Title: Towards a Theory of the QCD String

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URL: http://pirsa.org/15120021

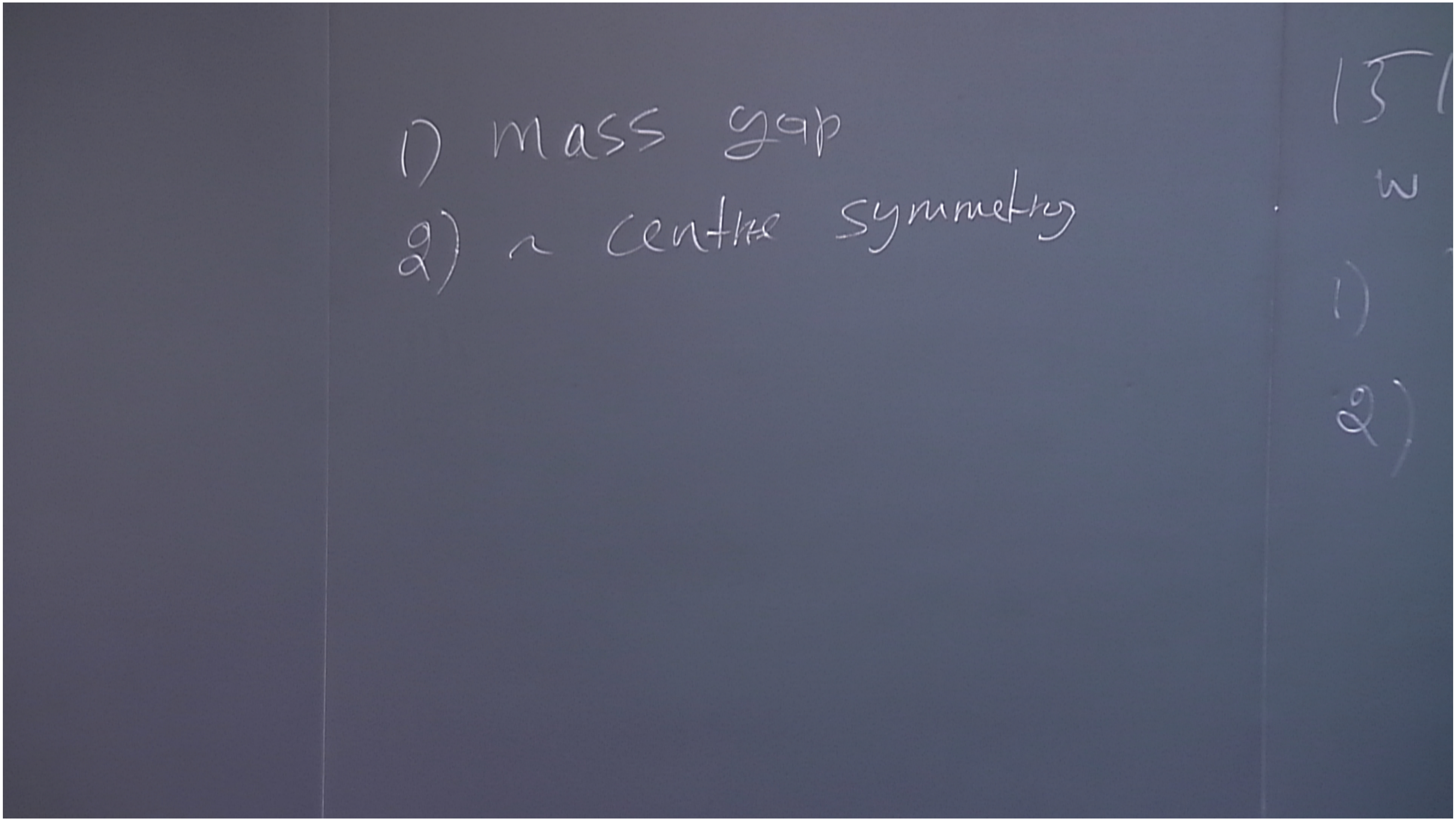
Abstract: <p>We construct a new model of four-dimensional relativistic strings with integrable dynamics on the worldsheet. In addition to translational modes this model contains a single massless pseudoscalar worldsheet field - the worldsheet axion. The axion couples to a topological density which counts the self-intersection number of a string. The corresponding coupling is fixed by integrability to Q=716Ï€â^'â^'â^'â^šâ‰ˆ0.37. We argue that this model is a member of a larger family of relativistic non-critical integrable string models. This family includes and extends conventional non-critical strings described by the linear dilaton CFT. Intriguingly, recent lattice data in SU(3) and SU(5) gluodynamics reveals the presence of a massive pseudoscalar axion on the worldsheet of confining flux tubes. The value of the corresponding coupling, as determined from the lattice data, is equal to QLâ‰ˆ0.38Â±0.04.</p>

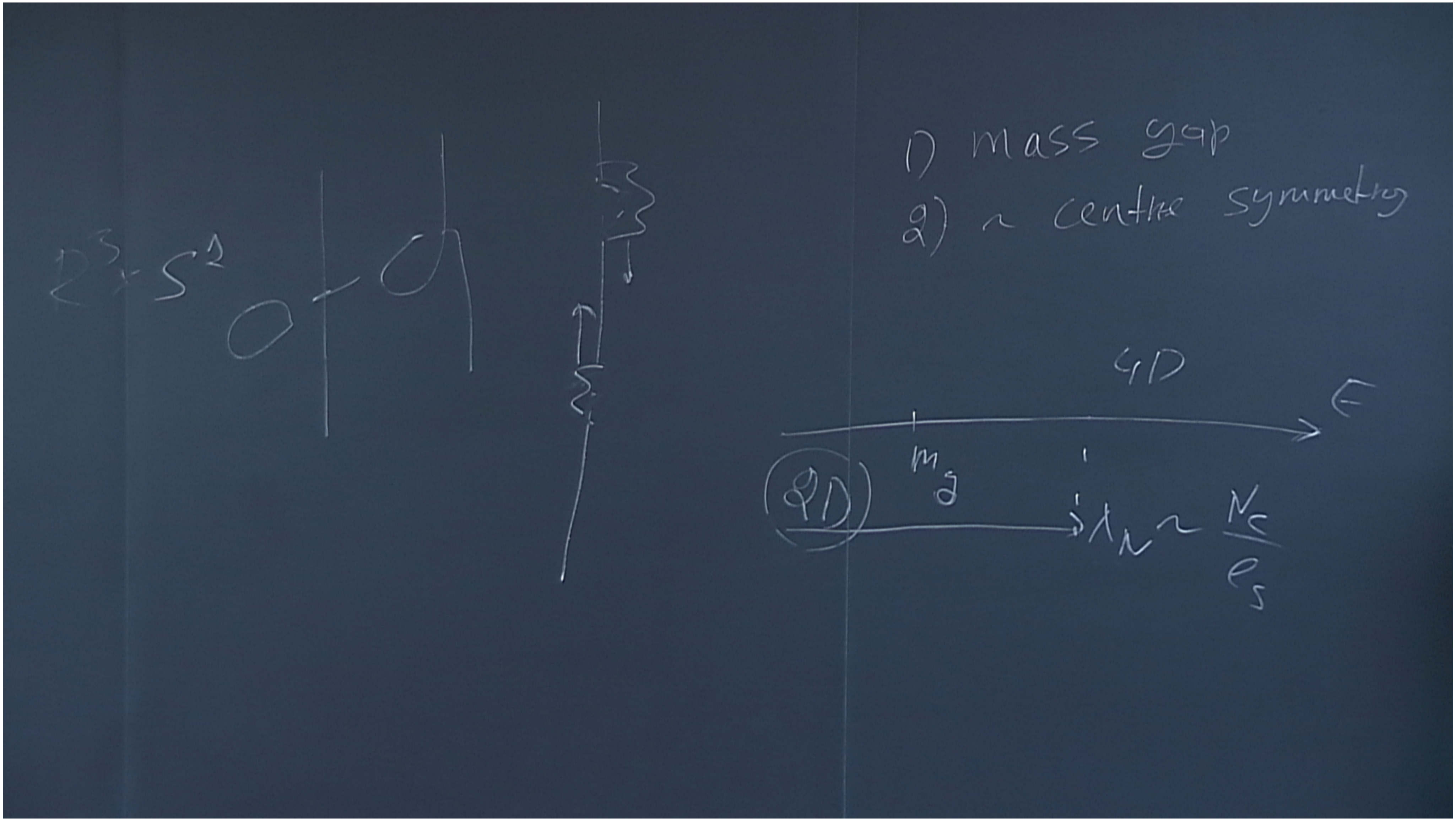
1511.01908

w Gorbenko

1) What is $SU(\infty)$ YM?

2) Are there other integrable th's in $D>2$?


1) mass gap
2) ~ centre symmetry


1) mass gap
2) ~ centre symmetry
$R^3 \times S^1$
4D
E
m_g
3D
$\Lambda_N \sim \frac{N_c}{e_s}$

No-go: integrability in $D=4$
requires extra massless states
on the worldsheet

$N_c = 3, 5$

$\Rightarrow 4$

$$S = -\int d^2\sigma \frac{1}{\ell_s^2}\sqrt{\det(\underbrace{\eta_{\alpha\beta} + \partial_\alpha X^i \partial_\beta X^i}_{h_{\alpha\beta}})}$$

$$+ \int d^2\sigma \sqrt{h}\left(R + K^{\alpha i}_{\alpha\beta} + (K_\alpha^{\alpha i})^2\right)$$

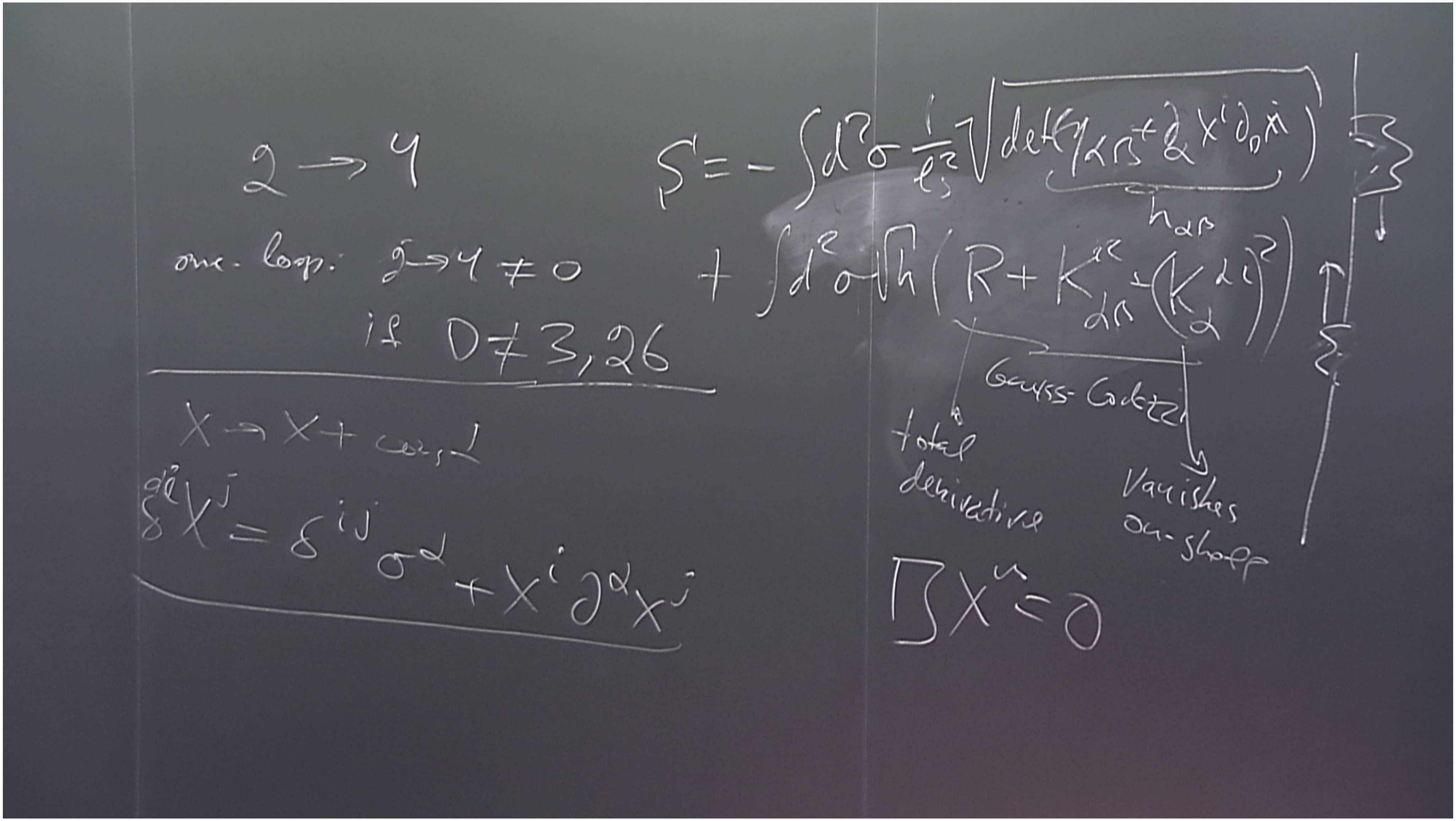
Gauss-Codazzi

total derivative

Vanishes on-shell

Σ_i

(QD)


2 → 4
one-loop: 2 → 4 ≠ 0
if D ≠ 3, 26
X → X + const
h_αβ
Gauss-Codazzi
total derivative
Vanishes on-shell

$$B^{\alpha i}_{\beta} = S^{i}_{\beta}\,\sigma^{\alpha} + K^{i\alpha}_{\beta}$$

B ↓ boost S ↓ shift

$$S^{i\alpha} = \partial^{\beta} K^{i\alpha}_{\beta}$$

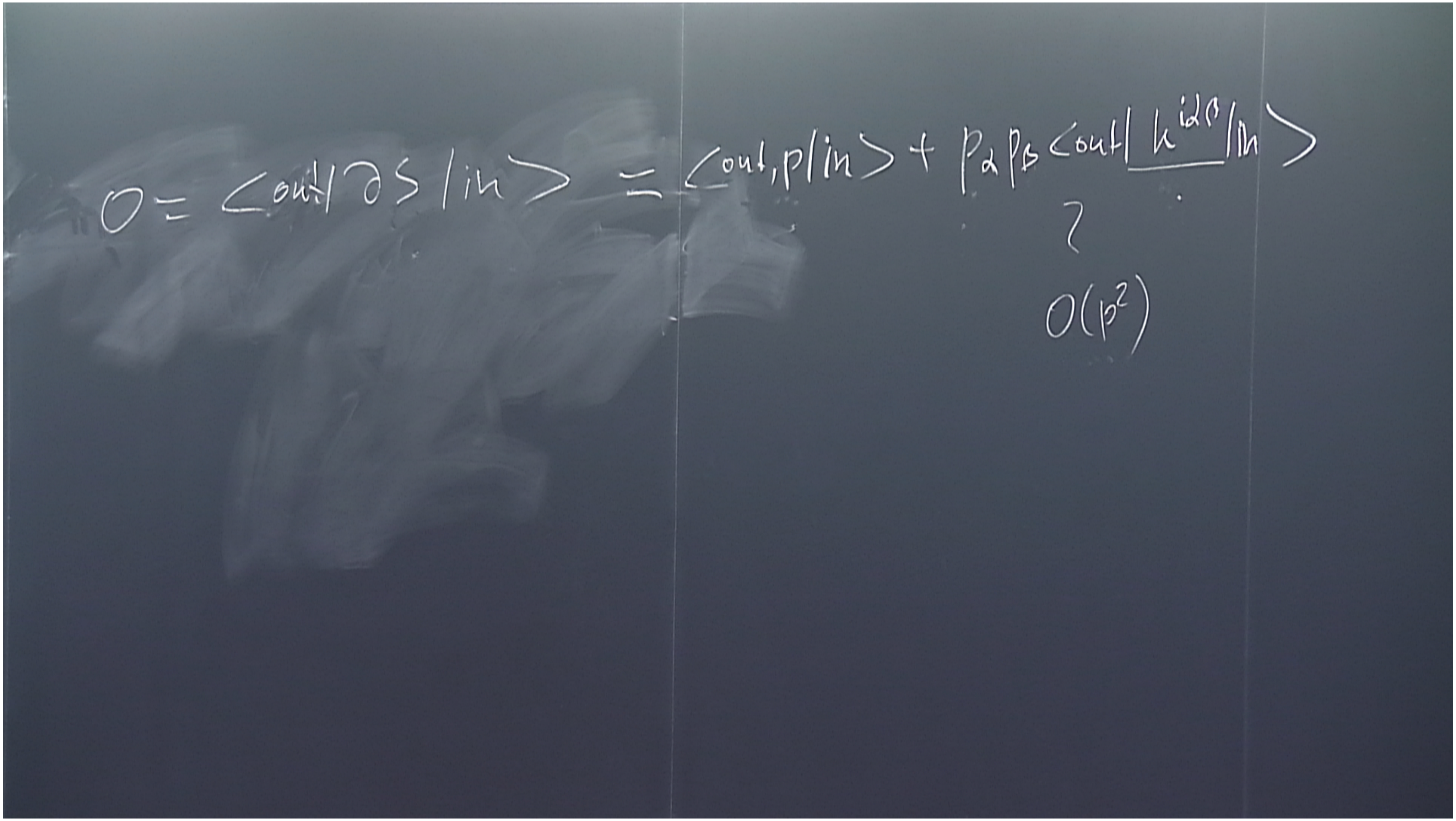
$$\sim \partial_{\alpha} X^{i} + \partial^{\beta} K^{i\alpha}_{\beta}$$

$$\sim \ell_s^2 X^{i} T^{\alpha}_{\beta\gamma} \ldots$$

on

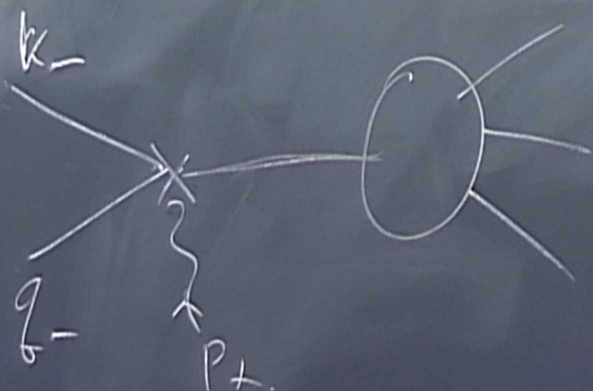
X

$\delta^{\alpha i} X$

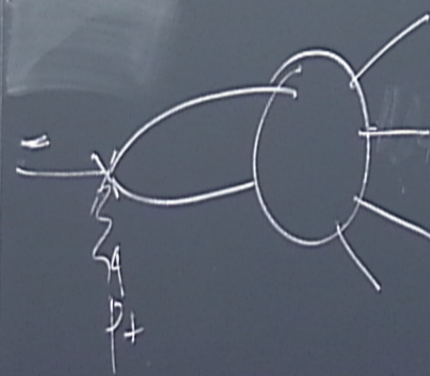

$0 = \langle out | \partial S | in \rangle = \langle out, p | in \rangle + p_\alpha p_\beta \langle out | \underline{h^{\alpha\beta}} | in \rangle$
$\sim$
$O(p^2)$

$$0 = \langle out | \partial S | in \rangle = \langle out, p | in \rangle + p_\alpha p_\beta \underbrace{\langle out | h^{\alpha\beta} | in \rangle}_{?}$$

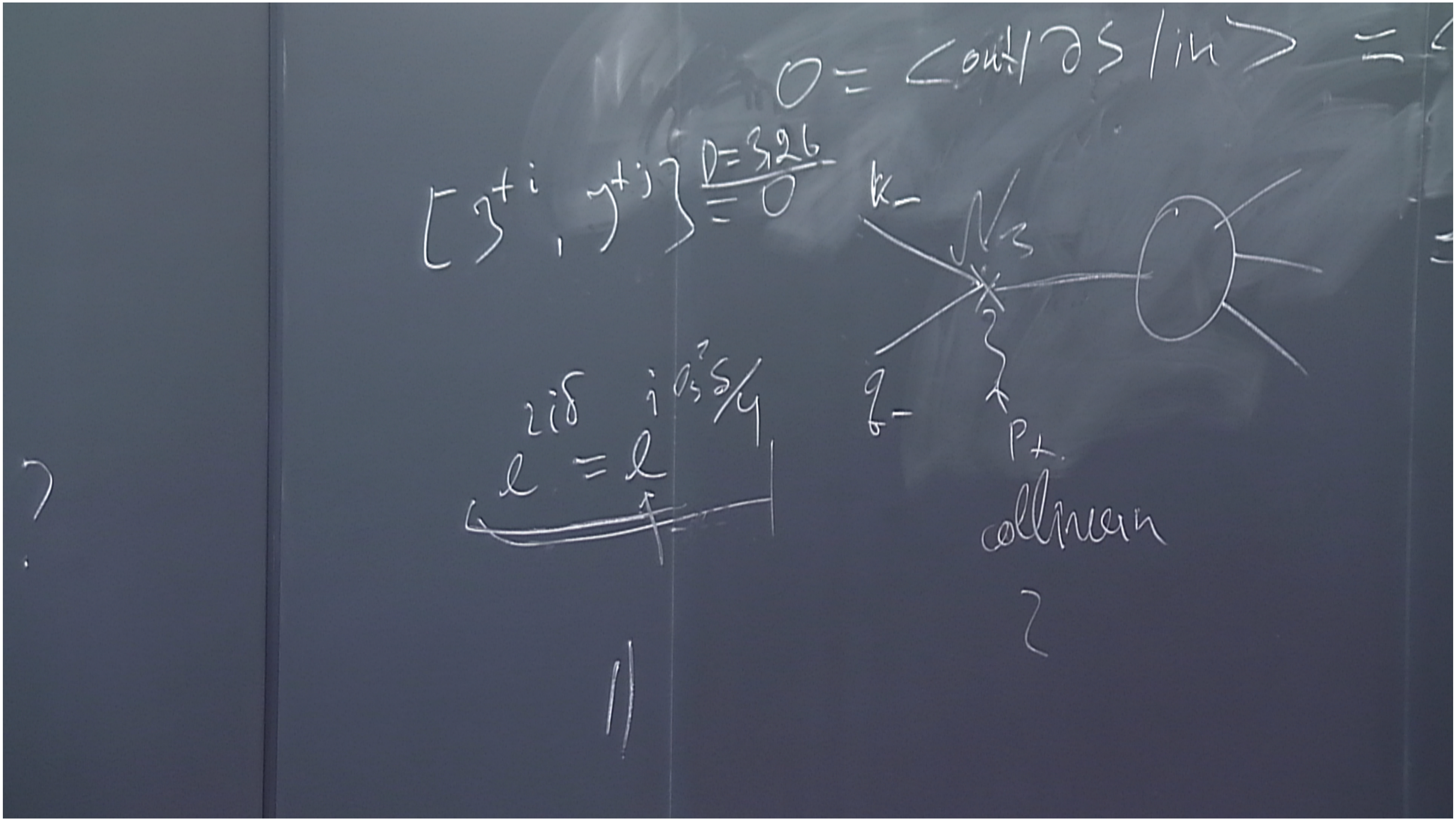
$O(p^2)$ $\quad p_+$

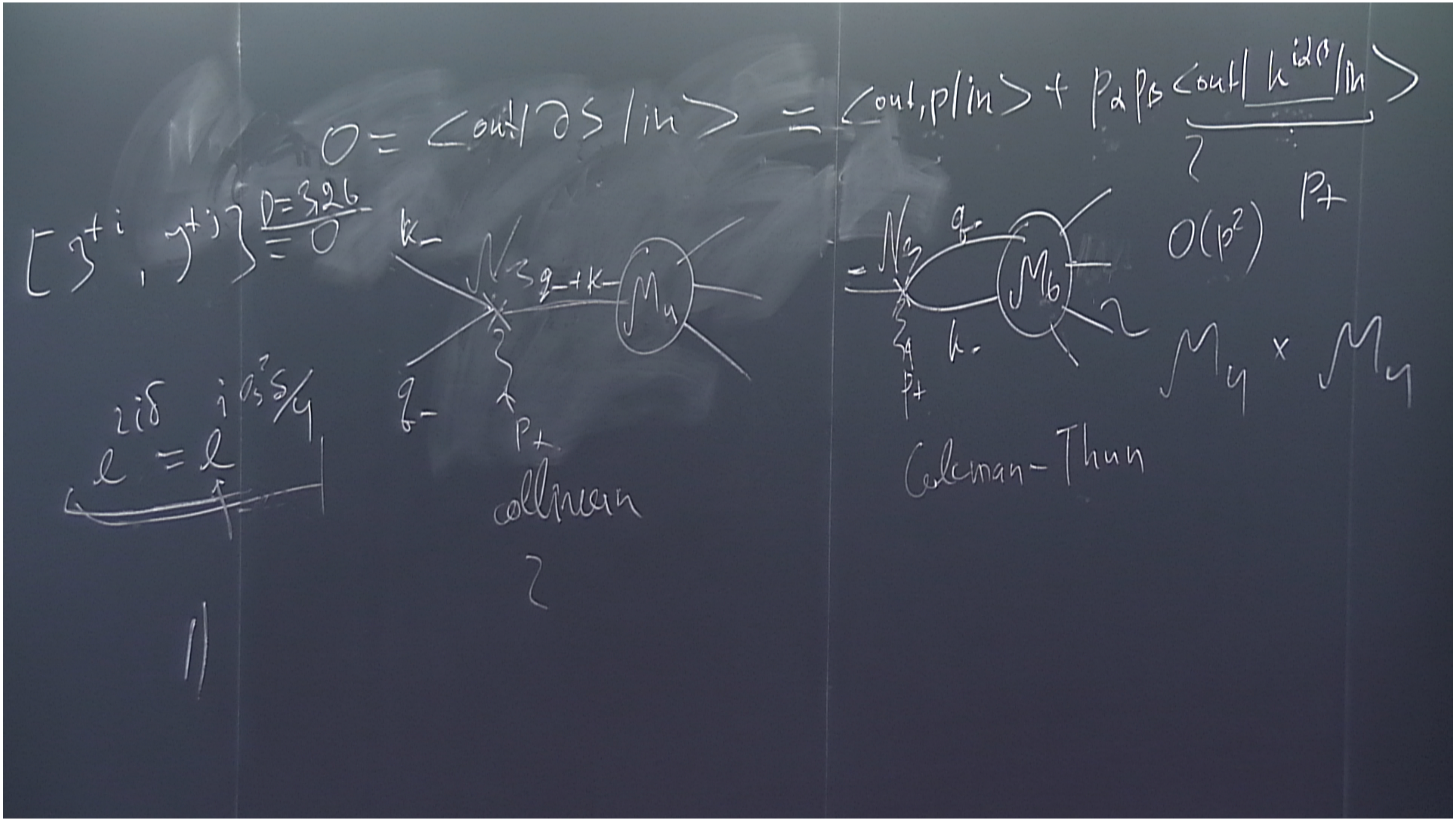


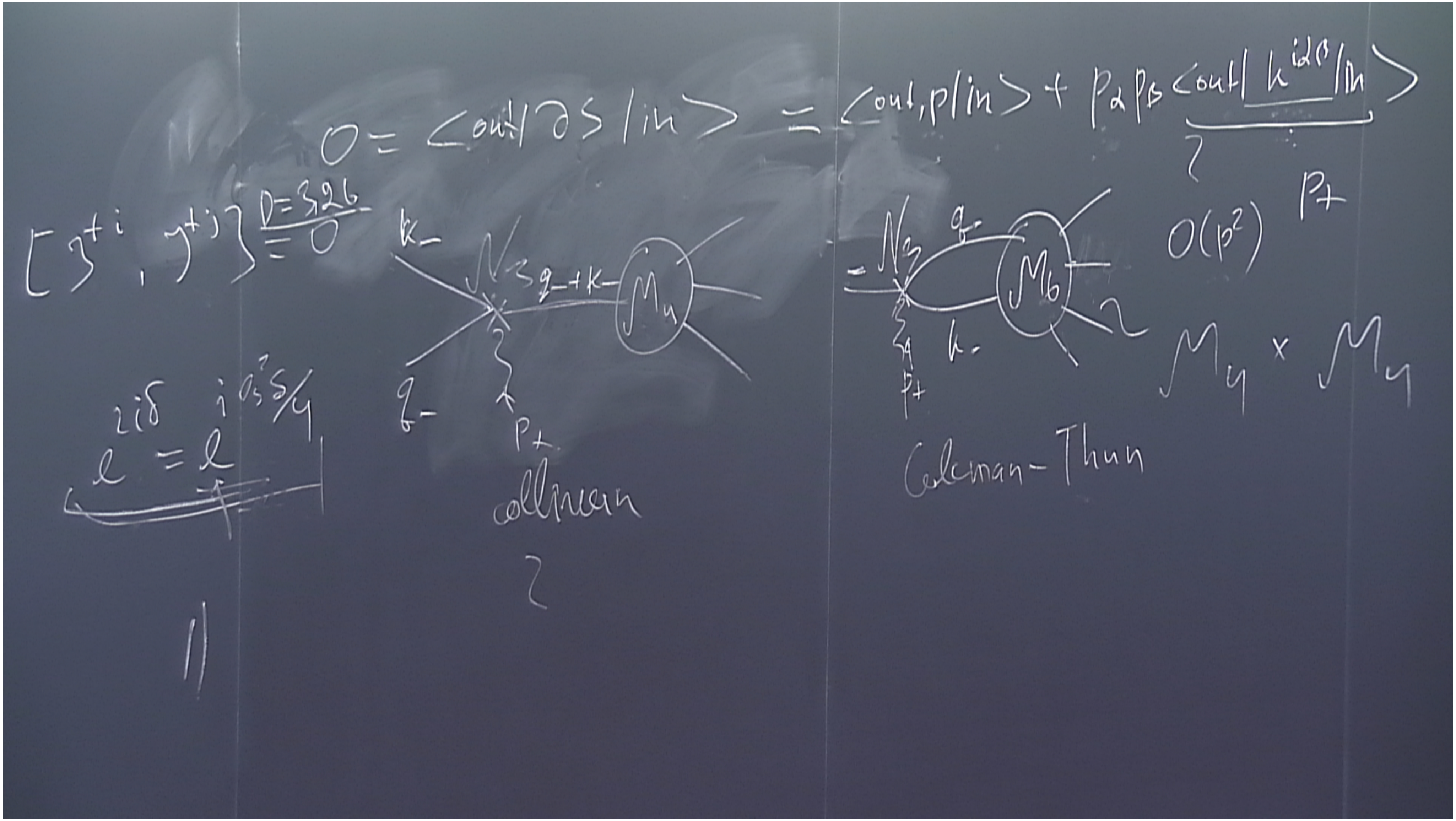
collinear



Coleman-Thun


0 = <out| ∂S |in> =
D=3,26
= 0
k_
q_
P+


0 = <out| ∂S |in> = <out, p|in> + pα pβ <out| h^{αβ} |in>
D=3,26
collinear
Coleman-Thun
O(p²)
M4 × M4

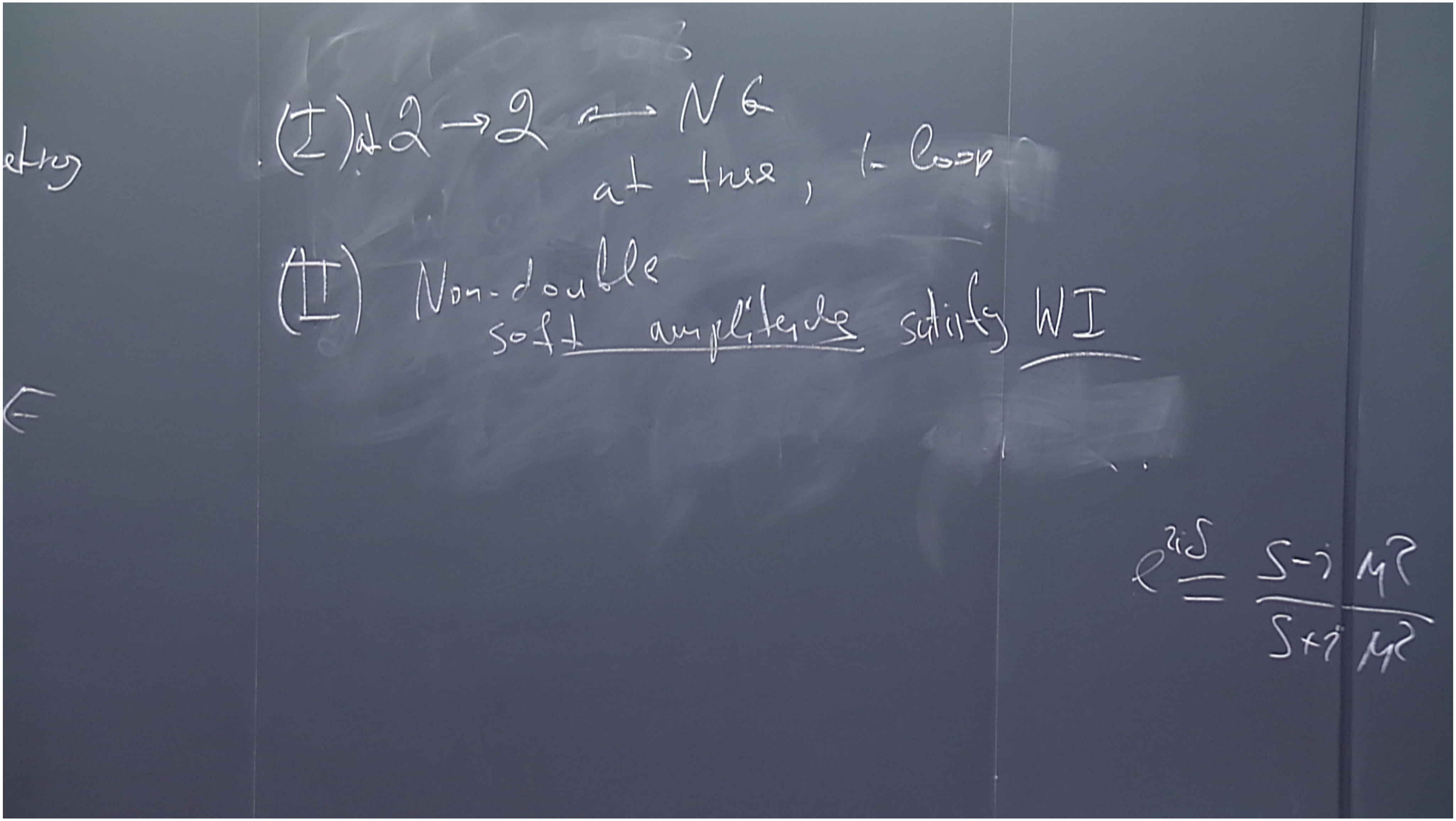

0 = <out| ∂S |in> = <out, p|in> + p_α p_β <out| ...|in>
D=3,26
k_-
q_- + k_-
M_4
q_-
p_+
collinear
2iδ
q_-
M_6
k_-
p_+
Coleman-Thun
O(p^2)
p_+
M_4 × M_4

hen

's in $D>2$?

$$e^{2i\delta} = e^{i\alpha_s^2 s/4}$$

$$e^{2i\delta} = \frac{s - i M^2}{s + i M^2}$$


(I) at 2 → 2 → NG
at tree, 1-loop
(II) Non-double soft amplitudes satisfy WI
e^{2iδ} = (s − i M²)/(s + i M²)

...metry

(I) at $2 \to 2 \longrightarrow NG$
at tree, 1-loop

$\mathcal{N}=4 \Leftrightarrow$ (II) Non-double soft amplitude satisfy WI
$\mathcal{N} > 4$

$\Rightarrow \in$

$\frac{\partial^2 X}{\partial}$

K

is induction N, L
less, loop

$S = S_{N,L} + V$

$\partial^{2L+2} (\partial X)^N , \; \partial^{2L} (\partial X)^{N+2}$

$e^{2i\delta} = \frac{s - i\mu^2}{s + i\mu^2}$

$m = 1.85\, \ell_s^{-1}$ $\quad N=3$

$m = 1.64\, \ell_s^{-1}$ $\quad N=5$

$N=3$

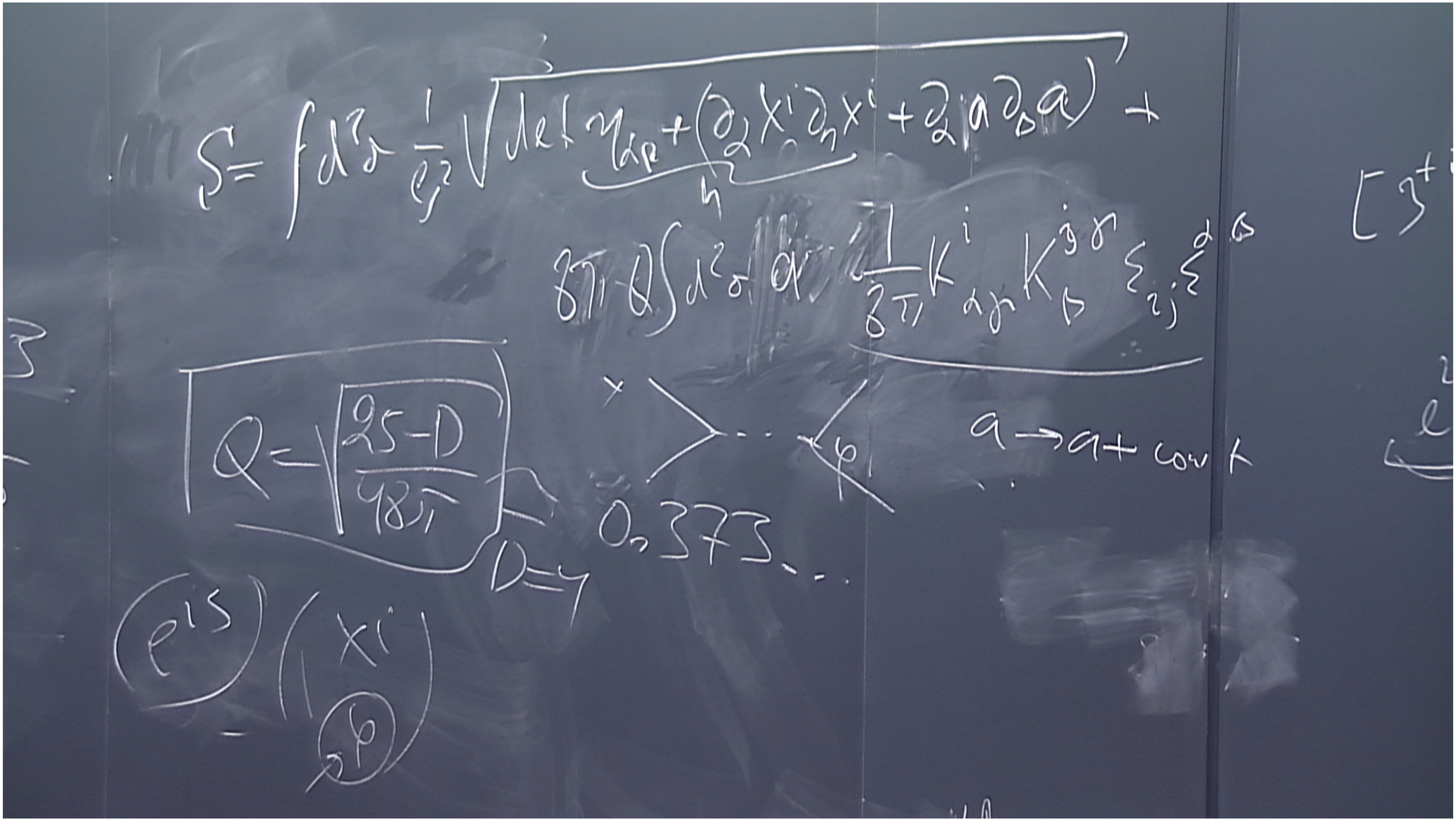
$N=5$

$$S = \int d^2\sigma \, \frac{1}{g_s^2} \sqrt{\det \underbrace{\eta_{\alpha\beta} + \partial_\alpha X^i \partial_\beta X^i}_{h} + \partial_\alpha \varphi \, \partial_\beta \varphi} \; +$$

$$+ Q \int d^2\sigma \sqrt{-h} \, \varphi \, R[h]$$

$$Q = \sqrt{\frac{25-D}{48\pi}} \simeq 0.373\ldots$$

$D=4$


Q = √((25-D)/48π)
D=4
0.373...
a → a + const

$$B^{\alpha i}_{\beta} = \delta^{i}_{\beta}\sigma^{\alpha} + K^{i\alpha}_{\beta}$$

boost shift

$$\delta^{i\alpha} = \partial^{\beta} K^{i\alpha}_{\beta}$$

$$\sim \partial_{\alpha} X^{i} + \partial^{\beta} K^{i\alpha}_{\beta} \sim Q\, \ell_s^2 \epsilon_{ij} X^{j} (\epsilon_{\alpha\alpha}\partial^{\alpha}\partial_{\beta} q + \dots)$$

$$\ell_s^2 X^{i} T^{\alpha}_{\beta} + \dots$$

$2 \to 4$

one-loop: $2 \to 4 \neq 0$

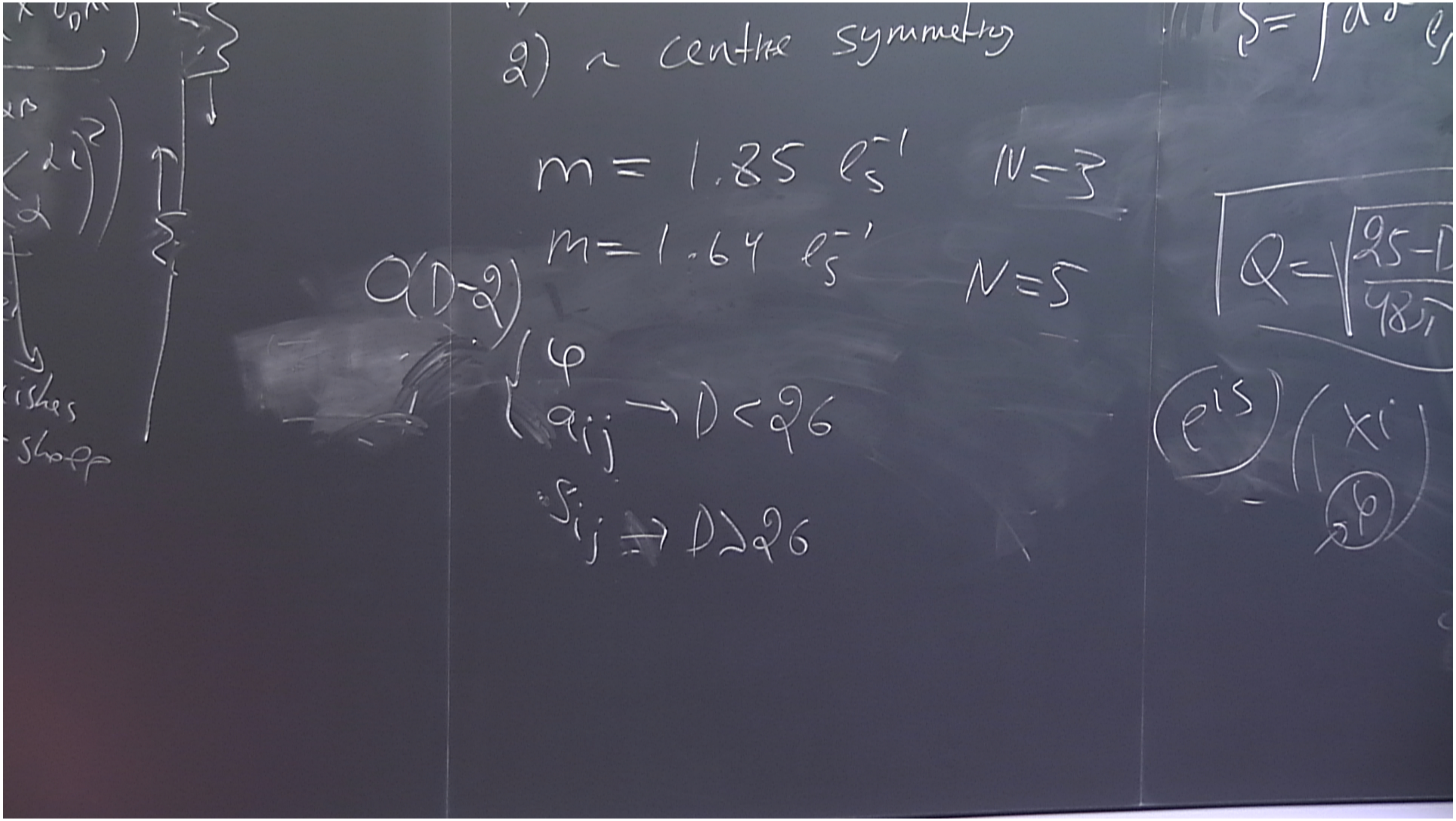
if $D \neq 3, 26$

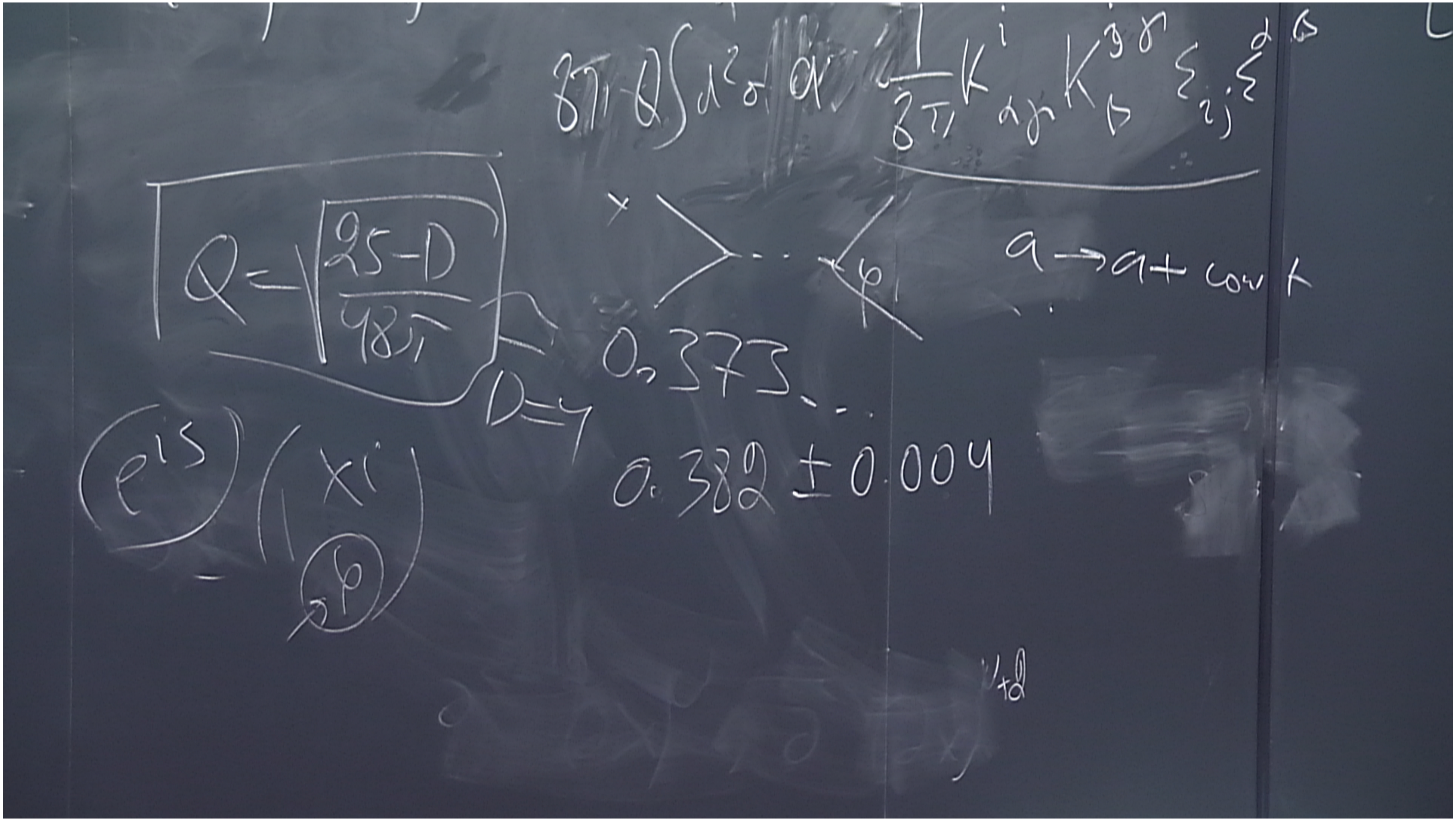
$X \to X + \text{const}$

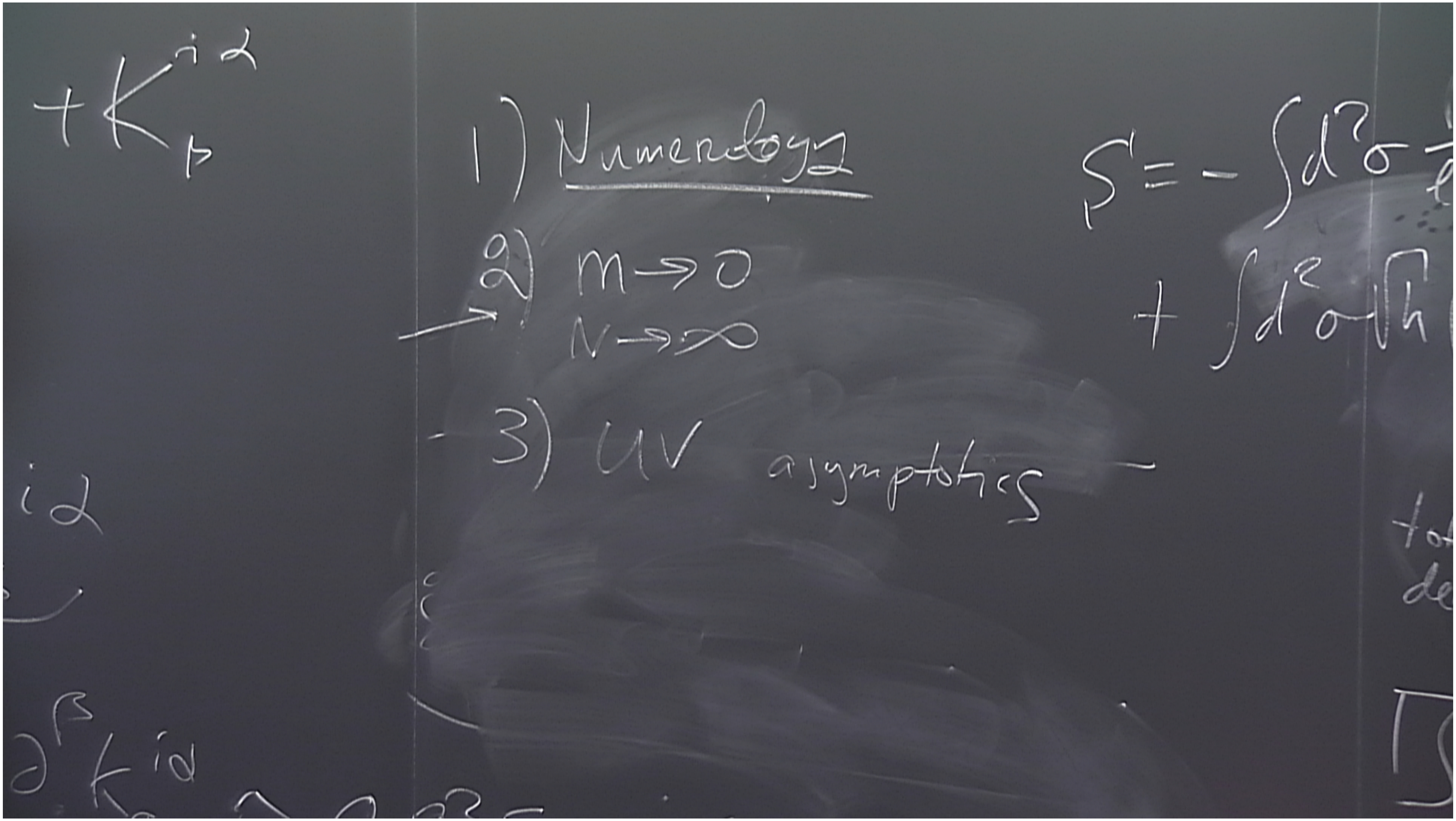
$$\delta^{\alpha i} X^{j} = \delta^{ij}\sigma^{\alpha} + X^{i}\partial^{\alpha}X^{j}$$

$S = -\int d^2\sigma$

$+ \int d^2\sigma \sqrt{\ldots}$


2) a centre symmetry
m = 1.85 l_s^{-1} N=3
m = 1.64 l_s^{-1} N=5
O(D-2)
φ
a_{ij} → D<26
S_{ij} → D>26
ishes
shelf


Q = √(25−D / 48π)
D=4
0.373...
0.382 ± 0.004
a → a + const


1) Numerology
2) m → 0
N → ∞
3) UV asymptotics