Title: Higher Spin Theories - Lecture 1

Date: Mar 24, 2011 09:30 AM

URL: http://pirsa.org/11030093

Abstract:

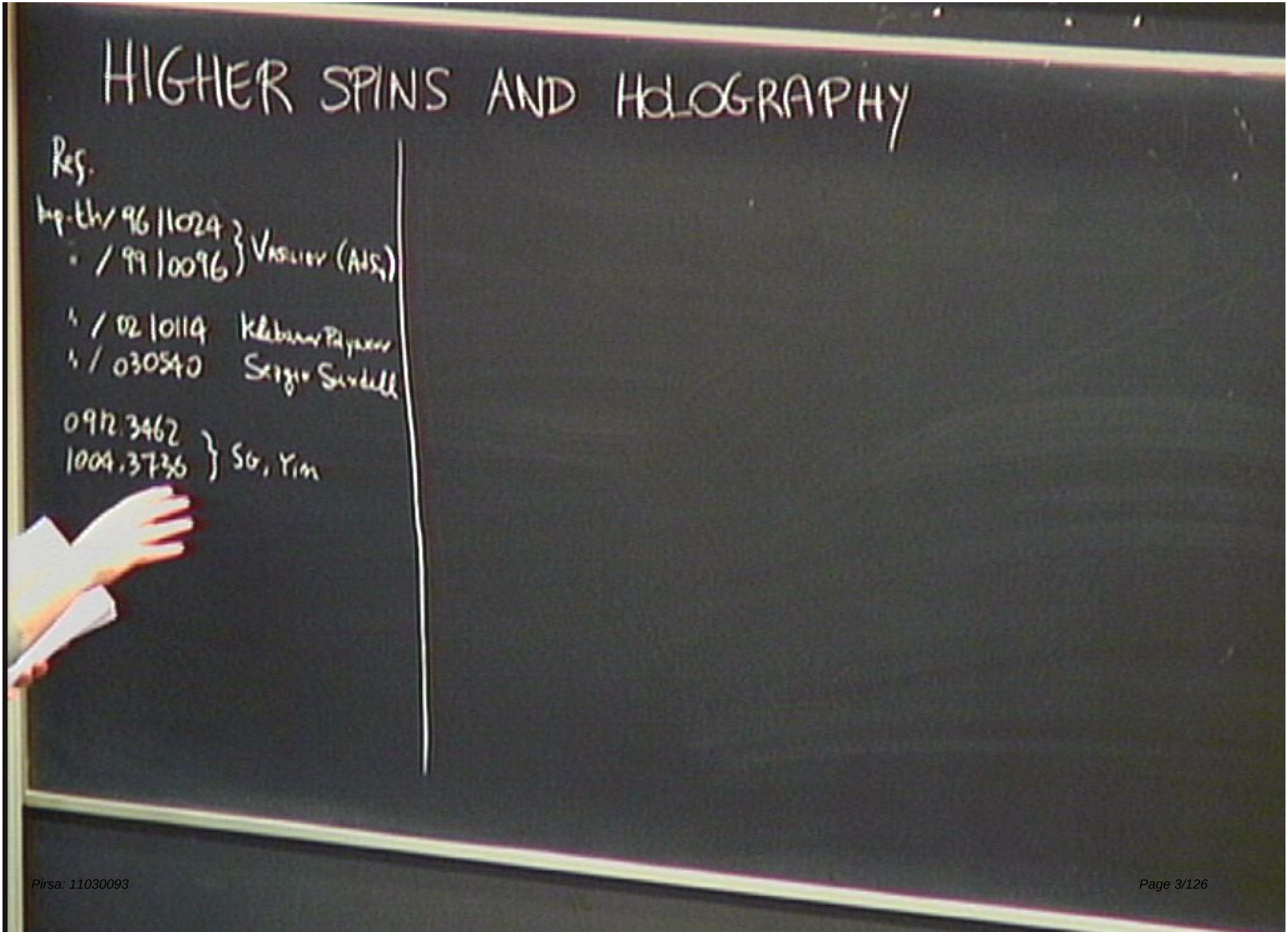
HIGHER SPINS AND HOLOGRAPHY

Refs.

hep-th/9611024 } Vasiliev (AdS_4)
" / 9910096 }

" / 0210114 Klebanov Polyakov
" / 030540 Sezgin Sundell

0912.3462 }
1004.3736 } SG, Yin


HIGHER SPINS AND HOLOGRAPHY
Refs.
hep-th/9611024
" /9910096
} Vasiliev (AdS4)
" /0210114 Klebanov Polyakov
" /030540 Sezgin Sundell
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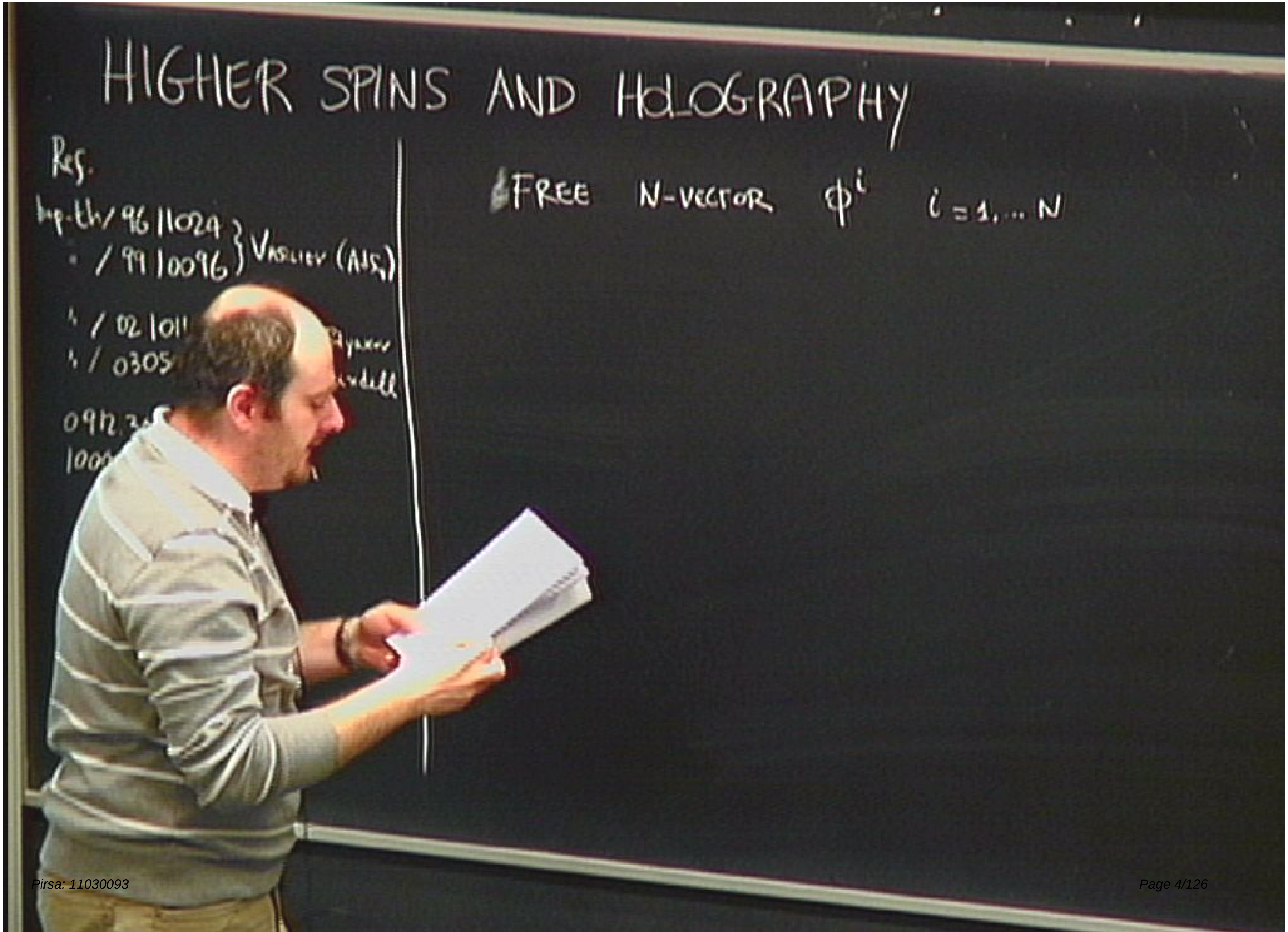
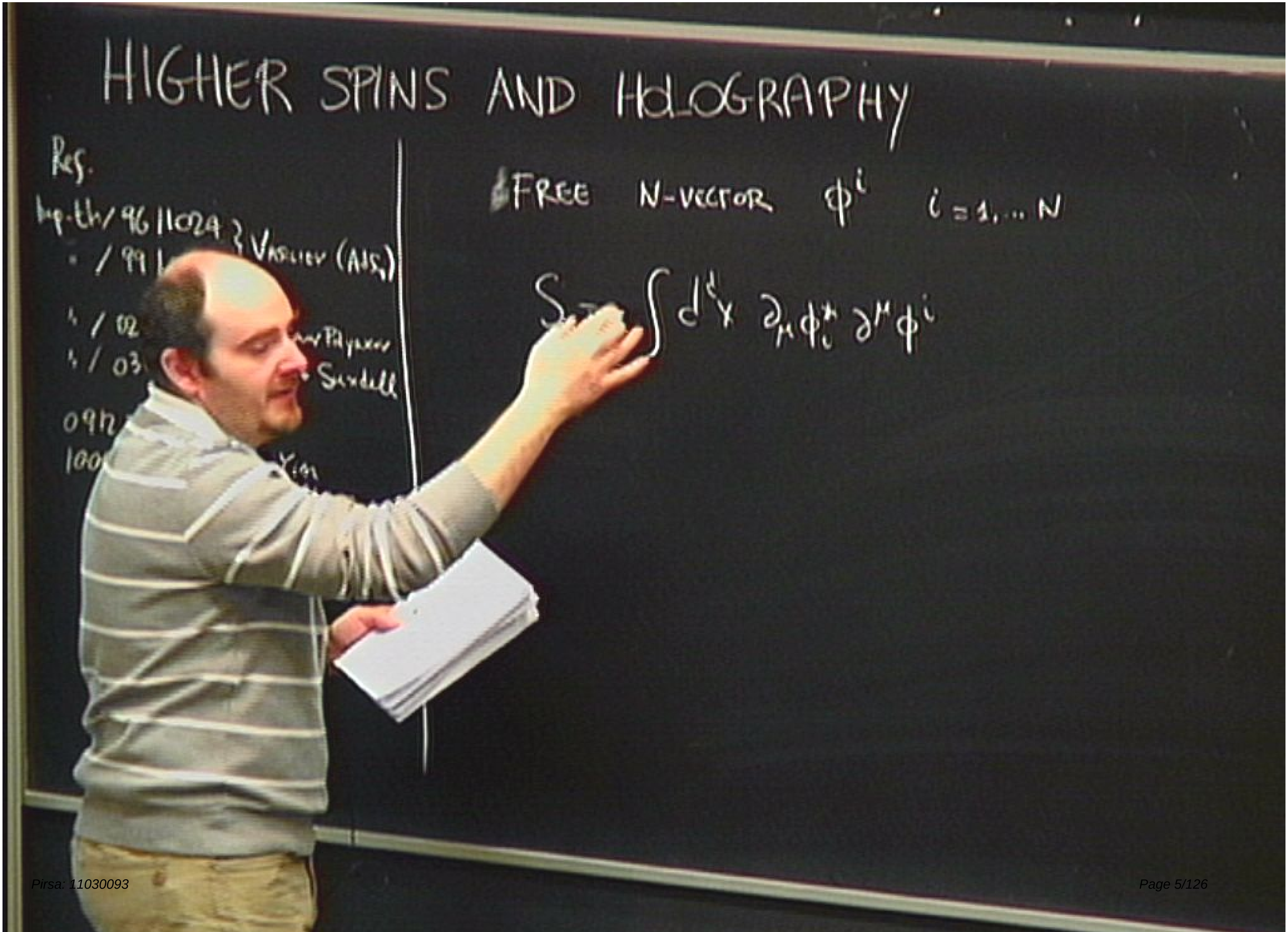
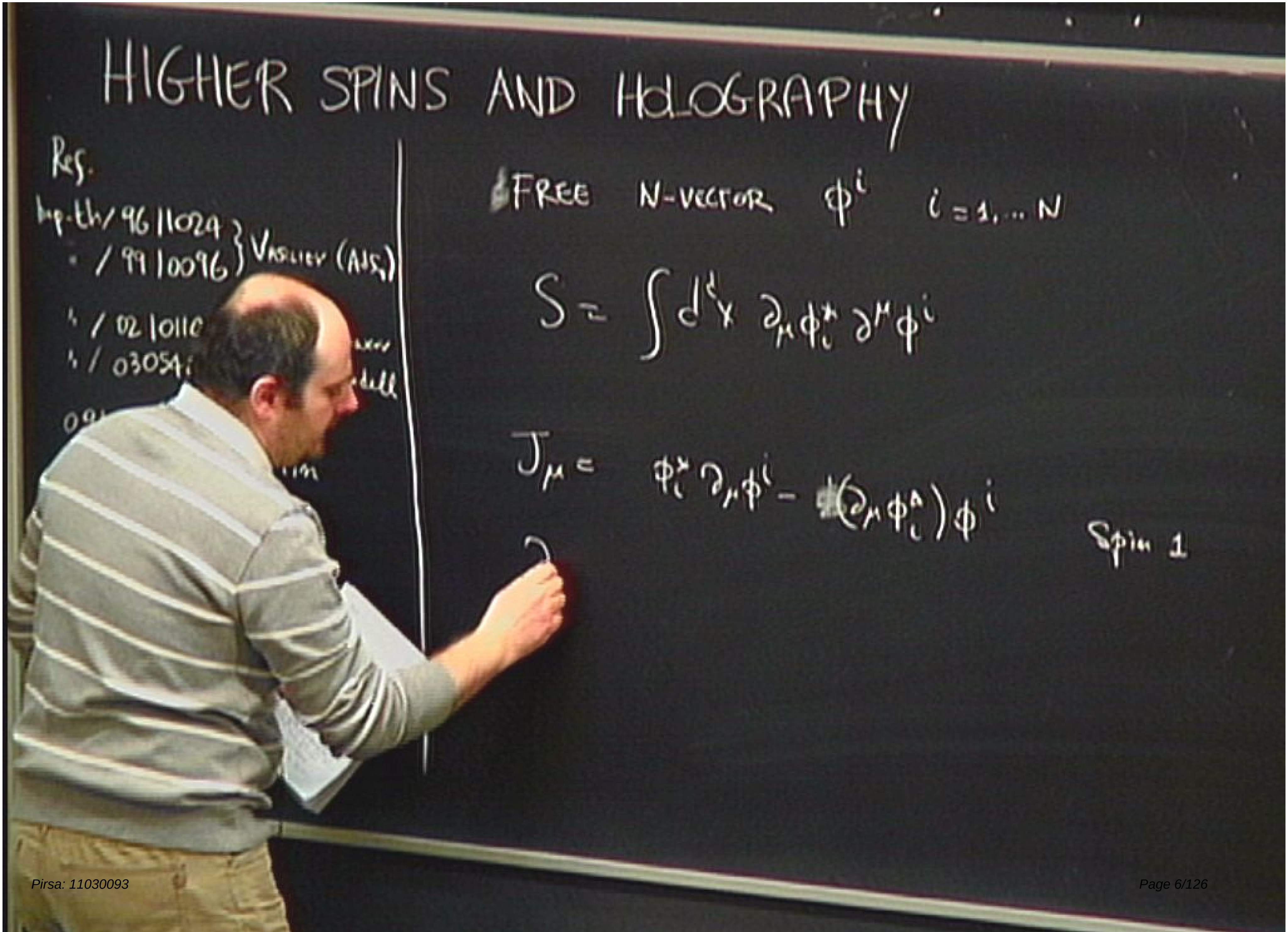

HIGHER SPINS AND HOLOGRAPHY
Refs.
hep-th/9611024
/9910096
Vasiliev (AdS4)
FREE N-VECTOR φ^i i = 1, ... N


HIGHER SPINS AND HOLOGRAPHY
Ref.
hep-th/96/11024
Vasiliev (AdS4)
FREE N-VECTOR ϕ^i $i = 1, \dots N$
$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i$


HIGHER SPINS AND HOLOGRAPHY
Ref.
hep-th/9611024
" /9910096
Vasiliev (AdS4)
" / 02 1011
" / 03054
FREE N-VECTOR ϕ^i $i = 1, \dots N$
$S = \int d^dx\, \partial_\mu \phi_i^* \partial^\mu \phi^i$
$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i$
Spin 1

HIGHER SPINS AND HOLOGRAPHY

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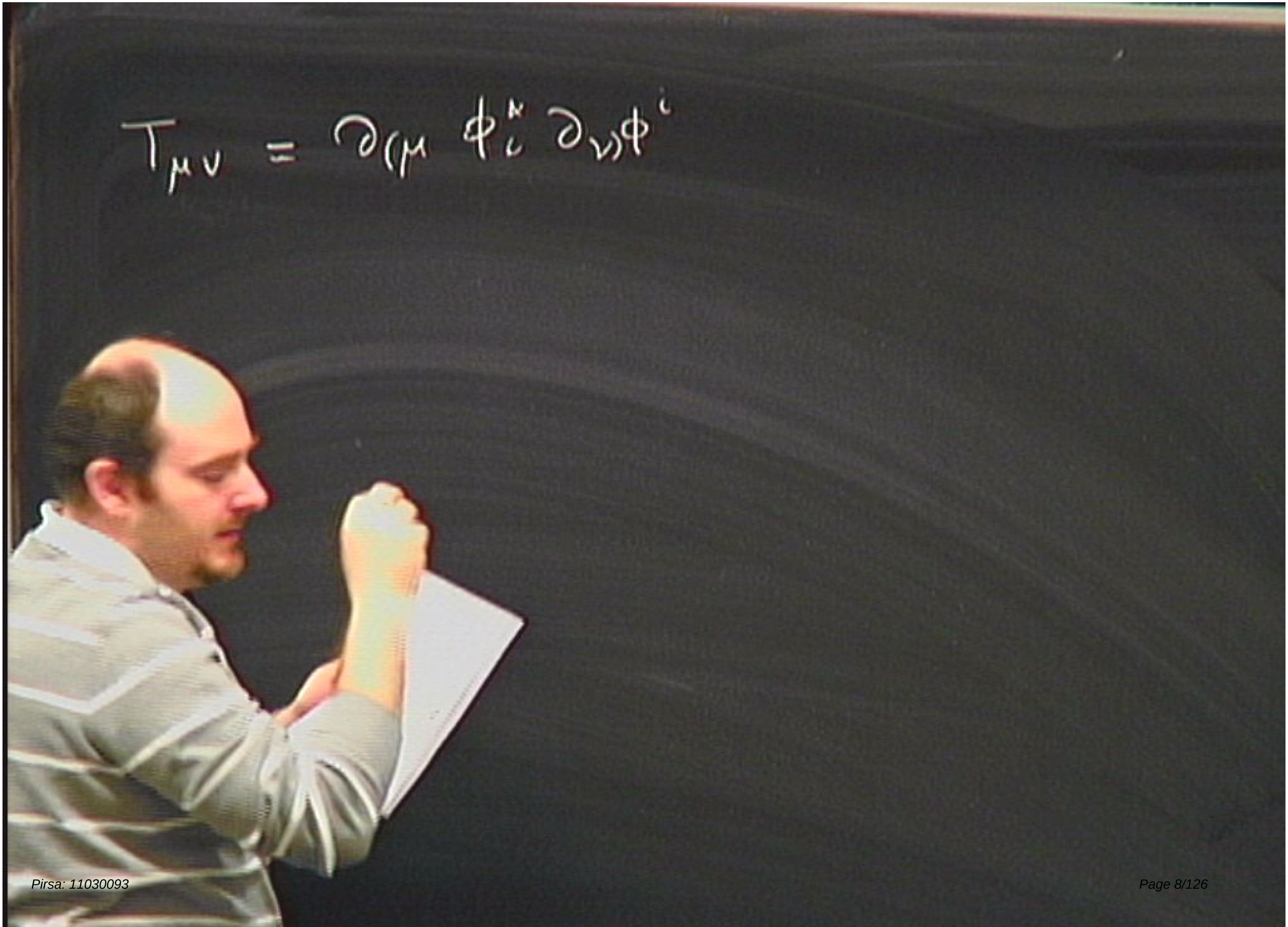
FREE N-VECTOR ϕ^i $\quad i = 1, \dots N$

$$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i$$

$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i \qquad \text{Spin } 1$$

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$


$T_{\mu\nu} = \partial_{(\mu} \phi^{*}_{i} \partial_{\nu)} \phi^{i}$

$$T_{\mu\nu} = \partial_{(\mu} \phi^{*}_{i} \partial_{\nu)} \phi^{i} - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

$$T_{\mu\nu} = \partial_{(\mu}\phi^{\mu}_{i}\,\partial_{\nu)}\phi^{i} - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu}T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

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FREE N-VECTOR ϕ^i $i = 1, \dots N$

$$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i$$

$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i$$ Spin 1

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$

$$\Delta(J_\mu) = d - 2 + 1 = d - 1$$

$$T_{\mu\nu} = \partial_{(\mu}\, \phi^{\mu}_{i}\, \partial_{\nu)}\phi^{i} - \frac{1}{4}\frac{1}{d-1}\left((d-2)\,\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2 \right)\phi^2$$

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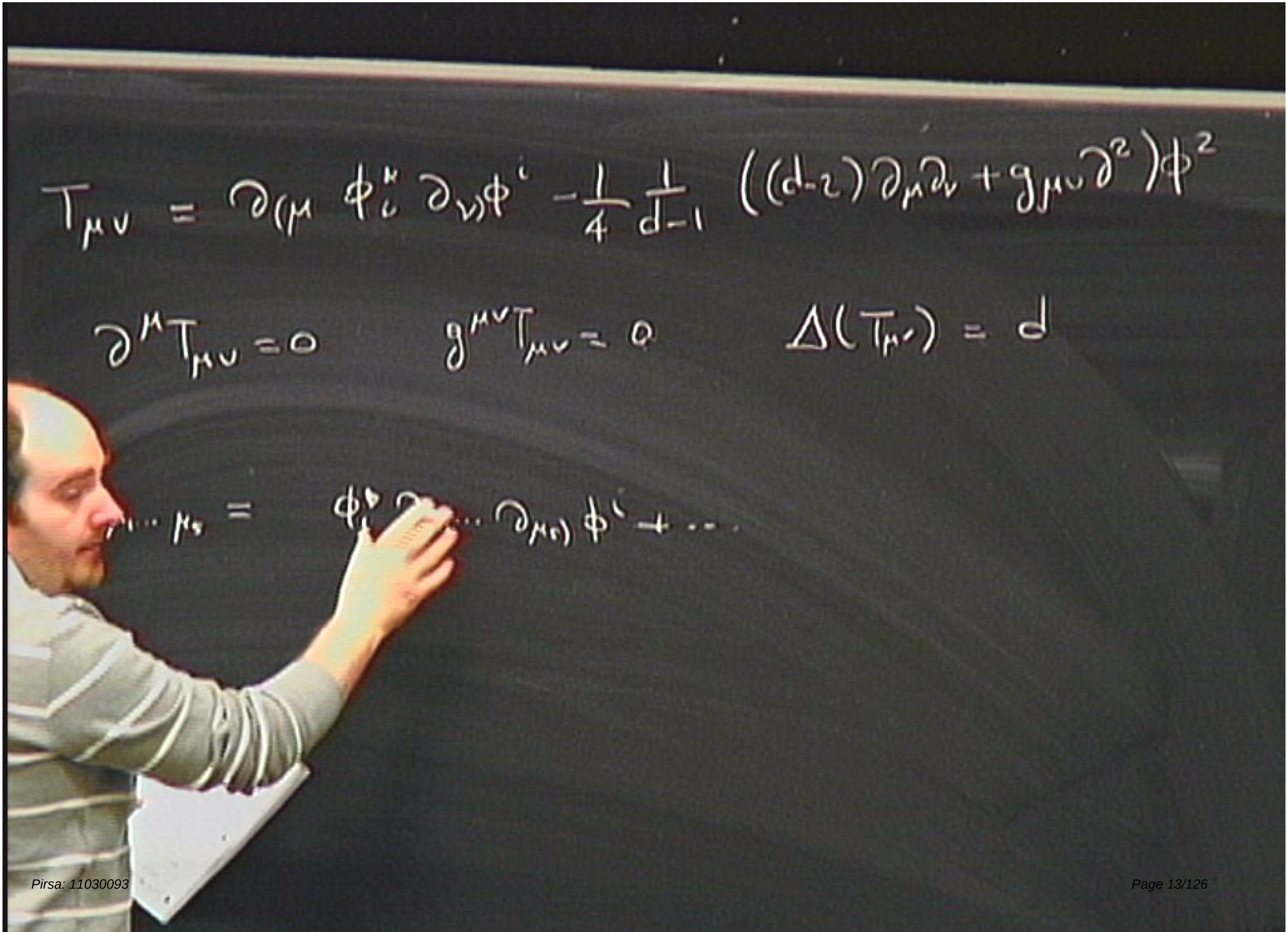

$T_{\mu\nu} = \partial_{(\mu}\phi^{\mu}_{i}\partial_{\nu)}\phi^{i} - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$
$\partial^\mu T_{\mu\nu} = 0$
$g^{\mu\nu}T_{\mu\nu} = 0$
$\Delta(T_{\mu\nu}) = d$
$\cdots\mu_s = \phi^i_{} \cdots \partial_{\mu_s)}\phi^i + \cdots$

$$T_{\mu\nu} = \partial_{(\mu}\,\phi_i^{*}\,\partial_{\nu)}\phi^i - \frac{1}{4}\,\frac{1}{d-1}\left((d-2)\,\partial_\mu\partial_\nu + g_{\mu\nu}\,\partial^2\right)\phi^2$$

$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu}T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

$$\ldots_{\mu_n} = \phi_i^{*}\,\partial_{(\mu_1}\cdots\partial_{\mu_n)}\phi^i + \cdots$$

$$=$$

$$T_{\mu\nu} = \partial_{(\mu} \phi_i^{\mu} \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu}T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

$$J_{(\mu_1 \cdots \mu_s)} = \phi_i \partial_{(\mu_1} \cdots \partial_{\mu_s)} \phi^i + \cdots$$

$$= \sum_{k=0}^{s} \frac{(-1)^k}{k!\,(k+\frac{d-2}{2})!\,(s-k)!\,\cdots} \cdots)(\partial_{\mu_{k+1}} \cdots$$

$$T_{\mu\nu} = \partial_{(\mu}\phi_i^* \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

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$$T_{\mu\nu} = \partial_{(\mu}\phi_i^* \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

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$$\partial^\mu J_{\mu\mu_2\cdots\mu_s} = 0$$

$$T_{\mu\nu} = \partial_{(\mu}\phi_i^* \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

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$$\partial^\mu J_{\mu\mu_2\cdots\mu_s} = 0$$

$$\Delta(J_{(s)}) = d-2+s$$

$$T_{\mu\nu} = \partial_{(\mu}\phi_i^* \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

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$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu}T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

$$\mathrm{Tr}(\phi^J)$$

$$J_{(\mu_1\cdots\mu_s)} = \phi_i^* \partial_{(\mu_1}\cdots\partial_{\mu_s)}\phi^i + \cdots$$

$$= \sum_{k=0}^{s} \frac{(-1)^k}{k!\,(k+\frac{d-2}{2})!\,(s-k)!\,(s-k+\frac{d-2}{2})!}(\partial_{\mu_1}\cdots\partial_{\mu_k}\phi_i^*)(\partial_{\mu_{k+1}}\cdots\partial_{\mu_s}\phi^i) - \text{traces}$$

$$\partial^\mu J_{\mu\mu_2\cdots\mu_s} = 0$$

$$\Delta(J_{(s)}) = d-2+s$$

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FREE N-VECTOR ϕ^i $\quad i = 1, \dots N$

$$S = \int d^d x \; \partial_\mu \phi_i^* \partial^\mu \phi^i$$

$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i$$

Spin 1

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$

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$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu} T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

$$\mathrm{Tr}(\phi^3)$$

$$J_{(\mu_1 \cdots \mu_s)} = \phi^*_i \, \partial_{(\mu_1} \cdots \partial_{\mu_s)} \phi^i + \cdots$$

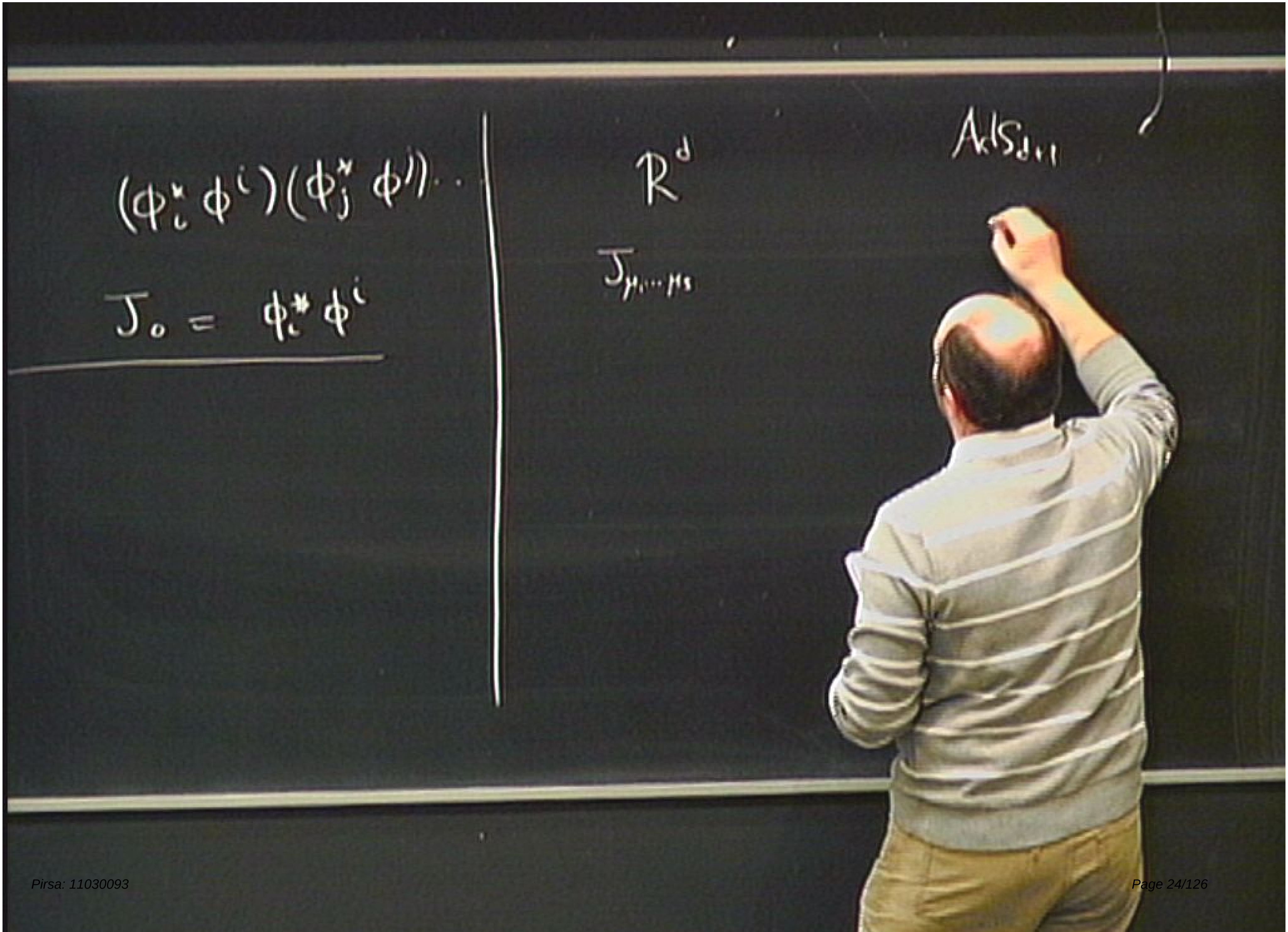
$$= \sum_{k=0}^{s} \frac{(-1)^k}{k!\left(k+\frac{d-2}{2}\right)!\,(s-k)!\left(s-k+\frac{d-2}{2}\right)!} \left(\partial_{\mu_1}\cdots\partial_{\mu_k}\phi^*_i\right)\left(\partial_{\mu_{k+1}}\cdots\partial_{\mu_s}\phi^i\right) - \text{traces}$$

$$\partial^\mu J_{\mu\mu_2\cdots\mu_s} = 0$$

$$\Delta(J_m) = d-2+s$$

$(\phi_i^* \phi^i)(\phi_j^* \phi^j) \cdots$

$J_0 = \phi_i^* \phi^i$


$(\phi_i^* \phi^i)(\phi_j^* \phi^j)\cdots$
$J_0 = \phi_i^* \phi^i$
R^d
$J_{\mu_1 \cdots \mu_s}$
AdS_{d+1}

$(\phi^*_i \phi^i)(\phi^*_j \phi^j) \cdots$

$J_0 = \phi^*_i \phi^i$

R^d

$J_{\mu_1 \cdots \mu_s}$

AdS_{d+1}

$\varphi_{\mu_1 \cdots \mu_s}$

$(\phi_i^* \phi^i)(\phi_j^* \phi^j)\cdots$

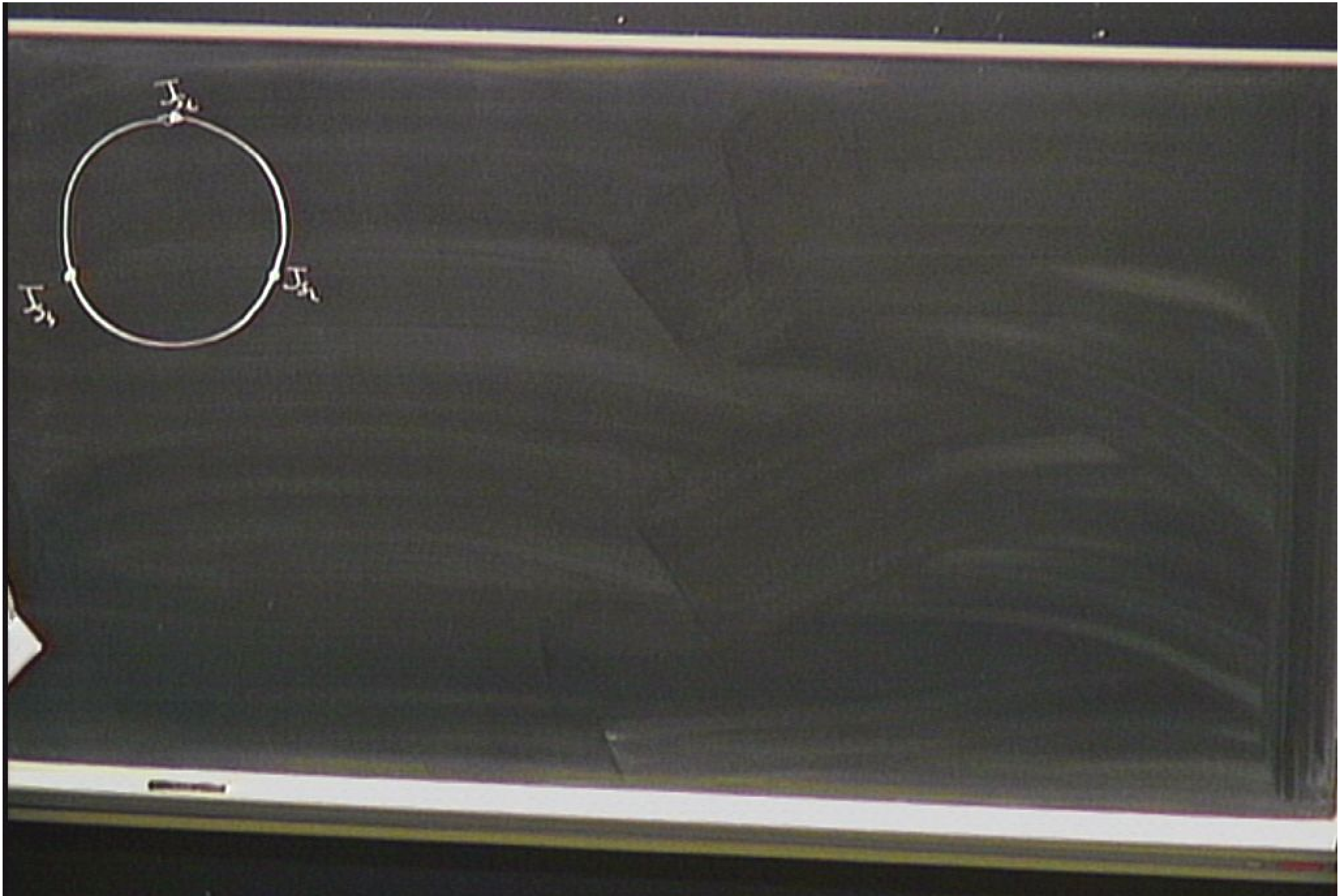
$J_0 = \phi_i^* \phi^i$

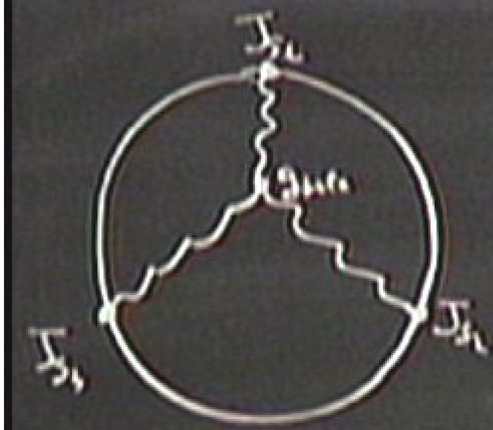
R^d

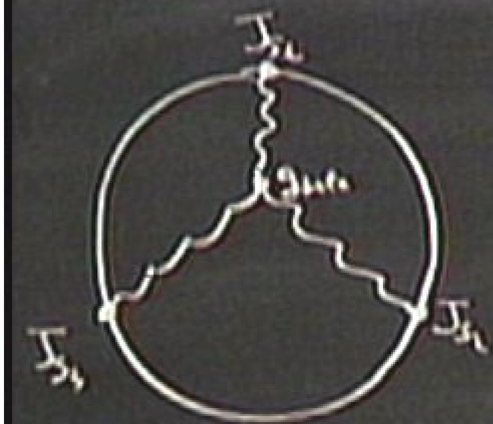
$J_{\mu_1 \cdots \mu_s}$

AdS_{d+1}

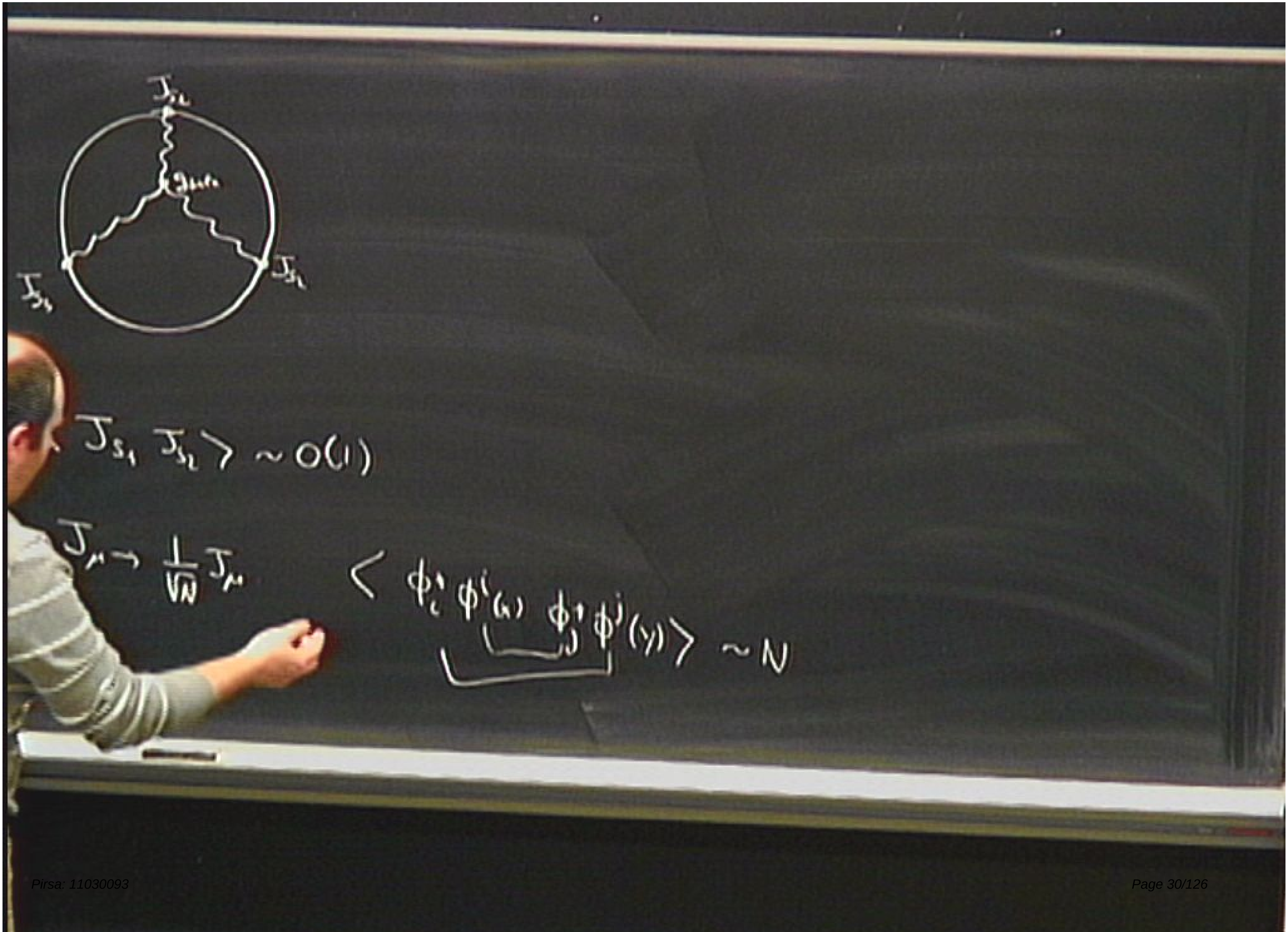
$\varphi_{\mu_1 \cdots \mu_s}$

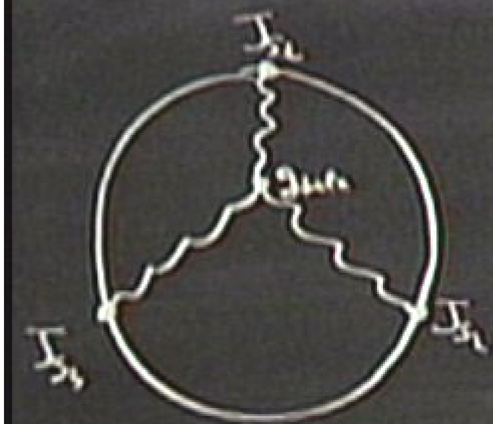



J_{j_2}
$g_{\mu\nu}$
J_{j_1}
J_{j_3}



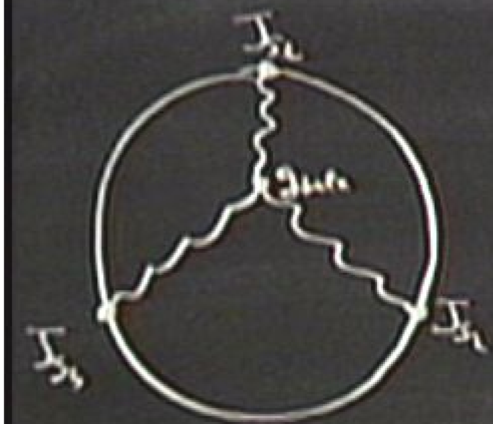
$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$


J_{s_2}
J_{s_1}
J_{s_3}
$J_{s_1}\, J_{s_2} \rangle \sim O(1)$
$J_\mu \to \frac{1}{\sqrt{N}} J_\mu$
$\langle \phi_i^\dagger \phi^i(x)\ \phi_j^\dagger \phi^j(y) \rangle \sim N$



$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

$$J_\mu \to \frac{1}{\sqrt{N}} J_\mu \qquad \langle \phi_i^\dagger \phi^i(x)\, \phi_j^\dagger \phi^j(y) \rangle \sim N$$

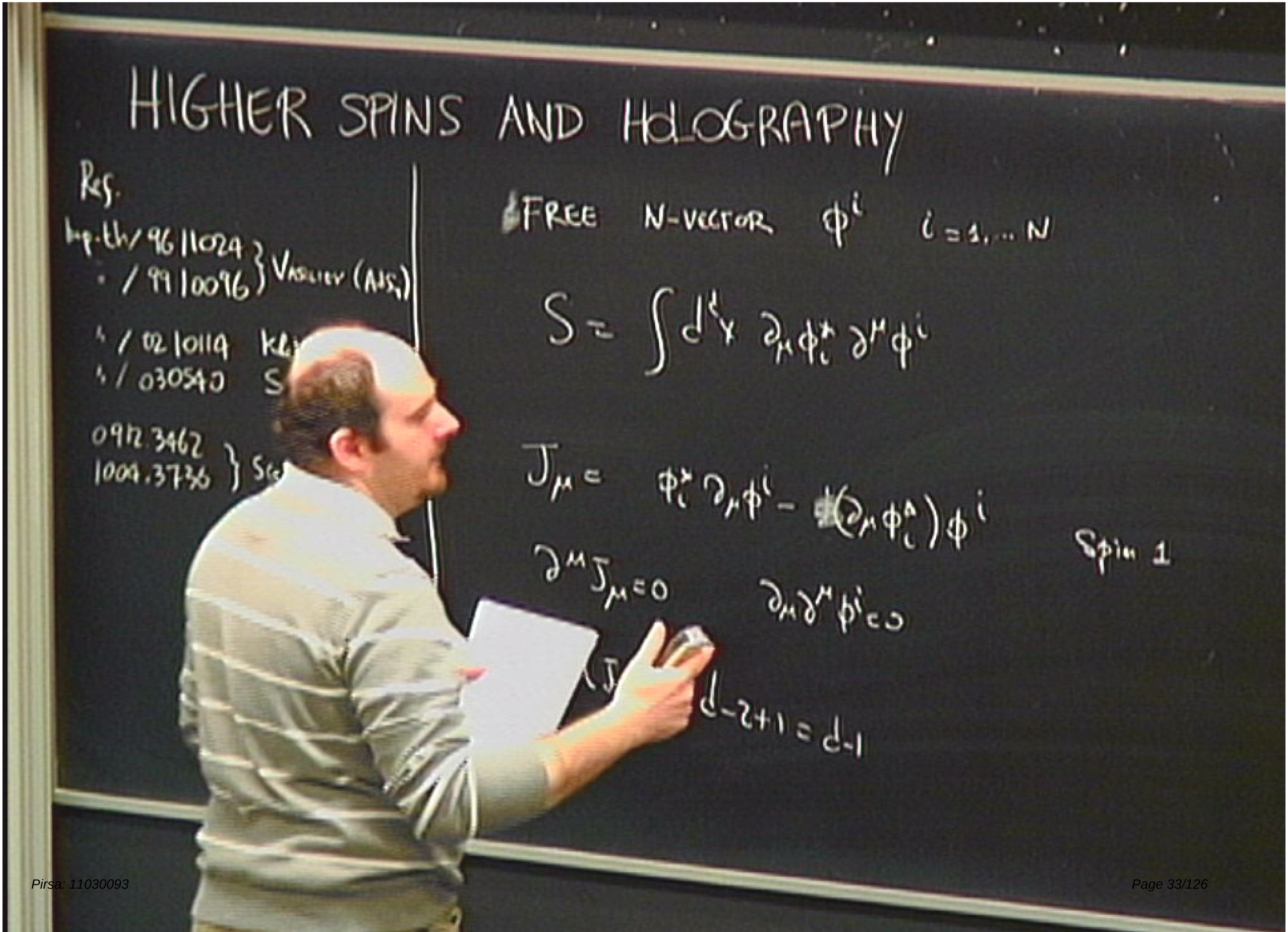


$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$

$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \approx \frac{1}{\sqrt{N}}$

$J_\mu \to \frac{1}{\sqrt{N}} J_\mu$

$\langle \phi_i^\dagger \phi^i(x) \, \phi_j^\dagger \phi^j(y) \rangle \sim N$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FREE N-VECTOR φ^i i = 1, ... N
S = ∫ d^d x ∂_μ φ_i^* ∂^μ φ^i
J_μ = φ_i^* ∂_μ φ^i − (∂_μ φ_i^*) φ^i
Spin 1
∂^μ J_μ = 0
∂_μ ∂^μ φ^i = 0
d − 2 + 1 = d − 1

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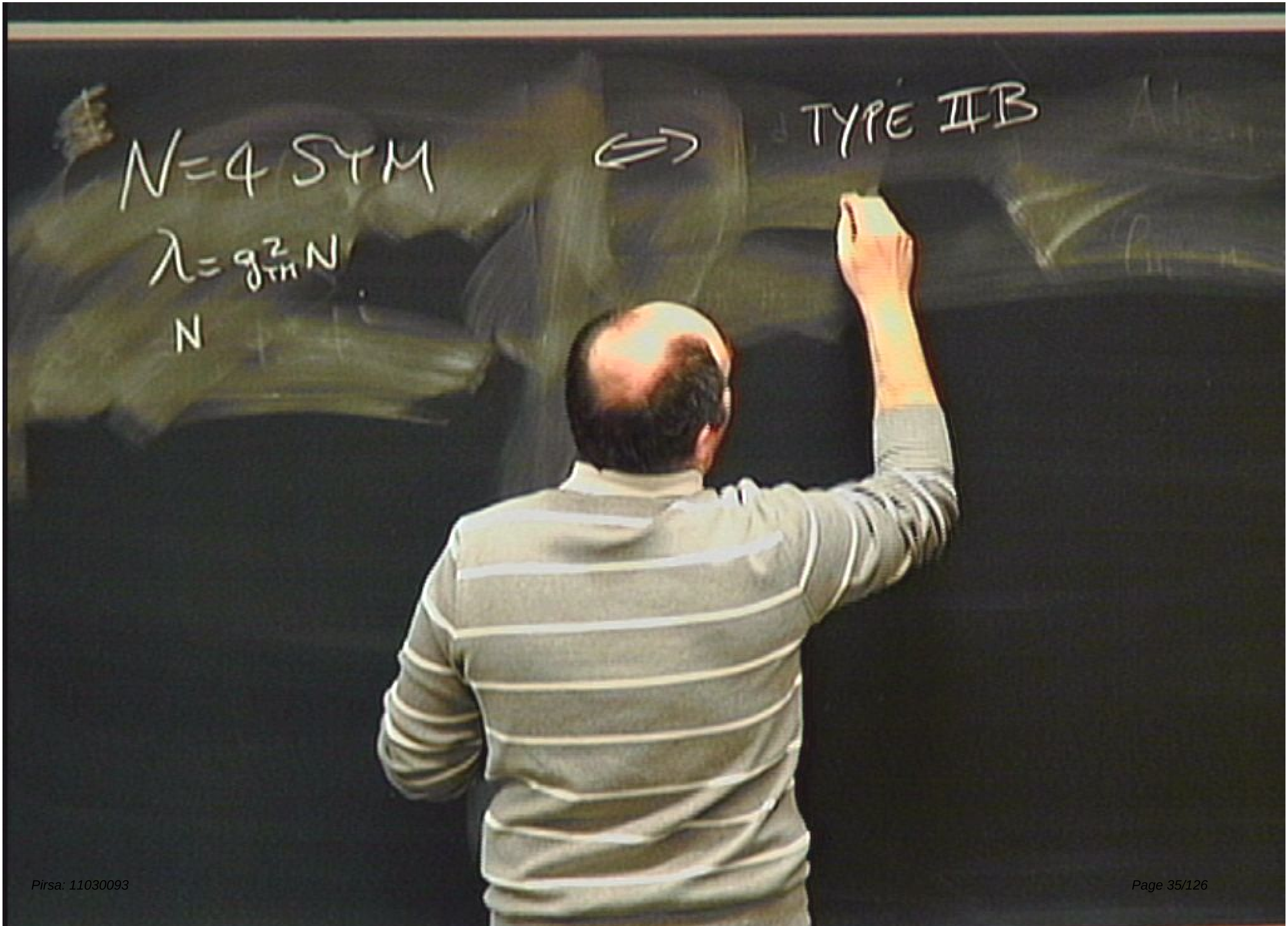
FREE N-VECTOR ϕ^i $i = 1, \dots N$

$$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i$$

$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i \qquad \text{Spin 1}$$

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$

$$\Delta(J_\mu) = d - 2 + 1 = d - 1$$


$\mathcal{N}=4$ SYM
$\Longleftrightarrow$
TYPE IIB
$\lambda = g_{YM}^2 N$
N

$\mathcal{N}=4$ SYM $\iff$ TYPE IIB

$\lambda = g_{YM}^2 N$

N

$$\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$$

$$\frac{R_{AdS}^4}{\ell_{pl}^4} = N$$

$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

$\lambda = g_{YM}^2 N$

N

$N \to \infty \quad \lambda$ fixed

$$\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$$

$$\frac{R_{AdS}^4}{\ell_{pl}^4} = N$$

$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

$\lambda = g_{YM}^2 N$

N

$$\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$$

$$\frac{R_{AdS}^4}{l_{pl}^4} = N$$

$N \to \infty$ λ fixed

1) $\lambda \gg 1$

2) $\lambda \ll 1$

$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

$\lambda = g_{YM}^2 N$ $\qquad$ $\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$

N $\qquad$ $\frac{R_{AdS}^4}{\ell_{pl}^4} = N$

$N \to \infty$ $\quad$ λ fixed

1) $\lambda \gg 1$

2) $\ll 1$, $\lambda \to 0$

$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

$\lambda = g_{YM}^2 N$

N

$$\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$$

$$\frac{R_{AdS}^4}{\ell_{pl}^4} = N$$

$N \to \infty$ λ fixed

1) $\lambda \gg 1$

2) $\lambda \ll 1$, $\lambda \to 0$ "TENSIONLESS STRINGS"

$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

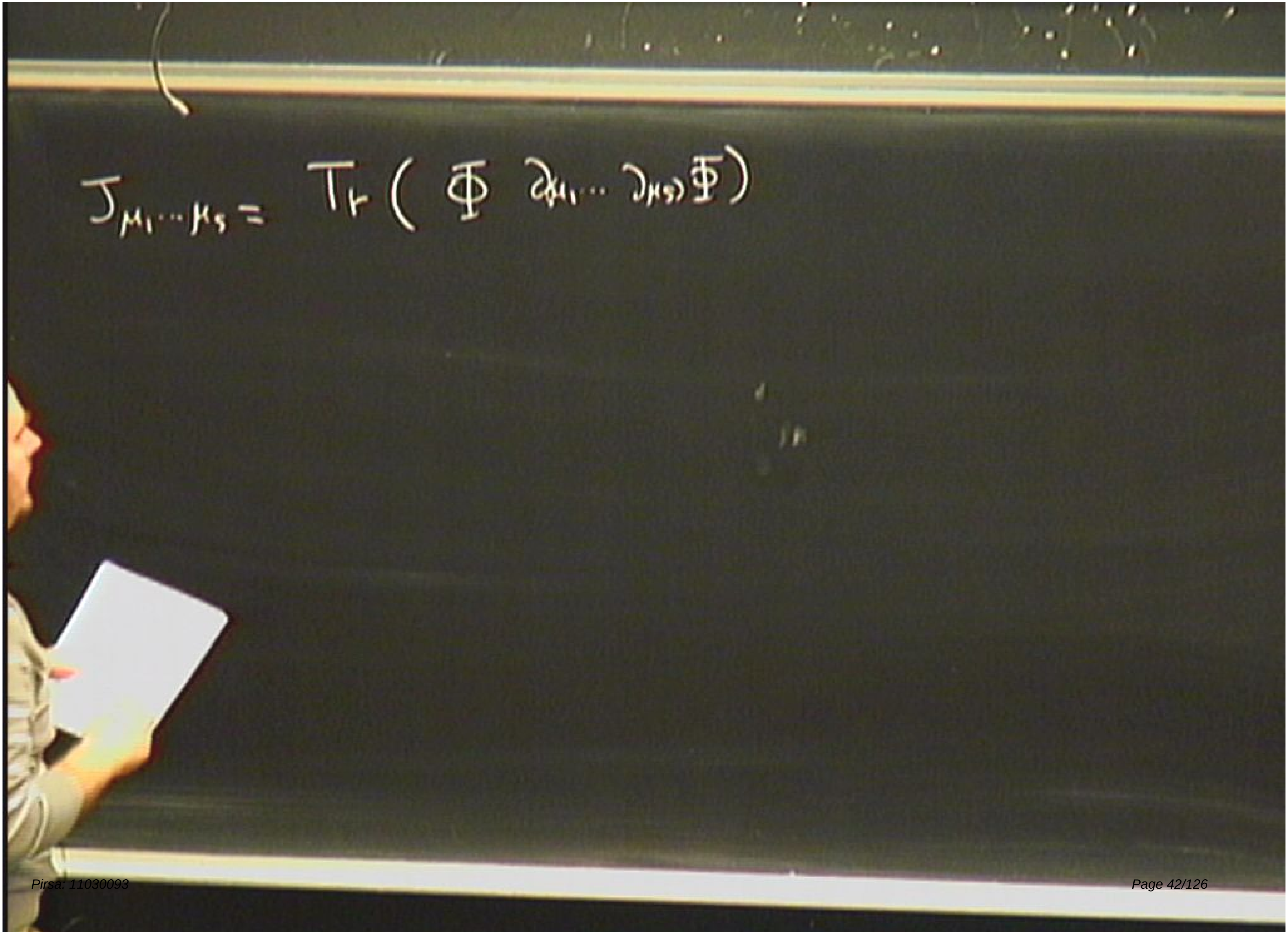
$\lambda = g_{YM}^2 N$ $\qquad$ $\frac{R_{AdS}^4}{(\alpha')^2} = \lambda$

N $\qquad$ $\frac{R_{AdS}^4}{\ell_{pl}^4} = N$

$N \to \infty \quad \lambda$ fixed

1) $\lambda \gg 1$

2) $\lambda \ll 1$, $\lambda \to 0$ "TENSIONLESS STRINGS"

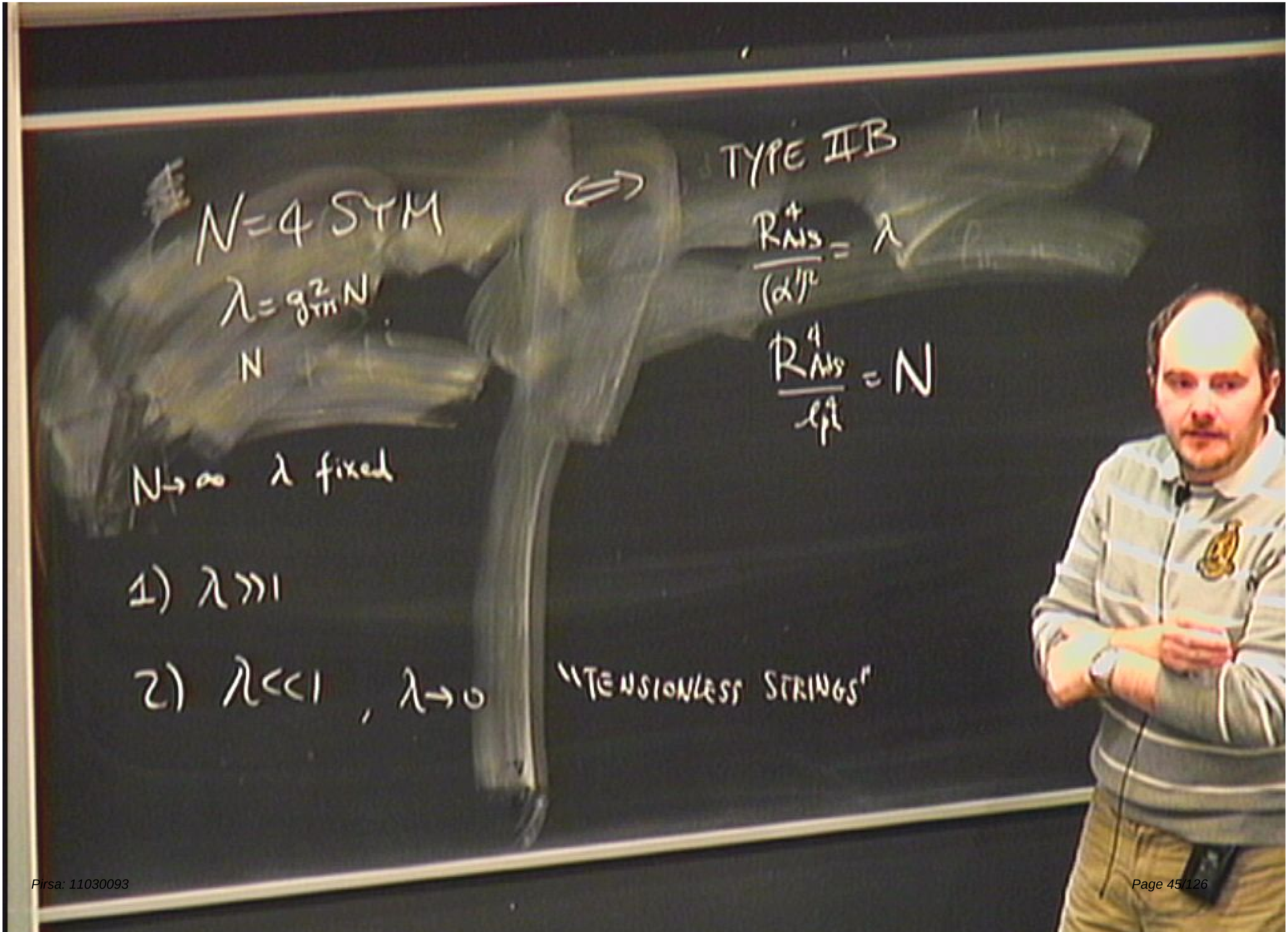

$J_{\mu_1\cdots\mu_s} = \mathrm{Tr}(\Phi\, \partial_{\mu_1}\cdots\partial_{\mu_s}\Phi)$

$$J_{\mu_1 \cdots \mu_s} = \mathrm{Tr}\left(\Phi \, \partial_{\mu_1} \cdots \partial_{\mu_s} \Phi \right)$$

$$\mathrm{Tr}\left(\Phi \, \partial \partial \Phi \cdots \partial \Phi \cdots \right)$$

$$J_{\mu_1 \cdots \mu_s} = \mathrm{Tr}\left(\Phi\, \partial_{\mu_1} \cdots \partial_{\mu_s} \Phi \right)$$

$$\mathrm{Tr}\left(\Phi\, \partial \partial\, \Phi \cdots \partial\, \Phi \cdots \right)$$


N=4 SYM
λ = g²YM N
N
⟺
TYPE IIB
R⁴AdS / (α')² = λ
R⁴AdS / ℓp⁴ = N
N→∞ λ fixed
1) λ >> 1
2) λ << 1 , λ→0
"TENSIONLESS STRINGS"

$$T_{\mu\nu} = \partial_{(\mu}\phi_i^* \partial_{\nu)}\phi^i - \frac{1}{4}\frac{1}{d-1}\left((d-2)\partial_\mu\partial_\nu + g_{\mu\nu}\partial^2\right)\phi^2$$

$$\partial^\mu T_{\mu\nu} = 0 \qquad g^{\mu\nu}T_{\mu\nu} = 0 \qquad \Delta(T_{\mu\nu}) = d$$

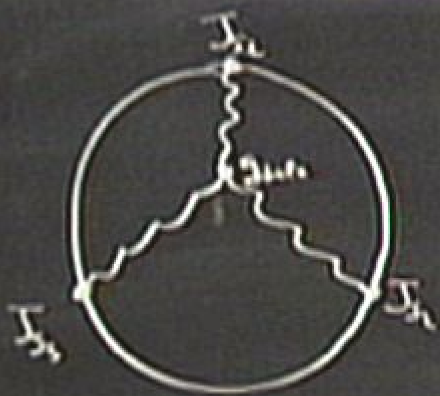
$$\mathrm{Tr}(\phi^3)$$

$$= \phi_i^* \partial_{\mu_1}\cdots\partial_{\mu_s}\phi^i + \cdots$$

$$= \sum_{k=0}^{s} \frac{(-1)^k}{k!\left(k+\frac{d-2}{2}\right)!(s-k)!\left(s-k+\frac{d-2}{2}\right)!}\left(\partial_{\mu_1}\cdots\partial_{\mu_k}\phi_i^*\right)\left(\partial_{\mu_{k+1}}\cdots\partial_{\mu_s}\phi^i\right) - \text{traces}$$

$$\mu_1\cdots\mu_s = 0$$

$$\Delta(J_{m}) = d-2+s$$

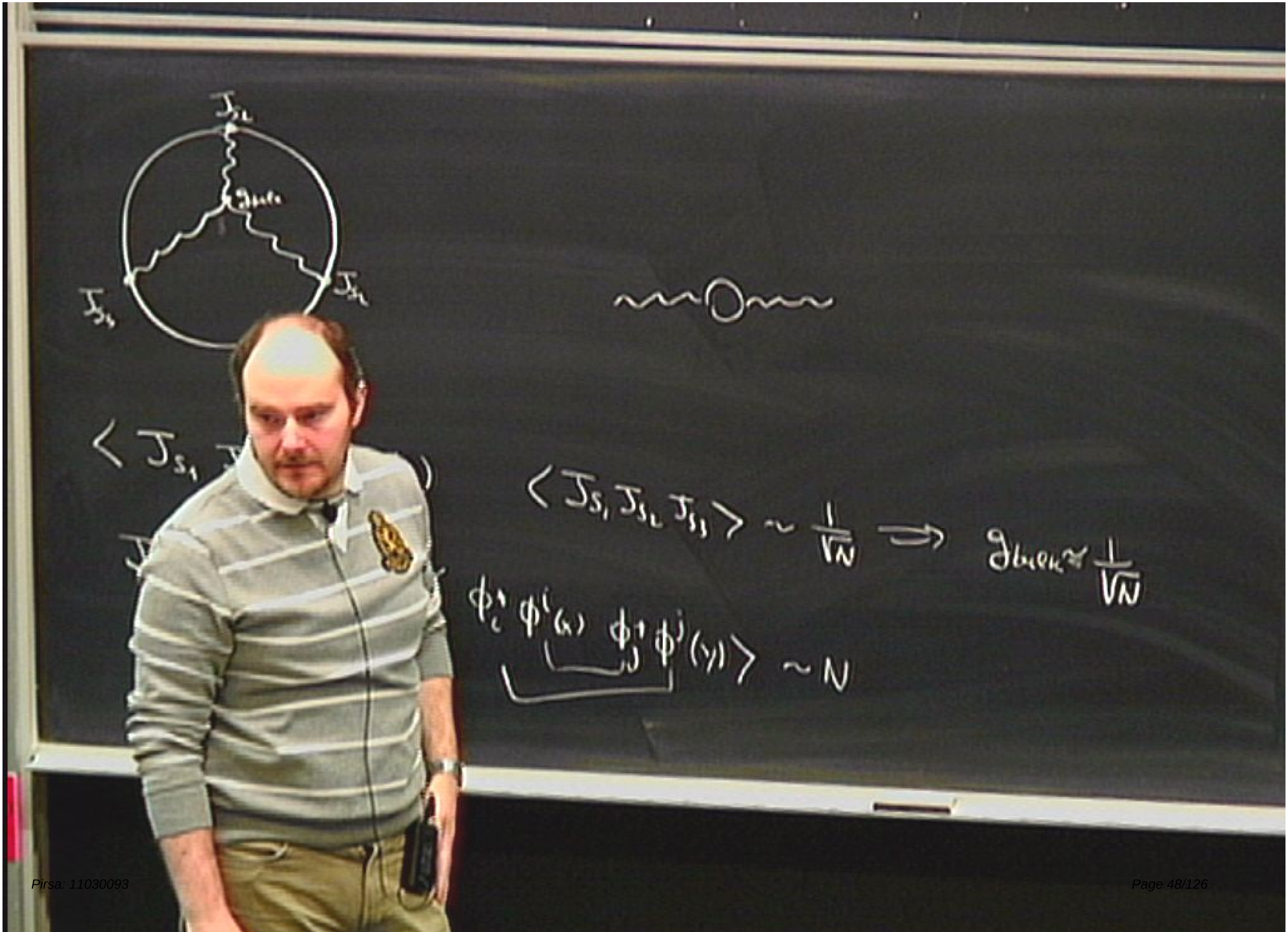


$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

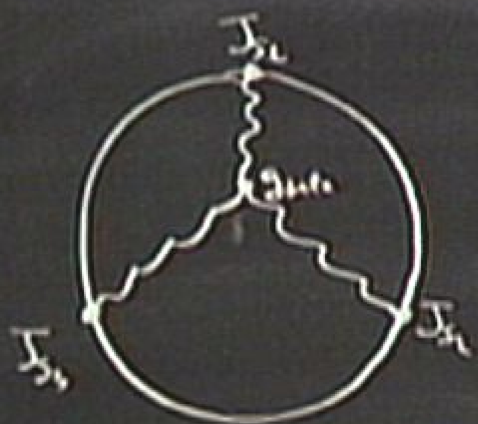
$$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \approx \frac{1}{\sqrt{N}}$$

$$J_\mu \to \frac{1}{\sqrt{N}} J_\mu$$

$$\langle \phi_i^\dagger \phi^i(x) \, \phi_j^\dagger \phi^j(y) \rangle \sim N$$



$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$
$\sim N$



$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

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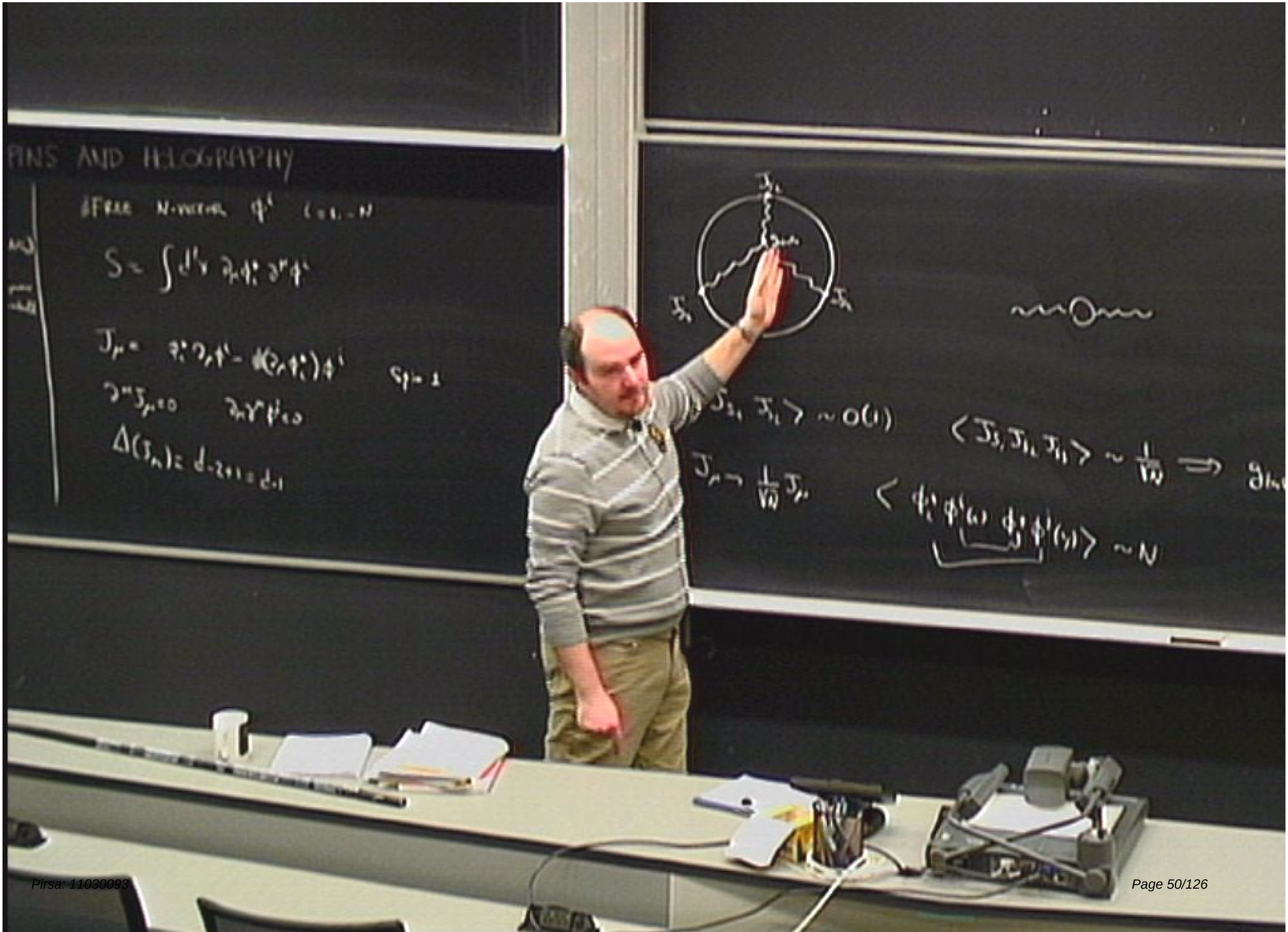
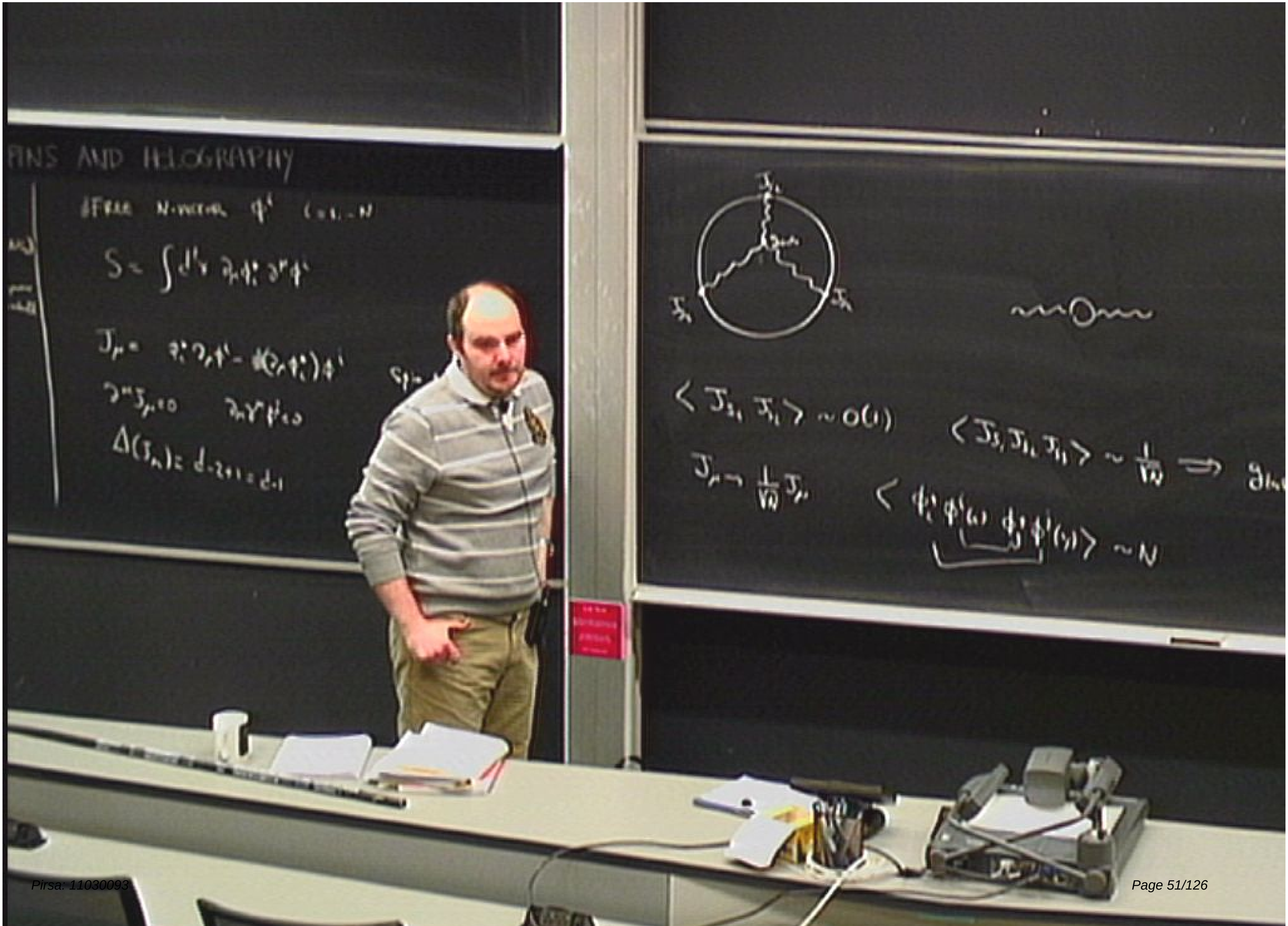
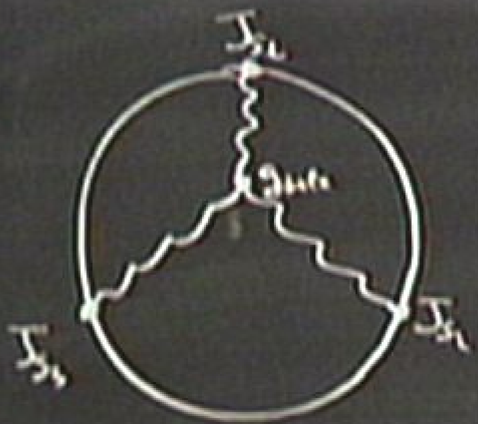

PINS AND HOLOGRAPHY
FREE N-VECTOR
~ O(1)
~ N


PINS AND HOLOGRAPHY
FREE N-VECTOR
~N

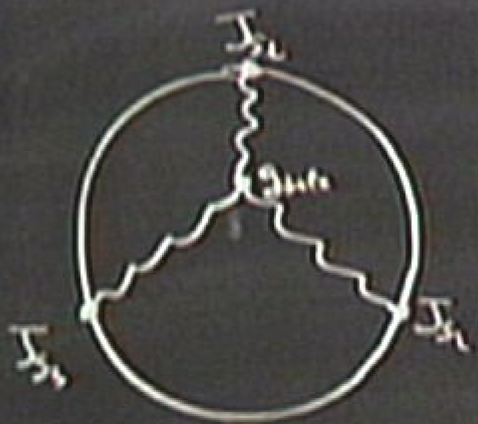


$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

$$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$$

$$J_\mu \to \frac{1}{\sqrt{N}} J_\mu$$

$$\langle \phi_i^\dagger \phi^i(x)\, \phi_j^\dagger \phi^j(y) \rangle \sim N$$



$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

$$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$$

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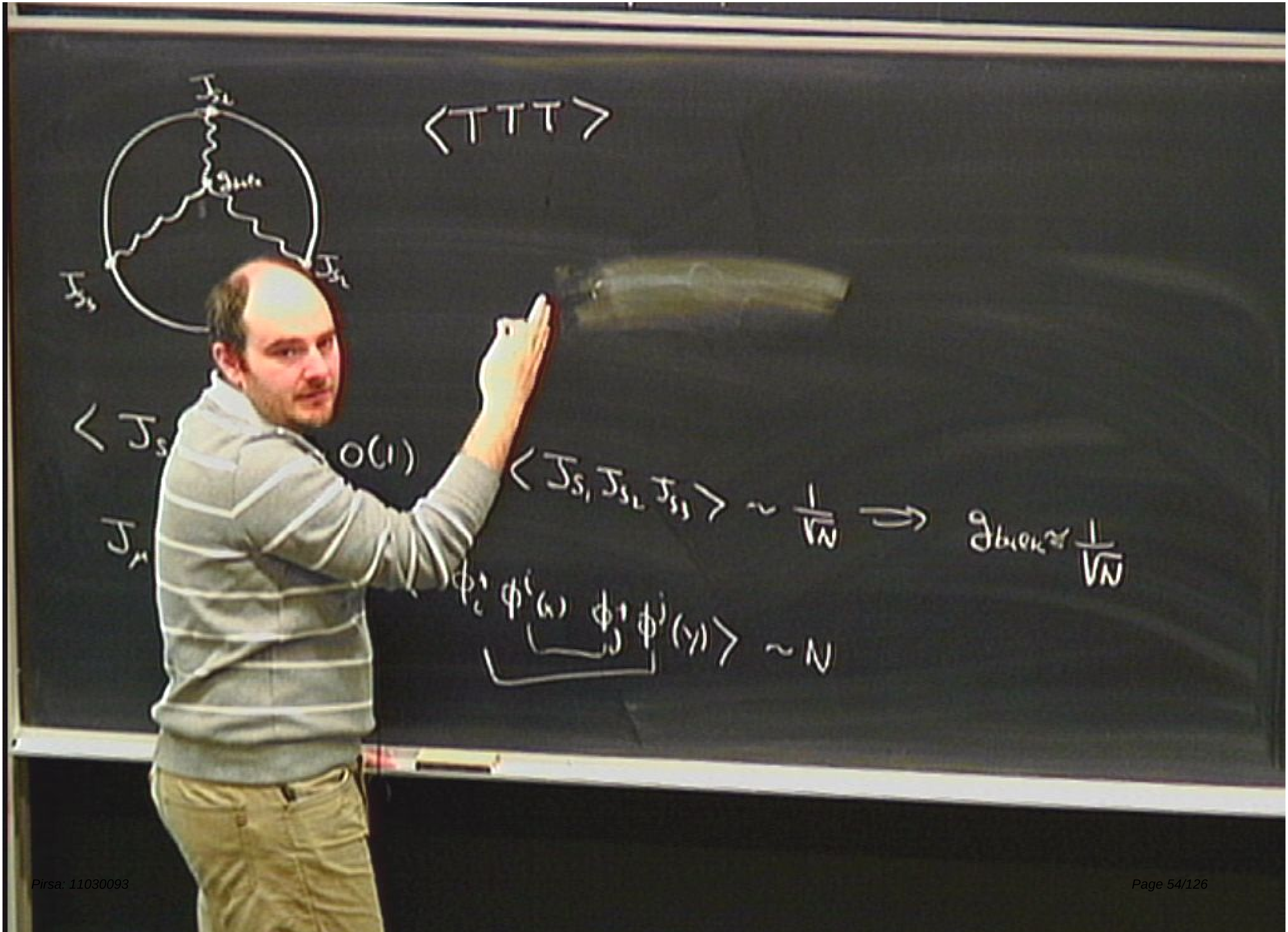
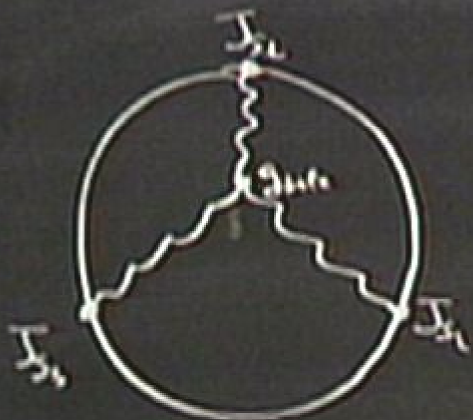

$\langle TTT \rangle$
J_{s_2}
g_{bulk}
J_{s_3}
J_{s_1}
$O(1)$
$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$
$\sim N$



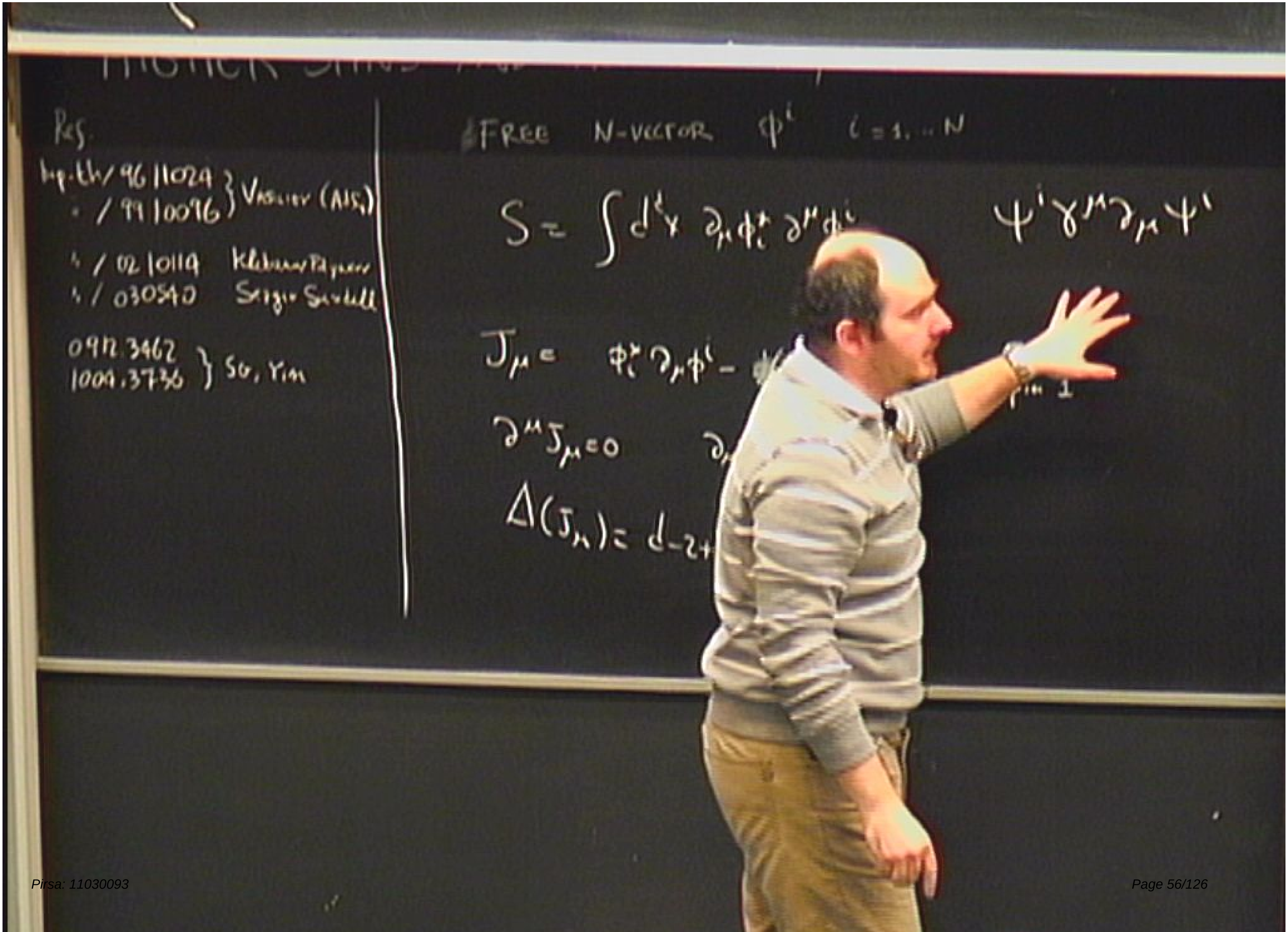
$$\langle TTT \rangle = a_B \langle TTT \rangle_B + a_F \langle TTT \rangle_F$$

$$\langle J_{s_1} J_{s_2} \rangle \sim O(1)$$

$$\langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Longrightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$$

$$J_\mu \to \frac{1}{\sqrt{N}} J_\mu$$

$$\langle \phi_i^\dagger \phi^i(x) \, \phi_j^\dagger \phi^j(y) \rangle \sim N$$


Refs.
hep-th/9611024 } Vasiliev (AdS)
/9910096
/0210114 Klebanov/Polyakov
/030540 Sezgin Sundell
0912.3462 } Gi, Yin
1009.3736
FREE N-VECTOR ϕ^i $i=1,\dots N$
$S = \int d^dx\, \partial_\mu \phi_i^* \partial^\mu \phi^i$
$\psi^i \gamma^\mu \partial_\mu \psi^i$
$J_\mu = \phi_i^* \partial_\mu \phi^i -$
$\partial^\mu J_\mu = 0$
$\Delta(J_\mu) = d-2+$

Refs.

hep-th/9611024 } Vasiliev (AdS)
" /9910096 }

" /0210114 Klebanov/Polyakov
" /030540 Sezgin Sundell

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FREE N-VECTOR ϕ^i $i = 1, \dots N$

$$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i$$

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$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i$$

Spin 1

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$

$$\Delta(J_\mu) = d - 2 + 1 = d - 1$$

Refs.

hep-th/9611024 } Vasiliev (AdS)
" / 9910096 }

" / 0210114 Klebanov Polyakov
" / 030540 Sezgin Sundell

0912.3462 } Su, Yin
1004.3736 }

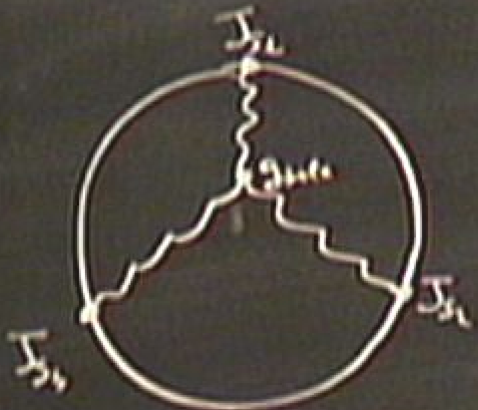
FREE N-VECTOR ϕ^i $i = 1, \dots N$

$$S = \int d^d x \, \partial_\mu \phi_i^* \partial^\mu \phi^i \qquad \psi^i \gamma^\mu \partial_\mu \psi^i$$

$$J_\mu = \phi_i^* \partial_\mu \phi^i - (\partial_\mu \phi_i^*) \phi^i \qquad \text{Spin } 1$$

$$\partial^\mu J_\mu = 0 \qquad \partial_\mu \partial^\mu \phi^i = 0$$

$$\Delta(J_\mu) = d - 2 + 1 = d - 1$$



$$\langle TTT \rangle = a_B \langle TTT \rangle_B + a_F \langle TTT \rangle_F$$

$$\langle TTT \rangle_{EH} \rightarrow a_B = a_F$$

$$\langle J_{s_1} J_{s_2} \rangle \sim O(1) \qquad \langle J_{s_1} J_{s_2} J_{s_3} \rangle \sim \frac{1}{\sqrt{N}} \Rightarrow g_{bulk} \sim \frac{1}{\sqrt{N}}$$

$$J_\mu \rightarrow \frac{1}{\sqrt{N}} J_\mu \qquad \langle \phi_i^\dagger \phi^i(x)\, \phi_j^\dagger \phi^j(y) \rangle \sim N$$

HIGHER SPIN GAUGE FIELDS

HIGHER SPIN GAUGE FIELDS

Massive HS

HIGHER SPIN GAUGE FIELDS

Massive HS

Fierz-Pauli ('39)

Flat space

$$(\Box - m^2)\varphi_{\mu_1\cdots\mu_s}=0$$

HIGHER SPIN GAUGE FIELDS

Massive HS

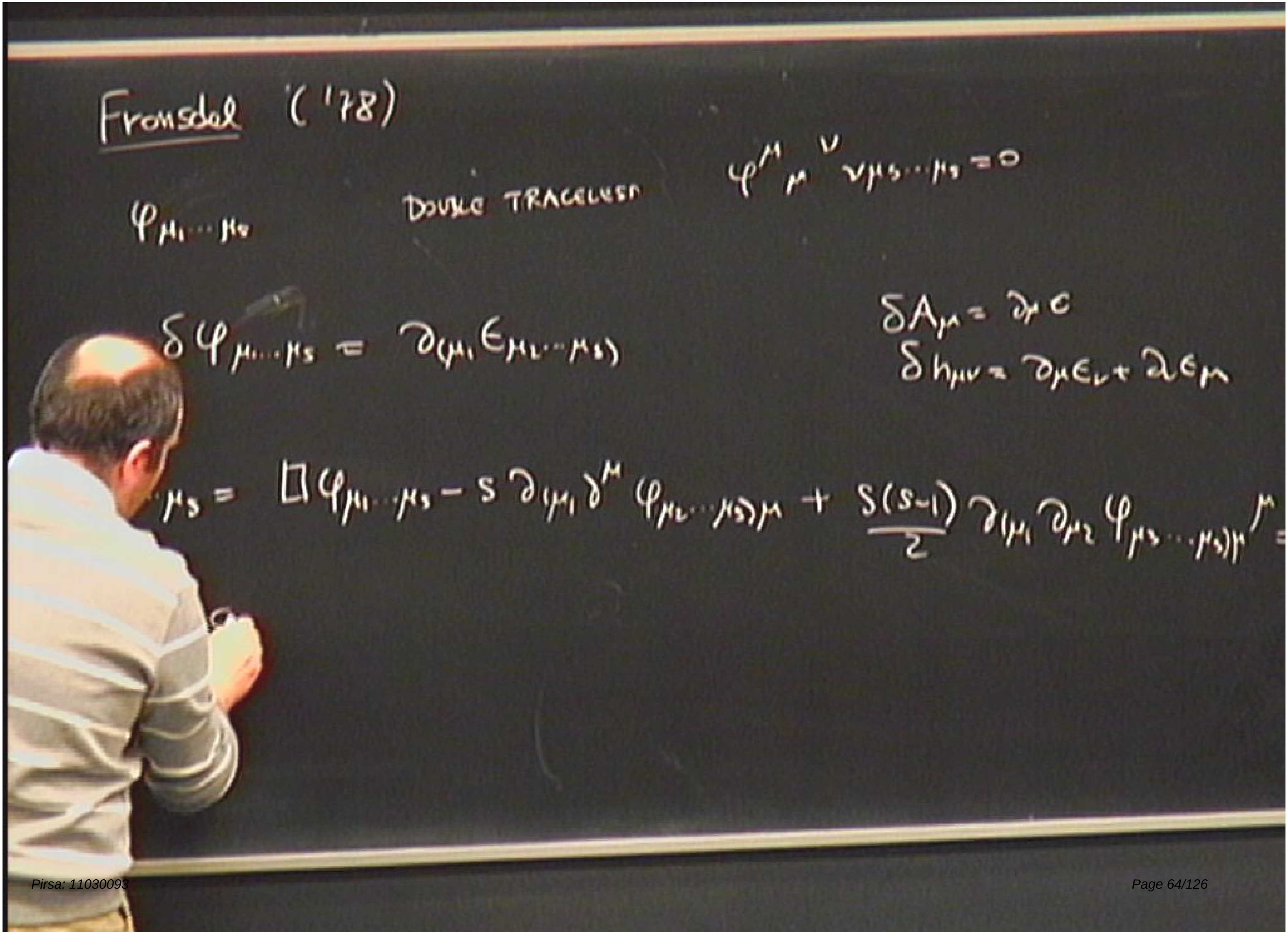
Fierz-Pauli ('39)

Flat space

$$(\Box - m^2)\varphi_{\mu_1\cdots\mu_s}=0$$

$$\partial^\mu \varphi_{\mu\mu_2\cdots\mu_s}=0 \qquad \varphi^\mu{}_{\mu\mu_3\cdots\mu_s}=0$$

$(2s+1)$


Fronsdal ('78)
$\varphi_{\mu_1 \cdots \mu_s}$
DOUBLE TRACELESS
$\varphi^{\mu}{}_{\mu}{}^{\nu}{}_{\nu \mu_5 \cdots \mu_s} = 0$
$\delta \varphi_{\mu_1 \cdots \mu_s} = \partial_{(\mu_1} \epsilon_{\mu_2 \cdots \mu_s)}$
$\delta A_\mu = \partial_\mu \epsilon$
$\delta h_{\mu\nu} = \partial_\mu \epsilon_\nu + \partial \epsilon_\mu$
$\mu_s = \Box \varphi_{\mu_1 \cdots \mu_s} - s\, \partial_{(\mu_1} \partial^{\mu} \varphi_{\mu_2 \cdots \mu_s)\mu} + \frac{s(s-1)}{2} \partial_{(\mu_1} \partial_{\mu_2} \varphi_{\mu_3 \cdots \mu_s))\mu}{}^{\mu} =$

<u>Fronsdal</u> ('78)

$\varphi_{\mu_1\cdots\mu_s}$ DOUBLE TRACELESS $\varphi^{\mu}{}_{\mu}{}^{\nu}{}_{\nu\mu_5\cdots\mu_s}=0$

$\delta A_\mu = \partial_\mu c$

$\delta h_{\mu\nu} = \partial_\mu \epsilon_\nu + \partial_\nu \epsilon_\mu$

$$\delta\varphi_{\mu_1\cdots\mu_s} = \partial_{(\mu_1}\underbrace{\epsilon_{\mu_2\cdots\mu_s)}}$$

$$\epsilon^{\mu}{}_{\mu\mu_4\cdots\mu_s}=0$$

$$G_{\mu_1\cdots\mu_s} = \Box\varphi_{\mu_1\cdots\mu_s} - s\,\partial_{(\mu_1}\partial^{\mu}\varphi_{\mu_2\cdots\mu_s)\mu} + \frac{s(s-1)}{2}\partial_{(\mu_1}\partial_{\mu_2}\varphi_{\mu_3\cdots\mu_s)\mu}{}^{\mu} =$$

$$\delta G_{\mu_1\cdots\mu_s} = \frac{s(s-1)(s-2)}{2}\partial_{\mu_1}\partial_{\mu_2}\partial_{\mu_3}\underbrace{\epsilon^{\mu}{}_{\mu\mu_4\cdots\mu_s}}$$

Fronsdal ('78)

$\varphi_{\mu_1 \cdots \mu_s}$ DOUBLE TRACELESS $\varphi^{\mu}{}_{\mu}{}^{\nu}{}_{\nu\mu_5\cdots\mu_s} = 0$

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$$\delta G_{\mu_1\cdots\mu_s} = \frac{s(s-1)(s-2)}{2}\partial_{\mu_1}\partial_{\mu_2}\partial_{\mu_3}\underbrace{\epsilon^{\mu}{}_{\mu\mu_4\cdots\mu_s}}$$

Fronsdal ('78)

$\varphi_{\mu_1 \cdots \mu_s}$ DOUBLE TRACELESS $\varphi^{\mu}{}_{\mu}{}^{\nu}{}_{\nu \mu_5 \cdots \mu_s} = 0$

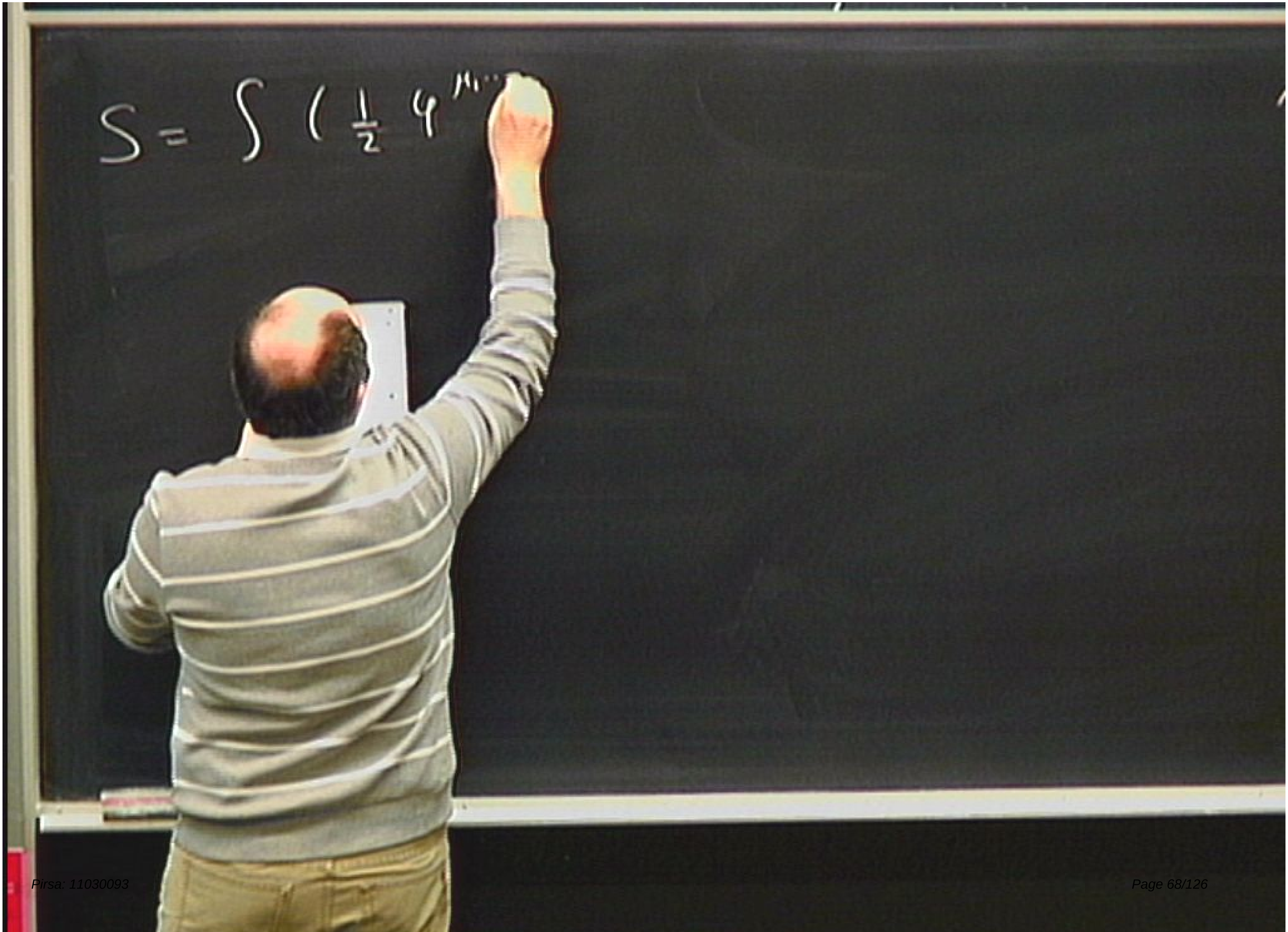
$$\delta \varphi_{\mu_1 \cdots \mu_s} = \partial_{(\mu_1} \underbrace{\epsilon_{\mu_2 \cdots \mu_s)}}_{\epsilon^{\mu}{}_{\mu \mu_4 \cdots \mu_s} = 0}$$

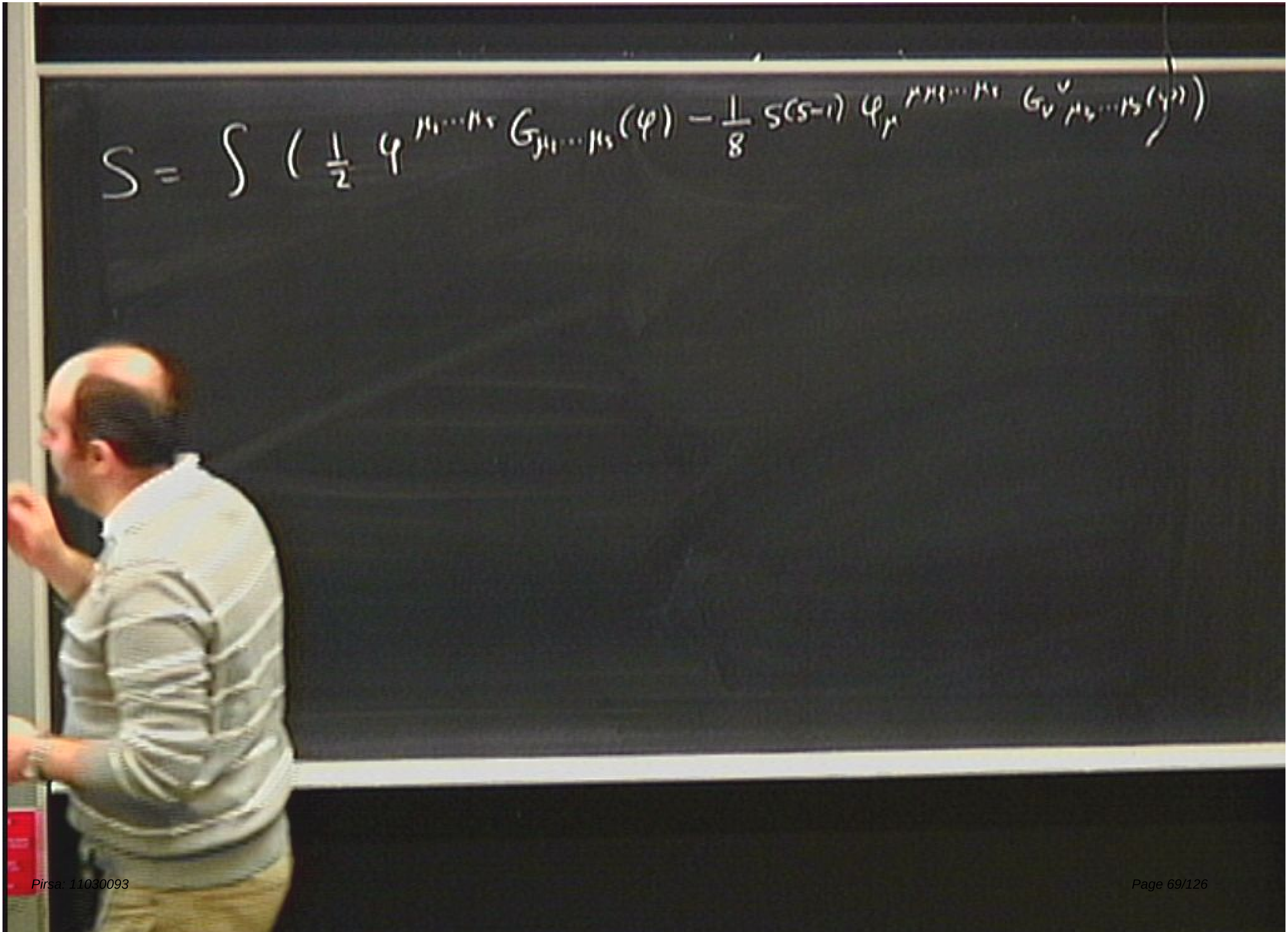
$\delta A_\mu = \partial_\mu c$

$\delta h_{\mu\nu} = \partial_\mu \epsilon_\nu + \partial_\nu \epsilon_\mu$

$$G_{\mu_1 \cdots \mu_s} = \Box \varphi_{\mu_1 \cdots \mu_s} - s\, \partial_{(\mu_1} \partial^{\mu} \varphi_{\mu_2 \cdots \mu_s)\mu} + \frac{s(s-1)}{2} \partial_{(\mu_1} \partial_{\mu_2} \varphi_{\mu_3 \cdots \mu_s)\mu}{}^{\mu} = 0$$

$$\delta G_{\mu_1 \cdots \mu_s} = \frac{s(s-1)(s-2)}{2} \partial_{\mu_1} \partial_{\mu_2} \partial_{\mu_3} \underbrace{\epsilon^{\mu}{}_{\mu \mu_4 \cdots \mu_s}}$$


$S = \int \left(\frac{1}{2} g^{\mu \cdots}\right.$


$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$

Fronsdal ('78)

4d

$\varphi_{\mu_1\cdots\mu_s}$ DOUBLE TRACELESS $\varphi^{\mu}{}_{\mu}{}^{\nu}{}_{\nu\mu_5\cdots\mu_s}=0$

$$\delta\varphi_{\mu_1\cdots\mu_s} = \partial_{(\mu_1}\underbrace{\epsilon_{\mu_2\cdots\mu_s)}}_{\epsilon^{\mu}{}_{\mu\mu_3\cdots\mu_s}=0}$$

$$\delta A_\mu = \partial_\mu c$$
$$\delta h_{\mu\nu} = \partial_\mu\epsilon_\nu + \partial_\nu\epsilon_\mu$$

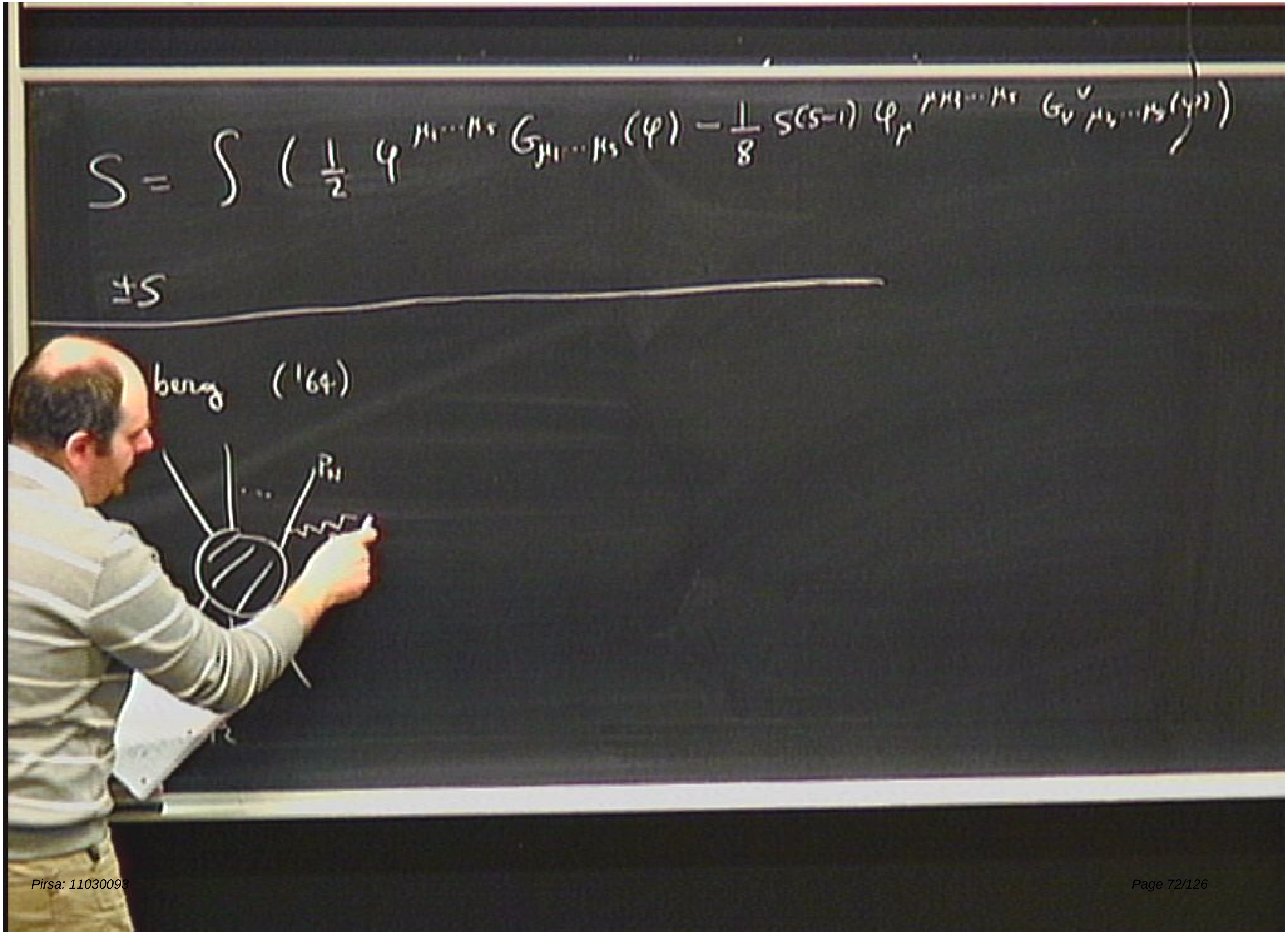
$$G_{\mu_1\cdots} \cdots \varphi_{\mu_1\cdots\mu_s} - s\,\partial_{(\mu_1}\partial^{\mu}\varphi_{\mu_2\cdots\mu_s)\mu} + \frac{s(s-1)}{2}\partial_{(\mu_1}\partial_{\mu_2}\varphi_{\mu_3\cdots\mu_s)\mu}{}^{\mu} = 0$$

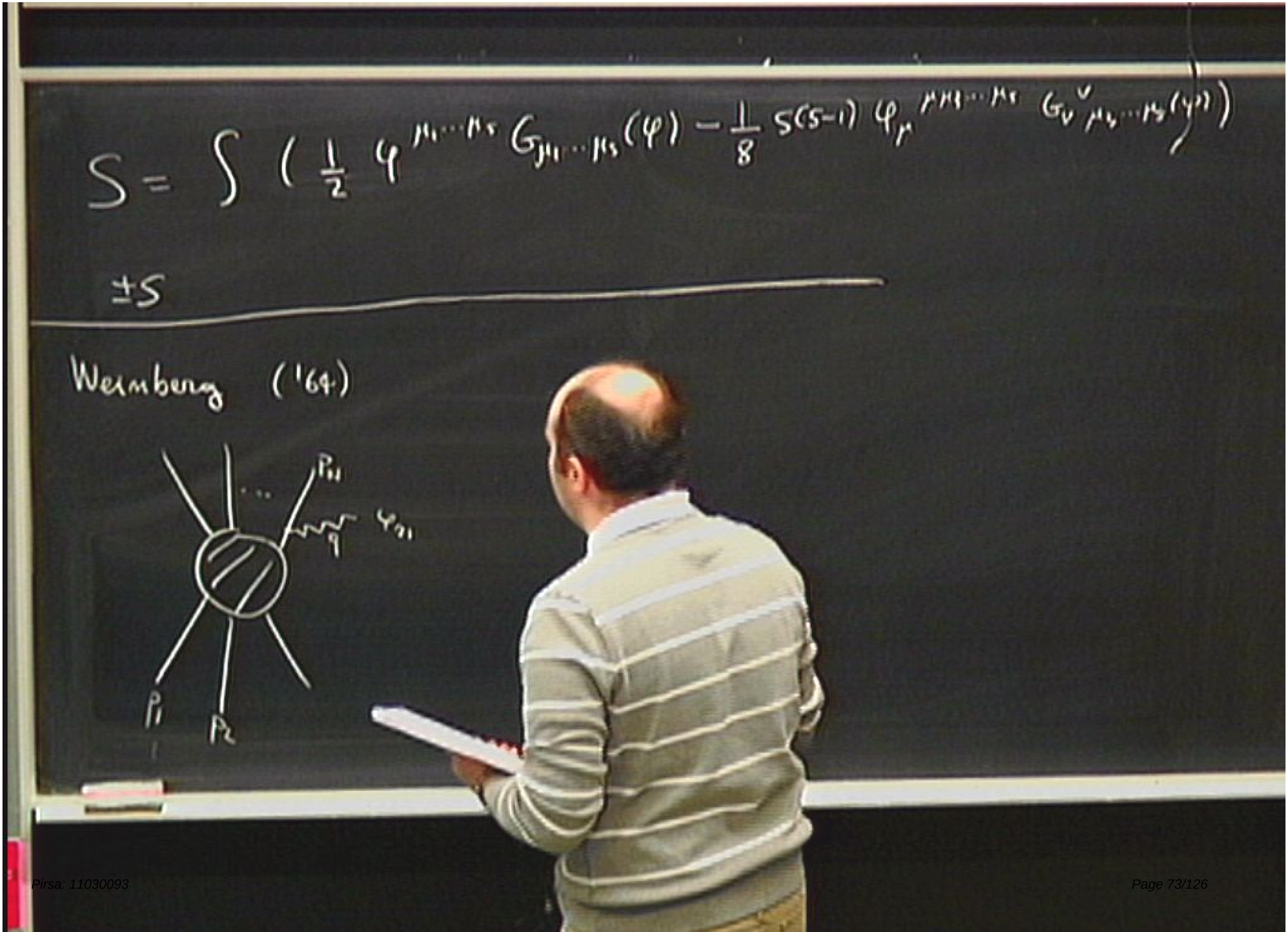
$$\cdots_{\mu_s} = \frac{s(s-1)(s-2)}{2}\partial_{\mu_1}\partial_{\mu_2}\partial_{\mu_3}\underbrace{\epsilon^{\mu}{}_{\mu\mu_4\cdots\mu_s}}$$

$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

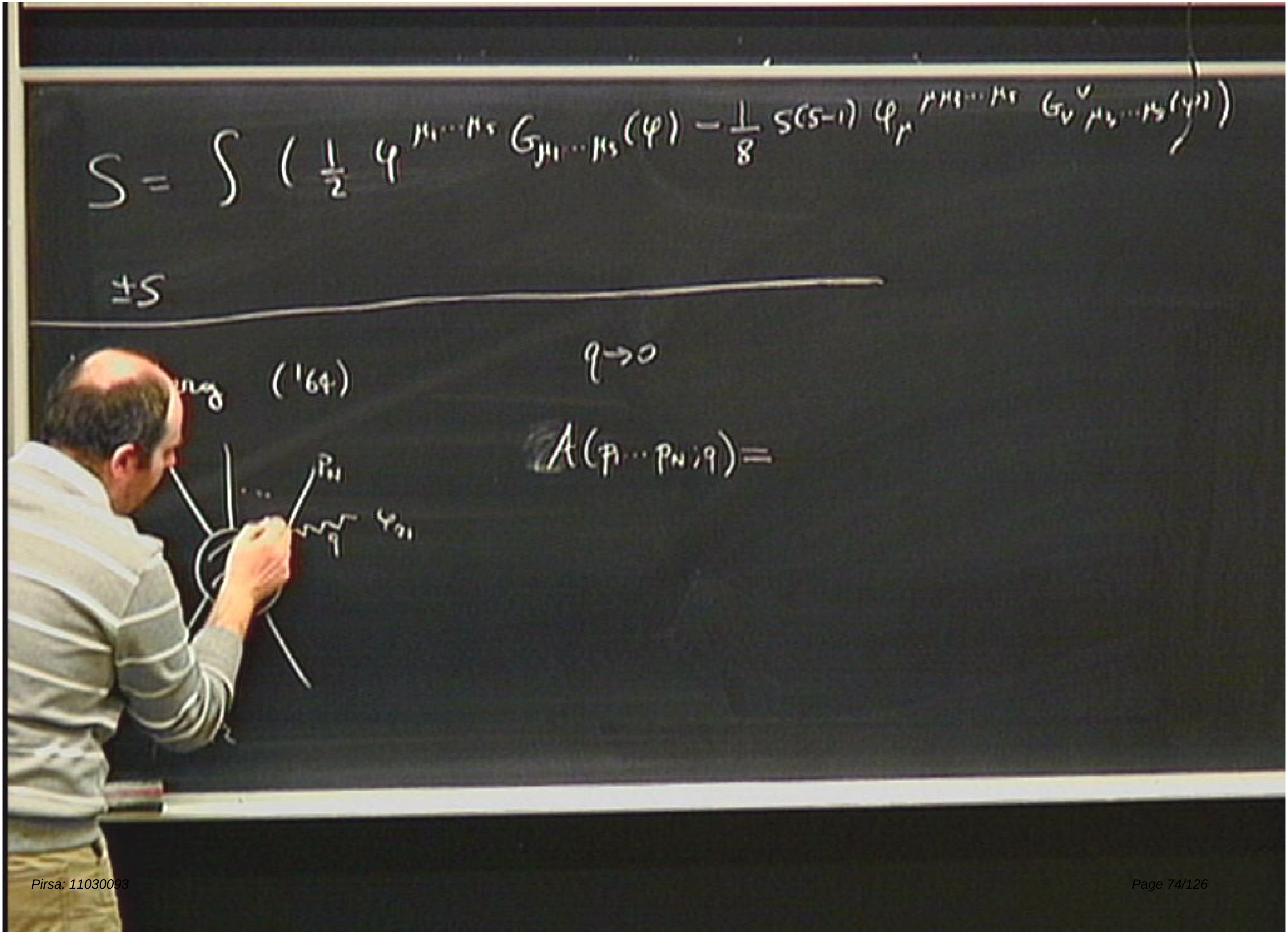
$\pm S$

Weinberg ('64)


$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$
$\pm S$
berg ('64)
p_N



$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu\mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$
$\pm S$
Weinberg ('64)
p_n
φ_n
q
p_1
p_2

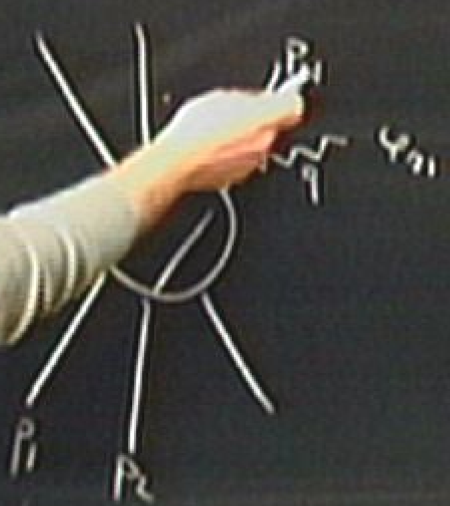

$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu\mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$
$\pm S$
ng ('64)
$q \to 0$
$A(p_1 \cdots p_N ; q) =$
p_N
$\varphi_{\mu\nu}$
q

$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1)\, \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

$\pm S$

Weinberg ('64)

$q \to 0$



$$A(p_1 \cdots p_N; q) =$$

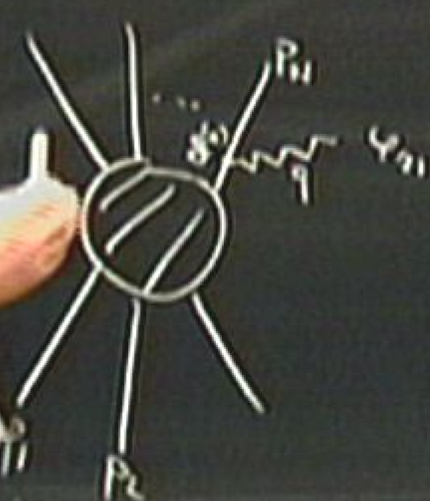
$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

$\pm S$

Weinberg ('64)

$q \to 0$

$A(p_1 \cdots p_N; q) =$



$$S = \int \left(\frac{1}{2}\, \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8}\, s(s-1)\, \varphi_{\mu}{}^{\mu \mu_3 \cdots \mu_s}\, G_{\nu}{}^{\nu}{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

$\pm S$

Wein... ('64)

$q \to 0$

$$A(p_1 \cdots p_N; q) = \sum g^{(i)} \frac{p^i_{\mu_1} \cdots p^i_{\mu_s}\, \epsilon^{\mu_1 \cdots \mu_s}(q)}{2 p^i \cdot q} A(p_1 \cdots p_N)$$

p_N

$g^{(i)}$

q

φ_{21}

$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\rho{}^{\rho \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

$\pm s$

Weinb... ('64)

$q \to 0$

$$A(p_1 \cdots p_N ; q) = \sum g^{(i)} \frac{p^i_{\mu_1} \cdots p^i_{\mu_s} \epsilon^{\mu_1 \cdots \mu_s}(q)}{2 p^i \cdot q} A(p_1 \cdots p_N)$$

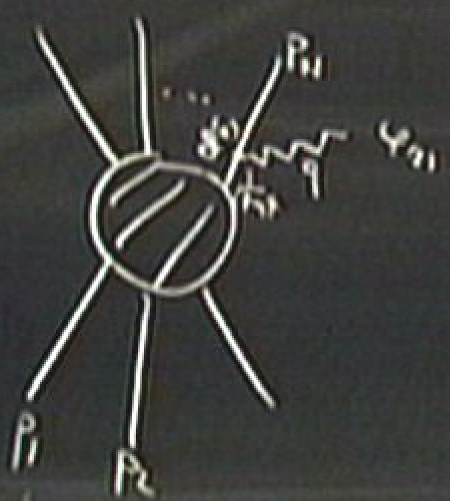
p_N q φ_{21}

$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

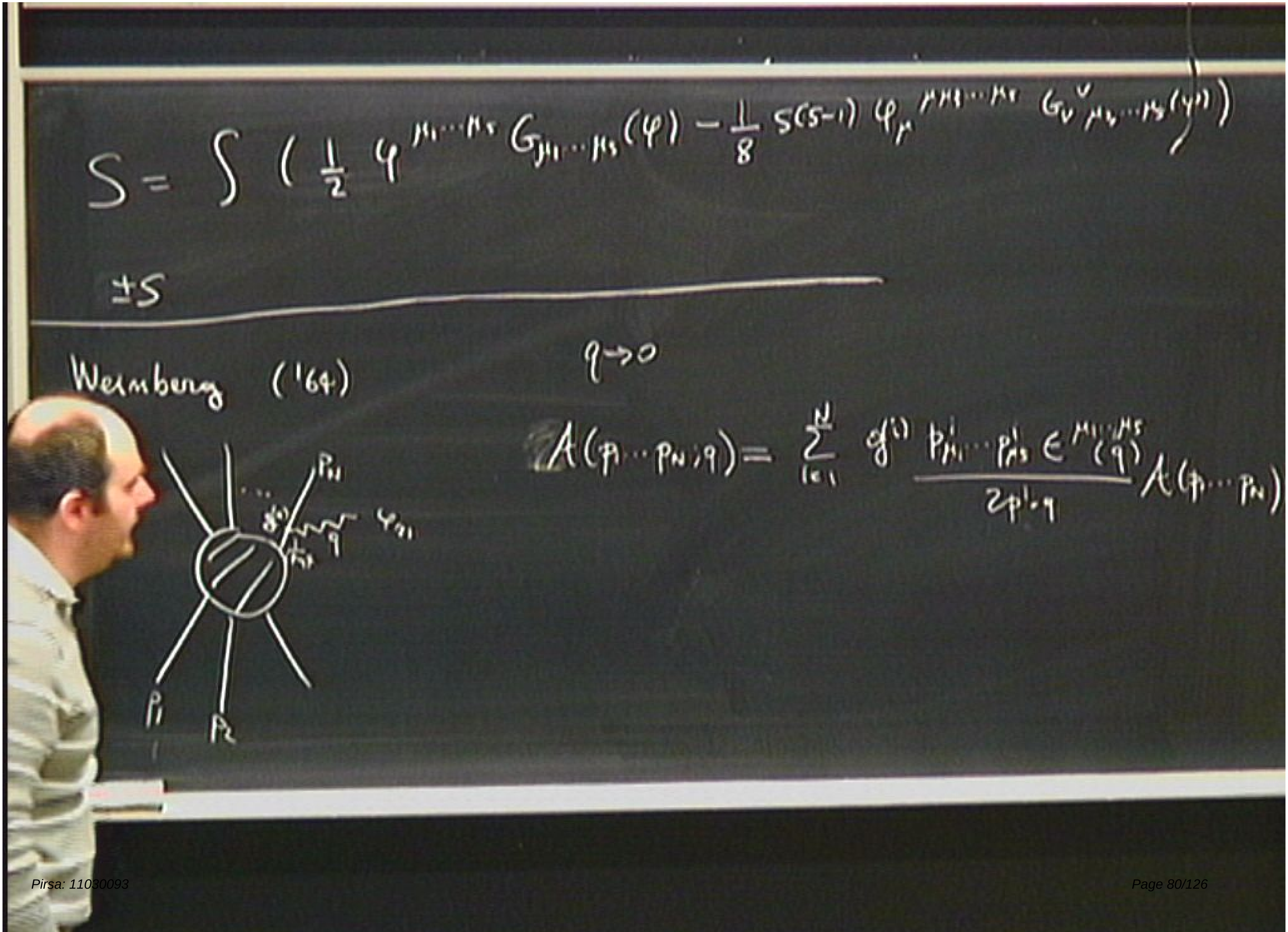
$\pm S$

Weinberg ('64)

$q \to 0$



$$A(p_1 \cdots p_N; q) = \sum g^{(i)} \frac{p'_{\mu_1} \cdots p'_{\mu_s} \epsilon^{\mu_1 \cdots \mu_s}(q)}{2p' \cdot q} A(p_1 \cdots p_N)$$


$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1) \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$
$\pm S$
Weinberg ('64)
$q \to 0$
$A(p_1 \cdots p_N; q) = \sum_{i=1}^{N} g^{(i)} \frac{p^i_{\mu_1} \cdots p^i_{\mu_s} \epsilon^{\mu_1 \cdots \mu_s}(q)}{2 p^i \cdot q} A(p_1 \cdots p_N)$
p_N
$g^{(i)}$
φ_{21}
q
p_1
p_2

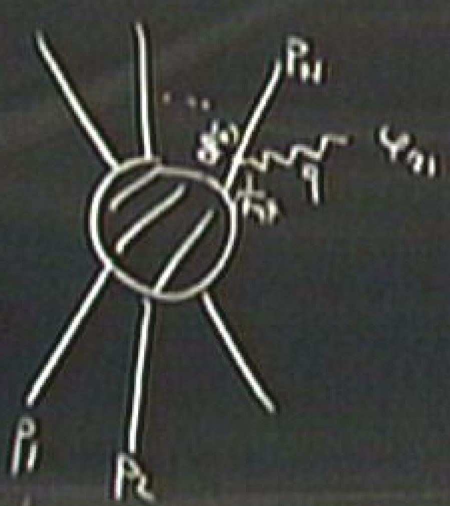
$$S = \int \left(\frac{1}{2} \varphi^{\mu_1 \cdots \mu_s} G_{\mu_1 \cdots \mu_s}(\varphi) - \frac{1}{8} s(s-1)\, \varphi_\mu{}^{\mu \mu_3 \cdots \mu_s} G_\nu{}^\nu{}_{\mu_3 \cdots \mu_s}(\varphi) \right)$$

$\pm s$

Weinberg ('64)

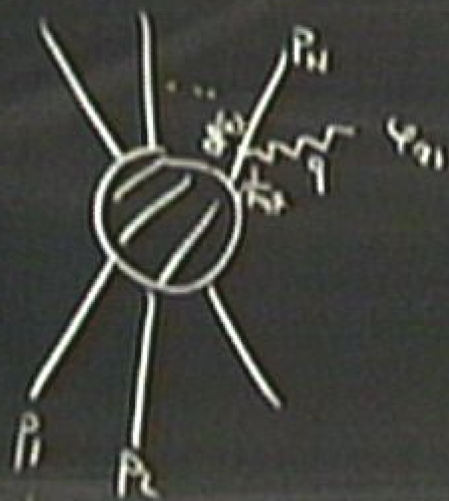
$q \to 0$

$$A(p_1 \cdots p_N; q) = \sum_{i=1}^{N} g^{(i)} \frac{p^i_{\mu_1} \cdots p^i_{\mu_s} \epsilon^{\mu_1 \cdots \mu_s}(q)}{2 p^i \cdot q} A(p_1 \cdots p_N)$$



$\pm S$

Weinberg ('64)



$q \to 0$

$$A(p_1 \cdots p_N; q) = \sum_{i=1}^{N} g^{(i)} \frac{p^i_{\mu_1} \cdots p^i_{\mu_s} \epsilon^{\mu_1 \cdots \mu_s}(q)}{2 p^i \cdot q} A(p_1 \cdots p_N)$$

$$\epsilon^{\mu_1 \cdots \mu_s}(q) = q^{\mu_1} \eta^{\mu_2 \cdots \mu_s}$$

$$\boxed{\sum_{i=1}^{N} g^{(i)} p^i_{\mu_1} \cdots p^i_{\mu_{s-1}} = 0}$$

2) $\lambda \ll 1$, $\lambda \to 0$ "TENSIONLESS STRINGS"

• $S=1$

$$\sum_{i=1}^{N} g^{(i)} = 0$$

CHARGE CONS.

• $S=2$

$$\sum_{i=1}^{N} g^{(i)} p_\mu^{(i)} = 0$$

- $S=1$

$$\sum_{i=1}^{N} g^{(i)} = 0 \qquad \text{CHARGE CONS.}$$

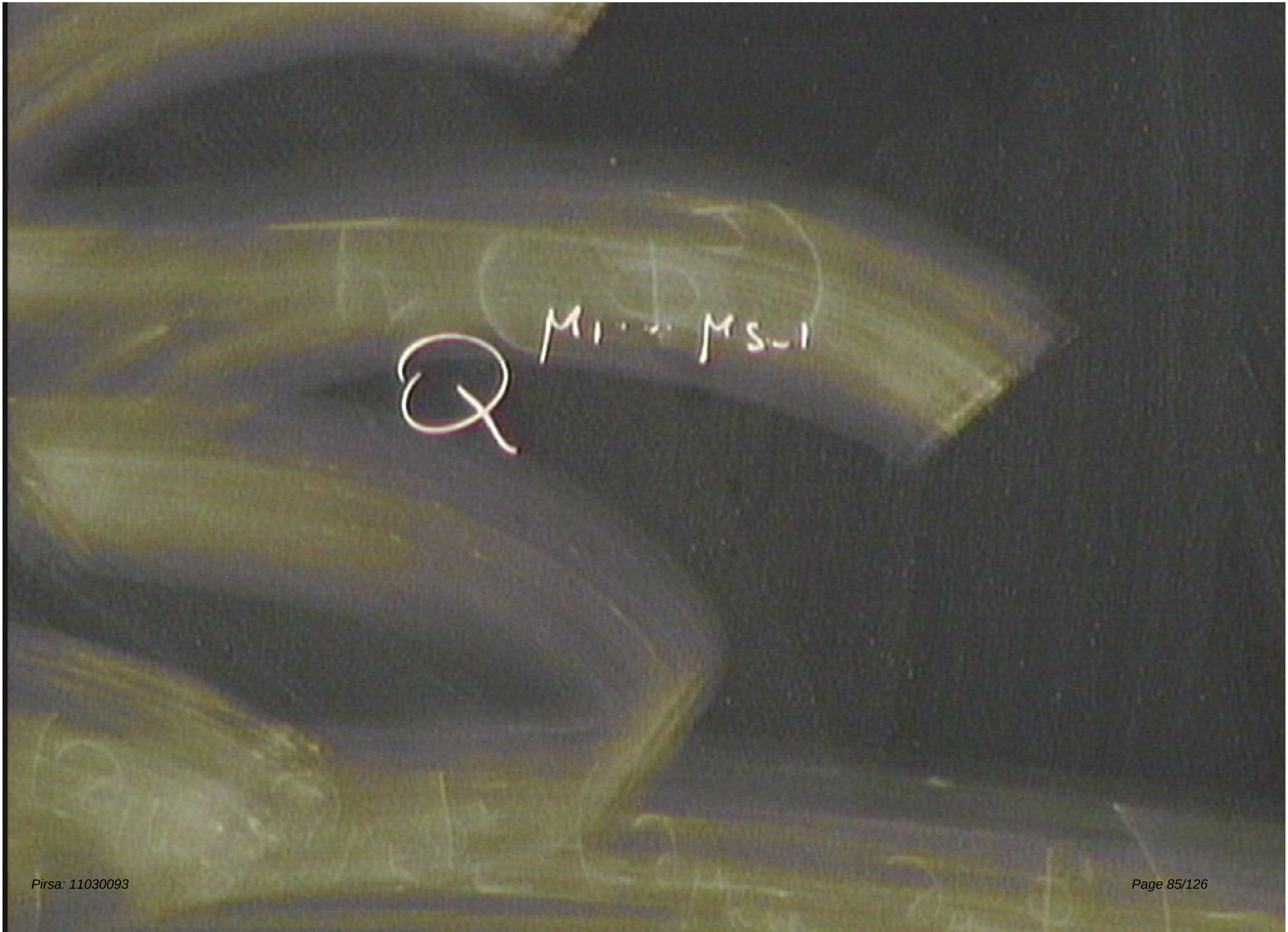
- $S=2$

$$\sum_{i=1}^{N} g^{(i)} p_\mu^{(i)} = 0$$

$$g^{(i)} = g \, , \quad \sum_{i=1}^{N} p_\mu^{(i)} = 0$$

- $S>2$

$$g^{(i)} = 0$$


Q

- $S=1$

$$\sum_{i=1}^{N} g^{(i)} = 0$$

CHARGE CONS.

- $S=2$

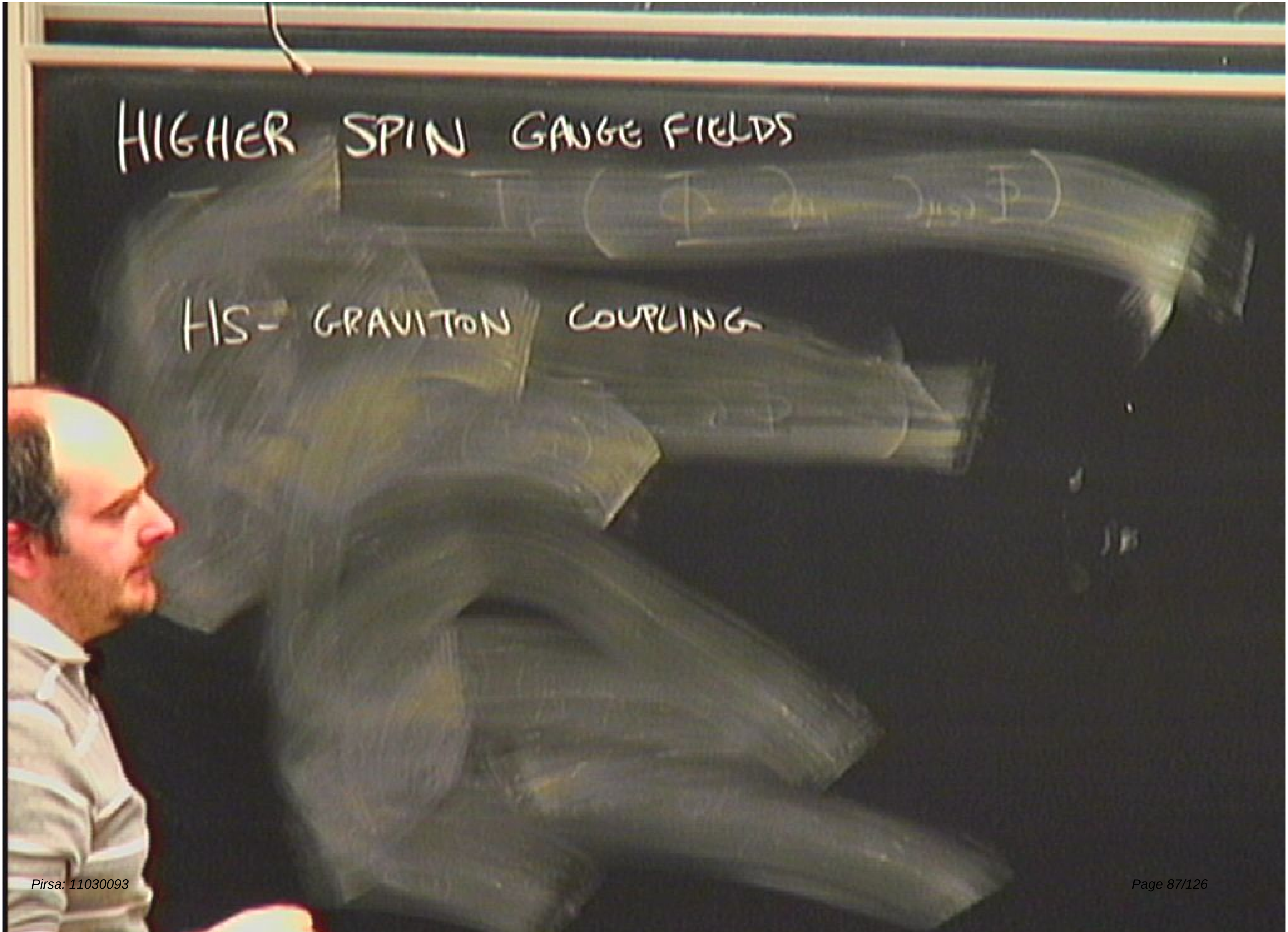
$$\sum_{i=1}^{N} g^{(i)} p_\mu^{(i)} = 0$$

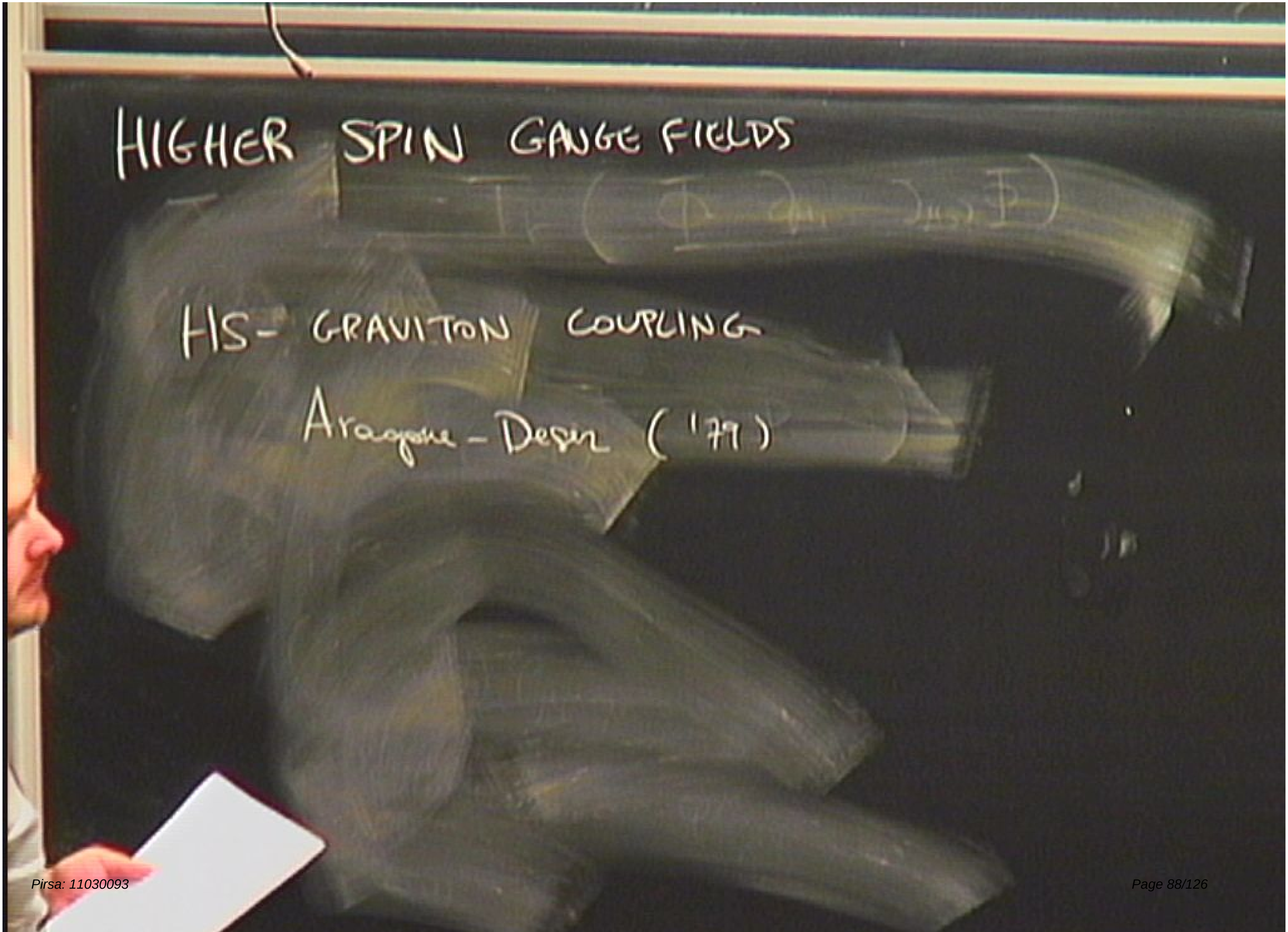
$$g^{(i)} = g \,, \quad \sum_{i=1}^{N} p_\mu^{(i)} = 0$$

$$Q^{\mu_1 \cdots \mu_{s-1}}$$

- $S>2$

$$g^{(i)} = 0$$

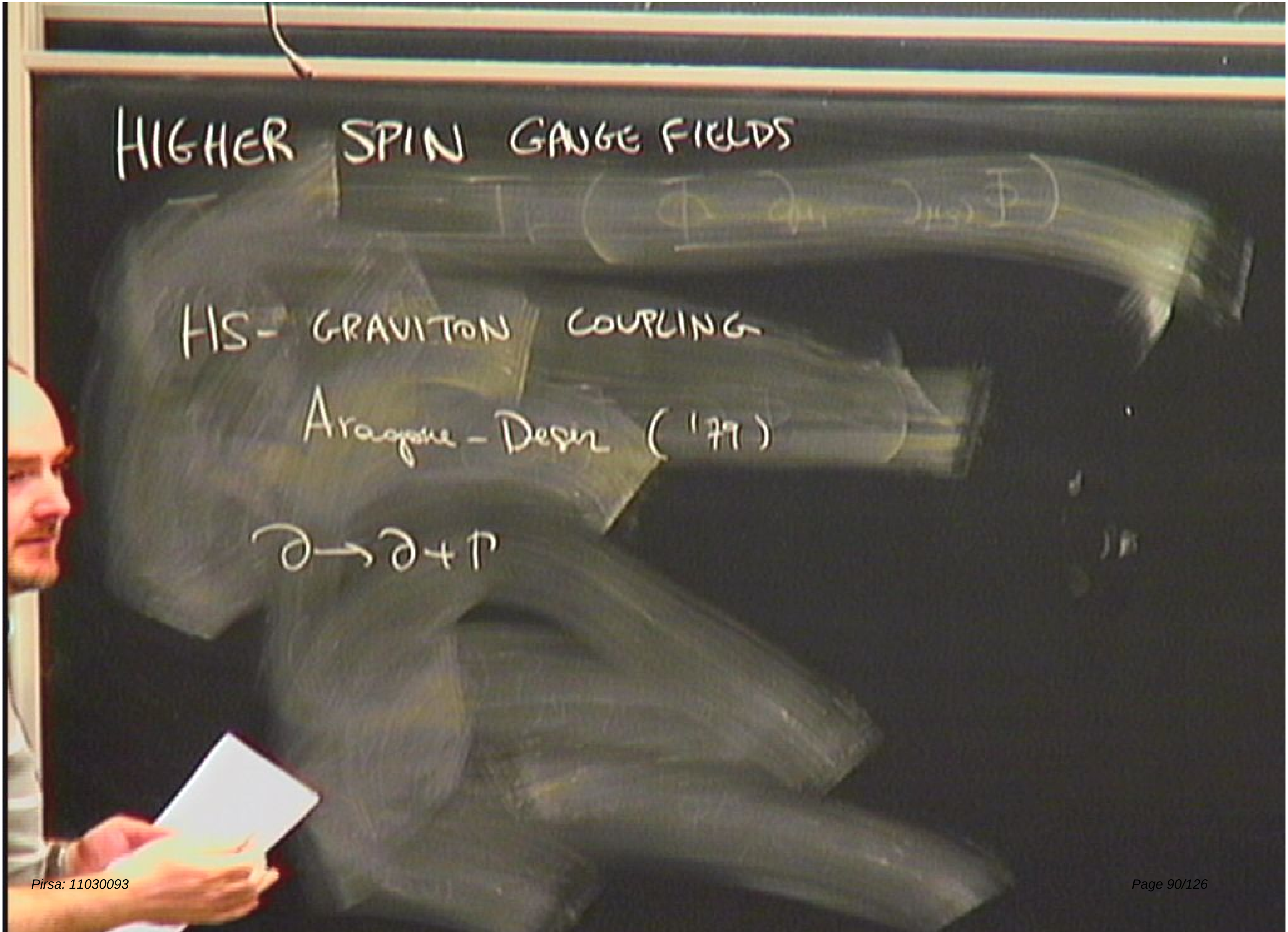

HIGHER SPIN GAUGE FIELDS
HS - GRAVITON COUPLING


HIGHER SPIN GAUGE FIELDS
HS- GRAVITON COUPLING
Aragone - Deser ('79)

HIGHER SPIN GAUGE FIELDS

HS- GRAVITON COUPLING

Aragone – Deser ('79)



HIGHER SPIN GAUGE FIELDS
HS - GRAVITON COUPLING
Aragone - Deser ('79)
$\partial \to \partial + \Gamma$

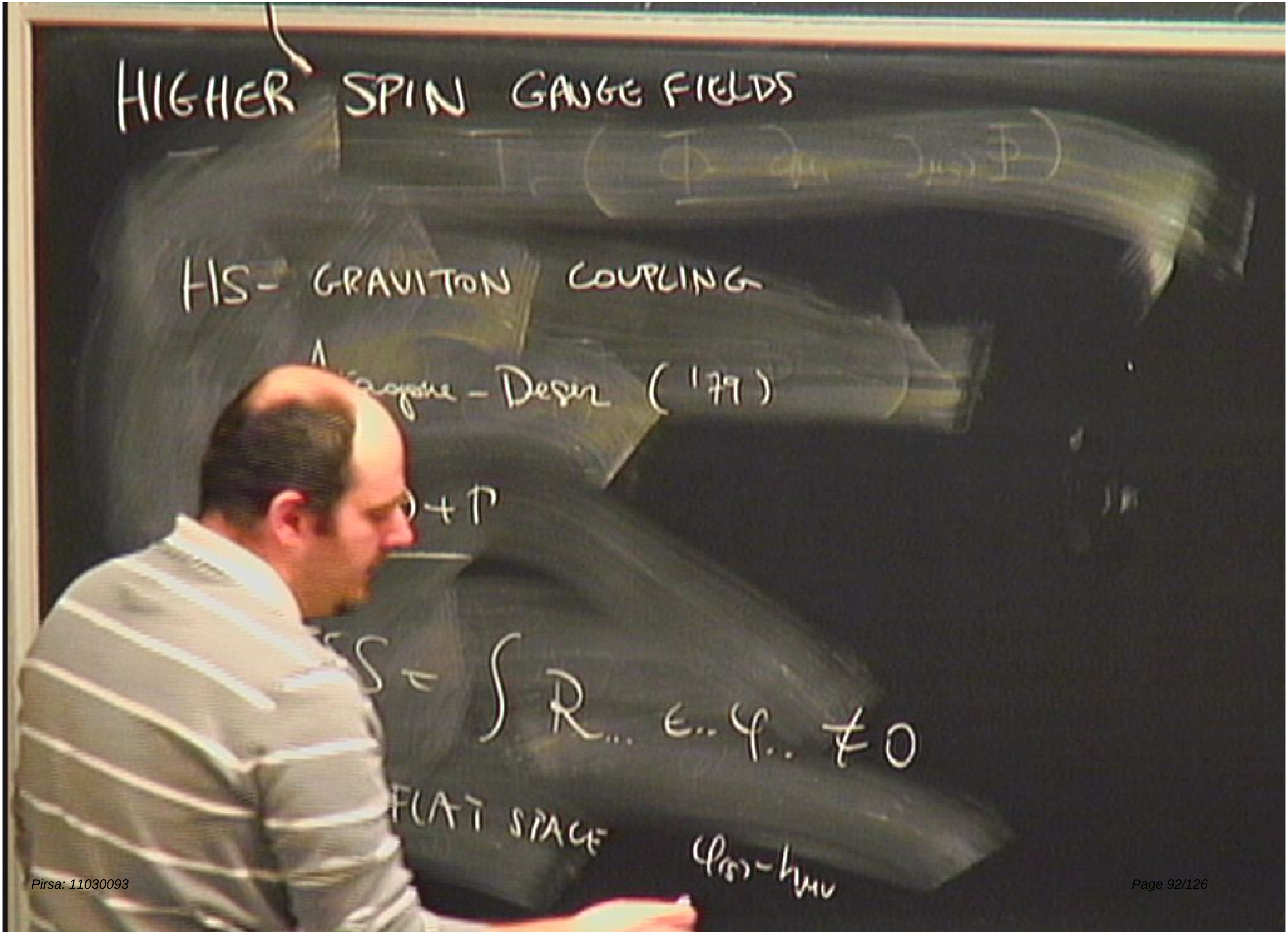
HIGHER SPIN GAUGE FIELDS

HS - GRAVITON COUPLING

Aragone - Deser ('79)

$\partial \to \partial + \Gamma$

$$\delta S = \int R_{..} \, \epsilon_{..} \, \psi_{..} \neq 0$$


HIGHER SPIN GAUGE FIELDS
HS - GRAVITON COUPLING
- Deser ('79)
S = ∫ R.. ε.. φ.. ≠ 0
FLAT SPACE

HIGHER SPIN GAUGE FIELDS

HS - GRAVITON COUPLING

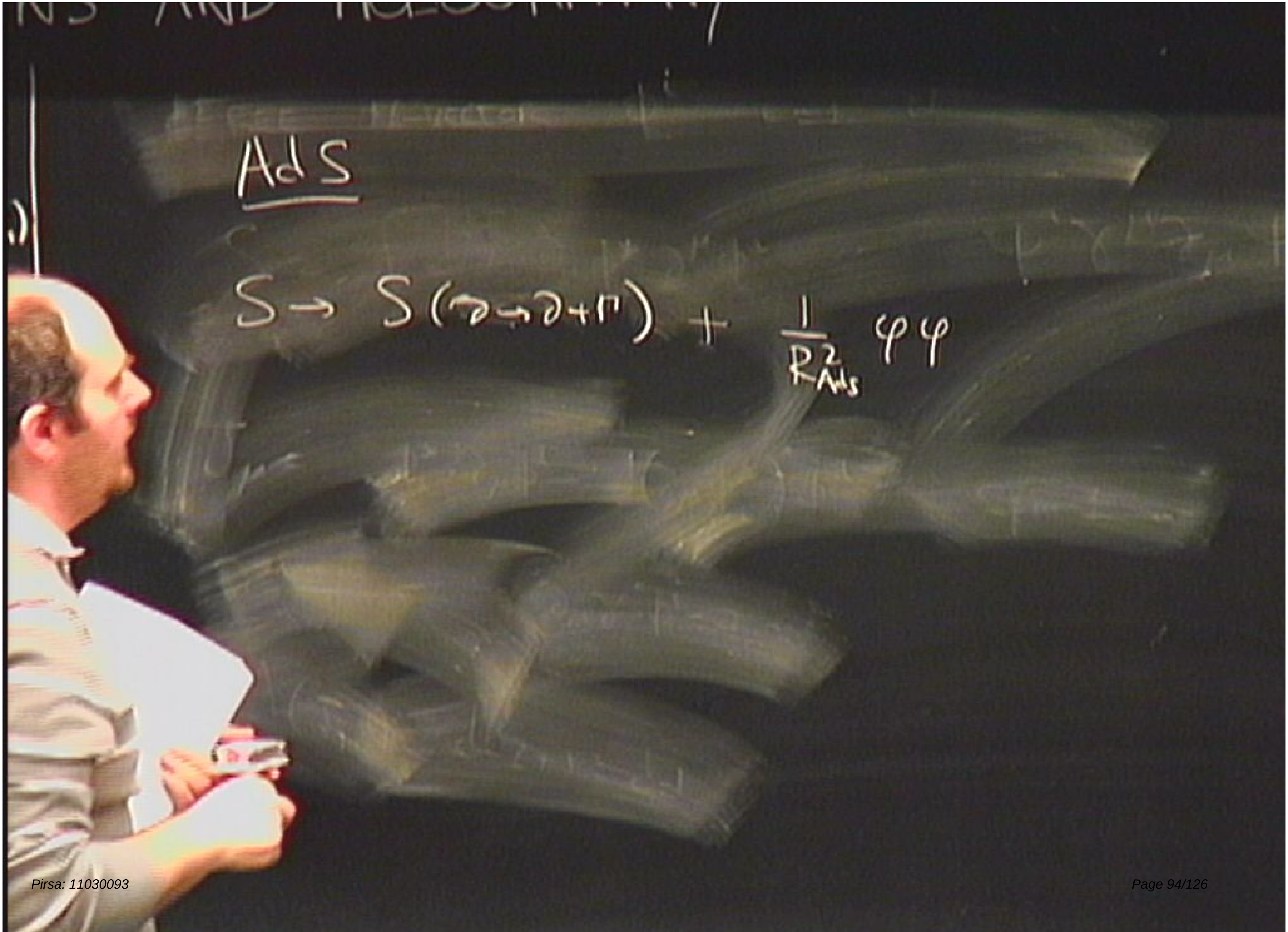
Aragone - Deser ('79)

$\partial \to \partial + \Gamma$

$$\delta S = \int R_{\ldots} \epsilon_{\ldots} \varphi_{\ldots} \neq 0$$

1) FLAT SPACE $\varphi_{\mu\nu\rho} \cancel{h_{\mu\nu}}$

2) NO HS GAUGE SYMM IN ARBITRARY BACKGROUND


AdS
S → S(∂→∂+Γ) + 1/R²_AdS φφ

AdS

$$S \to S(\partial \to \partial + \Gamma) + \frac{1}{R^2_{AdS}} \varphi\varphi$$

$$\delta\varphi_{\mu_1 \dots \mu_s} = D_{\mu_1} \epsilon_{\mu_2 \dots \mu_s}$$

AdS (dS)

$$S \to S(\partial \to \partial + \Gamma) + \frac{1}{R^2_{AdS}} \varphi\varphi$$

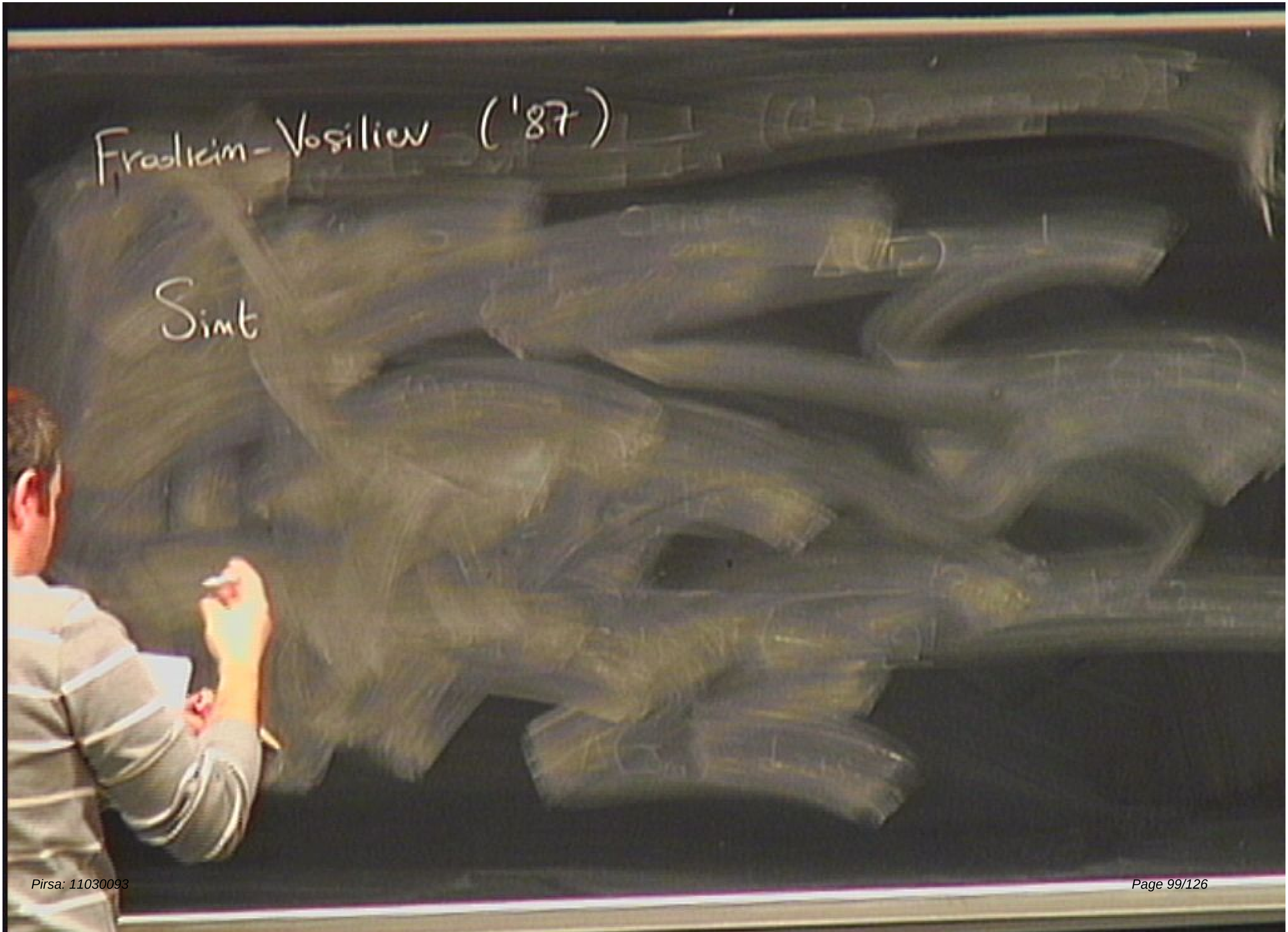
$$\delta\varphi_{\mu_1\ldots\mu_s} = D_{\mu_1}\epsilon_{\mu_2\ldots\mu_s}$$

AdS (dS)

$$S \to S(\partial \to \partial + \Gamma) + \frac{1}{R_{AdS}^2}\varphi\varphi$$

$$\delta\varphi_{\mu_1 \cdots \mu_s} = D_{\mu_1}\epsilon_{\mu_2 \cdots \mu_n}$$

Fradkin - Vasiliev ('87)


Fradkin-Vasiliev ('87)
S_int

Fradkim-Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi \, \partial^q \varphi \, \partial^r \varphi$$

AdS4)

yaxov

ndell

<u>AdS</u> (dS)

$$S \to S(\partial \to \partial + \Gamma) + \frac{1}{R^2_{AdS}} \varphi\varphi$$

$$\delta\varphi_{\mu_1 \dots \mu_s} = D_{\mu_1} \epsilon_{\mu_2 \dots \mu_s}$$

Fradkin-Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi\, \partial^q \varphi\, \partial^r \varphi$$

Fradkin-Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Fradkin-Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80-'90)

Fradkin-Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}}\, \partial^p \varphi_{(s_1)}\, \partial^q \varphi_{(s_2)}\, \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80-'90)

CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4

Fradkin - Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80 - '90)

[CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4
FULLY NON-LINEAR]

Fradkin-Vasiliev ('87)

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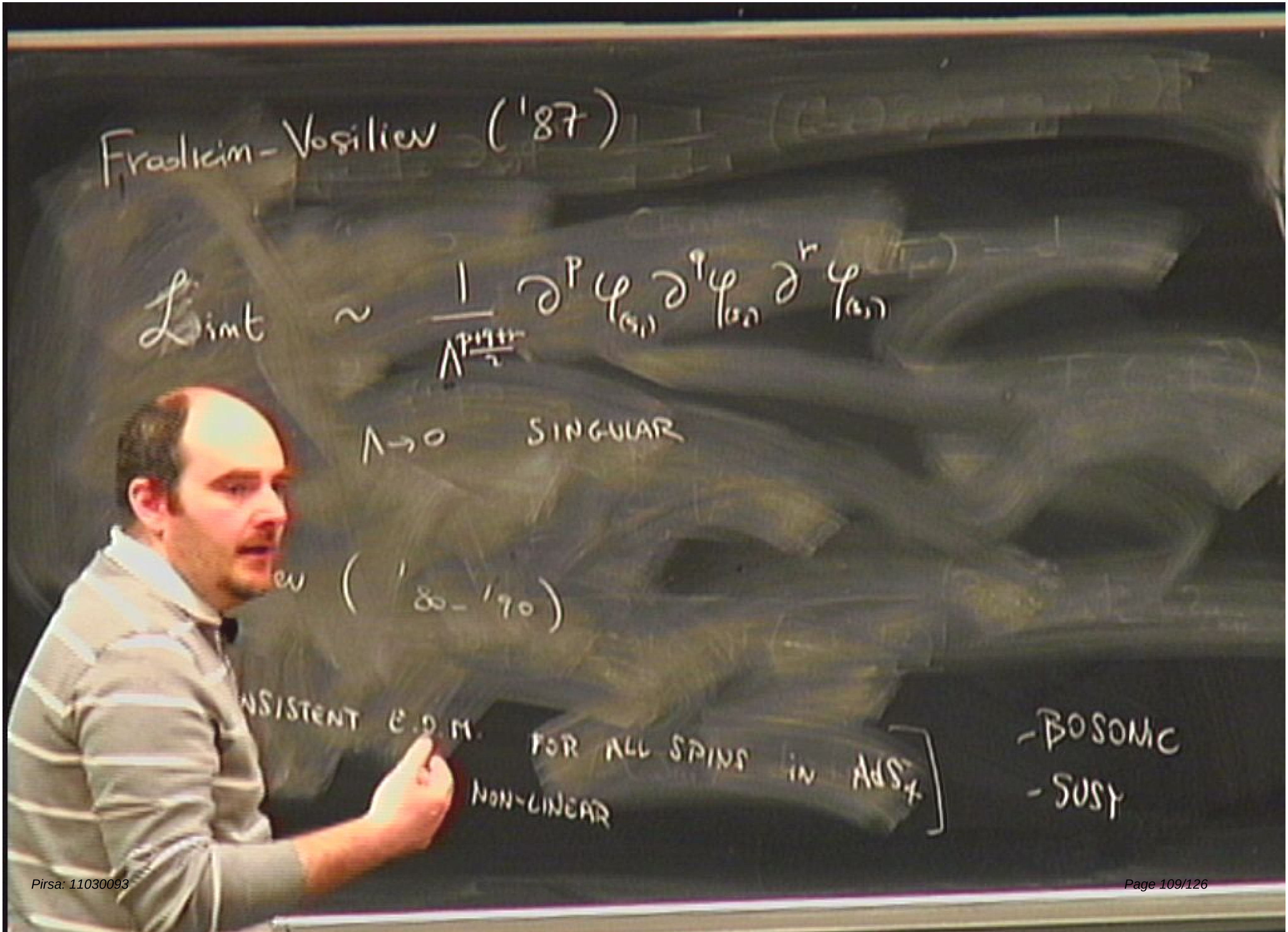
$\Lambda \to 0$ SINGULAR

Vasiliev ('80 - '90)

[CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4
FULLY NON-LINEAR]


Fradkin - Vasiliev ('87)
$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$
$\Lambda \to 0$ SINGULAR
ev ('80 - '90)
NSISTENT E.O.M. FOR ALL SPINS in AdS_4
NON-LINEAR
-BOSONIC
-SUSY

Fradkin - Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80 - '90)

[CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4
FULLY NON-LINEAR]

- BOSONIC
- SUSY

Fradkin - Vasiliev ('87)

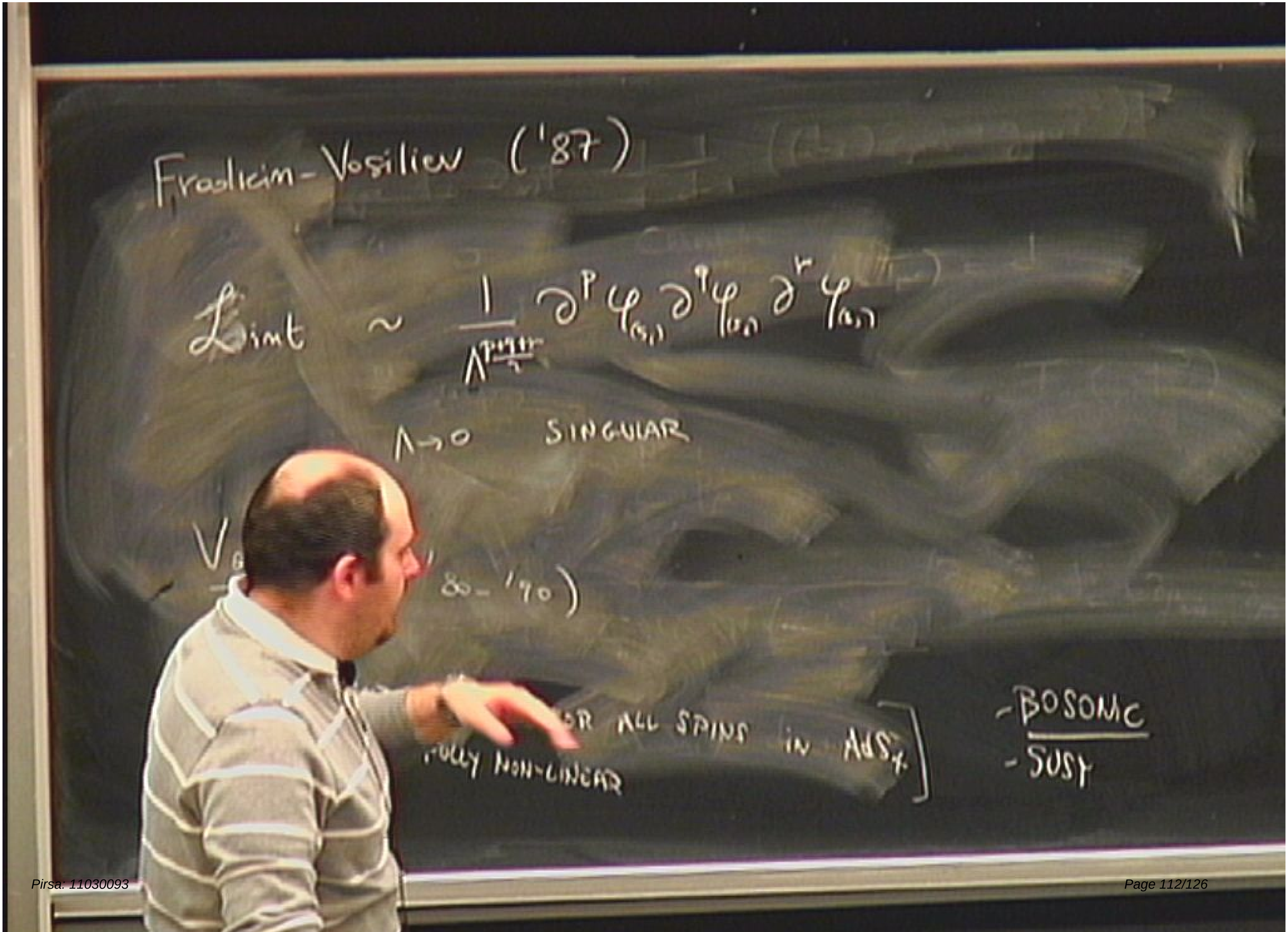
$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80 - '90)

[CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4
FULLY NON-LINEAR]

- BOSONIC
- SUSY


Fradkin-Vasiliev ('87)
Lint ~ 1/Λ ∂^p φ ∂^q φ ∂^r φ
Λ→0 SINGULAR
80-'90)
R ALL SPINS IN AdS4
ULLY NON-LINEAR
-BOSONIC
-SUSY

Fradkin - Vasiliev ('87)

$$\mathcal{L}_{int} \sim \frac{1}{\Lambda^{\frac{p+q+r}{2}}} \partial^p \varphi_{(s_1)} \partial^q \varphi_{(s_2)} \partial^r \varphi_{(s_3)}$$

$\Lambda \to 0$ SINGULAR

Vasiliev ('80 - '90)

[CONSISTENT E.O.M. FOR ALL SPINS IN AdS_4
FULLY NON-LINEAR]

- BOSONIC
- SUSY

FRAME-LIKE FORMULATION

$$g_{\mu\nu} \longrightarrow e_\mu^a \,, \ \omega_\mu^{ab}$$

$$\delta e_\mu^a = \partial_\mu \epsilon^a + \epsilon^a{}_b \, e_\mu^b$$

FRAME-LIKE FORMULATION

$$g_{\mu\nu} \longrightarrow (e_\mu^a \,,\, \omega_\mu^{ab})$$

$$\delta e_\mu^a = \partial_\mu \epsilon^a + \epsilon^a{}_b \, e_\mu^b$$

$$T^a = 0 = de^a + \omega^a{}_b \wedge e^b$$

$$g_{\mu a} = e_{(\mu a)}$$

CURVATURE

$$R_L^{ab} = d\omega^{ab} + \omega^a{}_c \wedge \omega^{cb}$$

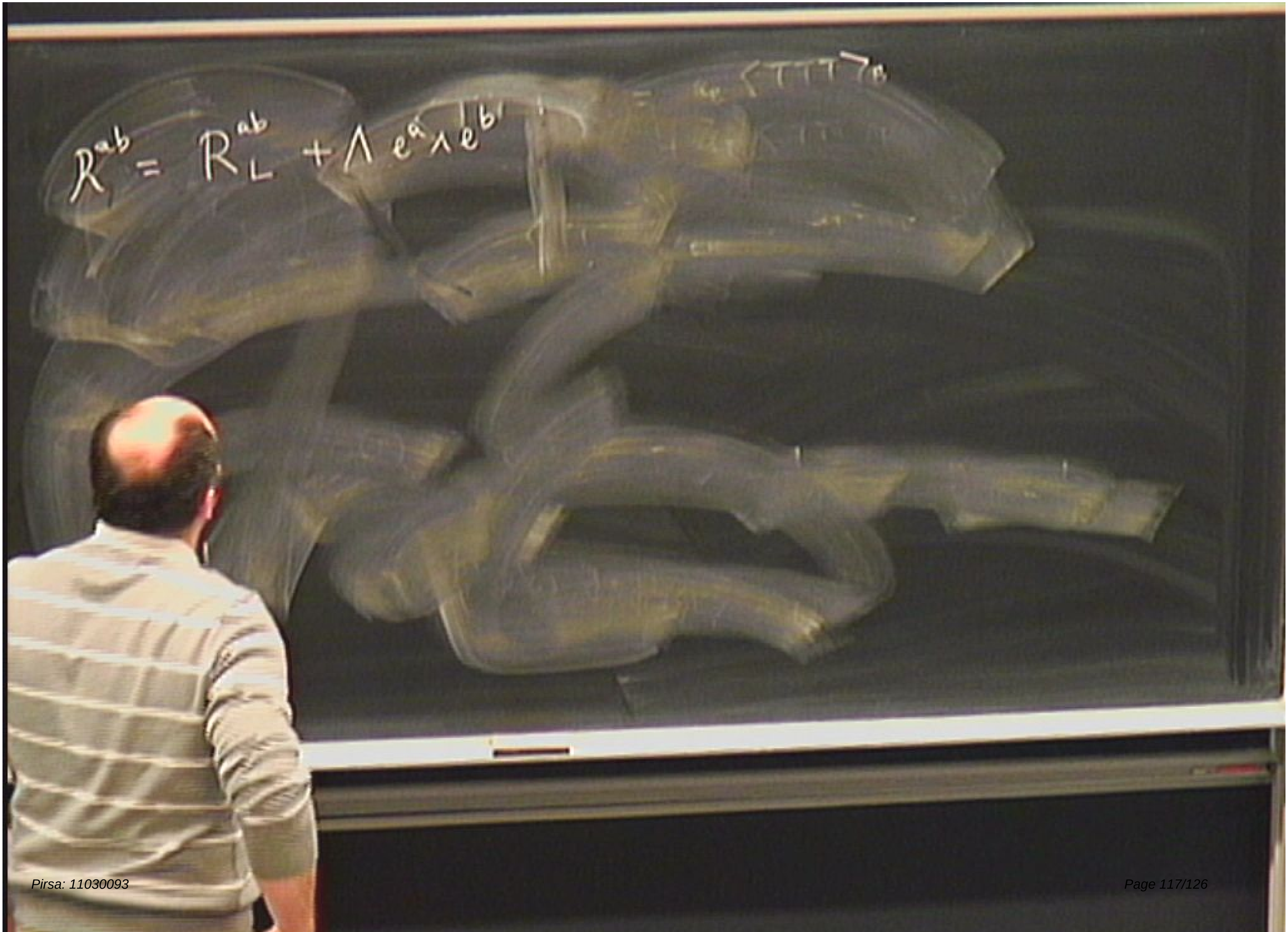
$\mathcal{N}=4$ SYM $\Longleftrightarrow$ TYPE IIB

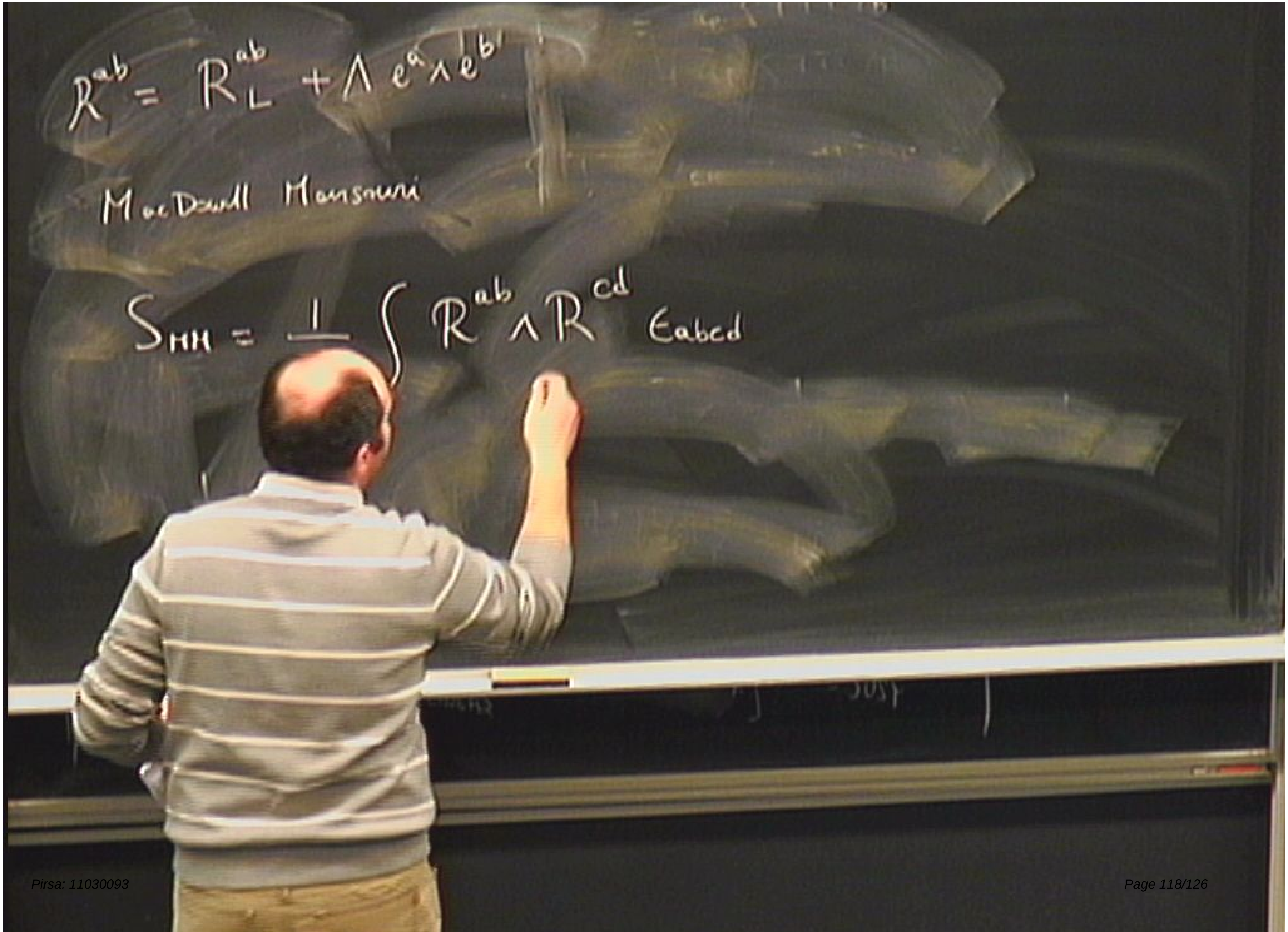
$$S_{EH} = \frac{1}{2k^2}\int e^a \wedge e^b \wedge R_{(\omega)}^{cd}\, \epsilon_{abcd}$$

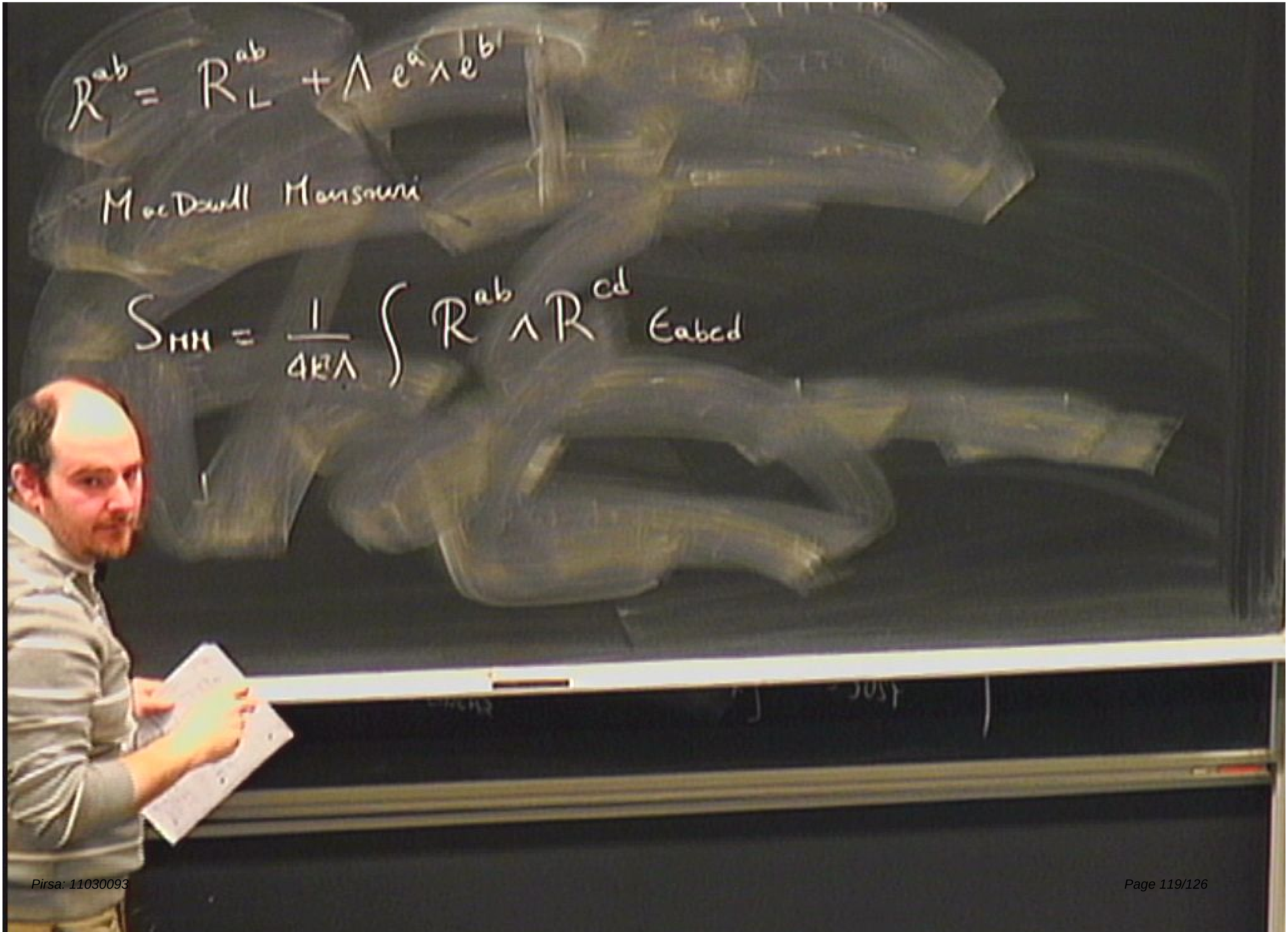
SO(3,2) CONNECTION

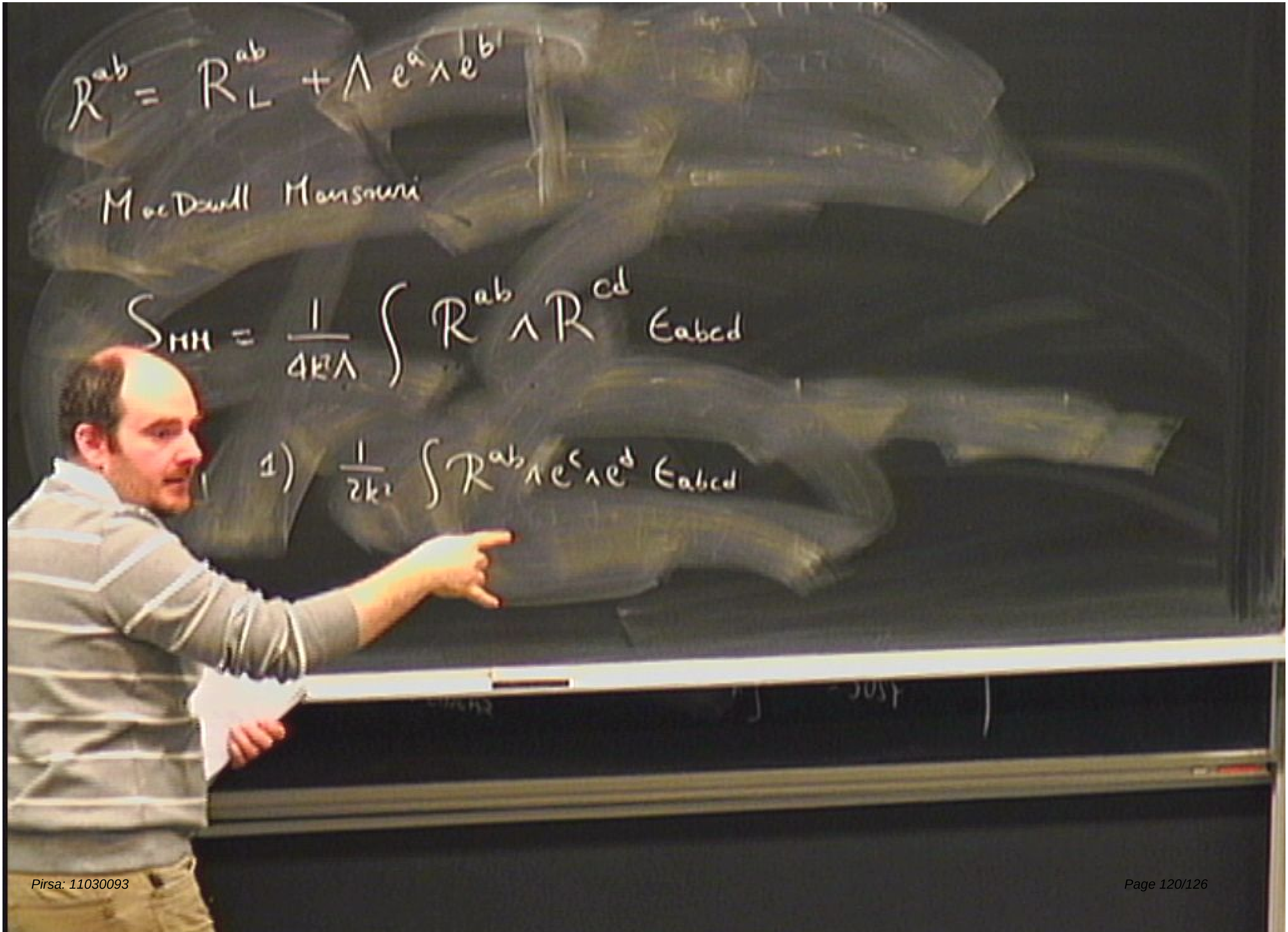
$$W = e^a P_a + \frac{1}{2}\omega^{ab} M_{ab}$$

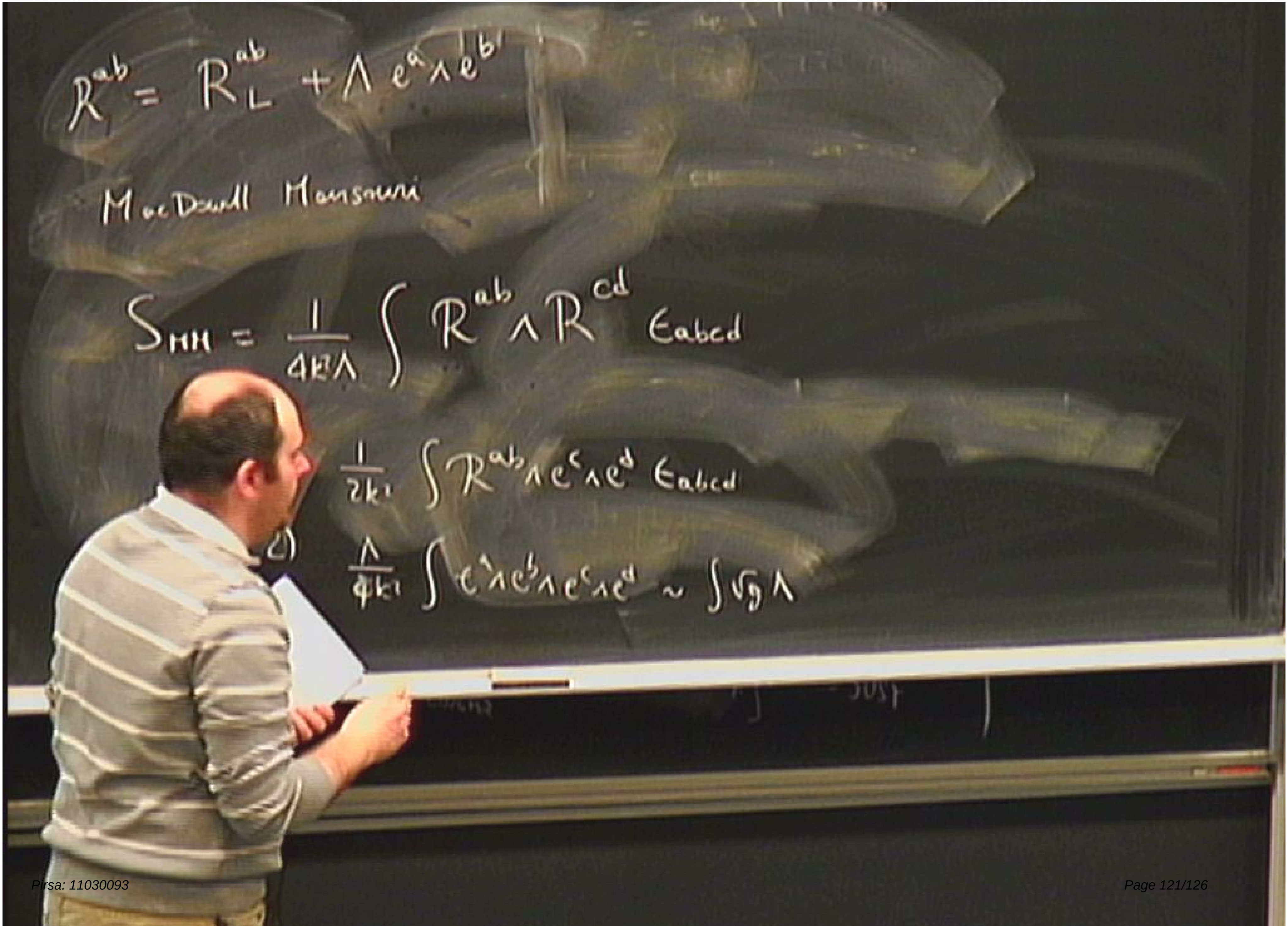
$$dW + W \wedge W = T^a P_a + \frac{1}{2} R^{ab} M_{ab}$$

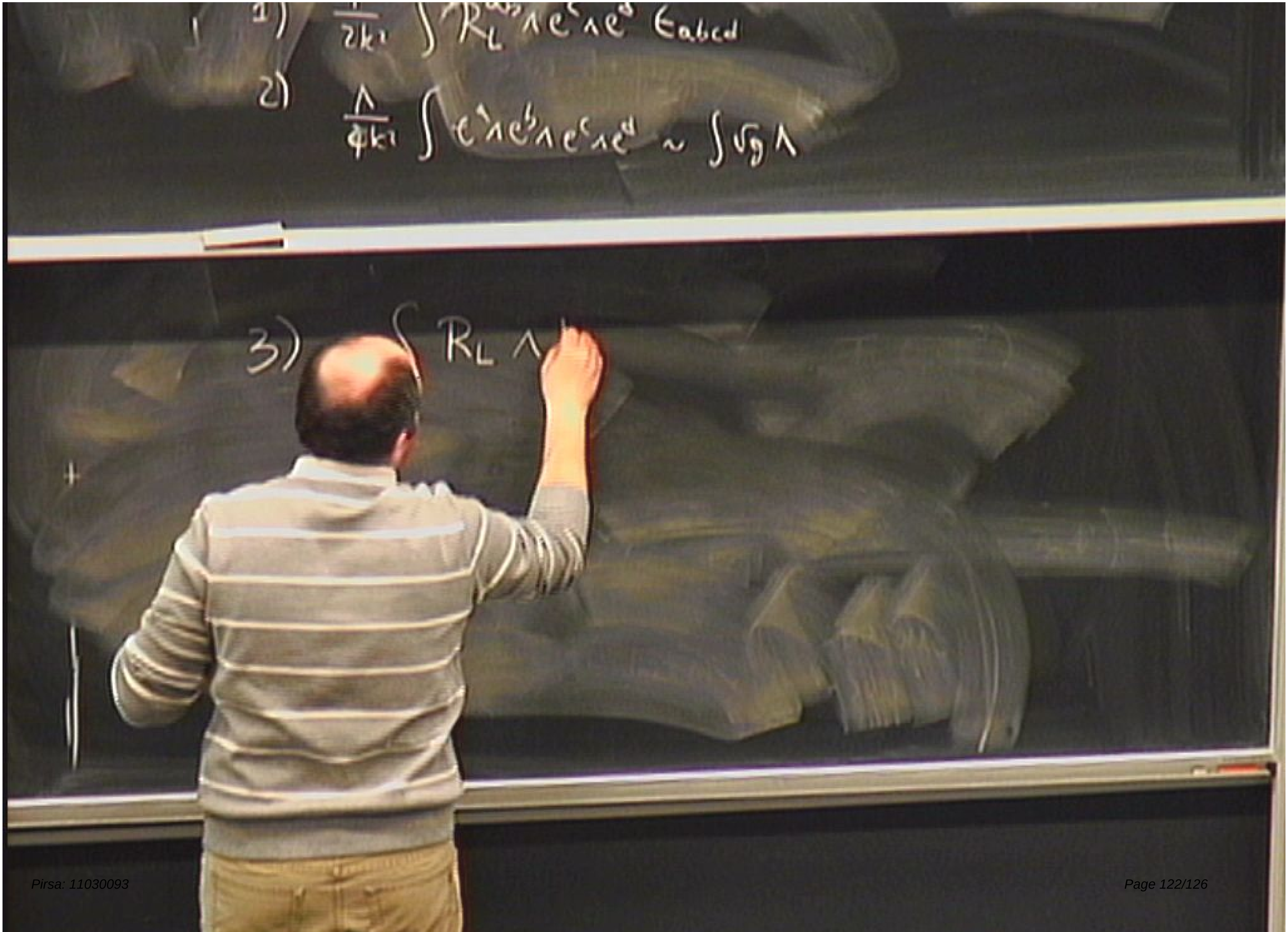

$R^{ab} = R_L^{ab} + \Lambda e^a \wedge e^b$

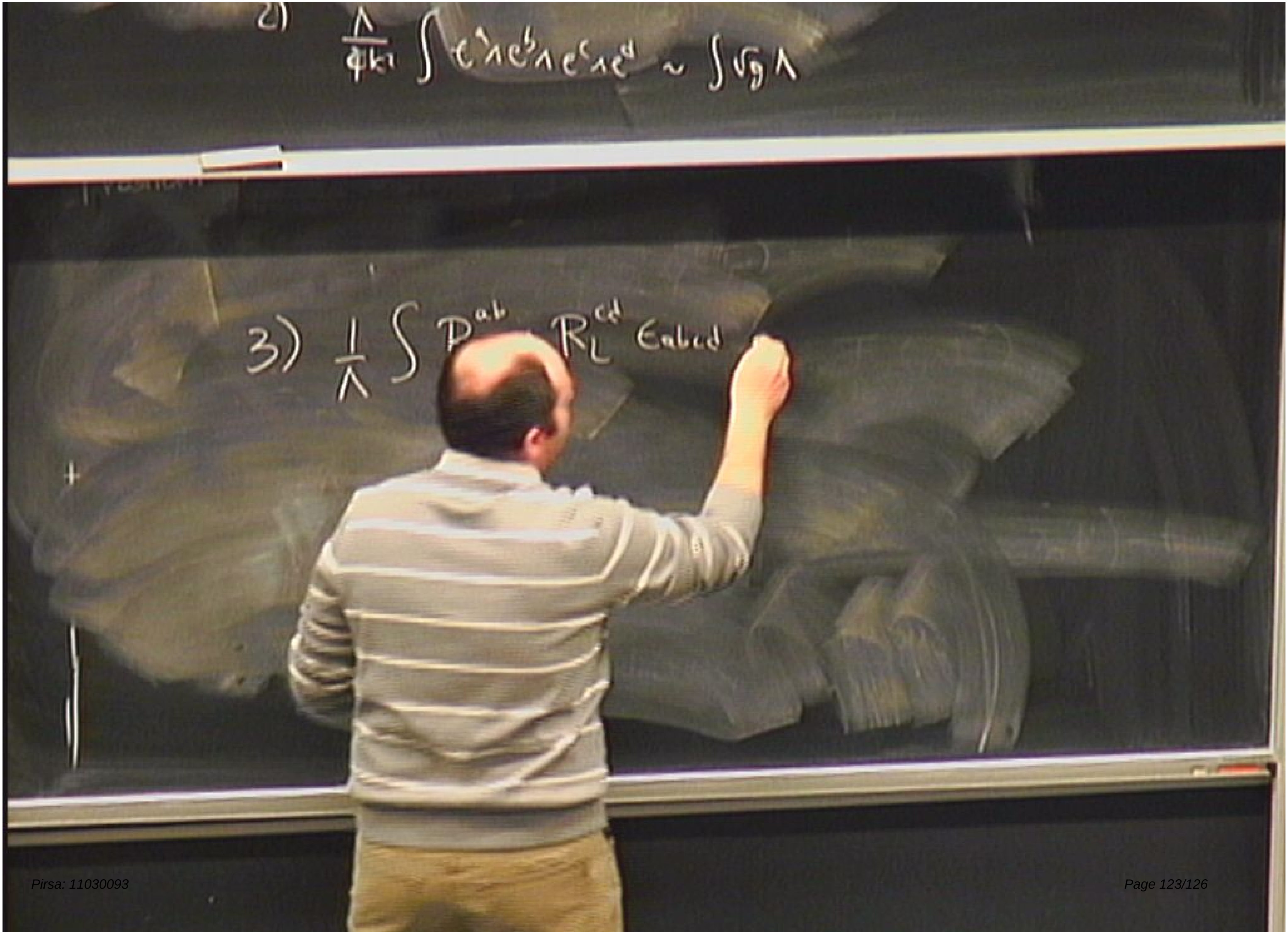

$R^{ab} = R_L^{ab} + \Lambda e^a \wedge e^b$
MacDowell Mansouri
$S_{MM} = \frac{1}{\ } \int R^{ab} \wedge R^{cd} \epsilon_{abcd}$

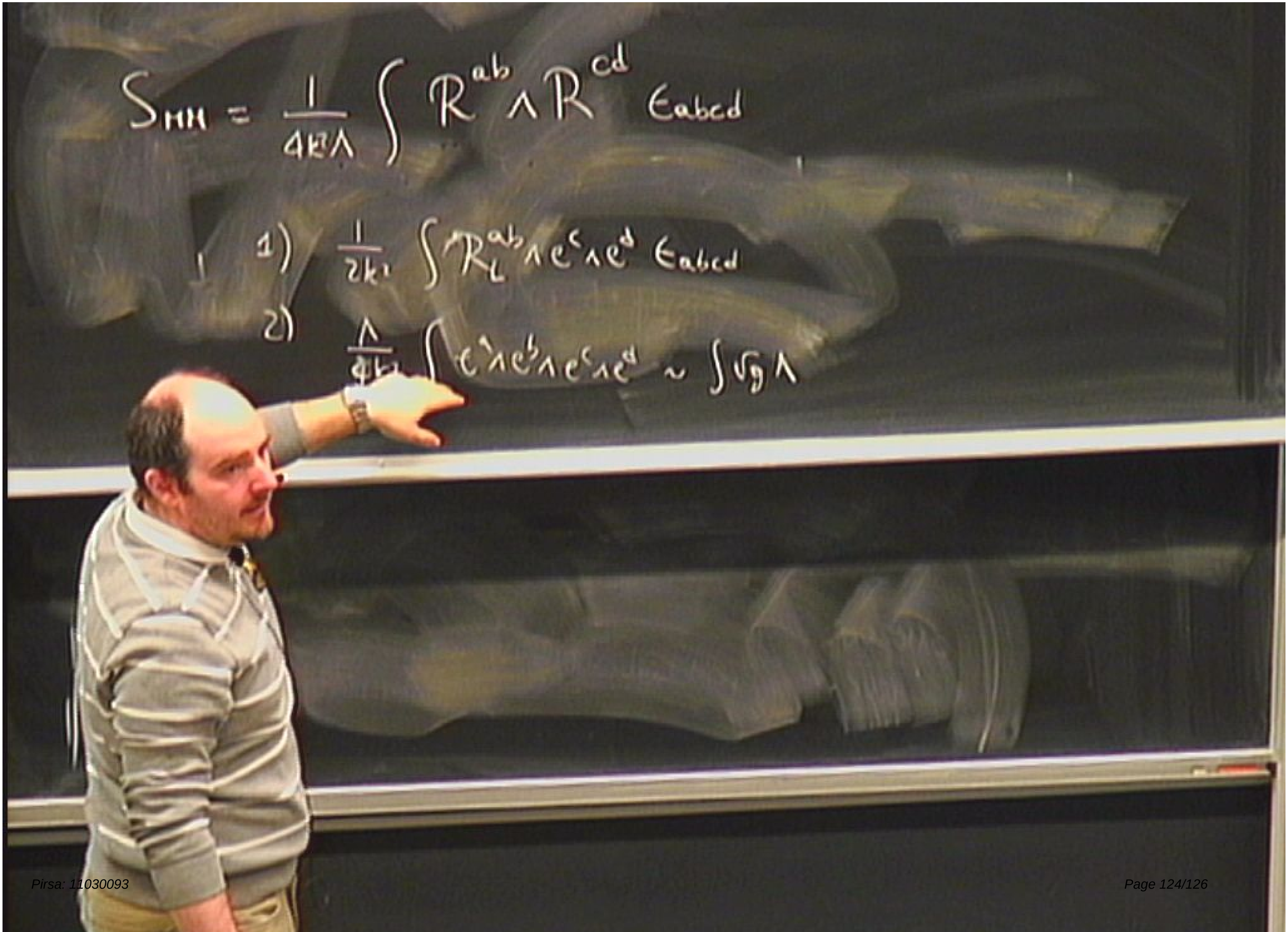

$R^{ab} = R_L^{ab} + \Lambda e^a \wedge e^b$
MacDowell Mansouri
$S_{MM} = \frac{1}{4k\Lambda} \int R^{ab} \wedge R^{cd} \epsilon_{abcd}$

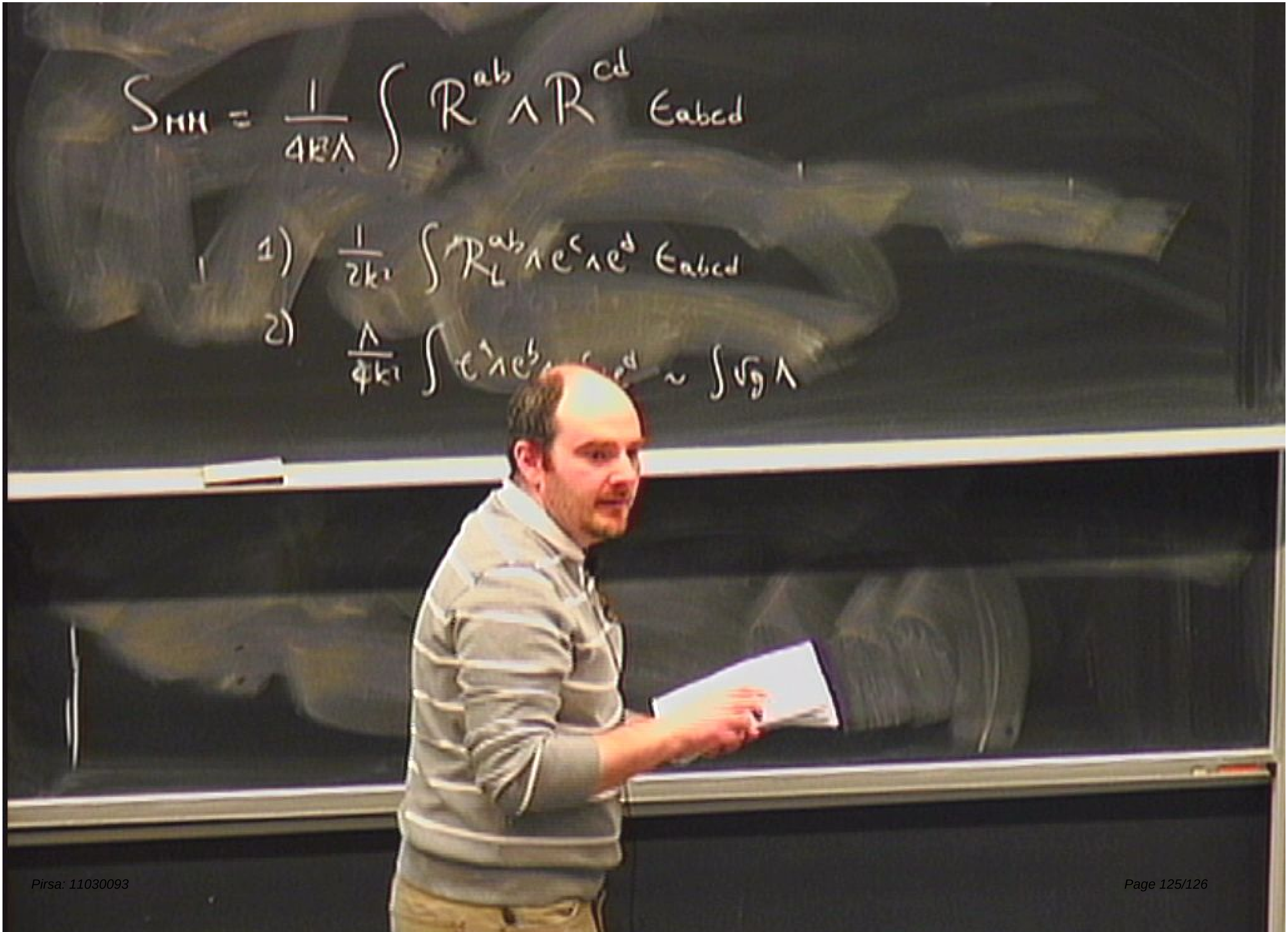

$R^{ab} = R_L^{ab} + \Lambda e^a \wedge e^b$
MacDowell Mansouri
$S_{MM} = \frac{1}{4k^2\Lambda} \int R^{ab} \wedge R^{cd} \epsilon_{abcd}$
1) $\frac{1}{2k^2} \int R^{ab} \wedge e^c \wedge e^d \epsilon_{abcd}$


$R^{ab} = R_L^{ab} + \Lambda e^a \wedge e^b$
MacDowell Mansouri
$S_{MM} = \frac{1}{4k^2\Lambda} \int R^{ab} \wedge R^{cd} \epsilon_{abcd}$
$\frac{1}{2k^2} \int R^{ab} \wedge e^c \wedge e^d \epsilon_{abcd}$
(2) $\frac{\Lambda}{4k^2} \int e^a \wedge e^b \wedge e^c \wedge e^d \sim \int \sqrt{g} \Lambda$


1) $\frac{1}{2k^2}\int R_L^{ab}\wedge e^c\wedge e^d\,\epsilon_{abcd}$
2) $\frac{\Lambda}{4k^2}\int e^a\wedge e^b\wedge e^c\wedge e^d \sim \int\sqrt{g}\,\Lambda$
3) $\int R_L \wedge$


2) $\frac{\Lambda}{4\pi G} \int e^a \wedge e^b \wedge e^c \wedge e^d \sim \int \sqrt{g}\,\Lambda$
3) $\frac{1}{\Lambda} \int R^{ab} \wedge R_L^{cd}\, \epsilon_{abcd}$


$S_{MM} = \frac{1}{4k^2\Lambda} \int R^{ab} \wedge R^{cd} \epsilon_{abcd}$
1) $\frac{1}{2k^2} \int R_L^{ab} \wedge e^c \wedge e^d \epsilon_{abcd}$
2) $\frac{\Lambda}{4k^2} \int e^a \wedge e^b \wedge e^c \wedge e^d \sim \int \sqrt{g}\Lambda$


$S_{MM} = \frac{1}{4k^2\Lambda}\int R^{ab}\wedge R^{cd}\,\epsilon_{abcd}$
1) $\frac{1}{2k^2}\int R_L^{ab}\wedge e^c\wedge e^d\,\epsilon_{abcd}$
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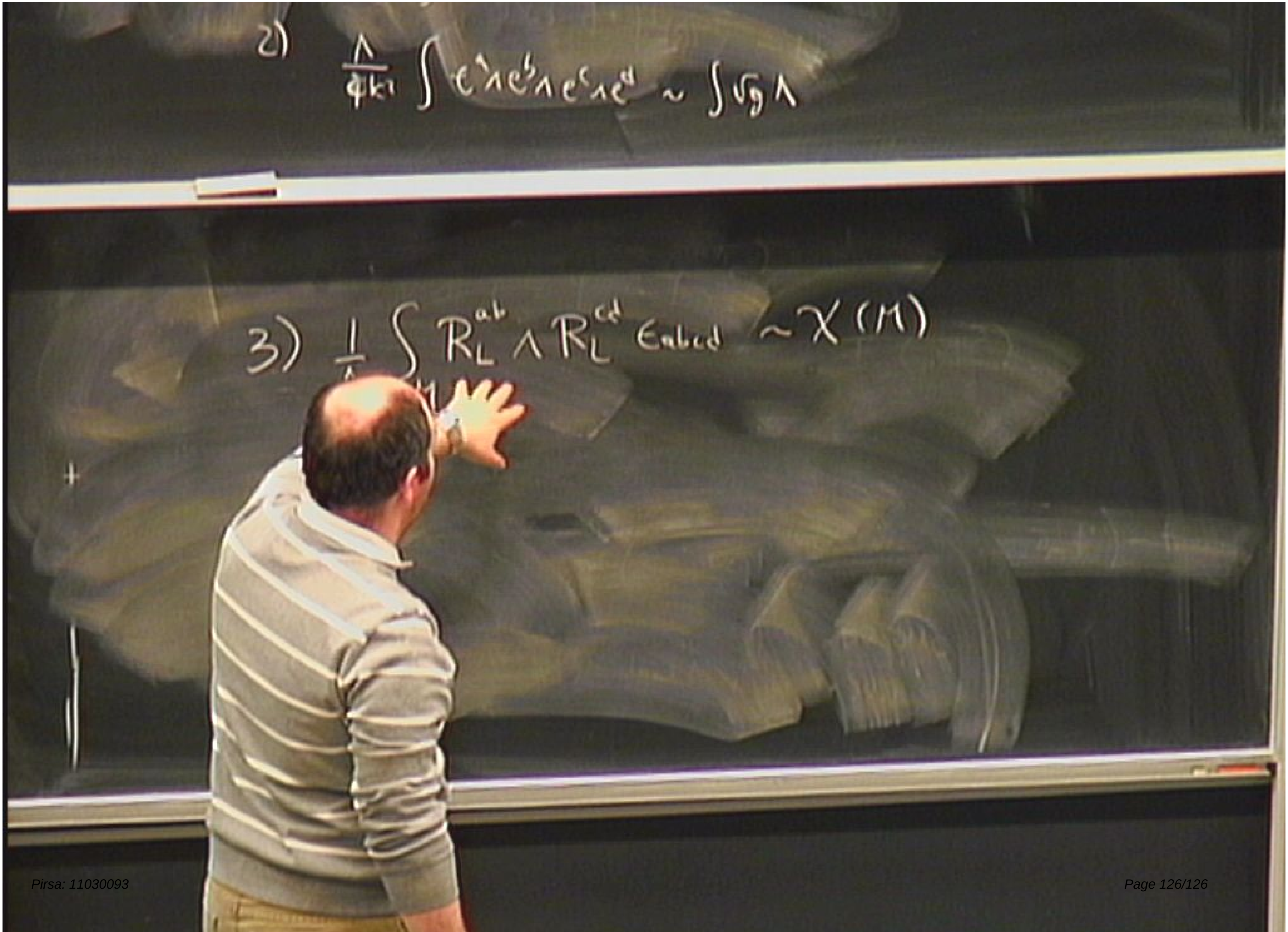
2)
$\int e^a \wedge e^b \wedge e^c \wedge e^d \sim \int \sqrt{g}\,\Lambda$
3)
$R_L^{ab} \wedge R_L^{cd}\, \epsilon_{abcd} \sim \chi(M)$