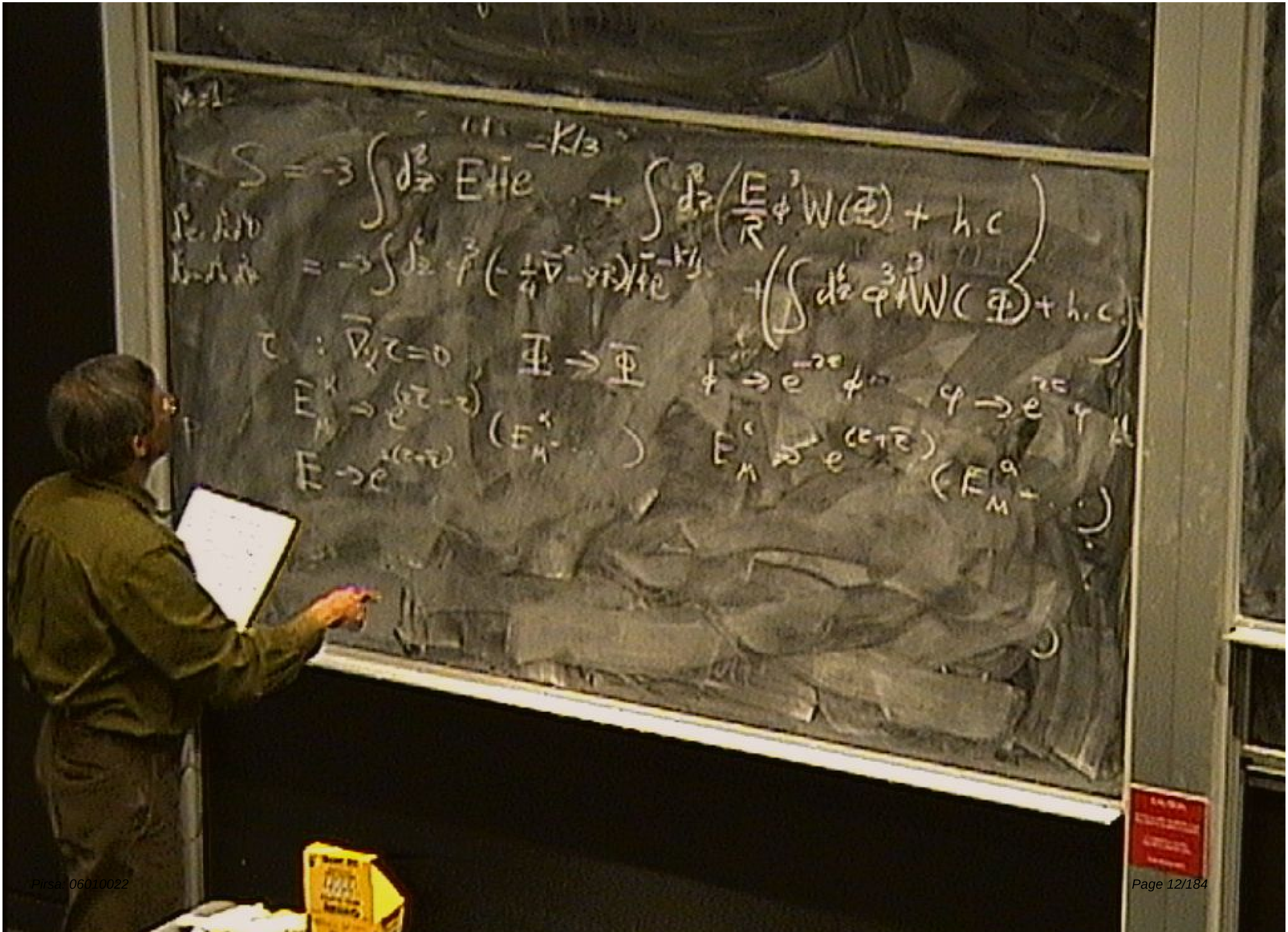
$$= -3\int d^6z\, \varphi^3 \left(-\tfrac{1}{4}\bar{\nabla}^2 - 8R \right) e^{-K/3} + \left(\int d^6z\, \varphi^3\, W(\Phi) + h.c. \right)$$

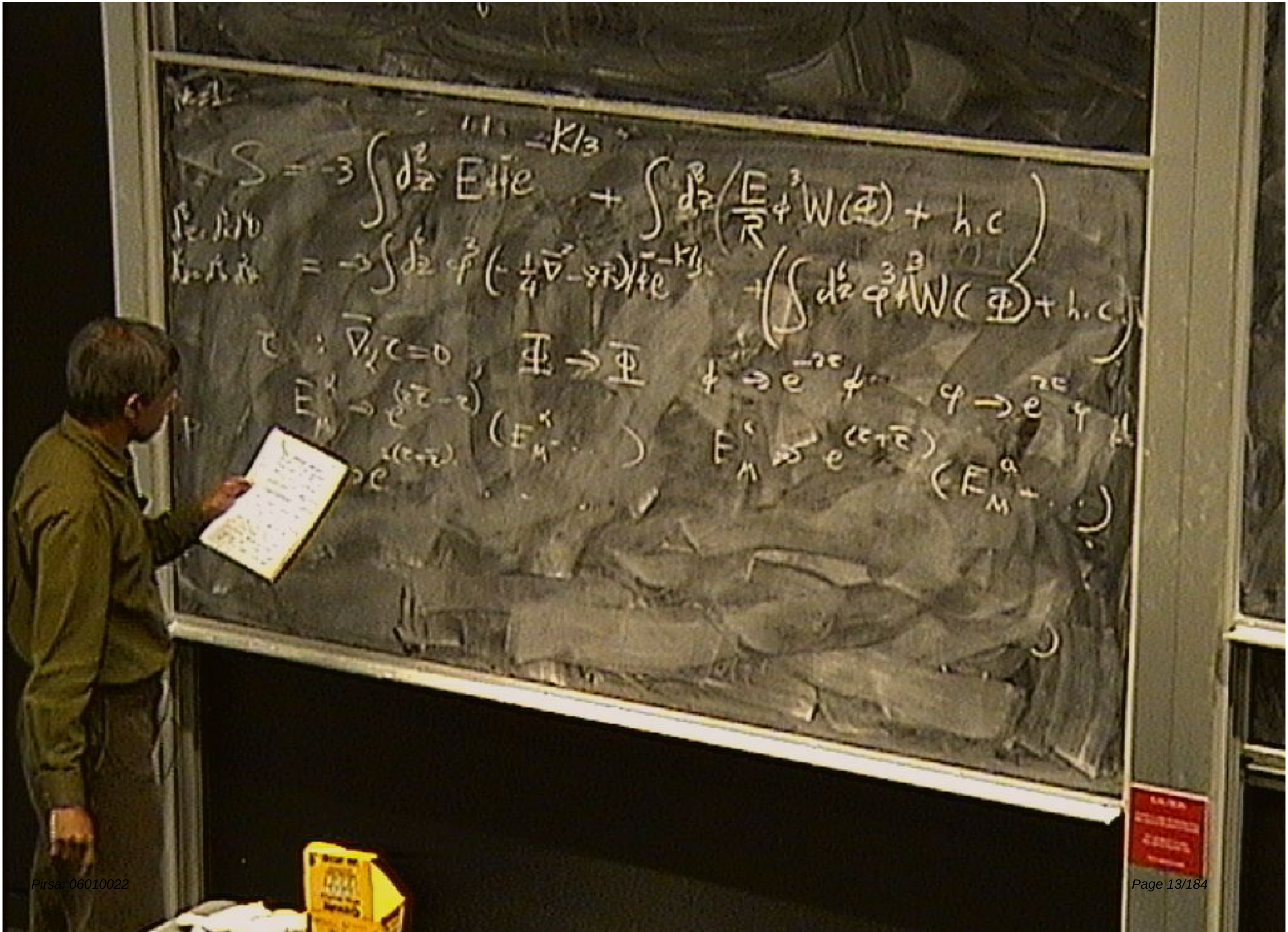


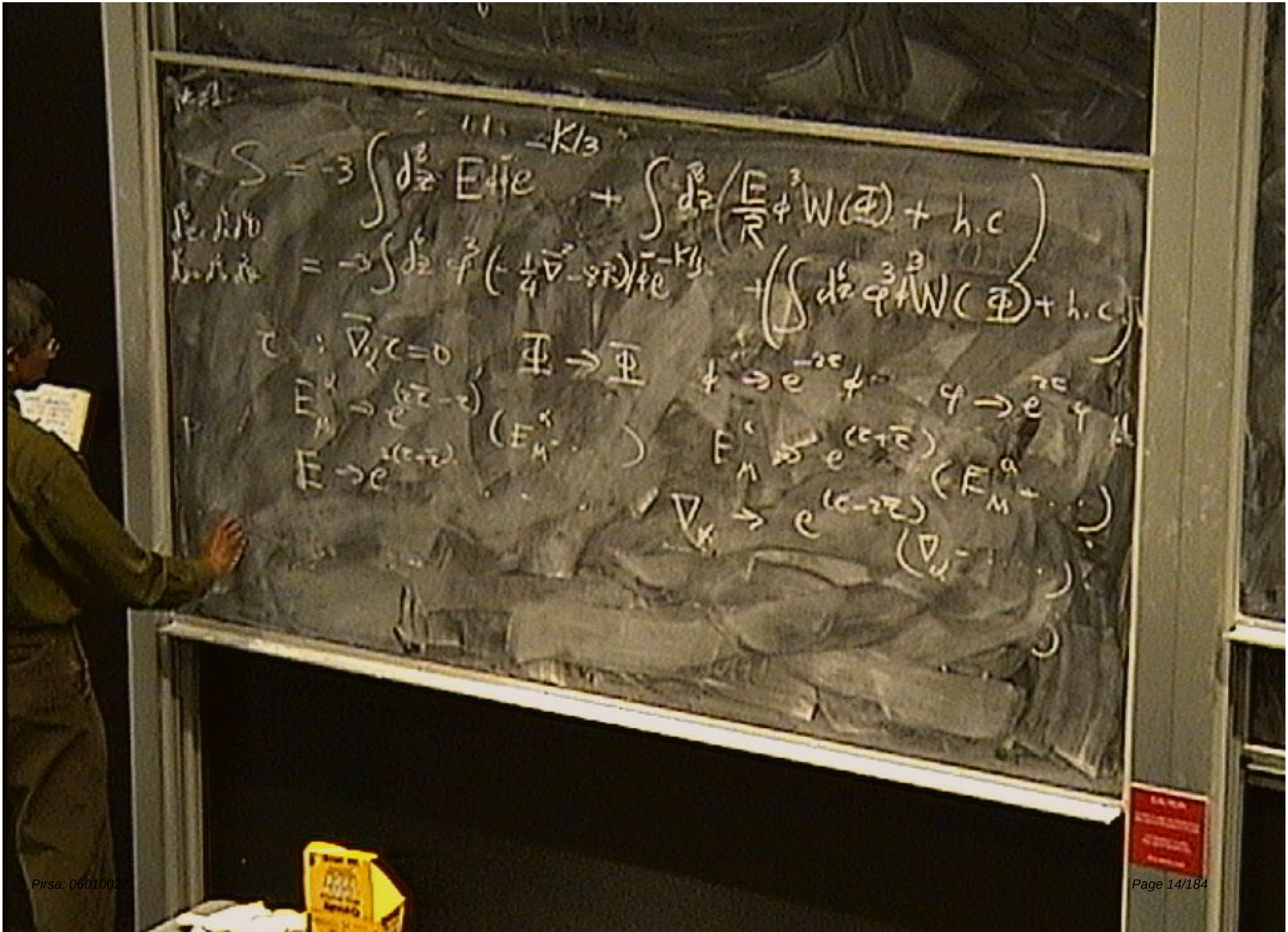




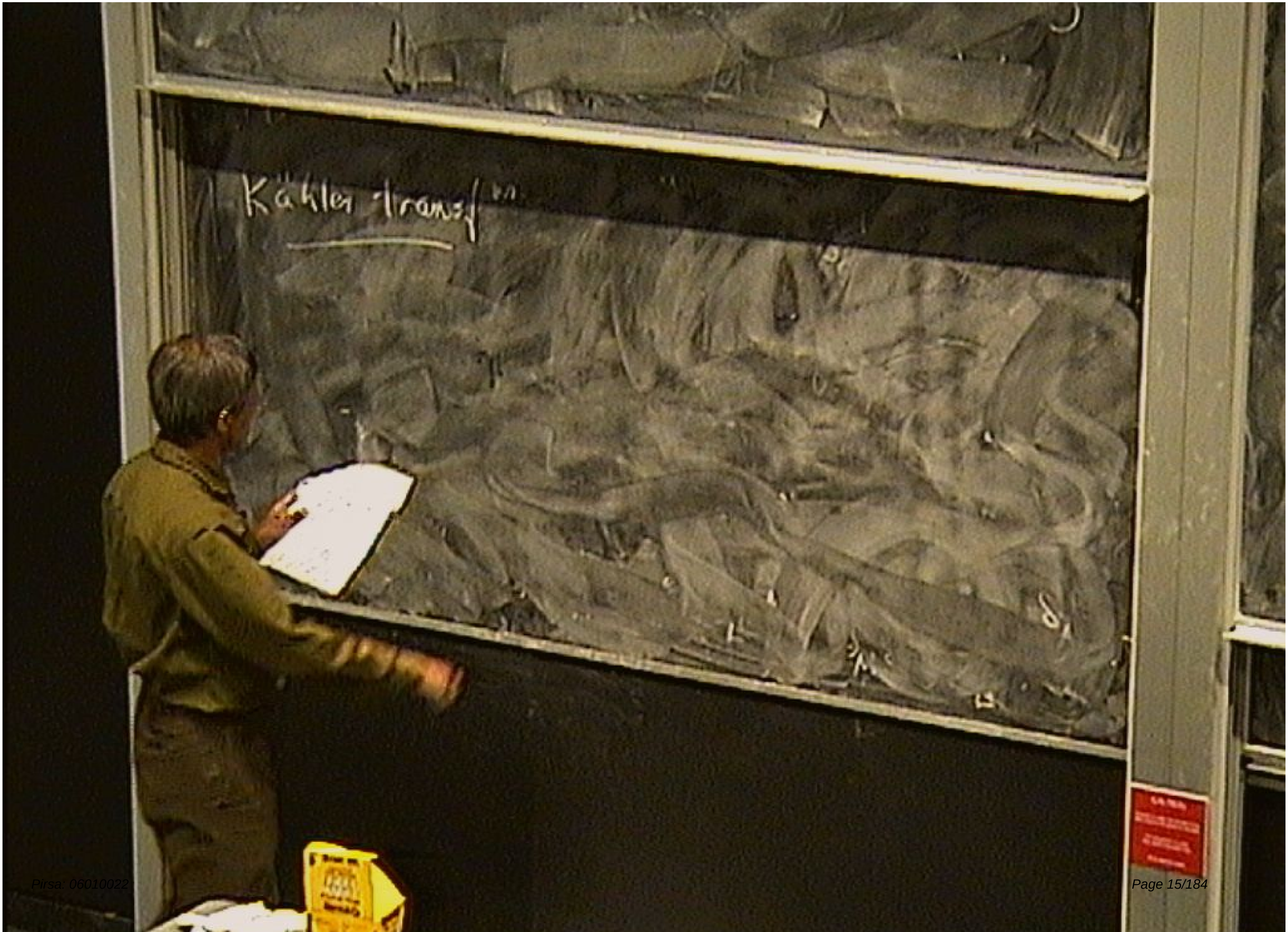


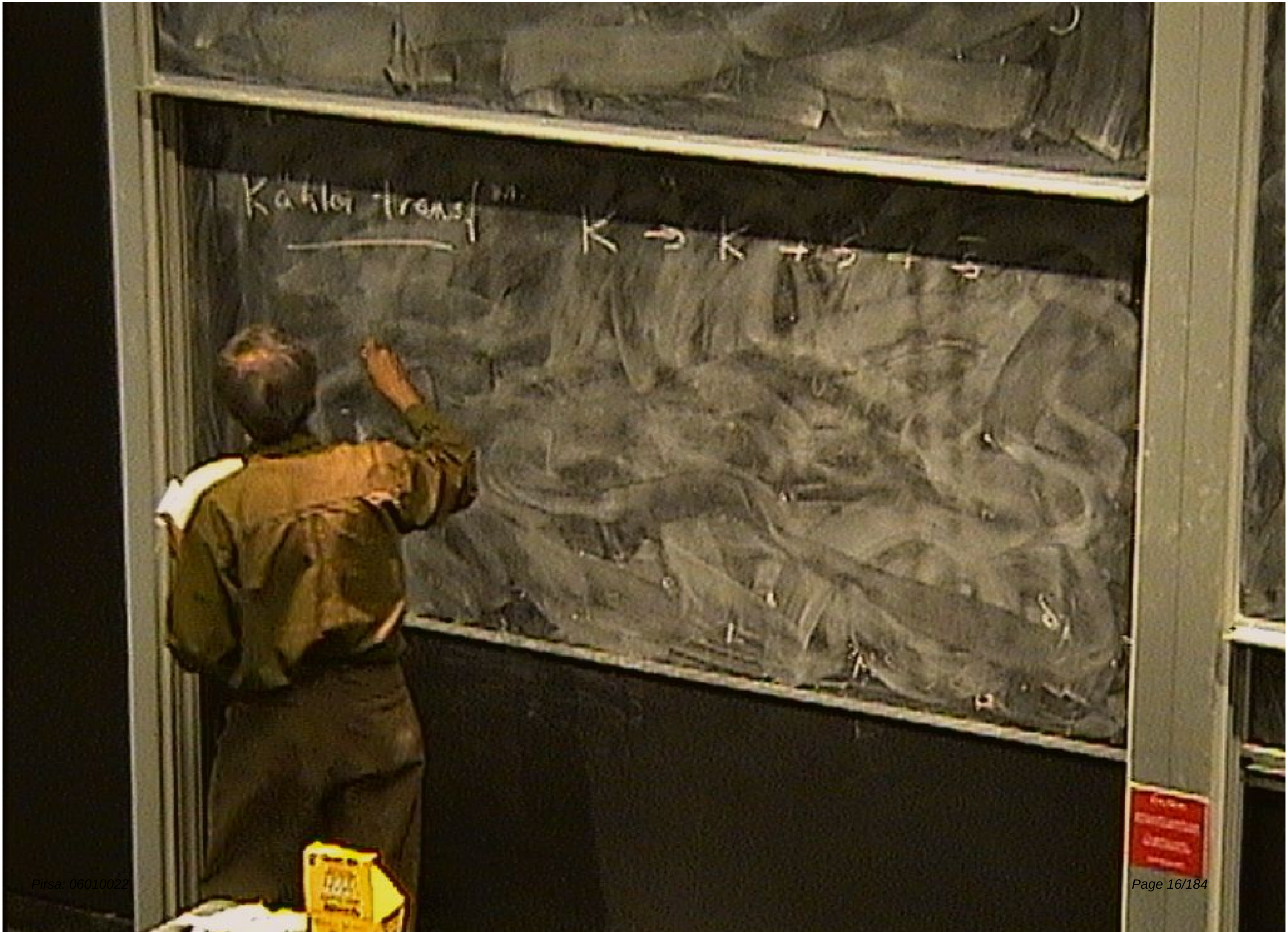


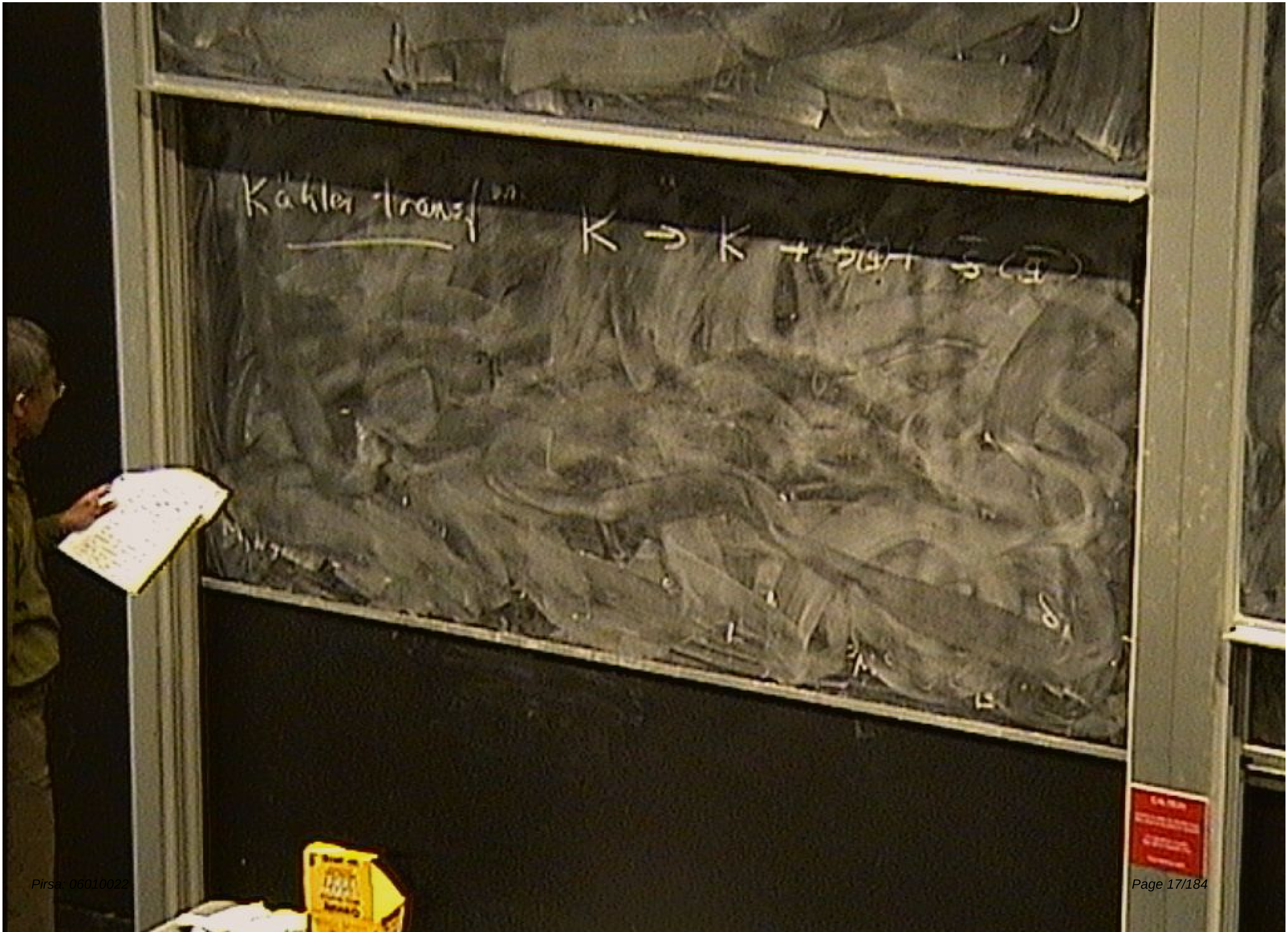




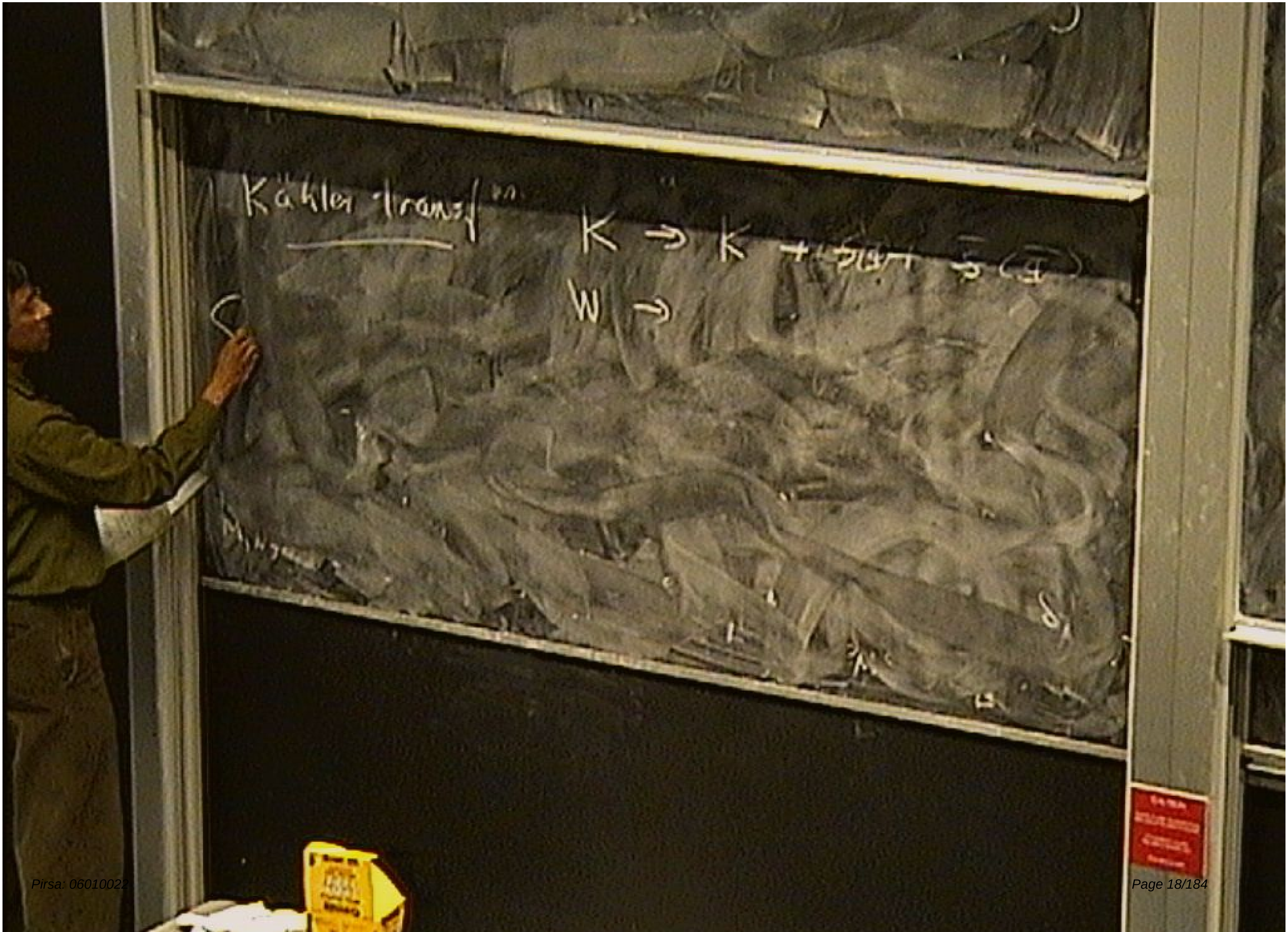
S = -3 ∫ d^8 z E ϕ ϕ̄ e^{-K/3} + ∫ d^6 z (E/R ϕ^3 W(Φ) + h.c)
Φ → Φ
ϕ → e^{-2τ} ϕ
E → e^{2(τ+τ̄)}
∇ → e^{(τ-2τ̄)} (∇ - ...)

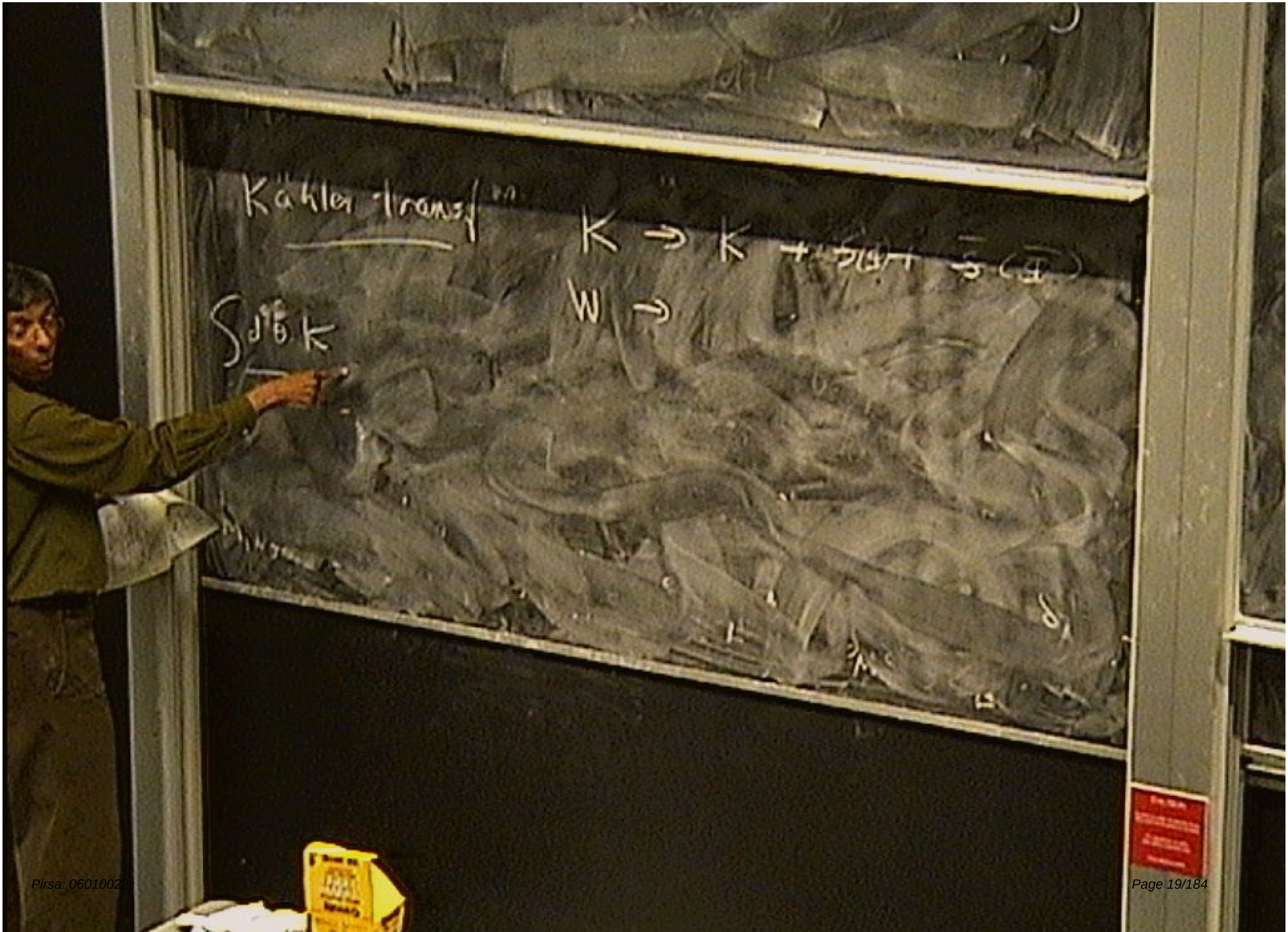

Kähler transf'n

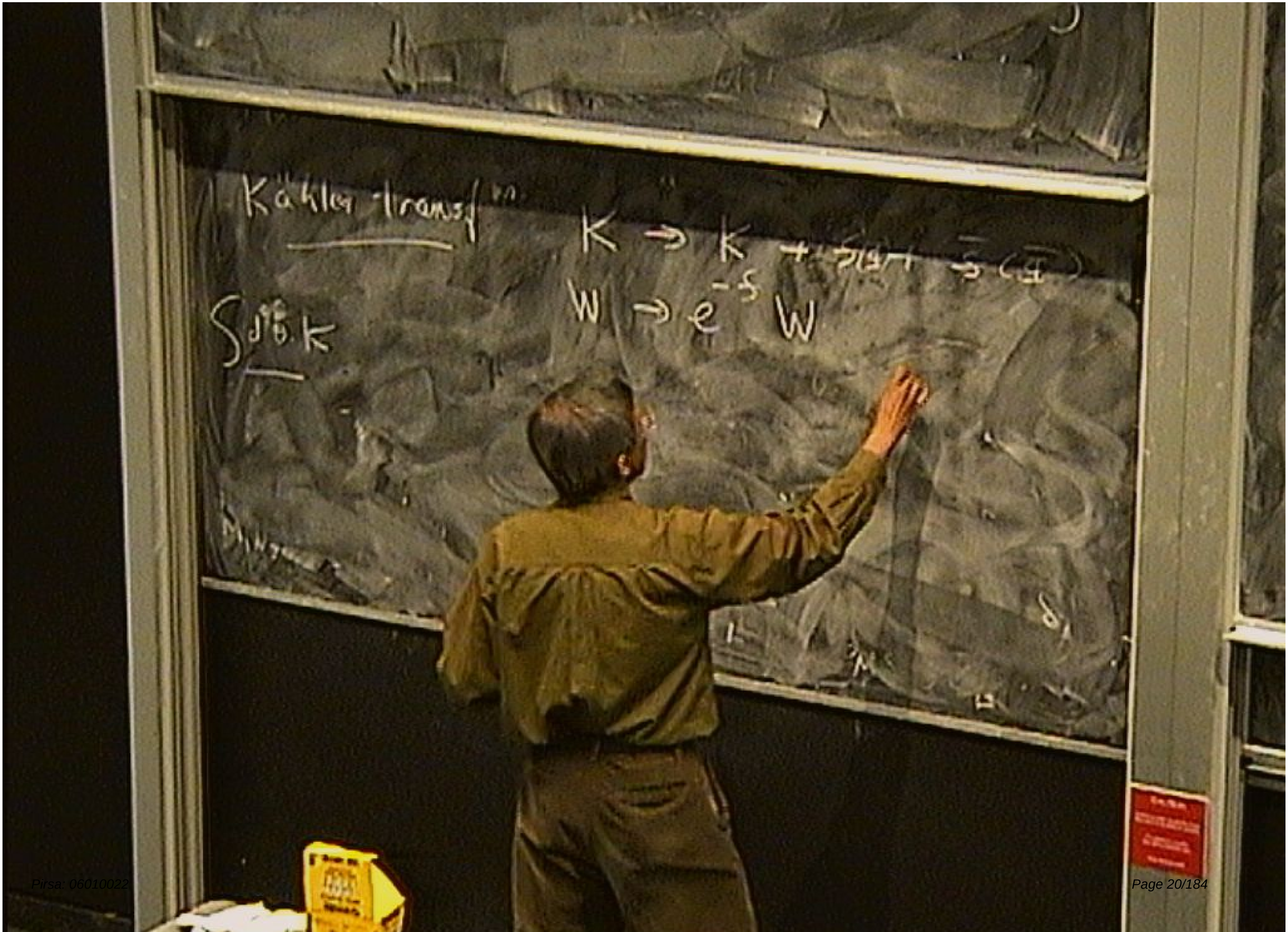

Kahler transf
K → K + f + f̄

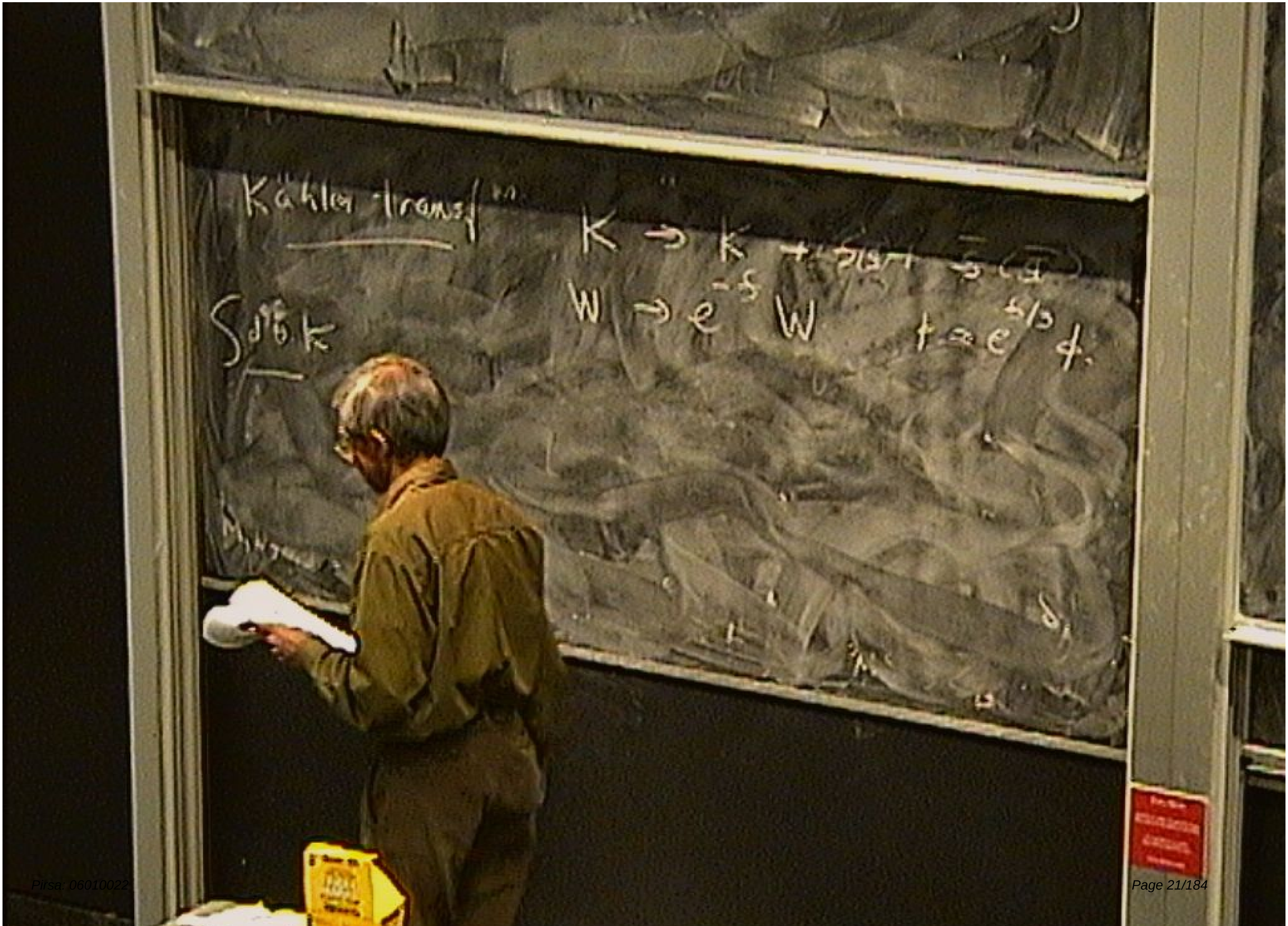


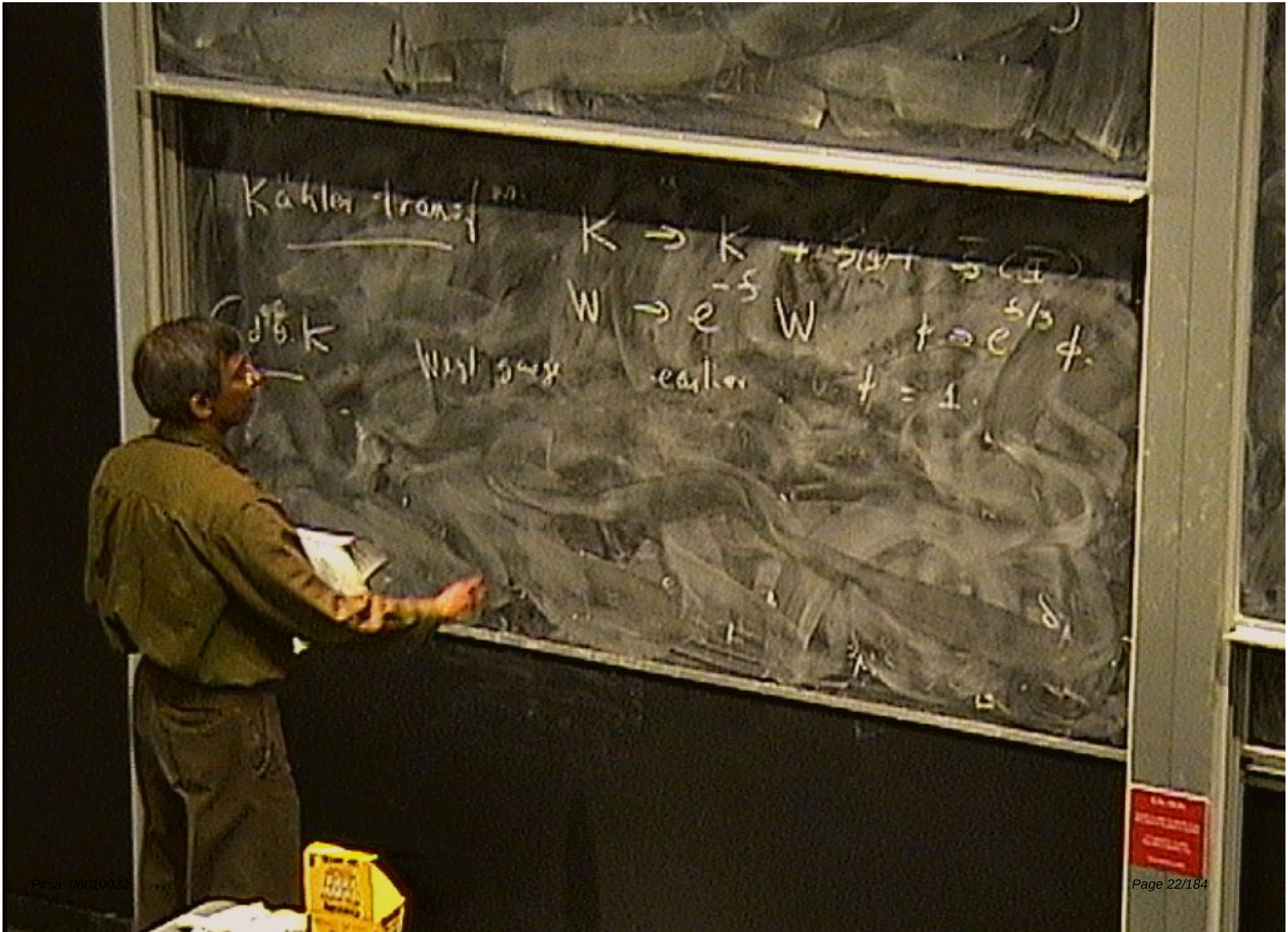
Kähler transf^n
K → K

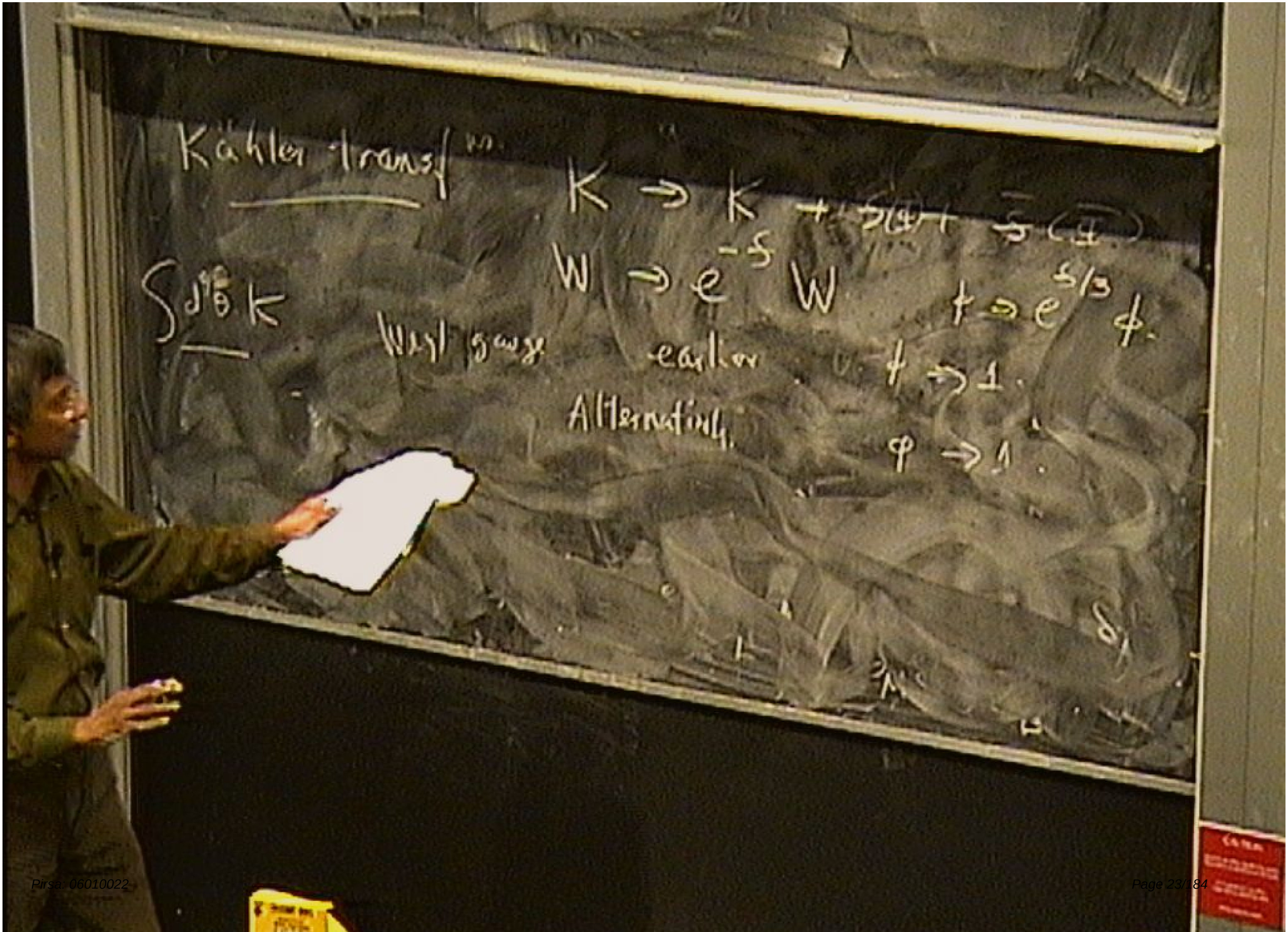

Kähler transf^n
K → K
W →

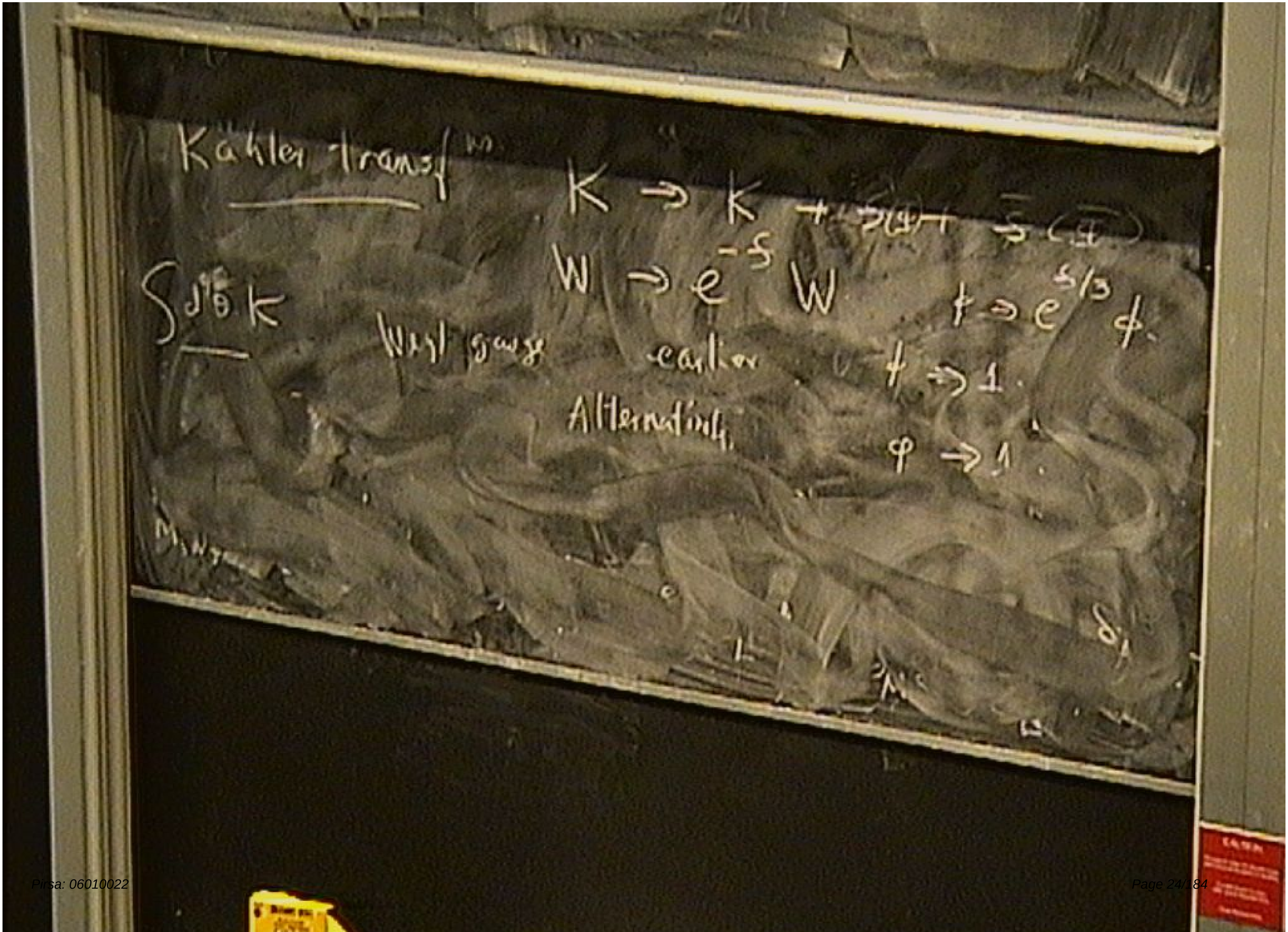

Kähler transf^n
K → K
W →

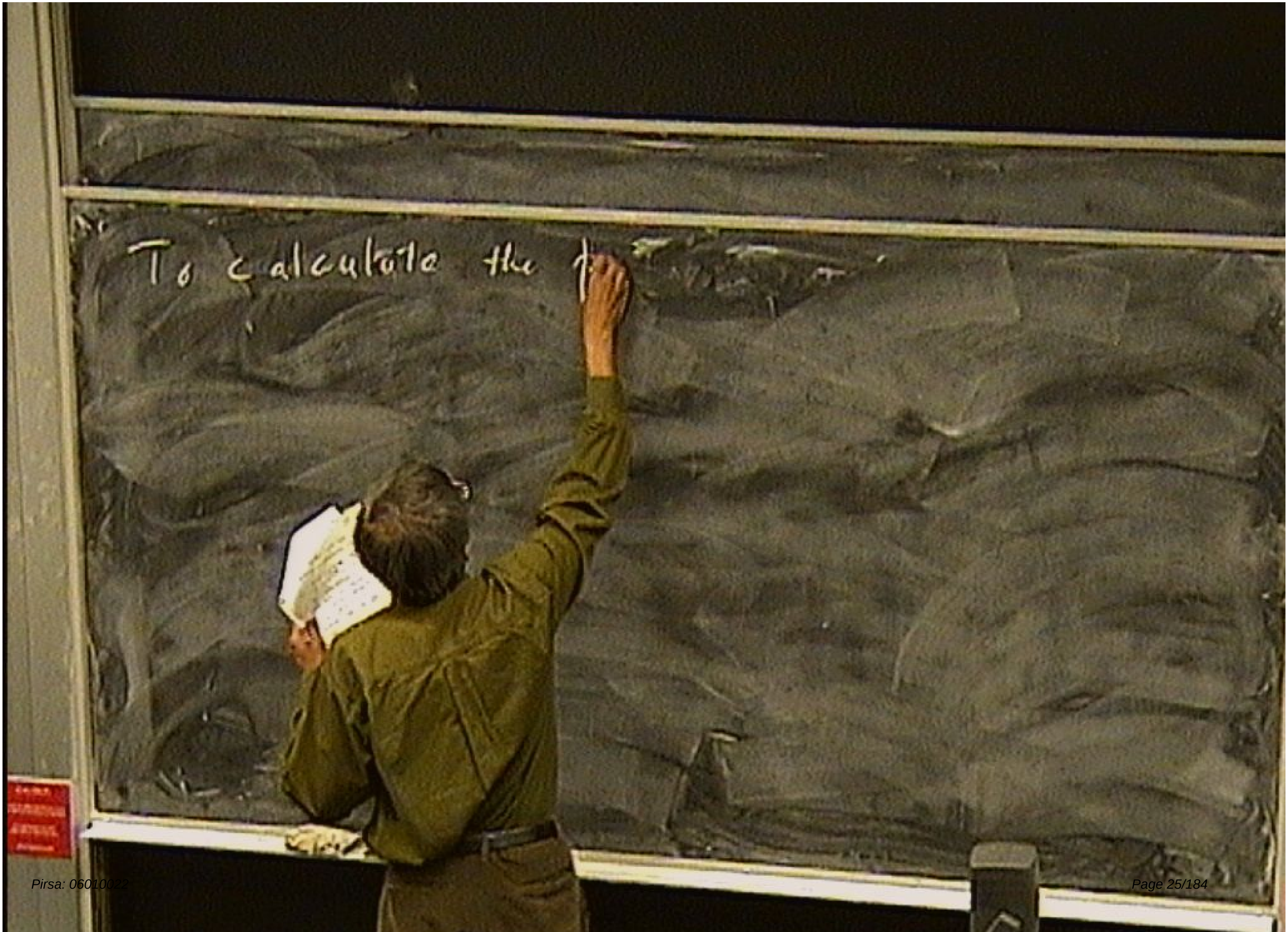

Kähler transf^n
$K \to K + S(\phi) + \bar{S}(\bar{\phi})$
$W \to e^{-S} W$

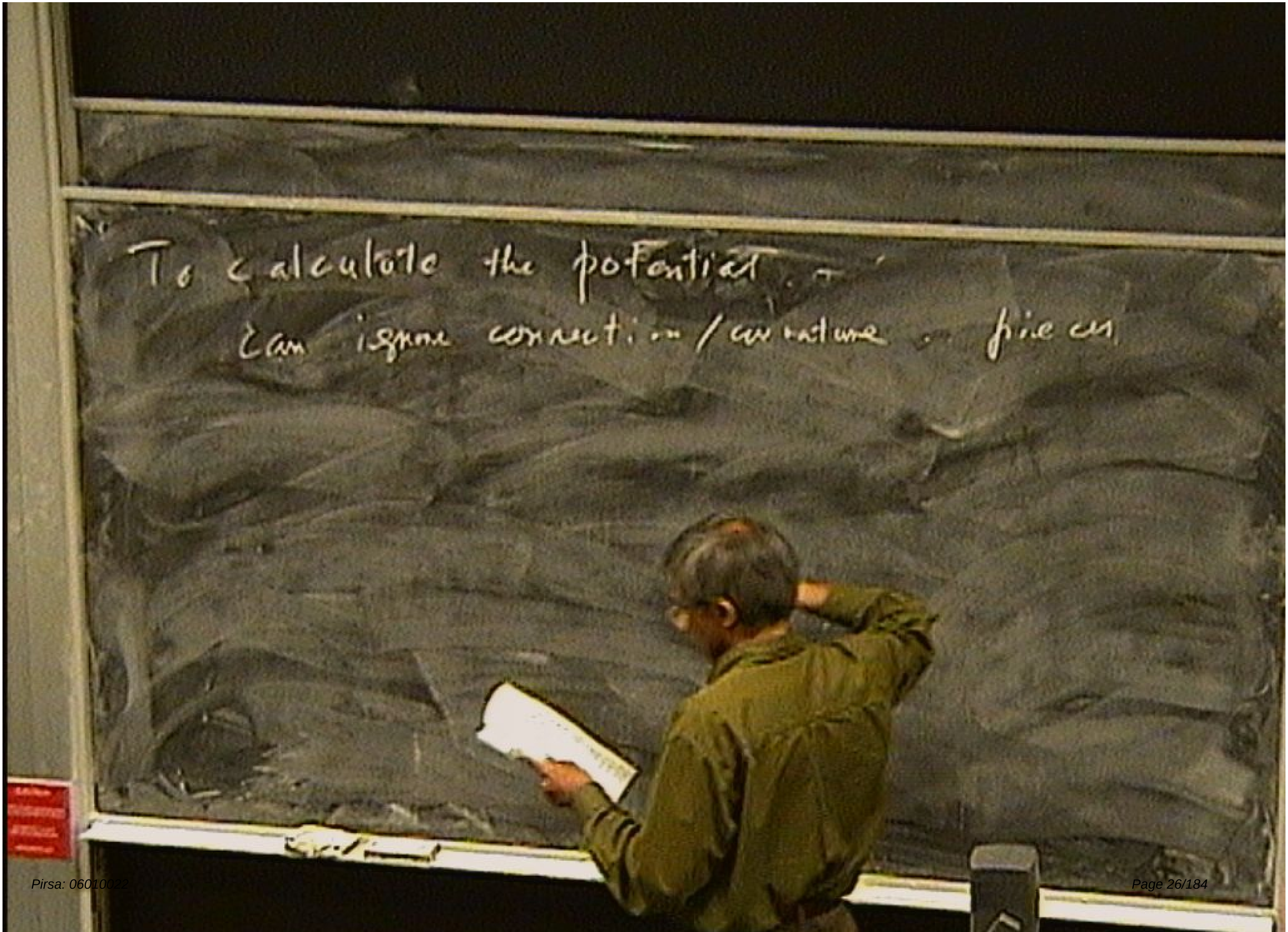

Kähler transf

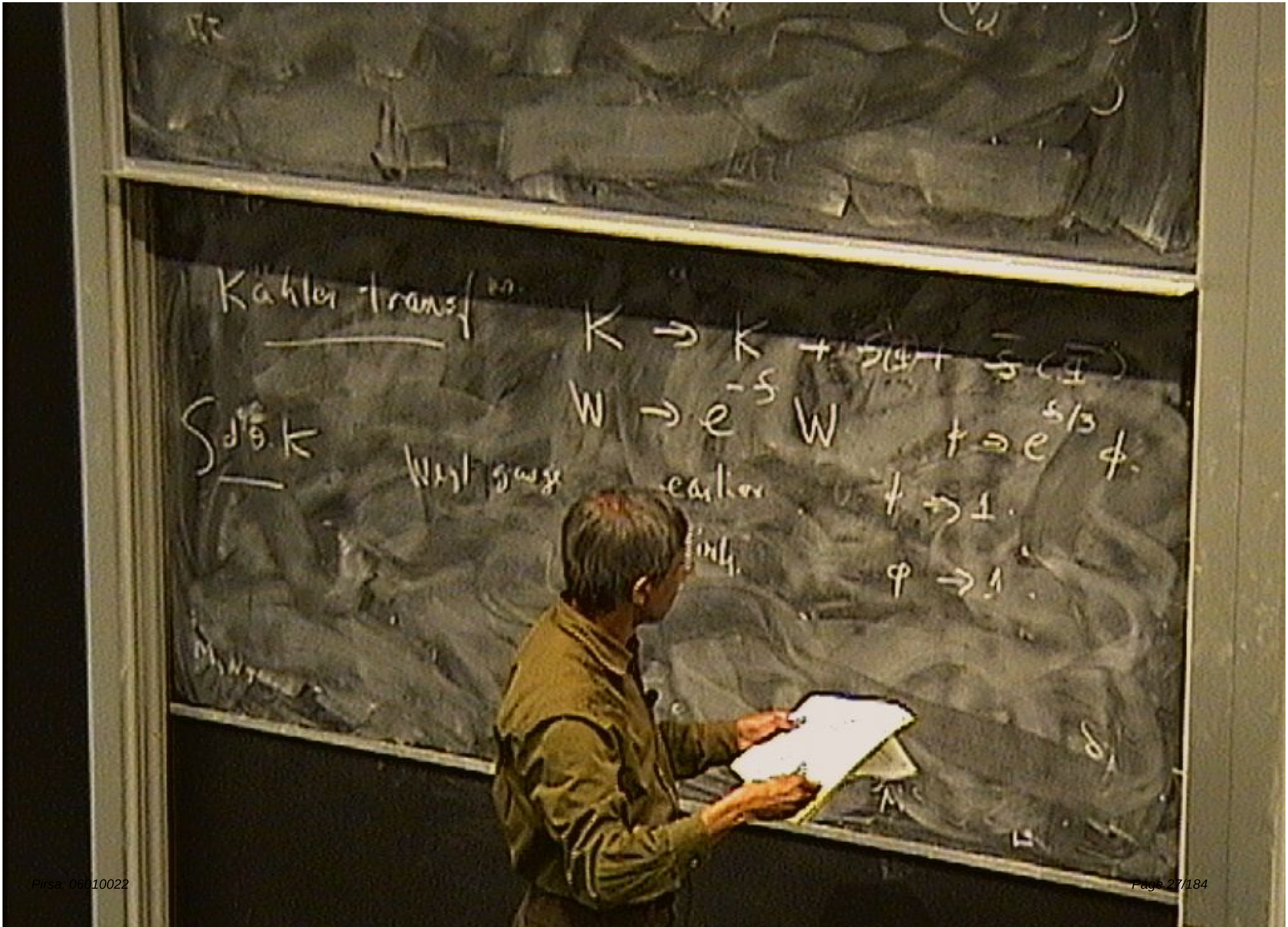

Kähler transf
K → K
W → e W

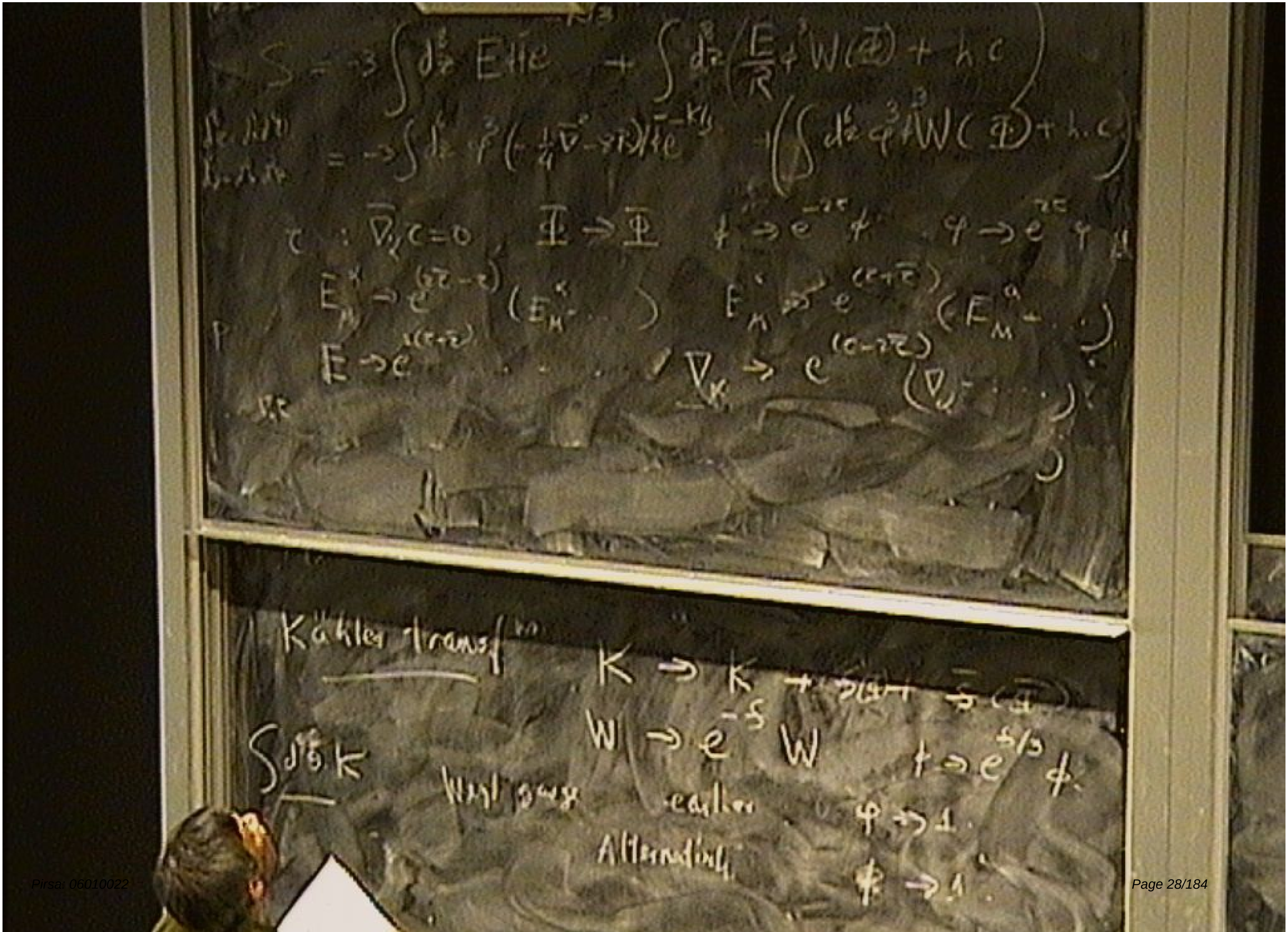

Kähler transf^m
K → K + f(Φ) + f̄(Φ̄)
W → e^{-f} W
φ → e^{f/3} φ.
∫d⁴θ K
Weyl gauge
earlier φ → 1.
Alternatively
φ → 1.


Kahler transf^m
K → K + δ(φ) + δ̄(φ̄)
W → e^{-δ} W
φ → e^{δ/3} φ
∫d^4θ K
Weyl gauge
earlier φ → 1
Alternatively
φ → 1


To calculate the


To calculate the potential
can ignore connection / curvature


Kahler transf
K → K
W → e^{-S} W
Weyl gauge
earlier
φ → 1


Kähler transf
Weyl gauge
earlier
Alternatively

Kahler transf^n

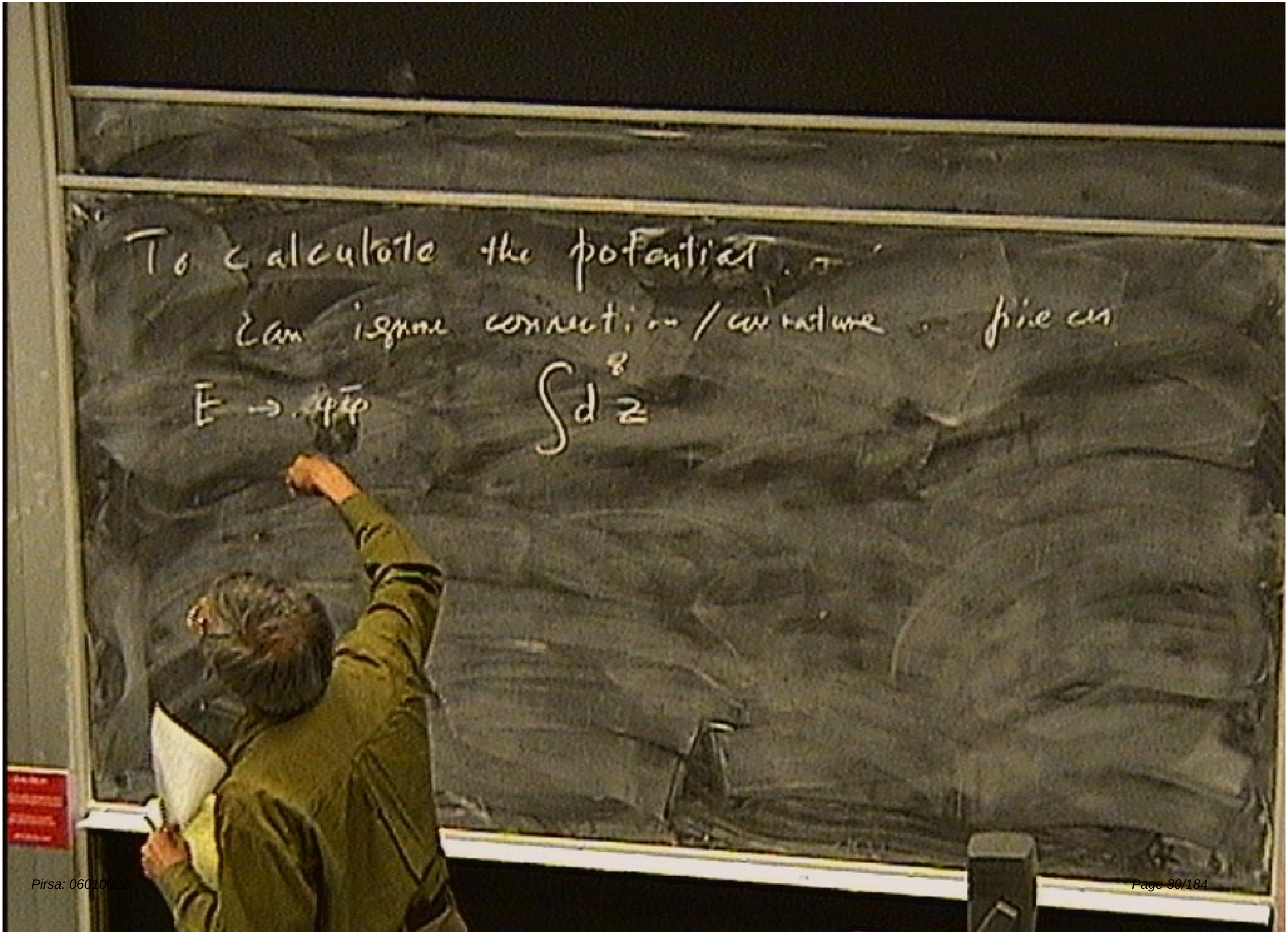
$$K \to K + \mathcal{F}(\Phi) + \bar{\mathcal{F}}(\bar{\Phi})$$

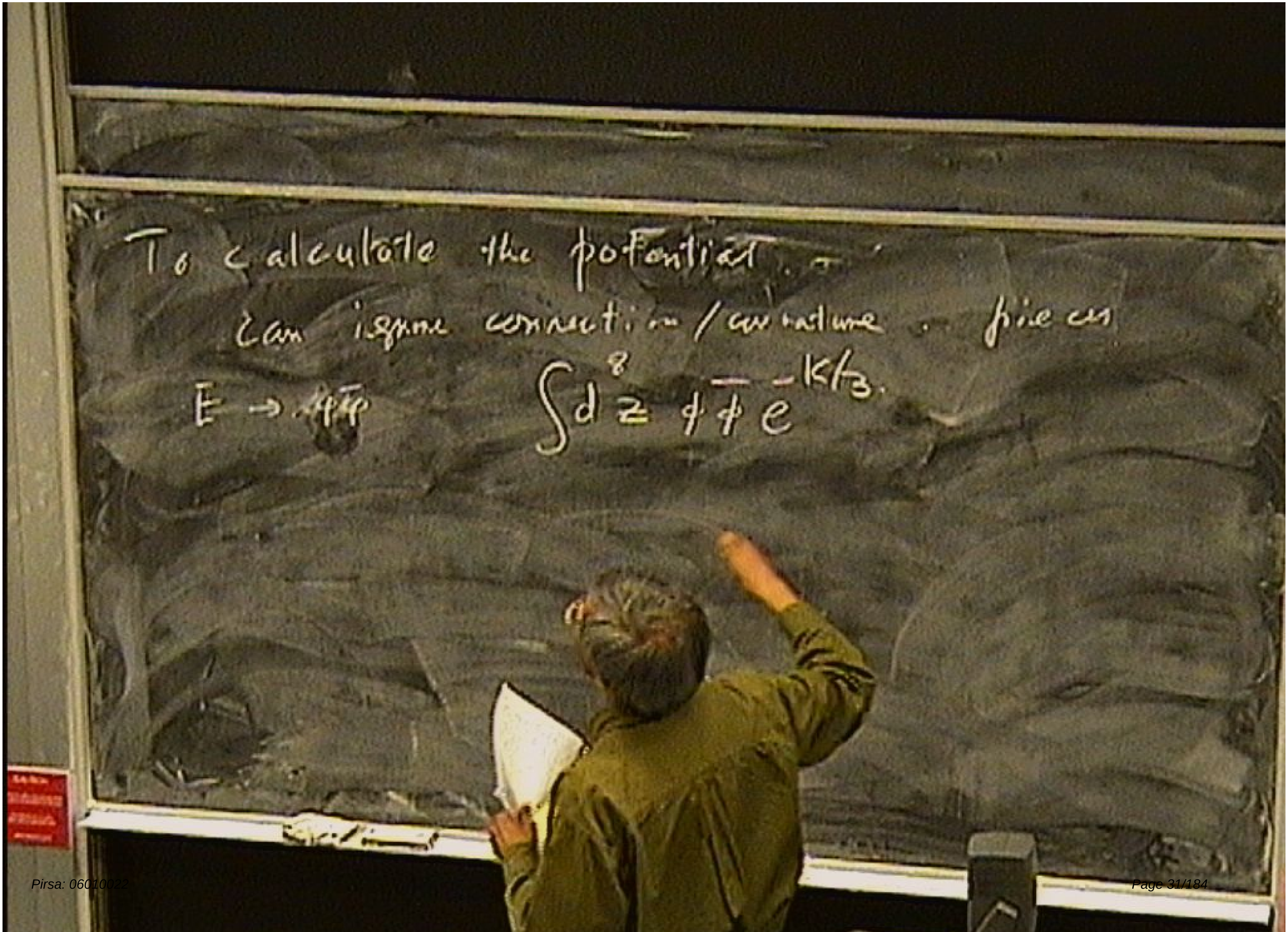
$$W \to e^{-\mathcal{F}}\, W \qquad \phi \to e^{\mathcal{F}/3}\, \phi$$

$\int d^4\theta\, K$

Weyl gauge   earlier $\phi \to 1$.

Alternatively $\phi \to 1$.


To calculate the potential
can ignore connection / curvature pieces
E → φφ̄
∫d^8 z


To calculate the potential
can ignore connection / curvature pieces
E → φφ̄
∫d^8z φφ̄ e^{-K/3}

To calculate the potential,

can ignore connection / curvature pieces

$$\Phi \to \phi\bar{\phi} \qquad \int d^8 z\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z\, \phi^3 W(\Phi) + h.c. \right]$$

To calculate the potential: [illegible]

can ignore connection / curvature pieces

$\Phi \to \phi\bar{\phi}$ $\int d^8 z \, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z \, \phi^3 W(\Phi) + h.c. \right]$

GGR? Chp 8

To calculate the potential:

can ignore connection / curvature pieces

$E \to \phi\bar{\phi}$ $\qquad \int d^8 z\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z\, \phi^3 W(\Phi) + h.c. \right]$

$\nabla_a \to D_\alpha$

GGW To calculate the potential ...

Chap 8 can ignore connection / curvature pieces

$\Phi \to \phi\bar{\phi}$ $\qquad \int d^8 z\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z\, \phi^3 W(\Phi) + h.c.\right]$

$\nabla_\alpha \to D_\alpha \qquad \delta\phi$

Kahler transf^{m}

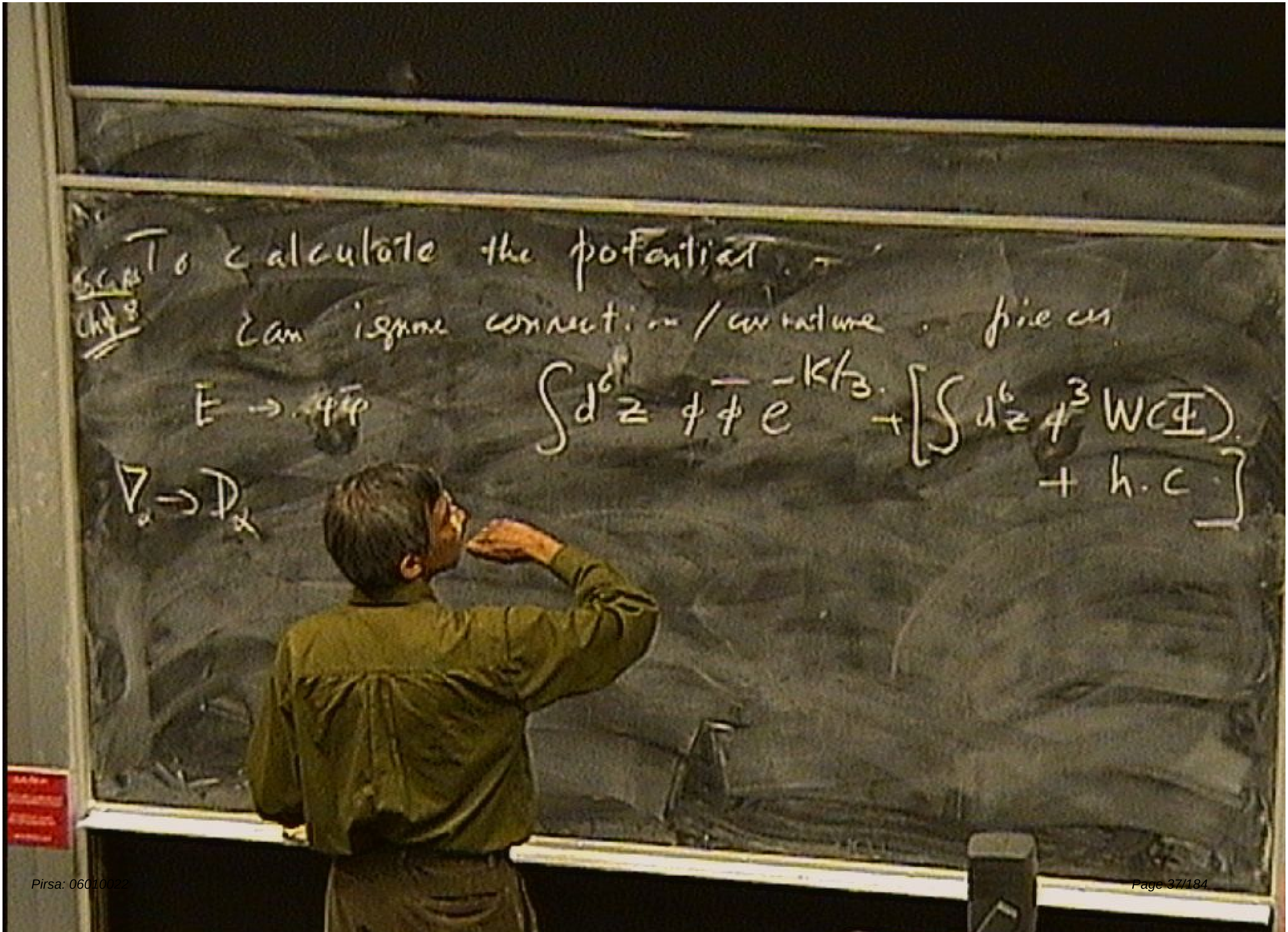
$$K \to K + S(\phi) + \bar{S}(\bar{\phi})$$

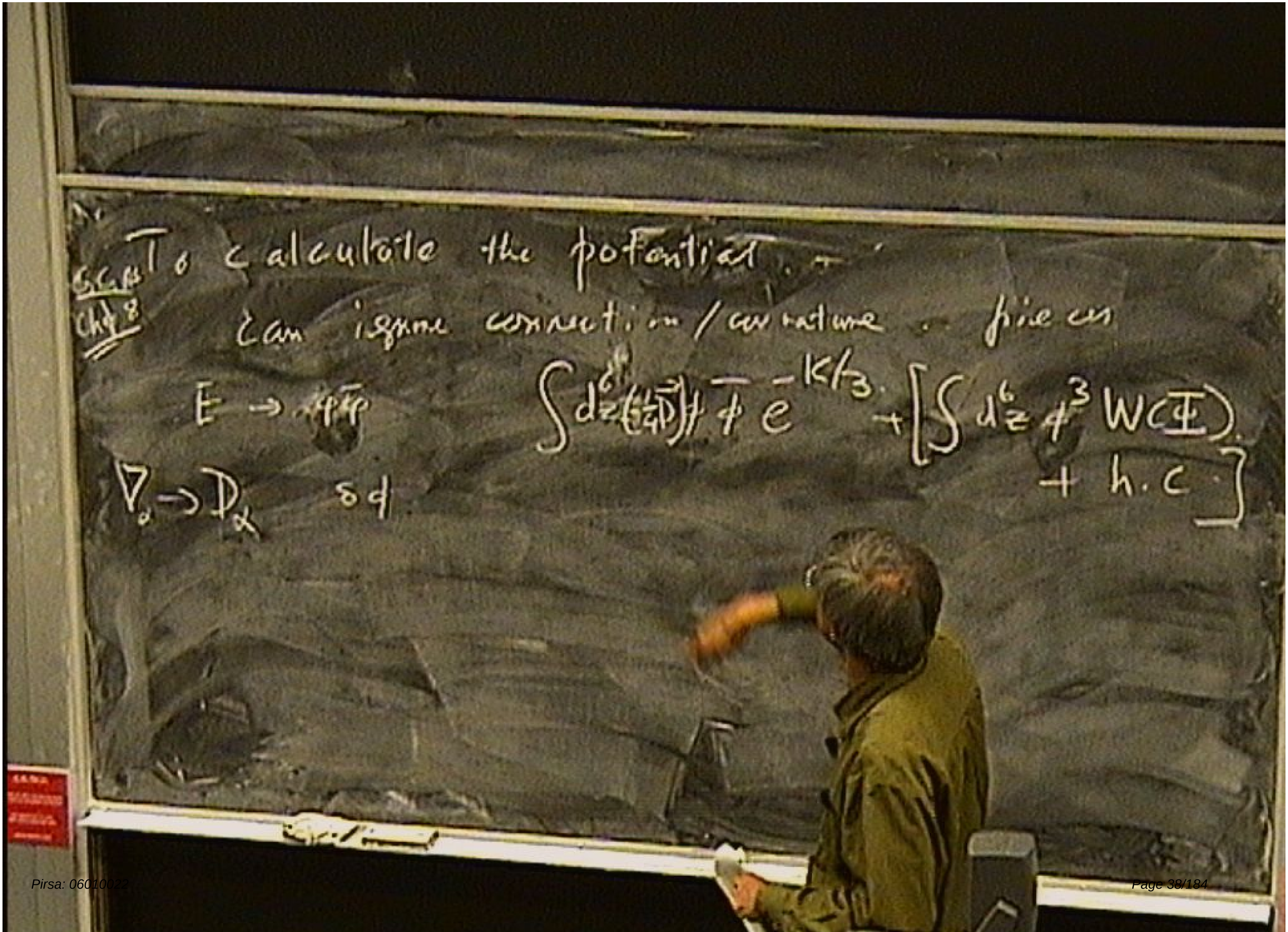
$$W \to e^{-S} W$$

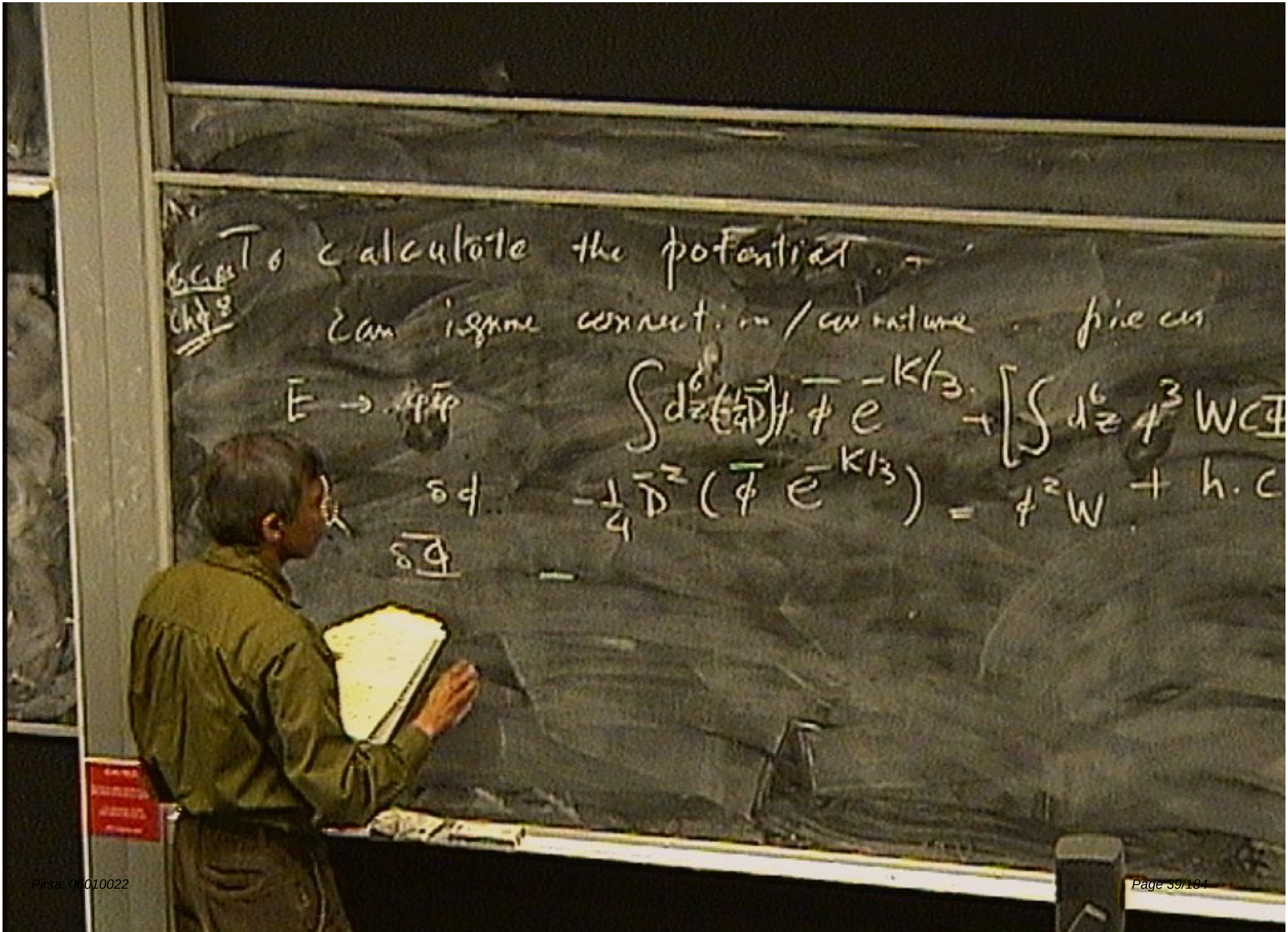
$\int d^4\theta\, K$ Weyl gauge earlier $\phi \to 1$.

$+ \phi e^{S/3} \phi$.

$R\phi$ Alternatively $\bar{\phi} \to 1$


To calculate the potential
Chp 8
can ignore connection / curvature pieces
E → φφ̄
∇_α → D_α
∫d^6z φ φ̄ e^{-K/3} + [∫d^6z φ^3 W(Φ) + h.c.]


To calculate the potential
Can ignore connection / curvature pieces
+ h.c


To calculate the potential
Can ignore connection / curvature pieces
$\int d^8z\, \bar{\phi}\, e^{-K/3} + [\int d^6z\, \phi^3 W$
$-\frac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3}) = \phi^2 W + h.c.$

To calculate the potential

can ignore connection / curvature pieces

$$E \to \phi\bar{\phi} \qquad \int d^8 z\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z\, \phi^3 W(\Phi)\right.$$

$$\nabla_\alpha \to D_\alpha \qquad \delta\phi \qquad -\frac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3}) - \phi^2 W \left. + h.c.\right]$$

$$-\frac{1}{4}\bar{D}^2(\phi\bar{\phi}\, e^{-K/3} K_i)$$

GGRS Ch 8 To calculate the potential

can ignore connection / curvature pieces

$E \to \phi\bar{\phi}$ $\quad \int d^8z \, (-\tfrac{1}{4}\bar{D}^2)\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6z \, \phi^3 W(\Phi) \right.$

$\nabla_\alpha \to D_\alpha$ $\quad \delta\phi \quad -\tfrac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3}) = \phi^2 W \left. + h.c. \right]$

$\Phi \to \{\Phi^i\}$ $\quad \delta\Phi^i \quad -\tfrac{1}{4}\bar{D}^2(\phi\bar{\phi}\, e^{-K/3} K_i) = -\phi^3 W_i$

GGRS Ch. 8

To calculate the potential

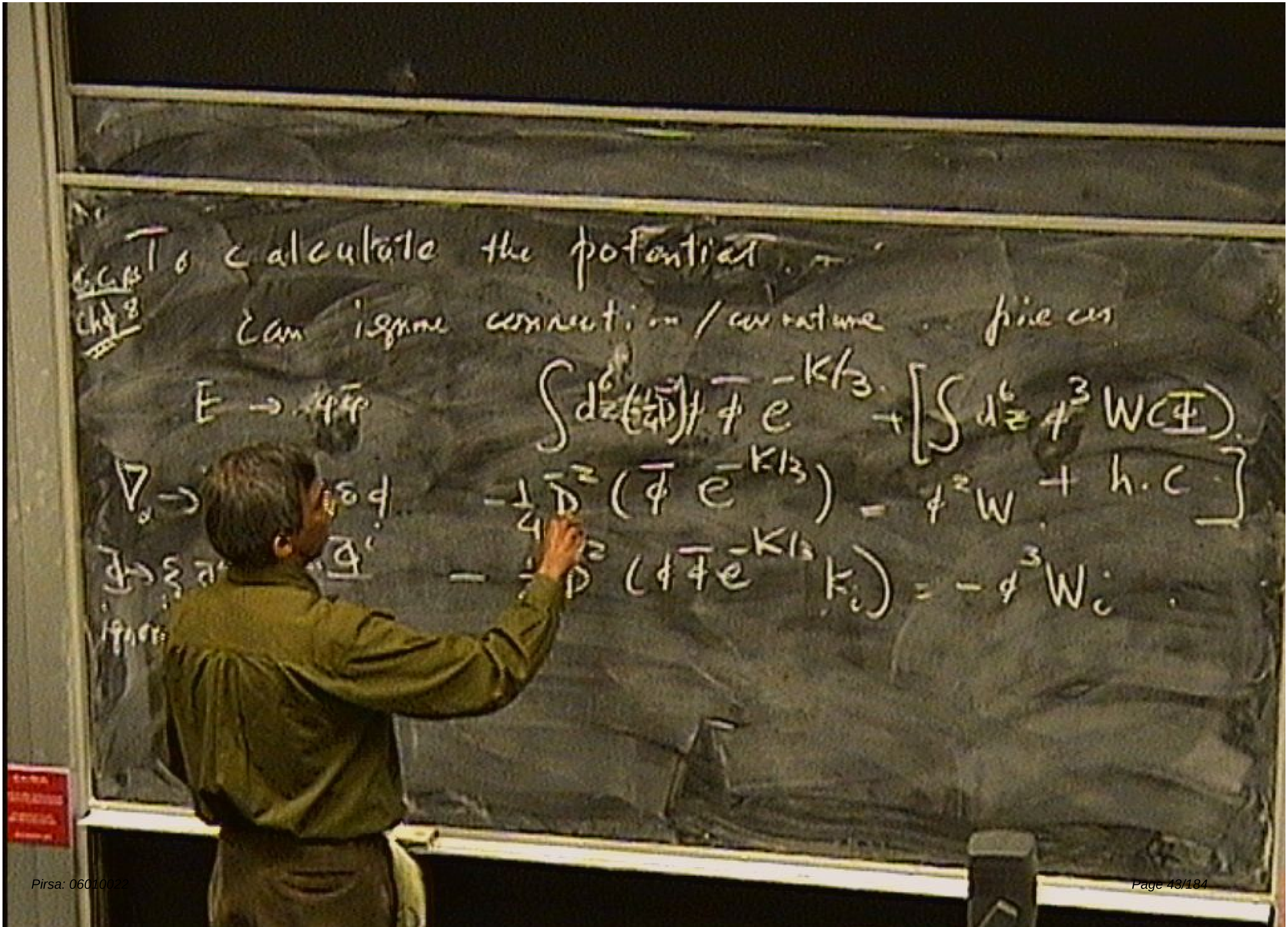
can ignore connection / curvature ∴ pieces

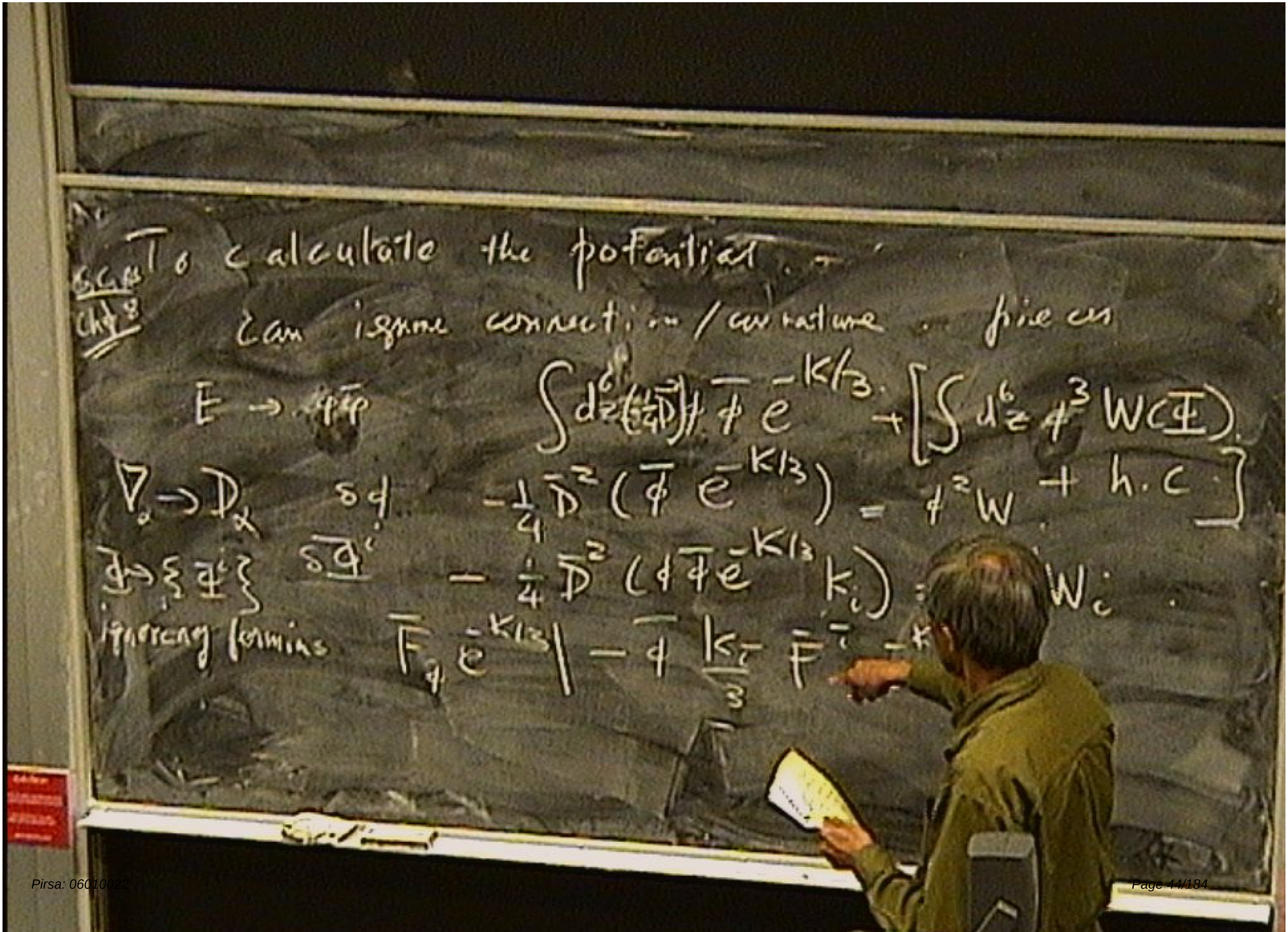
$E \to \phi\bar{\phi}$ $\qquad \int d^8 z \,(-\tfrac{1}{4}\bar{D}^2)\, \phi\bar{\phi}\, e^{-K/3} + \left[\int d^6 z\, \phi^3 W(\Phi) \right.$

$\nabla_\alpha \to D_\alpha \qquad \delta\phi \qquad -\tfrac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3}) = \phi^2 W \quad \left. + \text{ h.c.} \right]$

$\Phi^i \} \qquad \delta\Phi^i \qquad -\tfrac{1}{4}\bar{D}^2(\phi\bar{\phi}\, e^{-K/3} K_i) = -\phi^3 W_i \; .$

...ing fermions


To calculate the potential,
can ignore connection/curvature pieces


GGRS Chap 8
To calculate the potential
can ignore connection / curvature pieces
h.c.
ignoring fermions

GGRS Ch 8

To calculate the potential

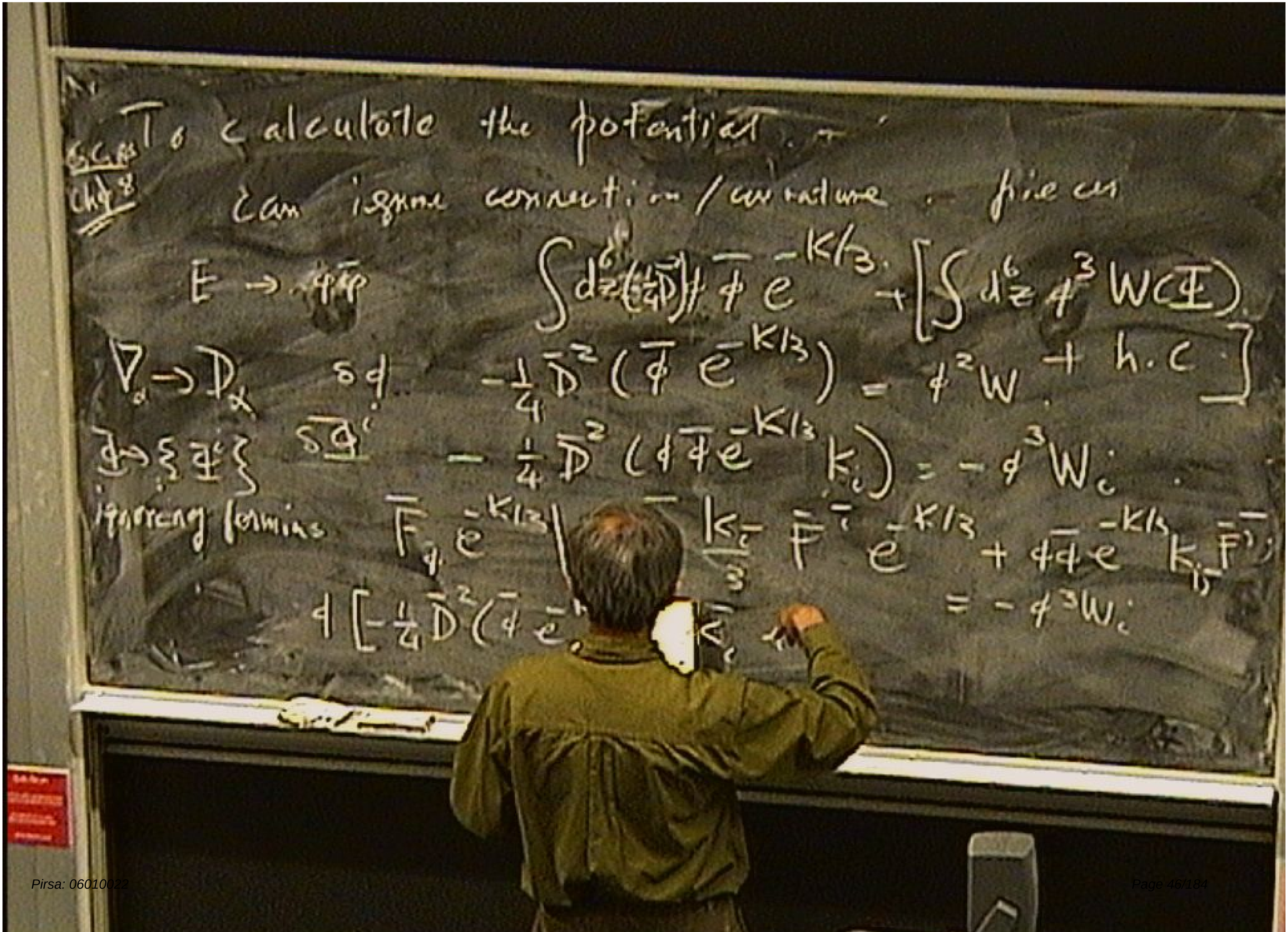
can ignore connection / curvature pieces

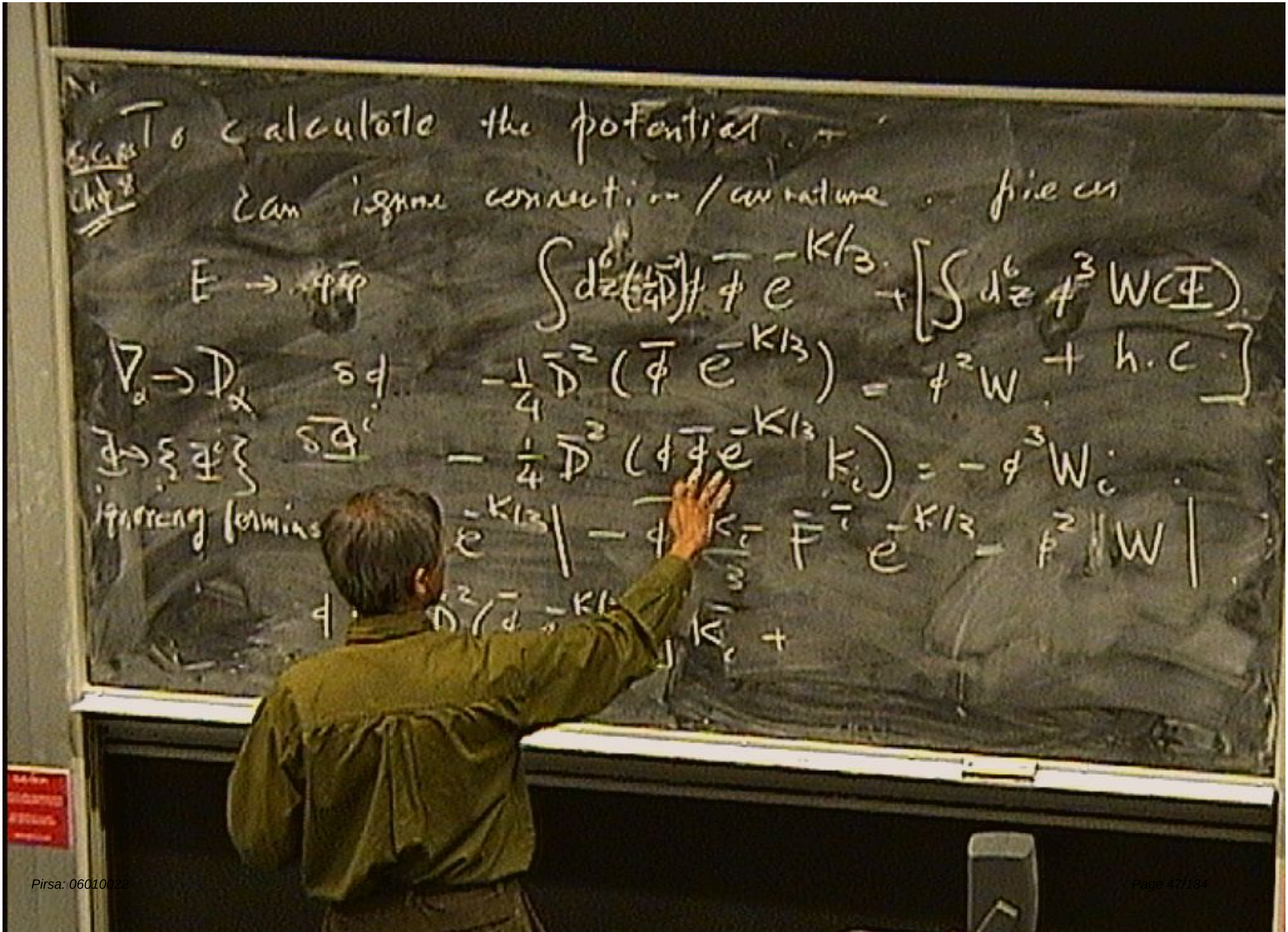
$$E \to \phi\bar\phi \qquad \int d^8z \left(-\tfrac{1}{4}\bar D^2\right) \phi\bar\phi\, e^{-K/3} + \left[\int d^6z\, \phi^3 W(\Phi) + h.c.\right]$$

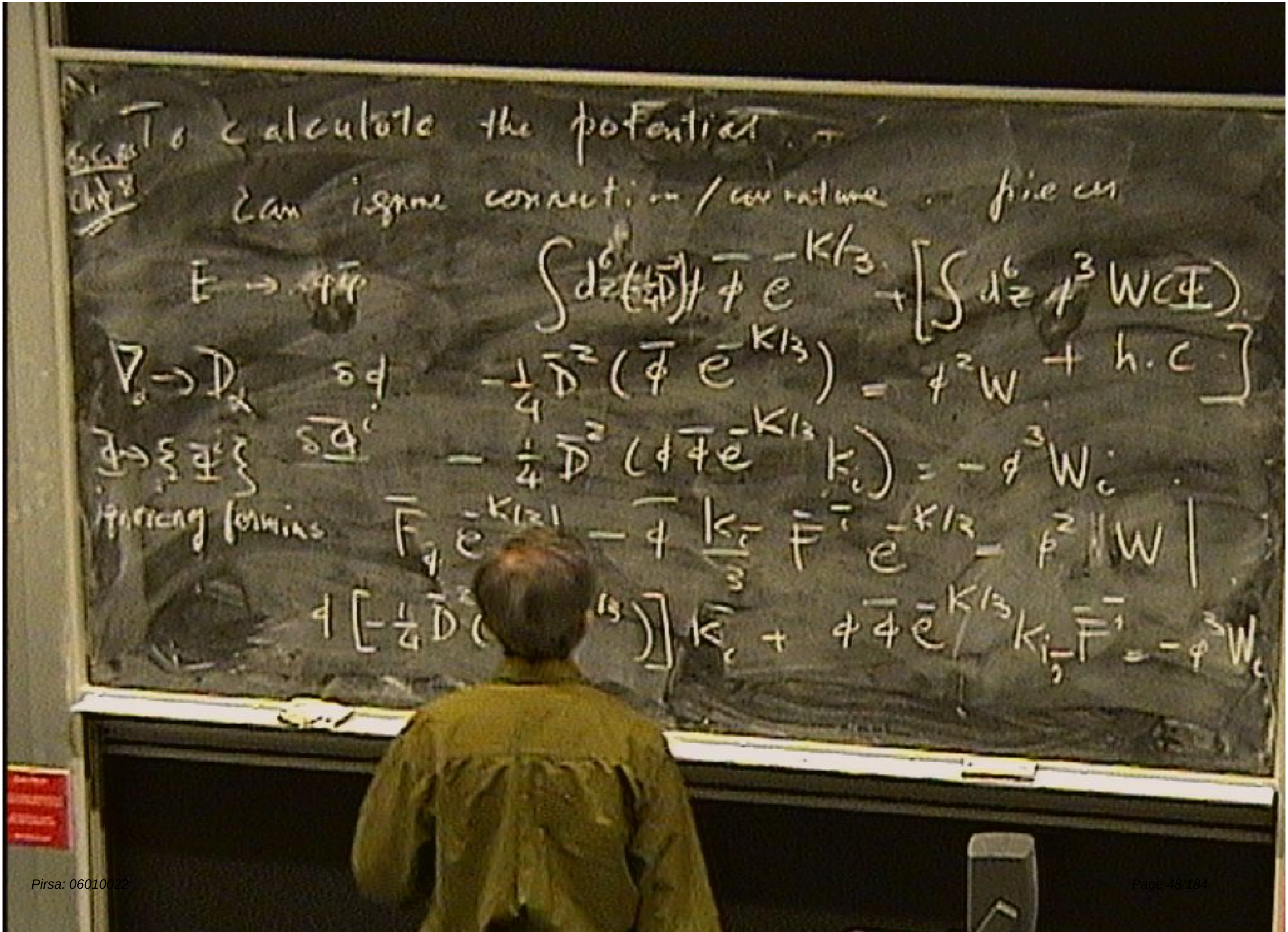
$$\nabla \to D \qquad \delta\phi \qquad -\tfrac{1}{4}\bar D^2\left(\bar\phi\, e^{-K/3}\right) - \phi^2 W$$

$$\delta\Phi^i \qquad -\tfrac{1}{4}\bar D^2\left(\phi\bar\phi\, e^{-K/3} K_i\right) = -\phi^3 W_i$$

$$\bar F_\phi\, e^{-K/3}\Big| - \bar\phi\, \frac{K_{\bar i}}{3}\, \bar F^{\bar i} e^{-K/3} + \phi\bar\phi\, e^{-K/3} K_{i\bar j} \bar F^{\bar j}$$
$$= -\phi^3 W_i$$


To calculate the potential
Can ignore connection / curvature : fine on
ignoring fermions


To calculate the potential
can ignore connection / curvature
ignoring fermions


To calculate the potential
can ignore connection / curvature
h.c
ignoring fermions

SGRS Ch 8

To calculate the potential . . .

can ignore connection / curvature . . . find an

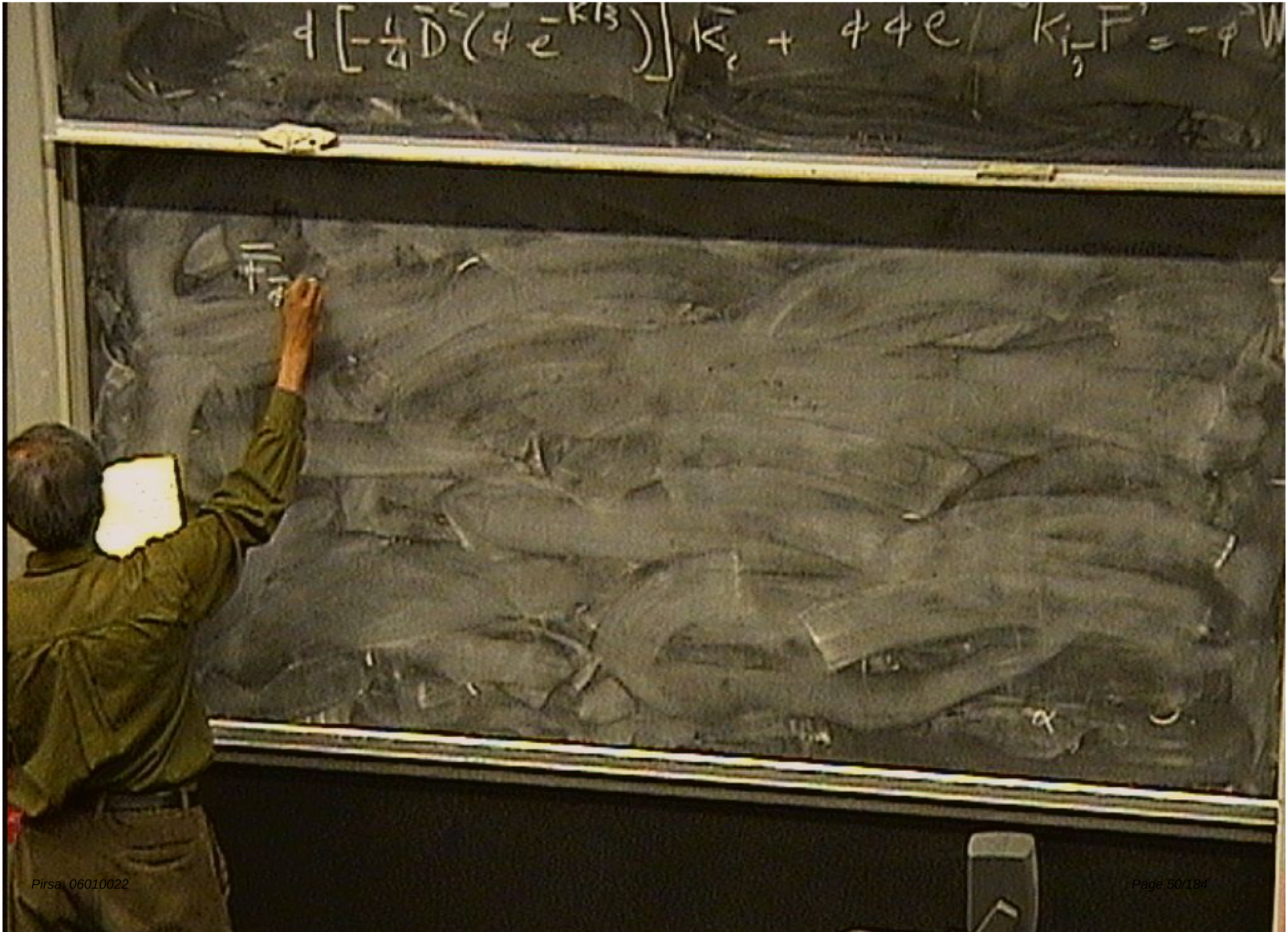
$$E \to \phi\bar{\phi} \qquad \int d^8z \left(\tfrac{1}{4}\bar{D}\right) \bar{\phi}\, e^{-K/3} + \left[\int d^6z\, \phi^3 W(\Phi)\right.$$

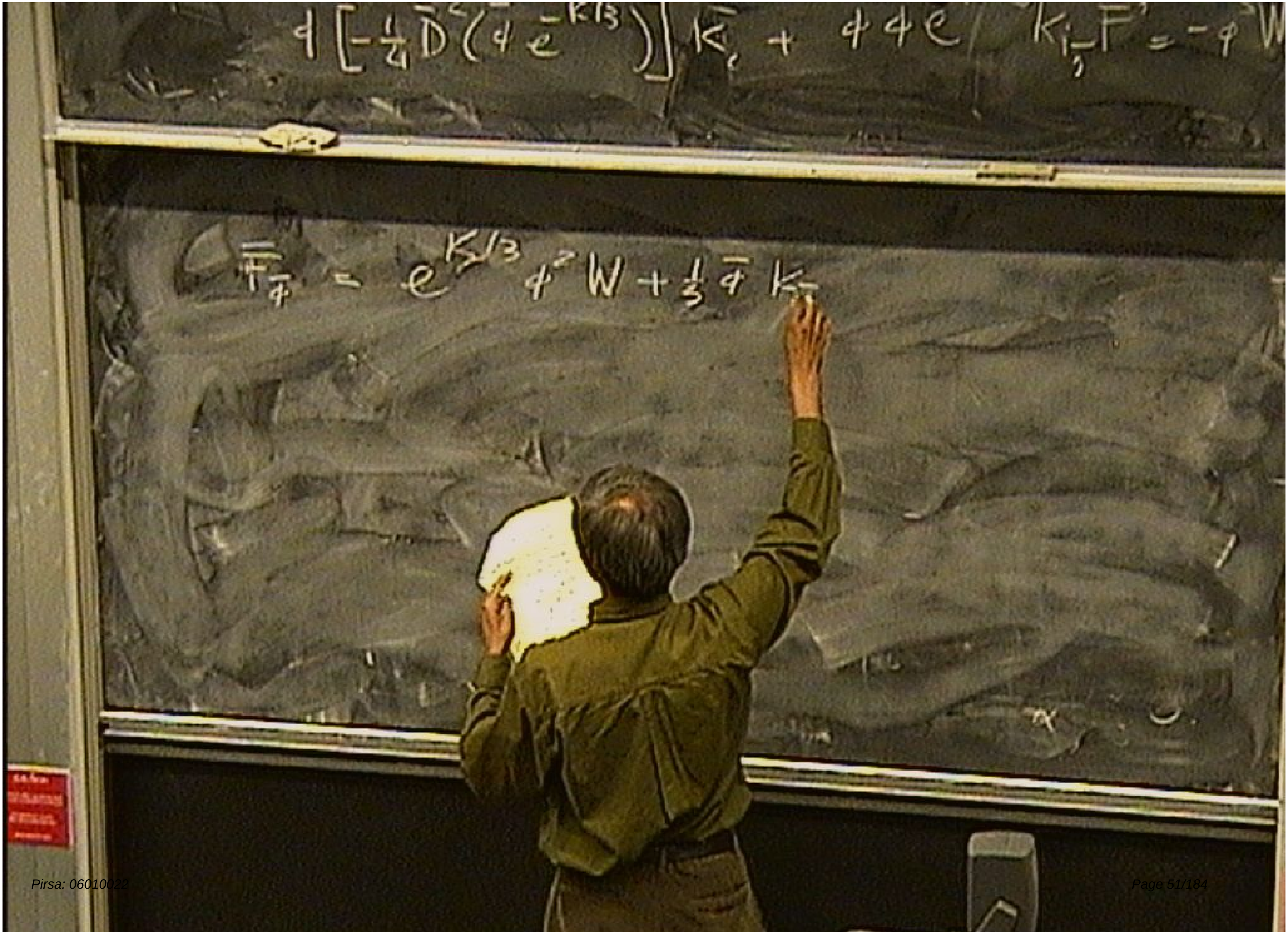
$$\nabla_\alpha \to D_\alpha \qquad \delta\phi \qquad -\tfrac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-K/3}\right) = \phi^2 W \left. + \text{h.c.}\right]$$

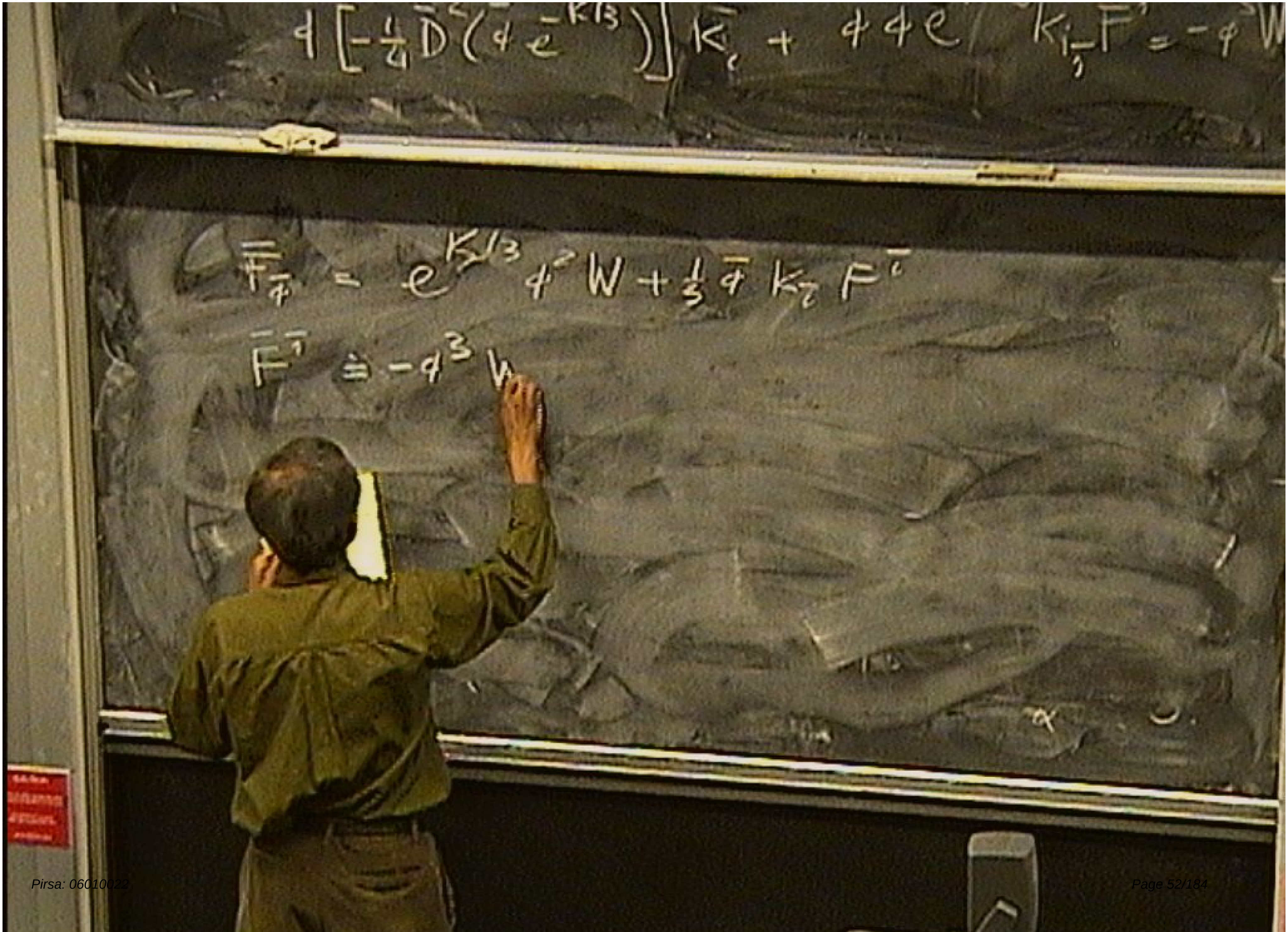
$$\Phi \to \{\Phi^i\} \qquad \delta\Phi^i \qquad -\tfrac{1}{4}\bar{D}^2\left(\phi\bar{\phi}\, e^{-K/3} K_i\right) = -\phi^3 W_i$$

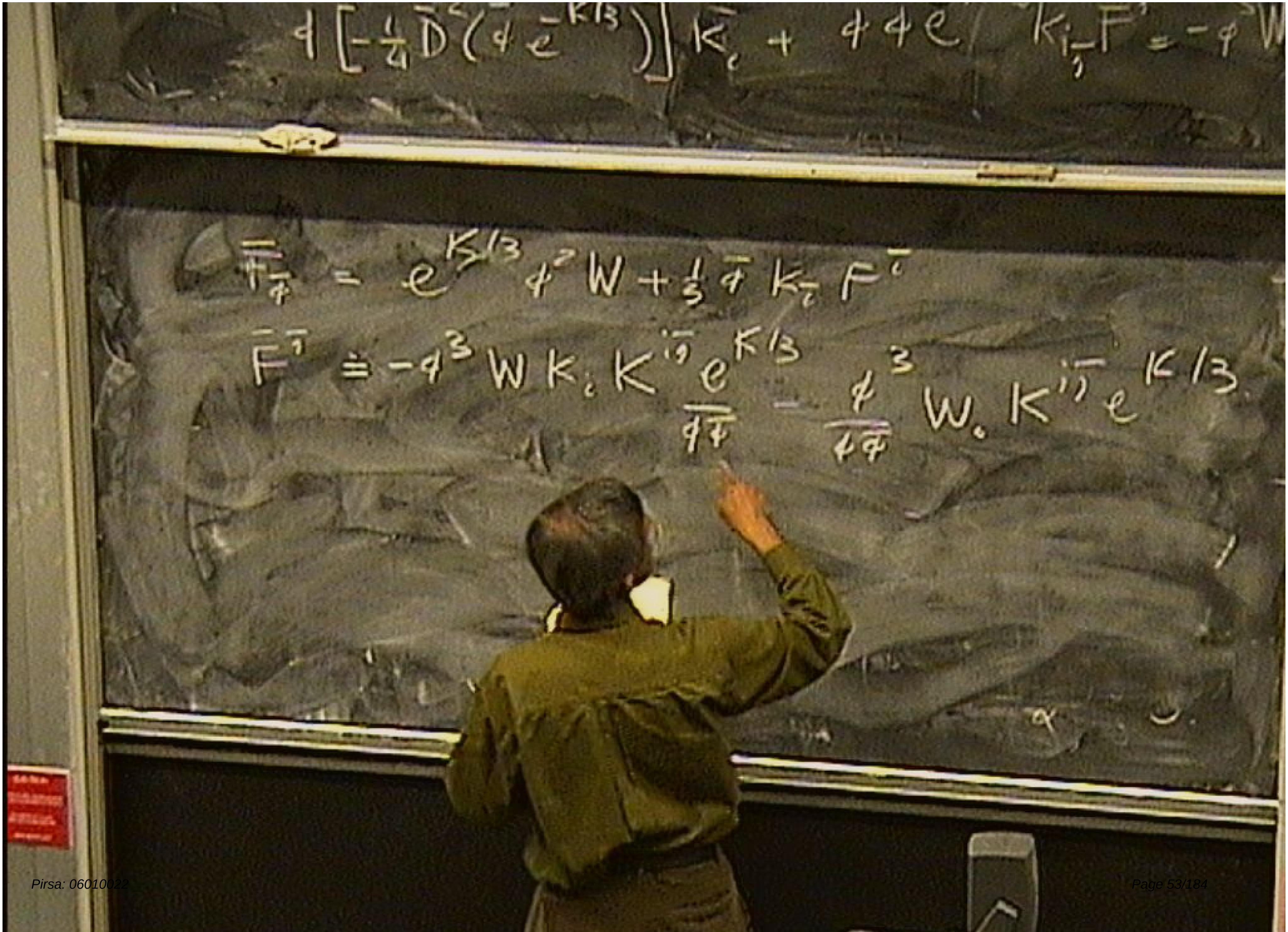
ignoring fermions $\quad \bar{F}_\phi\, e^{-K/3}\Big| - \bar{\phi}\, \frac{K_{\bar{i}}}{3} \bar{F}^{\bar{i}}\, e^{-K/3} = \phi^2 \big|W\big|$

$$\phi\left[-\tfrac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-K/3}\right)\right] K_i + \phi\bar{\phi}\, e^{-K/3} K_{i\bar{j}} \bar{F}^{\bar{j}} = -\phi^3 W_i$$






$\bar{F}_{\bar\phi} = e^{K/3} \phi^2 W + \frac{1}{3} \bar\phi K_{\bar i} F^{\bar i}$
$\bar{F}^{\bar i} = -\phi^3 W$


d[-¼ D̄²(φ e^{-K/3})] K_i + φφ e K_{i j̄} F̄^{j̄} = -φ W
F̄_φ̄ = e^{K/3} φ² W + ⅓ φ̄ K_i F^i
F̄^{j̄} = -φ³ W K_i K^{ij̄} e^{K/3} / (φφ̄) - φ³/(φφ̄) W_i K^{ij̄} e^{K/3}

$$\phi\left[-\tfrac{1}{4}\bar{D}^2\left(\bar\phi\, e^{-K/3}\right)\right]K_i + \phi\bar\phi\, e^{\cdots} K_{i\bar j}\bar F^{\bar j} = -\phi^3 W_i$$

$$\bar F_{\bar\phi} = e^{K/3}\phi^2 W + \tfrac{1}{3}\bar\phi K_{\bar i} \bar F^{\bar i}$$

$$\bar F^{\bar j} = -\phi^3 W K_i K^{i\bar j} \frac{e^{K/3}}{\phi\bar\phi} - \frac{\phi^3}{\phi\bar\phi} W_i K^{i\bar j} e^{K/3}$$

$$D_i W = \partial_i W + K_i W$$

$$\phi\left[-\tfrac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3})\right] K_i + \phi\phi e \ldots K_{i\bar{j}} \bar{F}^{\bar{j}} = -\phi^3 W \ldots$$

$$\bar{F}_{\bar{\phi}} = e^{K/3}\phi^2 W + \tfrac{1}{3}\bar{\phi} K_{\bar{i}} \bar{F}^{\bar{i}}$$

$$\bar{F}^{\bar{j}} = -\phi^3 W K_i K^{i\bar{j}} \frac{e^{K/3}}{\phi\bar{\phi}} - \frac{\phi^3}{\phi\bar{\phi}} W_i K^{i\bar{j}} e^{K/3}$$

$$D_i W = \partial_i W + K_i W$$

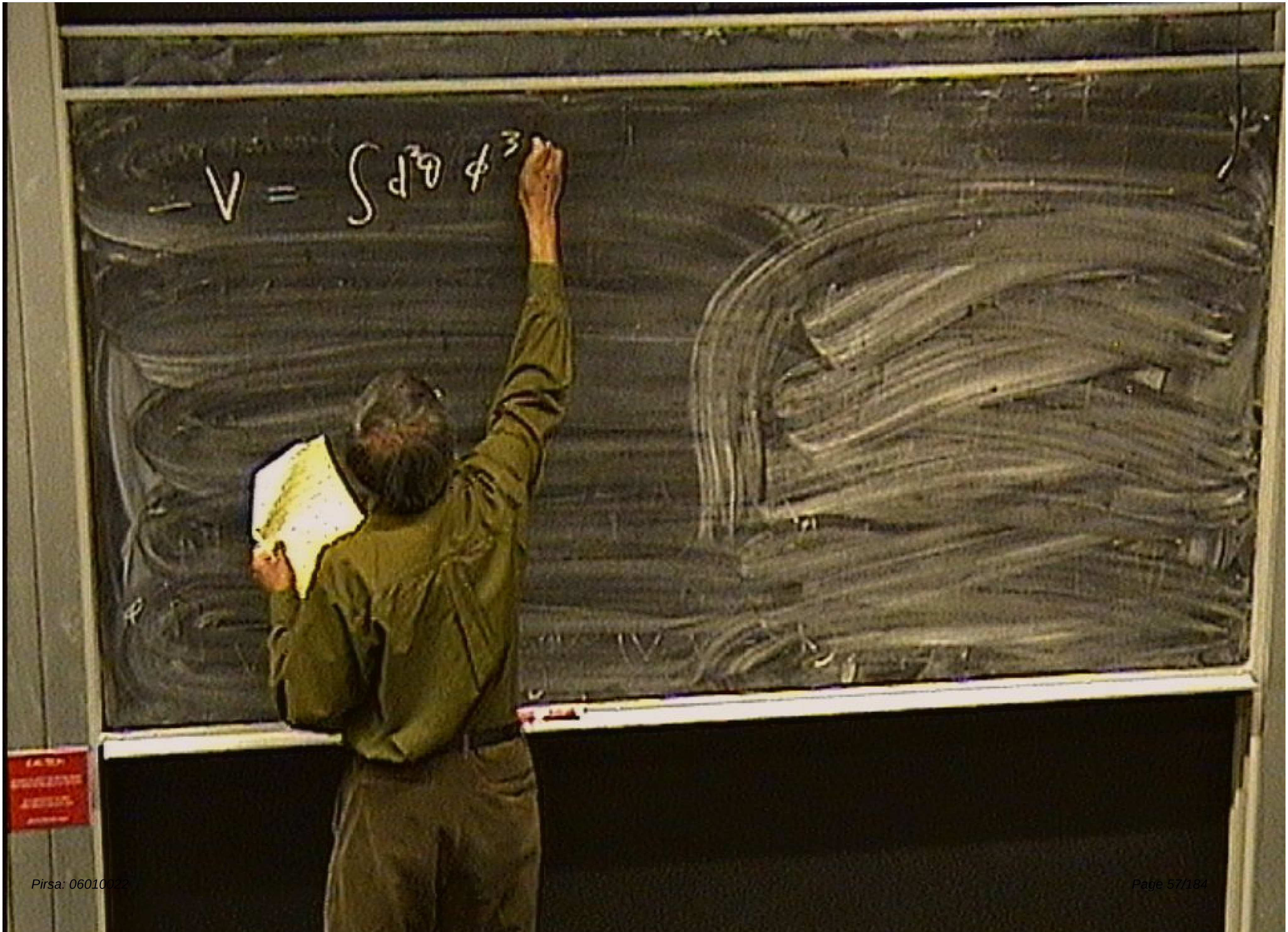
$$\phi\left[-\tfrac{1}{4}\bar{D}^2\left(\bar\phi\, e^{-K/3}\right)\right]K_i + \phi\phi e^{\ldots} K_{i\bar{j}} \bar{F}^{\bar{j}} = -\phi^3 W\ldots$$

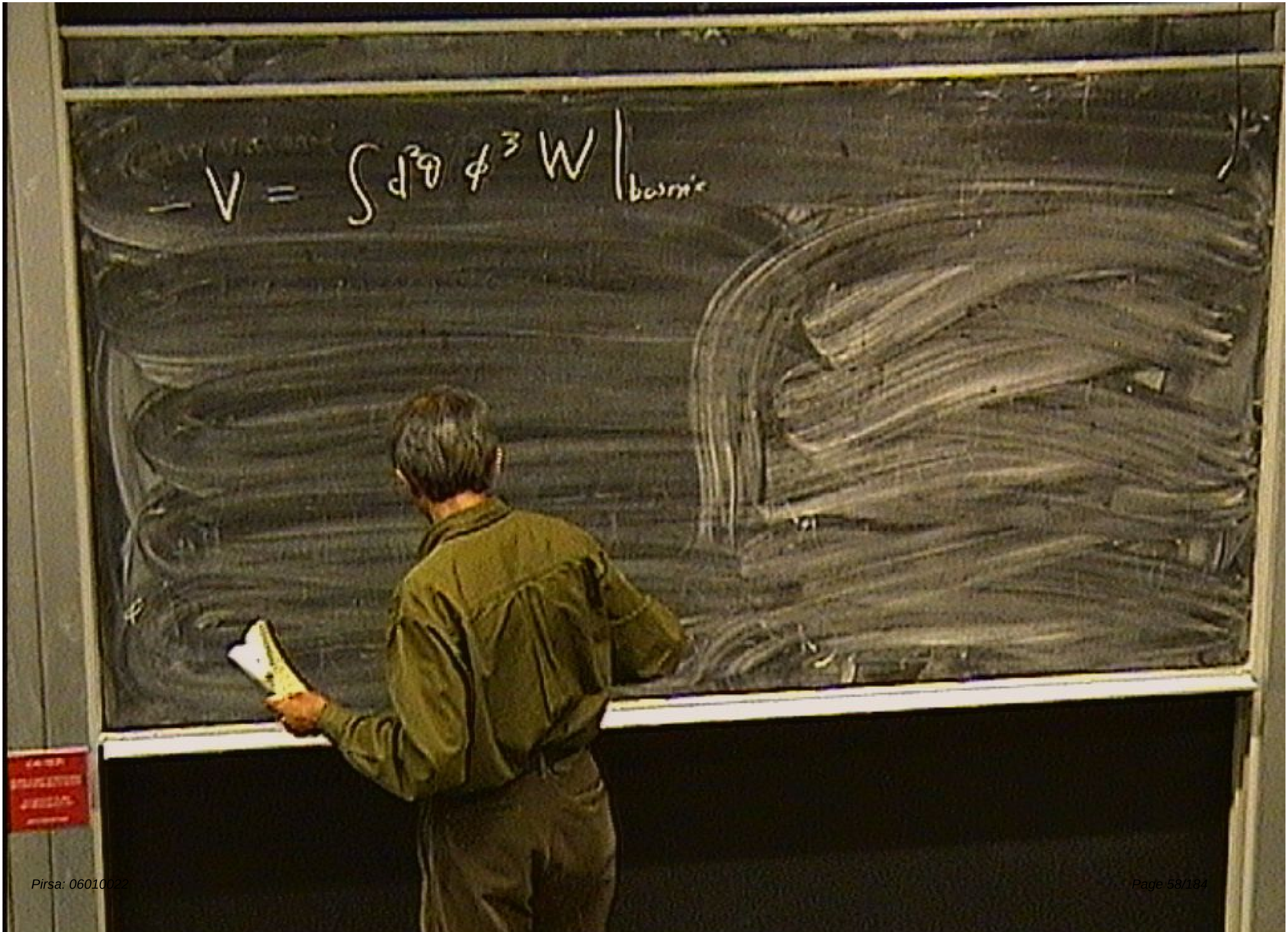
$$\bar{F}_{\bar\phi} = e^{K/3}\phi^2 W + \tfrac{1}{3}\bar\phi K_i F^i$$

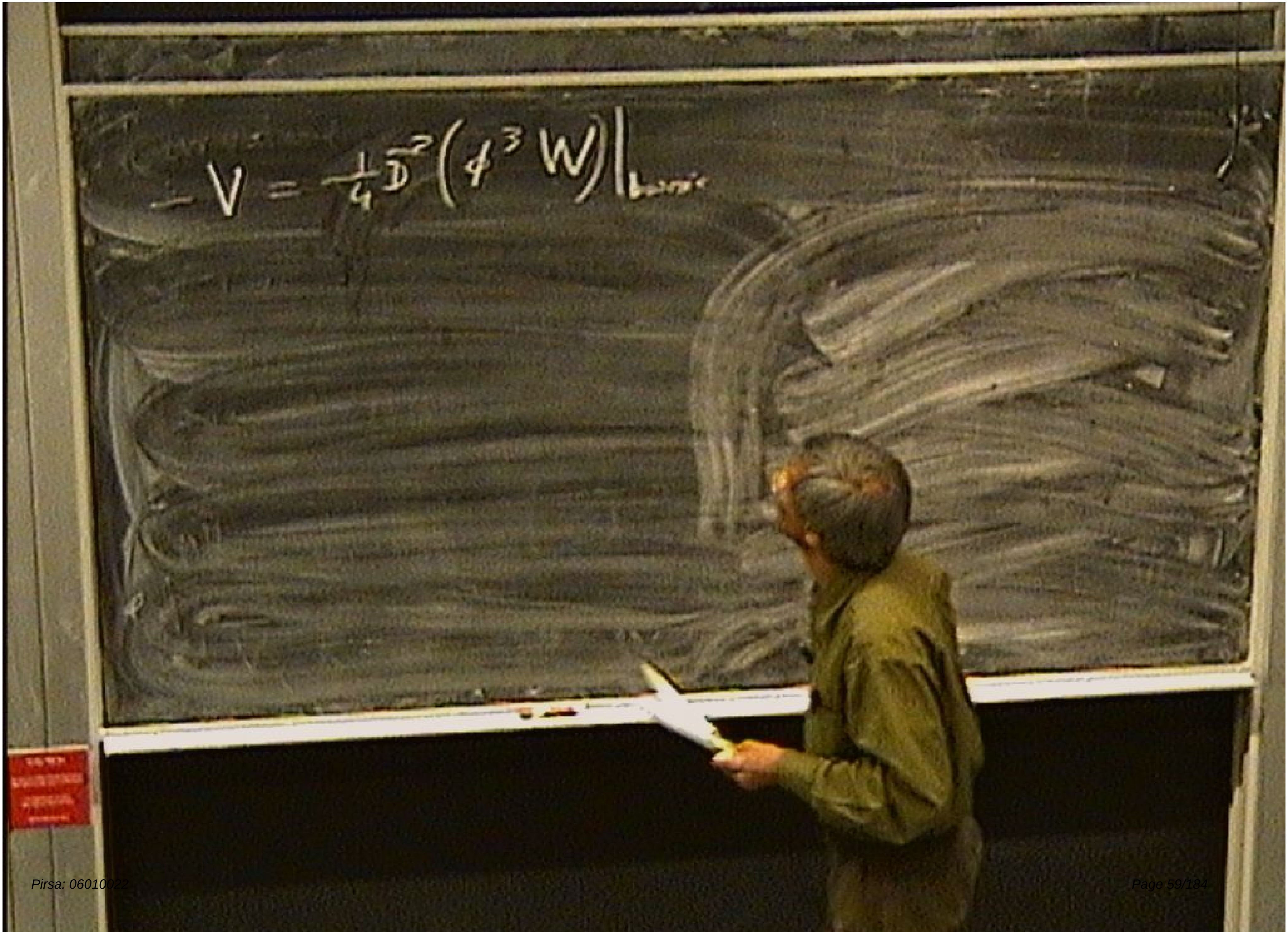
$$\bar{F}^{\bar{j}} = -\phi^3 W K_i K^{i\bar{j}} \frac{e^{K/3}}{\phi\bar\phi} - \frac{\phi^3}{\phi\bar\phi} W_i K^{i\bar{j}} e^{K/3}$$

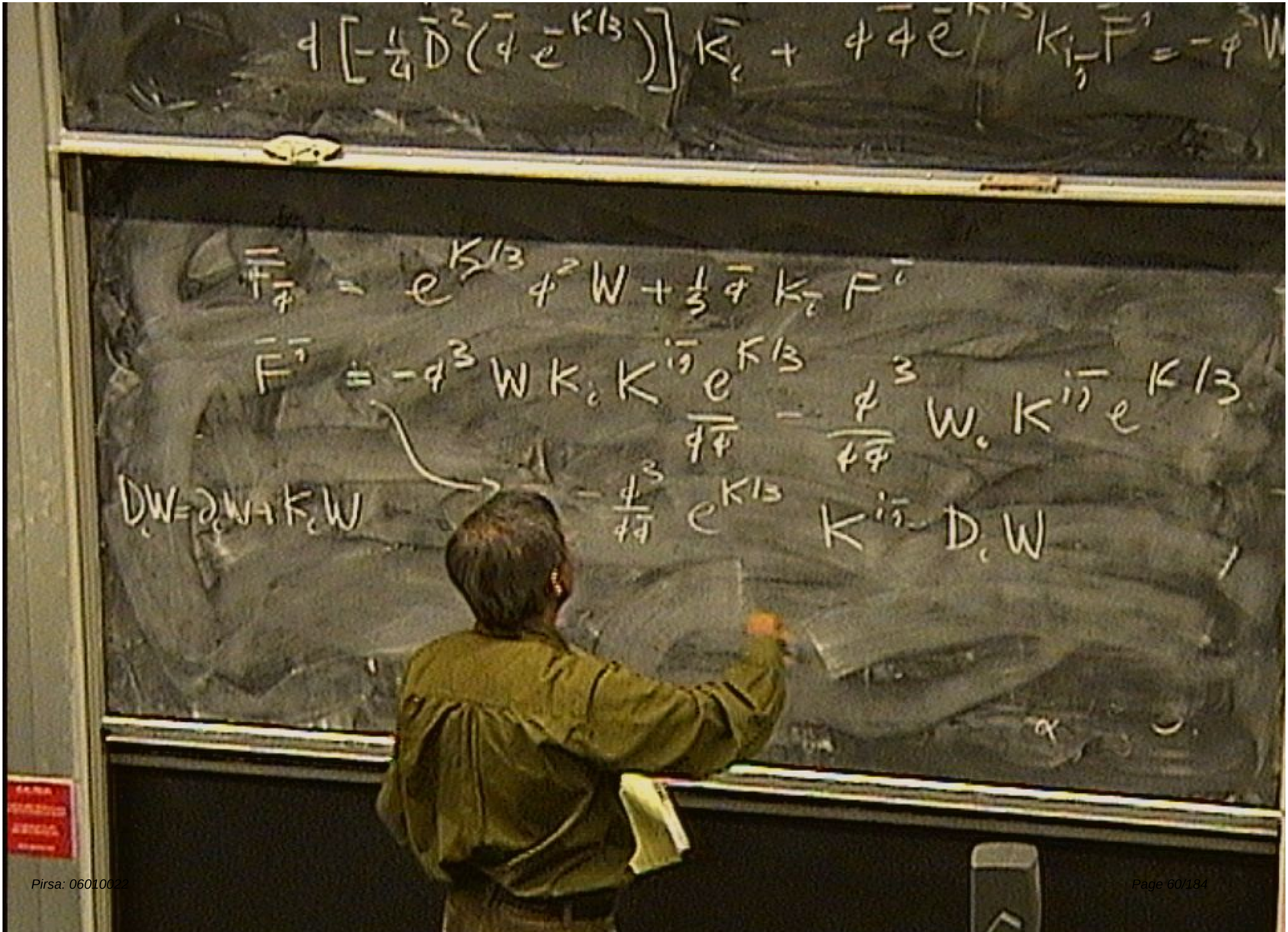
$$D_i W = \partial_i W + K_i W$$

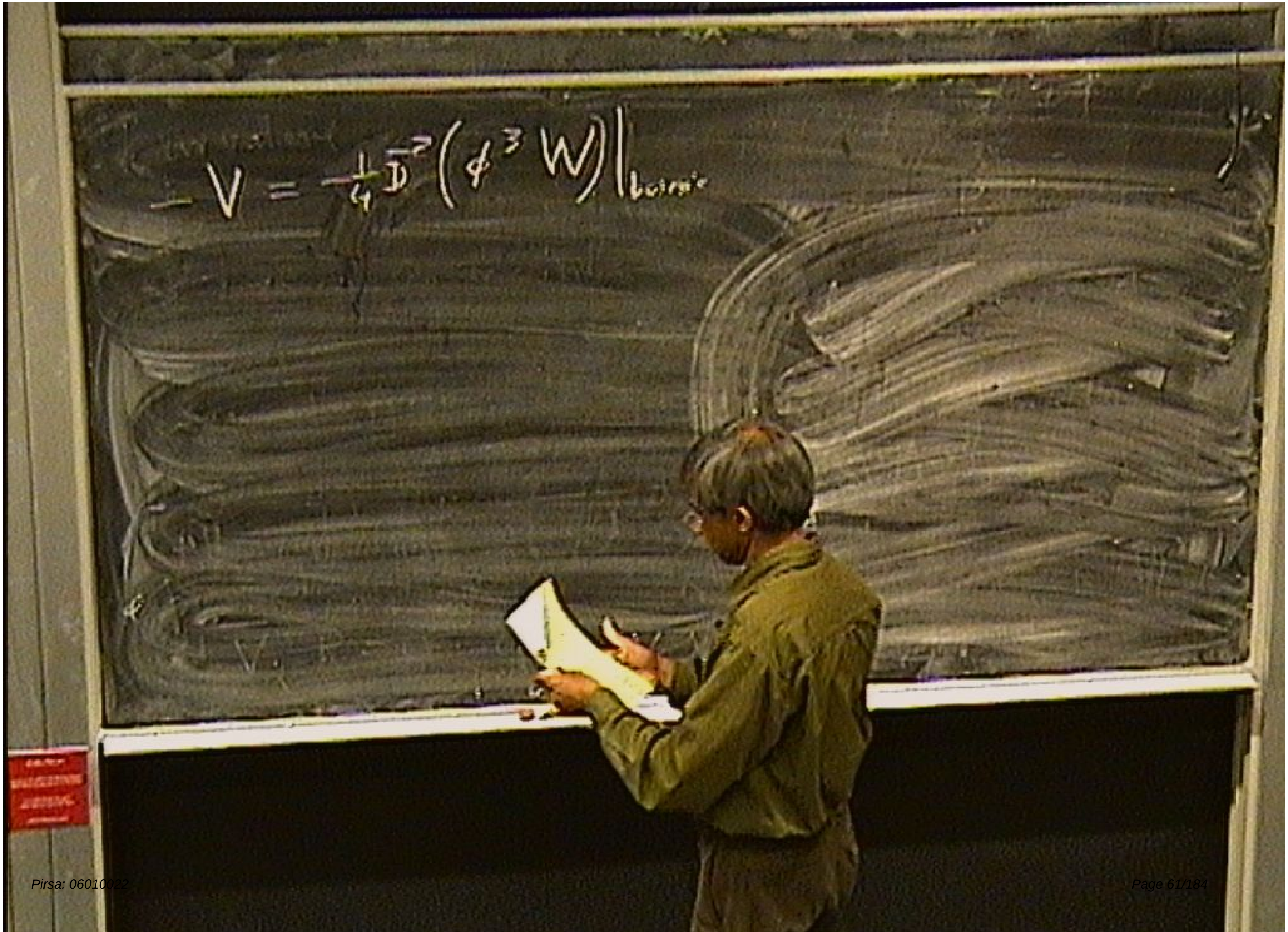
$$= -\frac{\phi^3}{\phi\bar\phi} e^{K/3} K^{i\bar{j}} D_i W$$

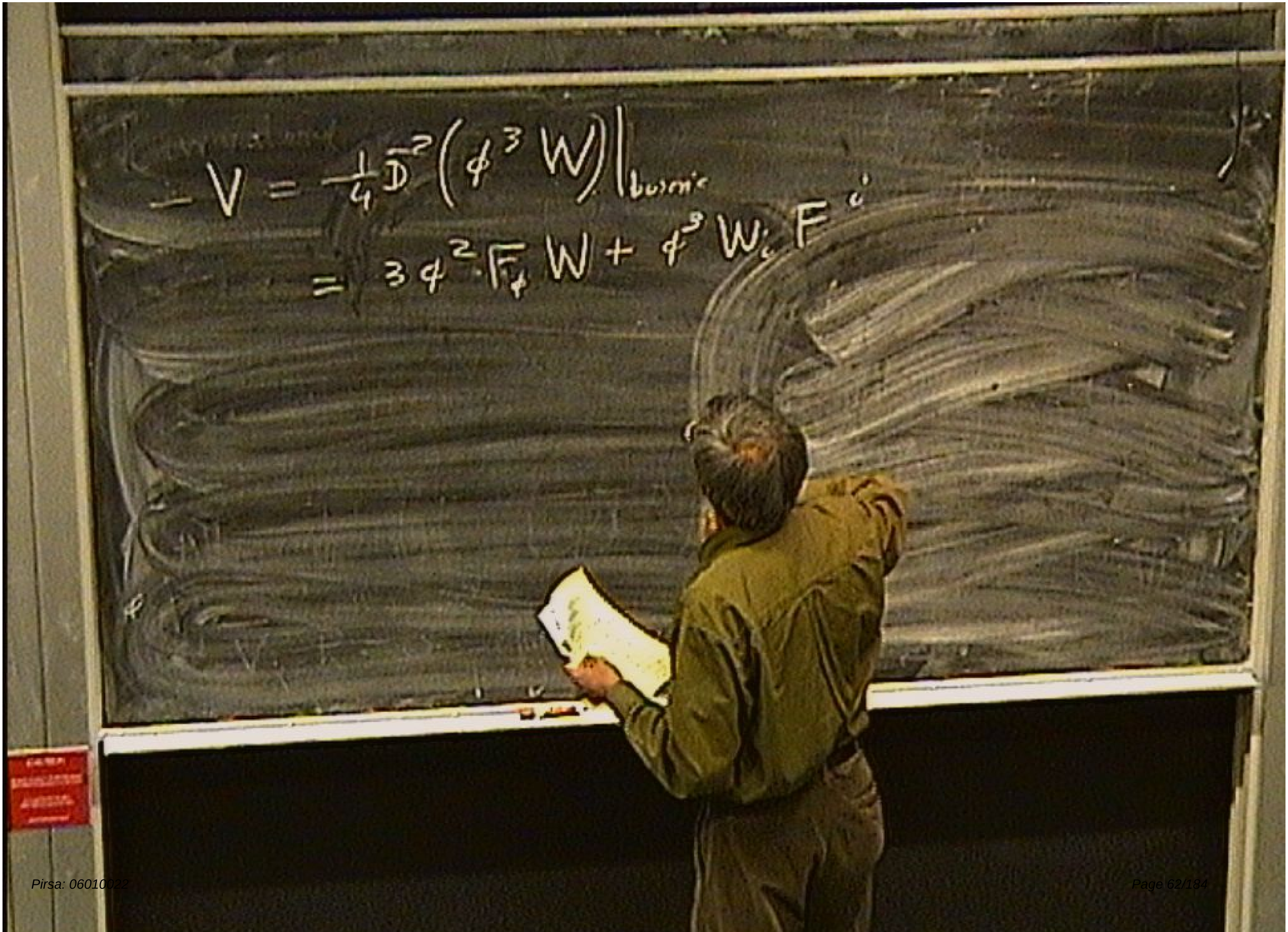

$-V = \int d^2\theta\, \phi^3$


$-V = \int d^2\theta\, \phi^3 W \Big|_{\text{bosonic}}$

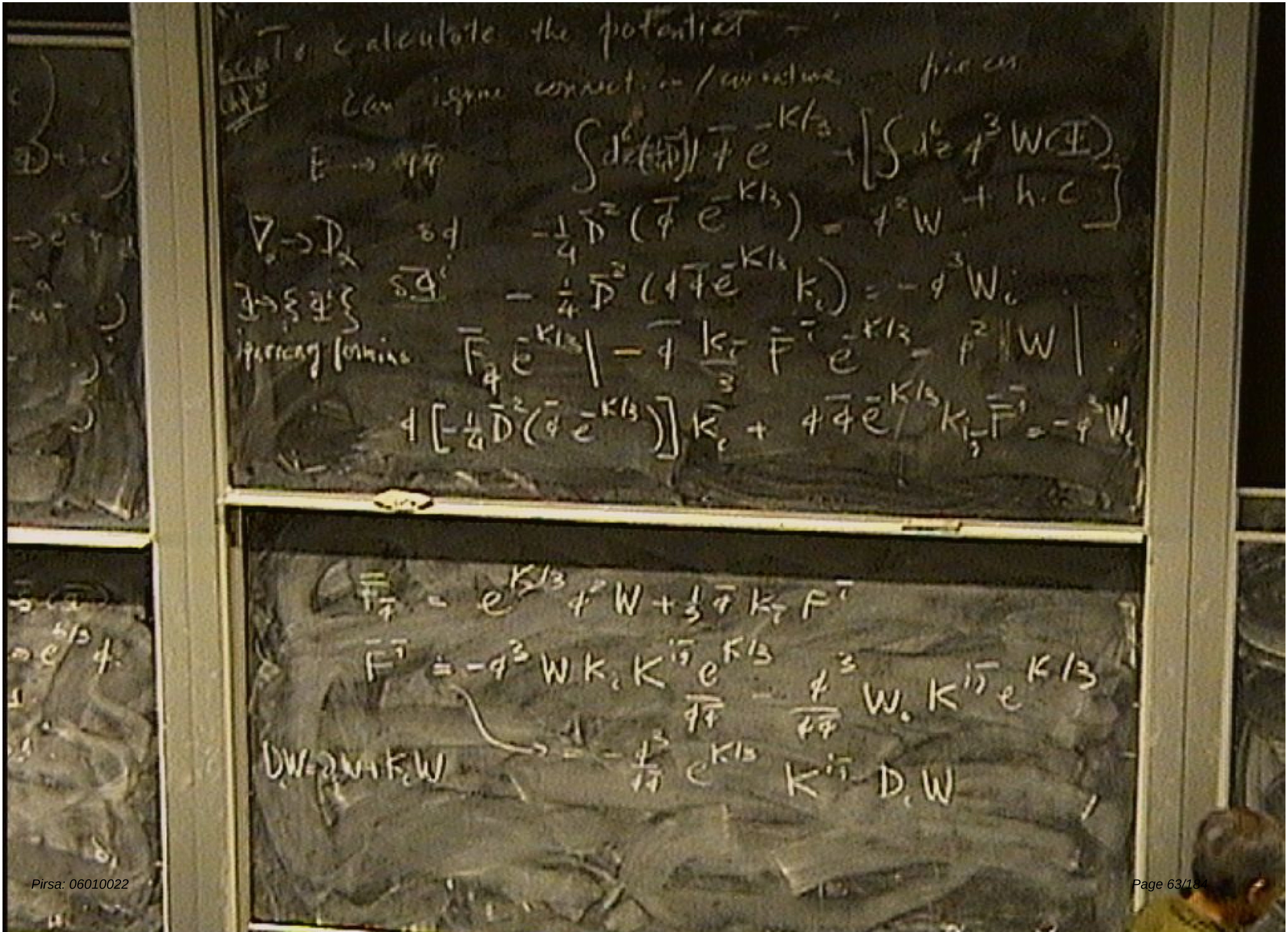

$-V = \frac{1}{4}\bar{D}^2(\phi^3 W)|$

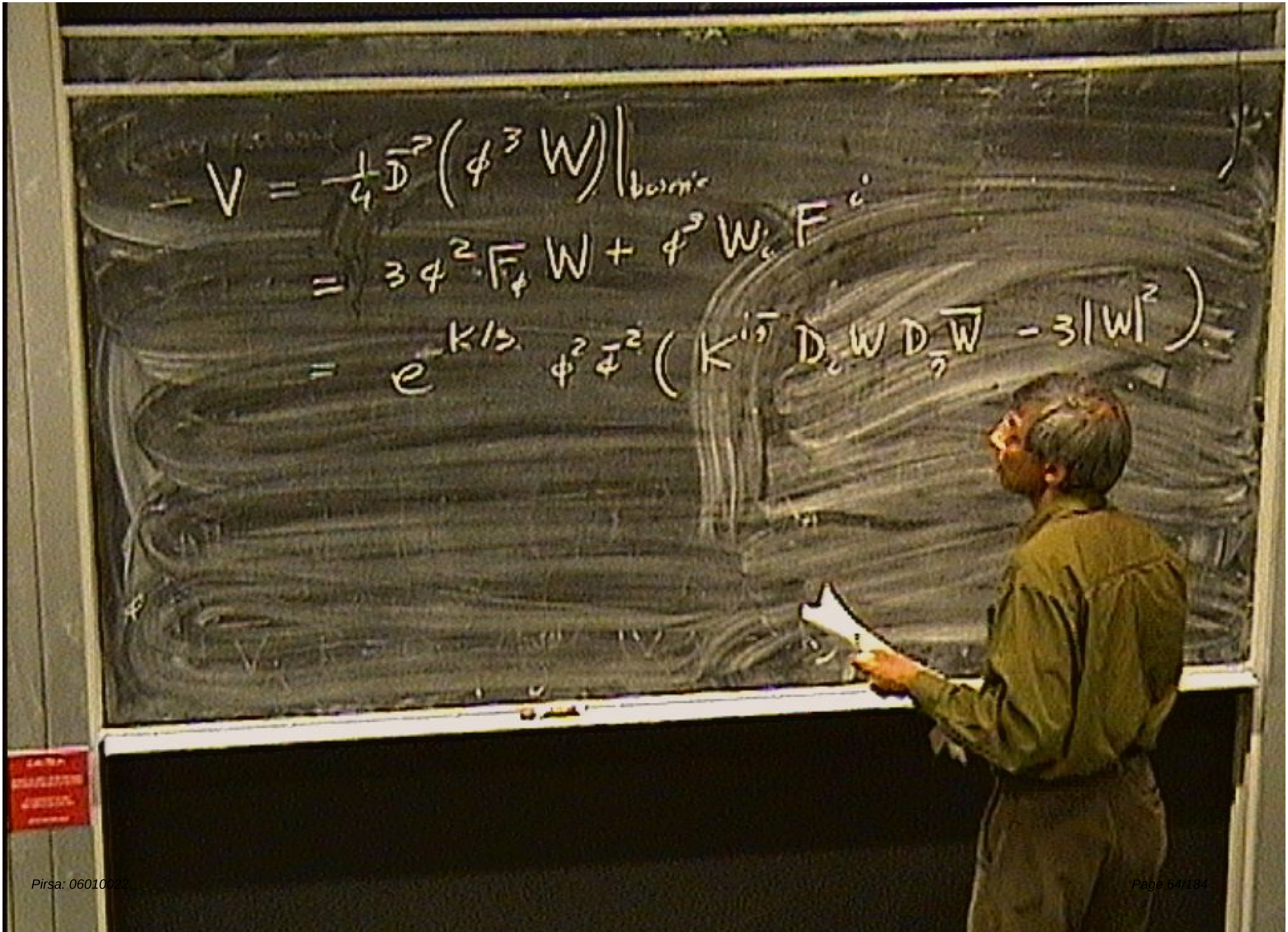

$\phi\left[-\frac{1}{4}\bar{D}^2(\bar{\phi}\, e^{-K/3})\right]K_i + \phi\bar{\phi}\, e^{-K/3} K_{i\bar{j}}\bar{F}^{\bar{j}} = -\phi^3 W$
$\bar{F}_{\bar{\phi}} = e^{K/3}\phi^2 W + \frac{1}{3}\bar{\phi} K_i F^i$
$F^i = -\phi^3 W K_{\bar{j}} K^{i\bar{j}} \frac{e^{K/3}}{\phi\bar{\phi}} - \frac{\phi^3}{\phi\bar{\phi}} W_{\bar{j}} K^{i\bar{j}} e^{K/3}$
$D_i W = \partial_i W + K_i W$
$= -\frac{\phi^3}{\phi\bar{\phi}} e^{K/3} K^{i\bar{j}} D_{\bar{j}} W$


$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)|_{\text{bosonic}}$



$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)|_{bosonic}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$

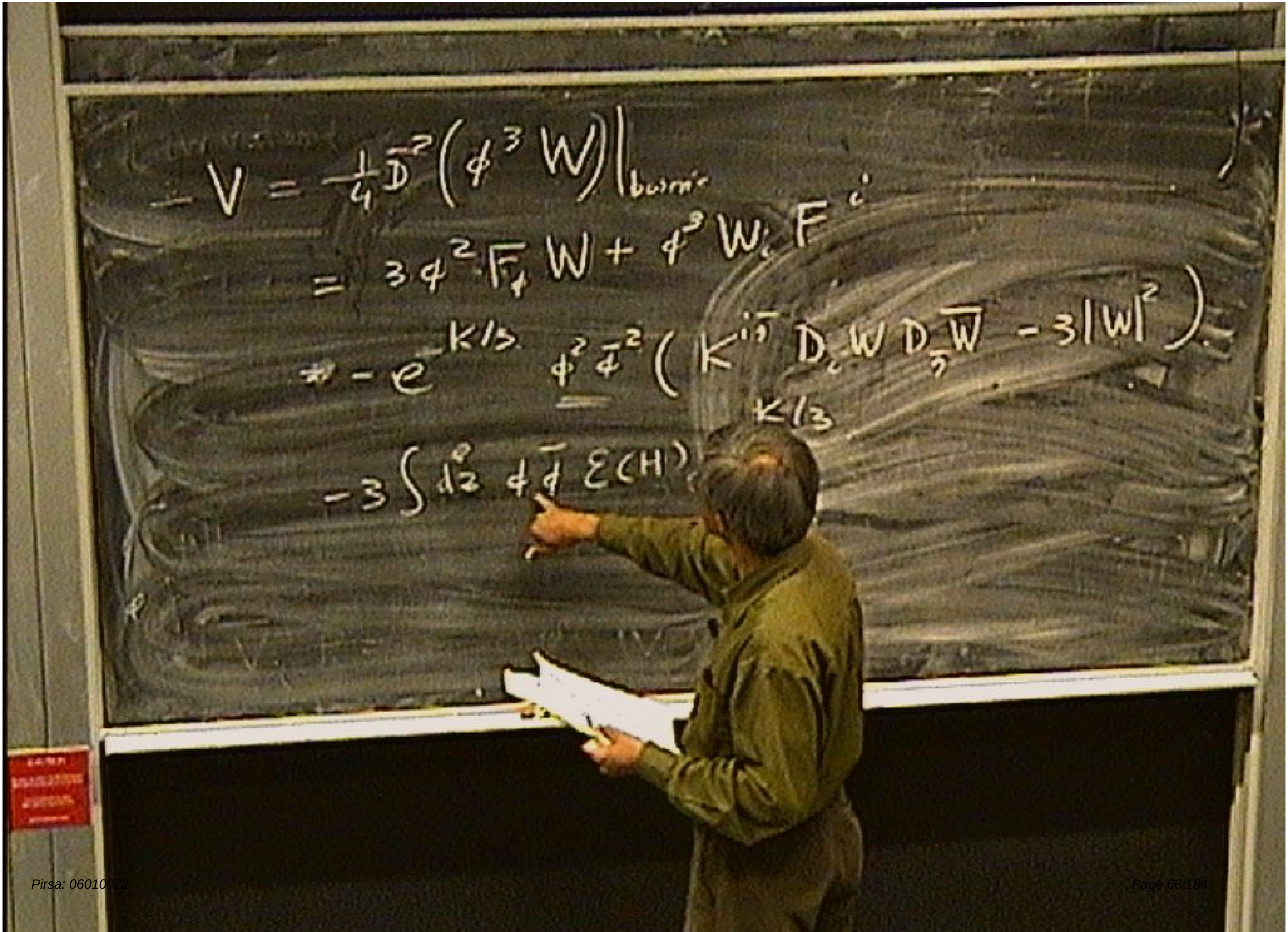

To calculate the potential
Can ignore connection / curvature pieces
$D_i W = \partial_i W + K_i W$

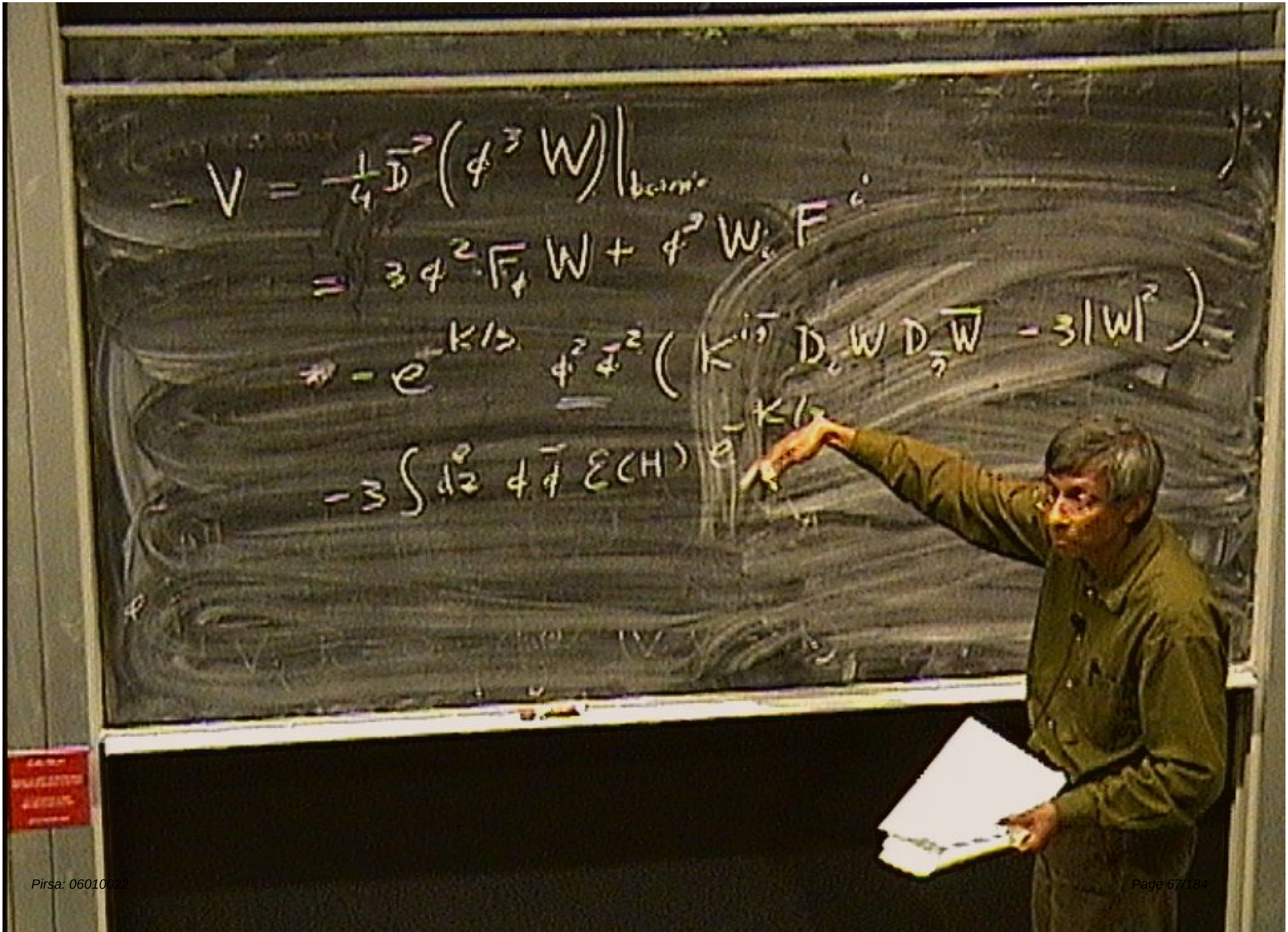

$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\big|_{\text{bosonic}}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$= e^{K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\overline{W} - 3|W|^2\right)$

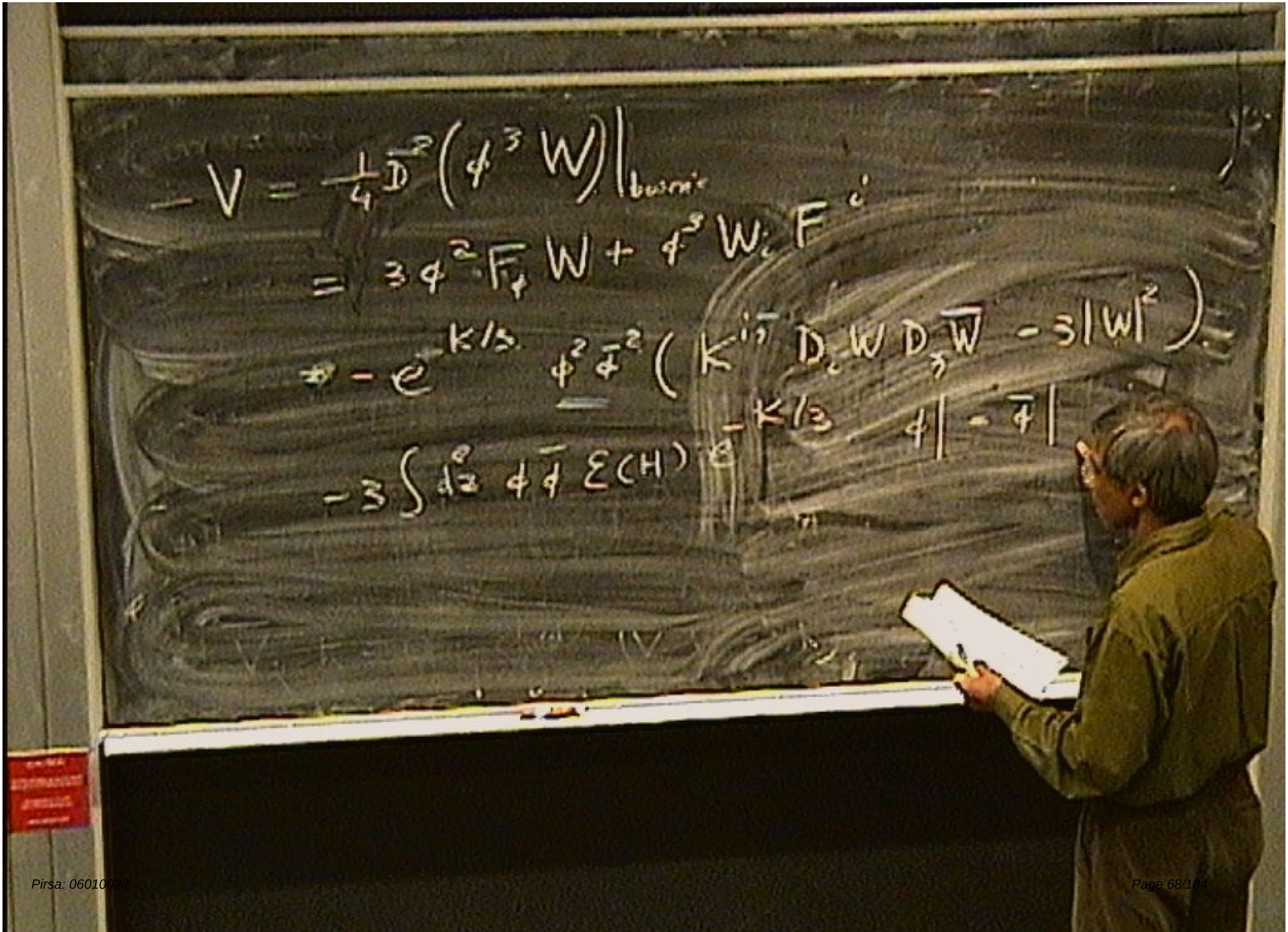
$$-V = -\frac{1}{4}\bar{D}^2\left(\phi^3 W\right)\Big|_{\text{bosonic}}$$

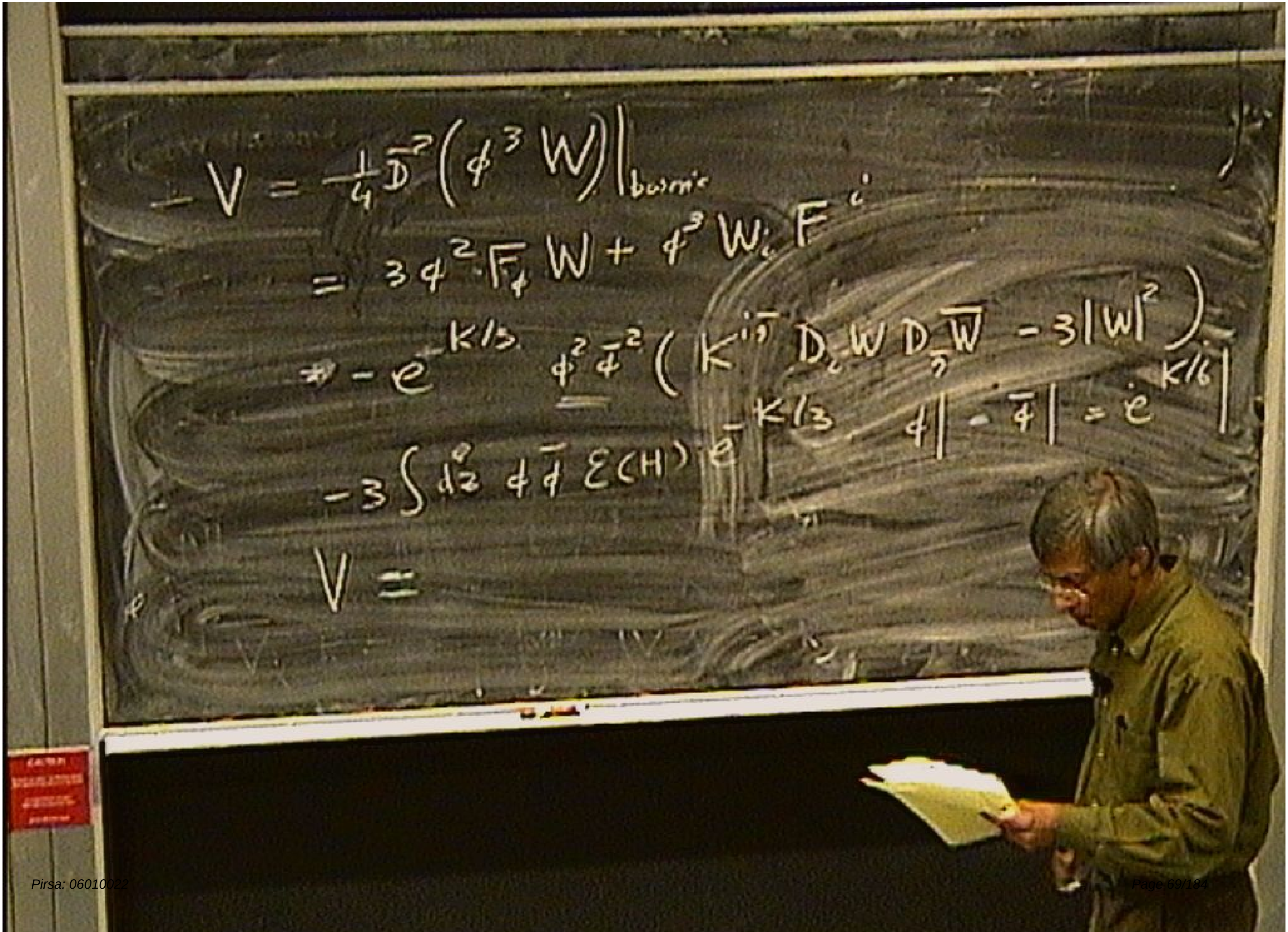
$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

$$= -e^{K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2\right)$$


$V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\big|_{bosonic}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$- e^{K/3}\,\phi^2\bar{\phi}^2\,(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2)$
$K/3$
$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)$


$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)|_{\text{bosonic}}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$= -e^{-K/3}\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2\right)$
$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3}$


$-V = -\frac{1}{4} D^2 (\phi^3 W)\big|_{\text{bosonic}}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$= -e^{K/3} \phi^2 \bar{\phi}^2 \left(K^{i\bar{j}} D_i W D_{\bar{j}} \bar{W} - 3|W|^2 \right)$
$-3 \int d^2 z \, \phi \bar{\phi} \, \mathcal{E}(H) \, e^{-K/3} \, \phi| - \bar{\phi}|$



$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)|_{\text{bosonic}}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$= -e^{-K/3}\phi^2\bar{\phi}^2(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2)$
$e^{-K/3} \quad \phi| = \bar{\phi}| = e^{K/6}|$
$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)$
$V =$

$$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\big|_{\text{bosonic}}$$

$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

$$-e^{-K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2\right)$$

$$\phi| = \bar{\phi}| = e^{K/6}|$$

$$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3}$$

$$V = e^K\left(D_i W D_{\bar{j}}\bar{W} K^{i\bar{j}} - 3|W|^2\right)$$

$$G = K + \ln|W|^2$$

$$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\Big|_{\text{bosonic}}$$

$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

$$= -e^{K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\overline{W} - 3|W|^2\right)$$

$$\phi\big| = \bar{\phi}\big| = e^{K/6}\big|$$

$$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3}$$

$$V = e^{K}\left(D_i W D_{\bar{j}}\overline{W} K^{i\bar{j}} - 3|W|^2\right)$$

$$G = K + \ln|W|^2$$

$$= e^{G}\left(\partial_i G\, \partial_{\bar{j}} G - 3\right)$$

$$V = -\frac{1}{4}\bar{D}^2 (\phi^3 W)\Big|_{\text{bosonic}}$$

$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

$$= -e^{K/3} \phi^2 \bar{\phi}^2 \left(K^{i\bar{j}} D_i W D_{\bar{j}} \bar{W} - 3|W|^2 \right)$$

$$\phi| = \bar{\phi}| = e^{K/6}|$$

$$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3}$$

$$V = e^K \left(D_i W D_{\bar{j}} \bar{W} K^{i\bar{j}} - 3|W|^2 \right)$$

$$G = K + \ln|W|^2$$

$$= e^G \left(\partial_i G \partial_{\bar{j}} G - 3 \right)$$

$$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\Big|_{\text{bosonic}}$$

$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

$$= -e^{-K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2\right)$$

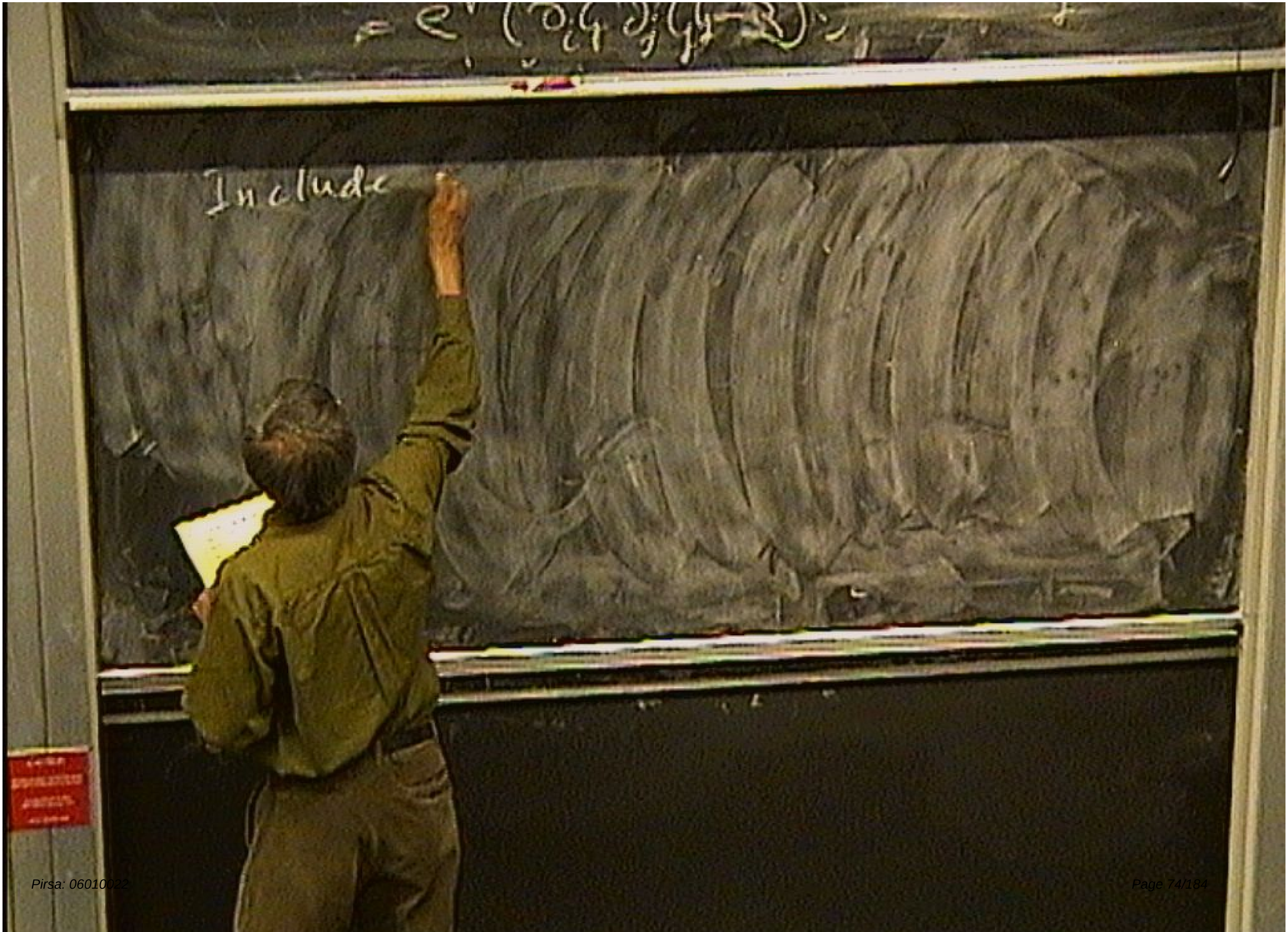
$$\phi| = \bar{\phi}| = e^{K/6}|$$

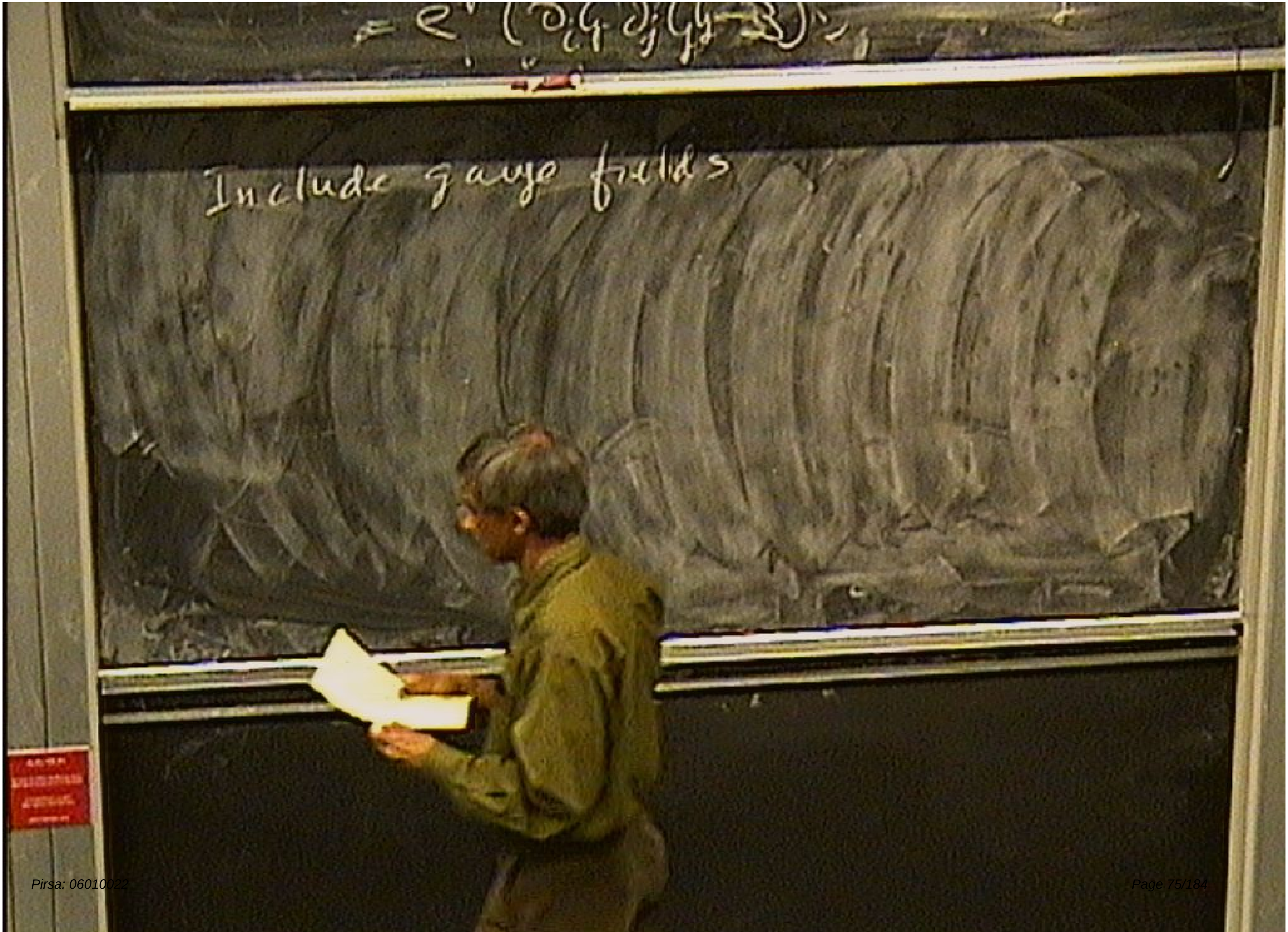
$$-3\int d^2z\,\phi\bar{\phi}\,\mathcal{E}(H)\,e^{-K/3}$$

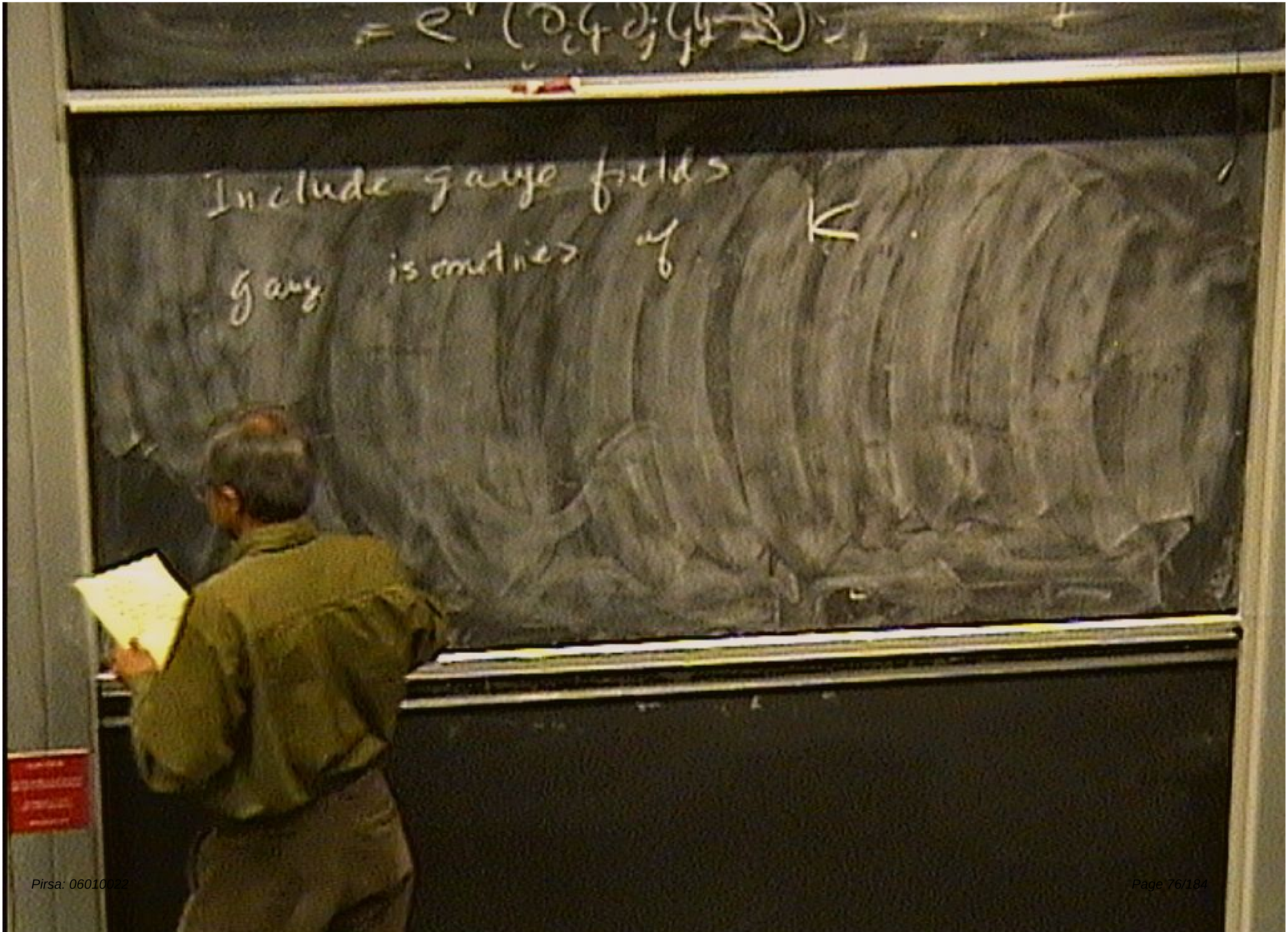
$$V = e^{K}\left(D_i W D_{\bar{j}}\bar{W} K^{i\bar{j}} - 3|W|^2\right)$$

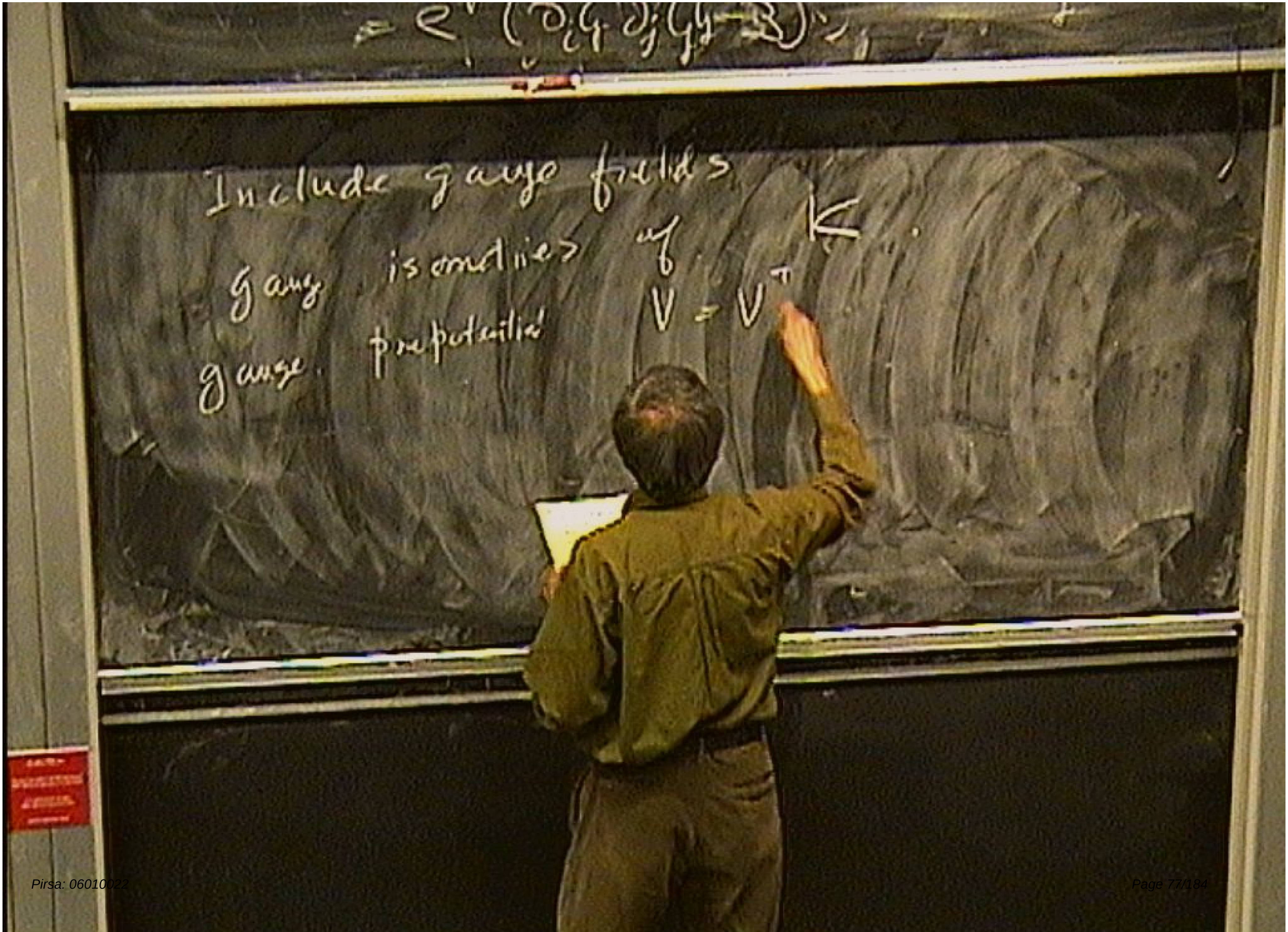
$$= e^{G}\left(\partial_i G\,\partial_{\bar{j}} G\, G^{i\bar{j}} - 3\right)$$

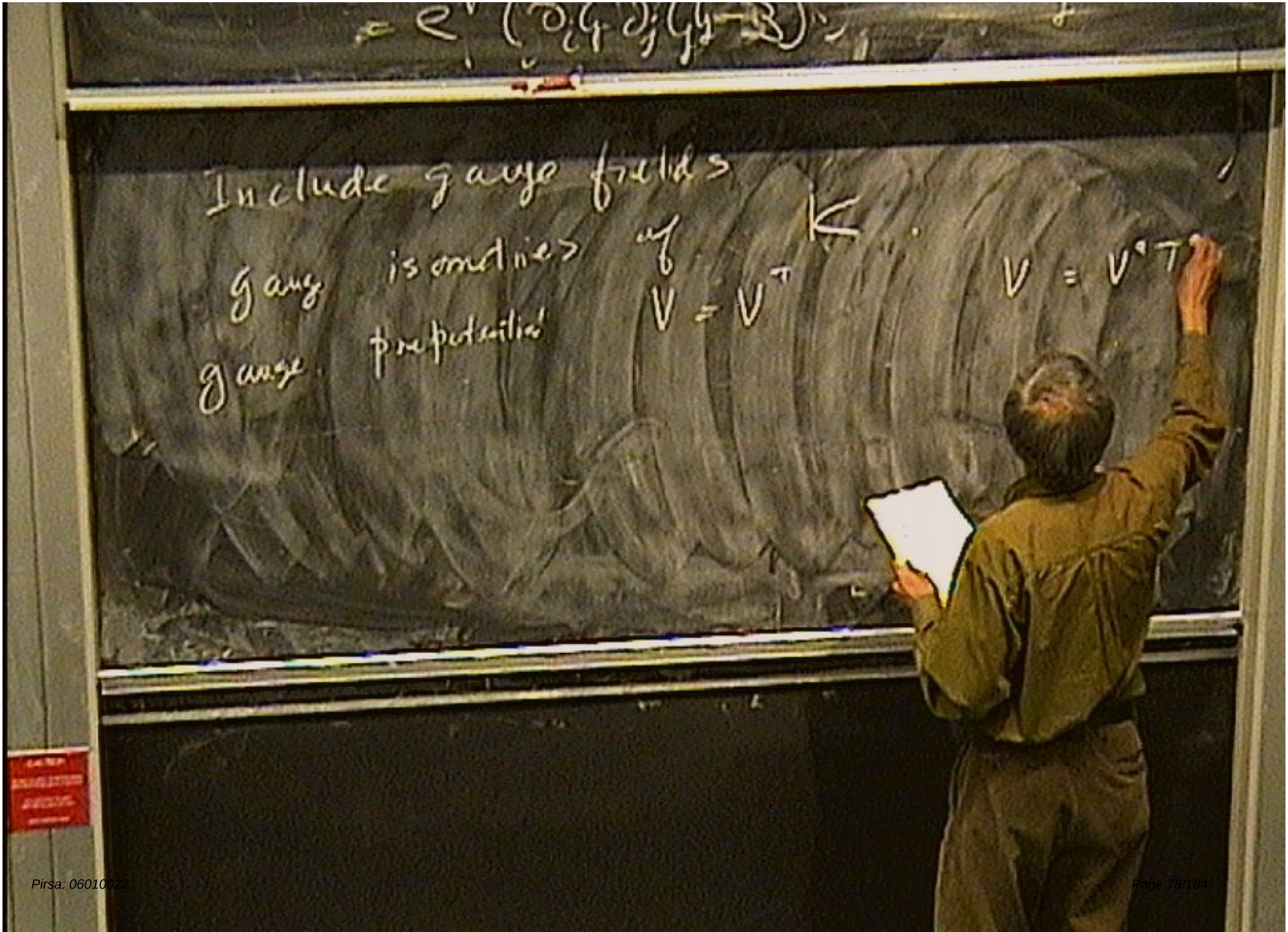
$$G = K + \ln|W|^2$$

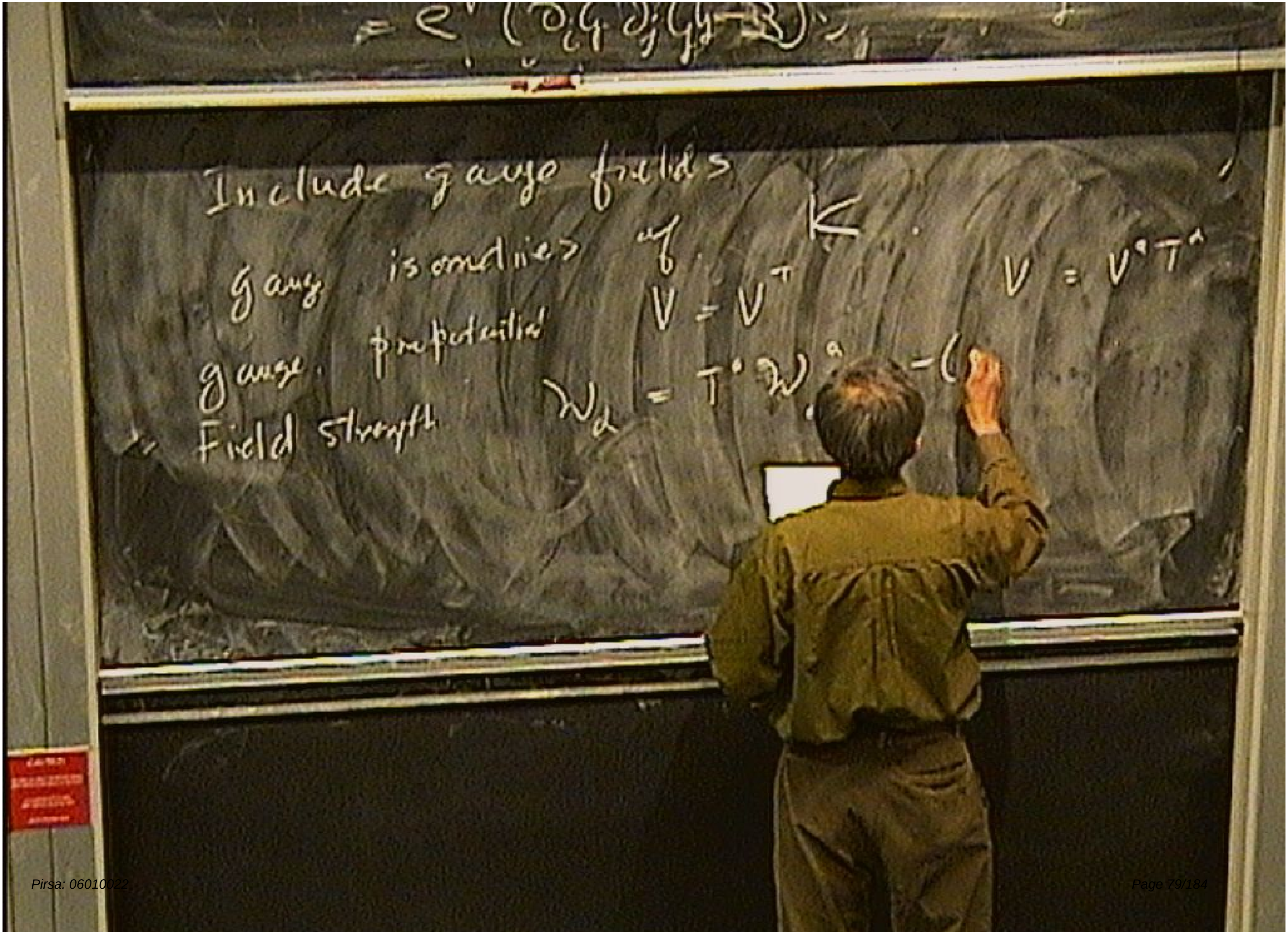

Include

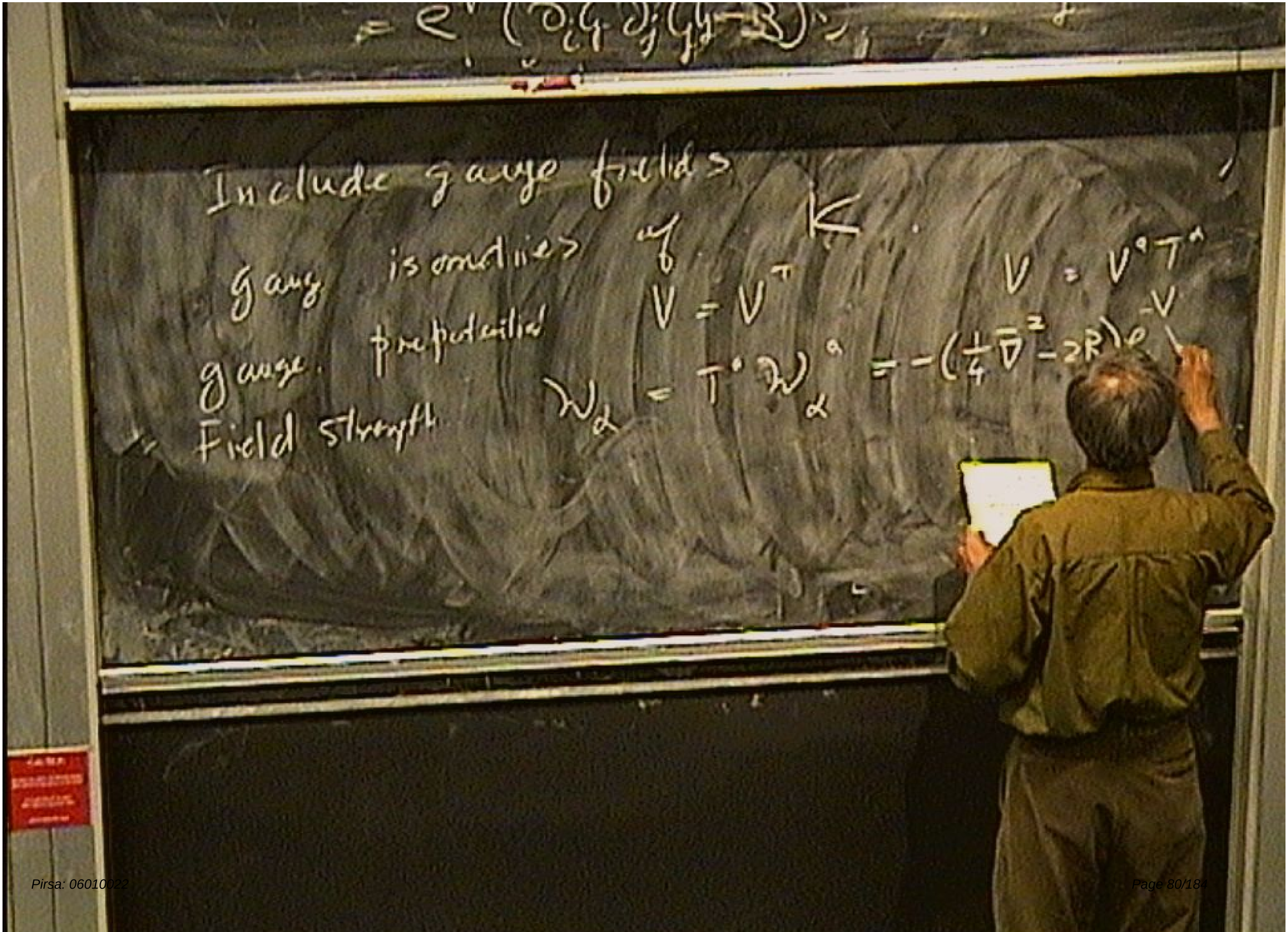

Include gauge fields

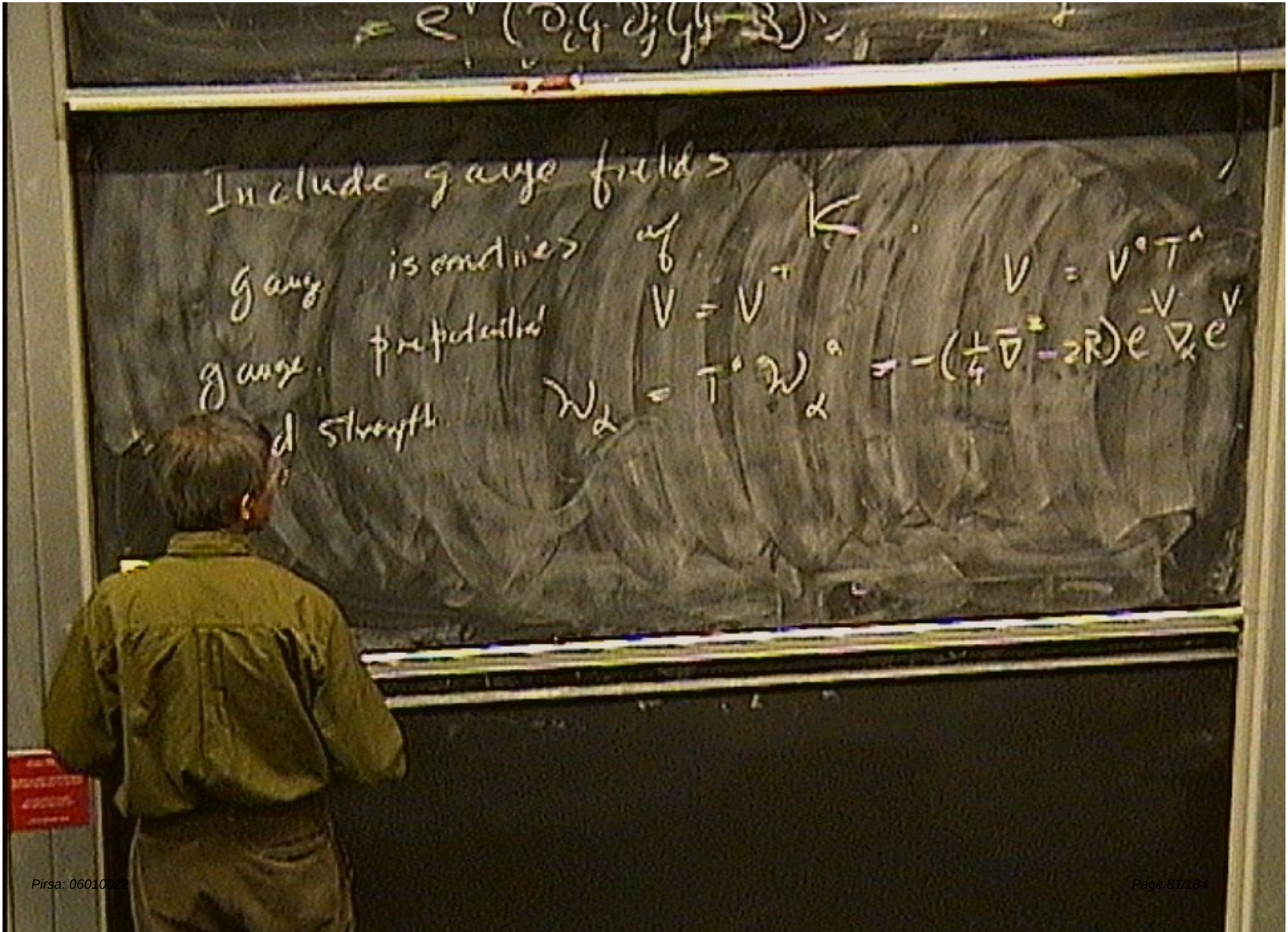

Include gauge fields
gauge isometries of K

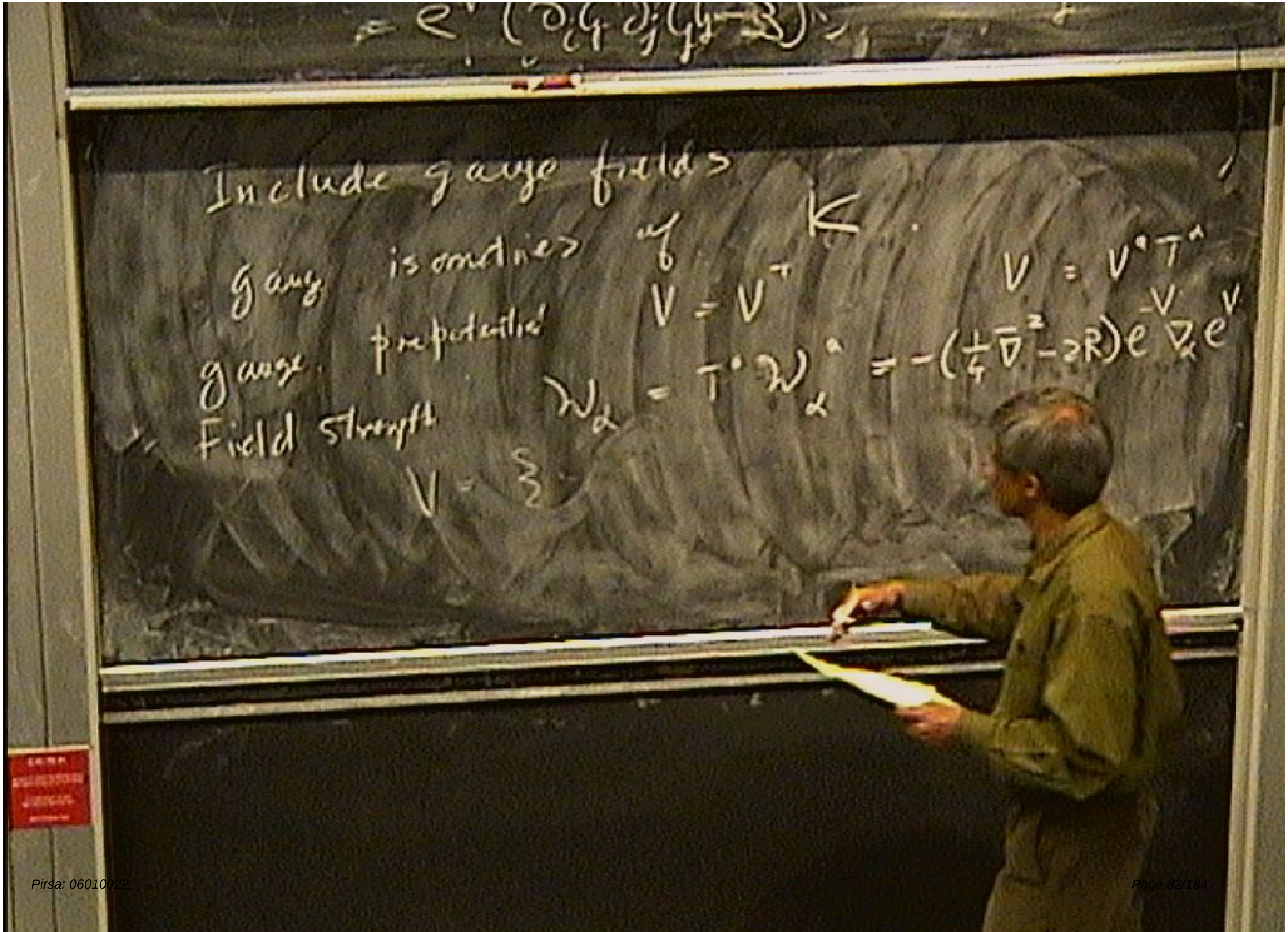

Include gauge fields
gauge isometries of K
gauge prepotential V = V†

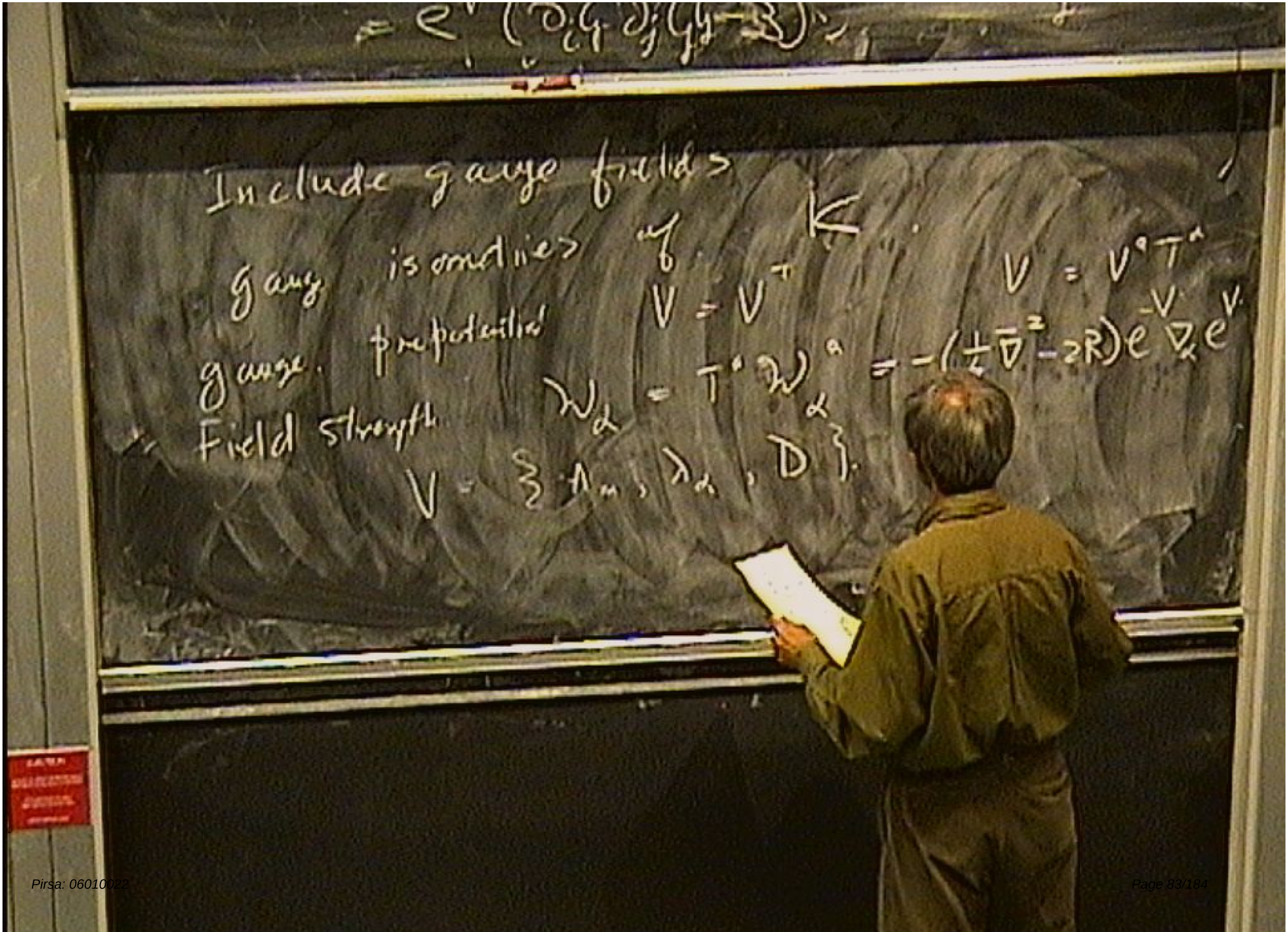

Include gauge fields
gauge isometries of K
gauge prepotential $V = V^\dagger$
$V = V' T$


Include gauge fields
gauge isometries of K
V = V^T
V = V^a T^a
gauge prepotential
Field strength
W_α = T^a W_α^a


Include gauge fields
gauge isometries of K
$V = V^a T^a$
gauge prepotential $V = V^\dagger$
Field strength $W_\alpha = T^a W_\alpha^a = -(\frac{1}{4}\bar{D}^2 - 2R)e^{-V}$


Include gauge fields
gauge isometries of K
V = V^a T^a
gauge prepotential V = V^†
gauge field strength W_α = T^a W_α^a = −(¼ D̄² − 2R) e^{−V} ∇_α e^V


Include gauge fields
gauge isometries of K
$V = V^a T^a$
gauge prepotential $V = V^\dagger$
$e^{-V} D_\alpha e^V$
gauge $W_\alpha = T^a W_\alpha^a = -(\frac{1}{4}\bar{D}^2 - 2R)$
Field strength
$V = \xi$


Include gauge fields
gauge isometries of K
$V = V^a T^a$
gauge prepotential $V = V^\dagger$
gauge. Field strength $\mathcal{W}_\alpha = T^a \mathcal{W}_\alpha^a = -(\frac{1}{4}\bar{\mathcal{D}}^2 - 2R) e^{-V} \mathcal{D}_\alpha e^{V}$
$V = \{ A_m, \lambda_\alpha, D \}$

$= e^{V}\left(\partial_i \partial_j G - \ldots\right)$

Include gauge fields

gauge isometries of K $\qquad V = V^a T^a$

gauge prepotential $\qquad V = V^\dagger$

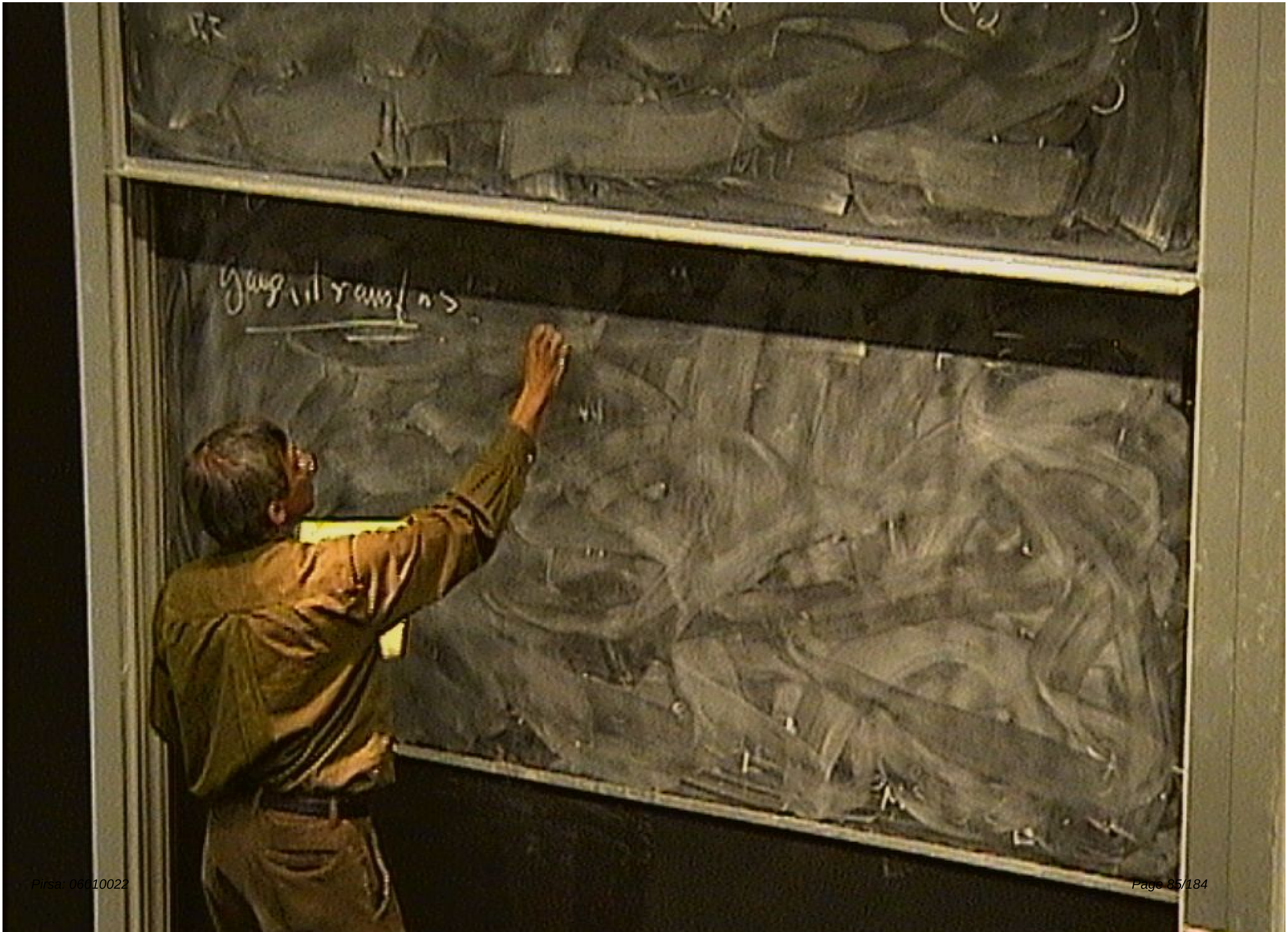
gauge

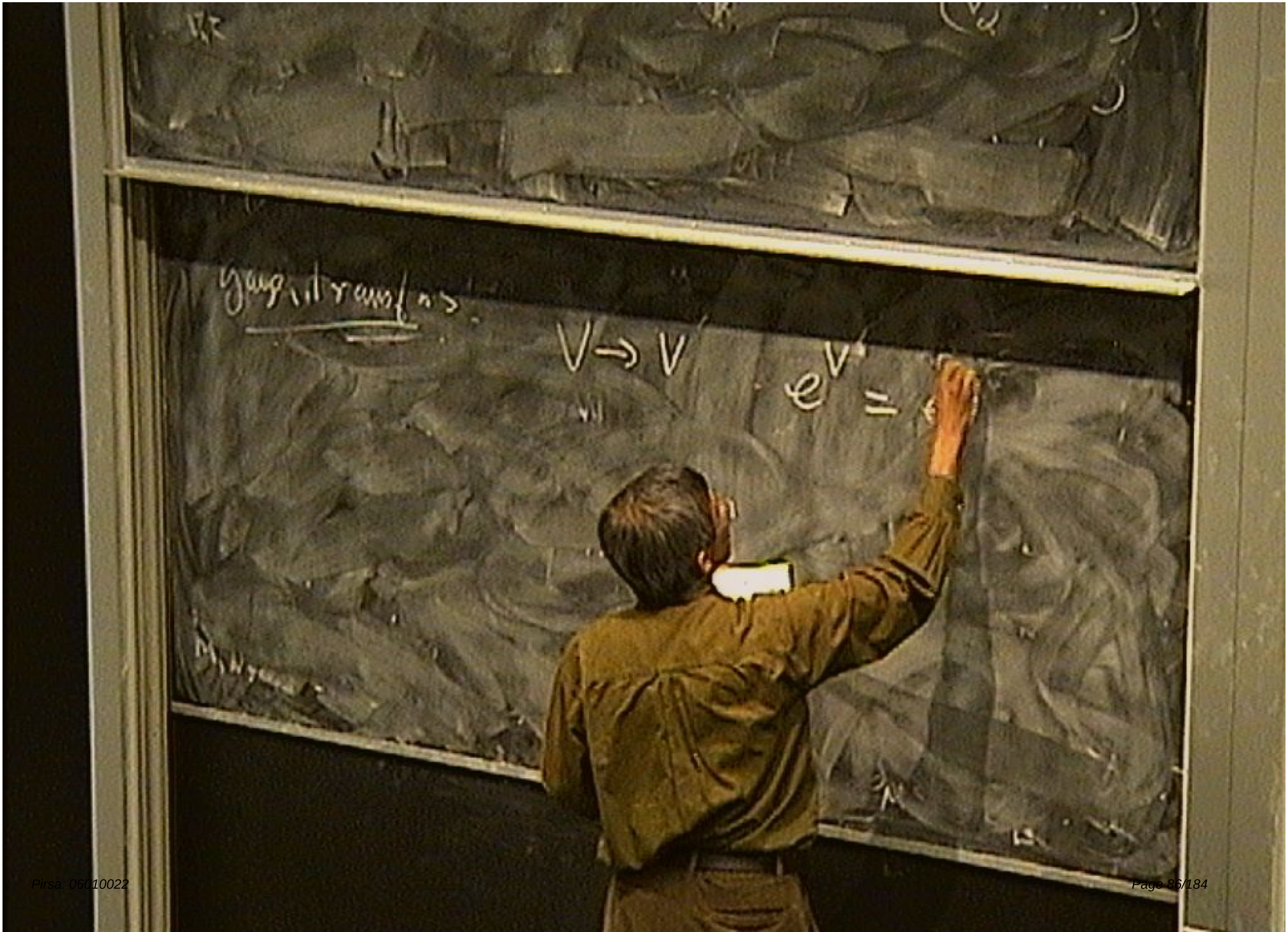
Field strength $\qquad \mathcal{W}_\alpha = T^a \mathcal{W}_\alpha^a = -\left(\frac{1}{4}\bar{\mathcal{D}}^2 - 2R\right) e^{-V} \mathcal{D}_\alpha e^{V}$

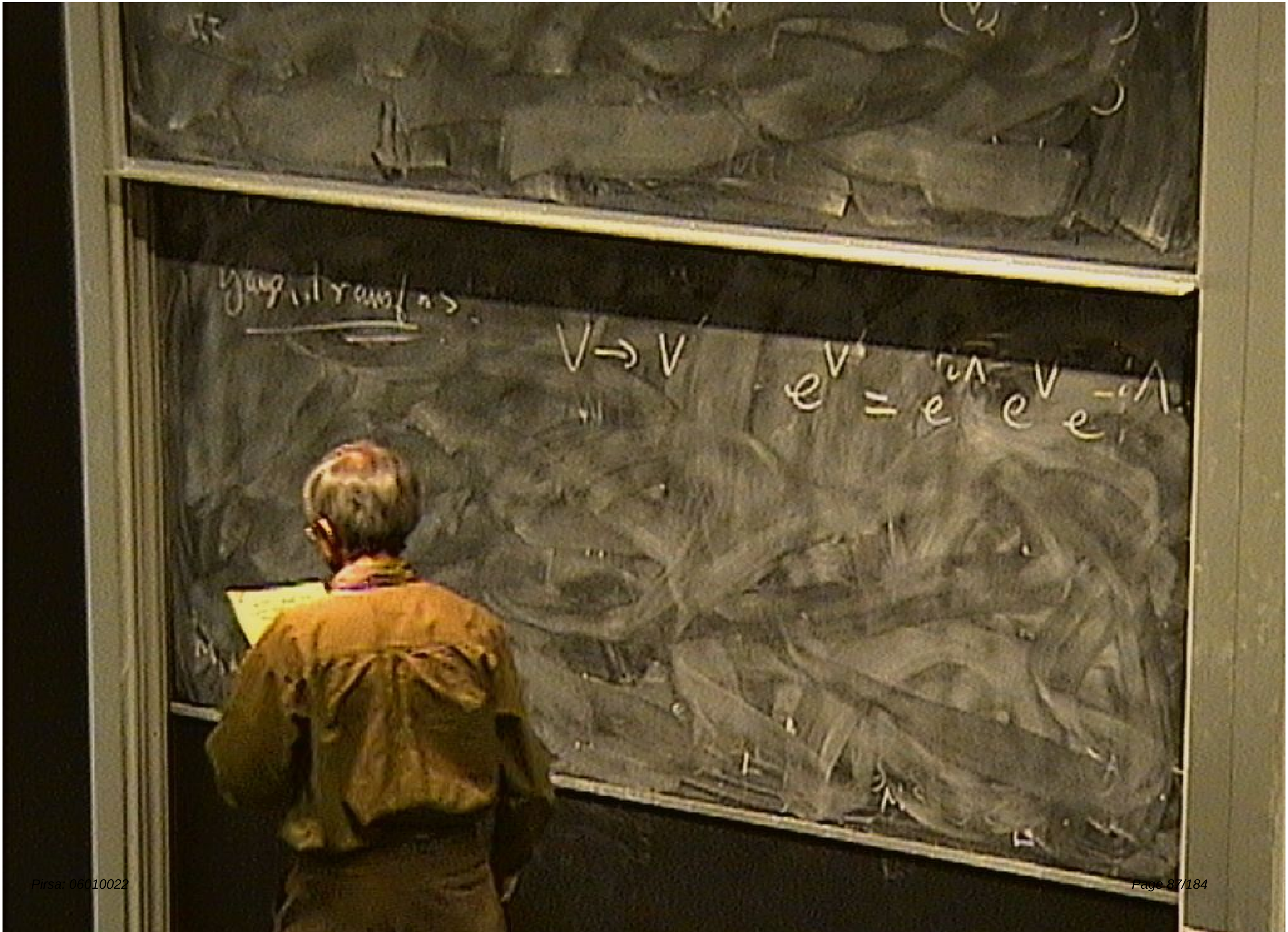
$\ldots$ WZ gauge

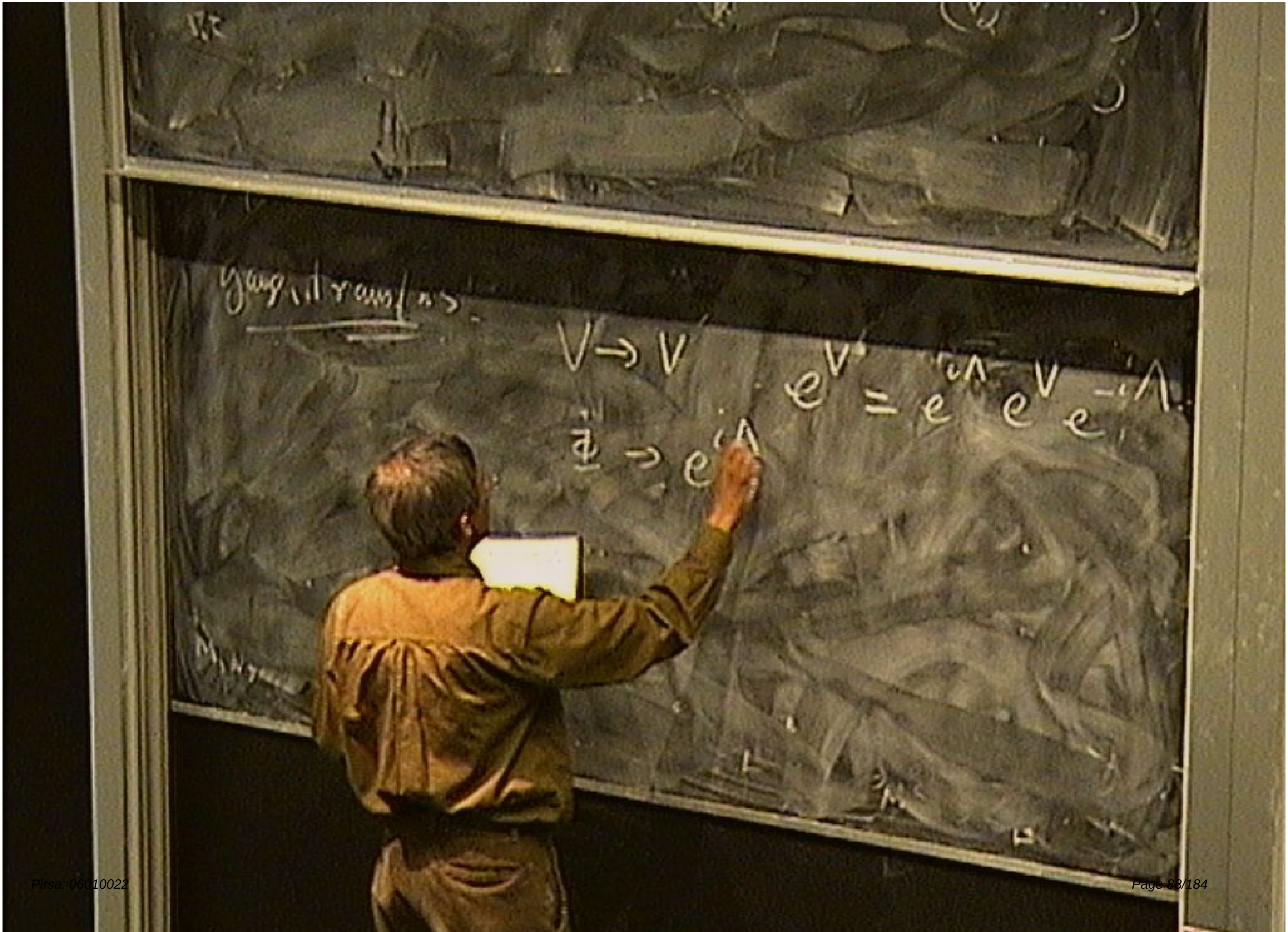
$$V = \{A_m, \lambda_\alpha, D\}$$

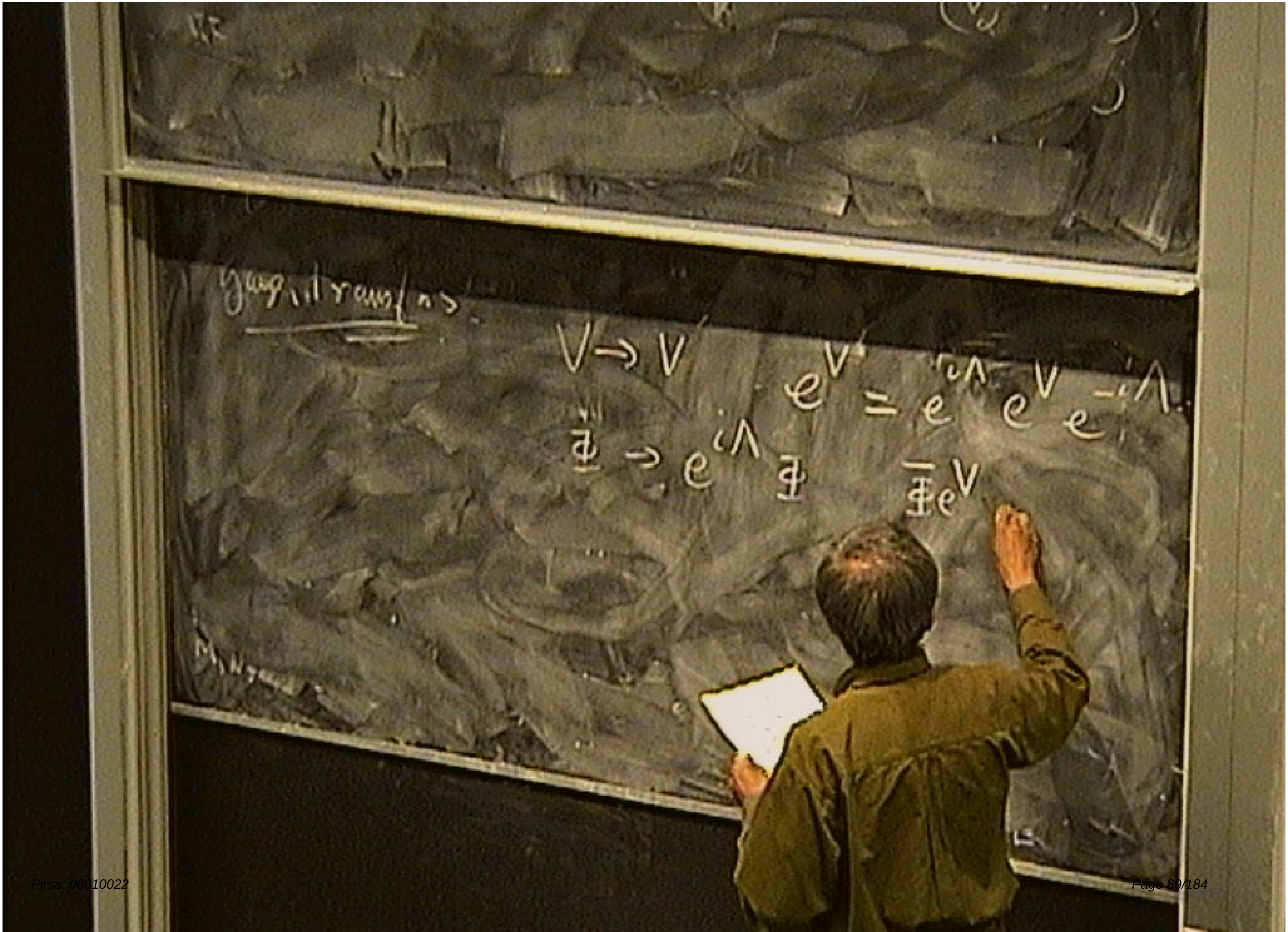
$$\mathcal{W}_\alpha = \{\lambda_\alpha, F_{mn}, D\}$$

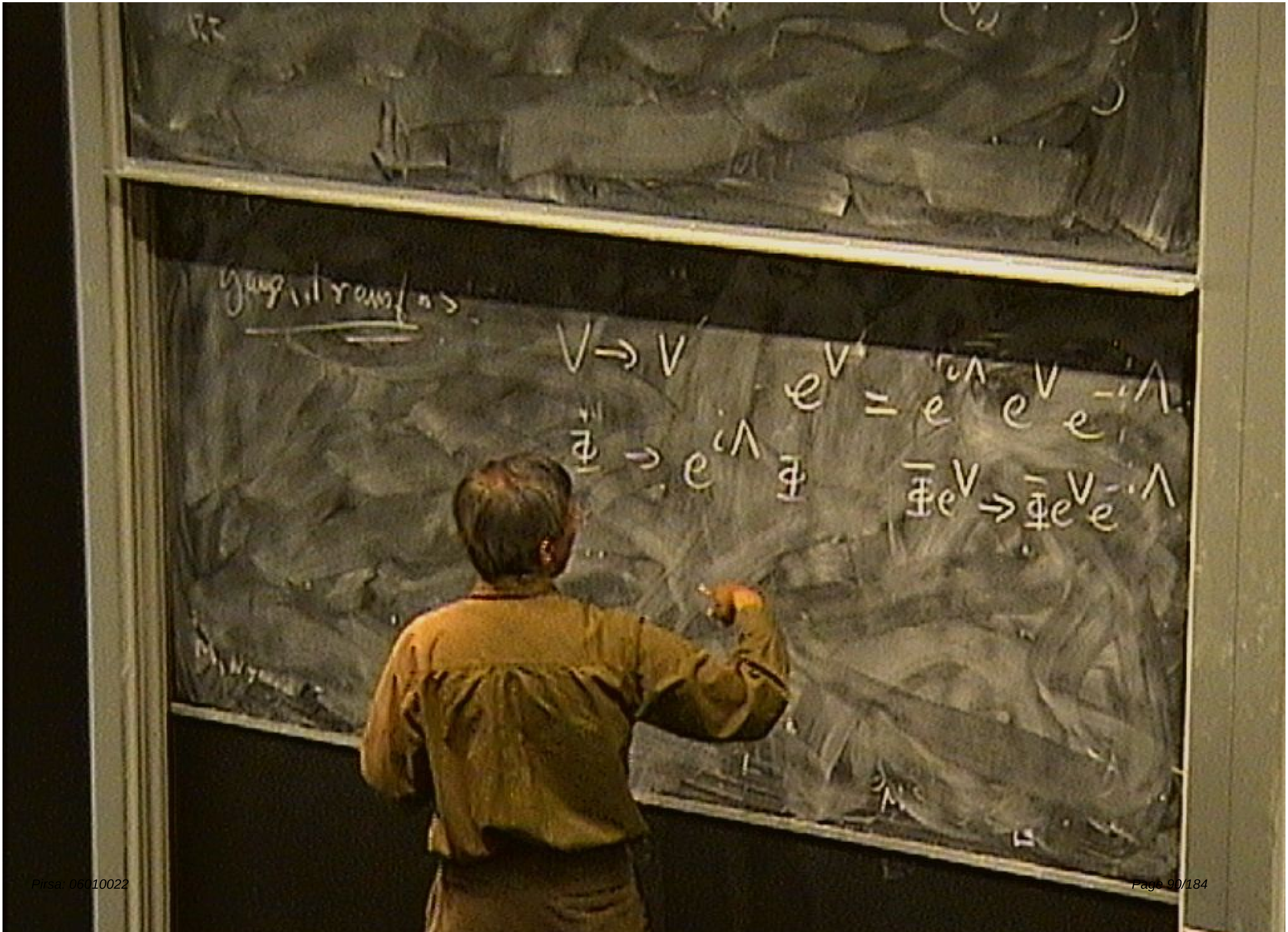


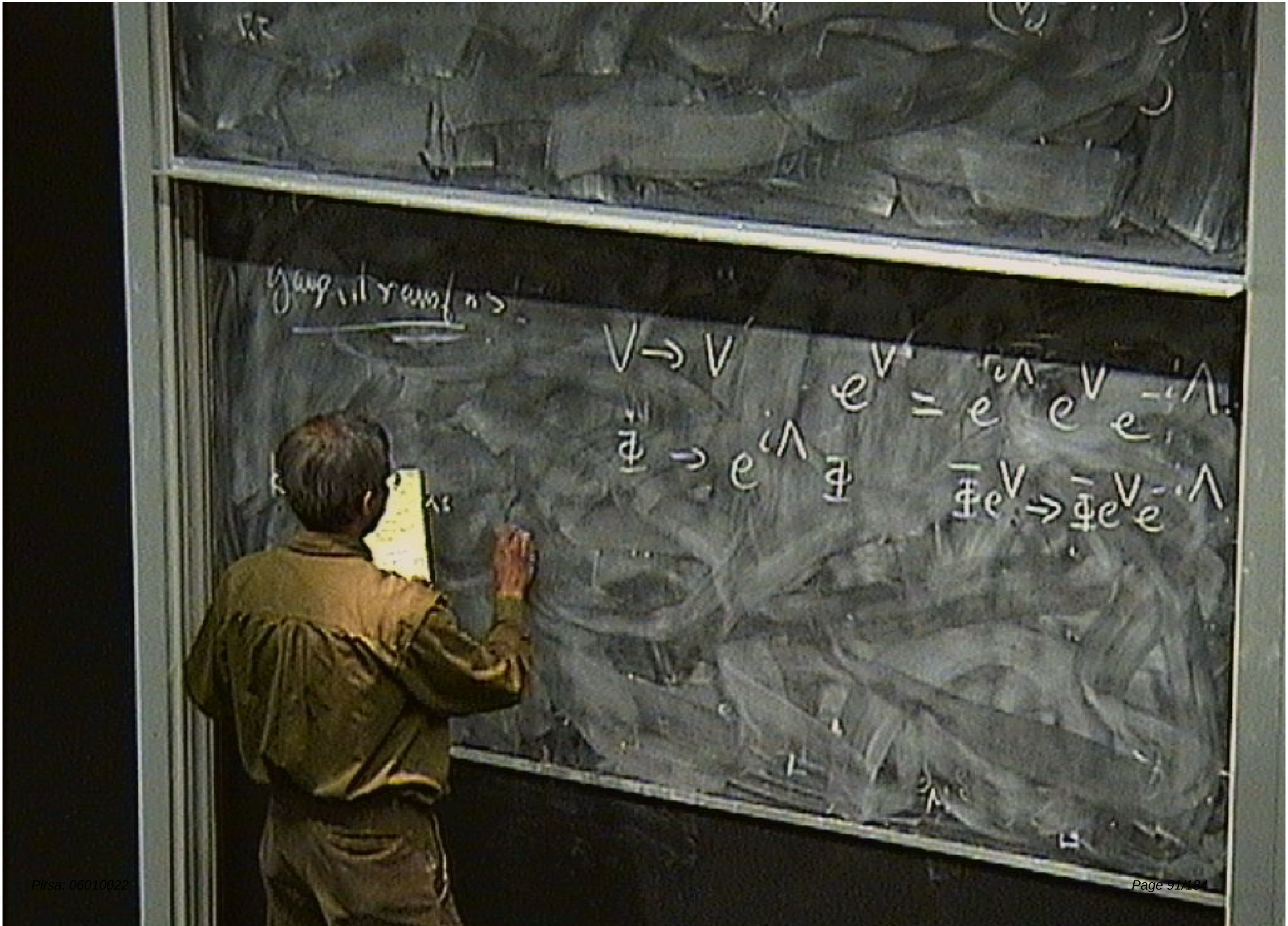

V→V

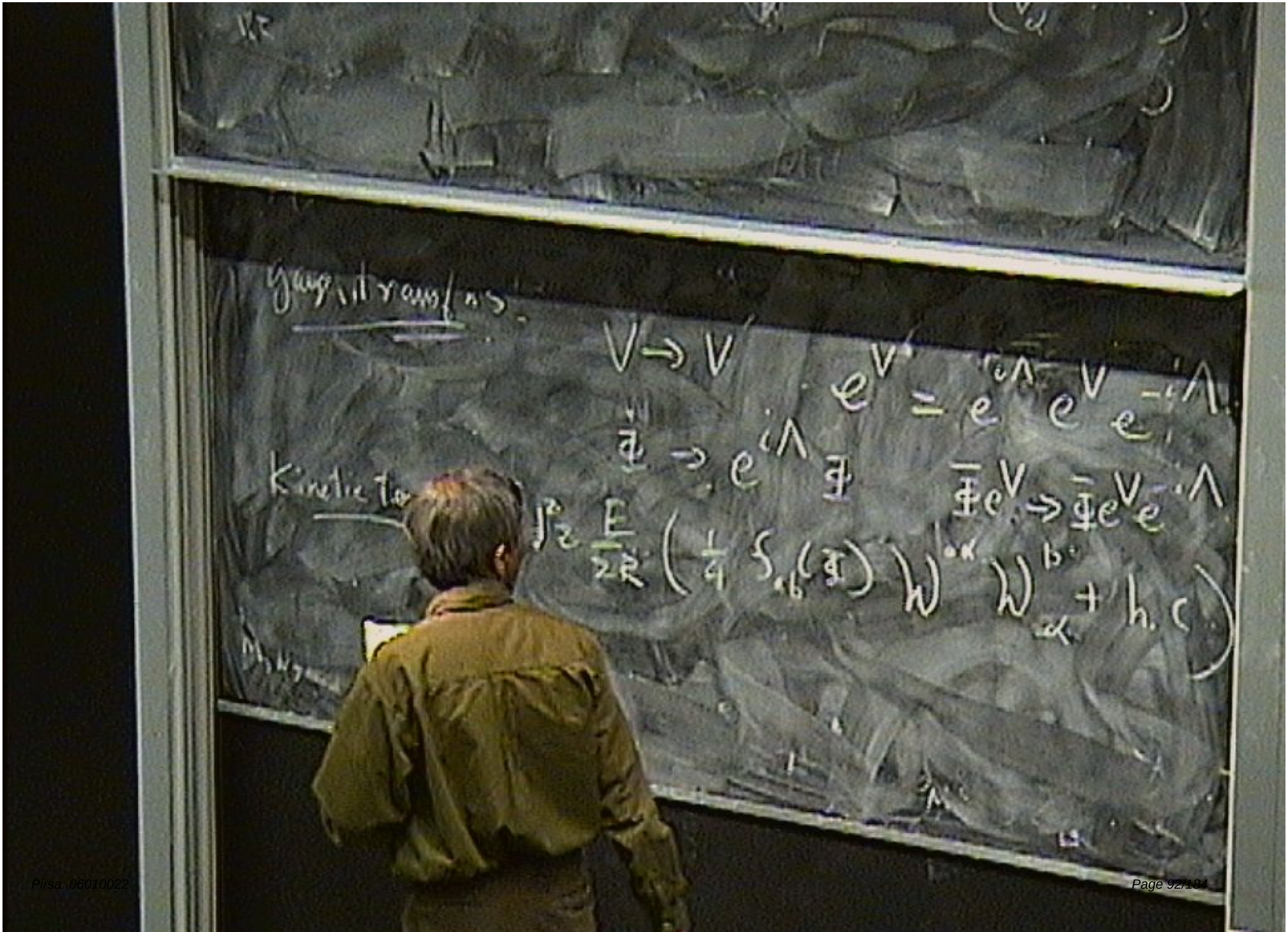

gauge transformations
V → V'
e^{V'} = e^{iΛ̄} e^{V} e^{-iΛ}

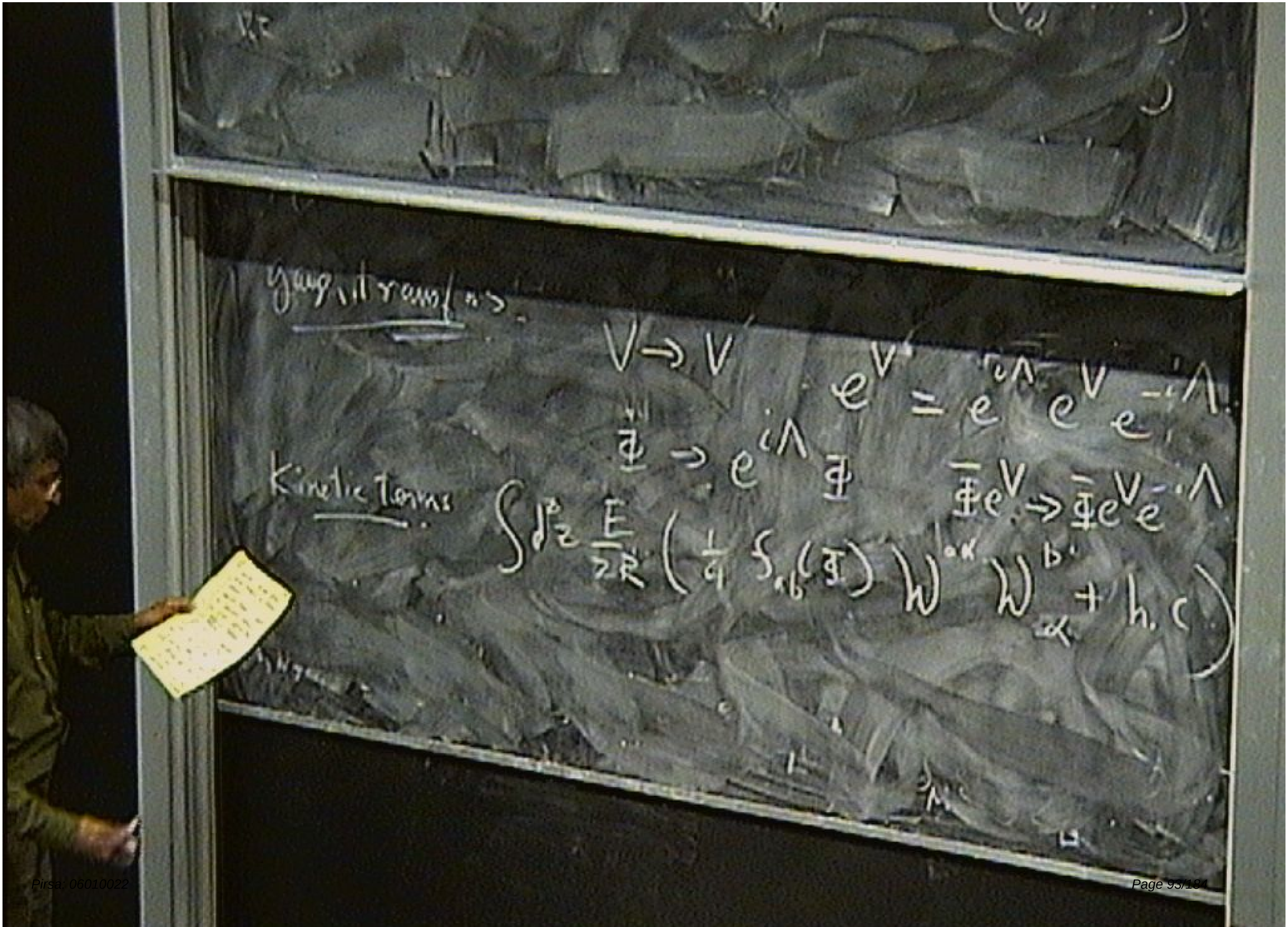

gauge transformations:
V → V'
e^V' = e^iΛ e^V e^-iΛ
Φ → e^iΛ

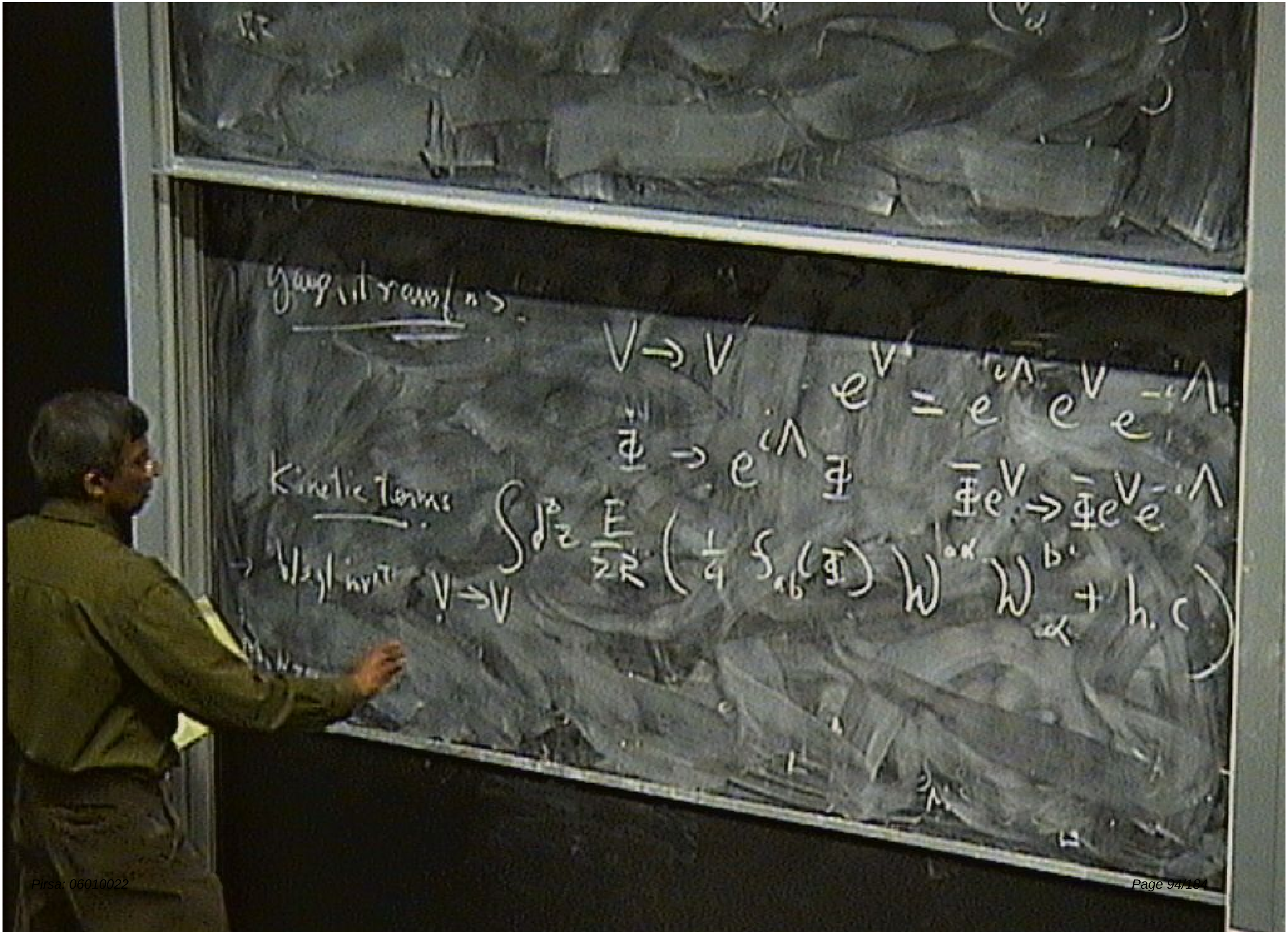

gauge transformations
V → V'
e^V' = e^iΛ̄ e^V e^-iΛ
Φ → e^iΛ Φ
Φ̄ e^V

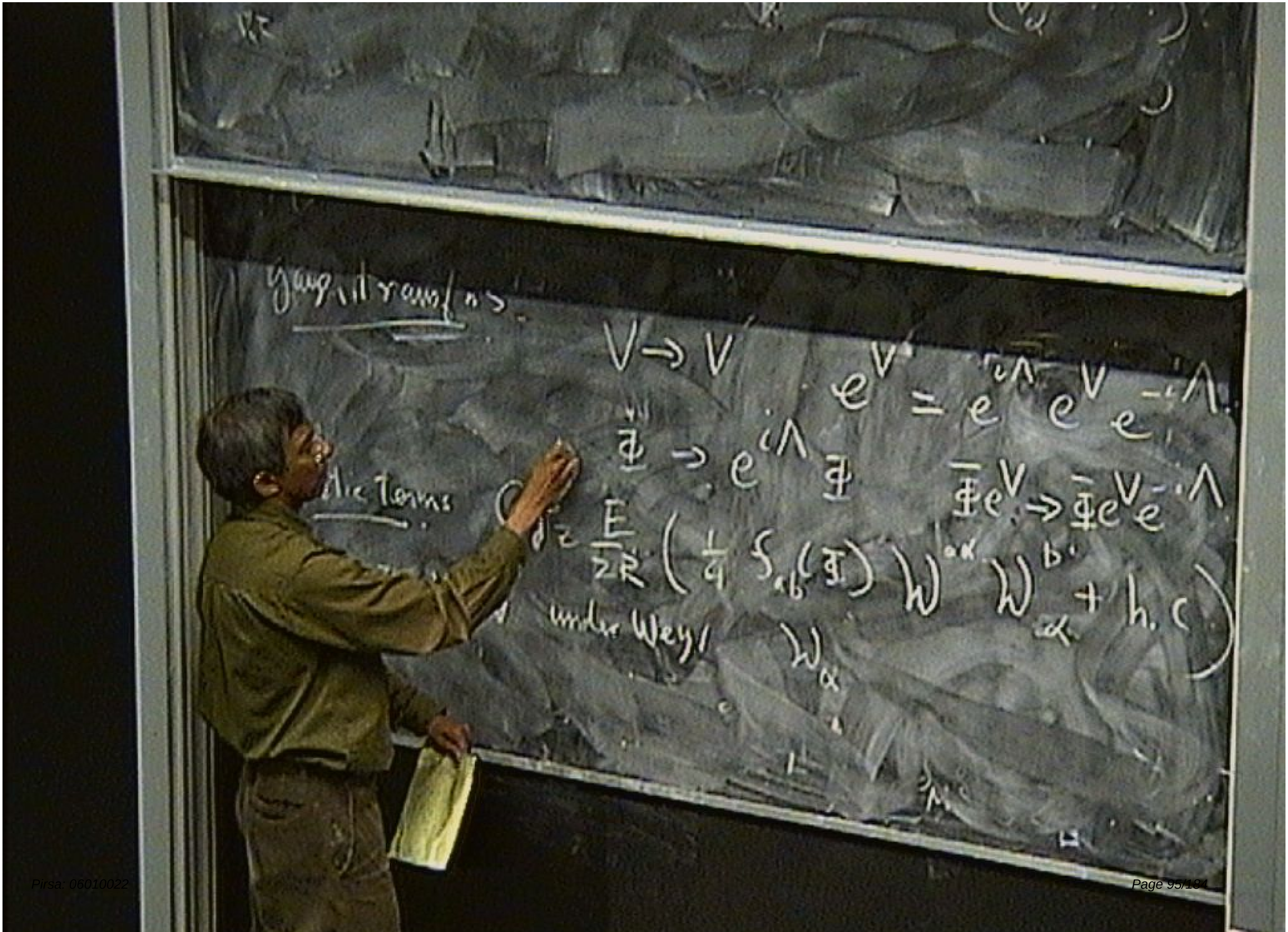

gauge transformations
$V \to V'$
$e^{V'} = e^{i\bar{\Lambda}} e^{V} e^{-i\Lambda}$
$\Phi \to e^{i\Lambda}\Phi$
$\bar{\Phi} e^{V} \to \bar{\Phi} e^{V} e^{-i\Lambda}$


gauge transformations
$V \to V$
$e^V = e^{i\bar\Lambda} e^V e^{-i\Lambda}$
$\Phi \to e^{i\Lambda}\Phi$
$\bar\Phi e^V \to \bar\Phi e^V e^{-i\Lambda}$


Gauge transformations
V → V
e^V = e^{iΛ̄} e^V e^{-iΛ}
Φ → e^{iΛ} Φ
Φ̄ e^V → Φ̄ e^V e^{-iΛ}
Kinetic
(1/4 f_ab(Φ) W^{αa} W^b_α + h.c.)


Gauge transformations
$V \to V'$ $e^{V'} = e^{-i\bar{\Lambda}} e^{V} e^{i\Lambda}$
$\Phi \to e^{i\Lambda}\Phi$ $\bar{\Phi}e^{V} \to \bar{\Phi}e^{V}e^{-i\Lambda}$
Kinetic Terms
$\int d^2\Theta \frac{E}{2R}\left(\frac{1}{4} f_{ab}(\Phi) W^{a\alpha} W^{b}_{\alpha} + h.c.\right)$


$V \to V$
$e^{V} = e^{i\bar{\Lambda}} e^{V} e^{-i\Lambda}$
$\Phi \to e^{i\Lambda} \Phi$
$\bar{\Phi} e^{V} \to \bar{\Phi} e^{V} e^{-i\Lambda}$
Kinetic Terms
$\int d^2z \frac{E}{2R} \left(\frac{1}{4} f_{ab}(\Phi) W^{a\alpha} W^{b}_{\alpha} + h.c. \right)$
$V \to V$


gauge transformations
V → V'
e^V' = e^{iΛ̄} e^V e^{-iΛ}
Φ → e^{iΛ} Φ
Φ̄ e^V → Φ̄ e^V e^{-iΛ}
the terms
∫d²θ E/2R (1/4 f_ab(Φ) W^{αa} W^b_α + h.c.)
under Weyl
W_α

Gauge transf'ns.

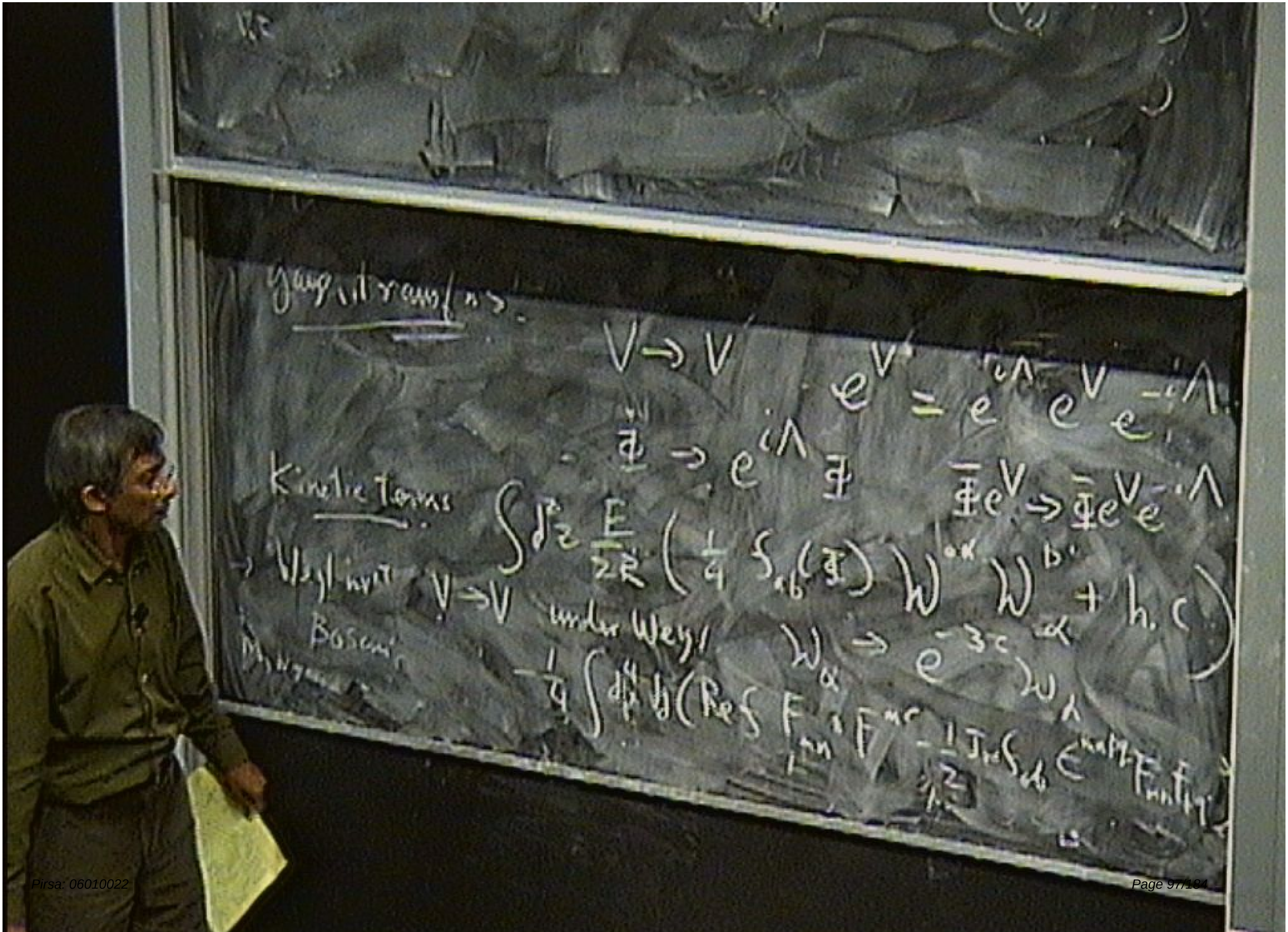
$$V \to V' \qquad e^{V'} = e^{i\bar{\Lambda}} e^{V} e^{-i\Lambda}$$

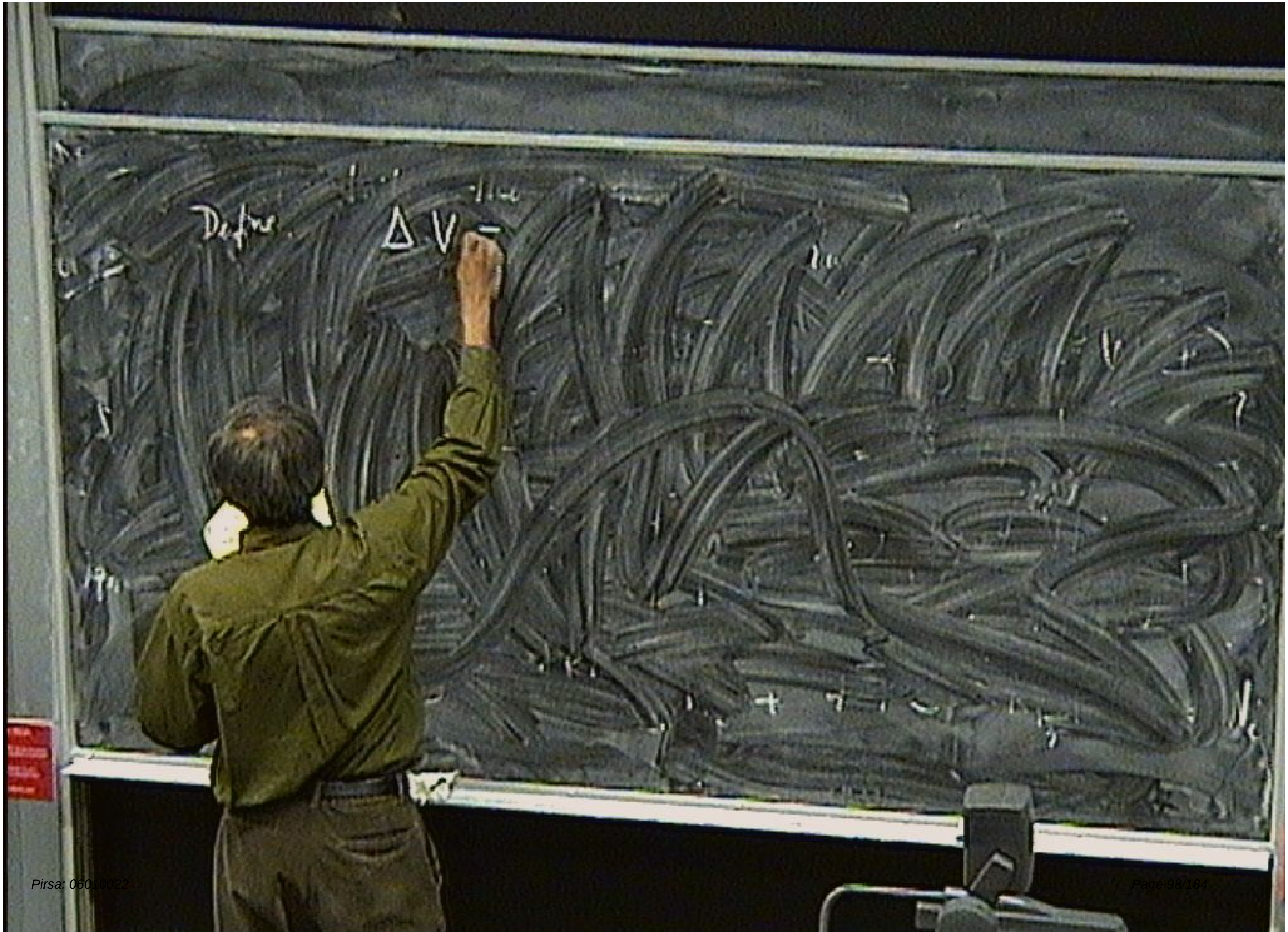
$$\Phi \to e^{i\Lambda}\Phi \qquad \bar{\Phi} e^{V} \to \bar{\Phi} e^{V} e^{-i\Lambda}$$

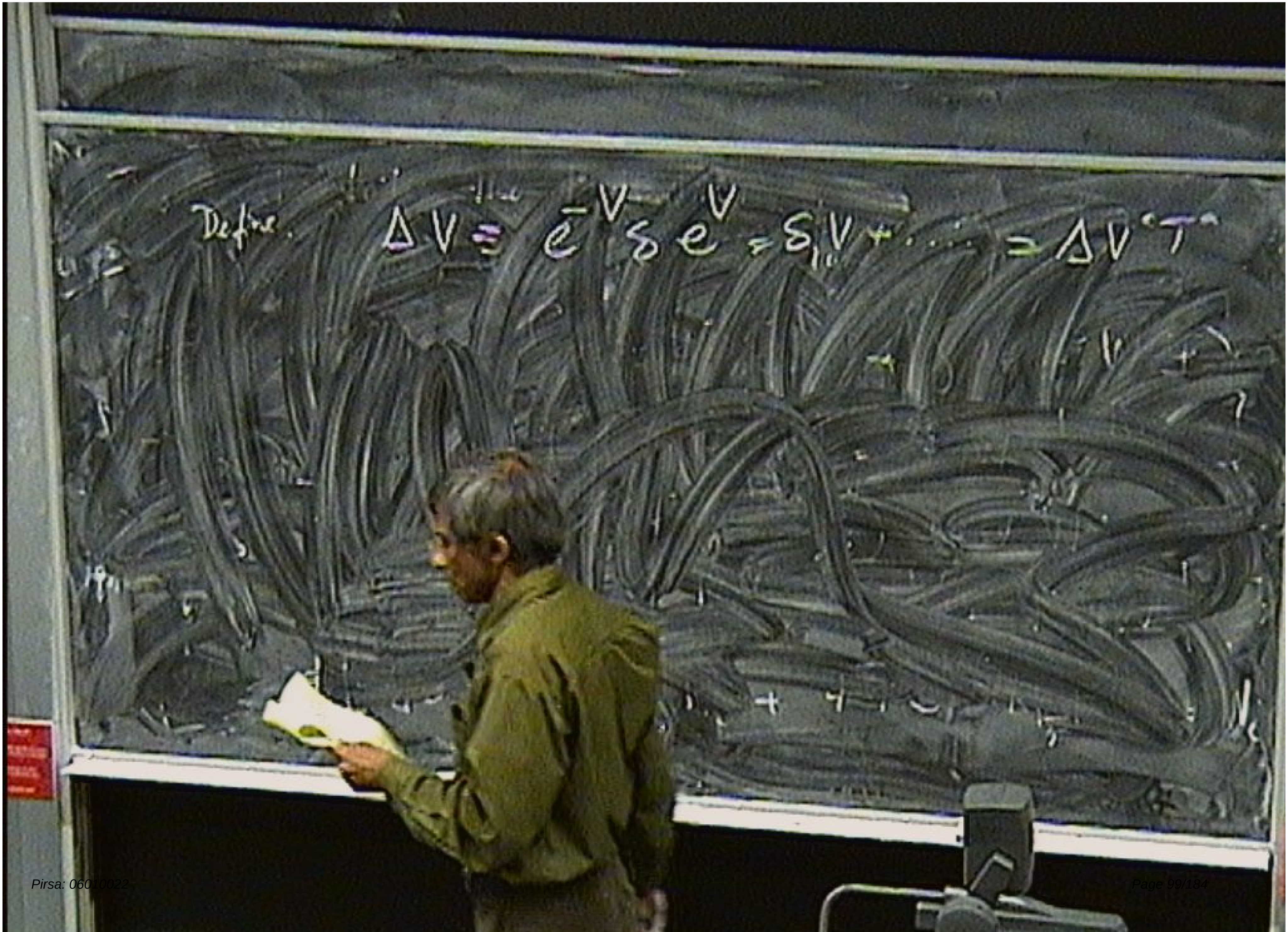
Kinetic Terms

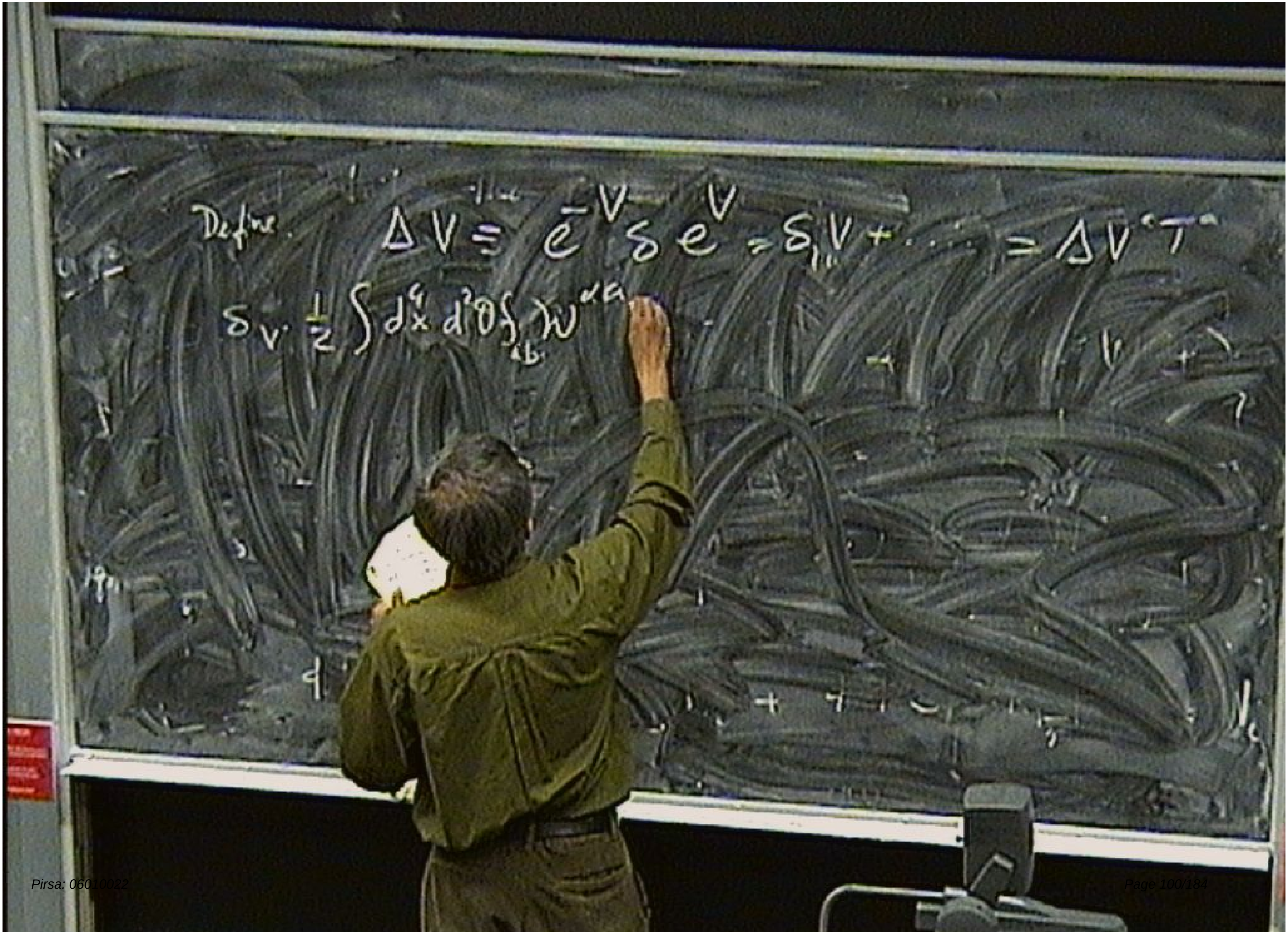
$$\int d^2z \, \frac{E}{2R} \left(\frac{1}{4} f_{ab}(\Phi) W^{\alpha a} W^{b}_{\alpha} + h.c. \right)$$

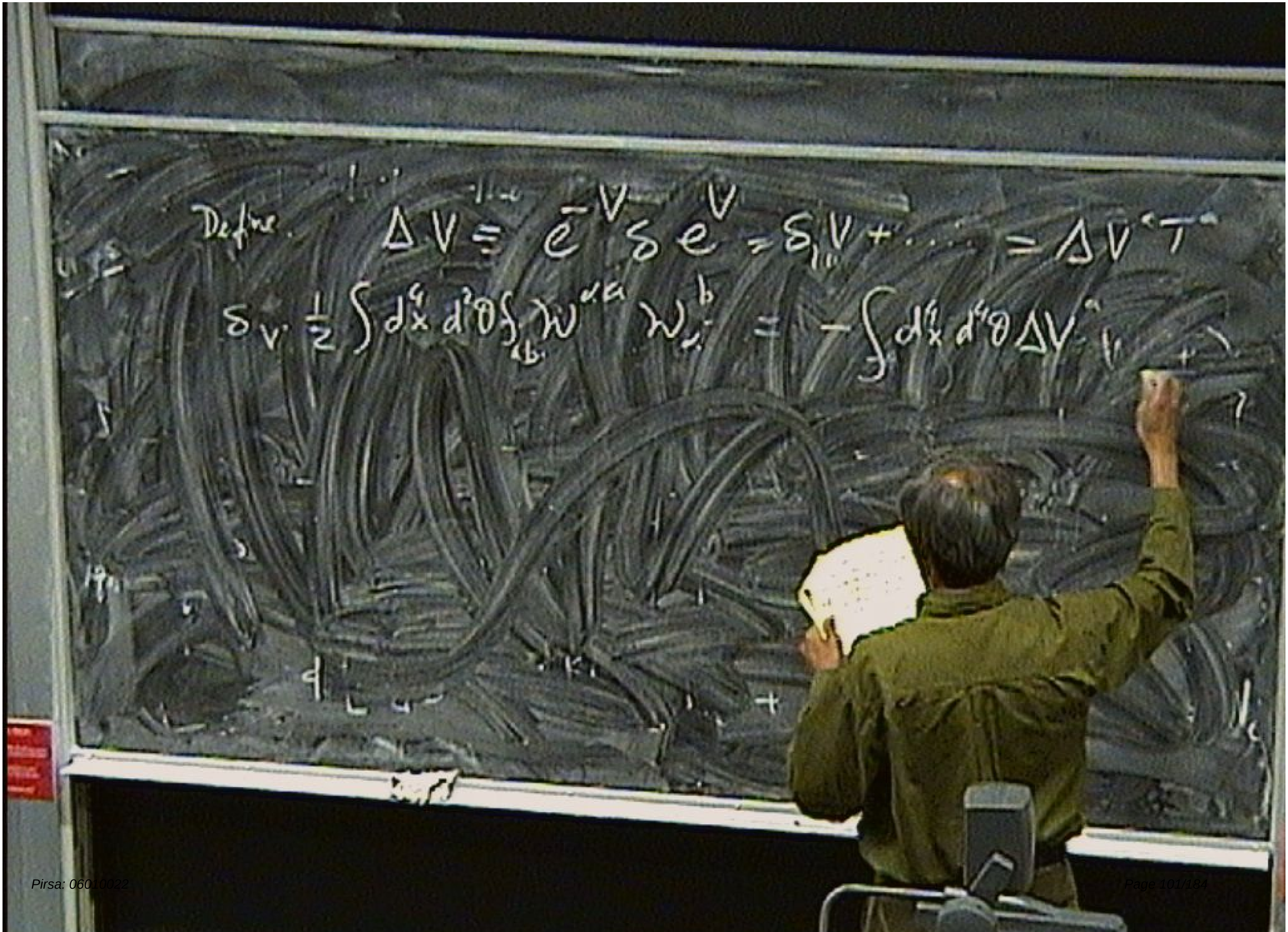
Weyl inv'ce $V \to V$ under Weyl $\qquad W_\alpha \to e^{-3\sigma} W_\alpha$

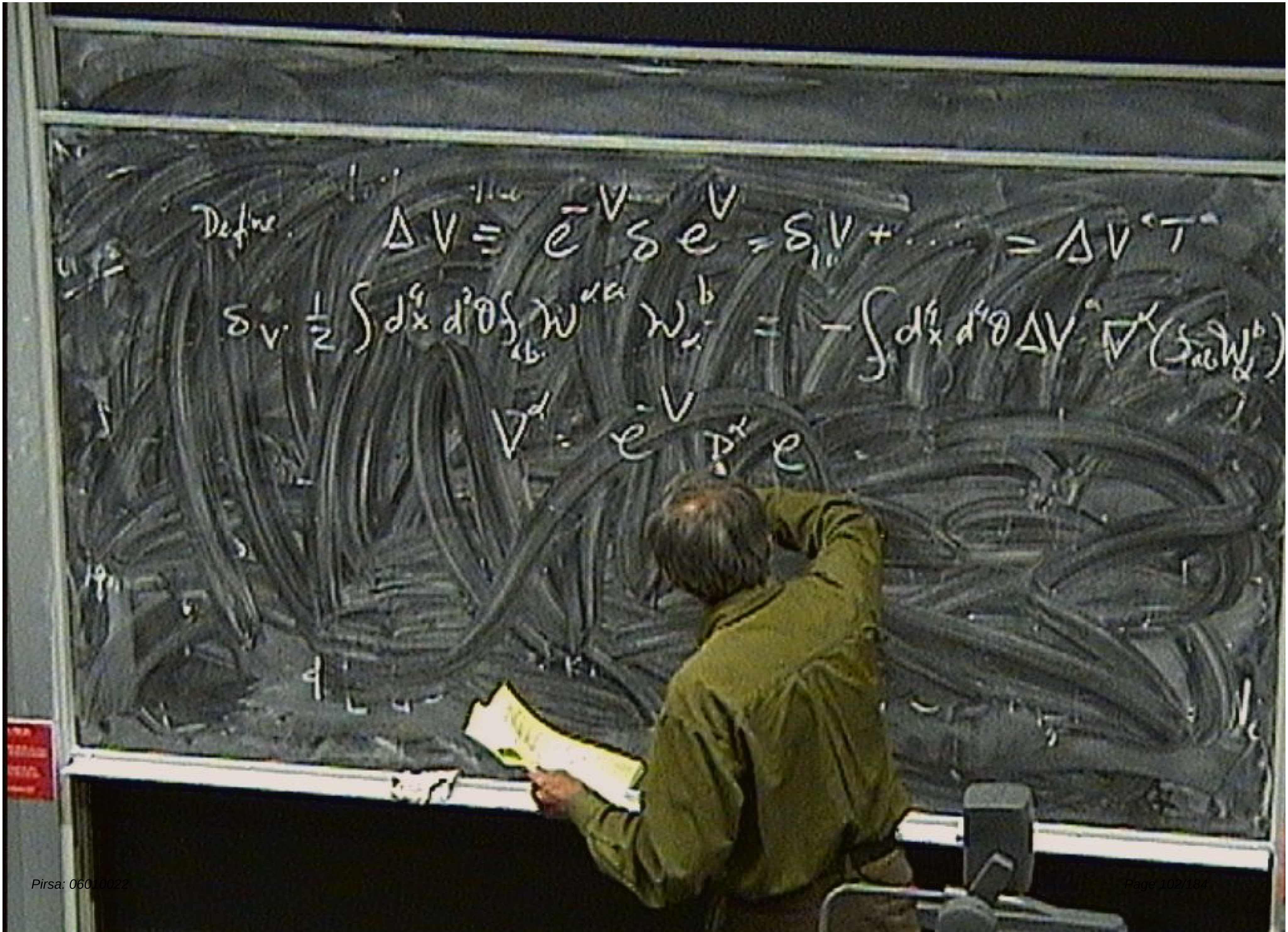

Kinetic Terms
under Weyl

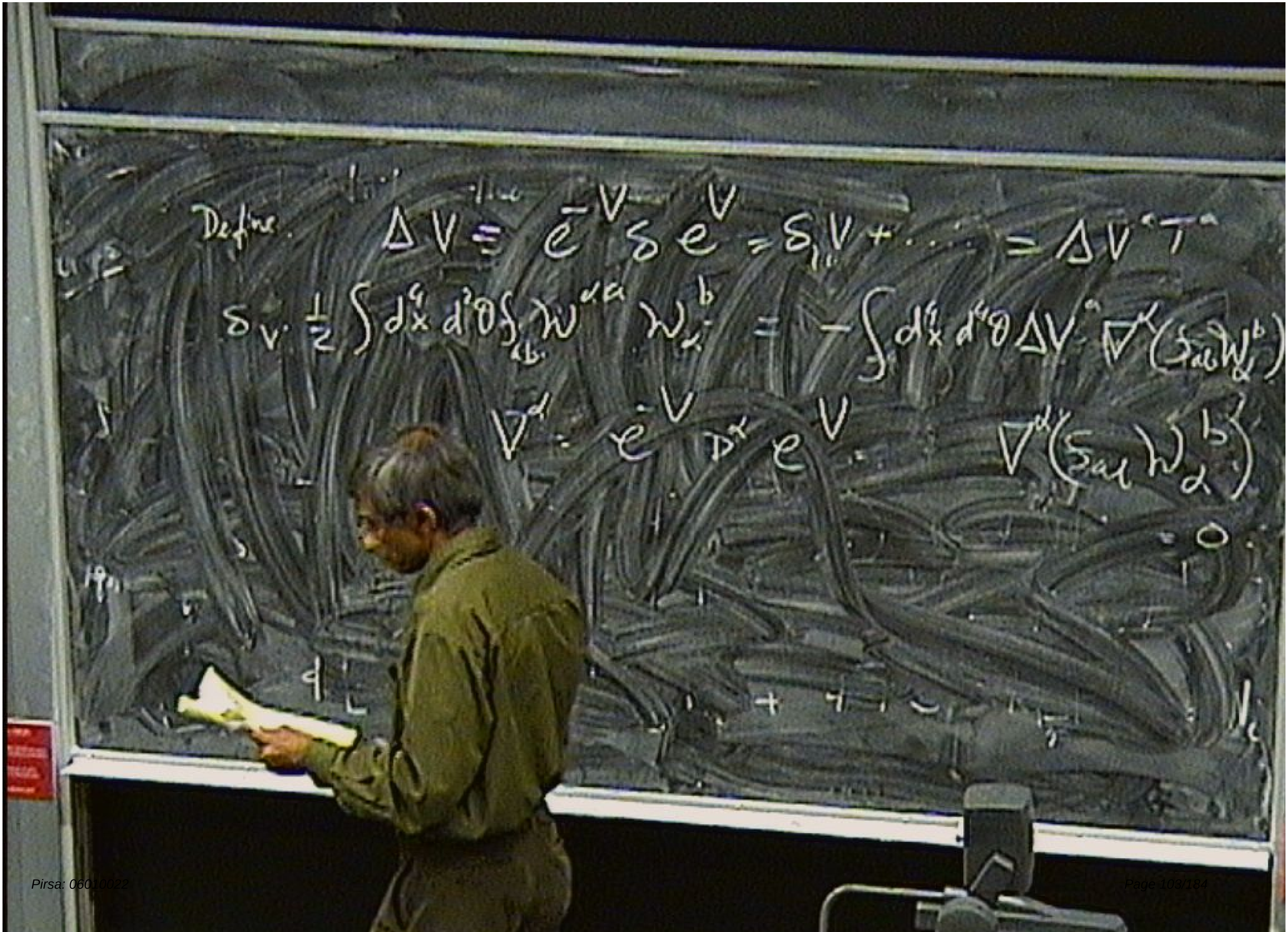

Define
ΔV


Define ΔV = e^{-V} δ e^{V} = δ_1 V + ... = ΔV^T


Define ΔV = e^-V δ e^V = δ_|| V + ... = ΔV^a T^a
δ_V 1/2 ∫ d^4x d^2θ f_ab W^αa


Define


Define $\Delta V \equiv e^{-V}\delta e^{V} = \delta_1 V + \ldots = \Delta V$ "T"
$\delta_V \frac{1}{2}\int d^4x\, d^2\theta\, f_{ab} W^{\alpha a} W_\alpha^{\ b} = -\int d^4x\, d^4\theta\, \Delta V^a \nabla^\alpha (f_{ab} W_\alpha^{\ b})$
$\nabla^\alpha = e^{-V} D^\alpha e^{V}$


Define
$\Delta V = e^{-V} \delta e^{V} = \delta_{\parallel} V + \cdots = \Delta V^a T^a$
$\delta_V \frac{1}{2} \int d^4x \, d^2\theta \, f_{ab} W^{\alpha a} W_\alpha^b = -\int d^4x \, d^4\theta \, \Delta V^a \nabla^\alpha (f_{ab} W_\alpha^b)$
$\nabla^\alpha = e^{-V} D^\alpha e^{V}$
$\nabla^\alpha (f_{ab} W_\alpha^b) = 0$

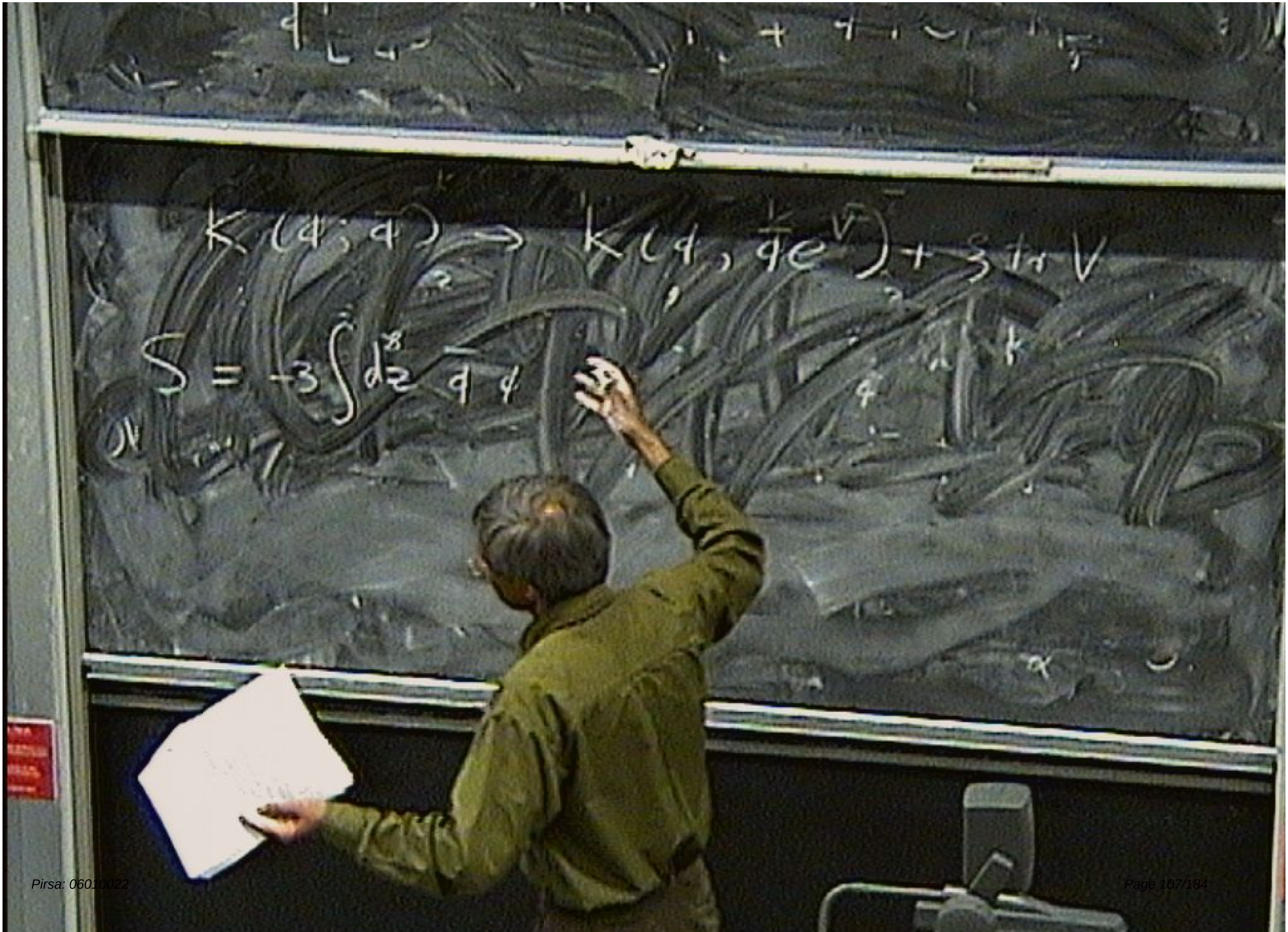
Define $\Delta V = e^{-V} \delta e^{V} = \delta_1 V + \dots = \Delta V^T$

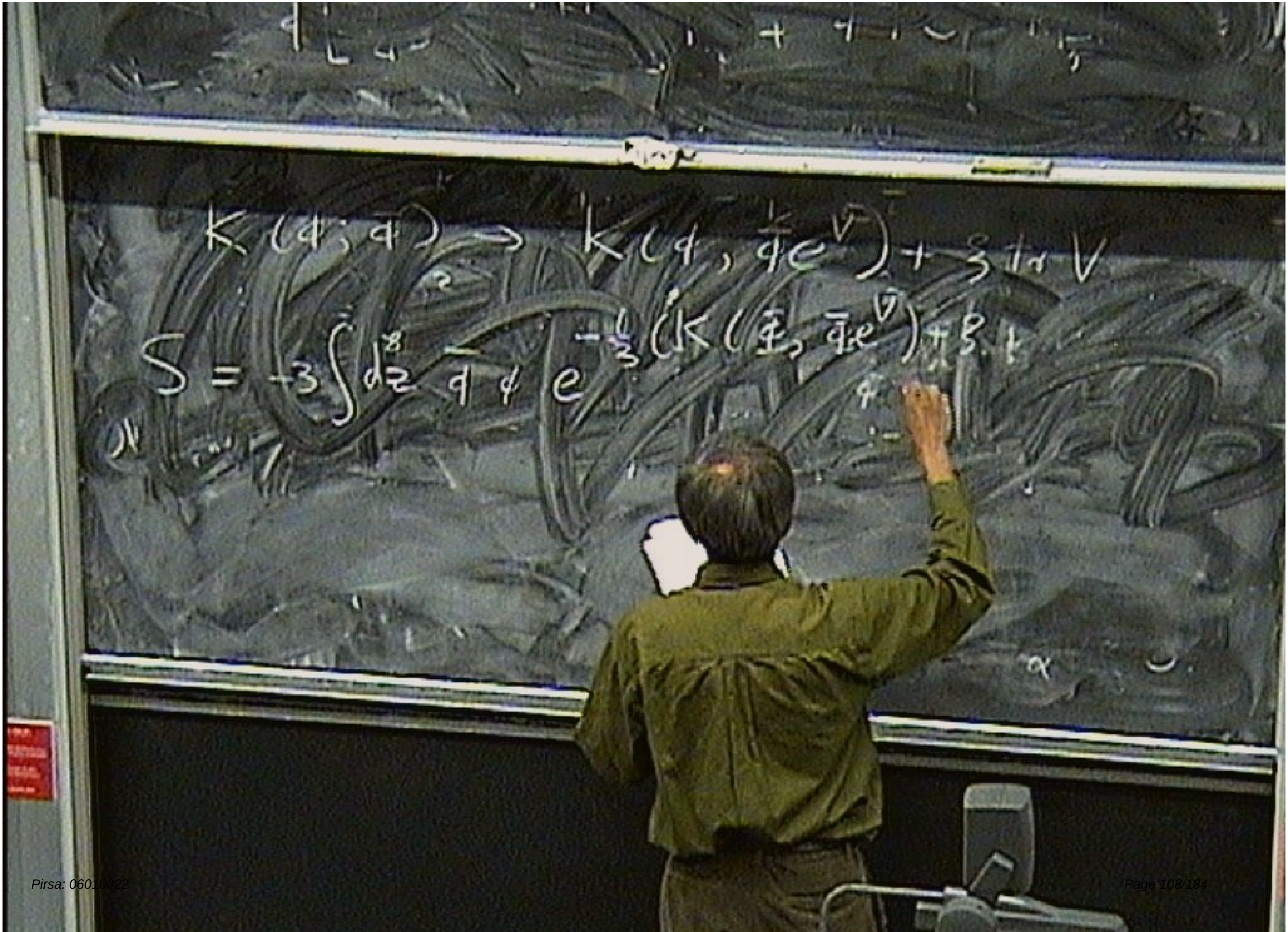
$$\delta_V \frac{1}{2} \int d^4x\, d^2\theta\, \xi_{ab} W^{\alpha a} W_\alpha^b = -\int d^4x\, d^4\theta\, \Delta V^a \nabla^\alpha (\xi_{ab} W_\alpha^b)$$

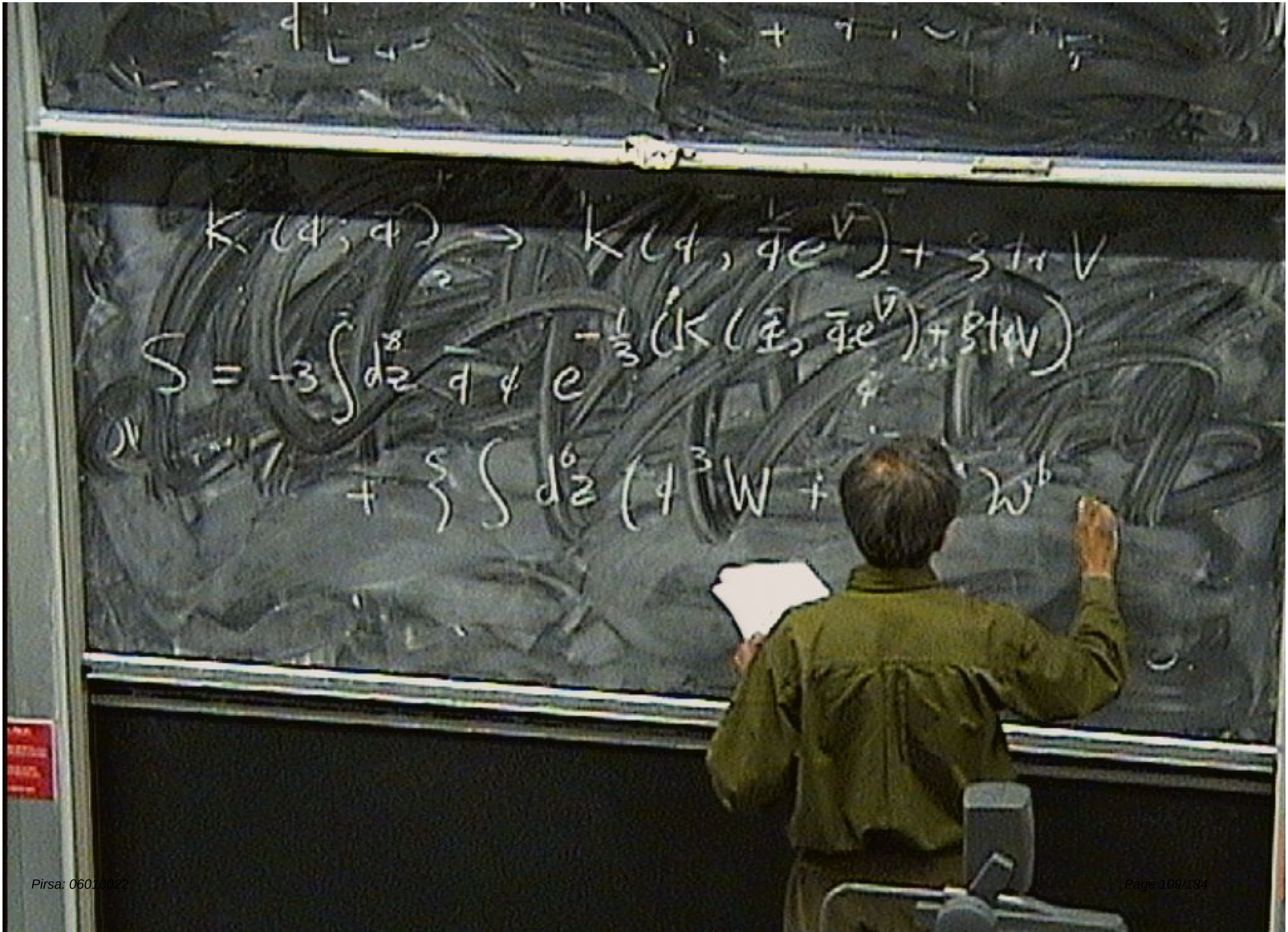
$$\nabla^\alpha = e^{-V} D^\alpha e^{V} \qquad \nabla^\alpha(\xi_{ab} W_\alpha^b) = 0$$

$$\Delta_\Lambda V = i\Lambda - i\tilde{\bar\Lambda} \qquad \tilde{\bar\Lambda} = e^{-V} \bar\Lambda e^{V}$$


K(q̄, q) → K(q̄, q e^V) + ξ tr V


K(q;q) → K(q, q e^V) + ξ ln V
S = -3 ∫ d^8 z q q




$K(\phi,\bar\phi) \to K(\phi,\bar\phi e^{V}) + \xi \operatorname{tr} V$
$S = -3\int d^8z\, \bar\phi\,\phi\, e^{-\frac{1}{3}(K(\Phi,\bar\Phi e^{V}) + \xi \operatorname{tr} V)}$
$+ \xi \int d^6z\, (\phi^3 W +$
w^6

$$K(\phi, \bar\phi) \to K(\phi, \bar\phi e^{V}) + \xi \,\mathrm{tr}\, V$$

$$S = -3 \int d^8 z \, \bar\phi \phi \, e^{-\frac{1}{3}\left(K(\Phi, \bar\Phi e^{V}) + \xi \,\mathrm{tr}\, V\right)}$$

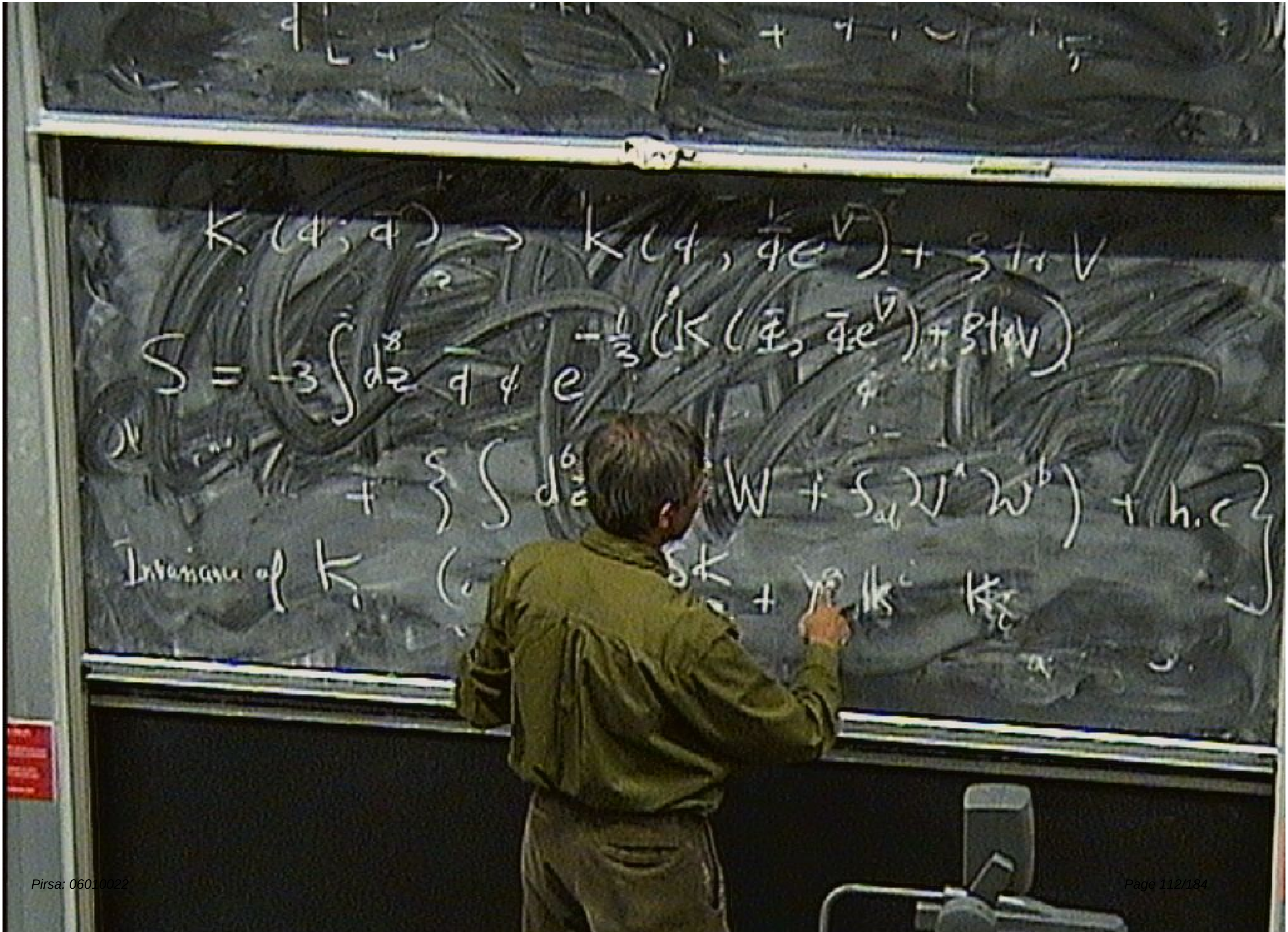
$$+ \left\{ \int d^6 z \left(\phi^3 W + f_{ab} \mathcal{W}^a \mathcal{W}^b \right) + h.c. \right\}$$

$$K(\phi, \bar\phi) \to K(\phi, \bar\phi e^{V}) + \xi \, \mathrm{tr}\, V$$

$$S = -3\int d^8z \, \bar\phi \phi \, e^{-\frac{1}{3}\left(K(\Phi, \bar\Phi e^{V}) + \xi \mathrm{tr} V\right)}$$

$$+ \left\{ \int d^6z \left(\phi^3 W + f_{ab} W^a W^b \right) + h.c. \right\}$$

Invariance of K, Λ

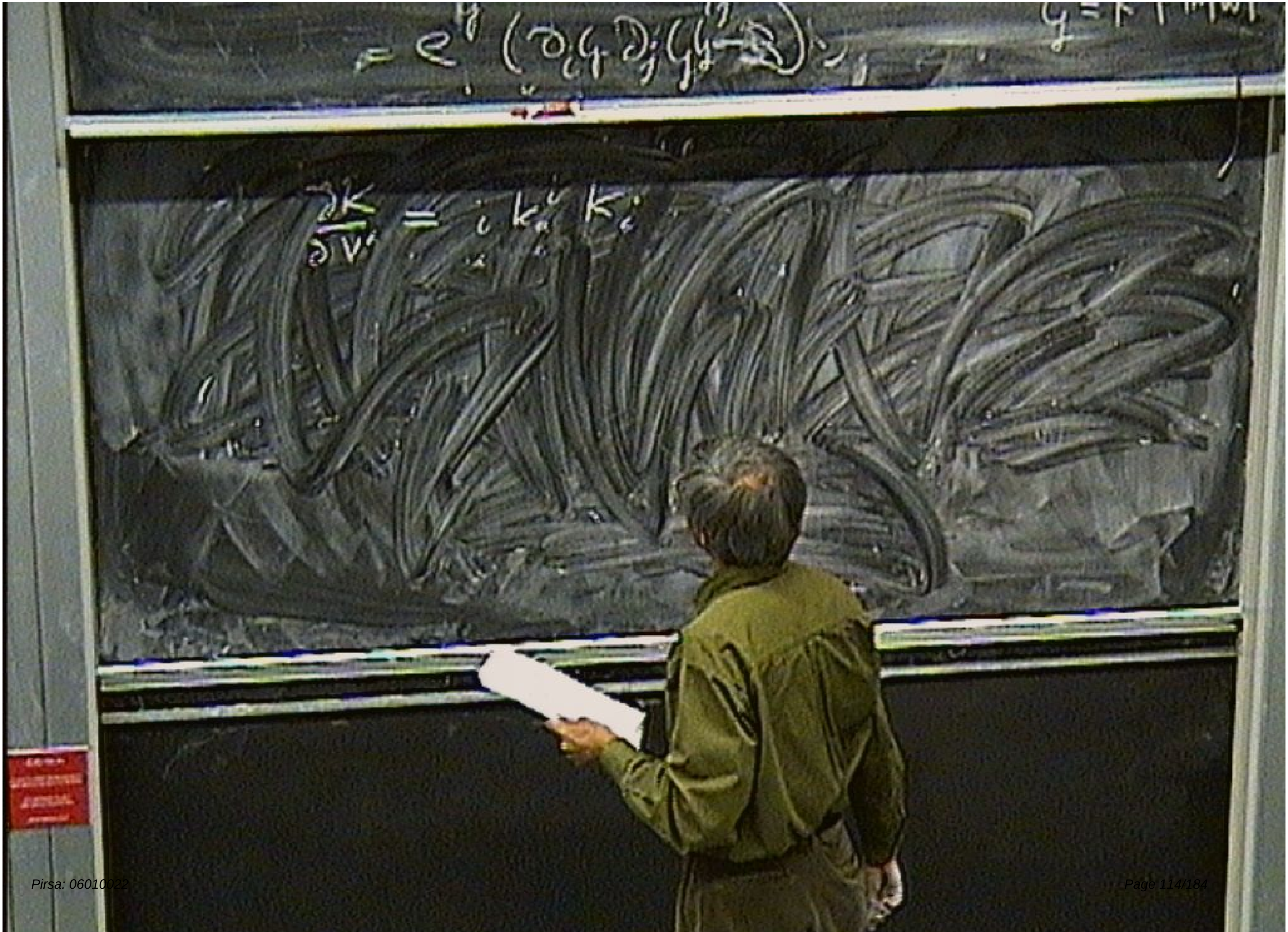

K(φ, φ̄) → K(φ, φ̄e^V) + ξ tr V
S = -3 ∫ d^8z φ φ e^{-1/3 (K(φ̄, φ̄e^V) + ξ tr V)}
+ { ∫ d^6z (W + f_ab W^a W^b) + h.c }
Invariance of K

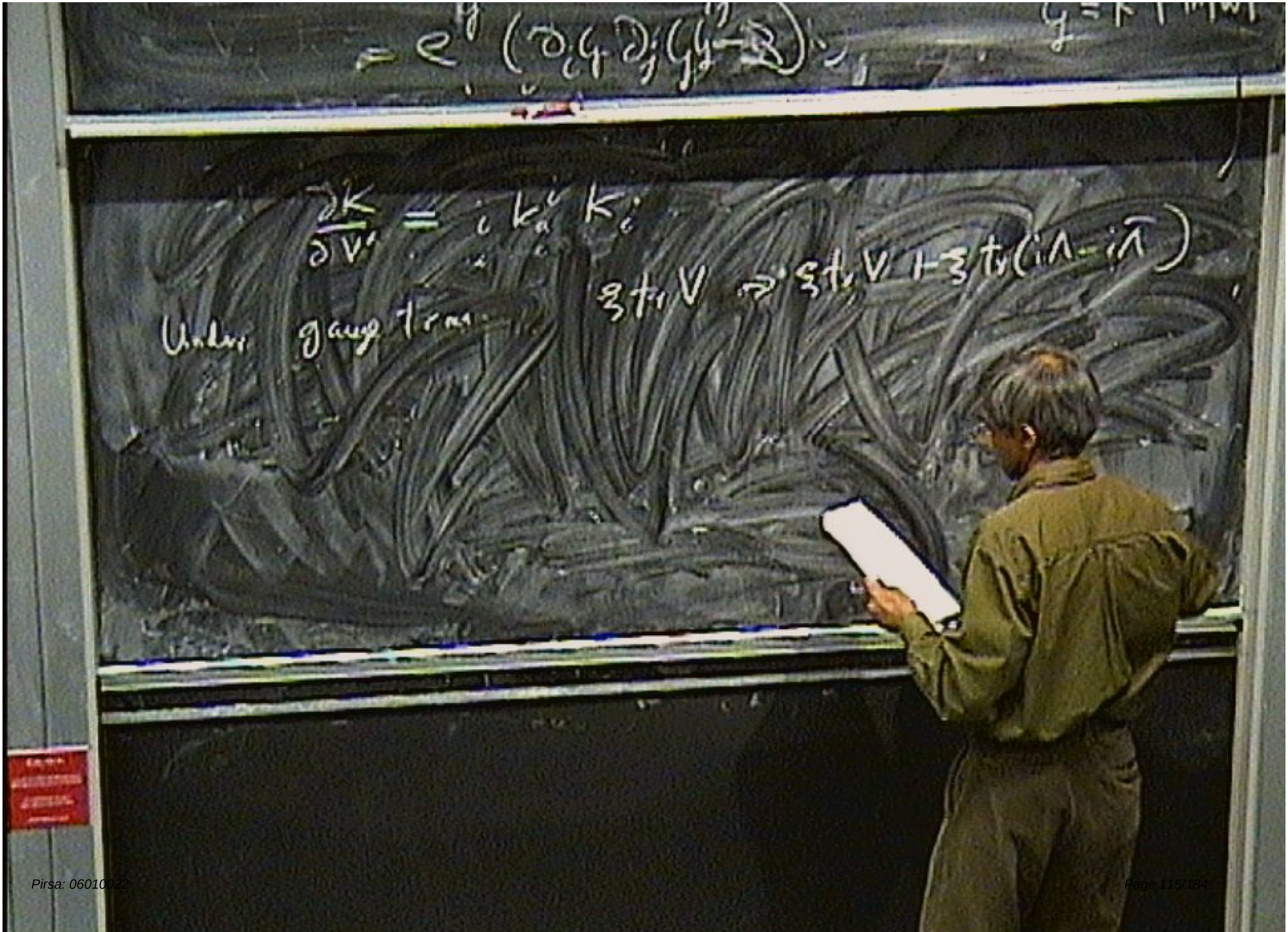
$$K(q,\bar q) \to K(q,\bar q e^{V}) + \xi \, \mathrm{tr}\, V$$

$$S = -3\int d^8z \, \bar q q \, e^{-\frac{1}{3}\left(K(\Phi,\bar\Phi e^{V}) + \xi\, \mathrm{tr} V\right)}$$

$$+ \left\{ \int d^6 z \left(q^3 W + f_{ab} W^a W^b \right) + h.c. \right\}$$

Invariance of K: $(i\Lambda - i\tilde\Lambda)\dfrac{\delta K}{\delta V} + \Lambda^a k_a^c K_c + \tilde\Lambda^a k_a^c K_c = 0$

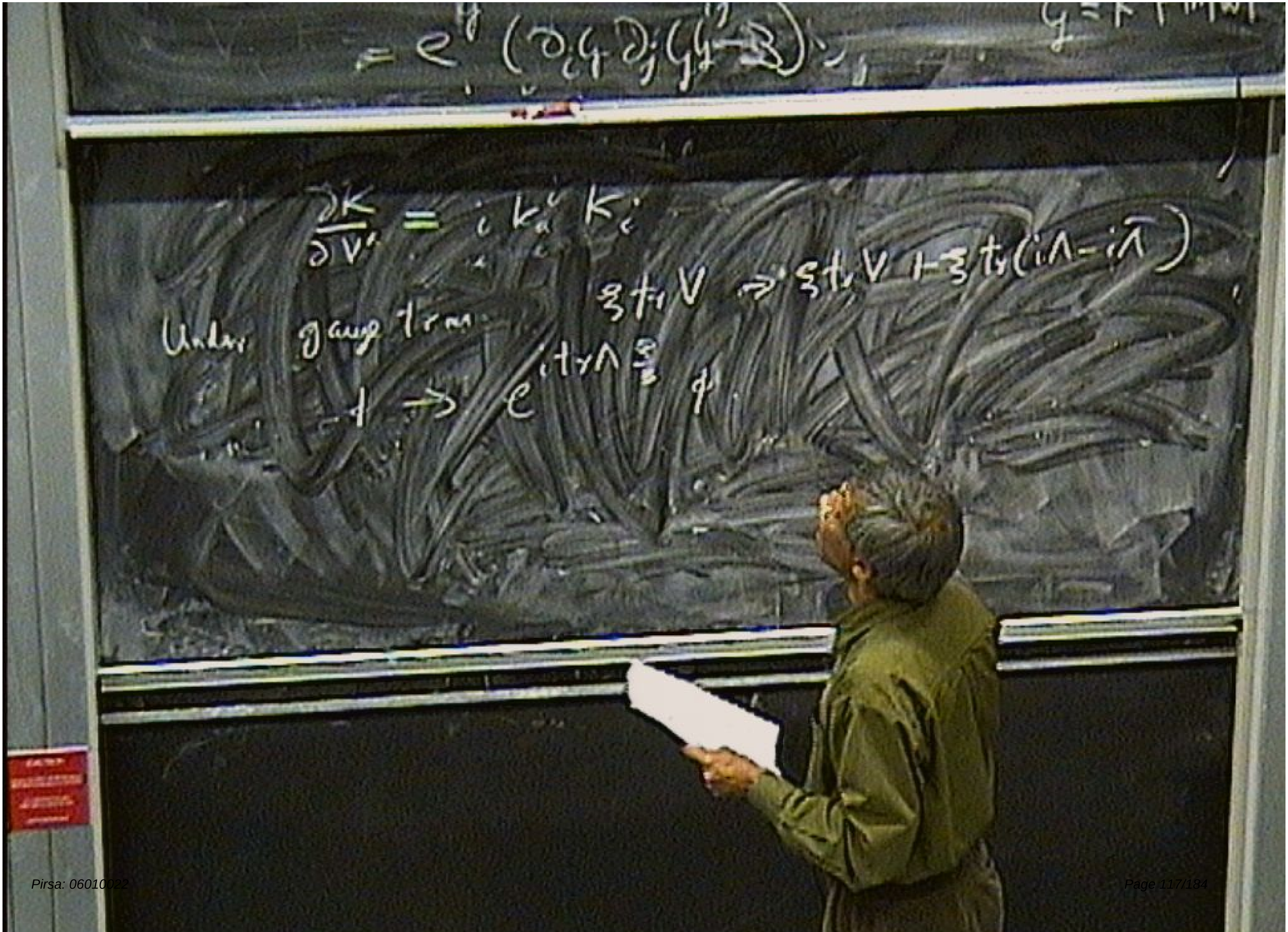


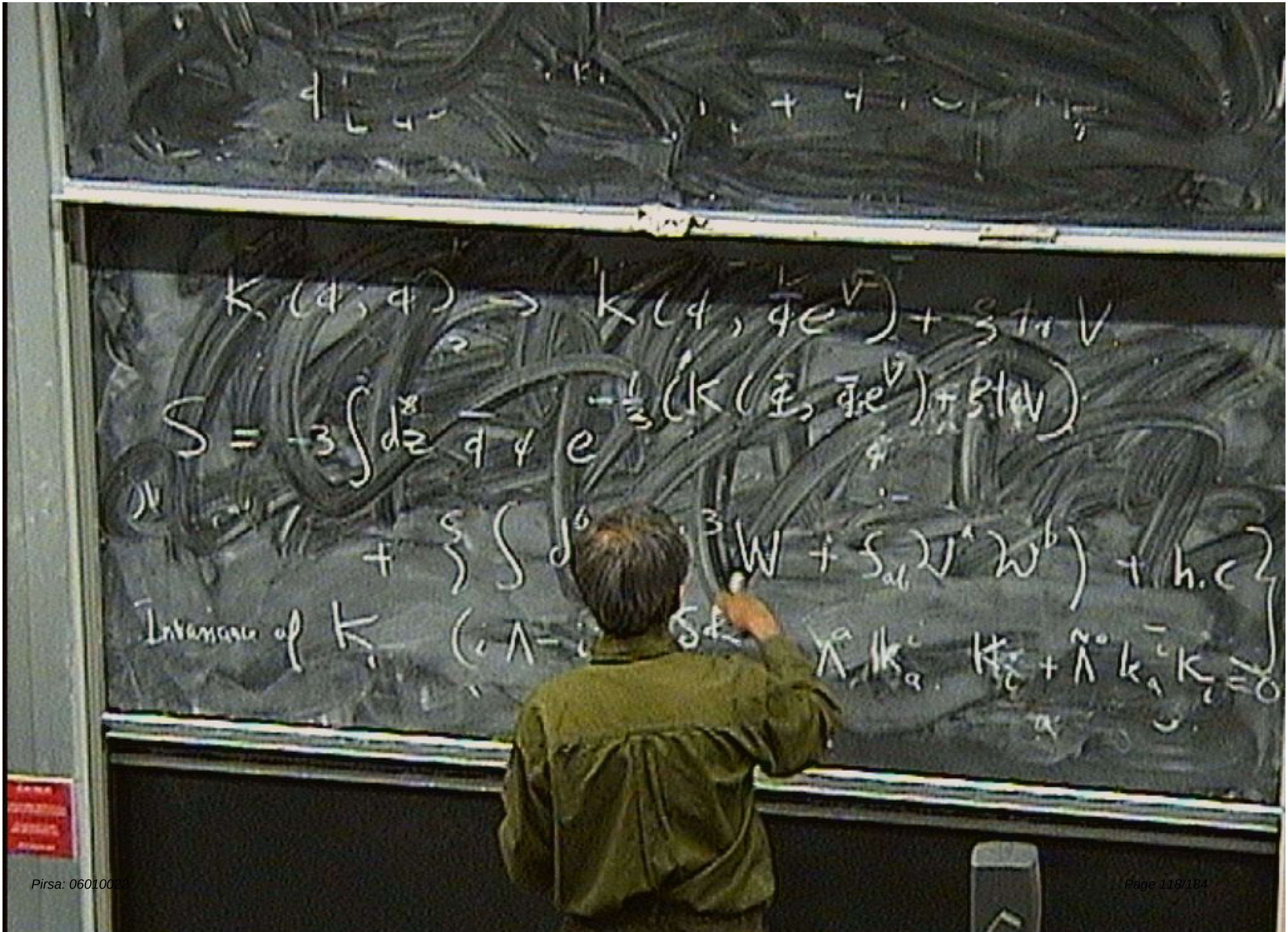

Under gauge trans

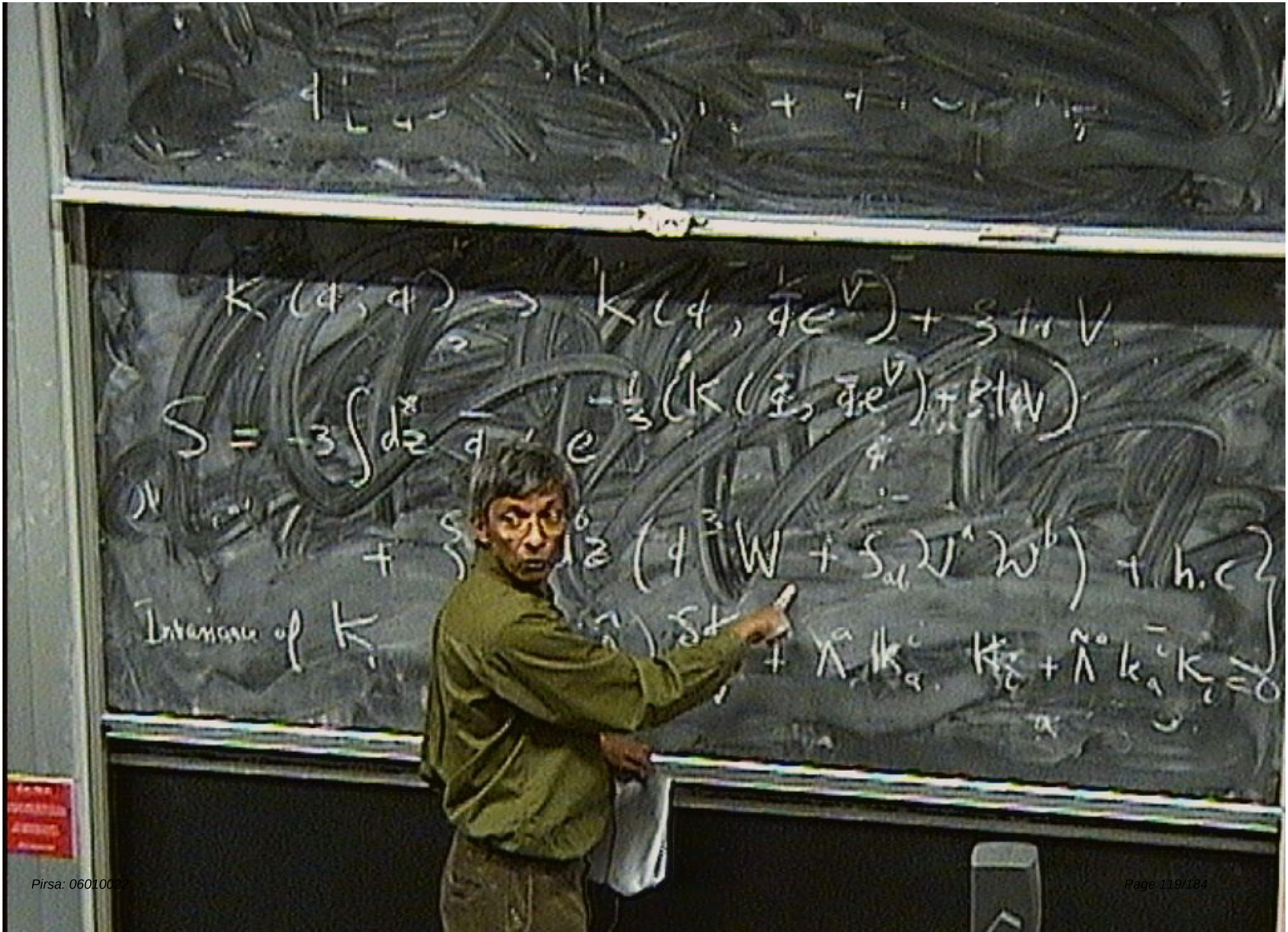
$= e^{G}\left(\partial_i G\, \partial_j G\, G^{i\bar{j}} - 3\right)$, $\quad G = K + \ln|W|^2$

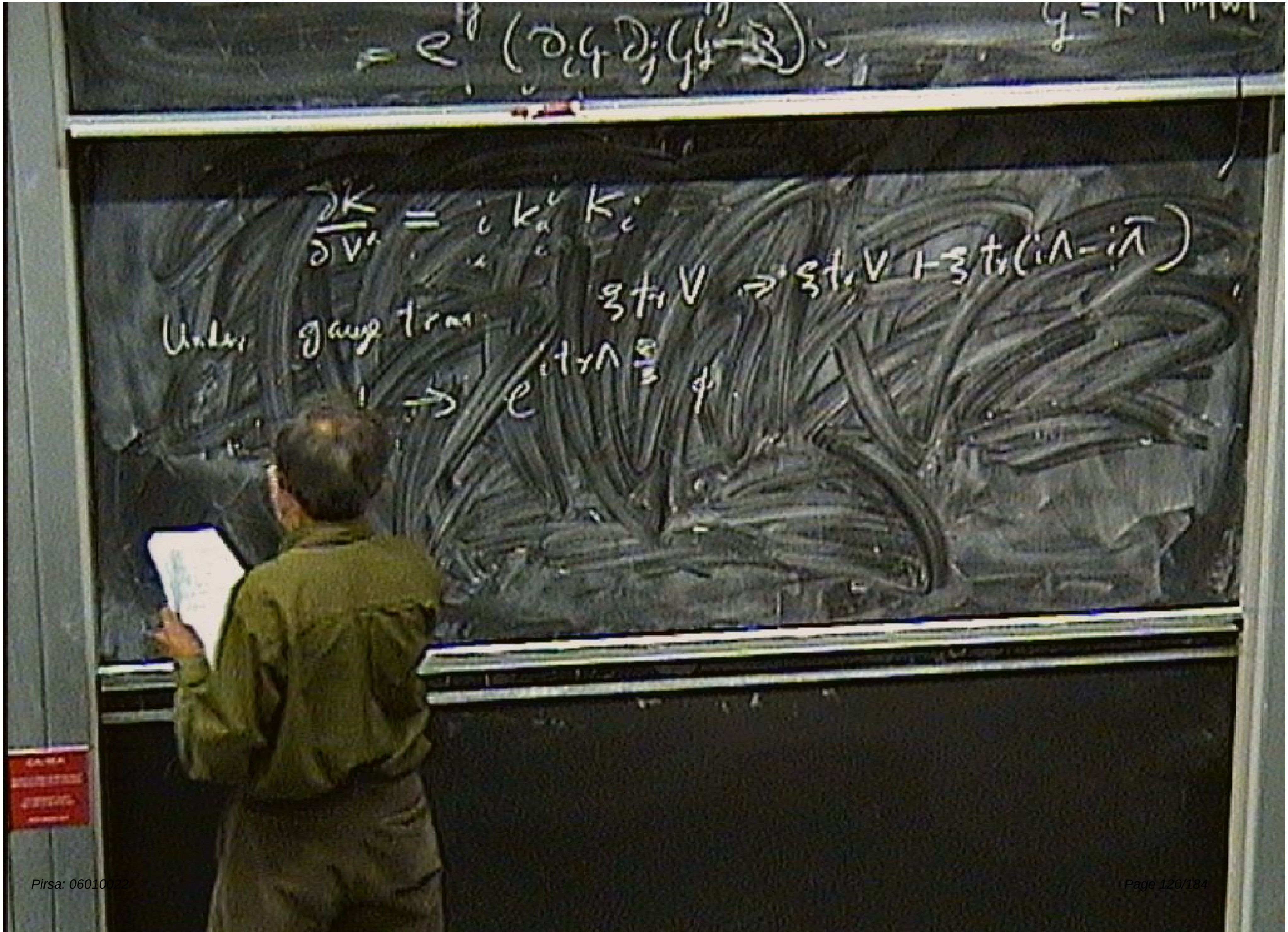
$$\frac{\partial K}{\partial V^a} = i k_a^i K_i$$

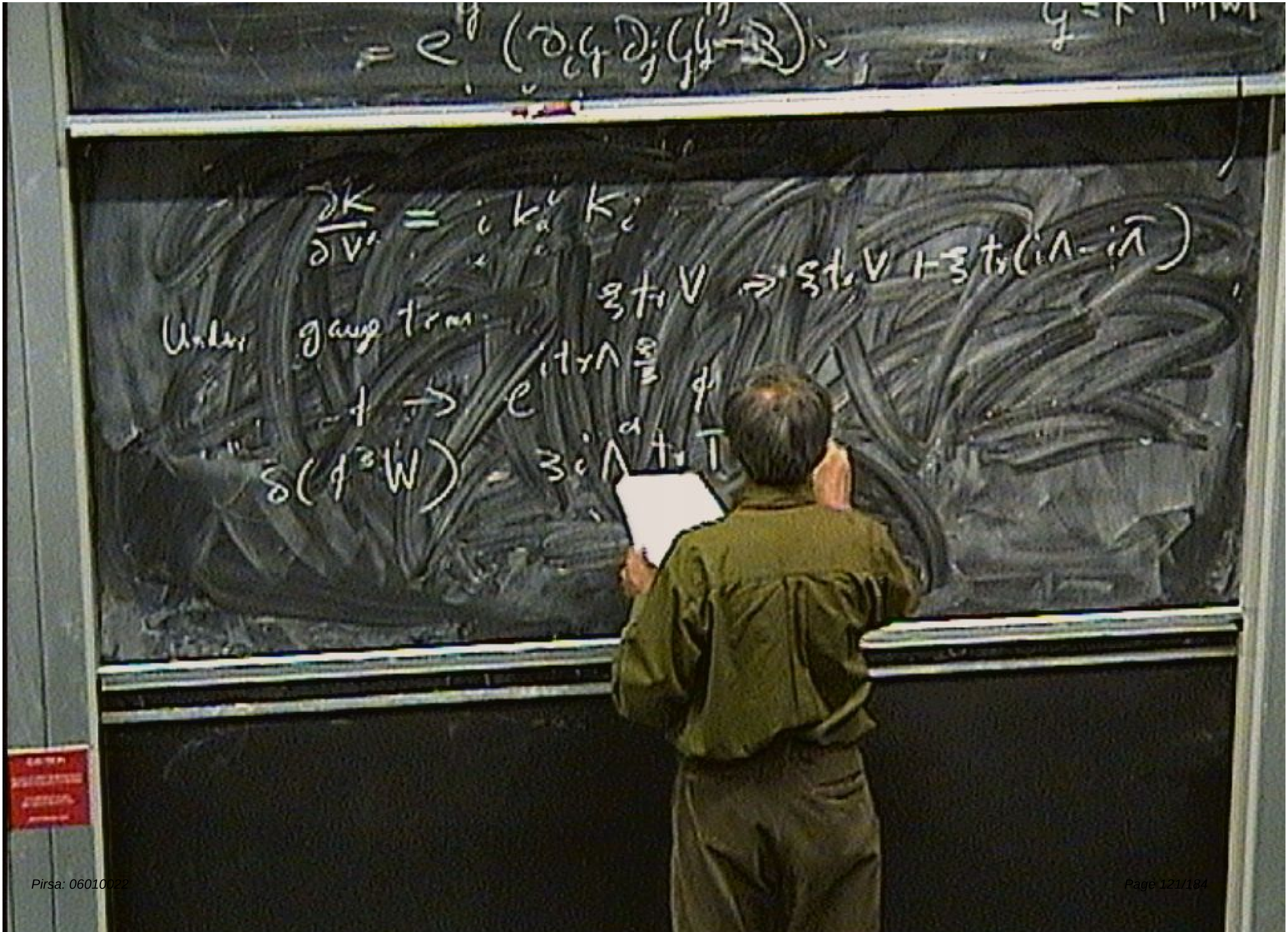
Under gauge tran: $\xi\, \mathrm{tr}\, V \to \xi\, \mathrm{tr}\, V + \xi\, \mathrm{tr}(i\Lambda - i\bar{\Lambda})$

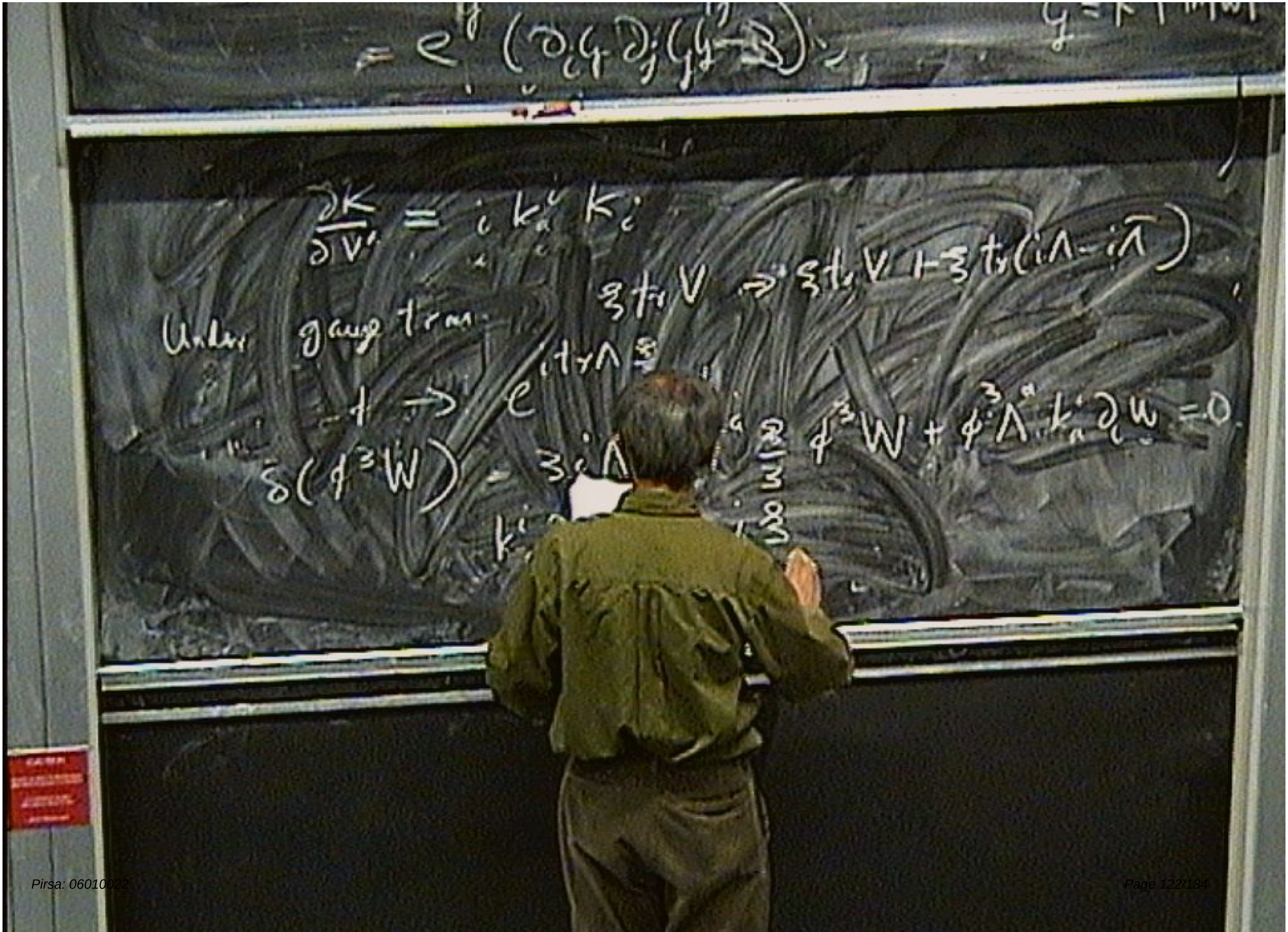

∂K/∂V^i = i k_a^i K_i
ξ tr V → ξ tr V + ξ tr(iΛ − iΛ̄)
Under gauge trans
φ → e^{i tr Λ ξ} φ


K(q, q̄) → K(q, q̄e^V) + ξ tr V
S = -3 ∫d^8z q̄ q e^{-1/3(K(Φ, Φ̄e^V) + ξ tr V)}
+ ξ ∫ d^6 … W + f_ab W^a W^b) + h.c
Invariance of K


K(q, q̄) → K(q, q̄e^V) + ξ tr V
+ h.c
Invariance of K


Under gauge tran


Under gauge trans


∂K/∂V^a = i k_a^i K_i
Under gauge tran.
δ(φ³W) = 3iΛ^a … φ³W + φ³Λ^a k_a^i ∂_i W = 0

$$= e^{G}\left(\partial_i G\, \partial_j G\, (G^{ij} - \ldots)\right) \qquad G = K + \ln|W|^2$$

$$\frac{\partial K}{\partial V^a} = i k_a^i K_i$$

$$\xi\, \mathrm{tr}\, V \to \xi\, \mathrm{tr}\, V + \xi\, \mathrm{tr}(i\Lambda - i\bar{\Lambda})$$

Under gauge tran.

$$\phi \to e^{i\, \mathrm{tr}\Lambda \frac{\xi}{3}}\, \phi$$

$$\delta(\phi^3 W) = 3 i \Lambda^a\, \mathrm{tr}\, T^a \frac{\xi}{3}\, \phi^3 W + \phi^3 \Lambda^a k_a^i \partial_i W = 0$$

$$k_a^i \partial_i W = -i \xi\, \mathrm{tr}\, T^a\, W$$

$$= e^{\mathcal{G}} \left(\partial_i \mathcal{G} \, \partial_j \mathcal{G} \, \mathcal{G}^{j} - 3 \right)$$

$$\frac{\partial K}{\partial V^a} = i k_a^i K_i$$

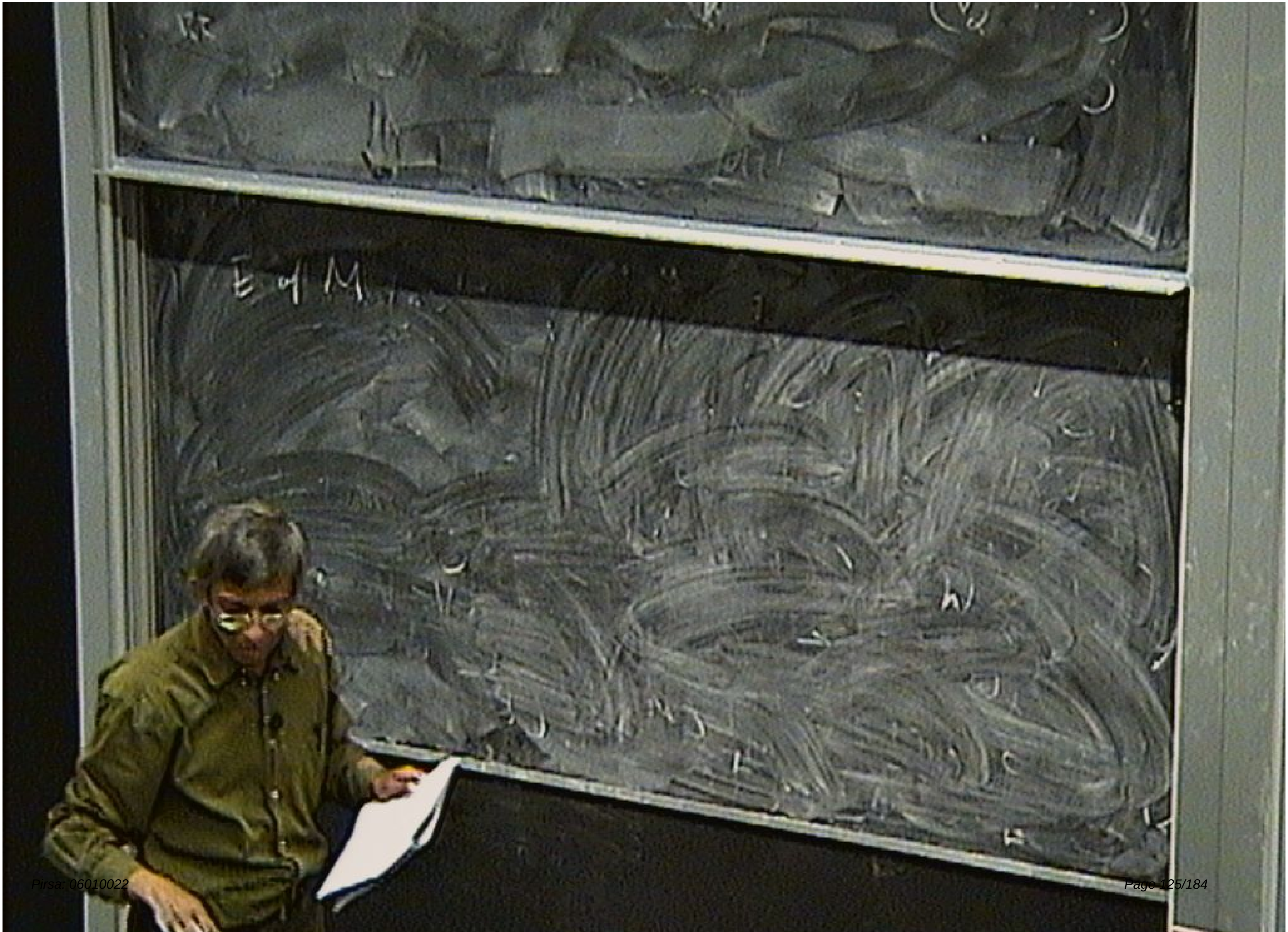
$$\xi \, \mathrm{tr}\, V \to \xi \, \mathrm{tr}\, V + \xi \, \mathrm{tr}(i\Lambda - i\bar{\Lambda})$$

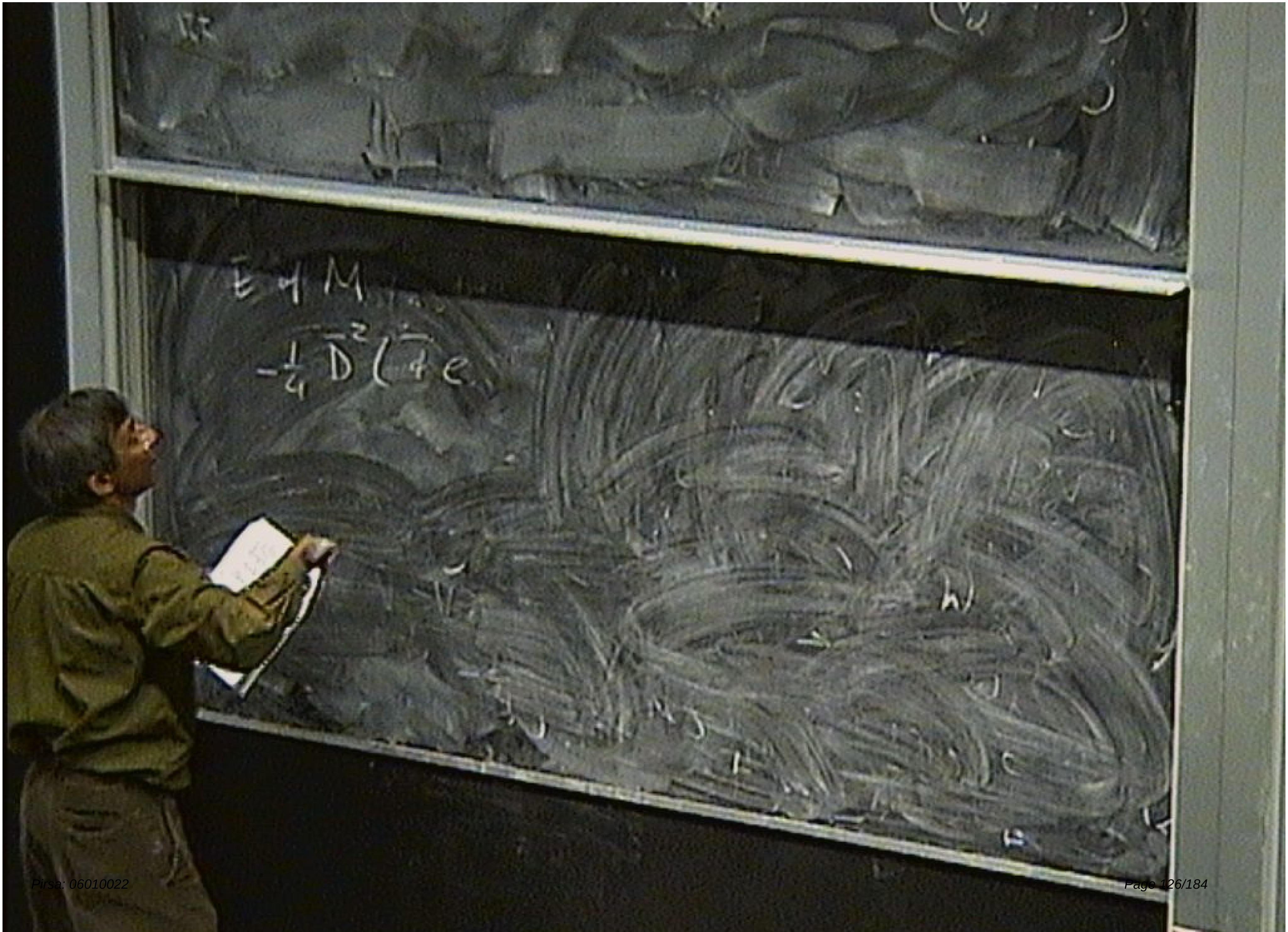
Under gauge tran.

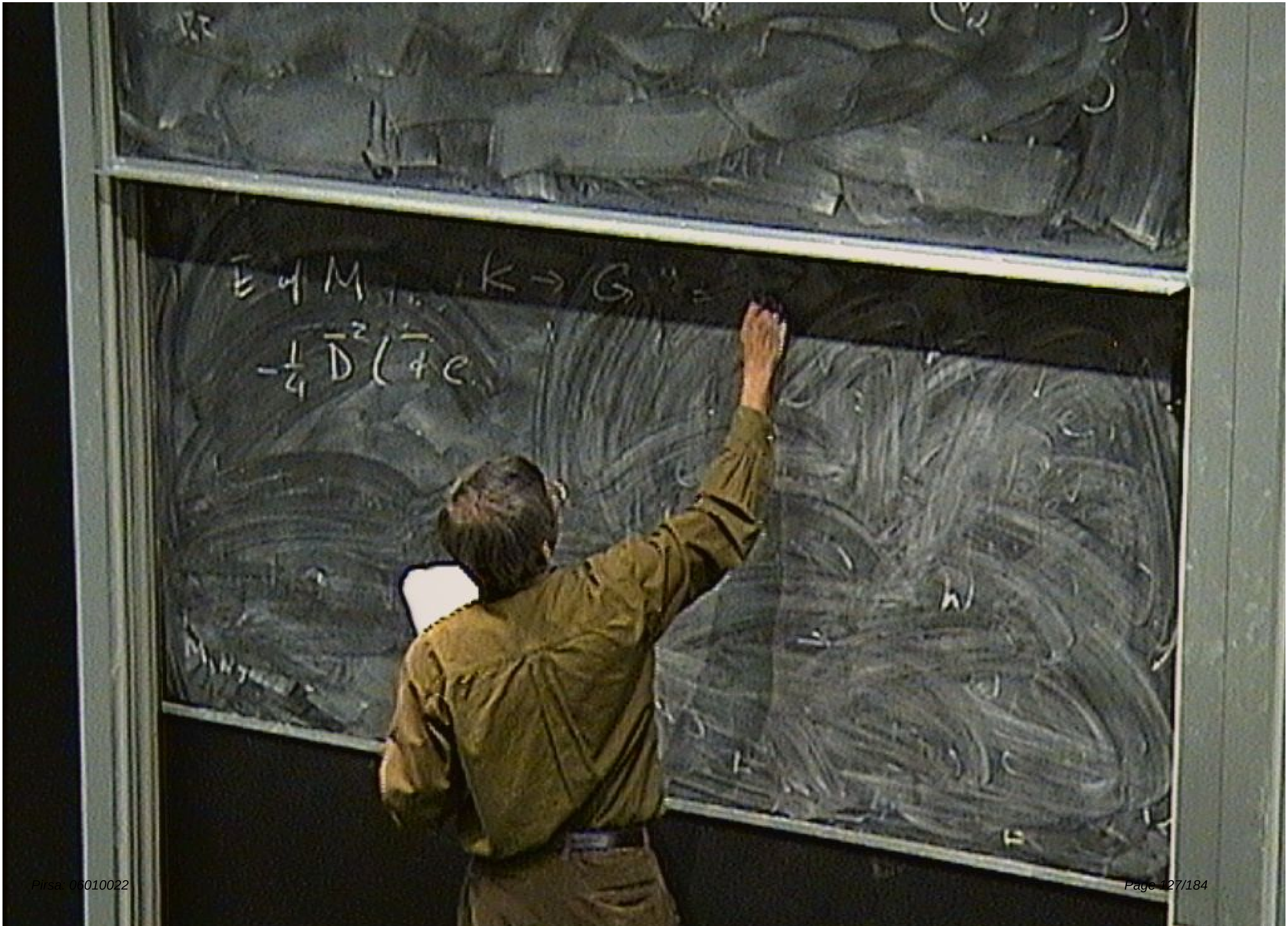
$$\phi \to e^{i \, \mathrm{tr}\, \Lambda \frac{\xi}{3}} \phi$$

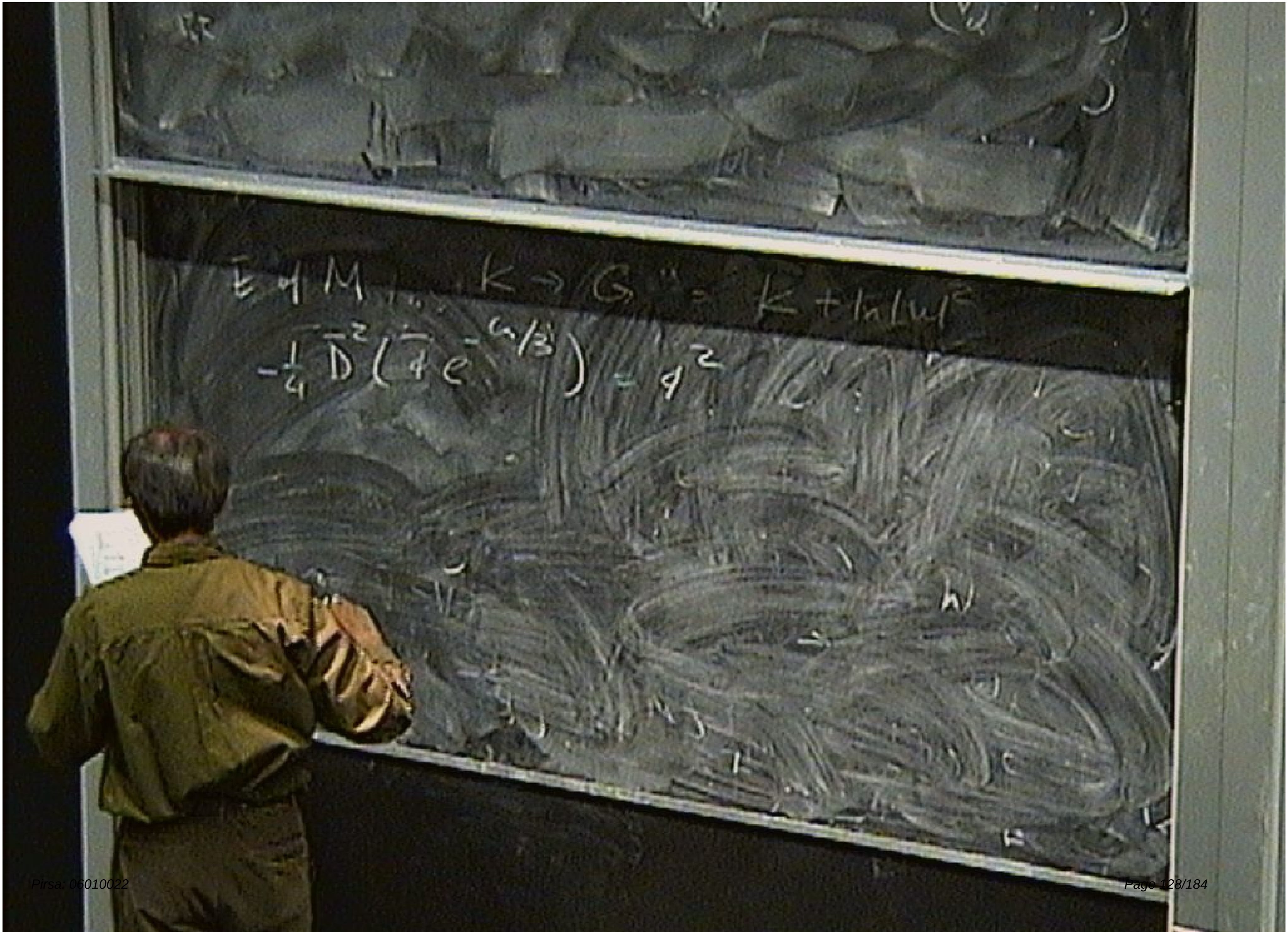
$$\delta(\phi^3 W) = \xi \, i \Lambda^a \, \mathrm{tr}\, T^a \frac{\xi}{3} \phi^3 W + \phi^3 \Lambda^a k_a^i \partial_i W = 0$$

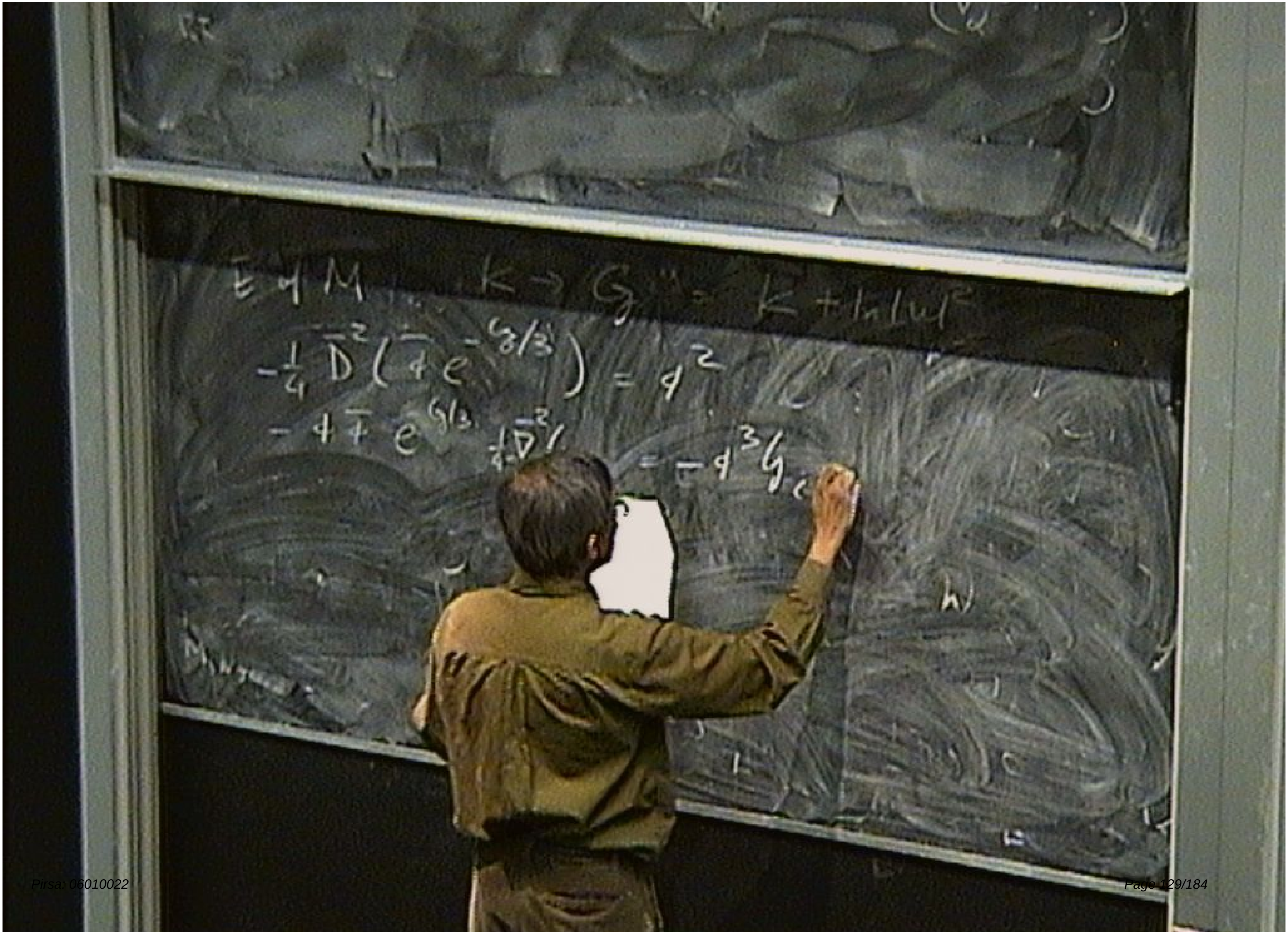
$$k_a^i \partial_i W = -i \frac{\xi}{3} \mathrm{tr}\, T^a W$$

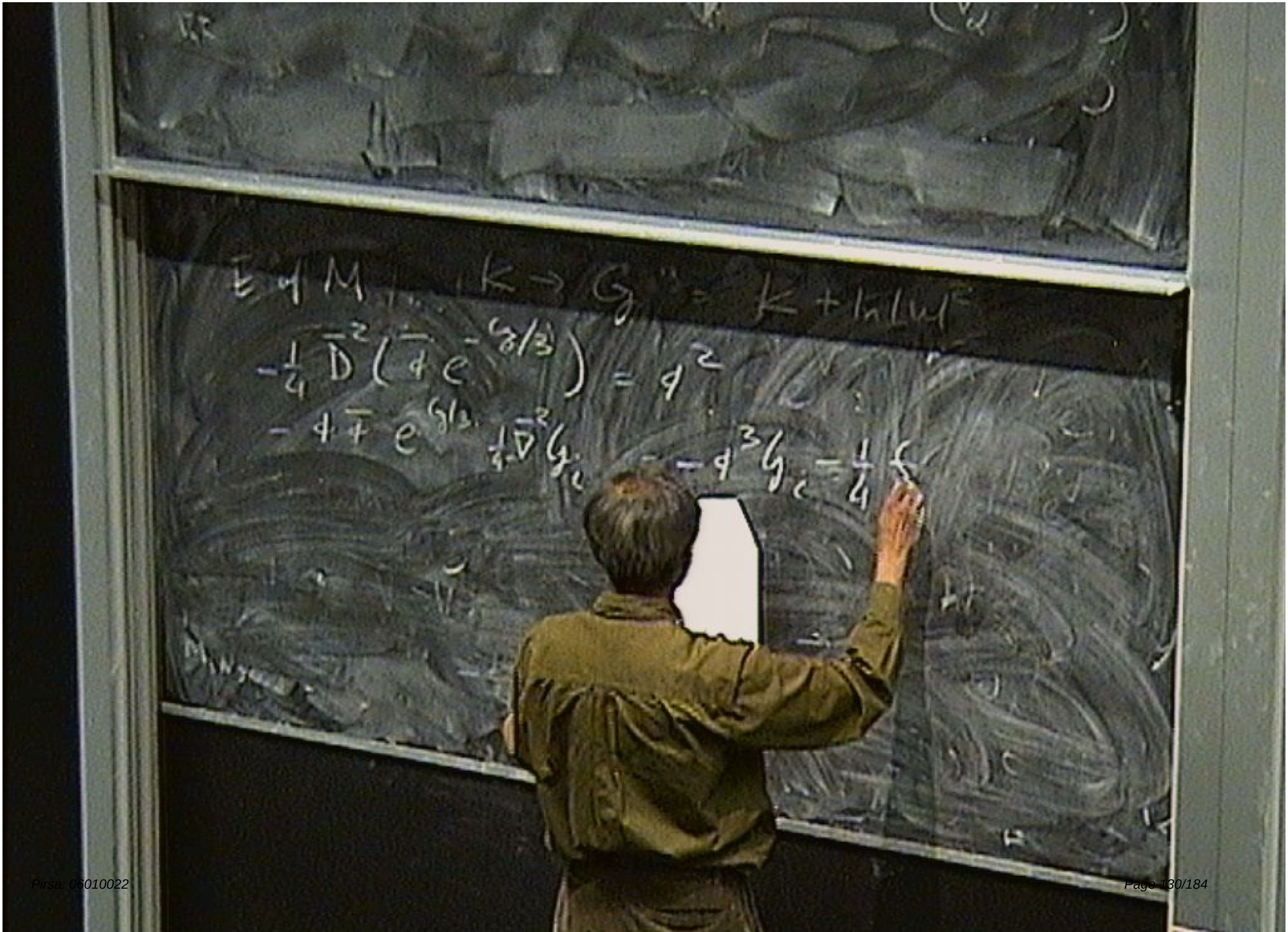

E & M

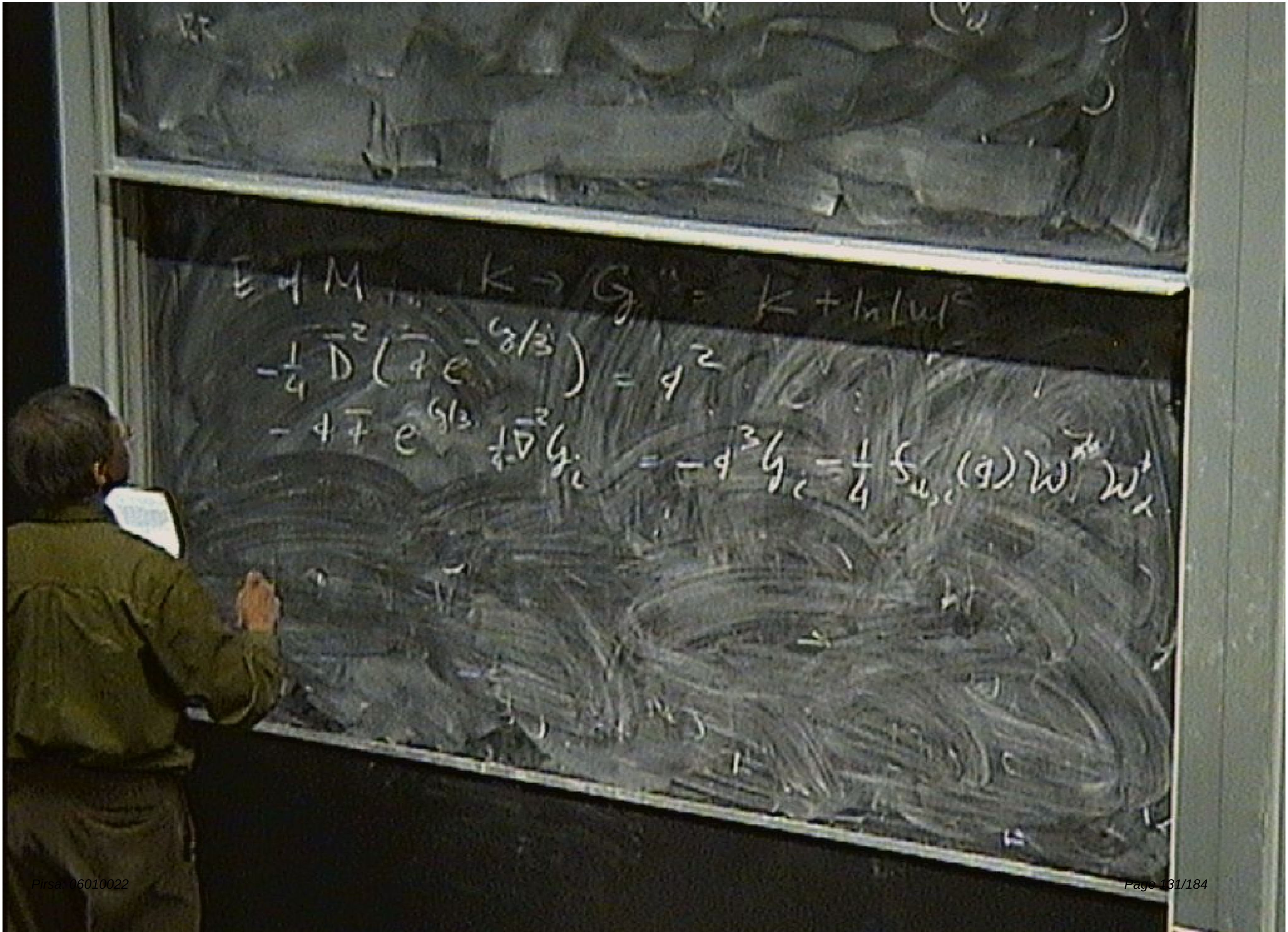

E+M











E of M $K \to G = K + \ln|W|^2$

$$-\frac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-G/3}\right) = \phi^2$$

$$-\phi\bar{\phi}\, e^{G/3} \quad \frac{1}{4}\bar{D}^2 G_i = -\phi^3 G_i - \frac{1}{4} f_{ab,i}(\phi)\, W^a W^b$$

SI

$$-\phi\bar{\phi}\, e^{-G/3} \; i k_a^i\, G_i$$

$$= e^{\mathcal{G}}\left(\partial_i \mathcal{G}\, \partial_j \left(\mathcal{G}^{ij} - \ldots\right)\right)$$

$\mathcal{G} = K + \ln|W|$

$$\frac{\partial K}{\partial V^a} = i k_a^i K_i$$

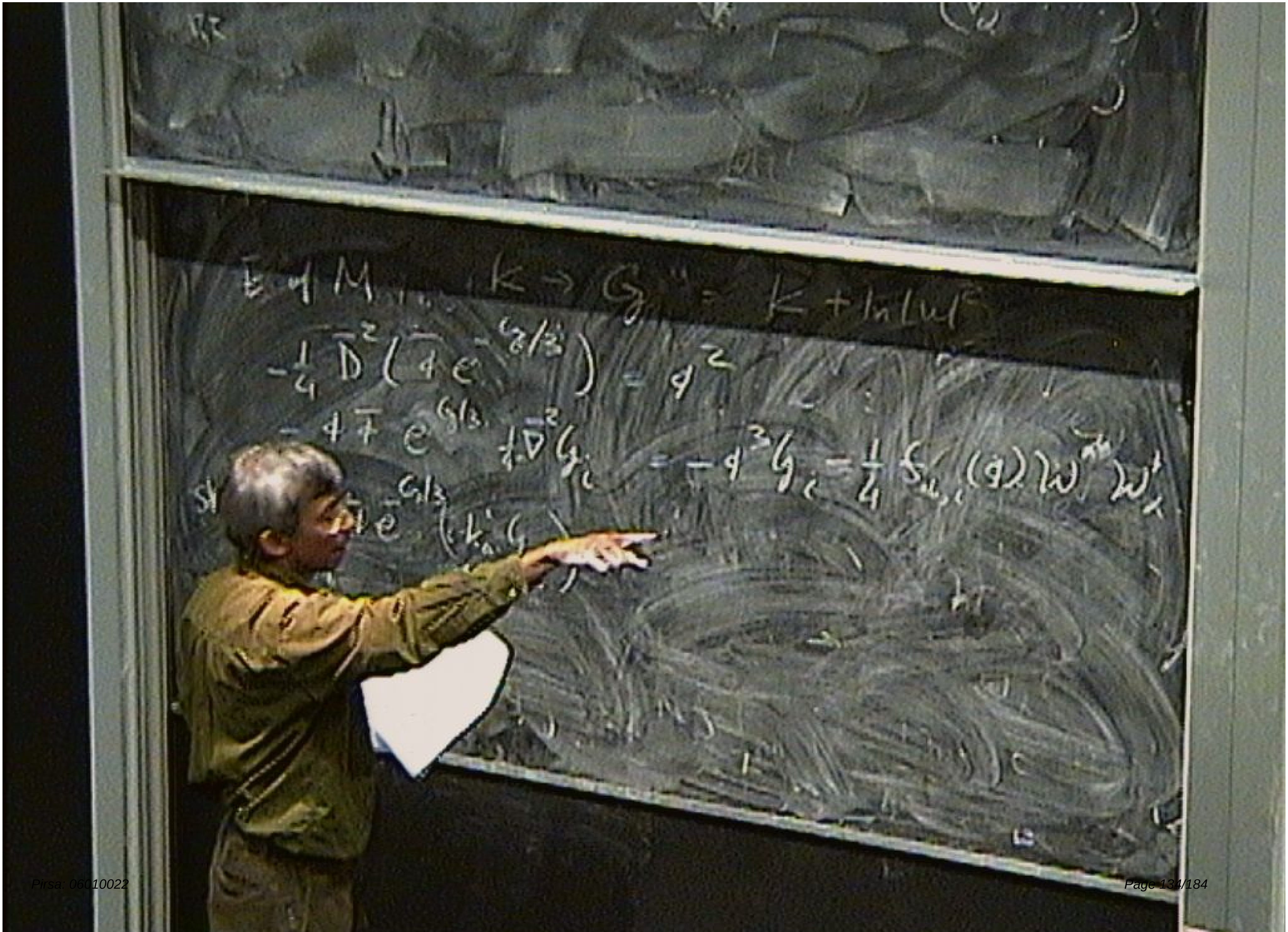
$$\xi\, \mathrm{tr}\, V \to \xi\, \mathrm{tr}\, V + \xi\, \mathrm{tr}(i\Lambda - i\bar{\Lambda})$$

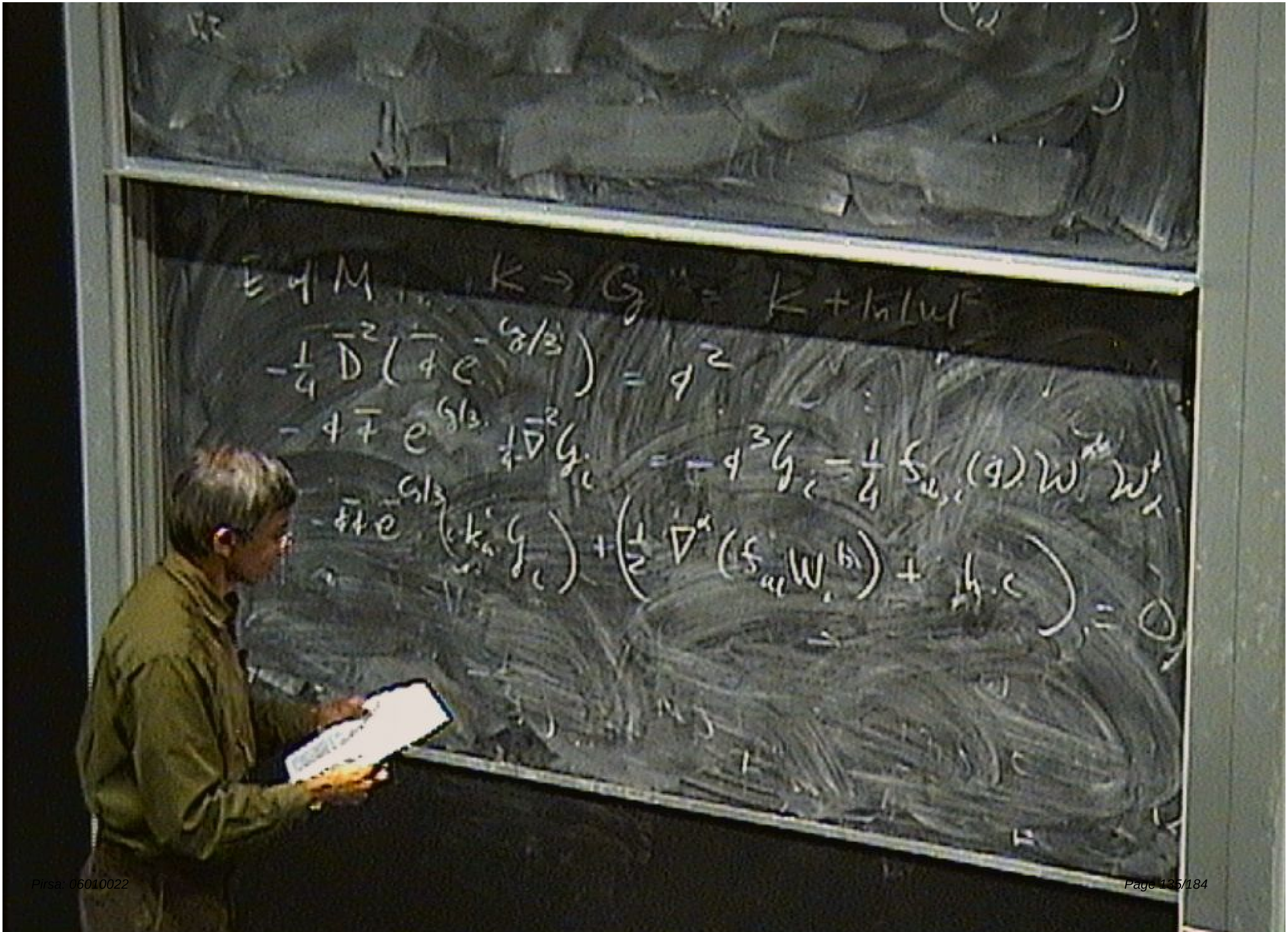
Under gauge tran.

$$\phi \to e^{i\, \mathrm{tr}\Lambda \frac{\xi}{3}} \phi$$

$$\delta(\phi^3 W) = 3 i \Lambda^a\, \mathrm{tr}\, T^a \frac{\xi}{3} \phi^3 W + \phi^3 \Lambda^a k_a^i \partial_i W = 0$$

$$k_a^i \partial_i W = -i \xi\, \mathrm{tr}\, T^a W$$


E of M
K → G = K + ln|W|²



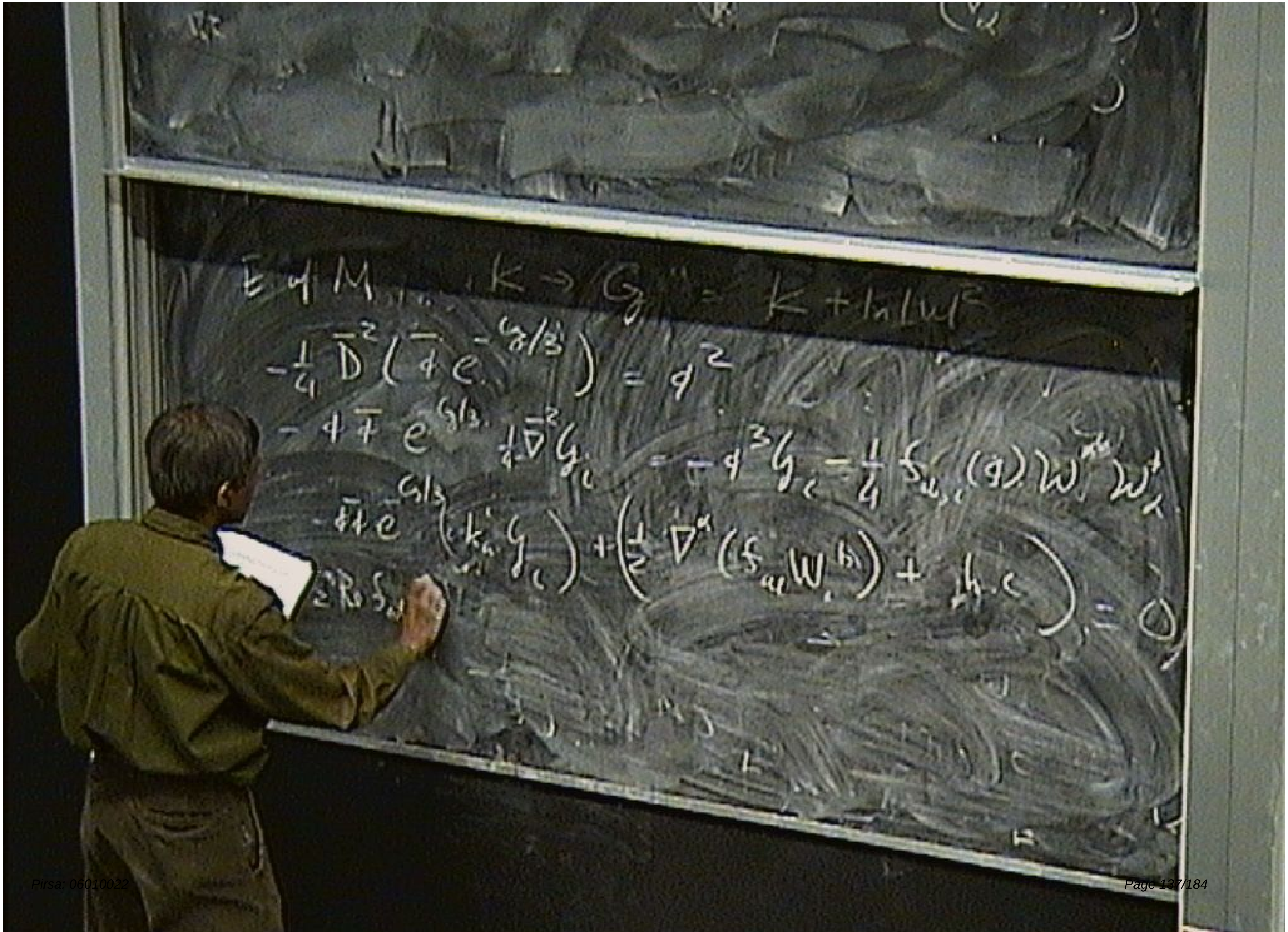
E of M $\quad K \to G = K + \ln|W|^2$

$$-\frac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-G/3}\right) = \phi^2$$

$$-\phi\bar{\phi}\, e^{G/3} \qquad \frac{1}{4}\bar{D}^2 G_i = -\phi^3 G_i - \frac{1}{4} f_{ab,i}(\phi)\, W^{\alpha a} W^b_\alpha$$

SU

$$-\bar{\phi}\phi\, e^{-G/3}\left(k_i G_i\right) + \left(\frac{1}{2}\nabla^\alpha\left(f_{ab} W^b_\alpha\right) + h.c.\right) = 0$$



E of M ... $K \to G = K + \ln|W|^2$

$$-\frac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-G/3}\right) = \phi^2$$

$$-\phi\bar{F}\, e^{G/3} \qquad \frac{1}{4}\bar{D}^2 G_i = -\phi^3 G_i - \frac{1}{4} f_{ab,i}(\phi)\, W^{a\alpha} W^b_\alpha$$

SY

$$-\bar{F}\, e^{-G/3}\left(i k_a^i G_i\right) + \left(\frac{1}{2} D^\alpha \left(f_{ab} W_\alpha^b\right) + h.c.\right) = 0$$

$$2\,\mathrm{Re} f_{ab}\, D^b = i k^{ai} G_i = i k^{ai} \frac{D_i W}{W}$$

$$= e^{\mathcal{G}}\left(\partial_i \mathcal{G}\, \partial_j \mathcal{G}\, \mathcal{G}^{ij} - 3\right)$$

$\mathcal{G} = K + \ln|W|^2$

$$\frac{\partial K}{\partial V^a} = i k_a^i K_i$$

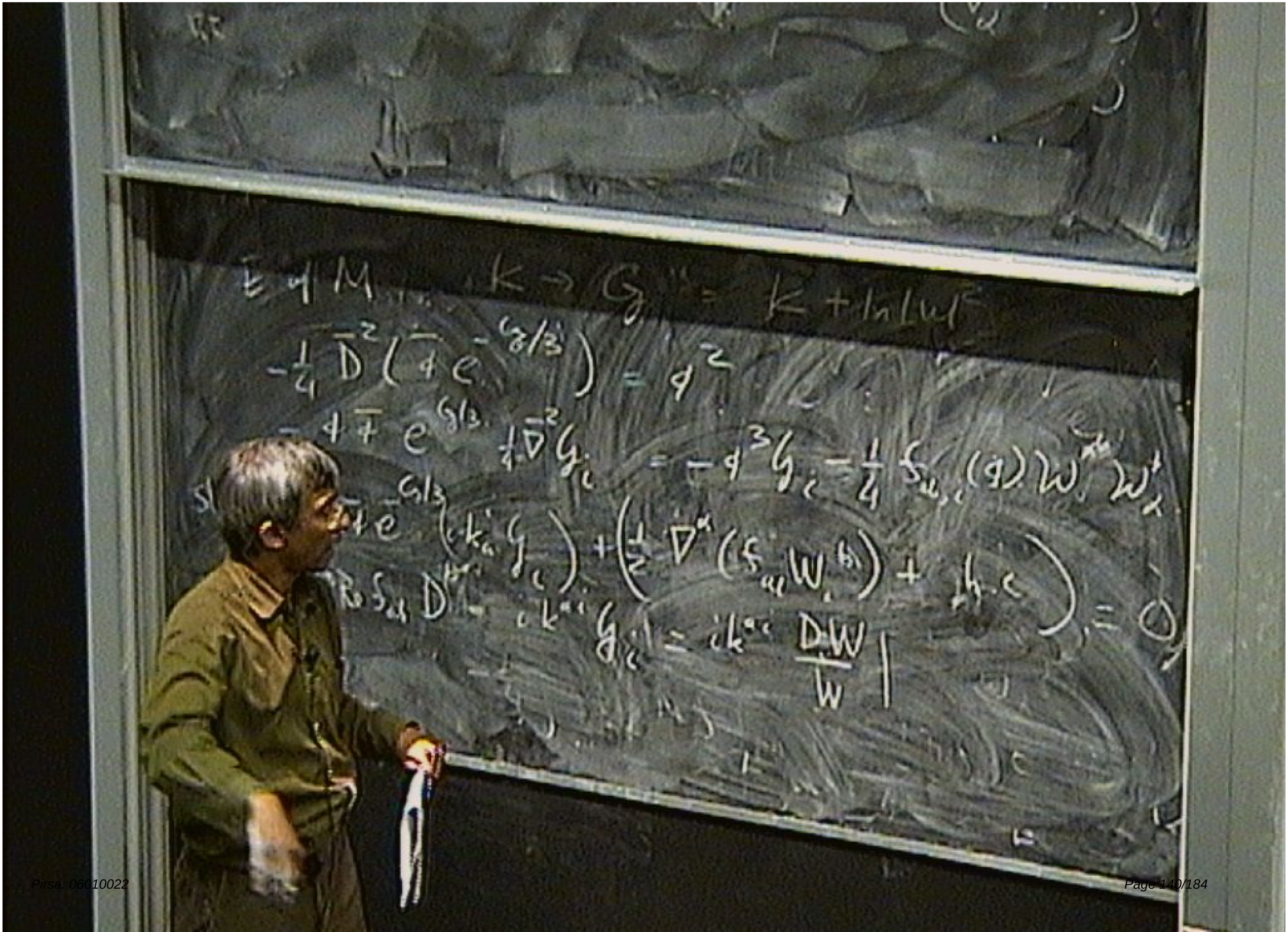
$$\xi\, \mathrm{tr}\, V \to \xi\, \mathrm{tr}\, V + \xi\, \mathrm{tr}(i\Lambda - i\bar{\Lambda})$$

Under gauge trans

$$\phi \to e^{i\, \mathrm{tr}\Lambda \frac{\xi}{3}} \phi$$

$$\delta(\phi^3 W) = 3 i \Lambda^a\, \mathrm{tr}\, T^a \frac{\xi}{3} \phi^3 W + \phi^3 \Lambda^a k_a^i \partial_i W = 0$$

$$k_a^i \partial_i W = -i \xi\, \mathrm{tr}\, T^a\, W$$



E of M $\quad K \to G = K + \ln|W|^2$

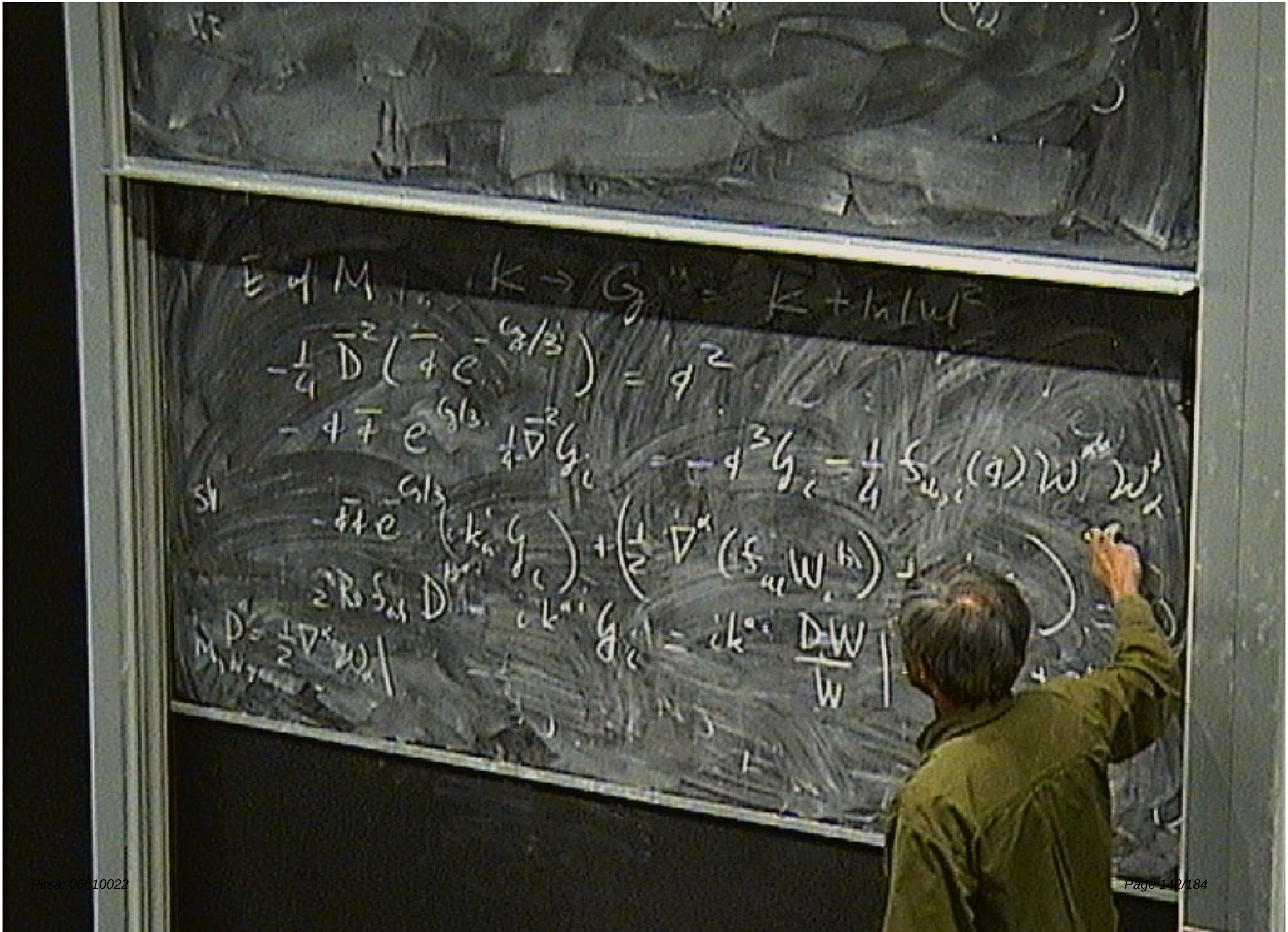
$$-\frac{1}{4}\bar{D}^2\left(\bar{\phi}\, e^{-G/3}\right) = \phi^2$$

$$-\phi\bar{\phi}\, e^{G/3}\, \frac{1}{4}\bar{D}^2 G_i = -\phi^3 G_i - \frac{1}{4} f_{ab,i}(\phi)\, W^a W^b$$

SI

$$-\phi\bar{\phi}\, e^{-G/3}\left(i k_a^i G_i\right) + \left(\frac{1}{2} D^\alpha \left(f_{ab} W_\alpha^b\right) + \text{h.c.}\right) = 0$$

$$2\,\mathrm{Re}\, f_{ab}\, D^{b}\ [\text{illegible}]\ i k^{ai} G_i = i k^{ai} \frac{D_i W}{W} \Big| = i k^{ai} K_i + \xi \mathrm{tr}\, T^a$$



E of M $K \to G = K + \ln|W|^2$

$$-\frac{1}{4}\bar{D}^2\left(\bar{\Phi}\, e^{-G/3}\right) = \Phi^2$$

$$-\Phi\bar{F}\, e^{G/3} \quad \frac{1}{4}\bar{\nabla}^2 G_i = -\Phi^3 G_i - \frac{1}{4} f_{ab,i}(\phi)\, W^a W^b_\alpha$$

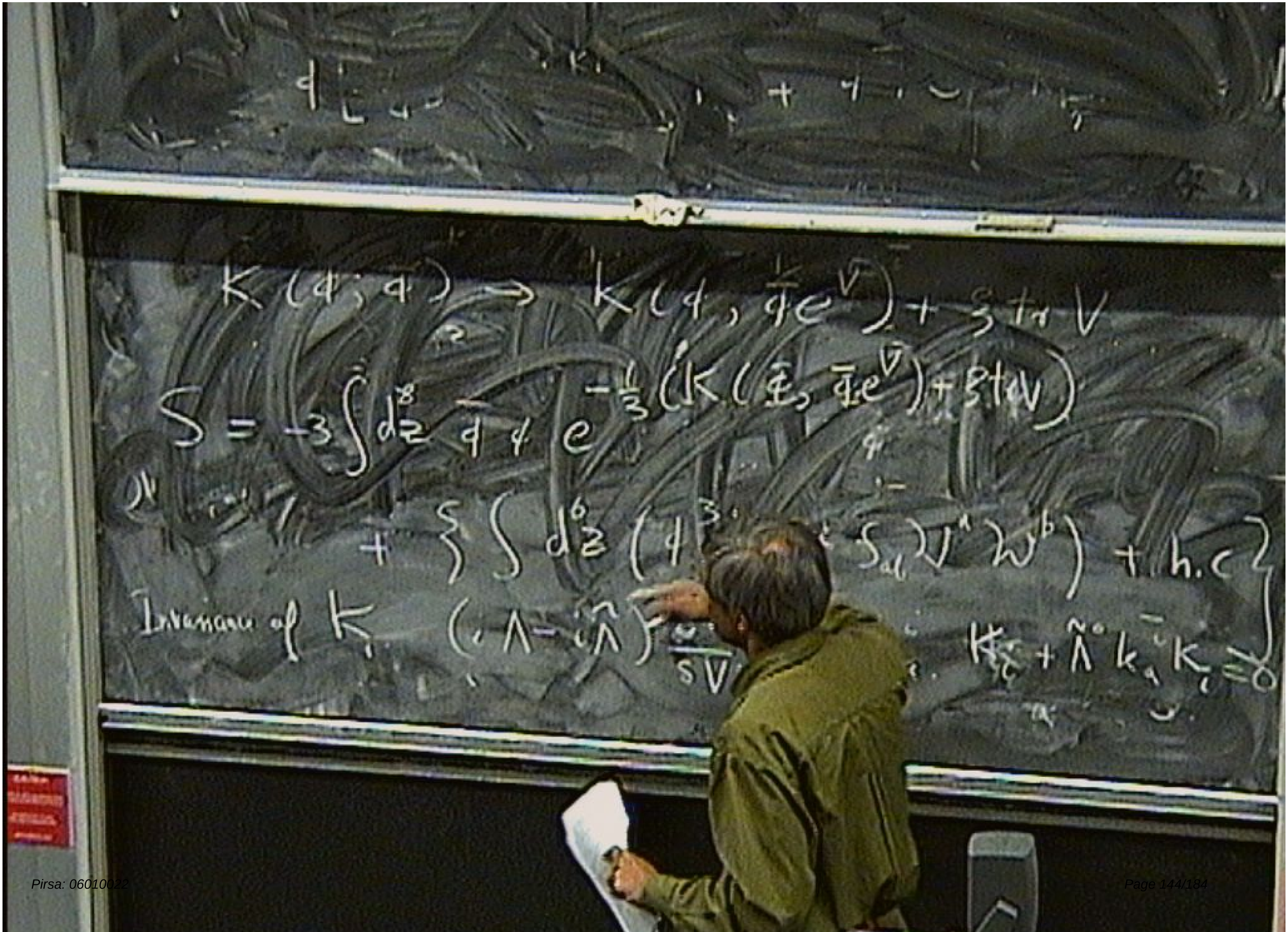
S

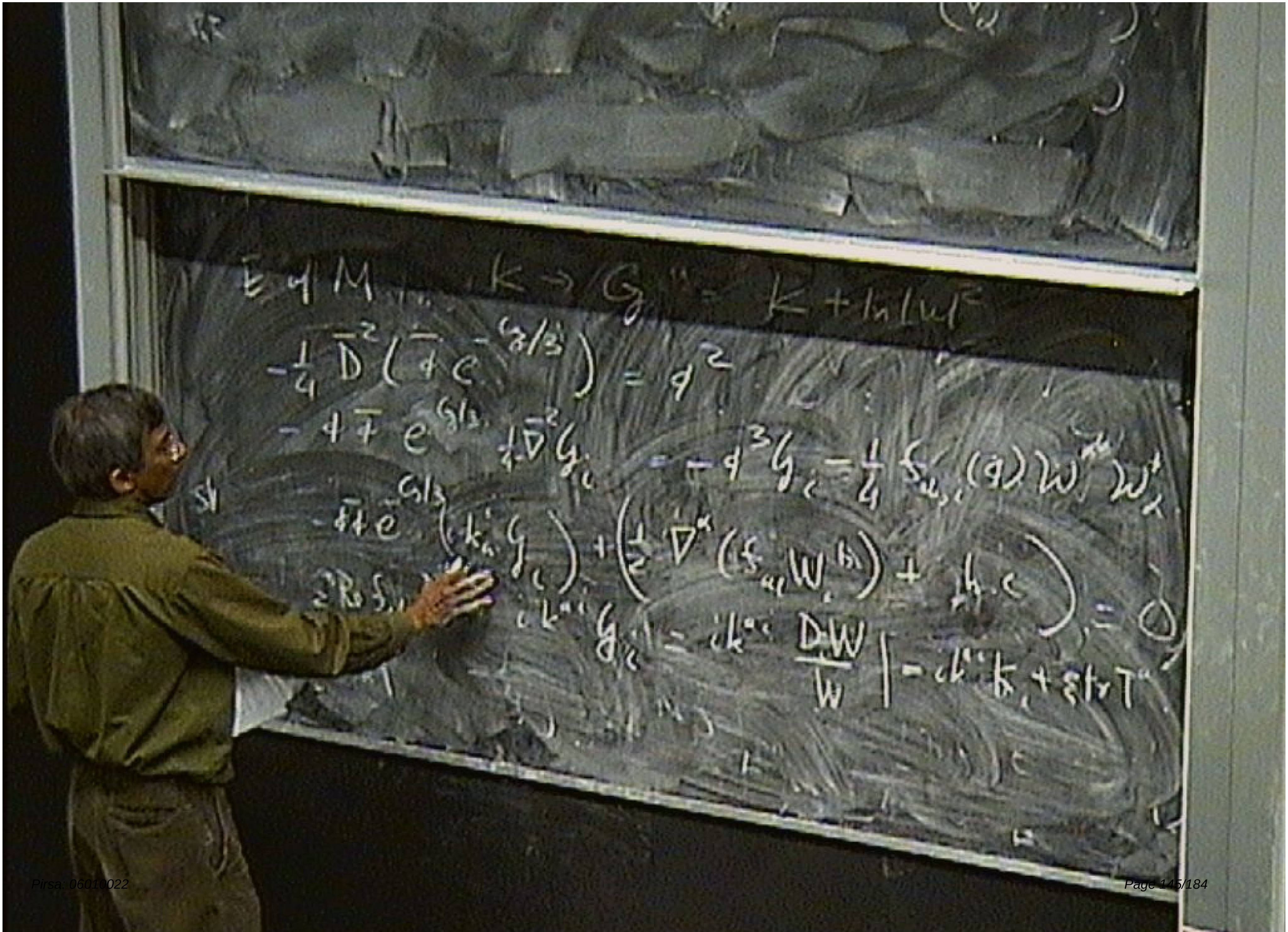
$$-\bar{\Phi}\Phi\, e^{-G/3}\left(i k_a^i G_i\right) + \left(\frac{1}{2}\nabla^\alpha\left(f_{ab} W_\alpha^b\right) + h.c.\right) = 0$$

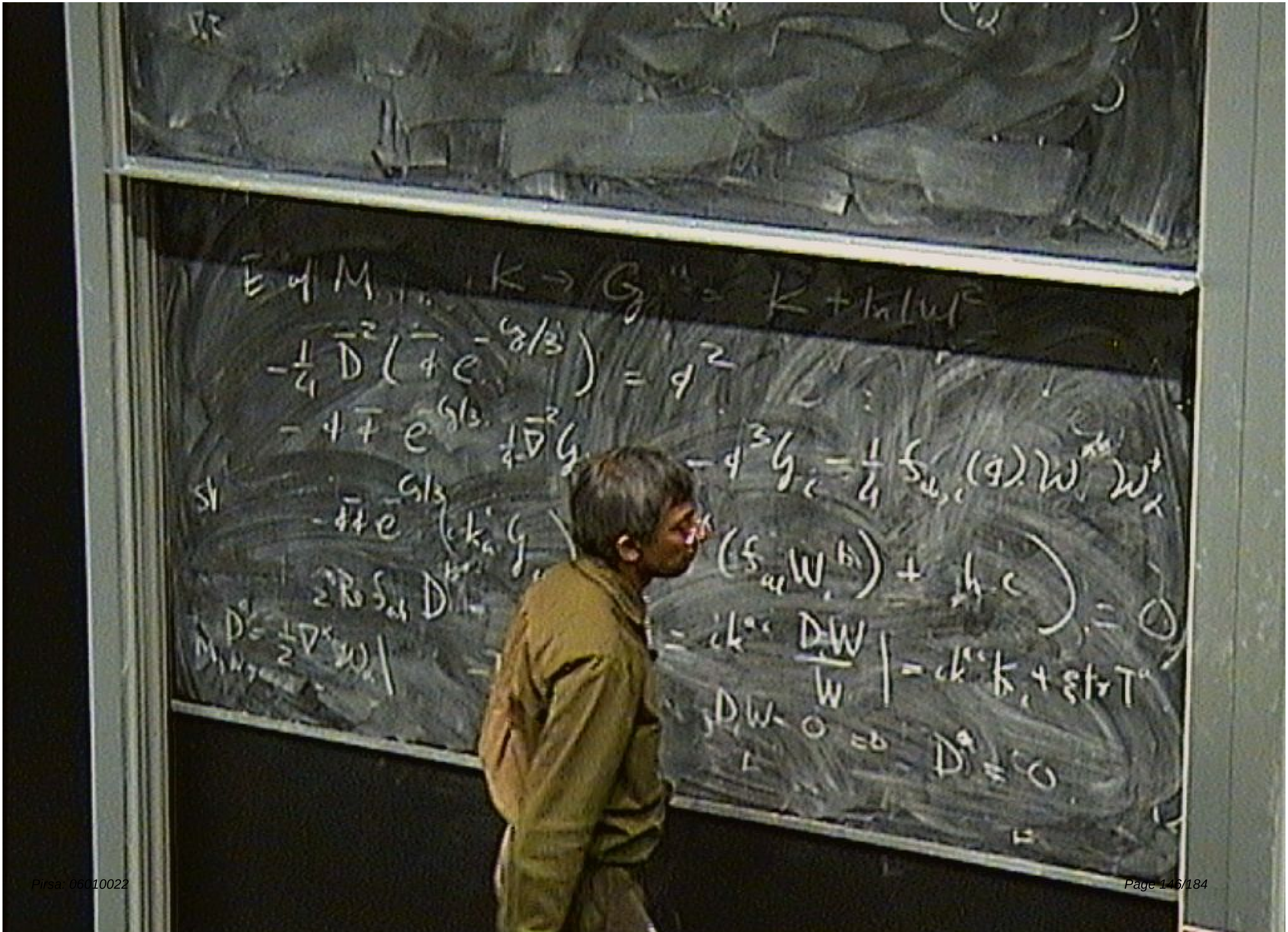
$$\Sigma\, \mathrm{Re} f_{ab} D^b = i k^{ai} G_i = i k^{ai} \frac{D_i W}{W} = i k^{ai} K_i + \xi \mathrm{tr}\, T^a$$

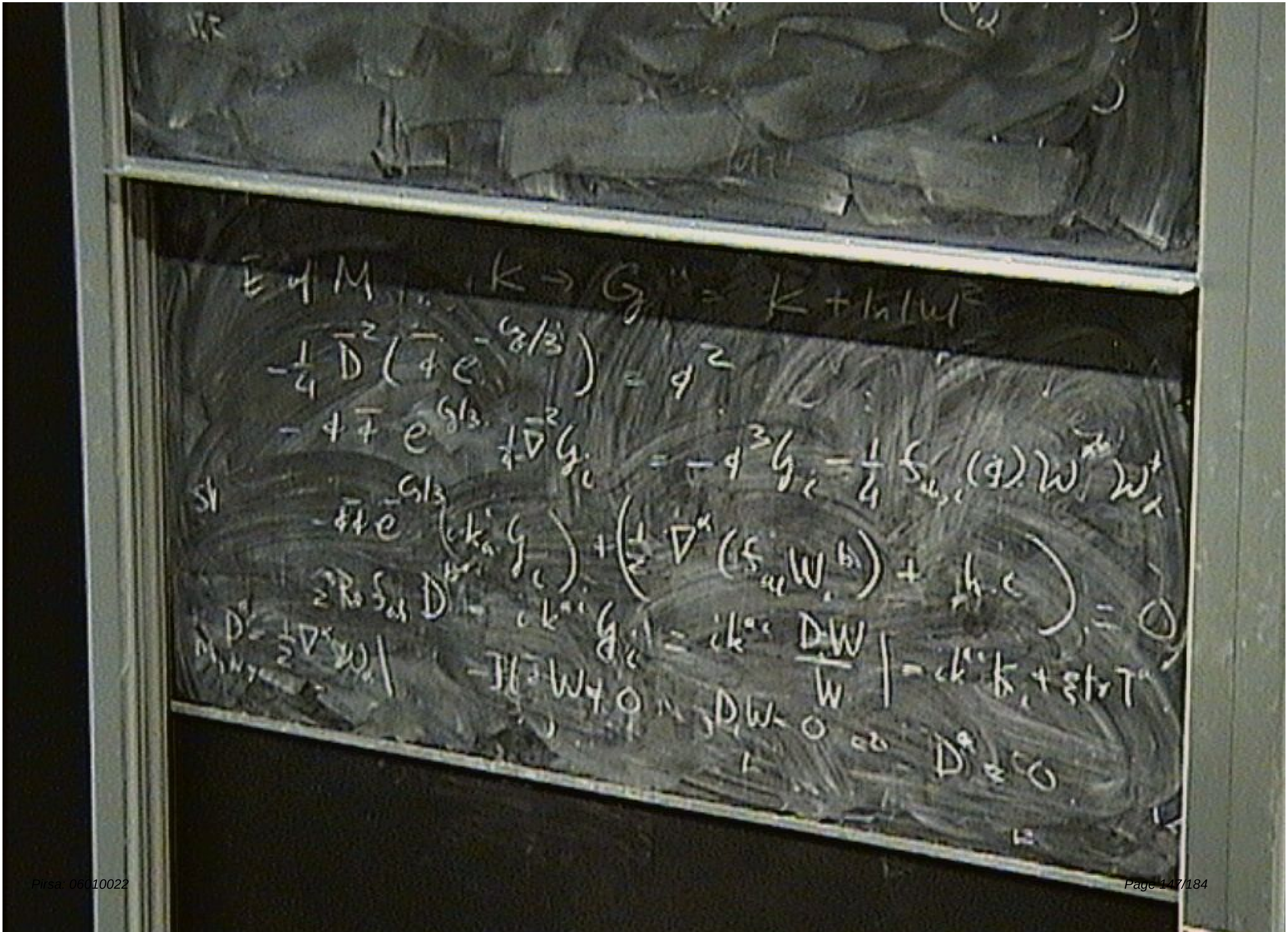
$D^a = \frac{1}{2}\nabla^\alpha W_\alpha|$

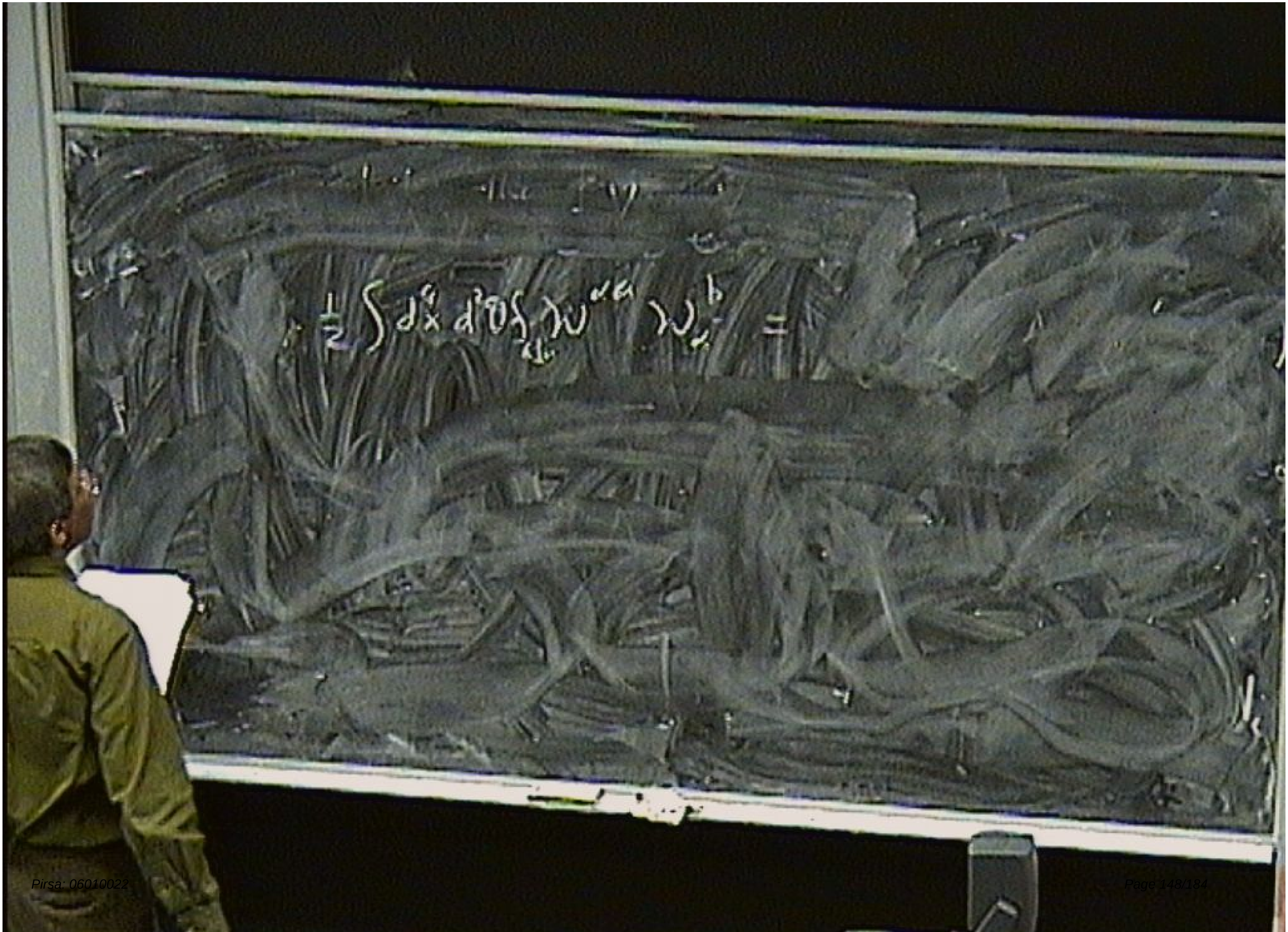
$M_1 M_2 \ldots$

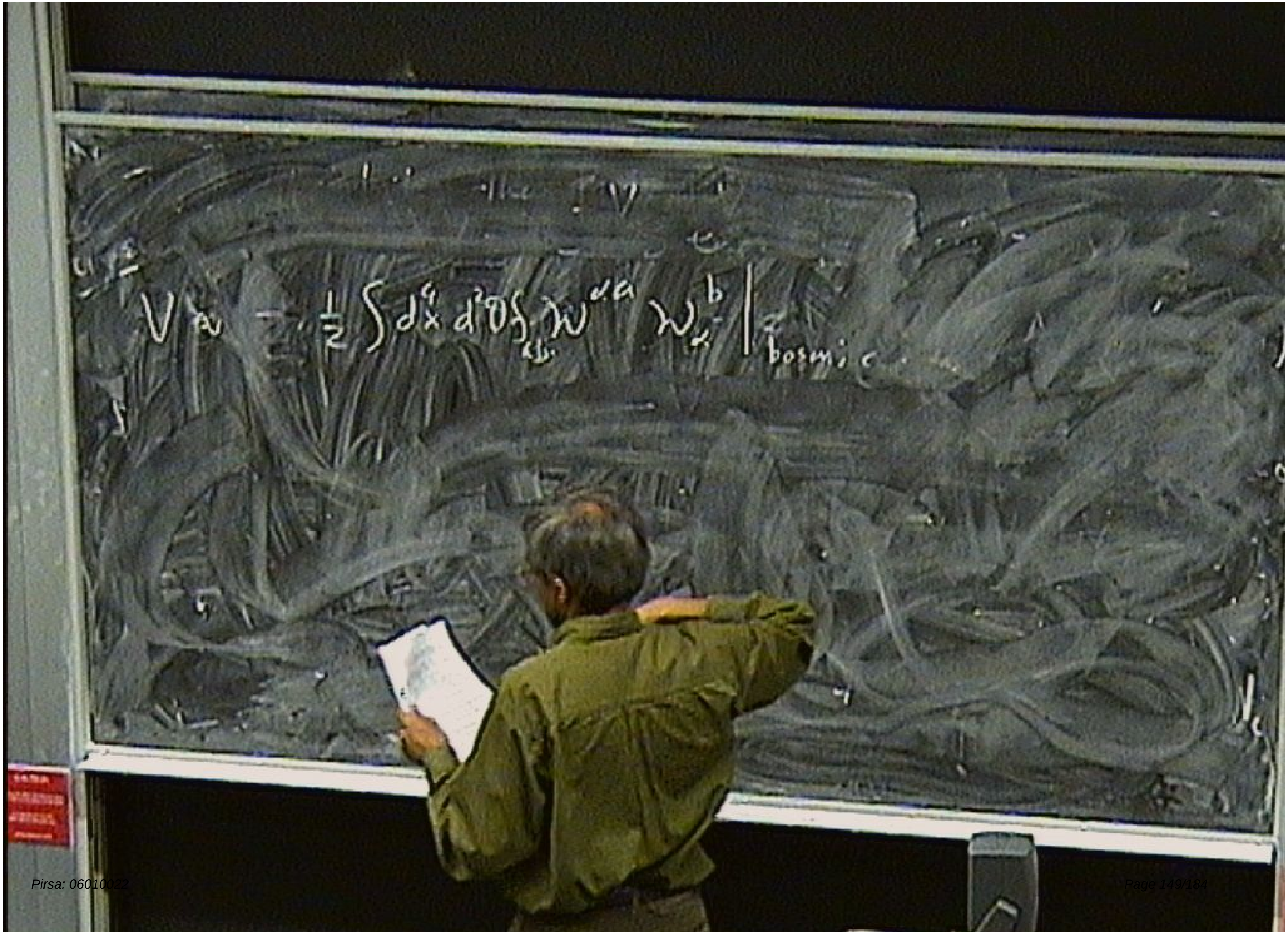

K(φ, φ̄) → K(φ, φ̄e^V) + ξ tr V
S = −3∫d^8z φ̄ φ e^{−1/3(K(Φ, Φ̄e^V) + ξ tr V)}
+ {∫d^6z (φ^3 … S_a) V^a W^b) + h.c}
Invariance of K
K_i + Λ̃^a k_a^i K_i = 0

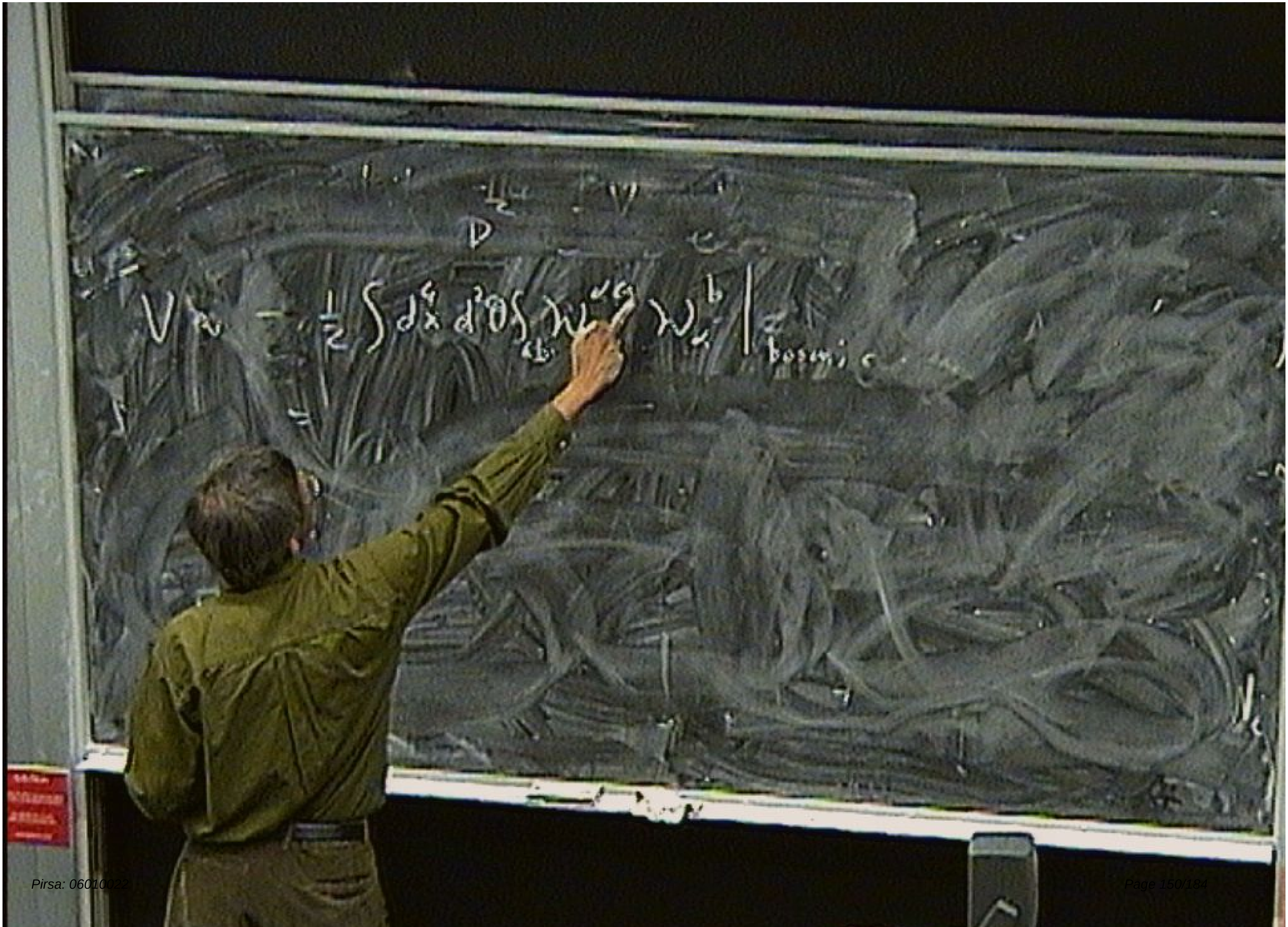






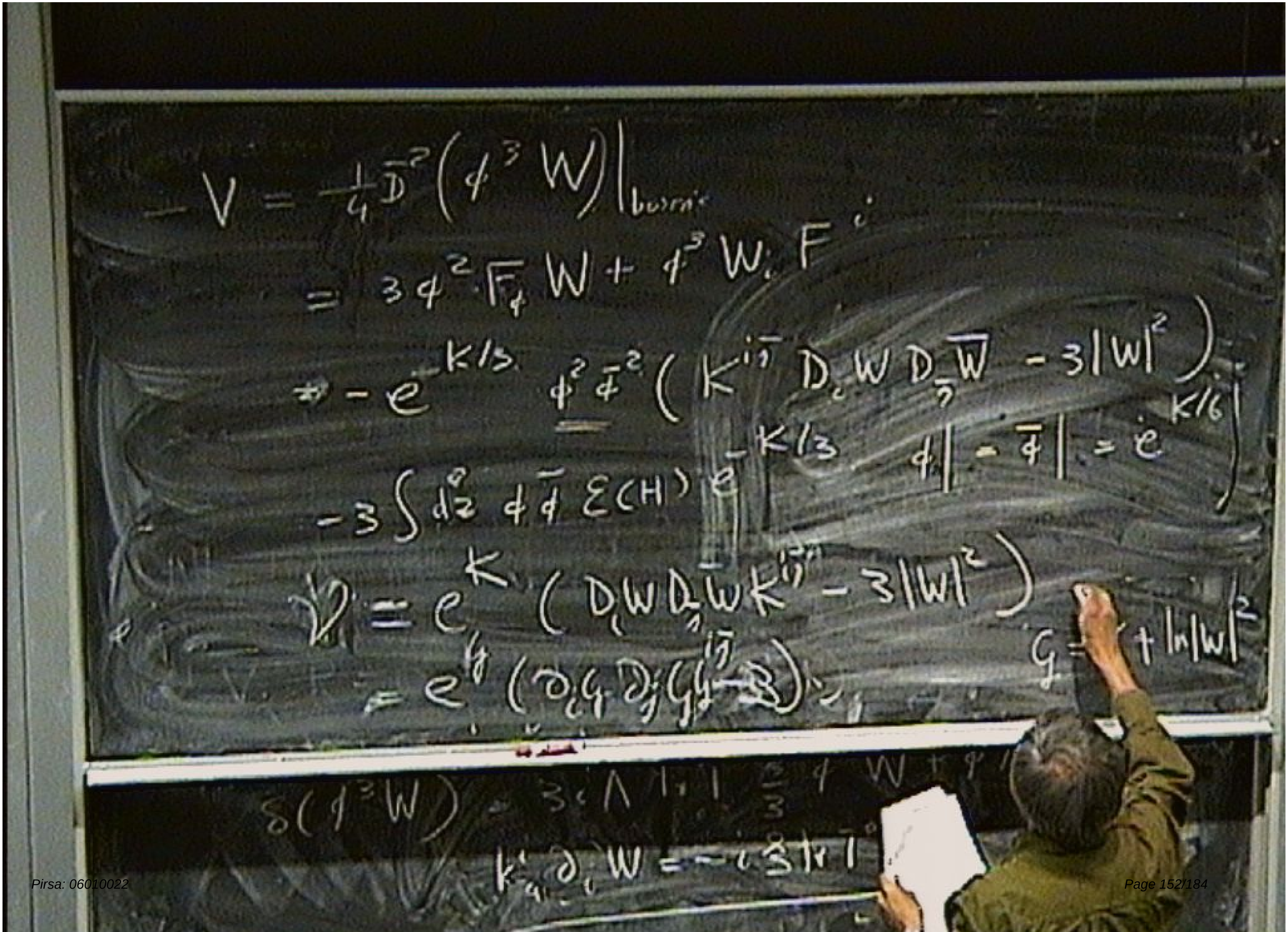

$\frac{1}{2}\int d^8x\, d^4\theta\, g_{ab}\, \partial W^{\alpha a}\, W_\alpha^{\ b} =$


bosonic



$$\mathcal{V}_N = \frac{1}{2}\int d^4x\, d^2\theta\, f_{ab}\, W^{\alpha a} W_\alpha^b \Big|_{\text{bosonic}}$$

$$= \frac{1}{2}(\mathrm{Re}\, f_{ab})\, D^a D^b$$


$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)|_{\text{bosonic}}$
$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$
$= -e^{-K/3}\phi^2\bar{\phi}^2(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2)$
$-3\int d^2z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3}$
$\phi| = \bar{\phi}| = e^{K/6}$
$V = e^K(D_i W D_{\bar{j}}\bar{W} K^{i\bar{j}} - 3|W|^2)$
$= e^G(\partial_i G \partial_{\bar{j}} G G^{i\bar{j}} - 3)$
$G = K + \ln|W|^2$
$\delta(\phi^3 W)$

$$-V = -\frac{1}{4}\bar{D}^2(\phi^3 W)\Big|_{\text{bosonic}}$$

$$= 3\phi^2 F_\phi W + \phi^3 W_i F^i$$

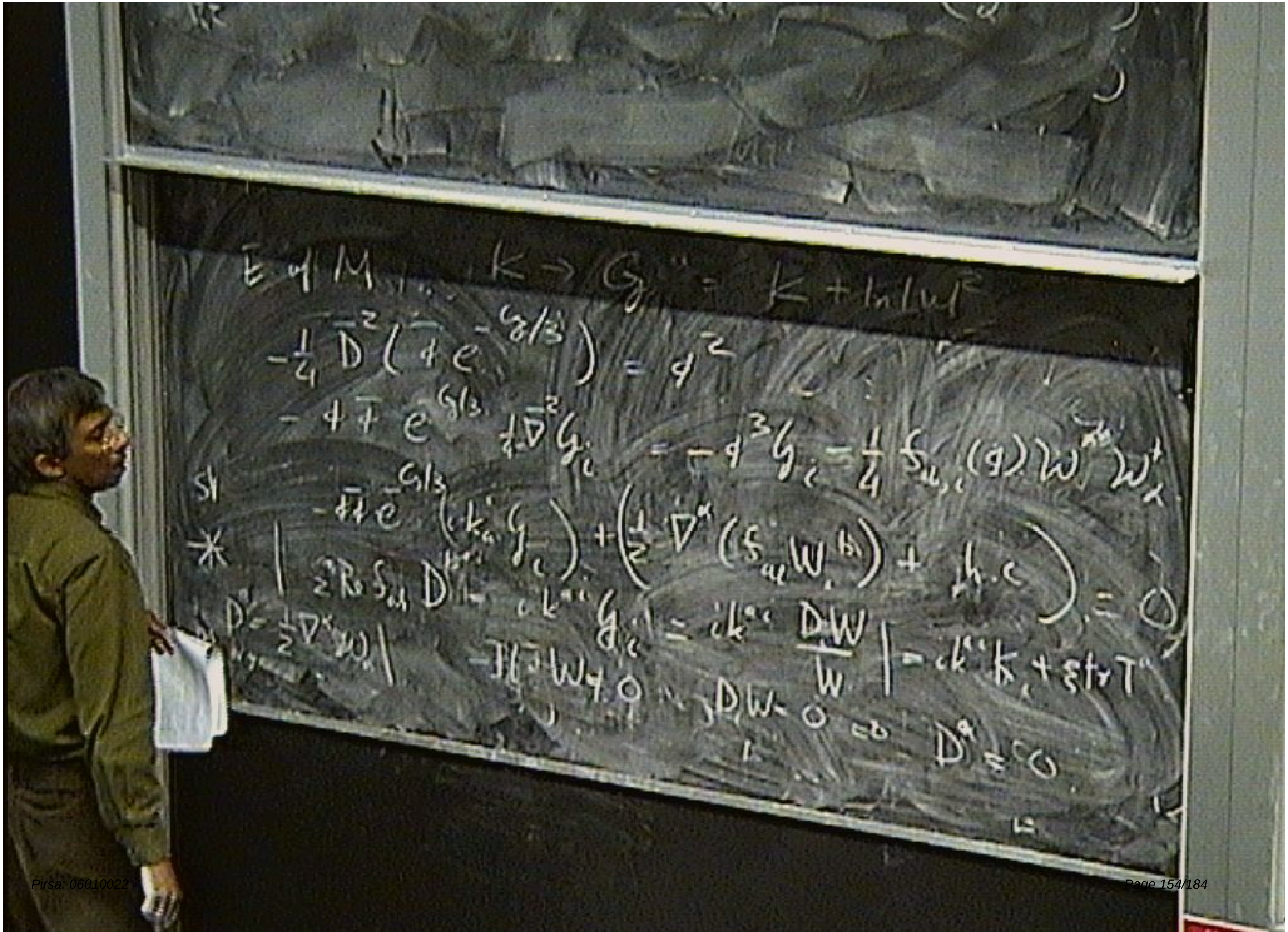
$$= -e^{-K/3}\,\phi^2\bar{\phi}^2\left(K^{i\bar{j}} D_i W D_{\bar{j}}\bar{W} - 3|W|^2\right)$$

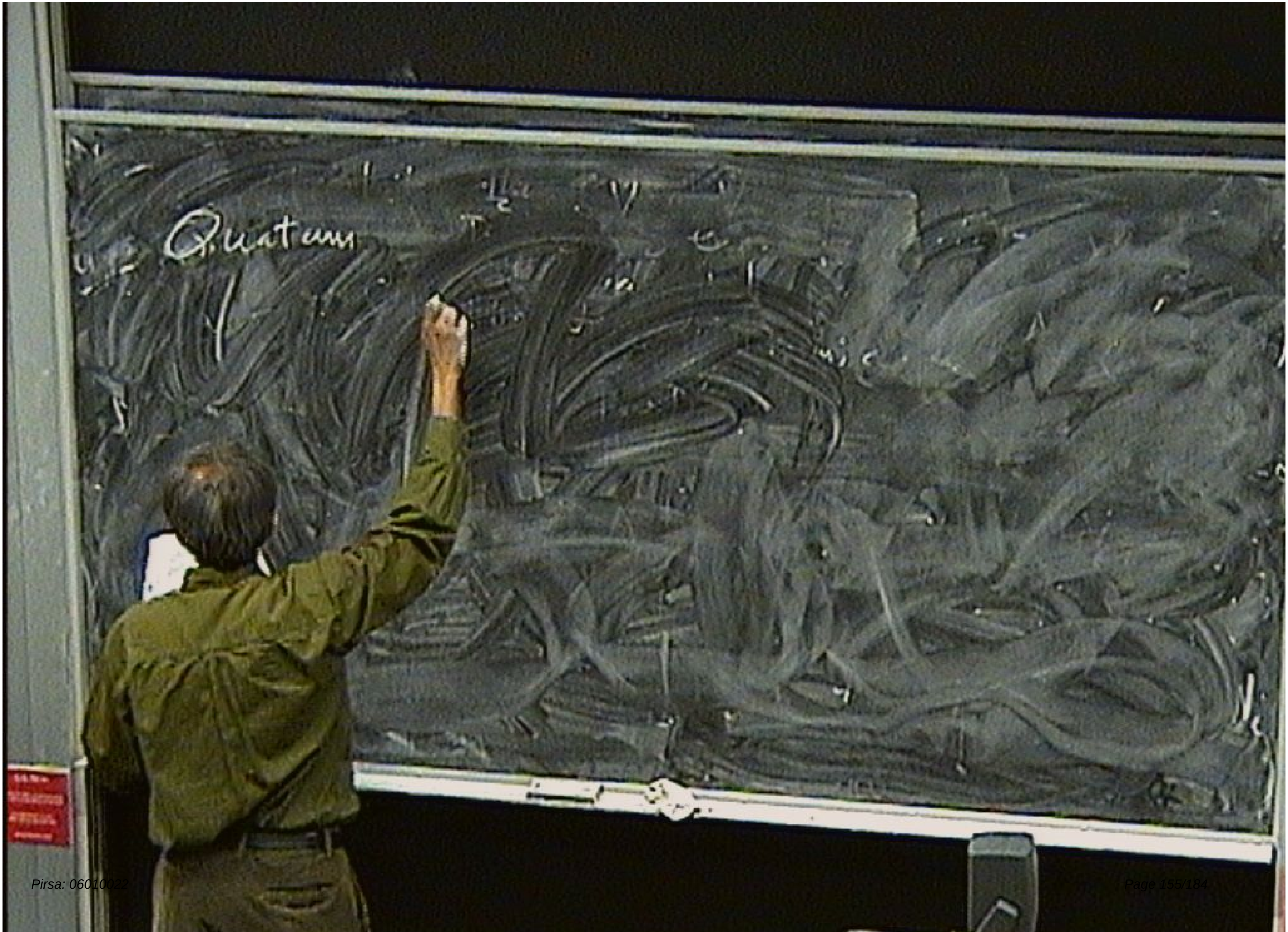
$$-3\int d^2 z\, \phi\bar{\phi}\, \mathcal{E}(H)\, e^{-K/3} \qquad \phi\big| = \bar{\phi}\big| = e^{K/6}$$

$$V = e^{K}\left(D_i W D_{\bar{j}} \bar{W} K^{i\bar{j}} - 3|W|^2\right) + \frac{1}{2}(\mathrm{Re} f_{ab}) D^a D^b$$

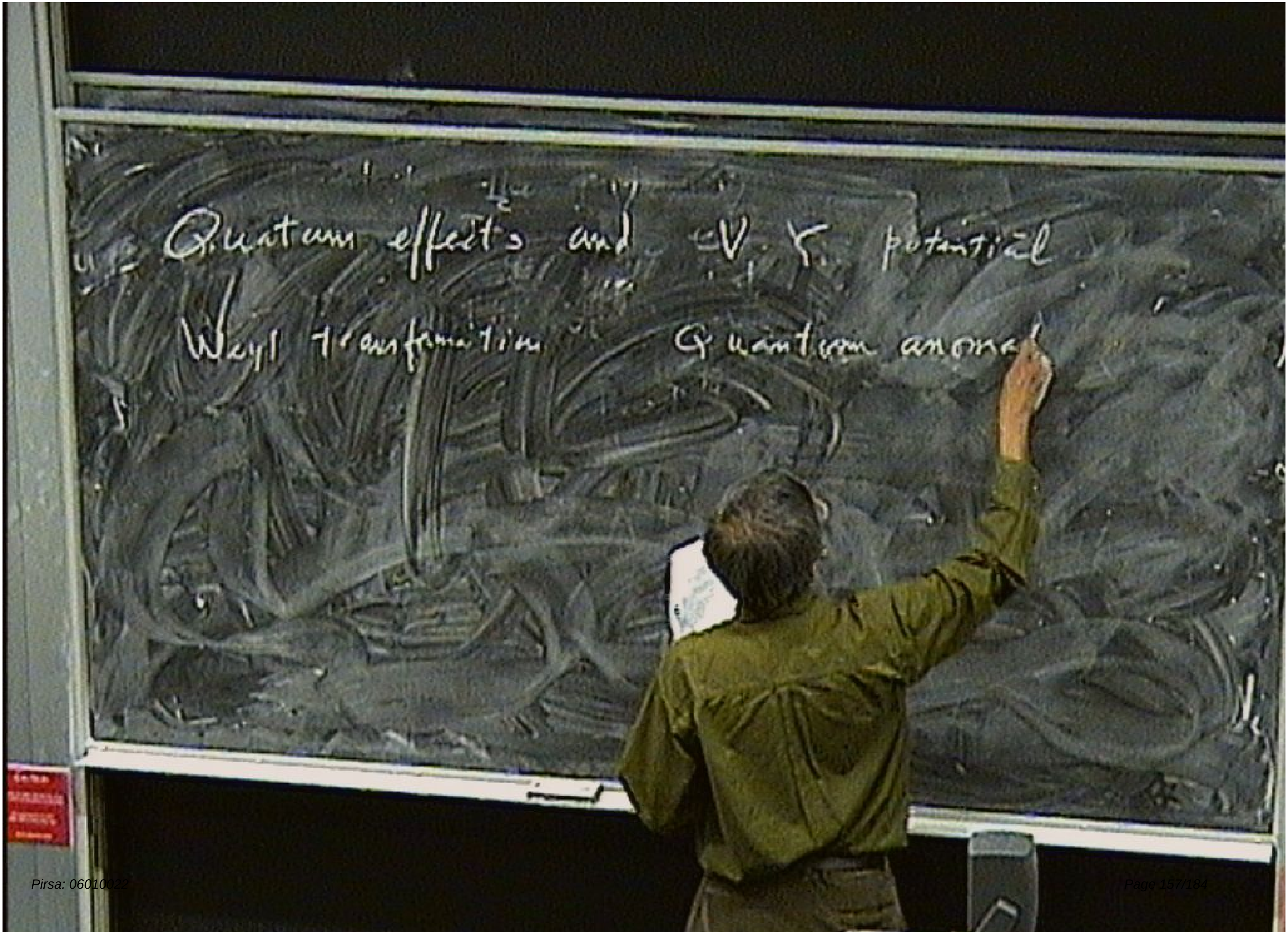
$$\delta(\phi^3 W) = 3 i \Lambda \frac{1}{3} \phi^3 W + \phi^3 \Lambda^a k^i_a \partial_i W$$

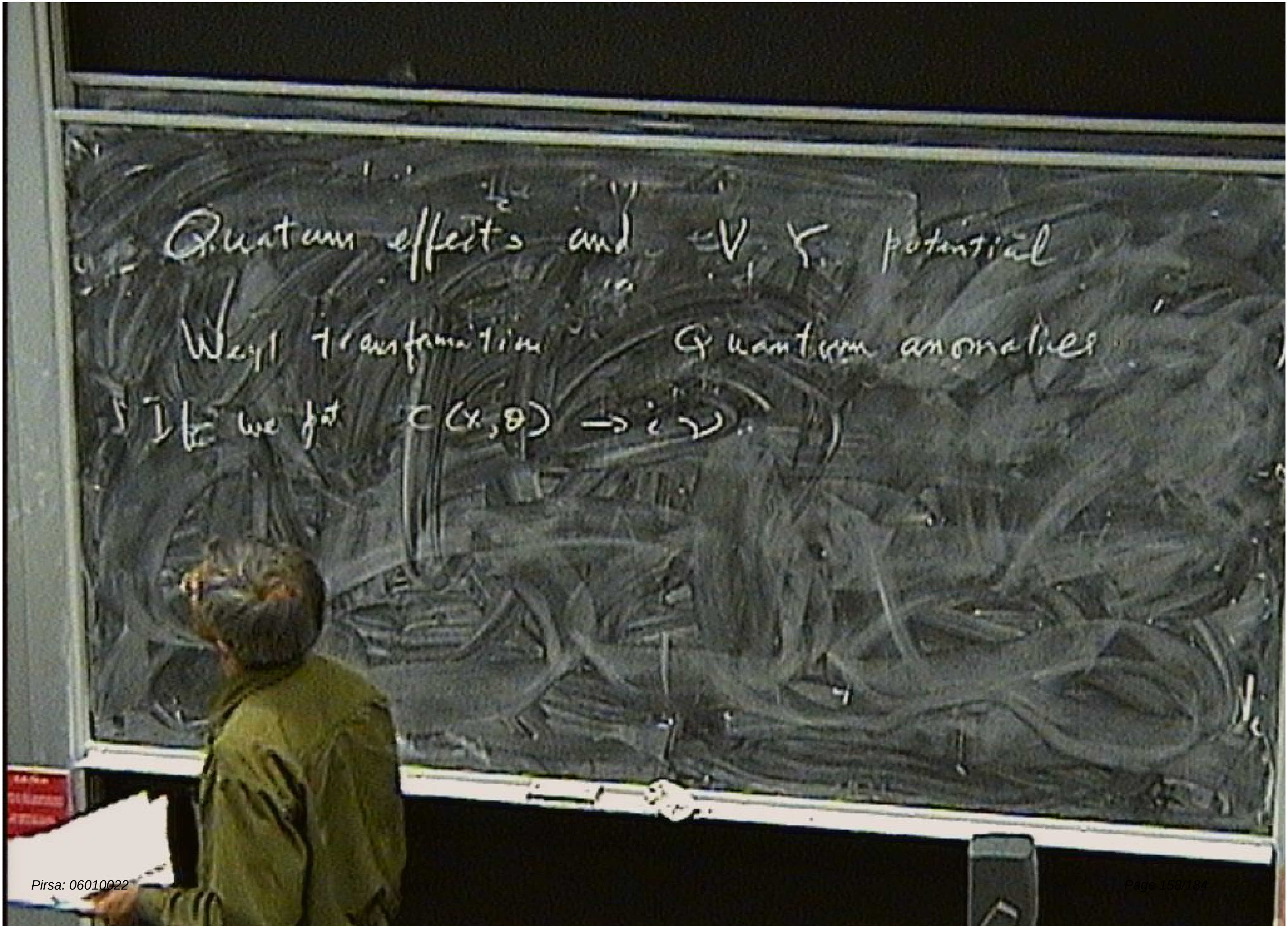
$$k^i_a \partial_i W = -i\, \xi\, T^a\, W$$

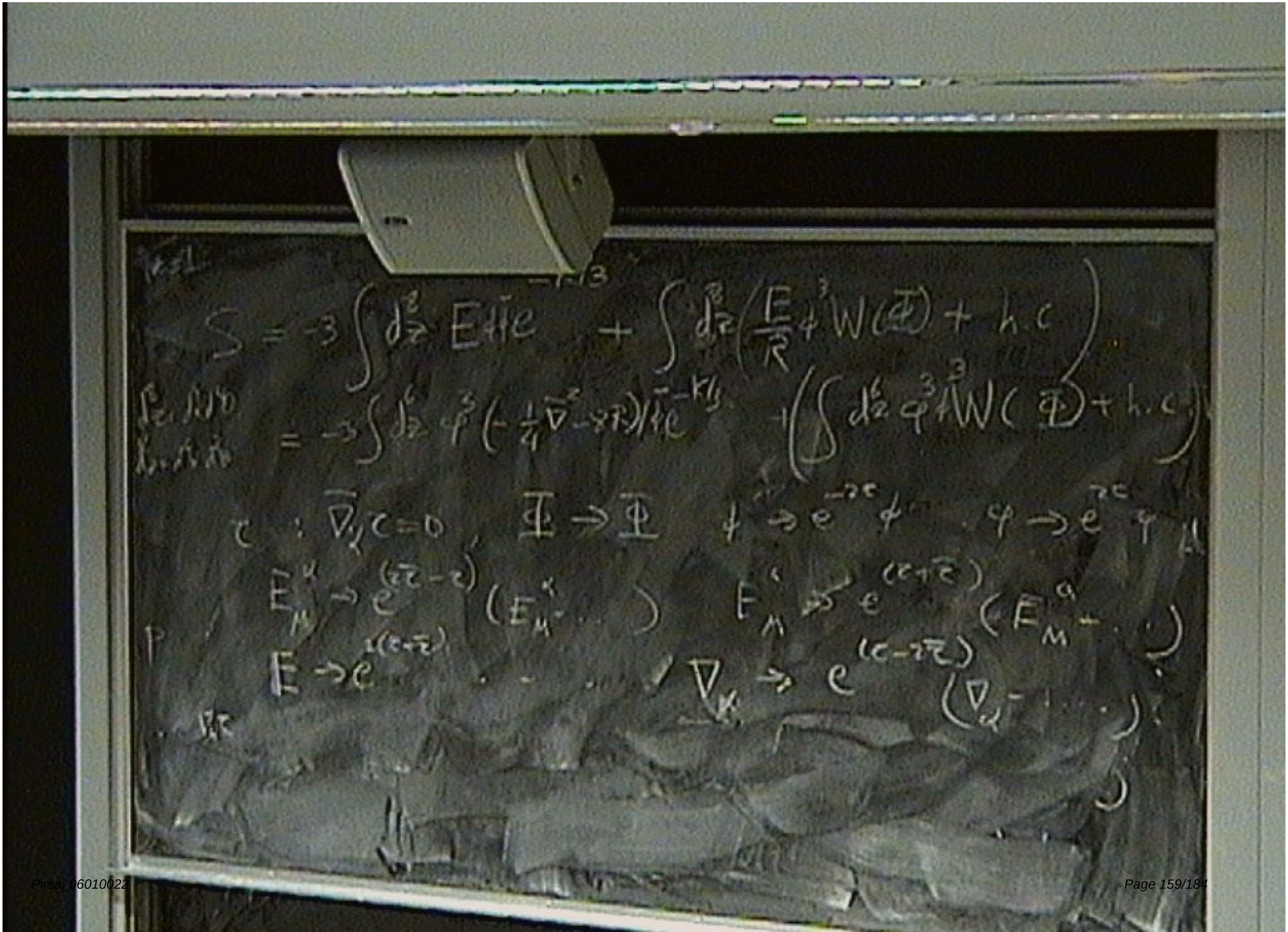

E of M
K → G = K + ln|W|²
DW
D^a = 0

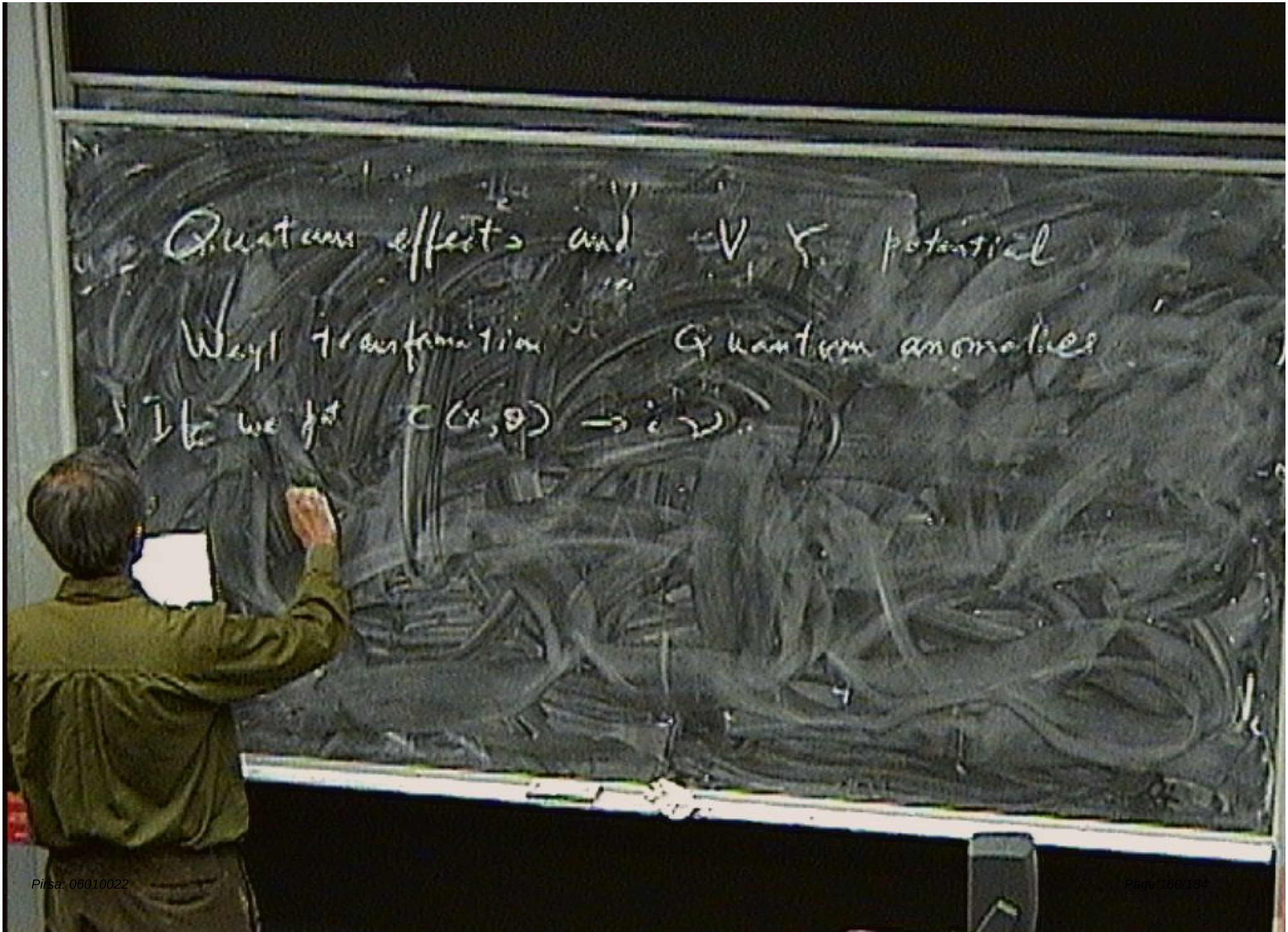

Quantum

Quantum effects and ϵ_V, ξ, potential


Quantum effects and
potential
Weyl transformation
Quantum anomal


Quantum effects and V. Y. potential
Weyl transformation
Quantum anomalies




Quantum effects and V, ξ potential
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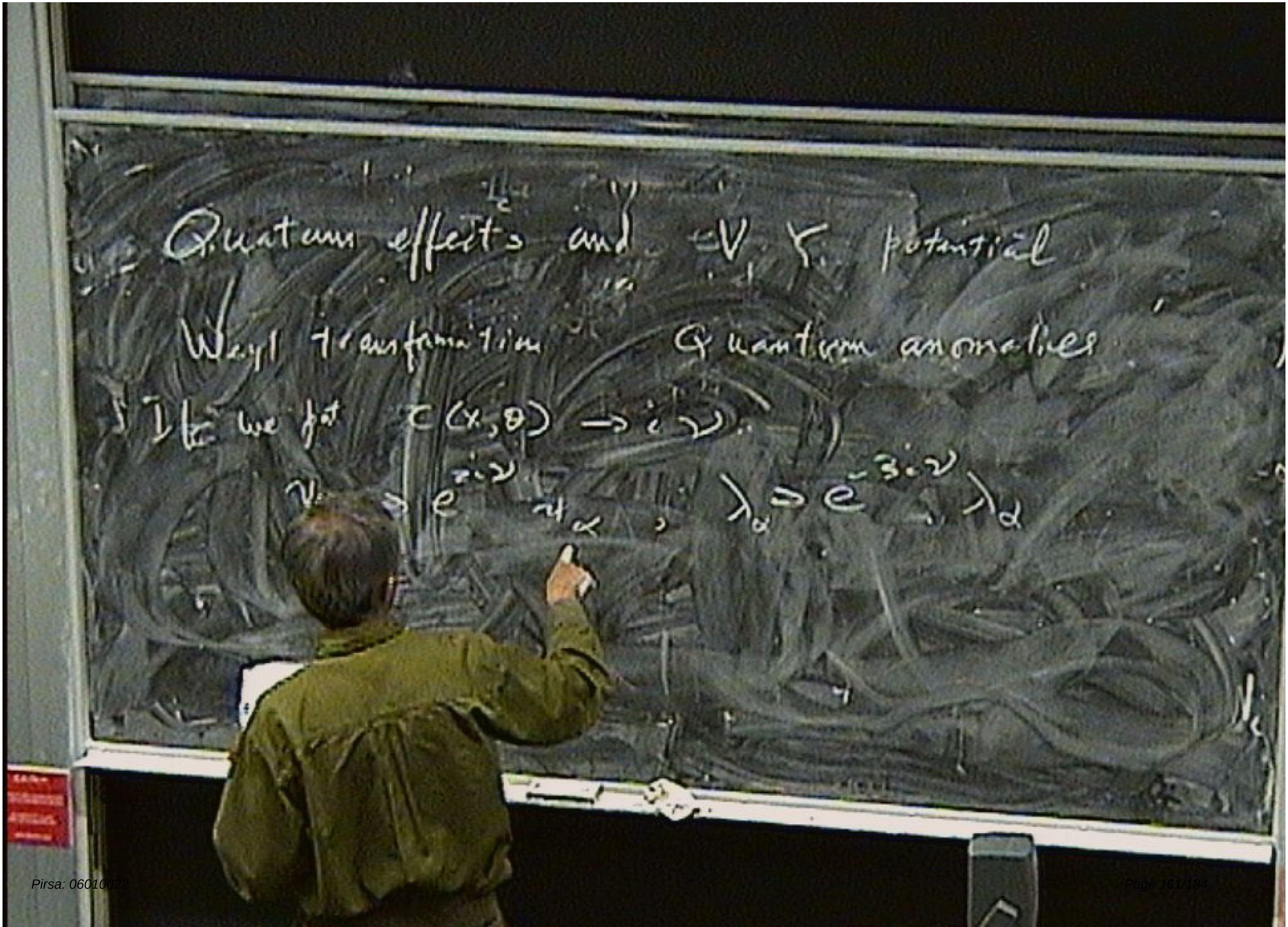
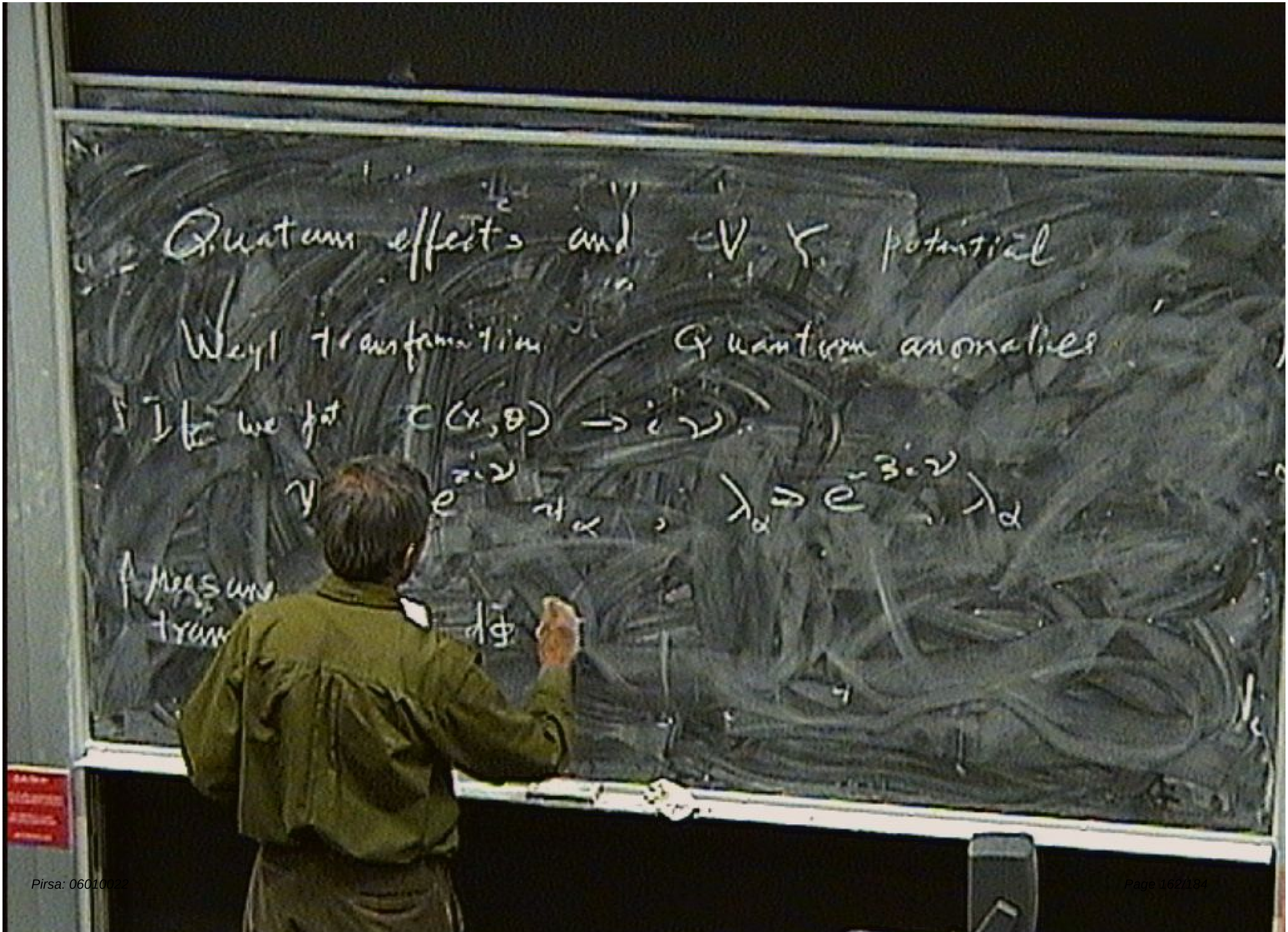

Quantum effects and V, Y, potential
Weyl transformation
Quantum anomalies
If we put τ(x,θ) → iν


Quantum effects and V. Y. potential
Weyl transformation
Quantum anomalies
If we put σ(x, θ) → iν
λ_α → e^{-3iν} λ_α

Quantum effects and V, Y potential

Weyl transformation   Quantum anomalies

If we let $\sigma(x,\theta) \to i\nu$

$$\psi_\alpha \to e^{i\nu}\psi_\alpha\ , \quad \lambda_\alpha \to e^{-3i\nu}\lambda_\alpha$$

Measure transforms! $[d\tilde{g}\; d\bar{g}\; dV] \to e^{i\nu\frac{3c_4}{16\pi^2}\int}$

Quantum effects and V. Γ. potential

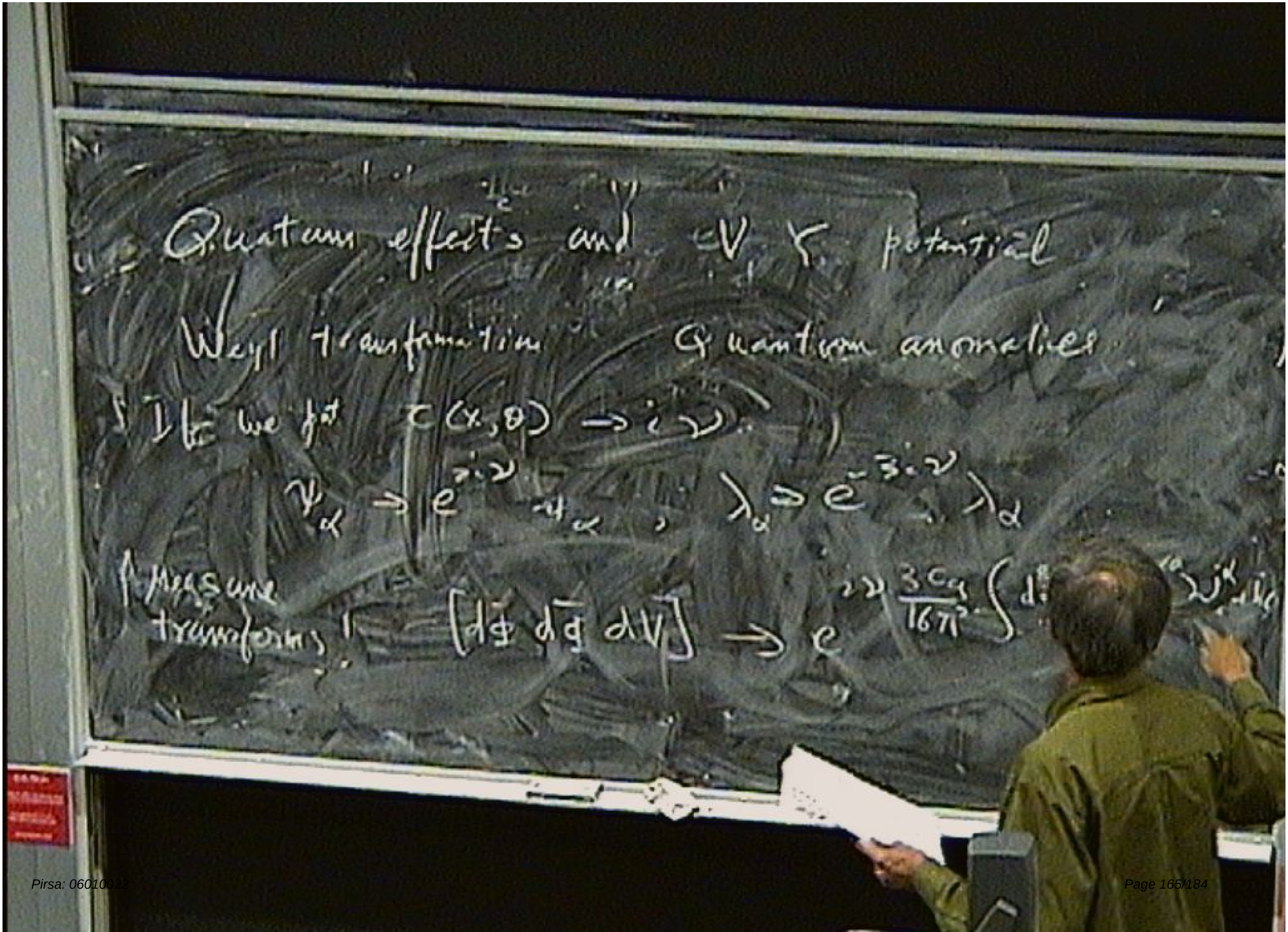
Weyl transformation   Quantum anomalies

If we put $\tau(x,\theta) \to i\nu$

$$\psi_\alpha \to e^{\frac{i\nu}{2}} \psi_\alpha \quad , \quad \lambda_\alpha \to e^{-\frac{3}{2} i\nu} \lambda_\alpha$$

measure transforms !

$$[d\Phi \, d\bar{\Phi} \, dV] \to e^{i\nu \frac{3 c_a}{16\pi^2} \int d^2\theta}$$


Quantum effects and V, Σ potential
Weyl transformation
Quantum anomalies
If we get τ(x,θ) → iν
ψ_α → e^{2iν} ψ_α , λ_α → e^{-3iν} λ_α
measure transforms!
[dΦ dΦ̄ dV] → e^{iν 3c_a/16π² ∫ d⁸ ...}

Quantum effects and V. Y. potential

Weyl transformation   Quantum anomalies

If we put $c(x,\theta) \to i\nu$.

$\psi_\alpha \to e^{i\nu}\,\psi_\alpha$, $\lambda_\alpha \to e^{-3i\nu}\,\lambda_\alpha$

labels
a. gauge grps

Measure transforms ! $[d\Phi\, d\bar{\Phi}\, dV] \to e^{i\nu \frac{3c_a}{16\pi^2}\int d^2\theta\, \frac{E}{2R}\, W^{\alpha} W^{\alpha}_{\alpha}}$

Quantum effects and V. Y. potential

Weyl transformation Quantum anomalies

If we put $C(x,\theta) \to i\nu$

$\psi_\alpha \to e^{i\nu} \psi_\alpha$, $\lambda_\alpha \to e^{-3i\nu} \lambda_\alpha$

labels
a. gauge
grps

Measure transforms!

$[d\Phi \, d\bar{\Phi} \, dV] \to e^{i\nu \frac{3c_a}{16\pi^2} \int d^2\theta \, \frac{E}{2R} W^{\alpha a} W^a_\alpha + h.c.}$

$T_a(r) = \mathrm{tr}_r(T_r^2)$ $c_a = T(G_a) - \sum_r n_r T_a(r)$

Quantum effects and V. Y. potential

Weyl transformation — Quantum anomalies

If we put $\varepsilon(x,\theta) \to i\nu$

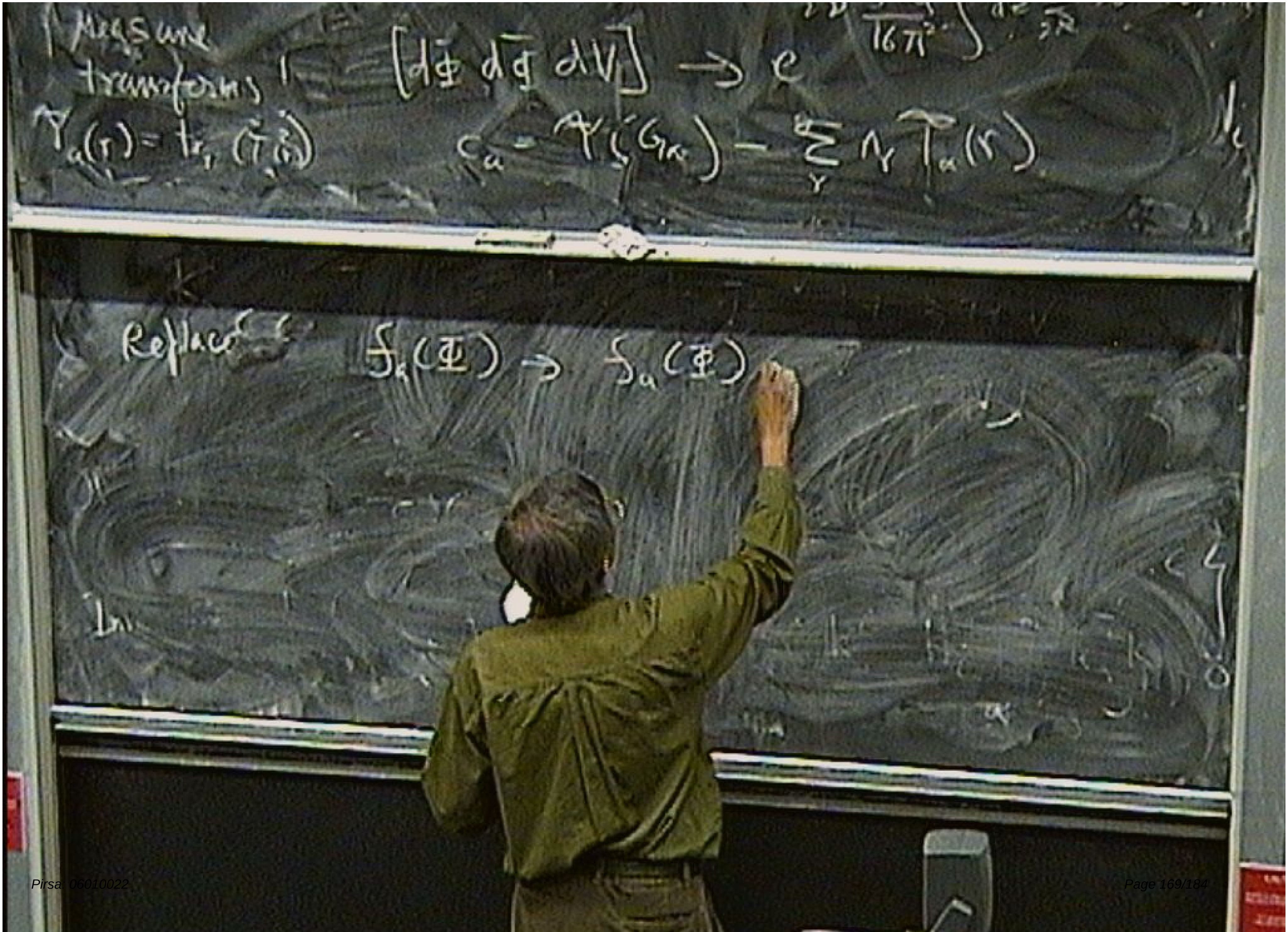
$$\psi_\alpha \to e^{-\frac{3}{2}i\nu}\psi_\alpha, \quad \lambda_\alpha \to e^{\frac{3}{2}i\nu}\lambda_\alpha$$

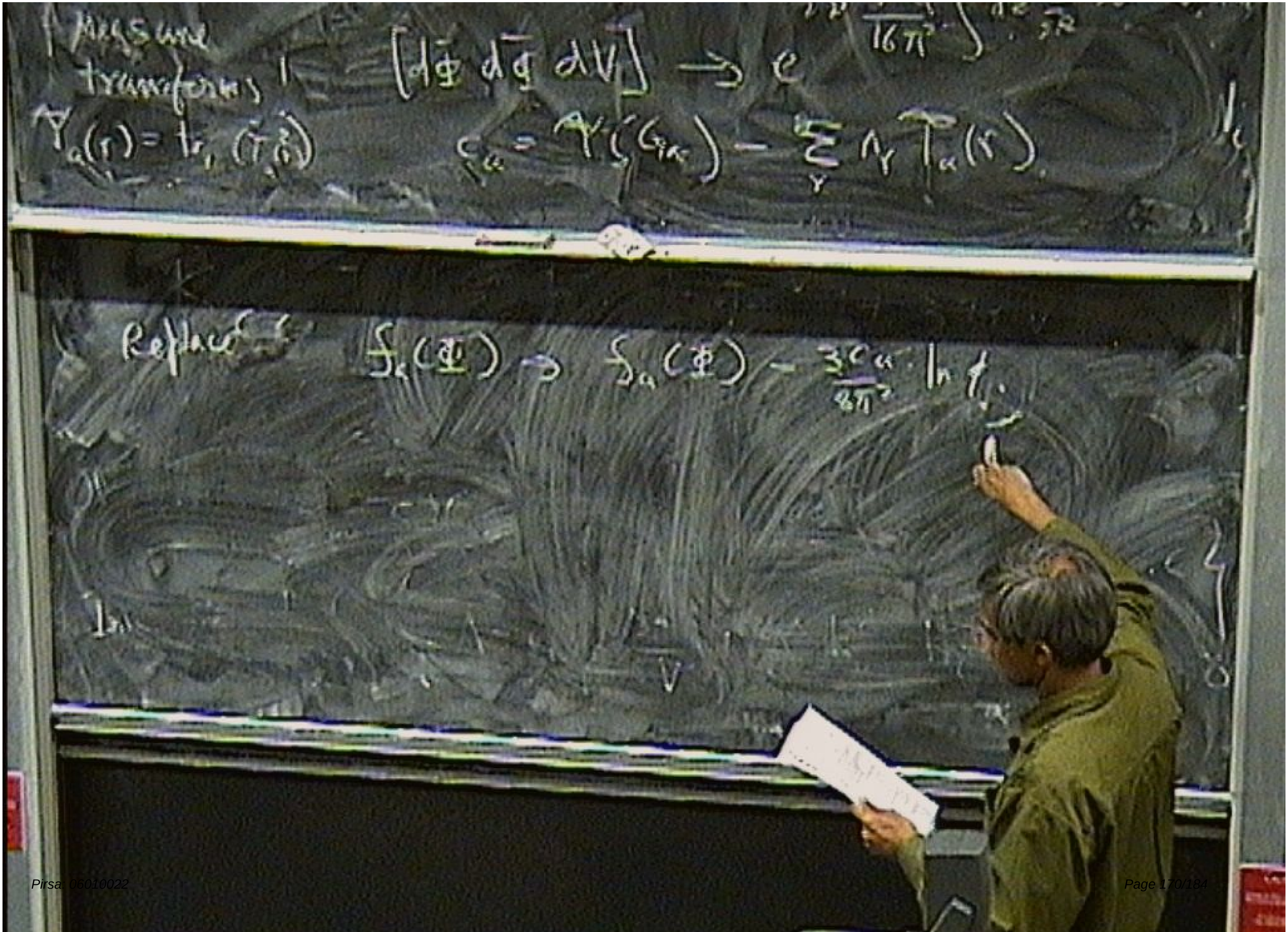
labels
a. gauge
gps

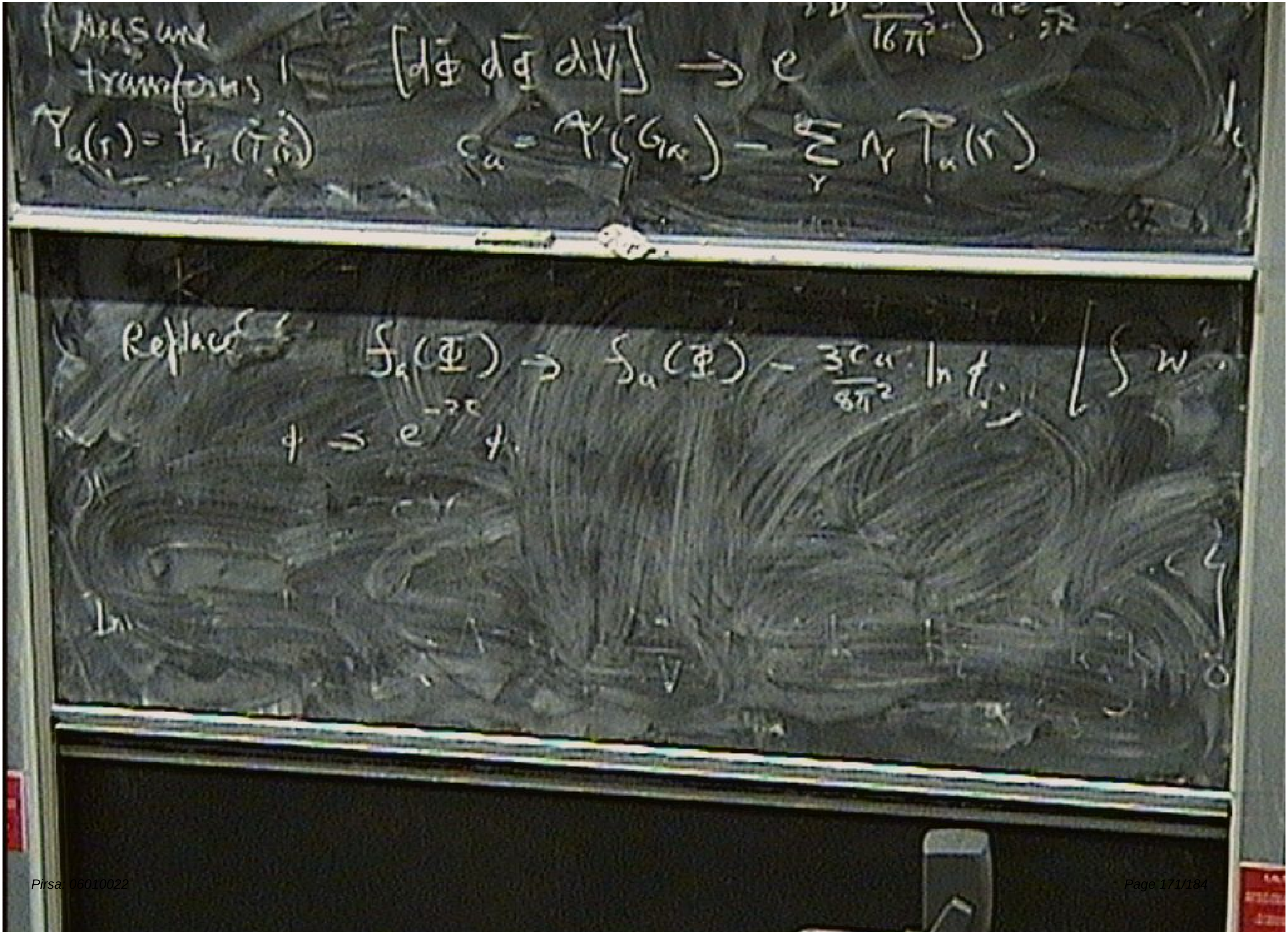
measure transforms!

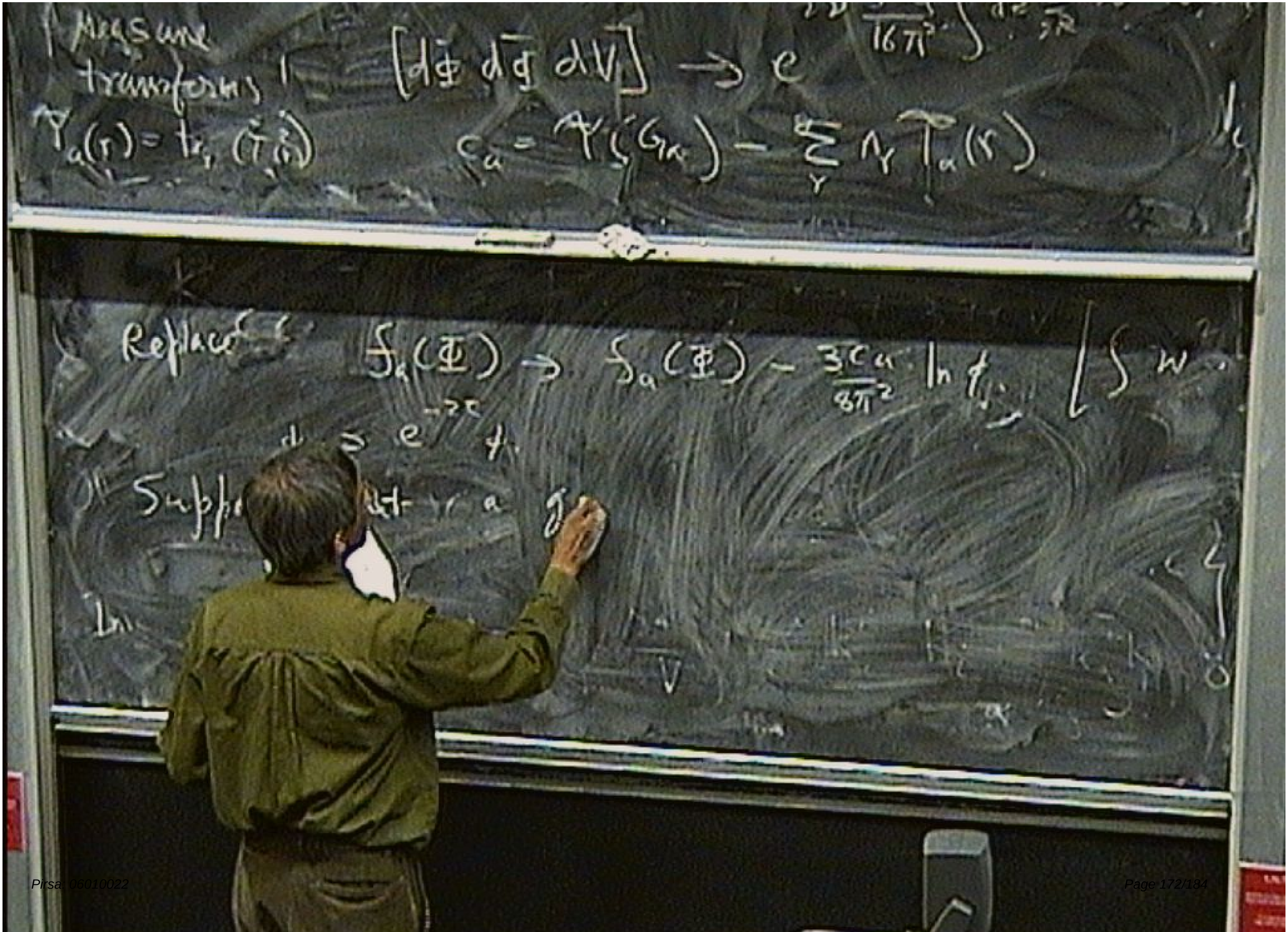
$$[d\Phi\, d\bar{\Phi}\, dV] \to e^{i\nu \frac{3 c_a}{16\pi^2}\int d^2\theta \frac{E}{2R} W^{\alpha a} W^a_\alpha}$$

$T_a(r) = \mathrm{tr}_r(T^a T^a)$ — $c_a = T(G_a) - \sum_r n_r T_a(r)$


Measure
transforms
Replace


Measure
transforms
Replace


Measure transforms!
$[d\Phi\, d\bar{\Phi}\, dV] \to e$
$16\pi^2$
$T_a(r) = \mathrm{tr}_r(T_a^2)$
$\xi_a = T(G_a) - \sum_r n_r T_a(r)$
Replace
$f_a(\Phi) \to f_a(\Phi) - \frac{3c_a}{8\pi^2} \ln \phi$


Measure
transforms
Replace

Measure transforms: $[d\bar{\Phi}\, d\bar{q}\, dV] \to e^{\frac{}{16\pi^2}\int d^2\theta}$

$T_a(r) = \mathrm{tr}_r(T_a^2(r))$ $\qquad c_a = T(G_a) - \sum_r N_r T_a(r)$

Replace: $f_a(\Phi) \to f_a(\Phi) - \frac{3c_a}{8\pi^2}\ln\phi_i$ $\quad \int W$

$\phi \to e^{-3c}\phi_i$

Suppose that a gauge group develops a mass gap.

In

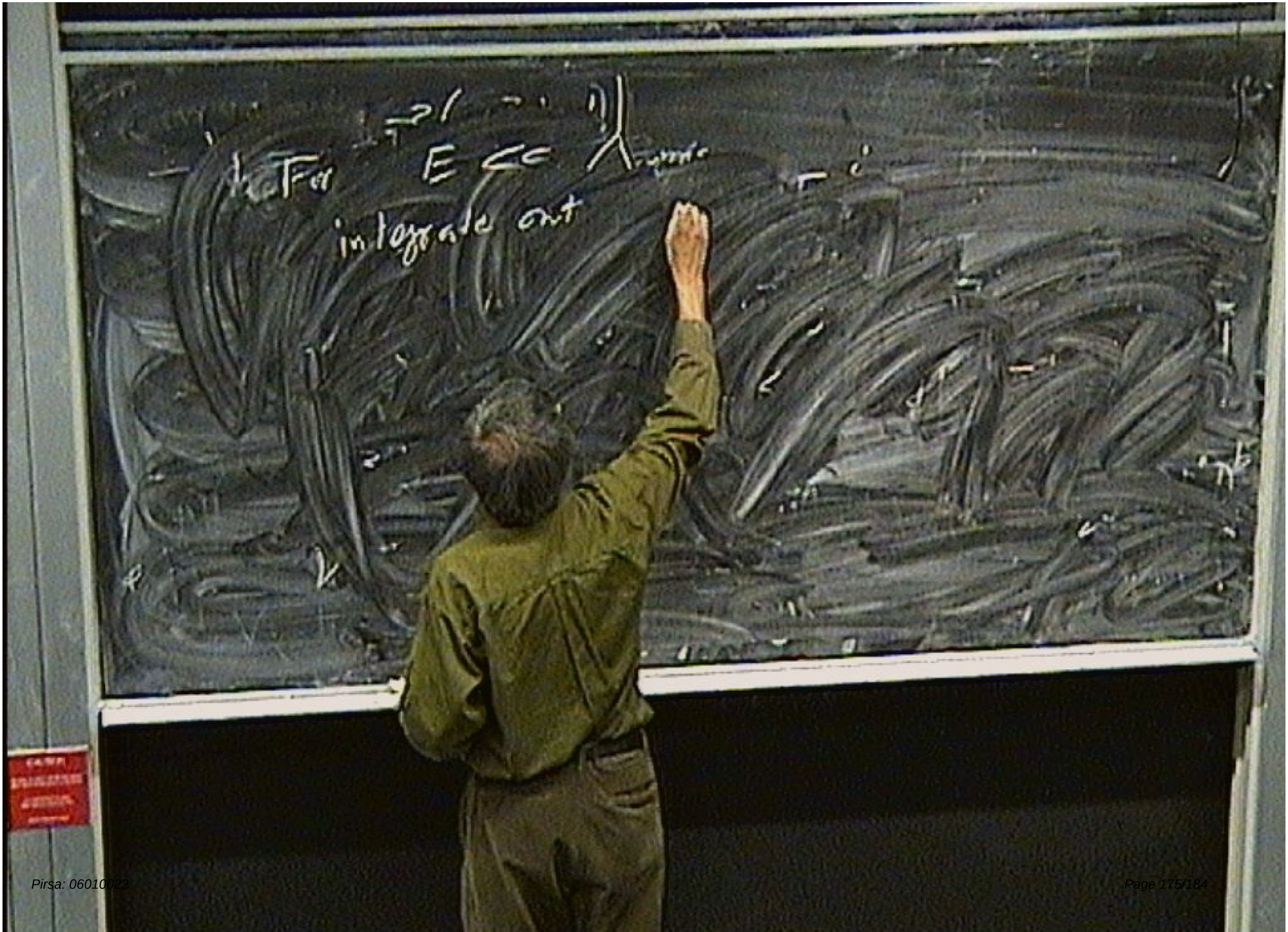
Measure transforms! $[d\Phi\, d\bar{\Phi}\, dV] \to e^{\ldots \frac{}{16\pi^2}\int d^2\ldots}$

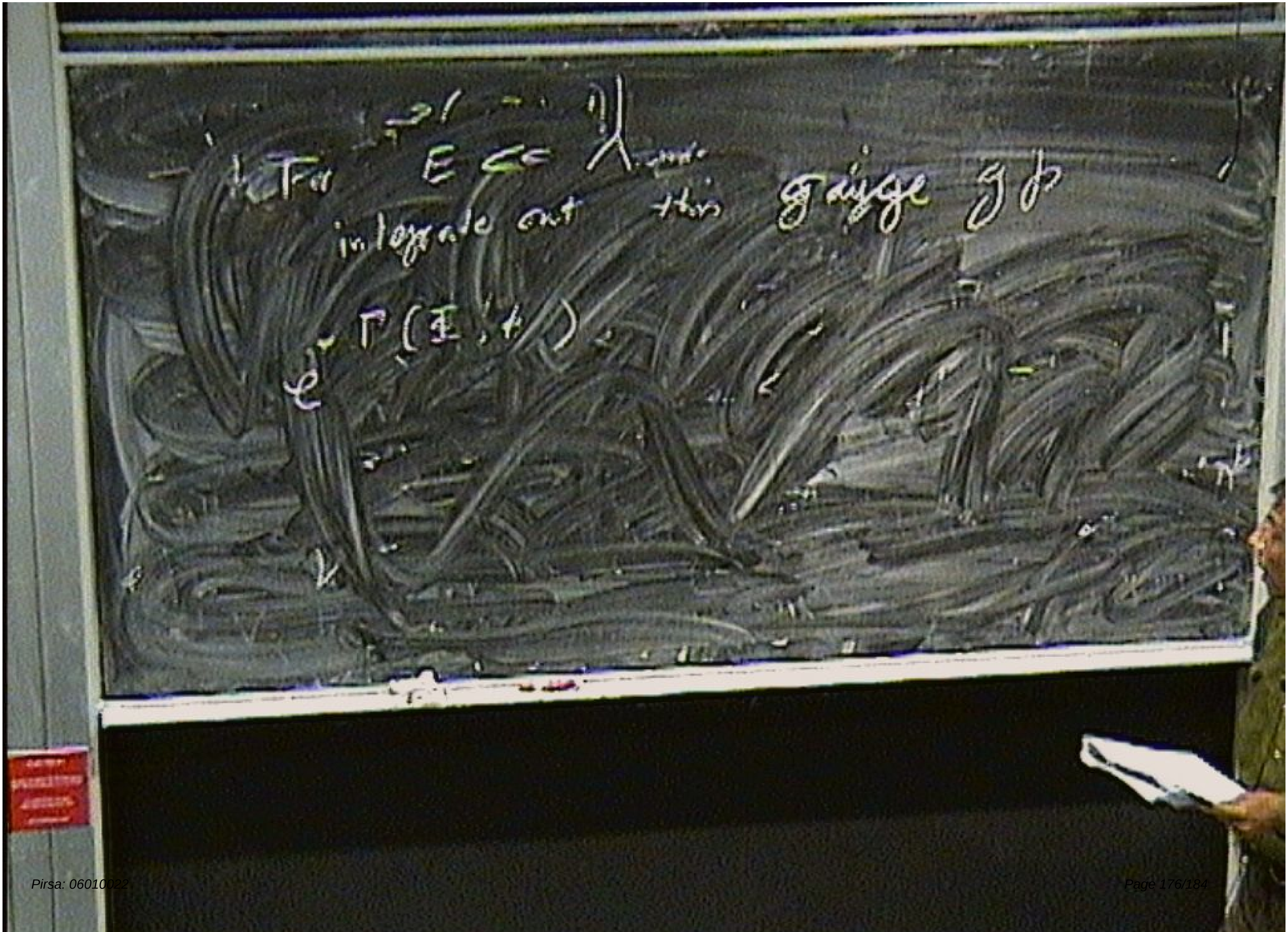
$T_a(r) = \mathrm{tr}_r(T_a^2)$ $\quad f_a = \ldots - \sum_r n_r T_a(r)$

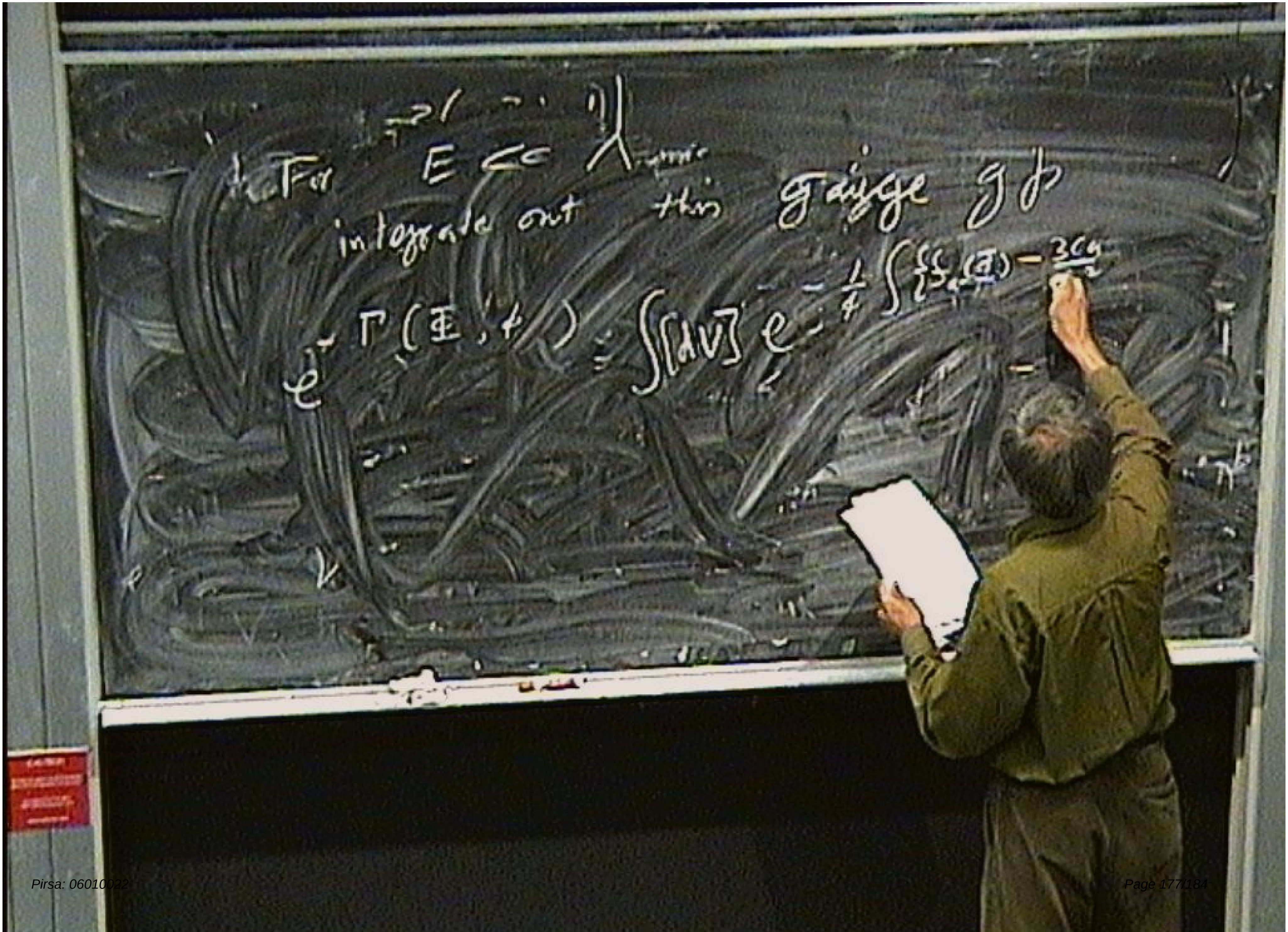
Replace $f_a(\Phi) \to f_a(\Phi) - \frac{3c_a}{8\pi^2}\ln t$

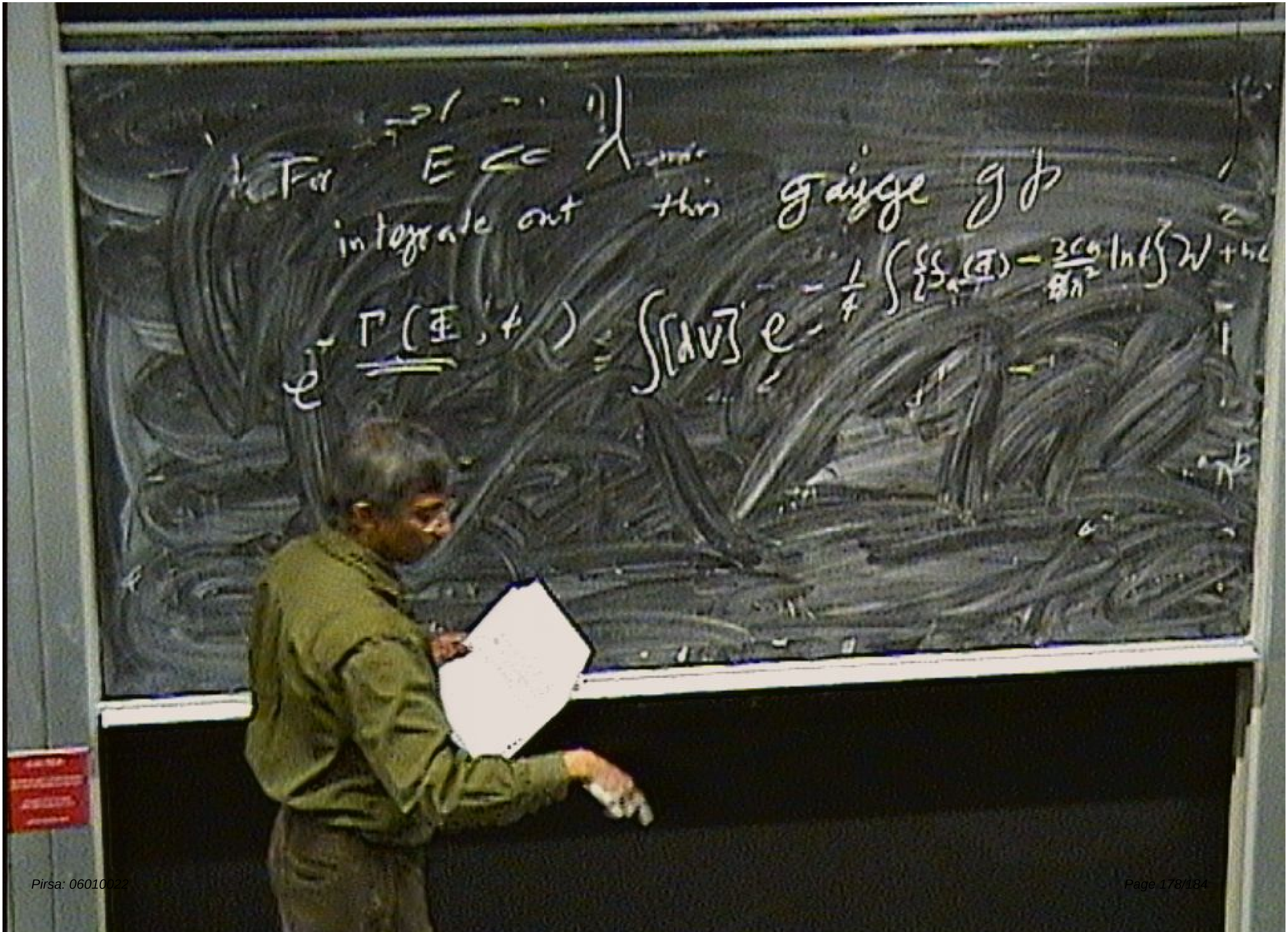
$t \to e^{-2c} t$

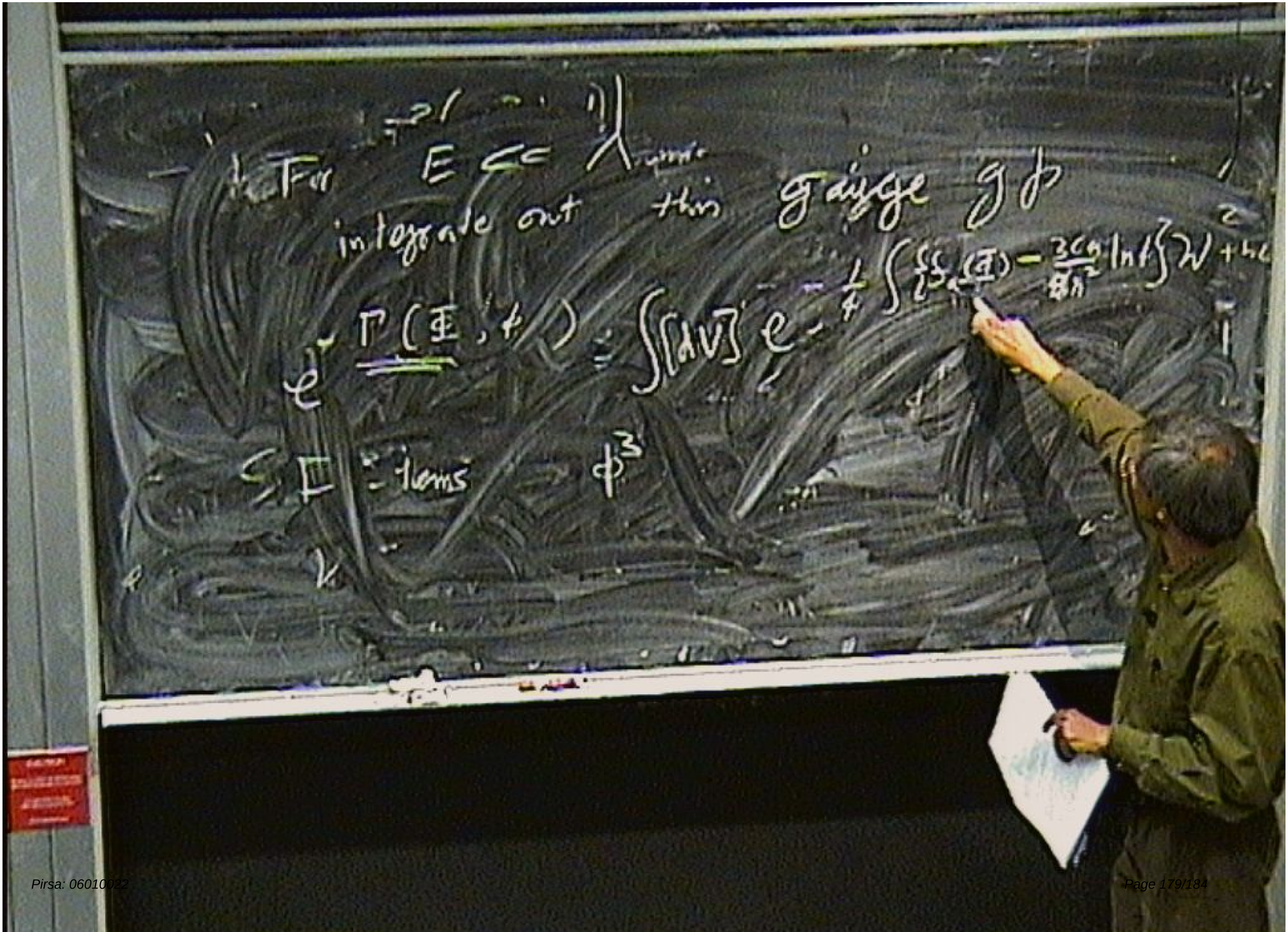
Suppose that a gauge groups develops a mass gap at some scale Λ

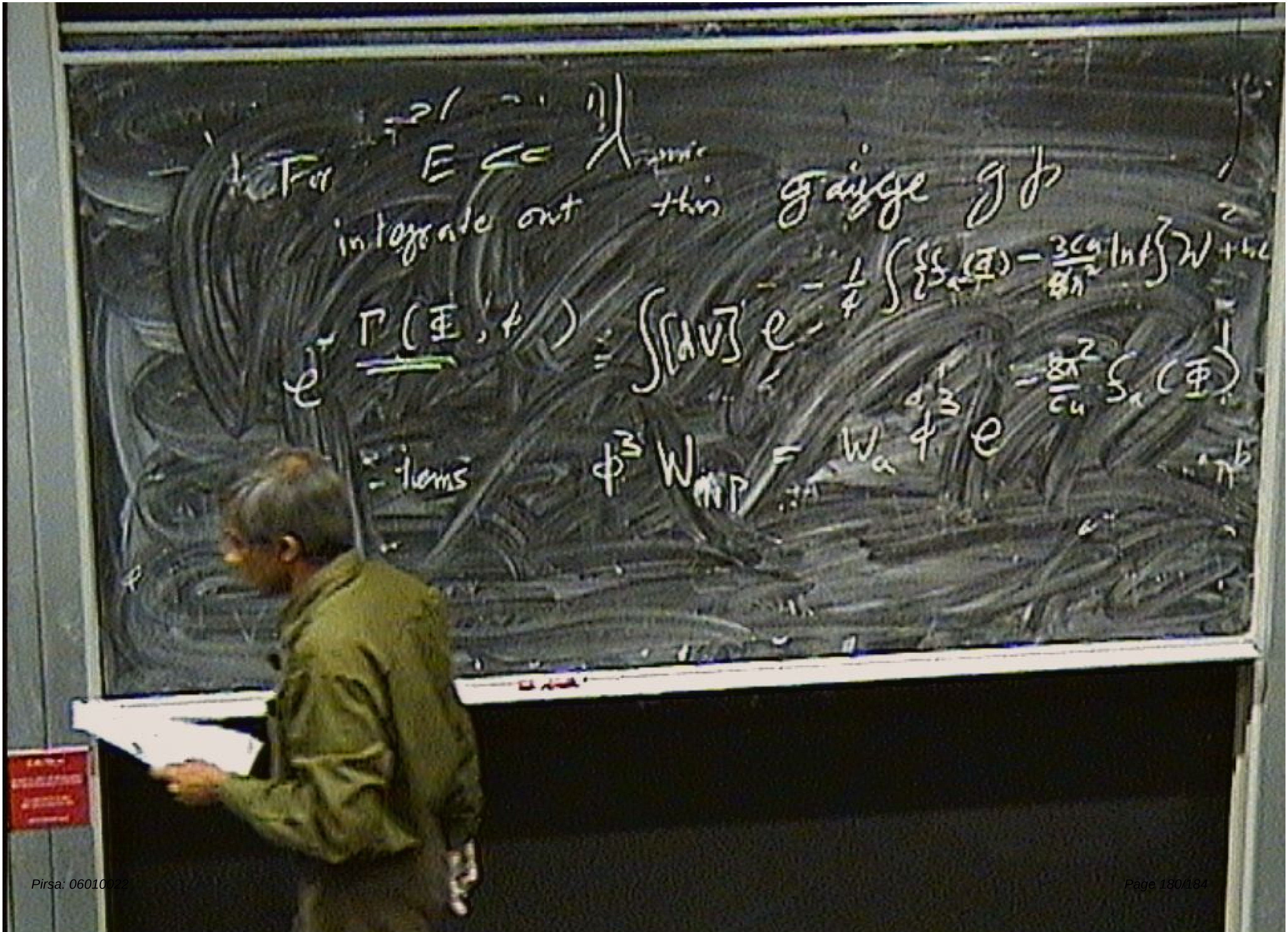

integrate out


For E << λ
integrate out this gauge gp
e^{-Γ(Φ, A)}


For E << λ
integrate out this gauge g.f.


For E << λ
integrate out this gauge


For E << λ
integrate out this gauge
terms


For E << λ
integrate out this gauge
terms

For $E \ll \lambda_{gaugino}$

integrate out this gauge g

$$e^{-\Gamma(\Phi, \ldots)} = \int [dV]\, e^{-\frac{1}{4}\int \left\{ S_a(\Phi) - \frac{3c_a}{8\pi^2} \ln (\ldots) \right\} W + h.c.}$$

$$= e^{-\frac{8\pi^2}{c_a} S_a(\Phi)}$$

$S\, \Phi$ - terms $\quad \phi^3\, W_{MP}\, F\, W_a \ldots d^3\, e$

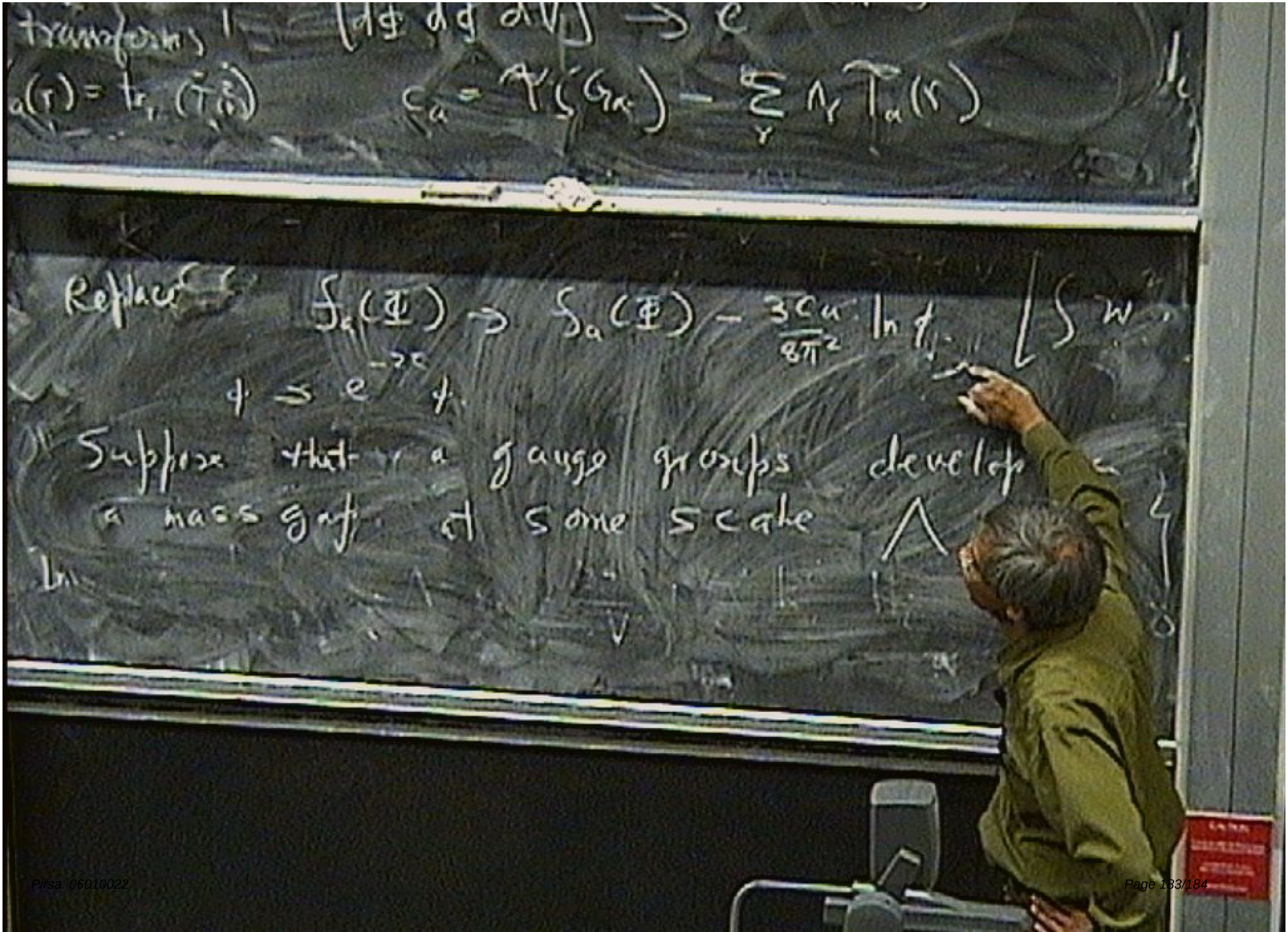
For $E \ll \lambda$

integrate out this gauge gp

$$e^{-\Gamma(\Phi, t)} = \int [dV]\, e^{-\frac{1}{4}\int \{S_a(\Phi) - \frac{3c_a}{8\pi^2}\ln t\} W + \text{h.c.}}$$

$$t^3 e^{-\frac{8\pi^2}{c_a} S_a(\Phi)}$$

$S\Phi$ terms $\quad \phi^3 W_{NP} = W_a\, t^3 e$


Replace
Suppose that a gauge groups develop
a mass gap at some scale Λ

For $E \ll \lambda_{gauge}$

integrate out this gauge grp

$$e^{-\Gamma(\Phi,\mu)} = \int [dV]\, e^{-\frac{1}{4}\int \left\{ S_a(\Phi) - \frac{3c_a}{8\pi^2}\ln(\ldots) \right\} \mathcal{W} + h.c.}$$

$$-\frac{8\pi^2}{c_a} S_a(\Phi)$$

$\int F^2$ terms $\quad d^2\theta\, W_{NP} = W_a\, d^2\theta\, e$

$(\mathrm{Im}\, S)\int F \wedge F$