Title: Black Rings and Supertubes 2

Date: Jul 06, 2005 04:30 PM

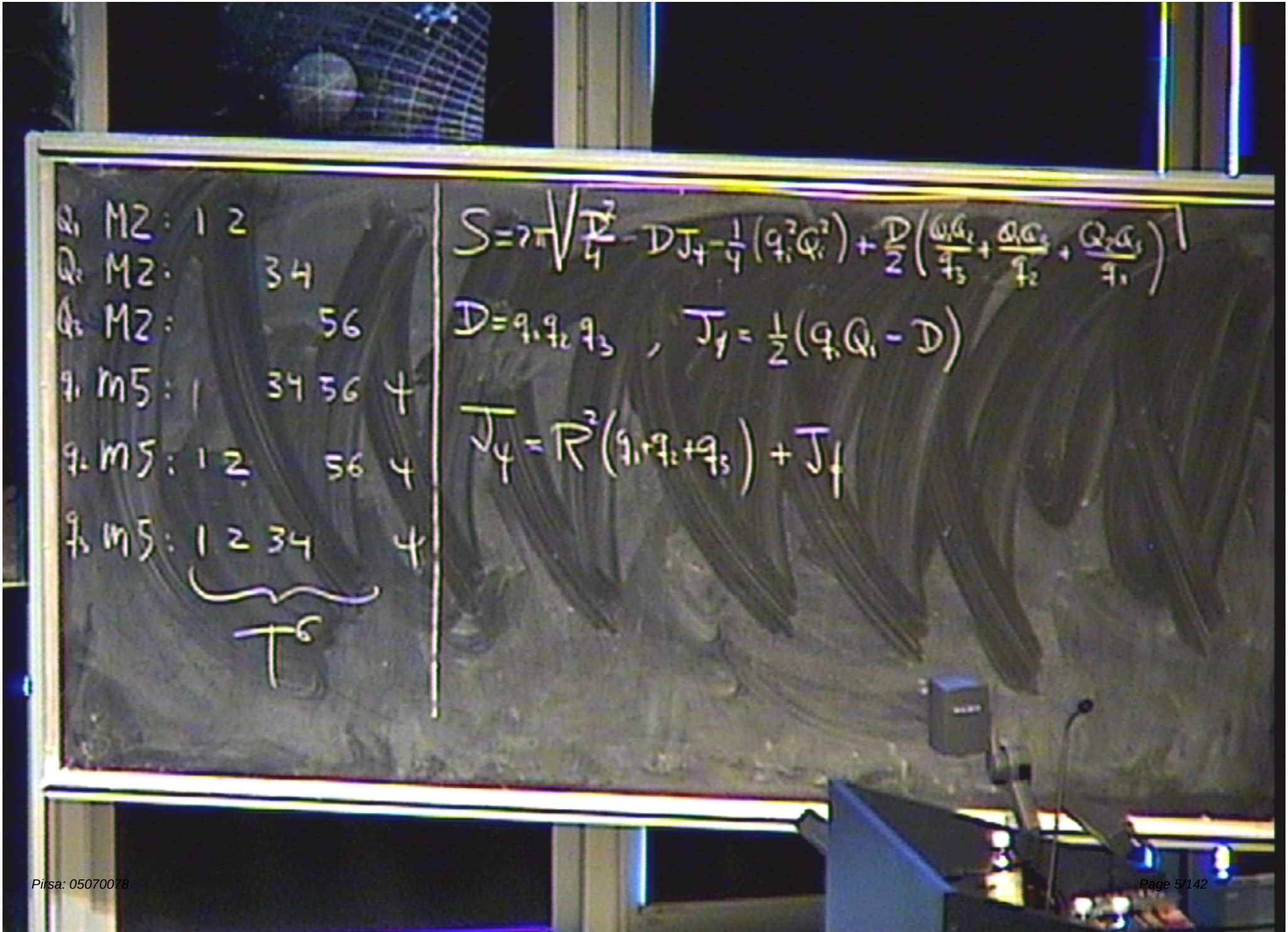
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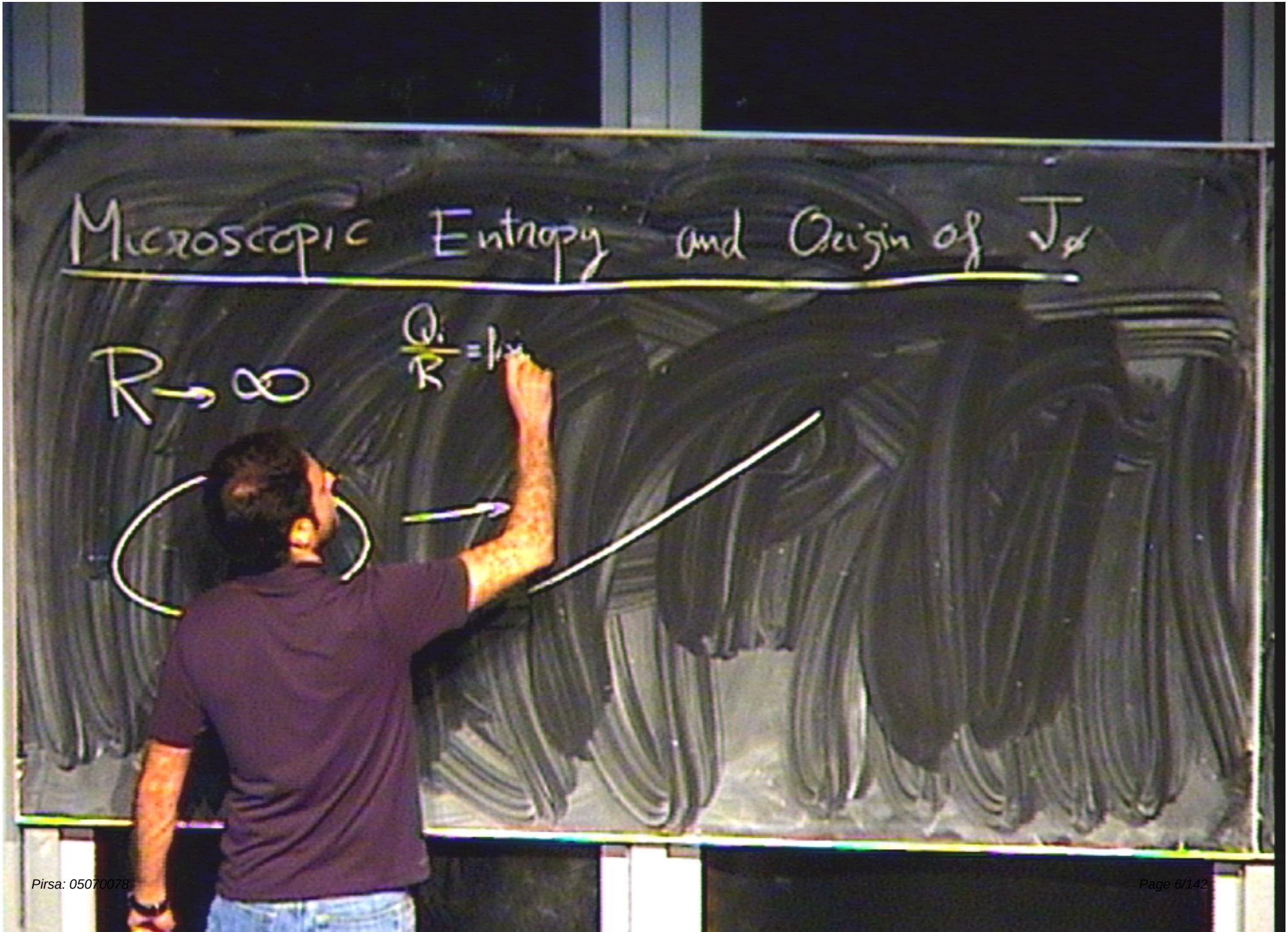
Abstract:

Microscopic Entropy and Origin of J_ϕ

Microscopic Entropy and Origin of J_ϕ

Microscopic Entropy and Origin of J_ϕ

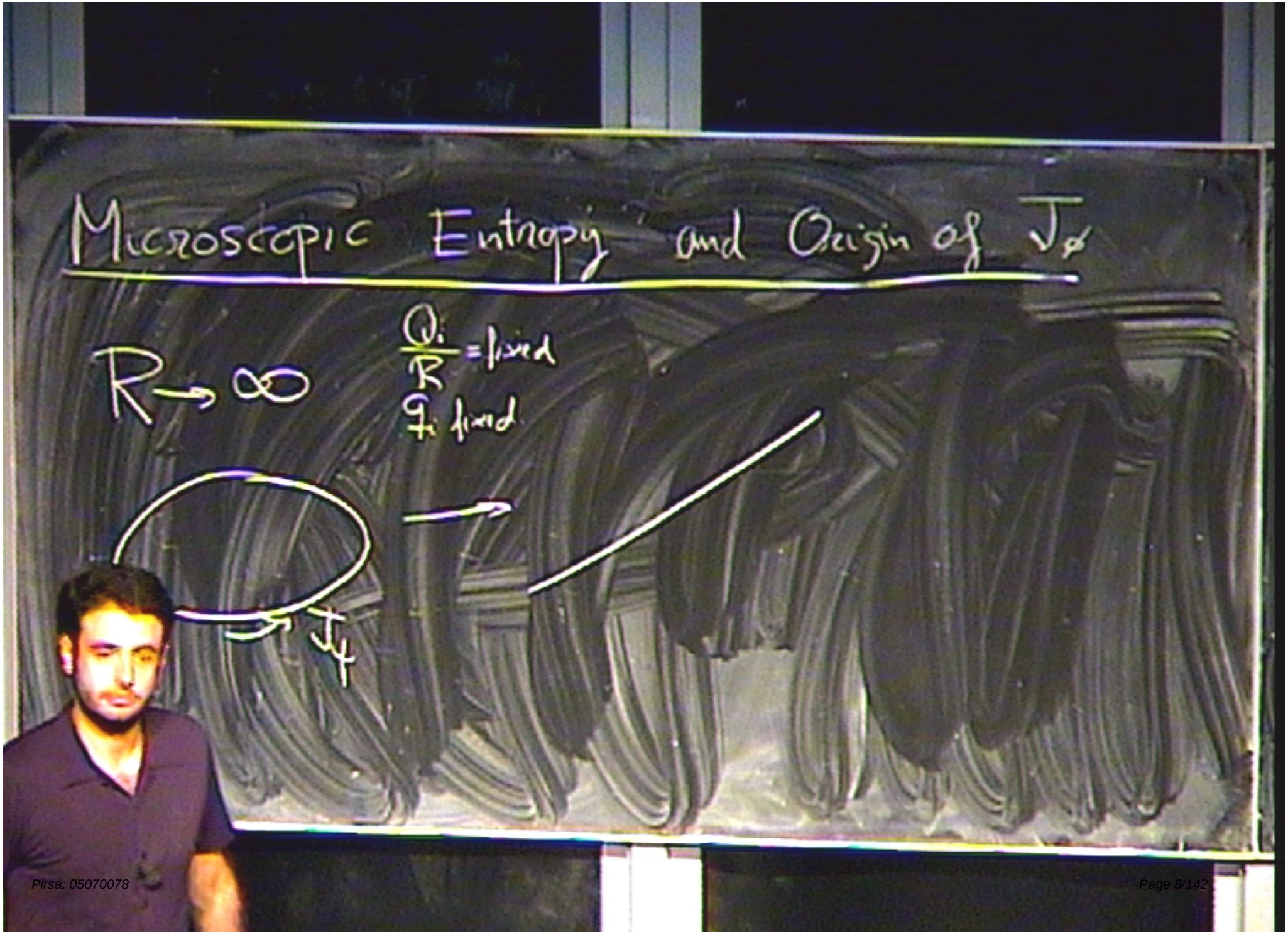

Q1 M2 : 1 2
Q2 M2 : 3 4
Q3 M2 : 5 6
q1 m5 : 1 3 4 5 6 4
q2 m5 : 1 2 5 6 4
q3 m5 : 1 2 3 4 4
T6
$S = 2\pi\sqrt{\frac{\Sigma^2}{4} - DJ_4 - \frac{1}{4}(q_1^2Q_1^2) + \frac{D}{2}\left(\frac{Q_1Q_2}{q_3} + \frac{Q_2Q_3}{q_2} + \frac{Q_3Q_1}{q_1}\right)}$
$D = q_1 q_2 q_3$, $J_1 = \frac{1}{2}(q_1Q_1 - D)$
$J_4 = R^2(q_1+q_2+q_3) + J_1$


Microscopic Entropy and Origin of J_ϕ
$R \to \infty$
$\frac{Q_i}{R} =$

Microscopic Entropy and Origin of J_α

$R \to \infty$ $\quad \frac{Q_i}{R} = \text{fixed}$




Microscopic Entropy and Origin of J_ϕ
$R \to \infty$
$\frac{Q_i}{R}$ = fixed
q_i fixed
J_ϕ

Microscopic Entropy and Origin of J_α

$R \to \infty$

$\frac{Q_i}{R}$ = fixed

q_i fixed



J_i

$J_i \sim P$

Microscopic Entropy and Origin of J_ϕ

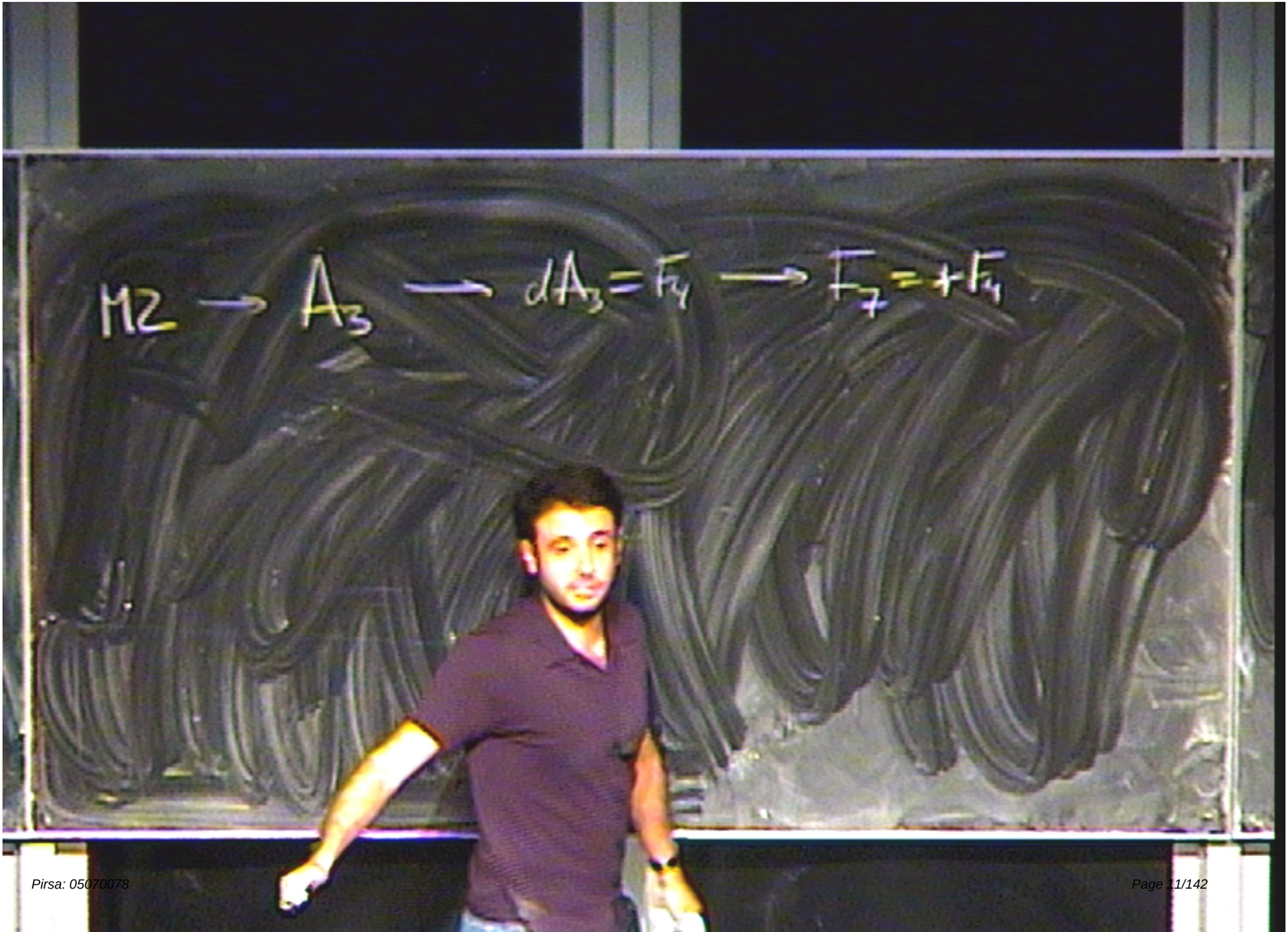
$R \to \infty$

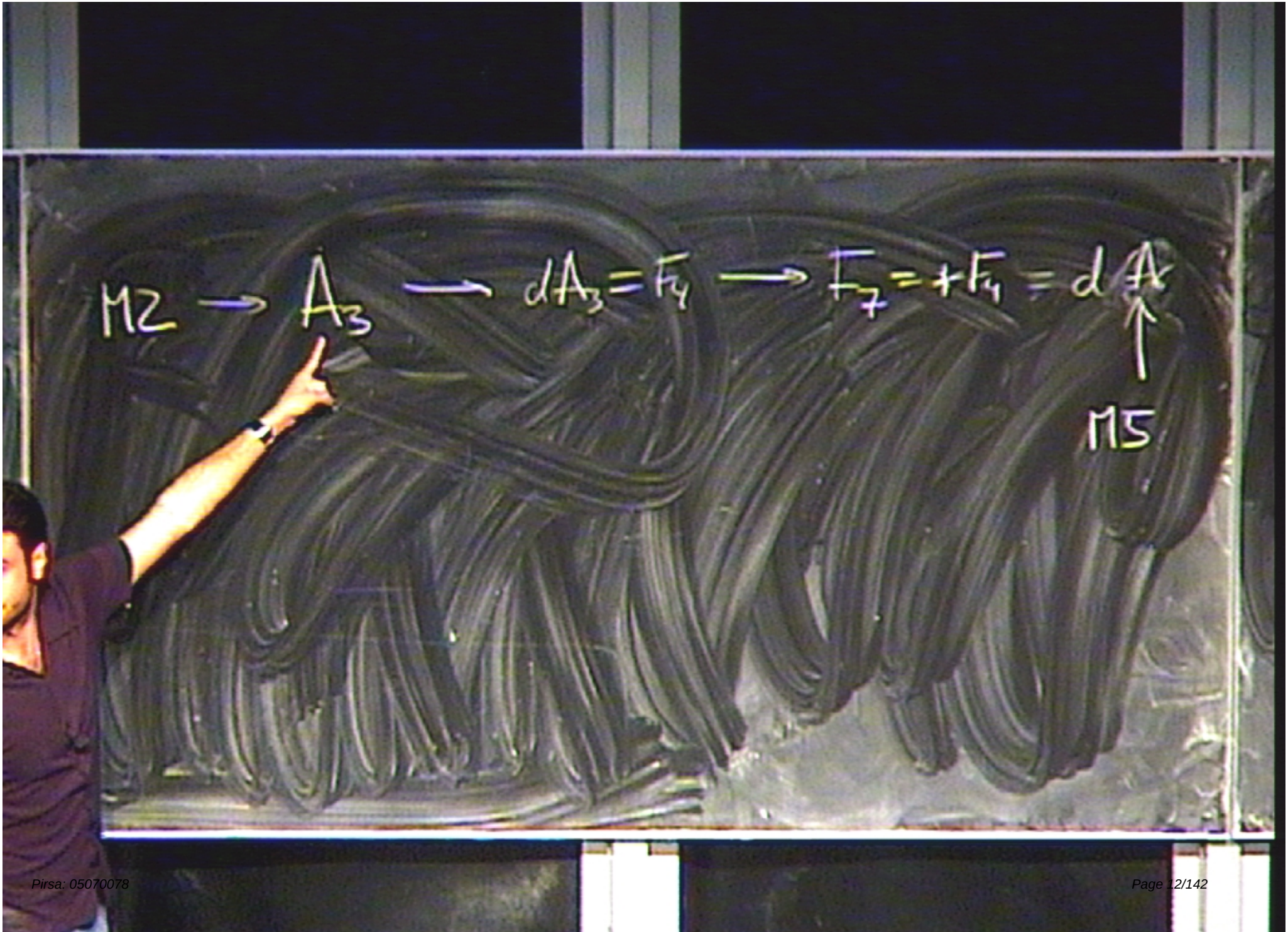
$\frac{Q_i}{R}$ = fixed

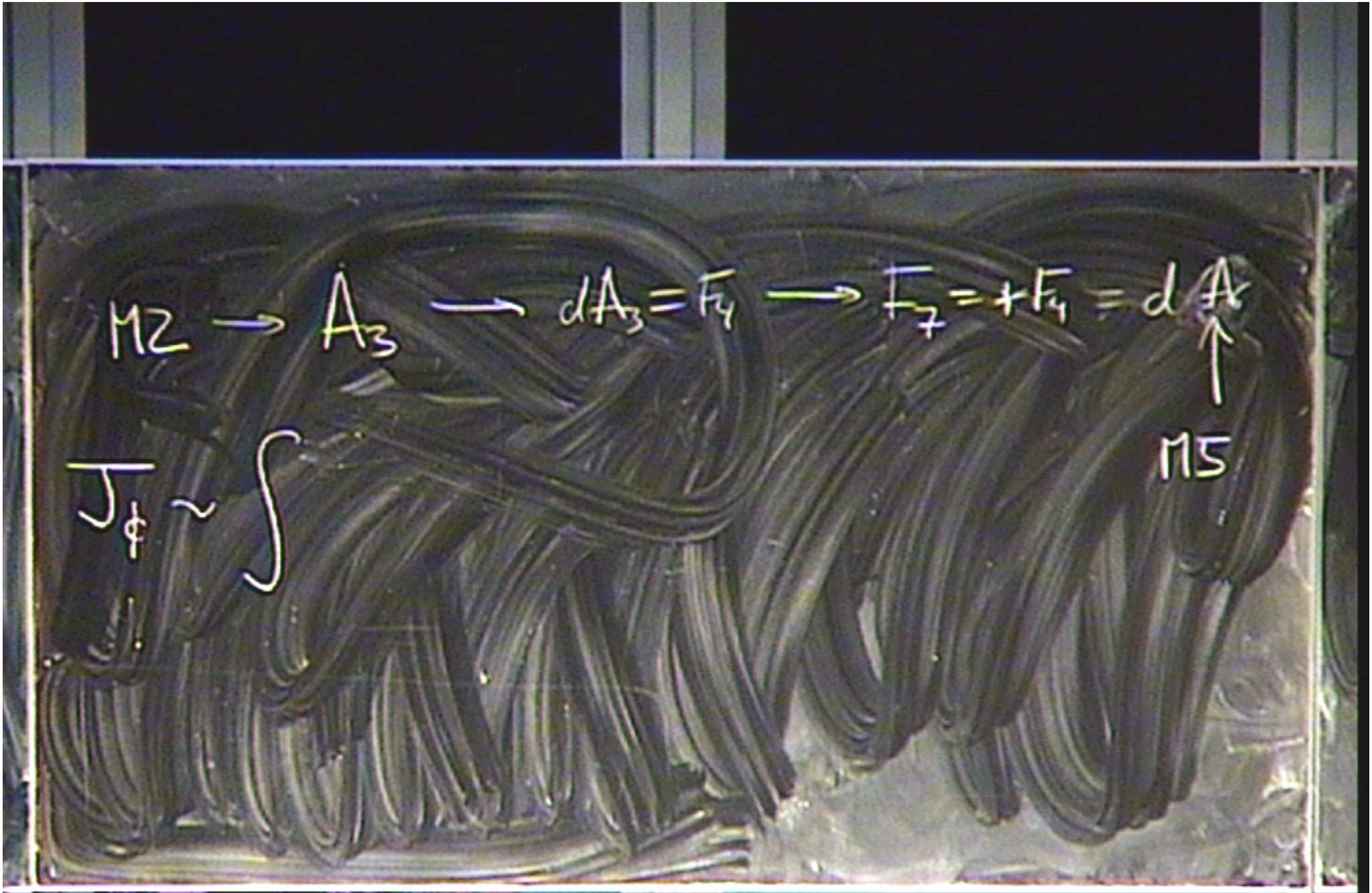
q_i fixed

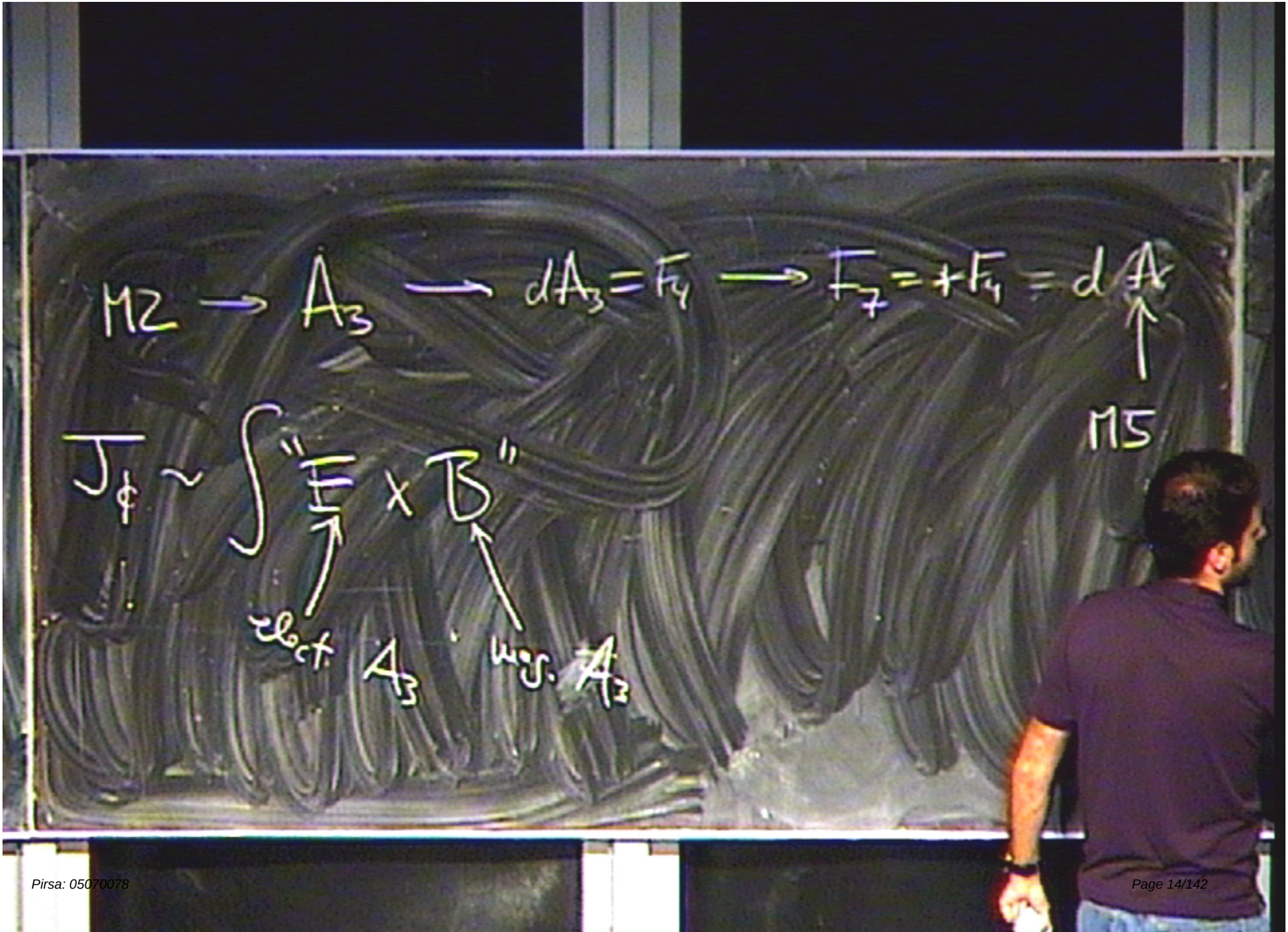
$J_\phi \to 0$

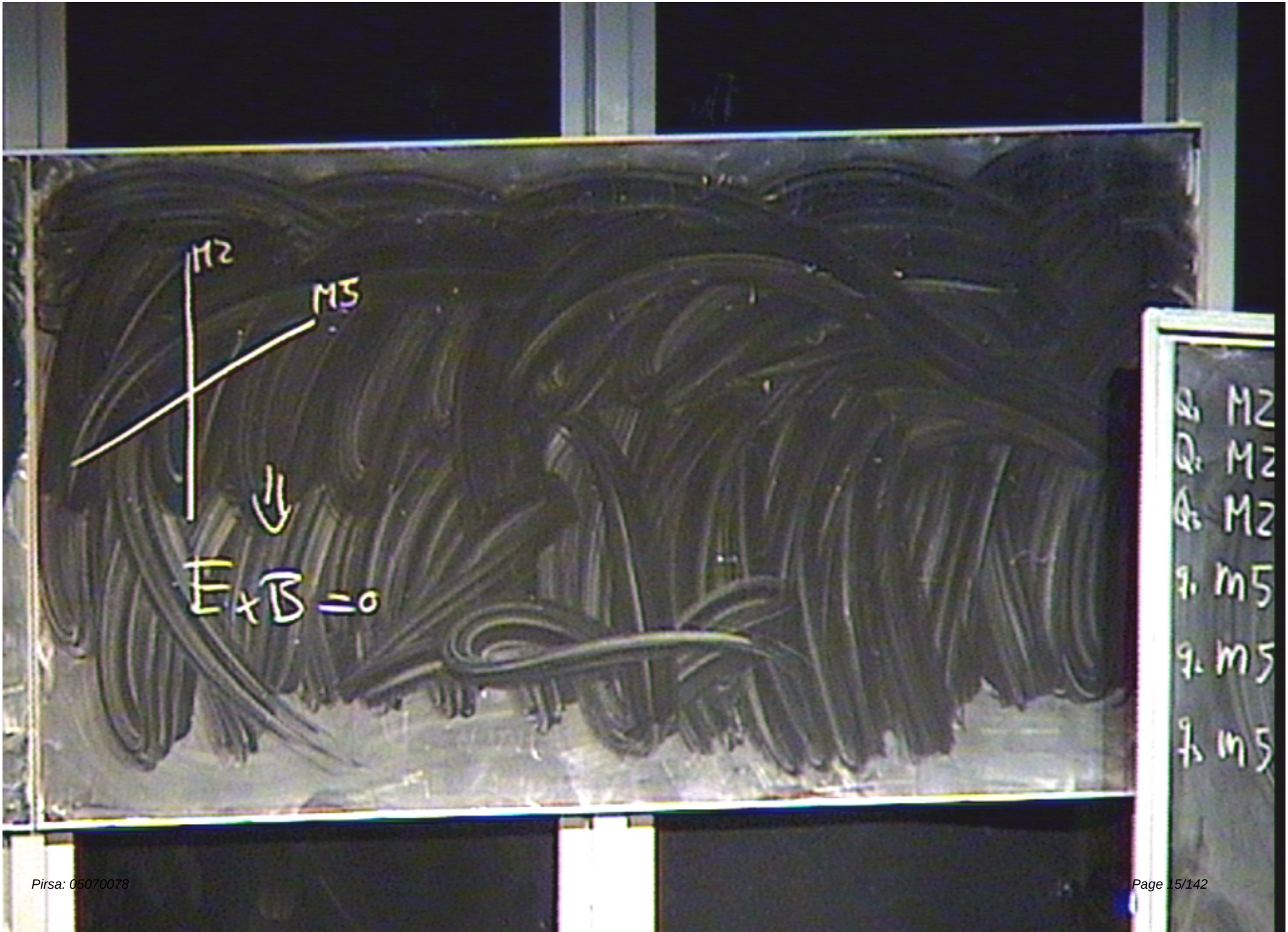


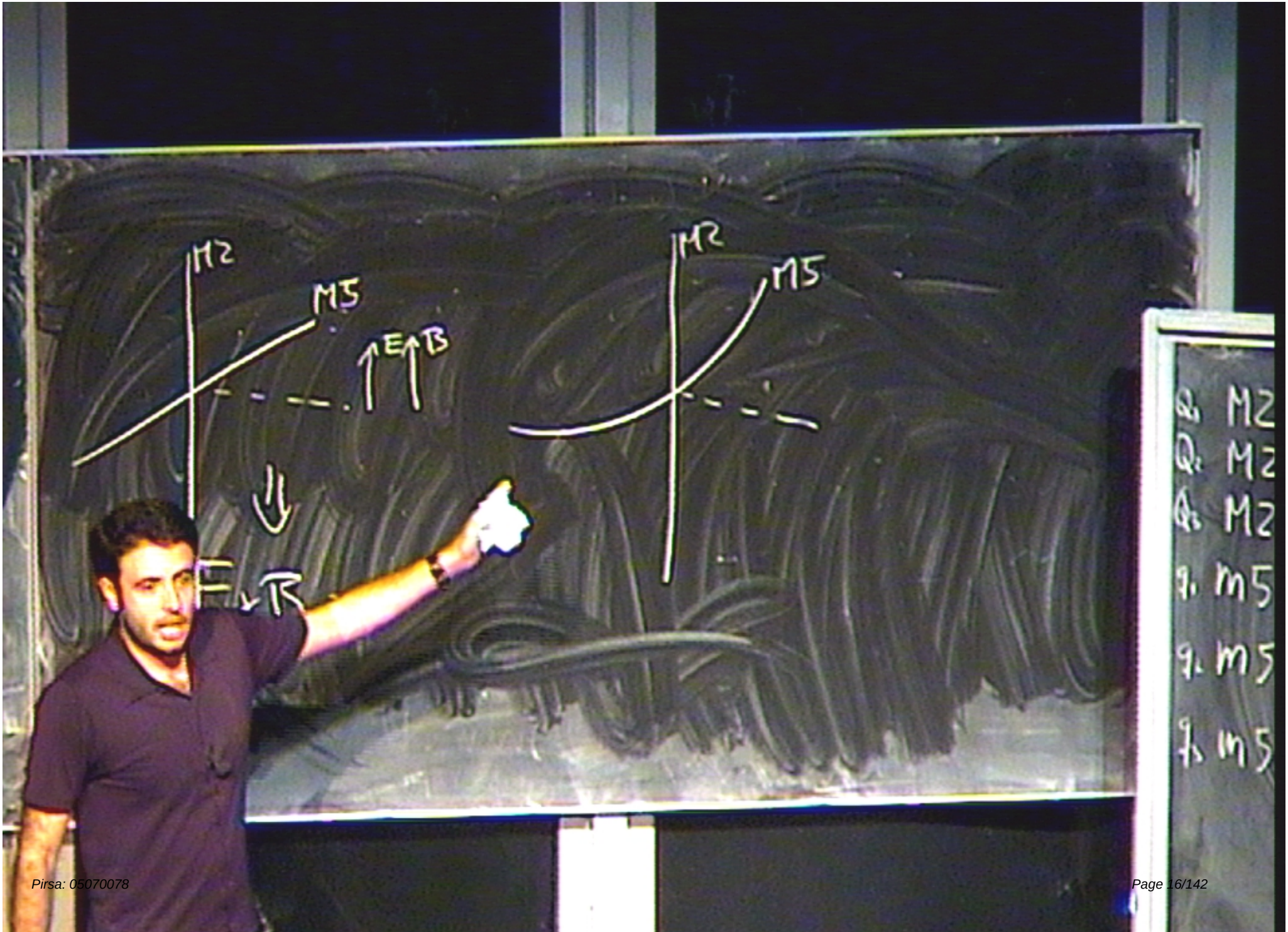

M2 → A3 → dA3 = F4 → F7 = *F4

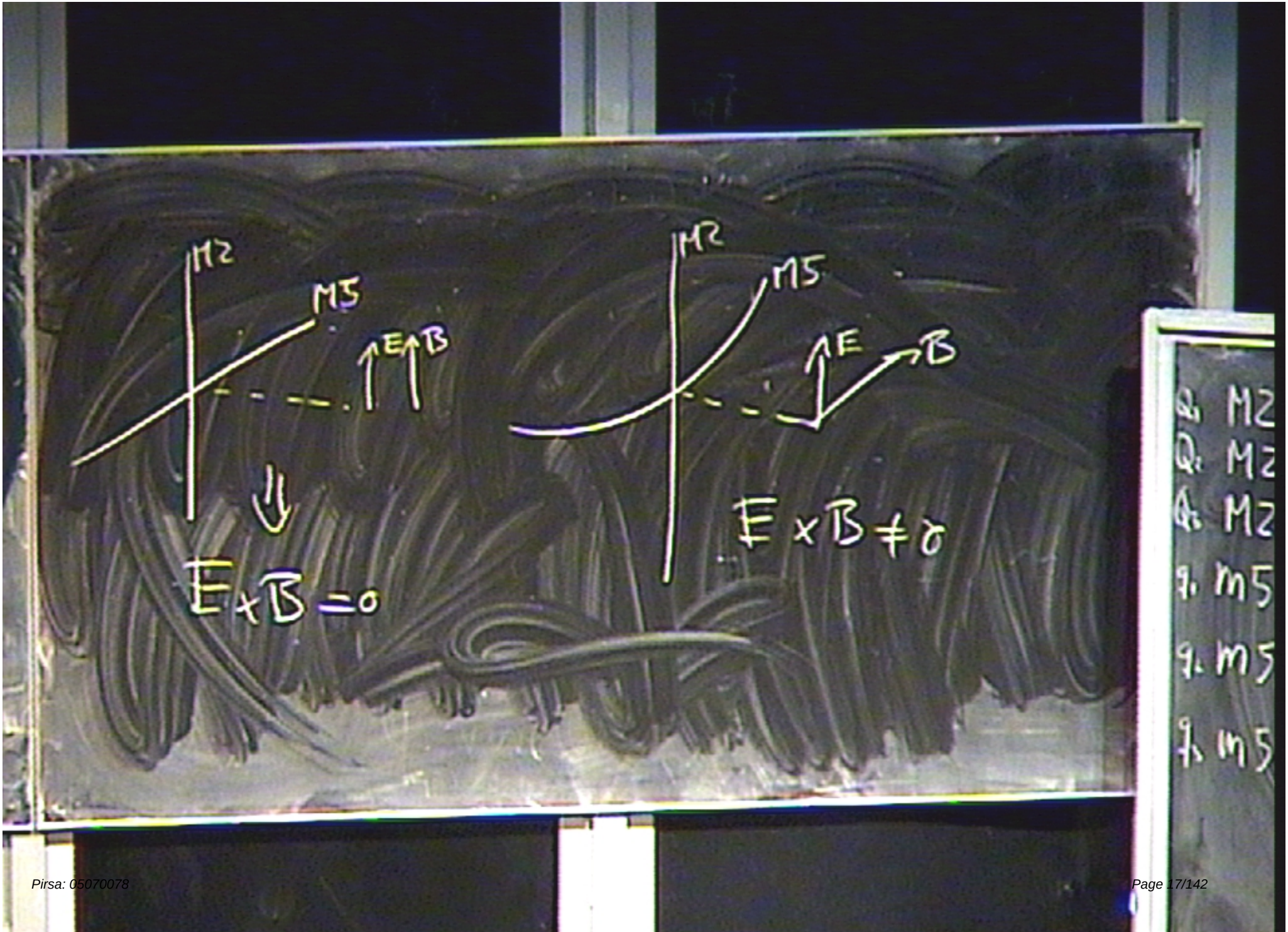

M2 → A3 → dA3 = F4 → F7 = +F4 = dA5
M5

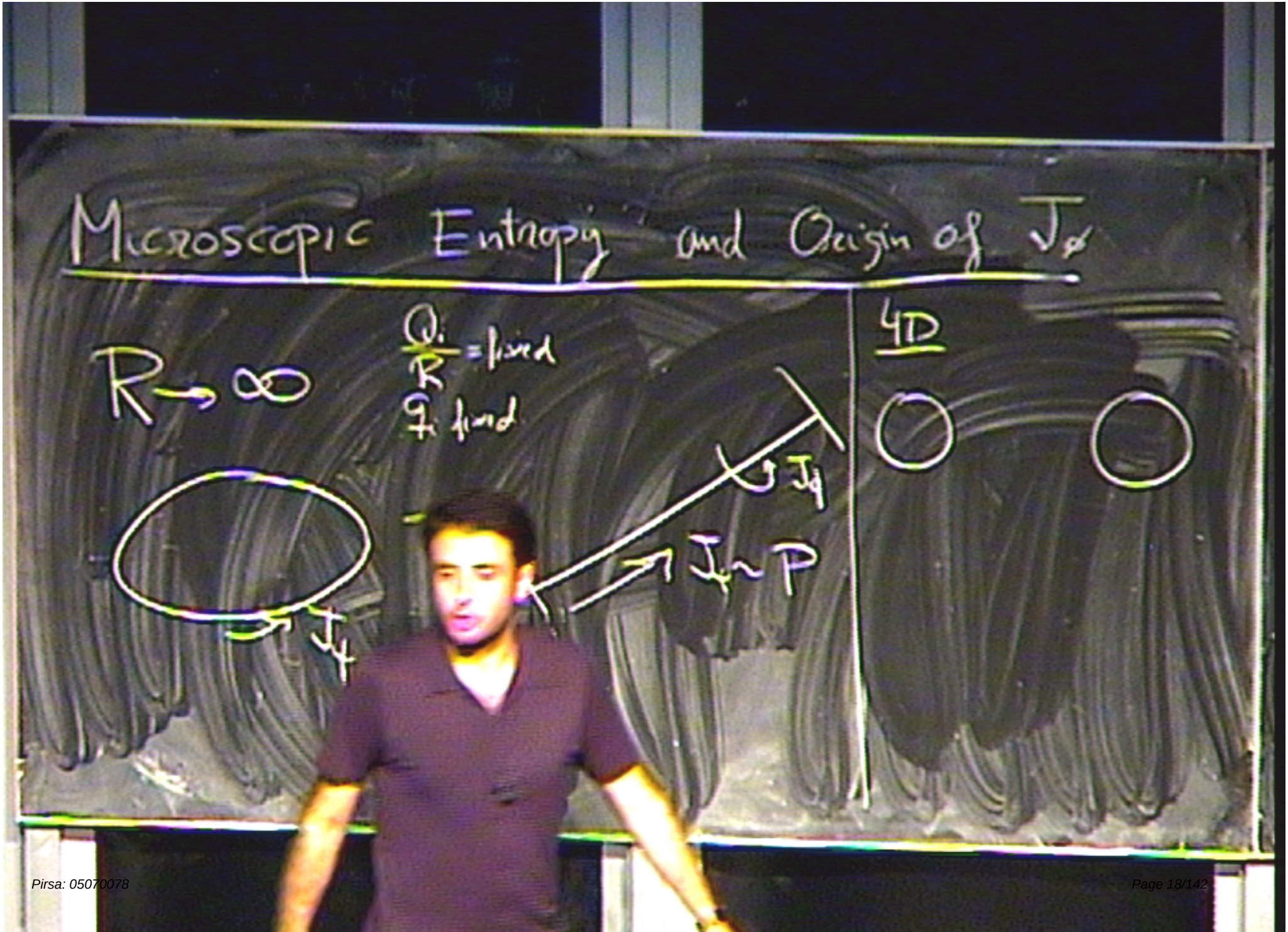

M2 → A3 ⟶ dA3 = F4 ⟶ F7 = +F4 = dA7
M5
J¢ ~ ∫

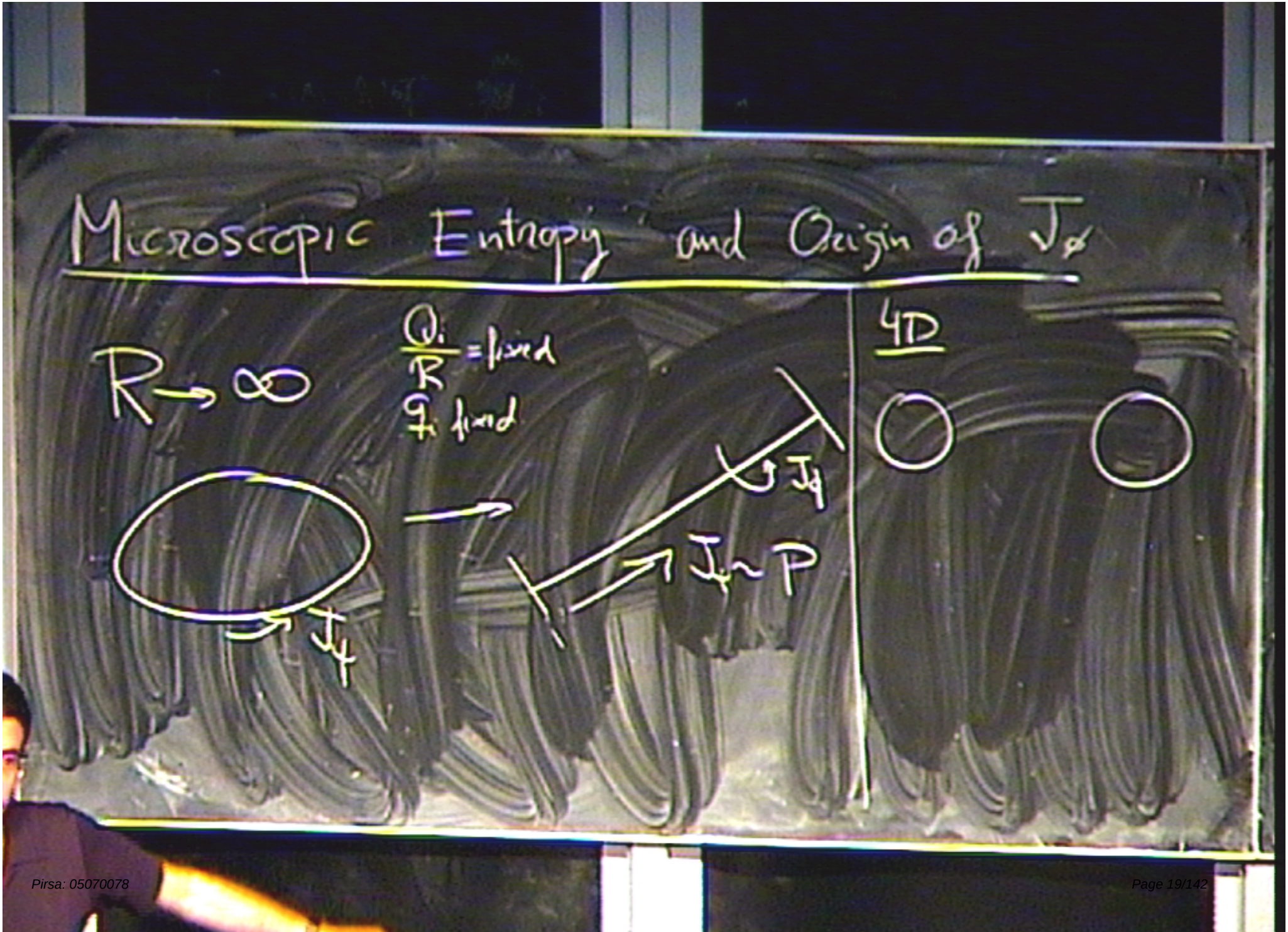

M2 → A3 → dA3 = F4 → F7 = + F4 = d A7
M5
J¢ ~ ∫ "E × B"
vel. A3
mag. A3

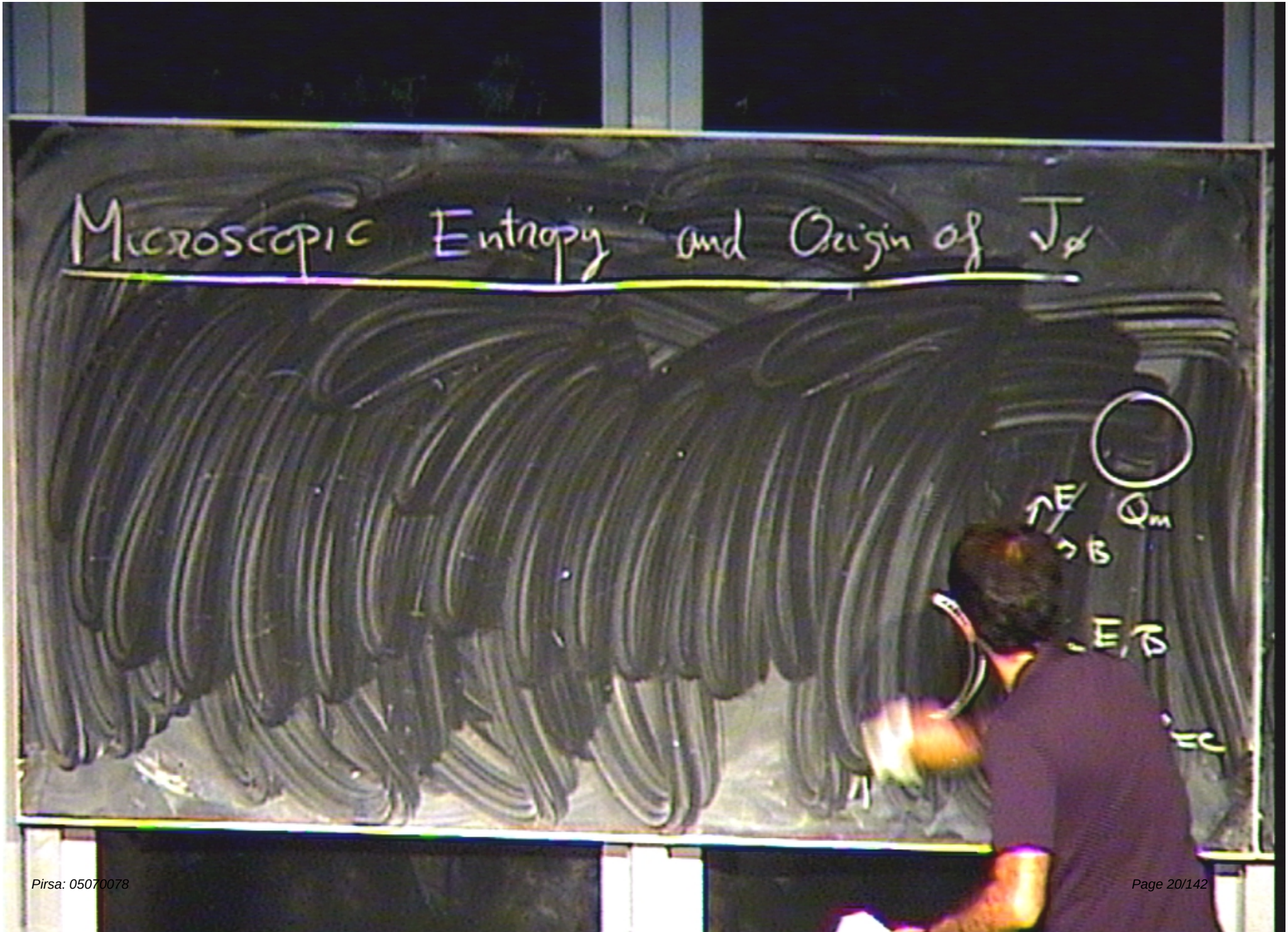

M2
M5
E+B=0
Q1 M2
Q2 M2
Q3 M2
q1 m5
q2 m5
q3 m5

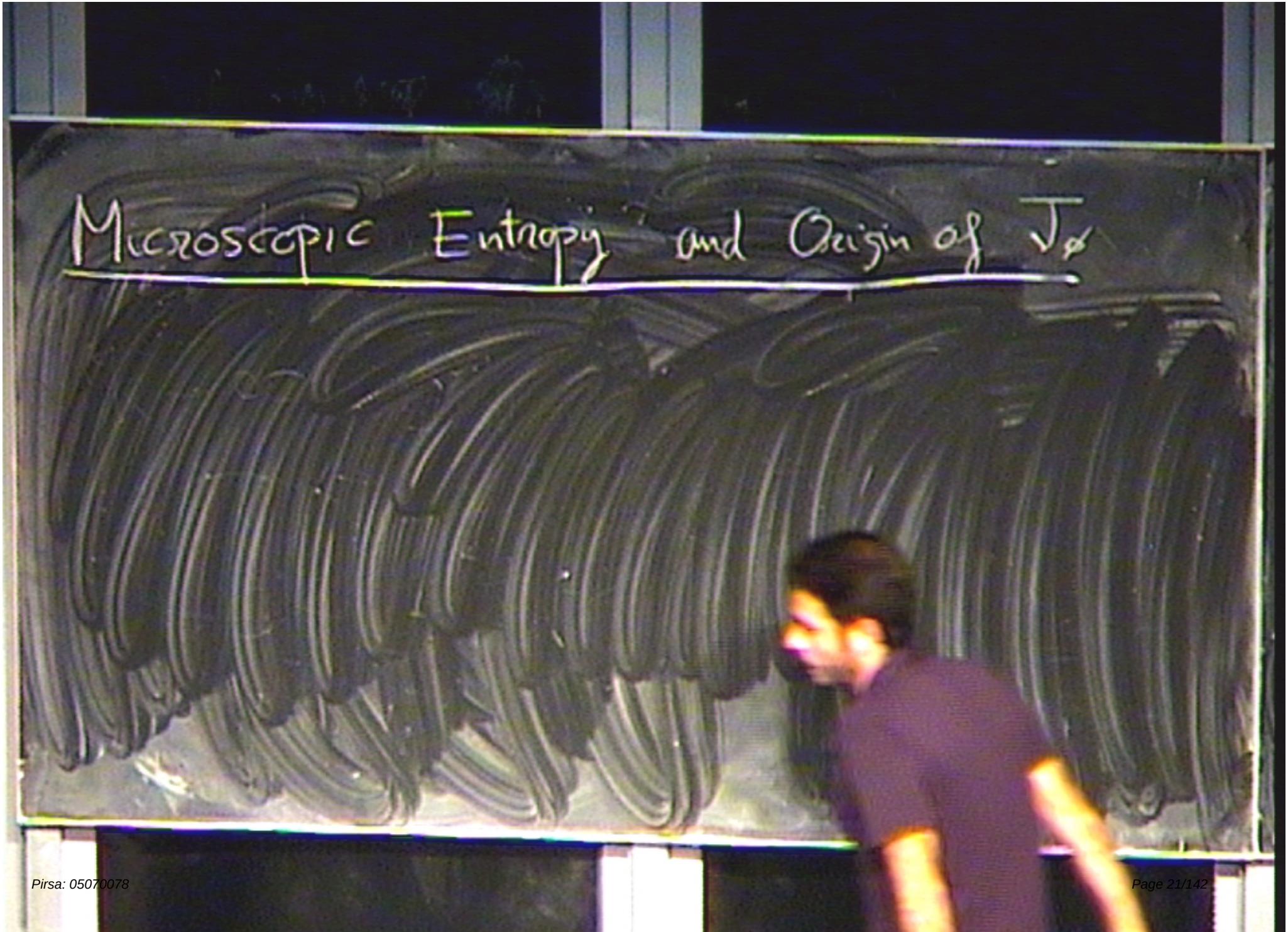

M2
M5
E↑B
F↓R
M2
M5
Q1 M2
Q2 M2
Q3 M2
q1 m5
q2 m5
q3 m5

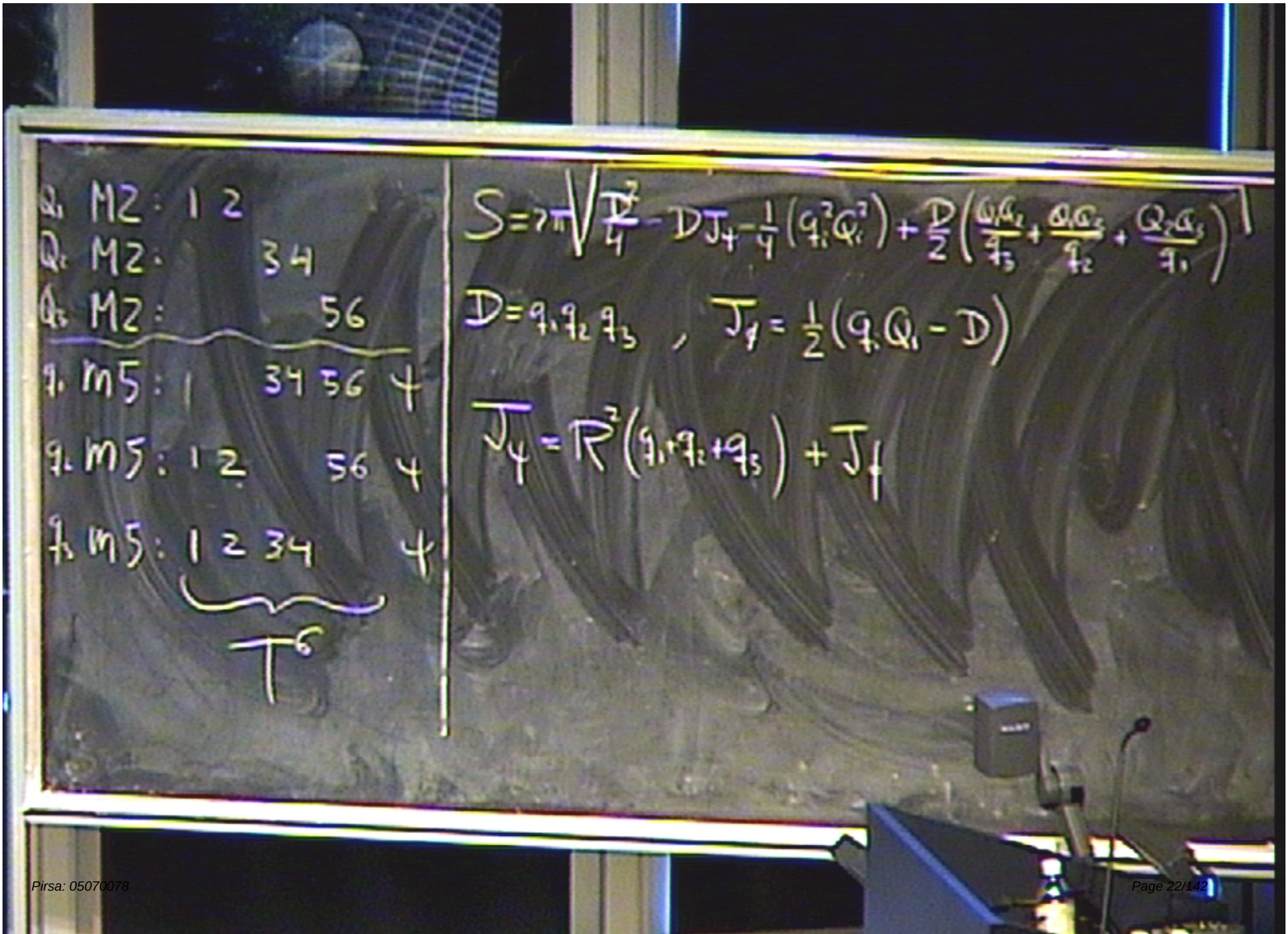

M2
M5
E
B
E × B = 0
M2
M5
E
B
E × B ≠ 0
Q1 M2
Q2 M2
Q3 M2
q1 m5
q2 m5
q3 m5

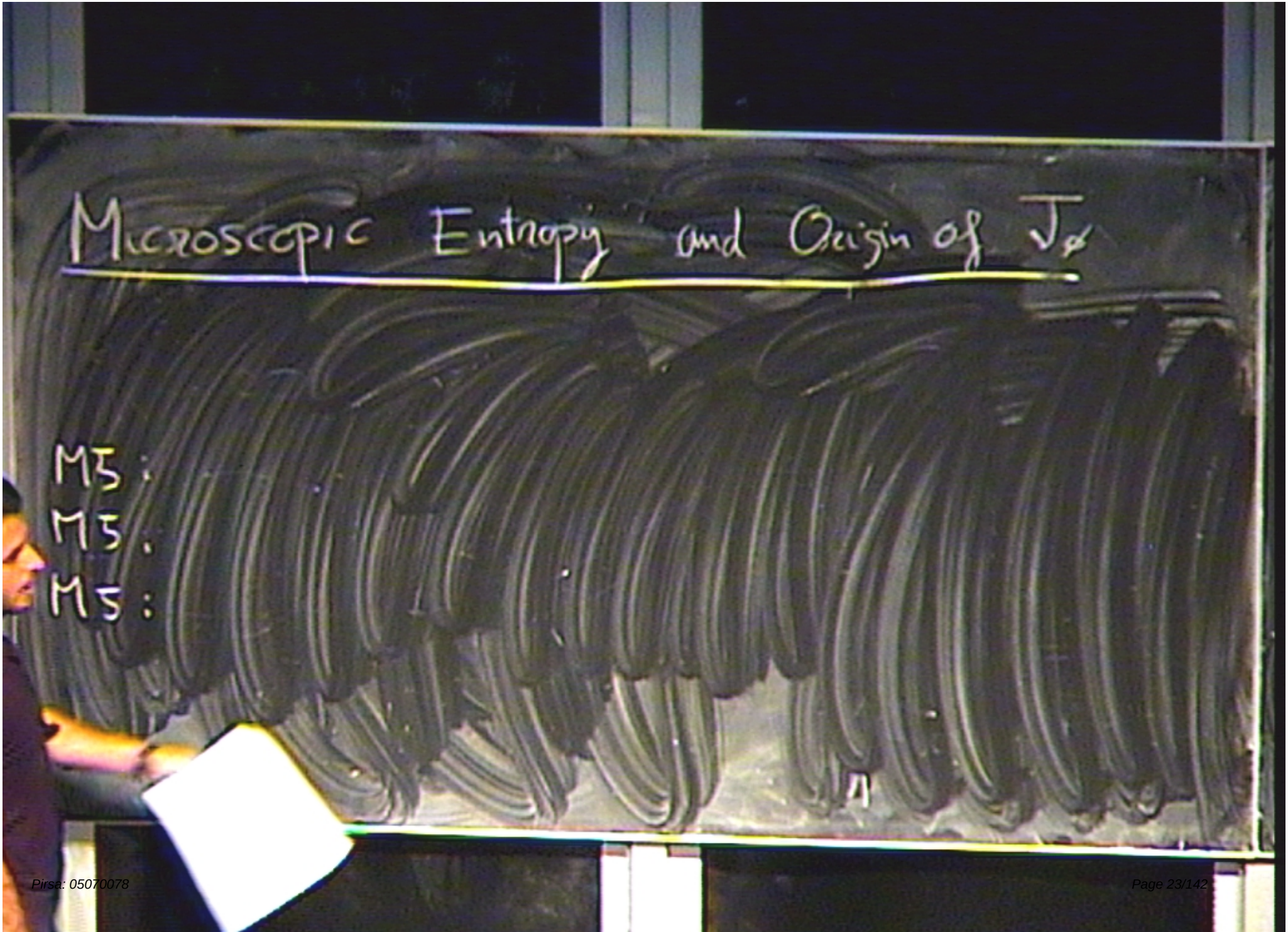

Microscopic Entropy and Origin of J_α
$R \to \infty$
$\frac{Q_i}{R}$ = fixed
q_i fixed
J_4
J_4
$J_4 \sim P$
4D

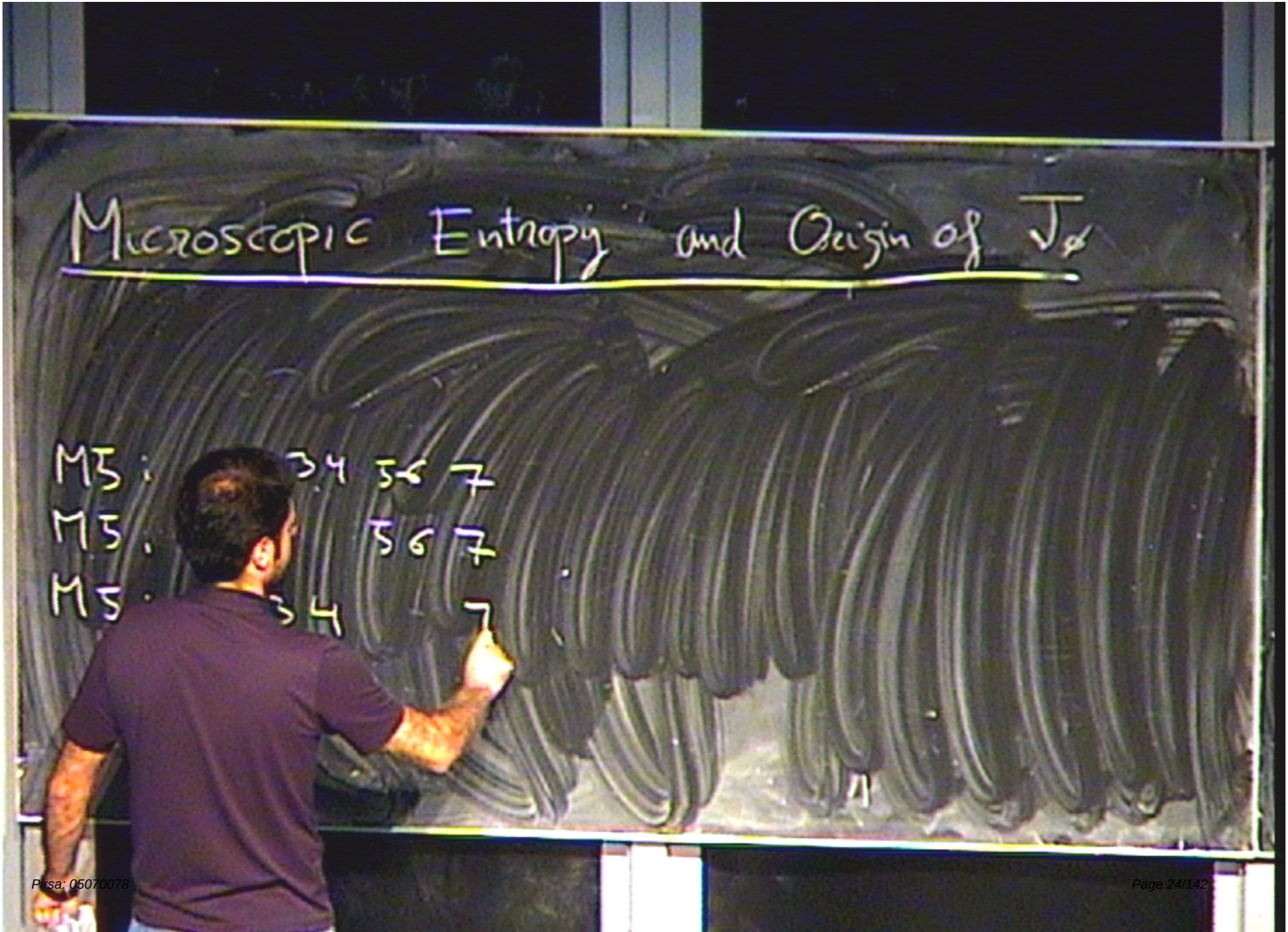

Microscopic Entropy and Origin of J_4
$R \to \infty$
$\frac{Q_i}{R}$ = fixed
g_4 fixed
J_4
J_4
$J_4 \sim P$
4D

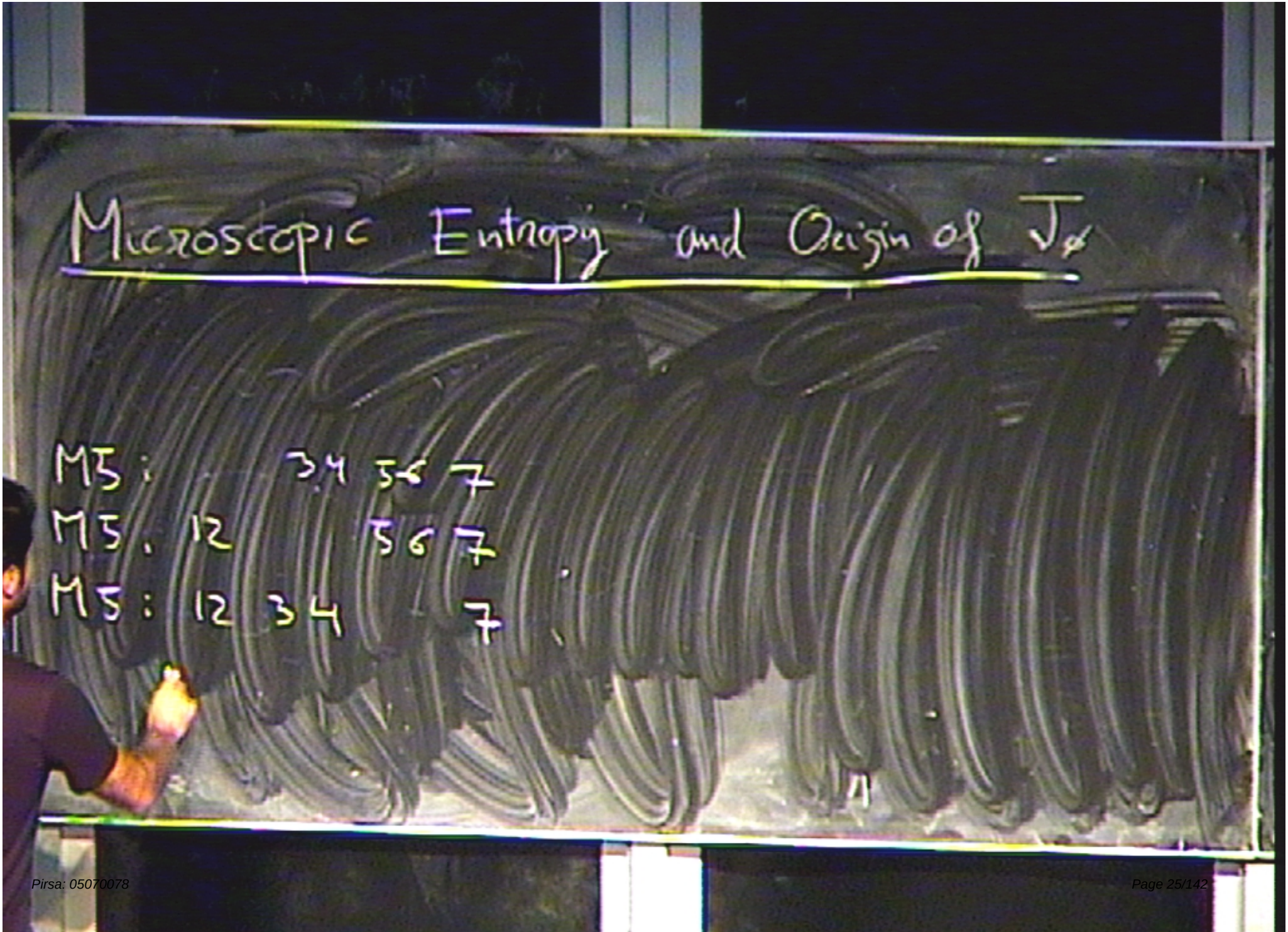

Microscopic Entropy and Origin of J_a
Q_m
E, B

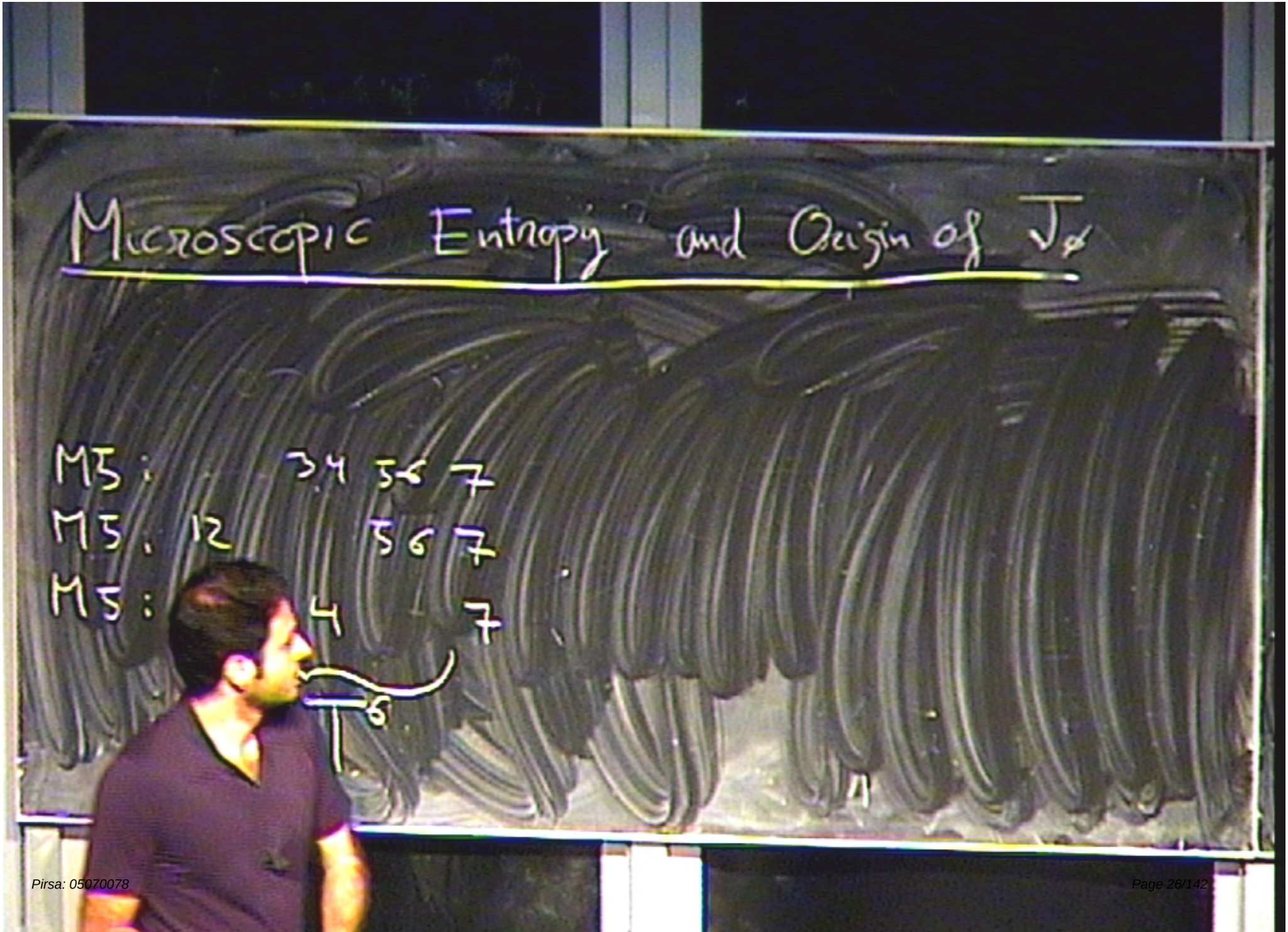

Microscopic Entropy and Origin of J_ϕ

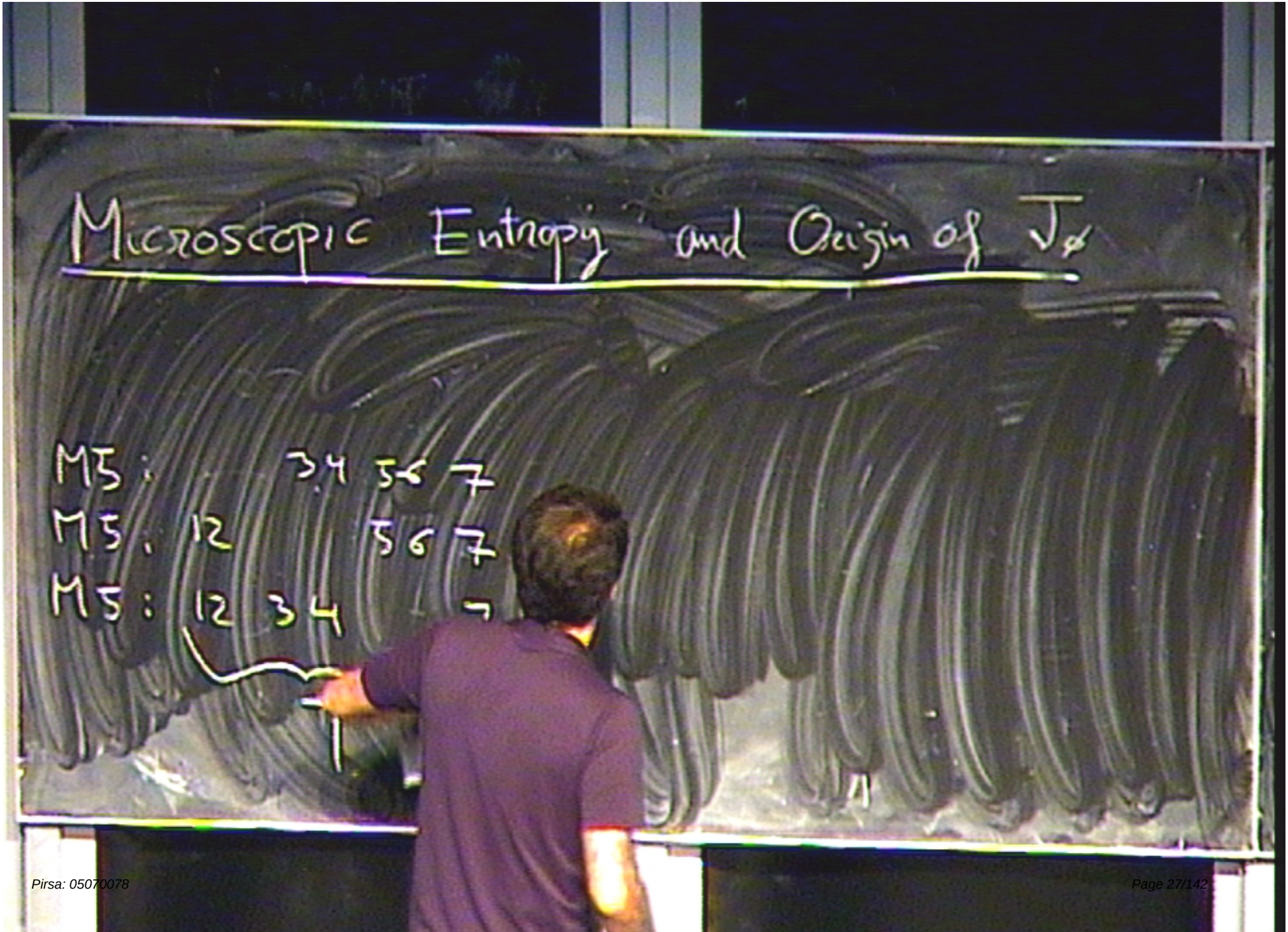

Q1 M2 : 1 2
Q2 M2 : 3 4
Q3 M2 : 5 6
q1 M5 : 1 3 4 5 6 4
q2 M5 : 1 2 5 6 4
q3 M5 : 1 2 3 4 4
T6
$S = 2\pi\sqrt{\frac{N^2}{4} - DJ_4 - \frac{1}{4}(q_1^2 Q_1^2) + \frac{D}{2}\left(\frac{Q_1 Q_2}{q_3} + \frac{Q_1 Q_3}{q_2} + \frac{Q_2 Q_3}{q_1}\right)}$
$D = q_1 q_2 q_3$, $J_4 = \frac{1}{2}(q_1 Q_1 - D)$
$J_4 = R^2(q_1 + q_2 + q_3) + J_1$

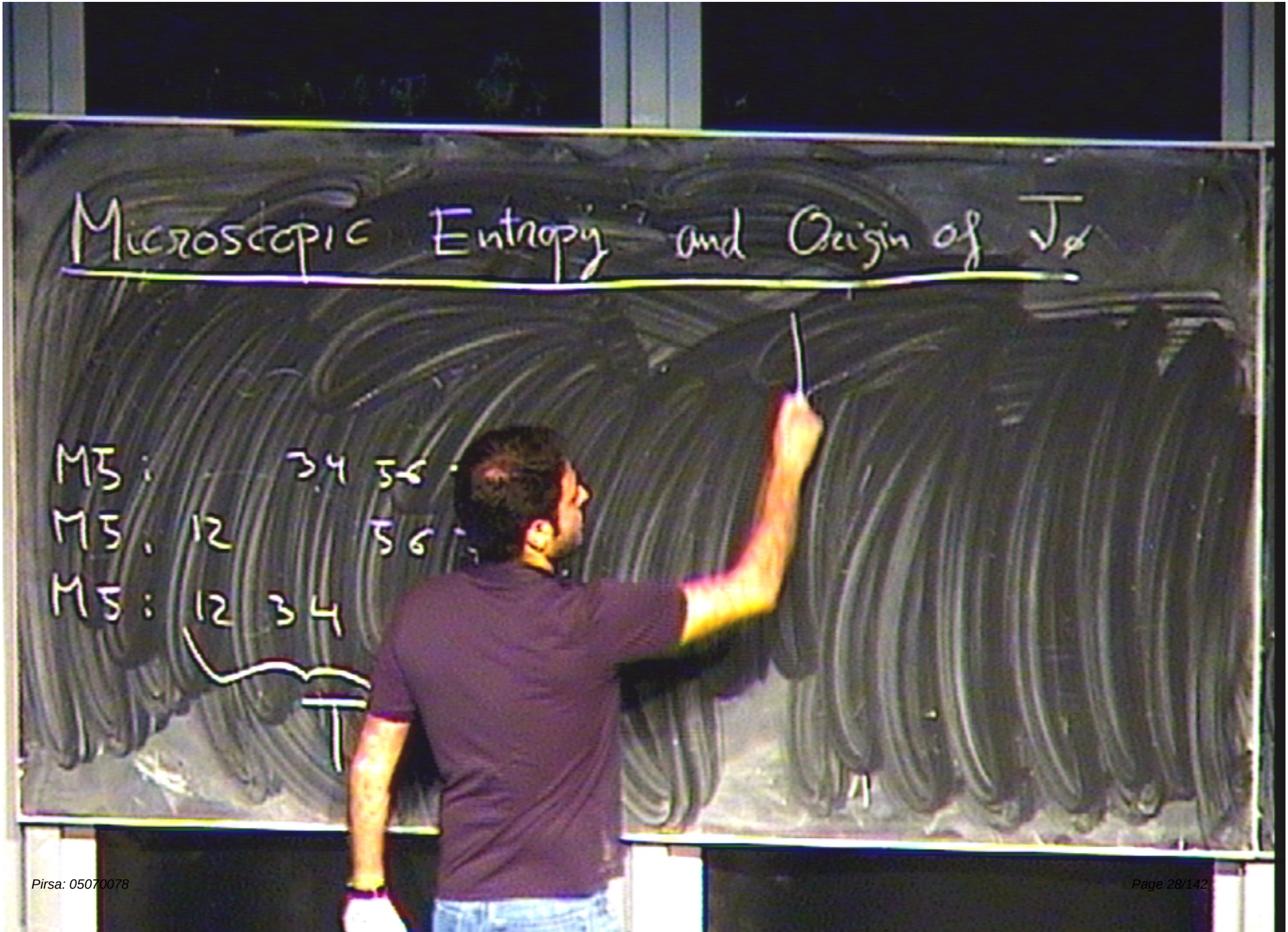

Microscopic Entropy and Origin of J_ϕ
M5 :
M5 :
M5 :

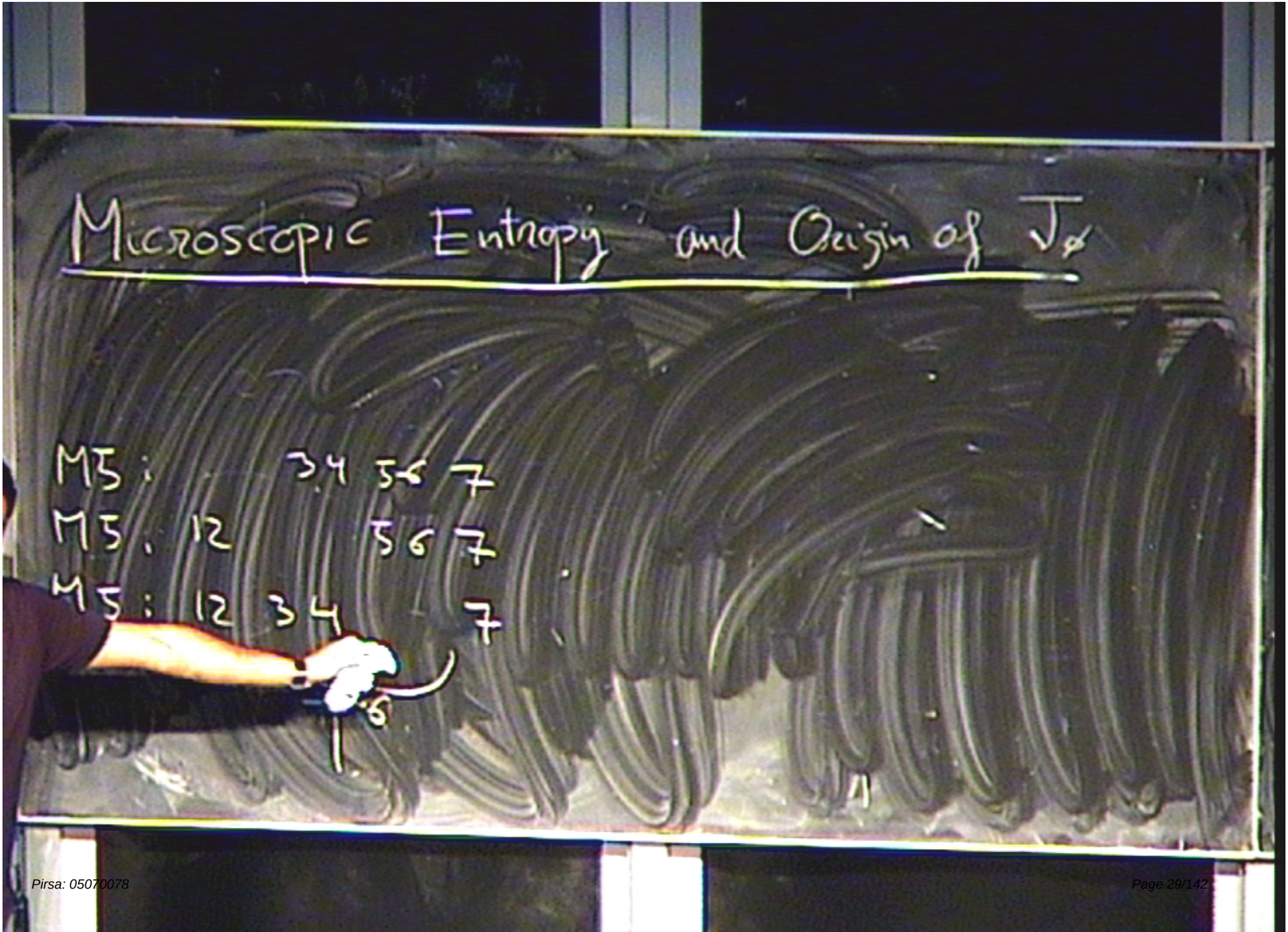

Microscopic Entropy and Origin of J_ϕ
M5: 3 4 5 6 7
M5: 5 6 7
M5: 3 4 7

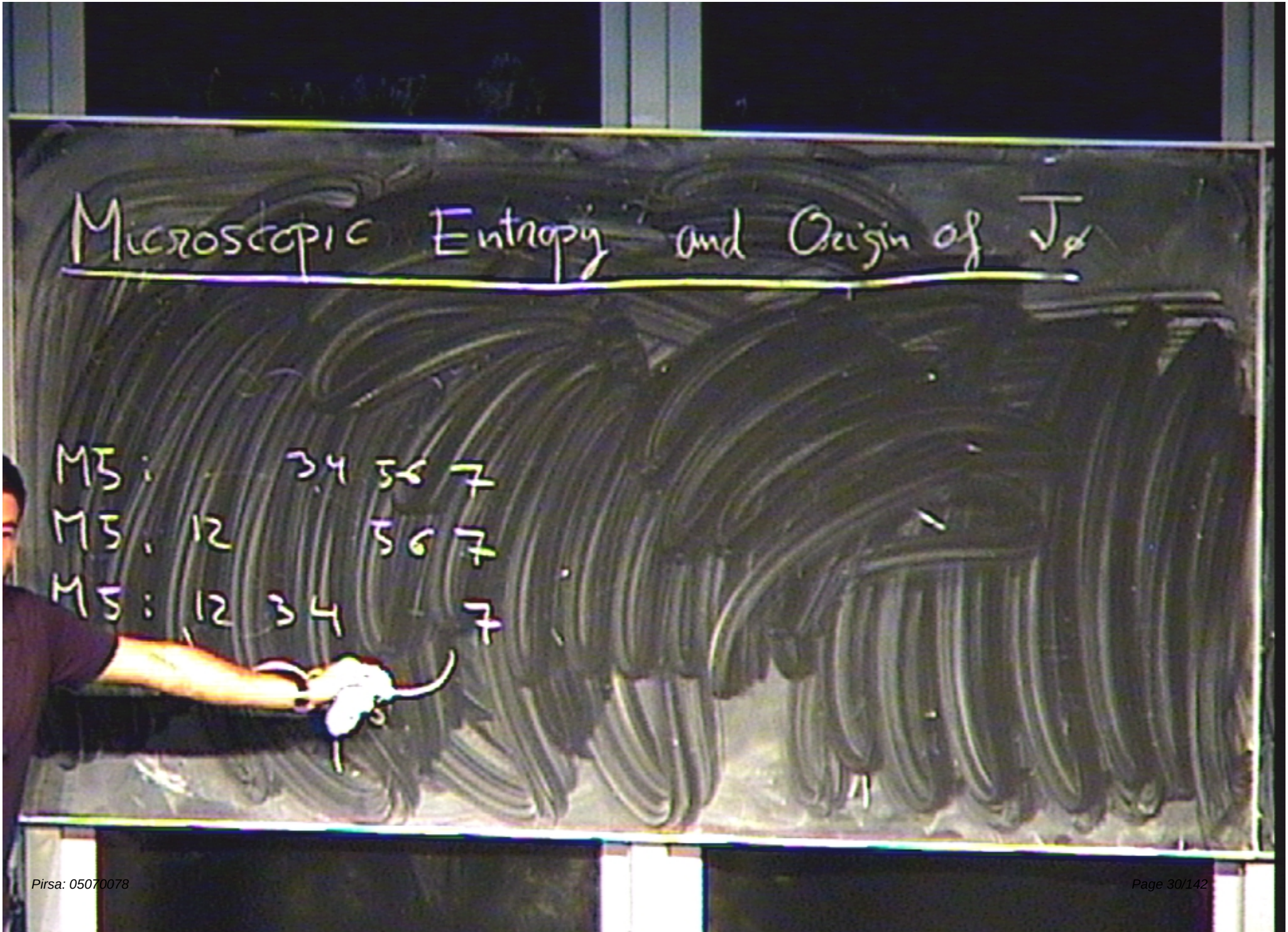

Microscopic Entropy and Origin of J_α
M5: 3 4 5 6 7
M5: 1 2 5 6 7
M5: 1 2 3 4 7


Microscopic Entropy and Origin of J
M3: 3 4 5 6 7
M5: 12 5 6 7
M5: 4 7
6

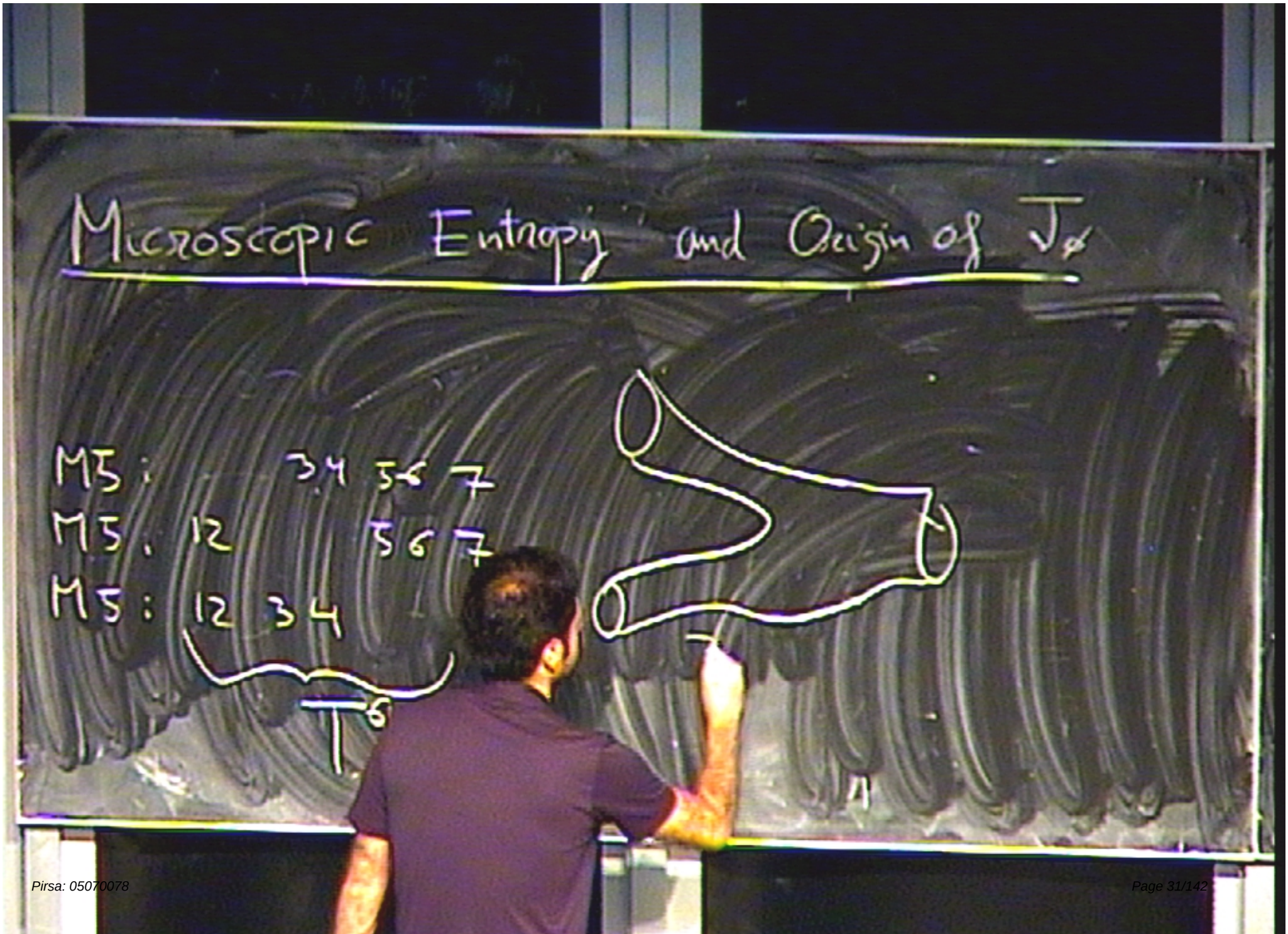

Microscopic Entropy and Origin of J₀
M5: 3 4 5 6 7
M5: 1 2 5 6 7
M5: 1 2 3 4 7


Microscopic Entropy and Origin of J_φ
M5 : 34 56
M5 : 12 56
M5 : 12 34


Microscopic Entropy and Origin of J_α
M5 : 3 4 5 6 7
M5 : 1 2 5 6 7
M5 : 1 2 3 4 7
6


Microscopic Entropy and Origin of J_α
M5: 3 4 5 6 7
M5: 1 2 5 6 7
M5: 1 2 3 4 7

Microscopic Entropy and Origin of J_ϕ



Microscopic Entropy and Origin of J_α

M5 : 4 5 6 7

M5 : 12 5 6 7

M5 : 1 7

6

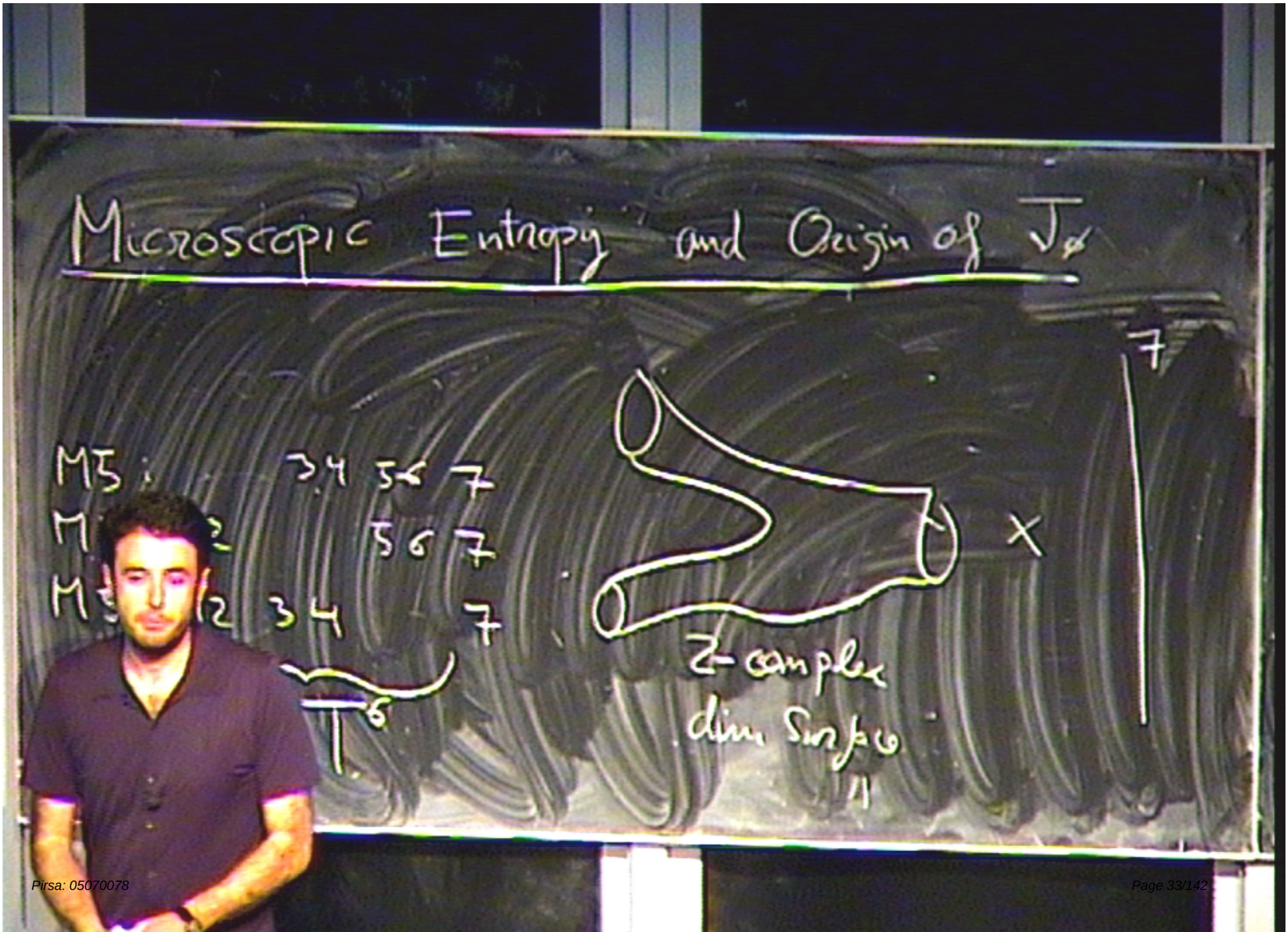


2-complex

dim Surface

11

Microscopic Entropy and Origin of J_α



Microscopic Entropy and Origin of J_α

M5 : 3 4 5 6 7
M5 : 1 2 5 6 7
M5 : 1 2 3 4 7

T^6



2-complex
dim Surface
11

X

7

Microscopic Entropy and Origin of J_ϕ

M5: 3 4 5 6 7
M5: 1 2 5 6 7
M5: 1 2 3 4 7

T^6



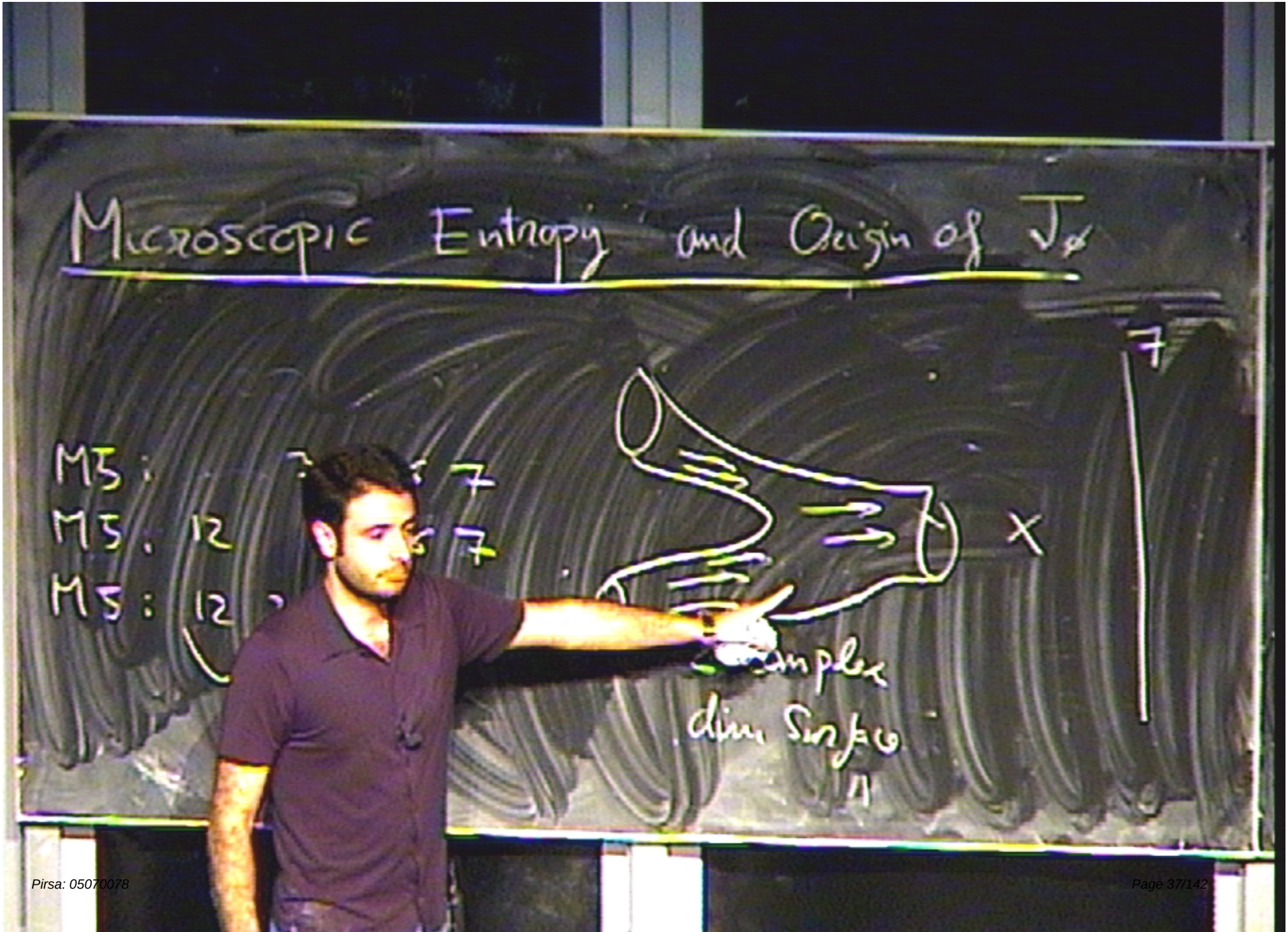
Z-complex
dim Simplex
11

X

7

Microscopic Entropy and Origin of J_α




Microscopic Entropy and Origin of J∂
M3 :
M5 : 12
M5 : 12
x
dim Simplex

Microscopic Entropy and Origin of J_α

M5 : 3 4 5 6
M5 : 1 2 5 6
M5 : 1 2 3 4

T^6



Z-complex
dim Singular
4

Microscopic Entropy and Origin of J_α

M5: 3 4 5 C
M5: 1 2 5 6 C
M5: 1 2 3 4 C

T^6



Z-complex
dim Singular
4

Microscopic Entropy and Origin of J_ϕ

M2: 12

M2: 34

M2:

M5: 34 56 C

M5: 12 56 C

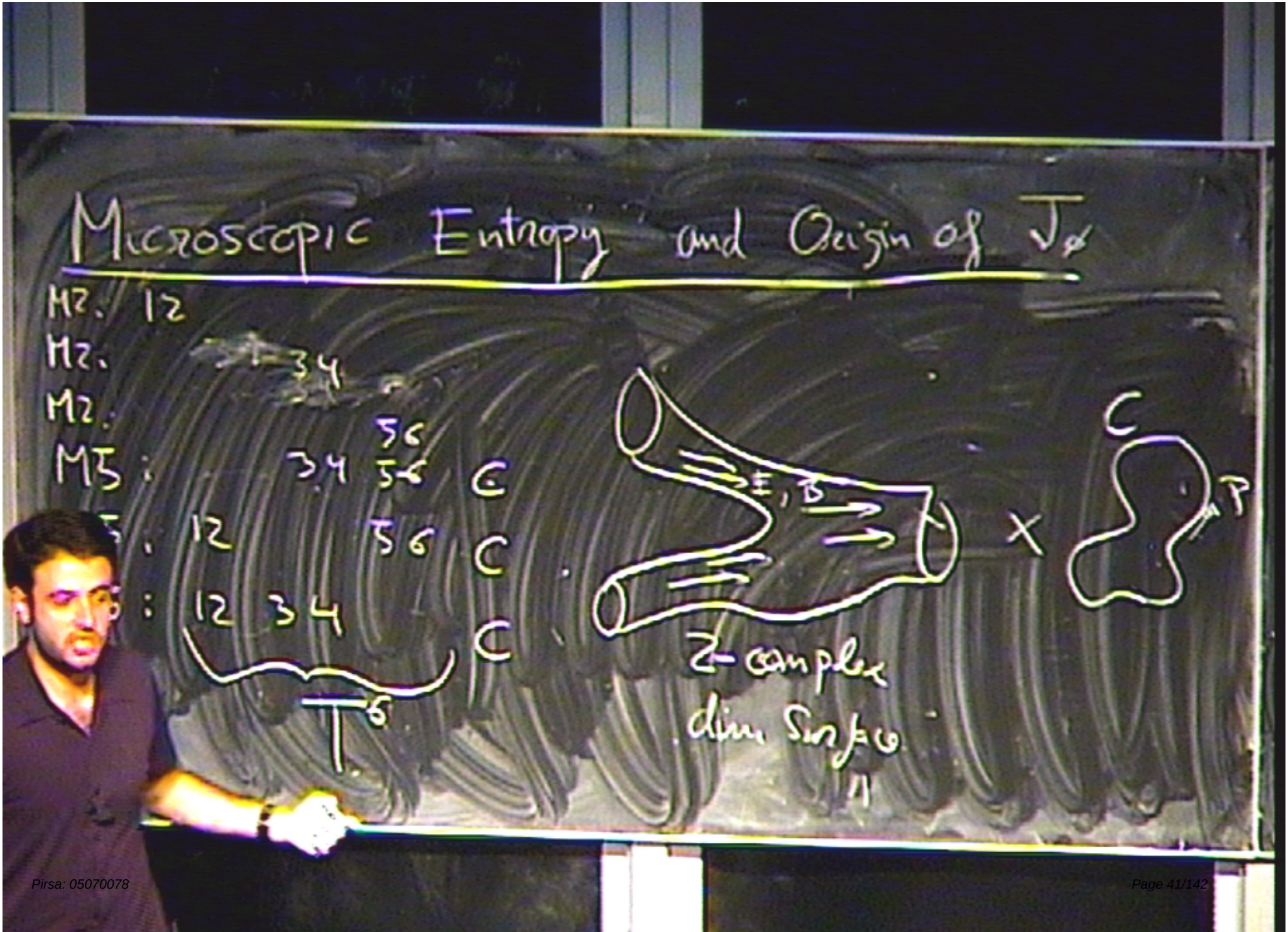
M5: 12 34 C

T^6

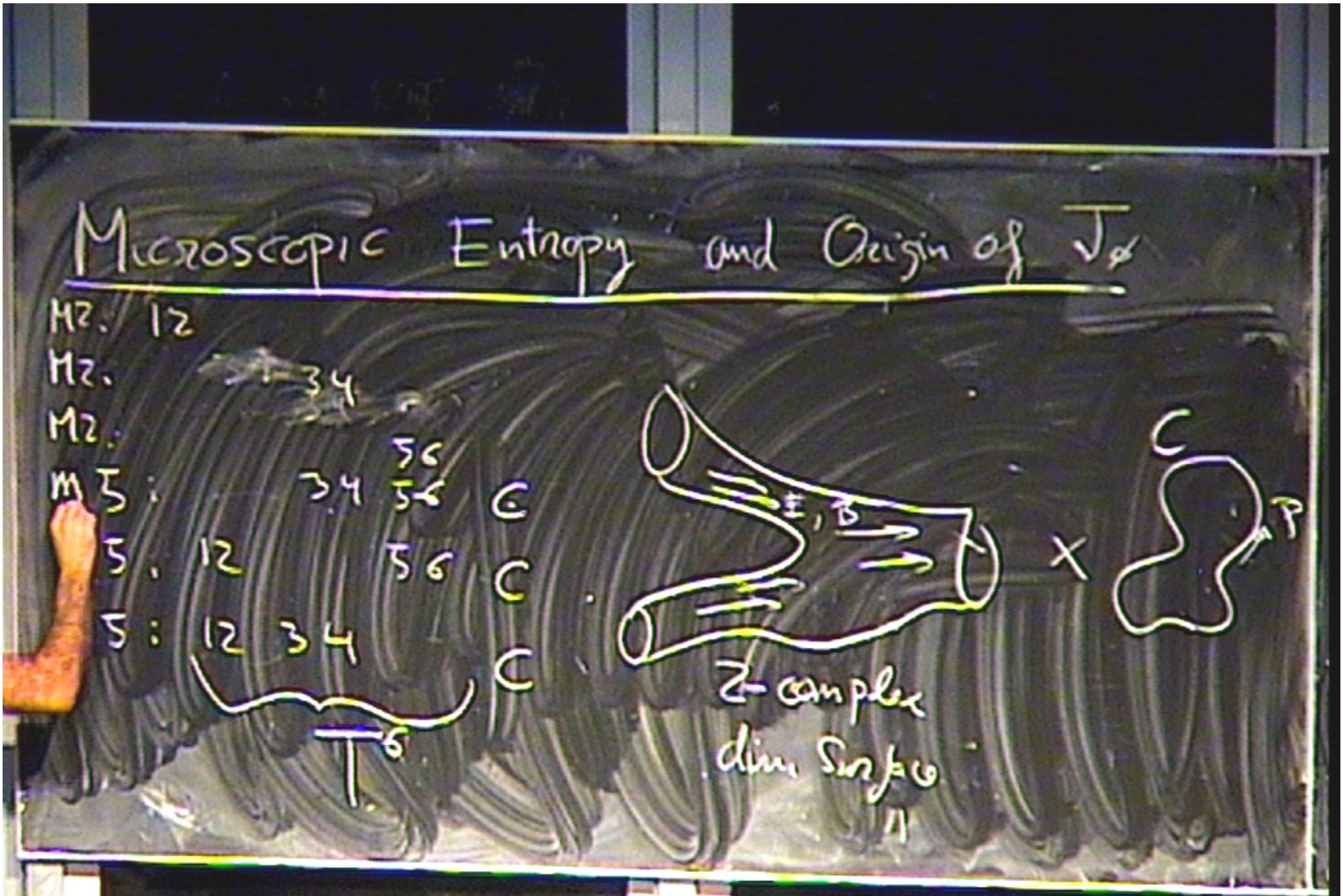


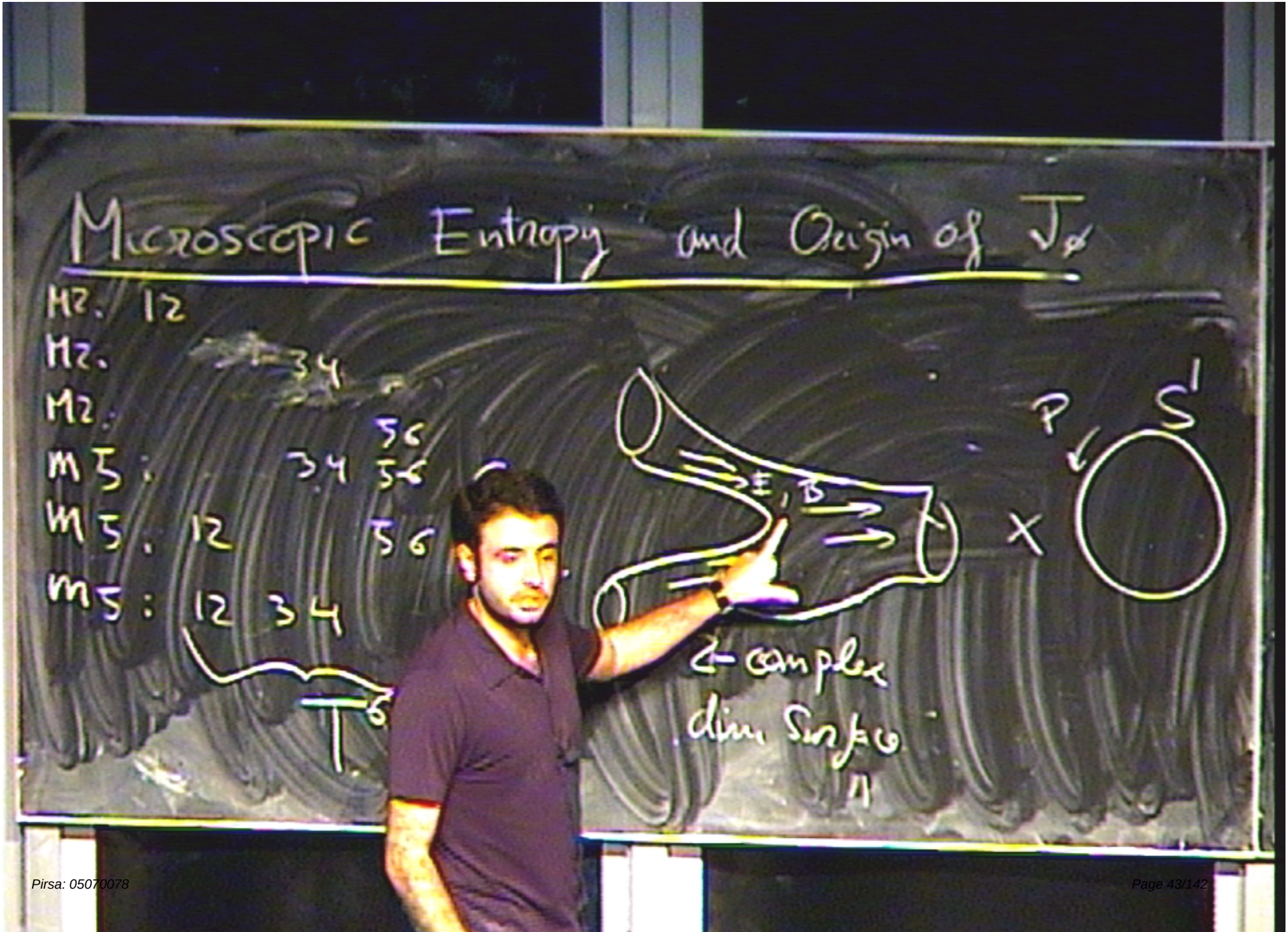
Z_r

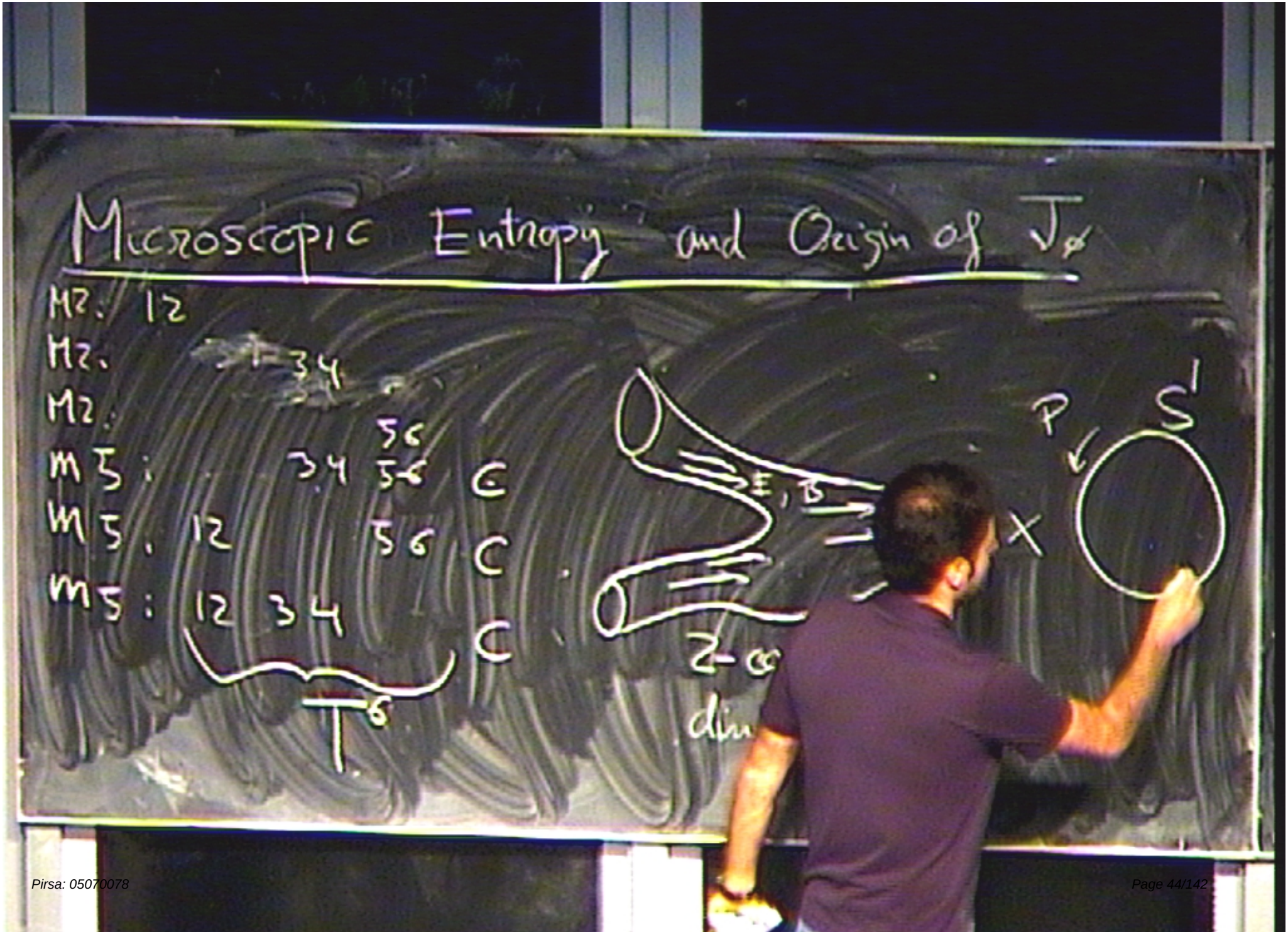
d_1

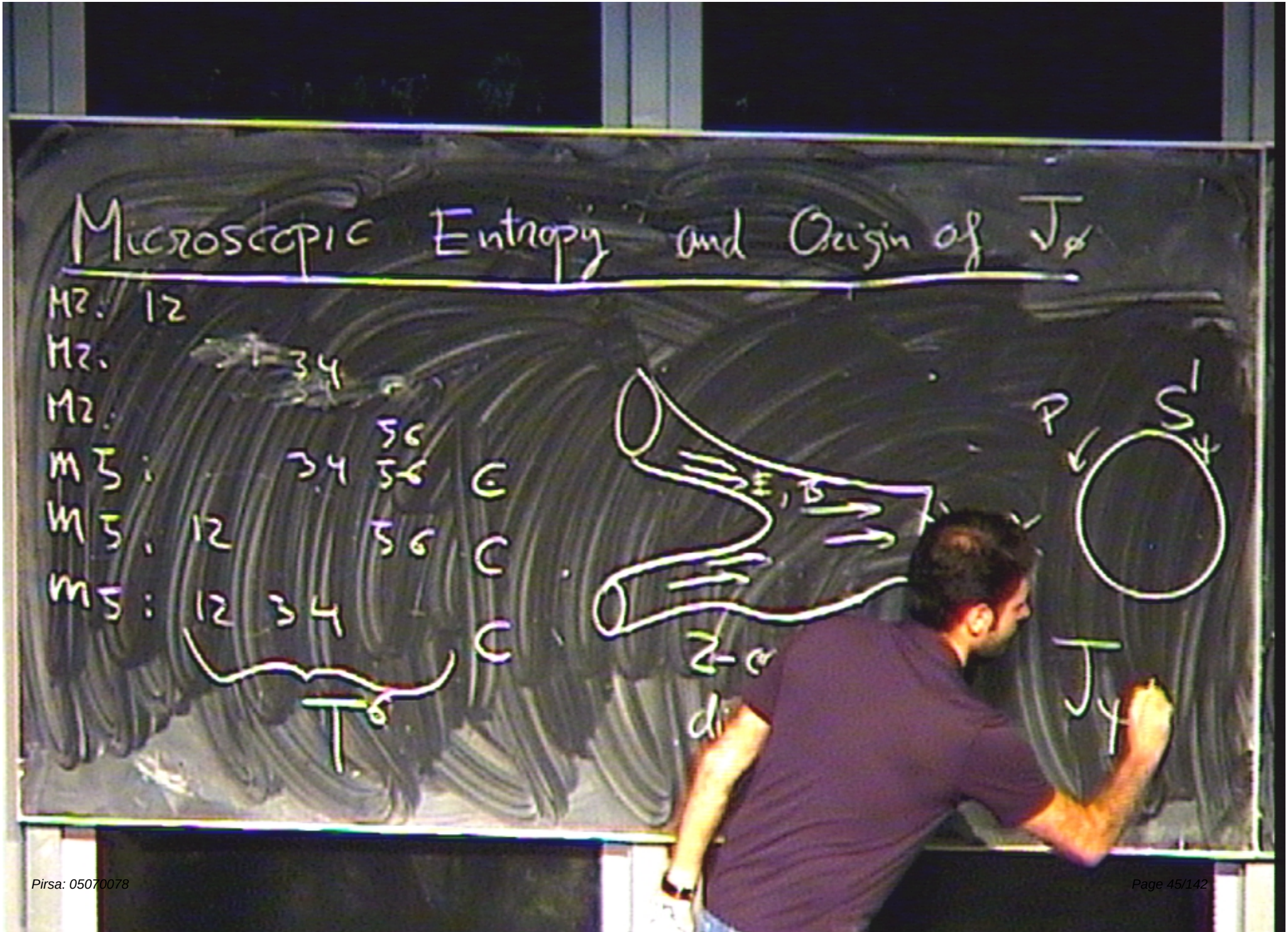

Microscopic Entropy and Origin of J_α
M2. 12
M2. 34
M2. 56
M3: 34 56 C
12 56 C
12 34 C
T^6
E, B
C
P
X
Z-complex
dim Surface
11

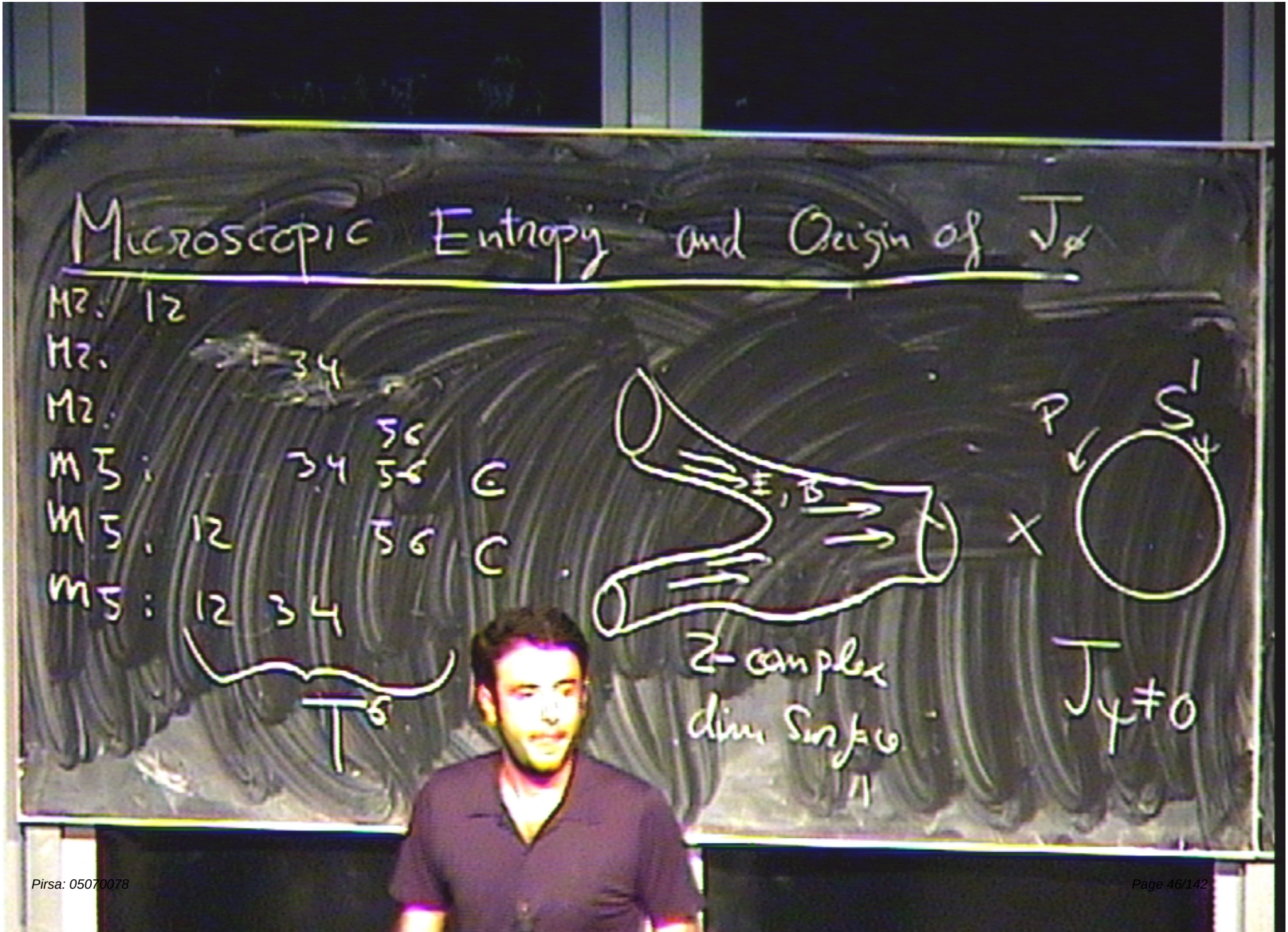
Microscopic Entropy and Origin of J_α




Microscopic Entropy and Origin of J_ϕ
M2: 12
M2: 34
M2: 56
M5: 34 56
M5: 12 56
M5: 12 34
T6
E, B
P
S1
X
← complex
dim Surface
11


Microscopic Entropy and Origin of J_0
M2: 12
M2: 34
M2: 56
M5: 34 56 C
M5: 12 56 C
M5: 12 34 C
T^6
E, B
P
S'
X
Z-CC
dim


Microscopic Entropy and Origin of J_α
P
S
E, B
T
J


Microscopic Entropy and Origin of J_4
M2: 12
M2: 34
M2: 56
M5: 34 56 C
M5: 12 56 C
M5: 12 34
T^6
E, B
Z-complex
dim Singular
P
S^1
X
$J_4 \neq 0$

Microscopic Entropy and Origin of J_ϕ

M2: 12
M2: 34
M2: 56
M5: 34 56 C
M5: 12 56 C
M5: 12 34 C

T^6



2-cycles
dim Singular 4



$J_\psi \neq 0$

Microscopic Entropy and Origin of J_ϕ

M2: 12
M2: 34
M2: 56
M5: 34 56 C
M5: 12 56 C
M5: 12 34 C

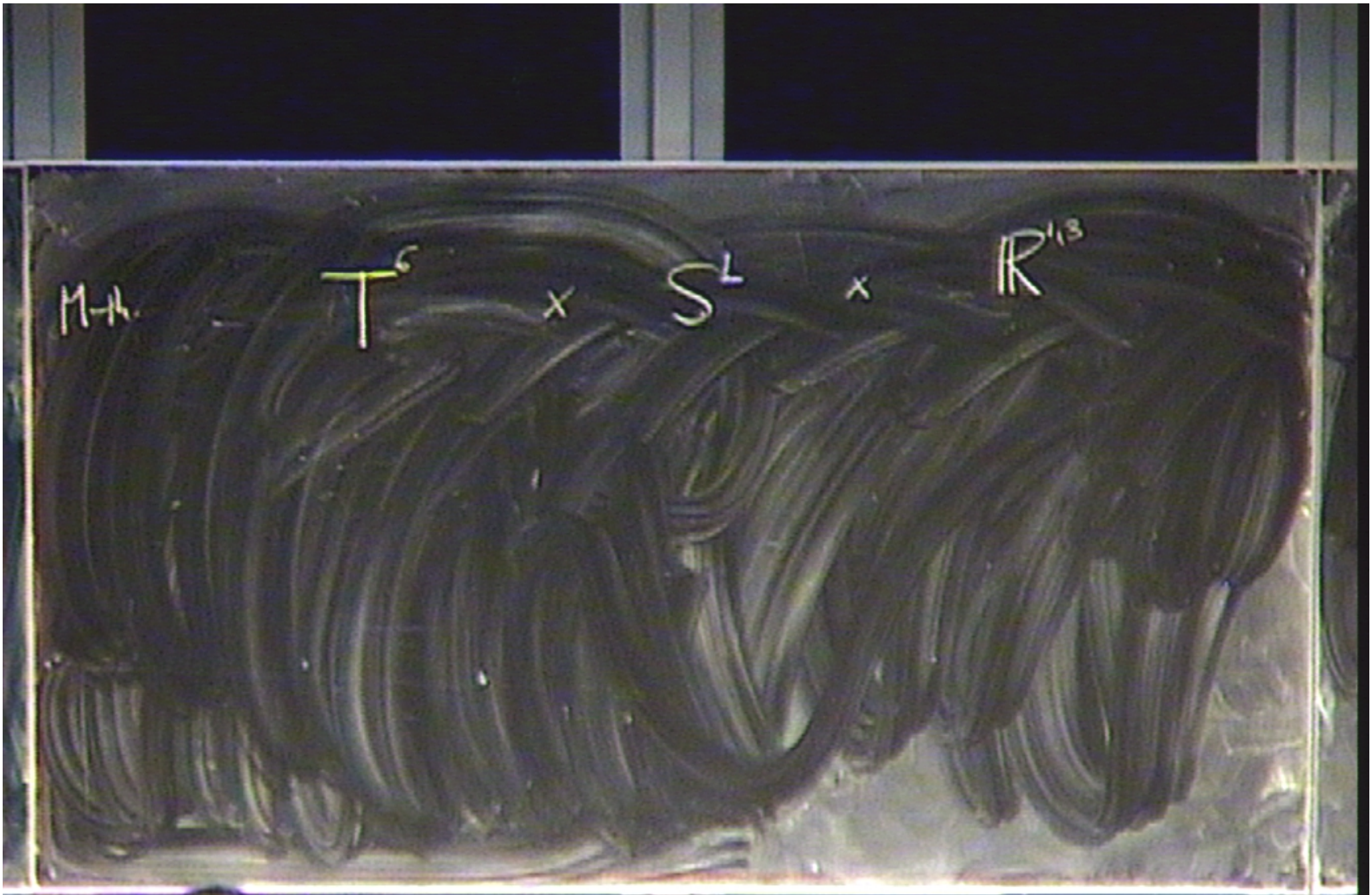
T^6

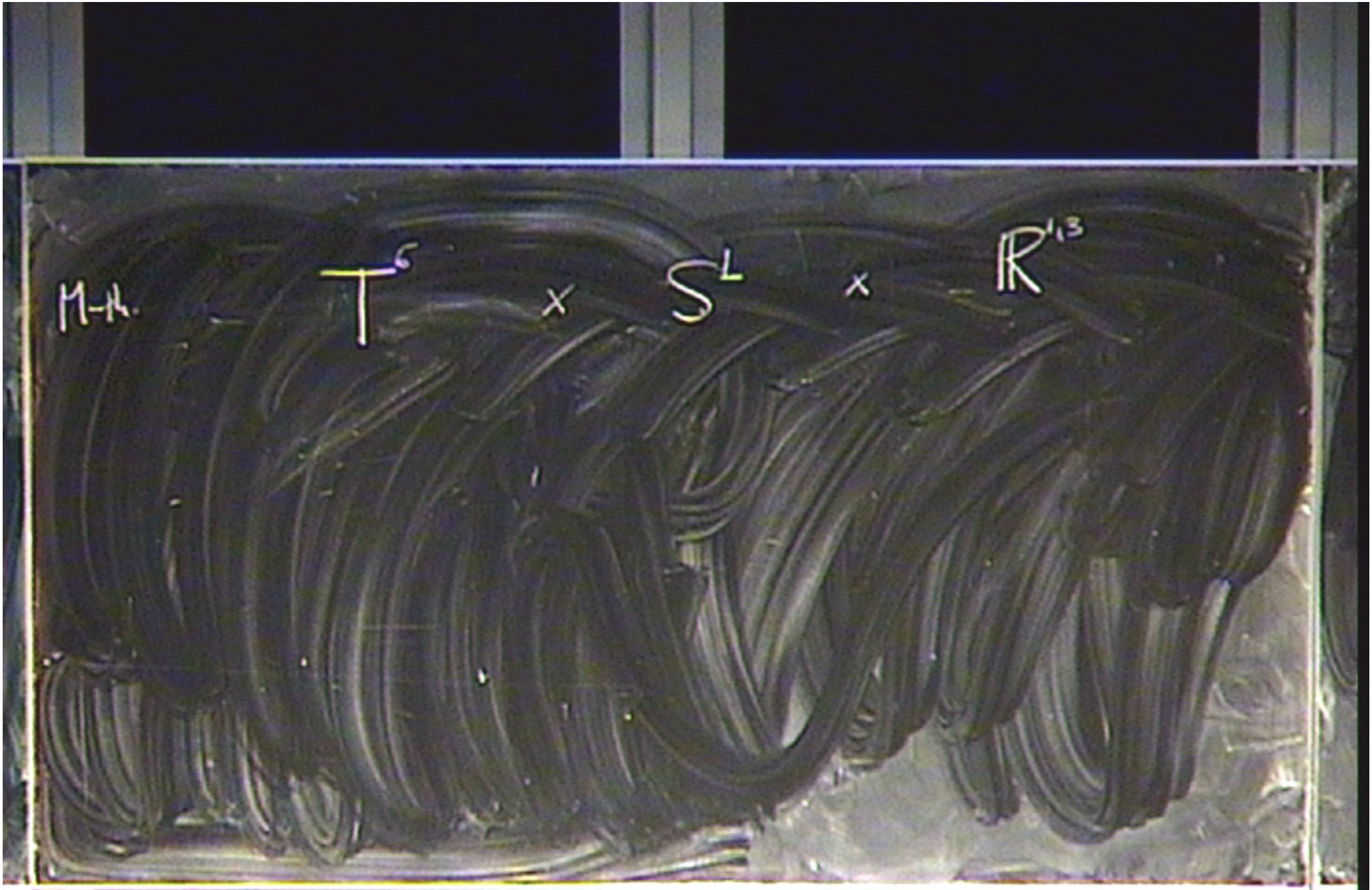


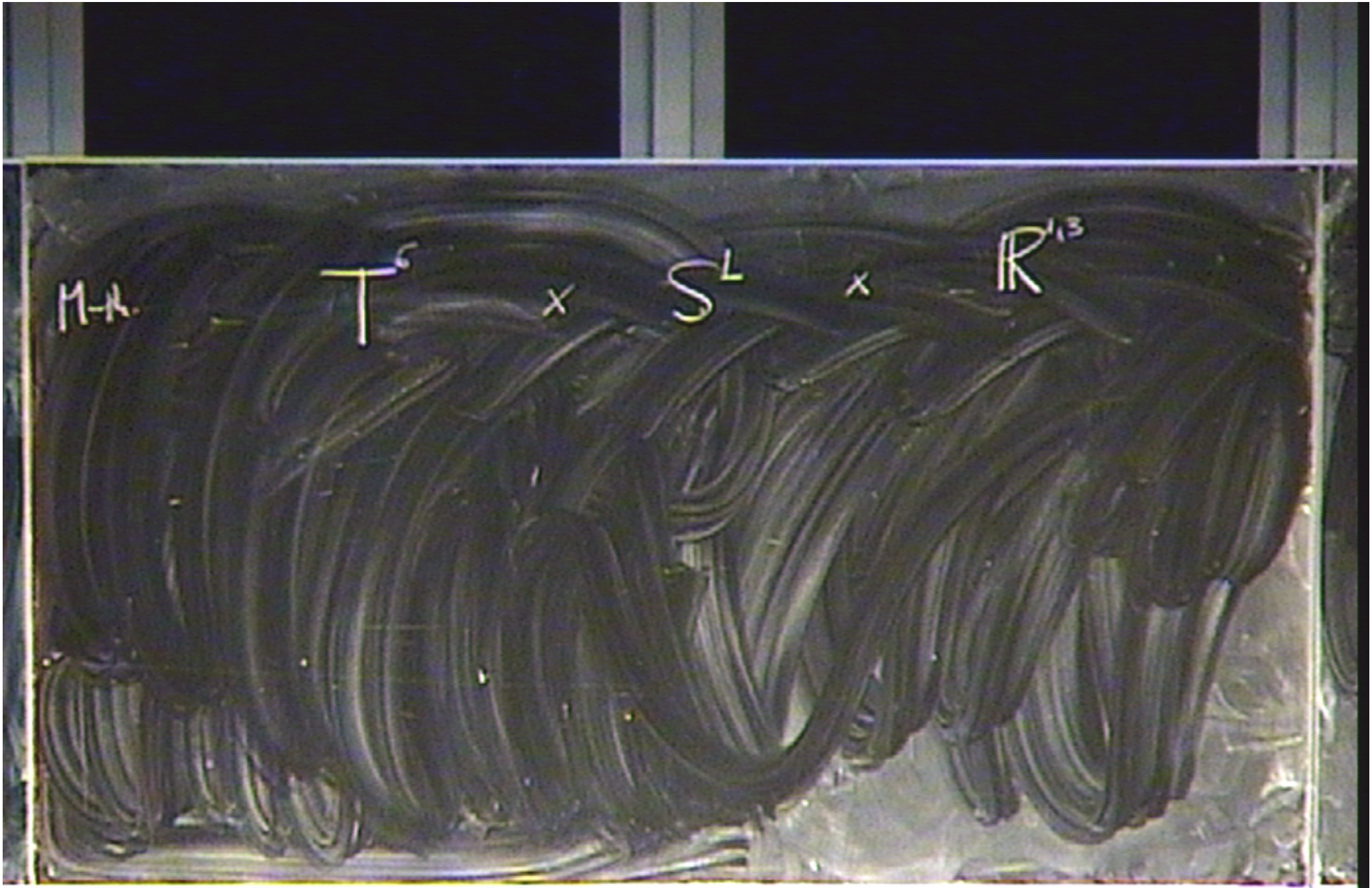
2-complex
dim Singular 1



$J_\psi \neq 0$


M-th.
$T^6 \times S^1 \times \mathbb{R}^{1,3}$


M-H.
$T^6 \times S^L \times \mathbb{R}^{1,3}$


M-R.
$T^6 \times S^L \times \mathbb{R}^{1,3}$

M-th. $T^6 \times S^L \times \mathbb{R}^{13}$

M5



Helm 4-cycle.

M-th. $T^6 \times S^L \times \mathbb{R}^{13}$

M5



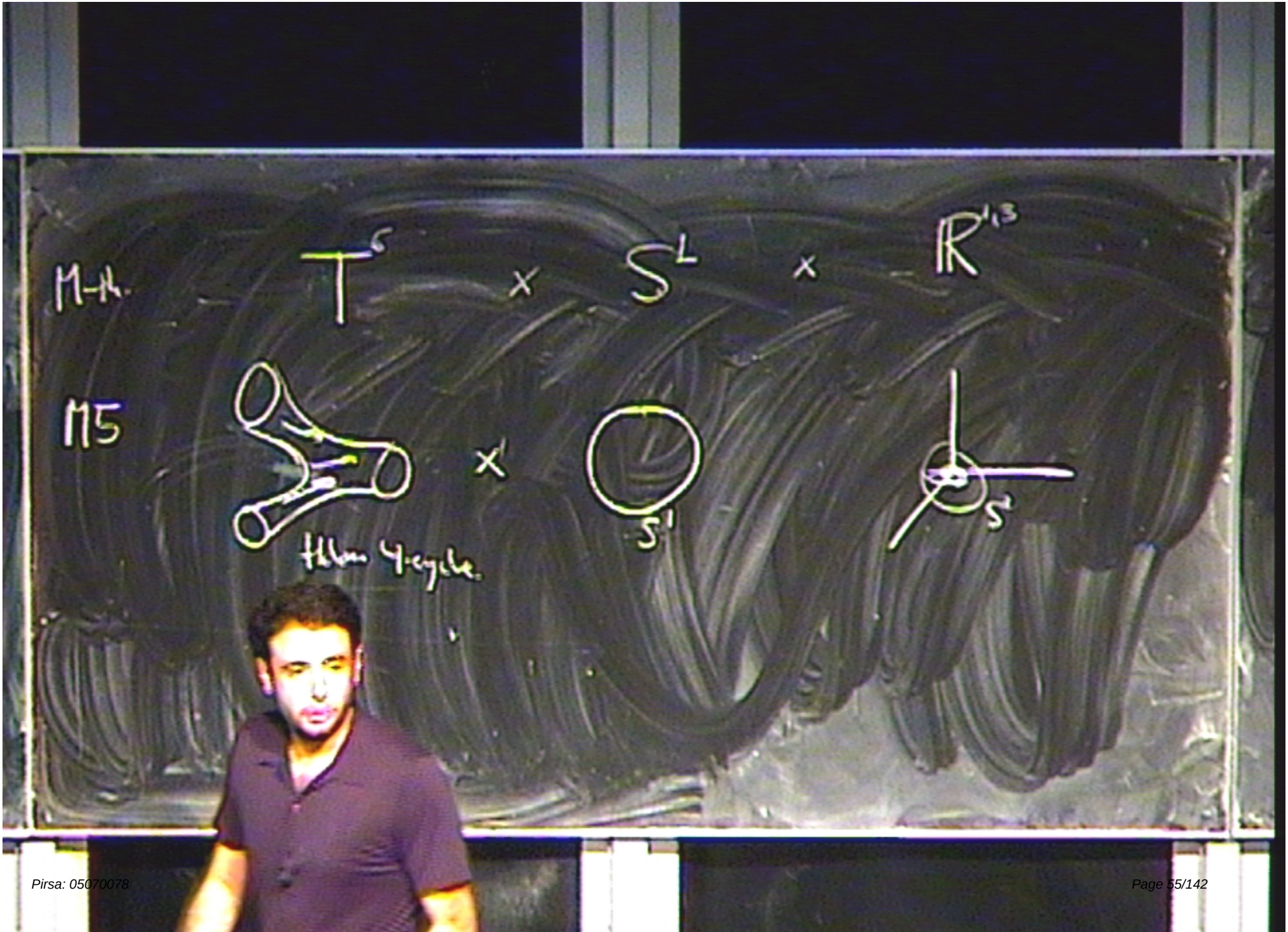
Holom 4-cycle.

M-th. $T^6 \times S^L \times \mathbb{R}^{13}$

M5



Helton 4-cycle.


M-th.
T^6 x S^1 x $\mathbb{R}^{1,3}$
M5
x
S^1
S^1
Helium 4-cycle.

M-th. $T^6 \times S^1 \times \mathbb{R}^{1,3}$

M5



$\times$

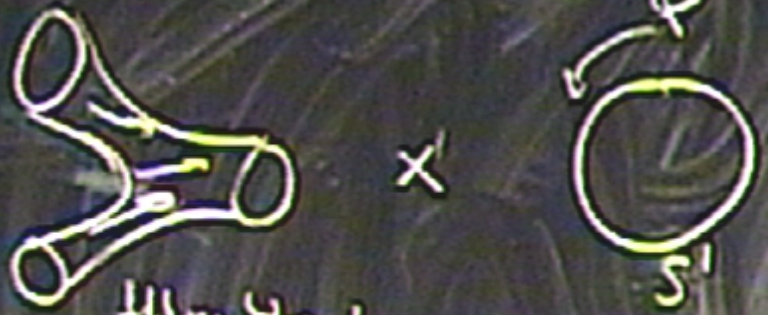


$\times$

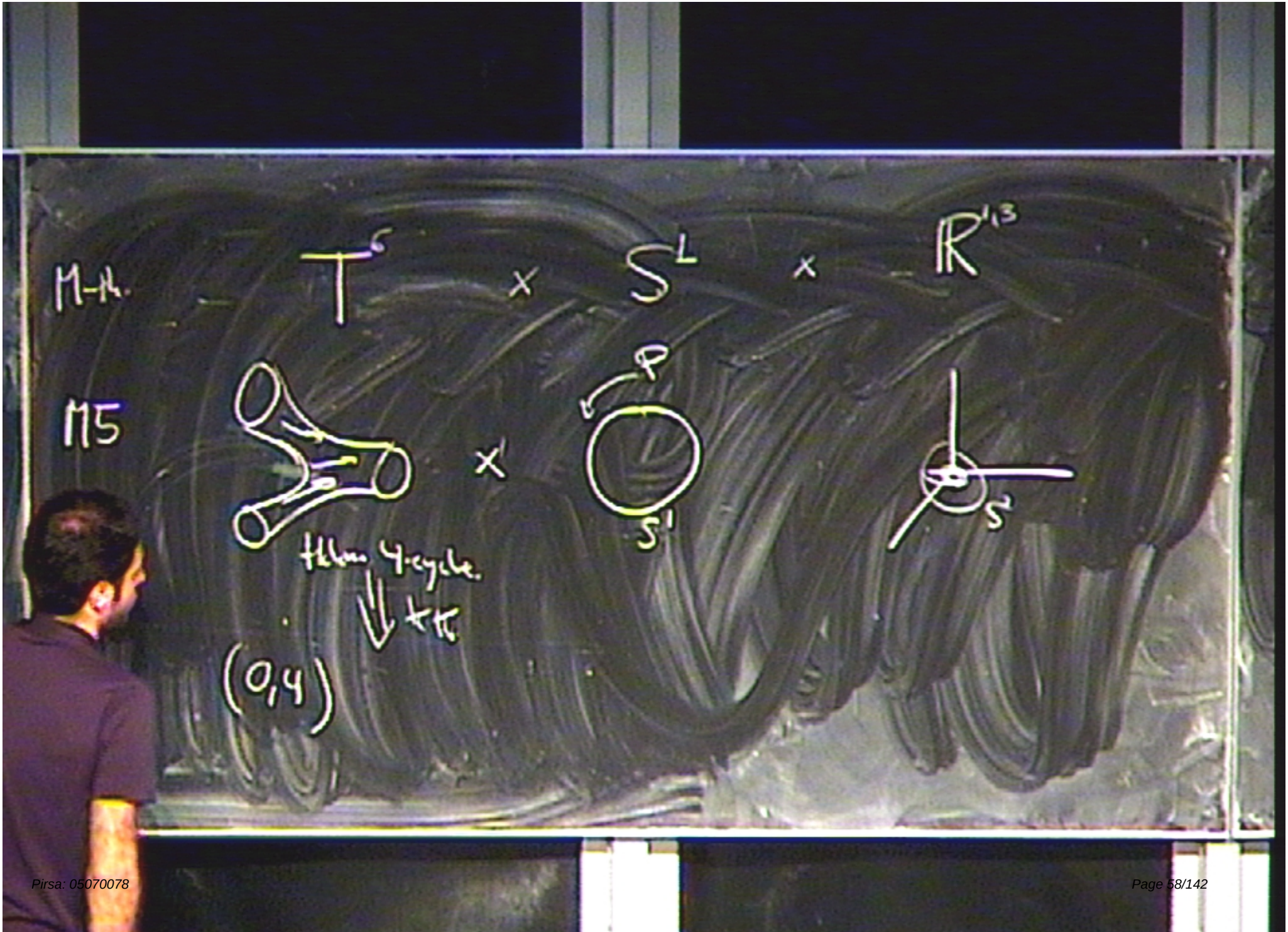


Holonomy 4-cycle.

M-th. $T^6 \times S^1 \times \mathbb{R}^{13}$

M5  $\times$  $\times$ 

Holom 4-cycle.


M-th.
T^6 × S^L × $\mathbb{R}^{13}$
M5
P
S^1
S^5
Klebanov-Tseytlin
(0,4)

M-th. $T^6 \times S^1 \times \mathbb{R}^{1,3}$

M5 

Klein 4-cycle.

$\Downarrow$ t.f.t.

(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$

M-th. $T^6 \times S^L \times \mathbb{R}^{1,3}$

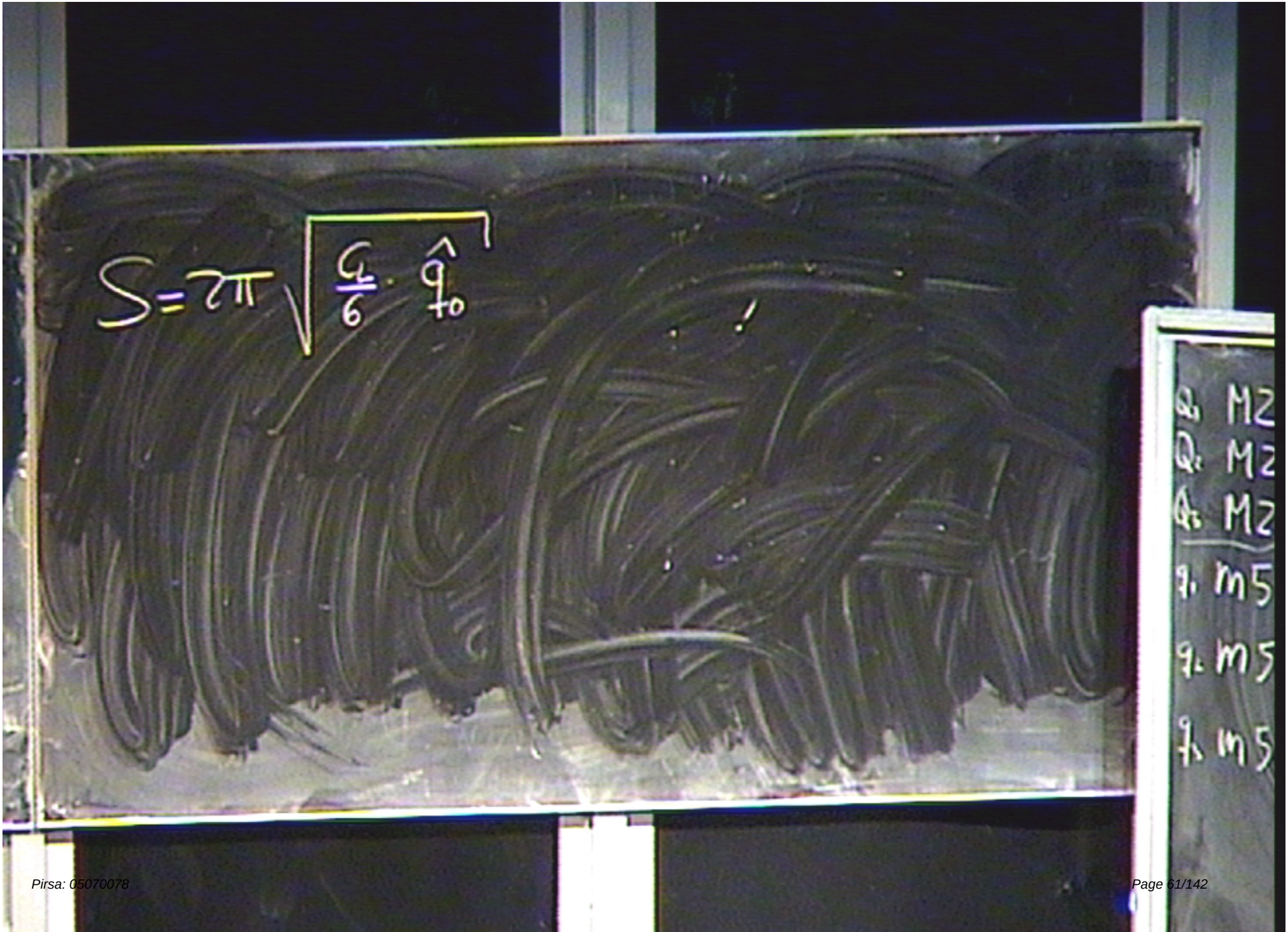
M5

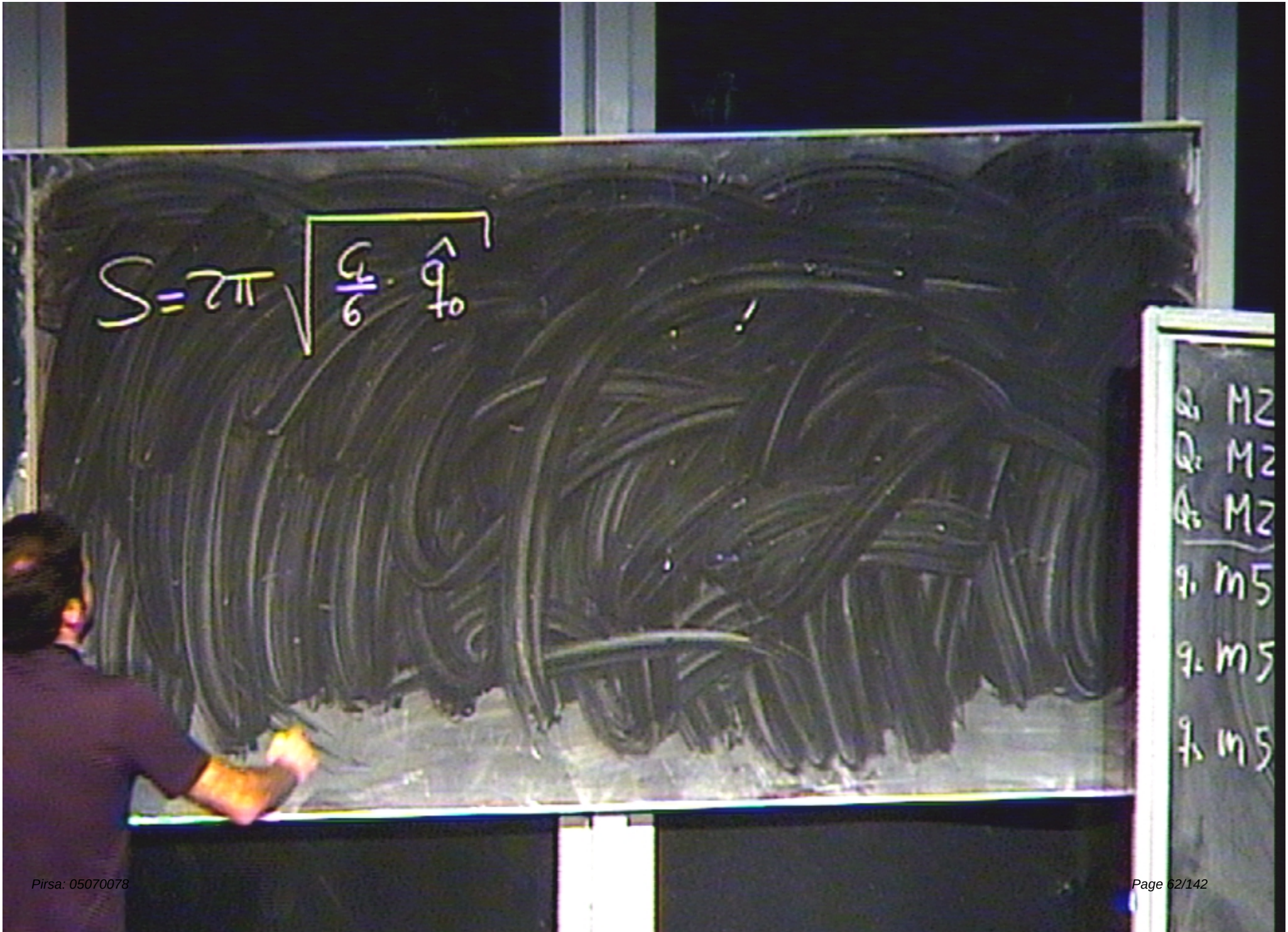


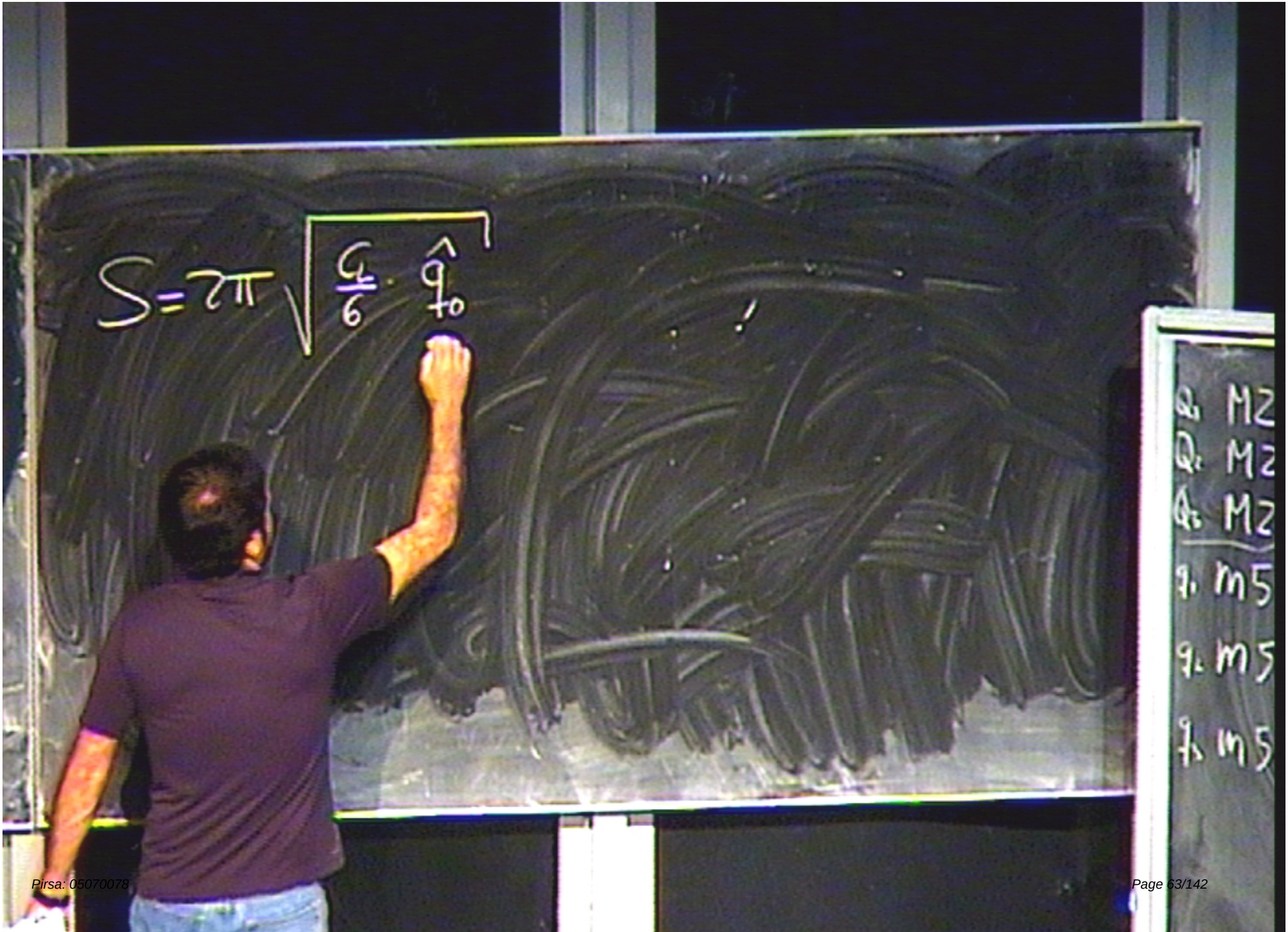
Holom 4-cycle.

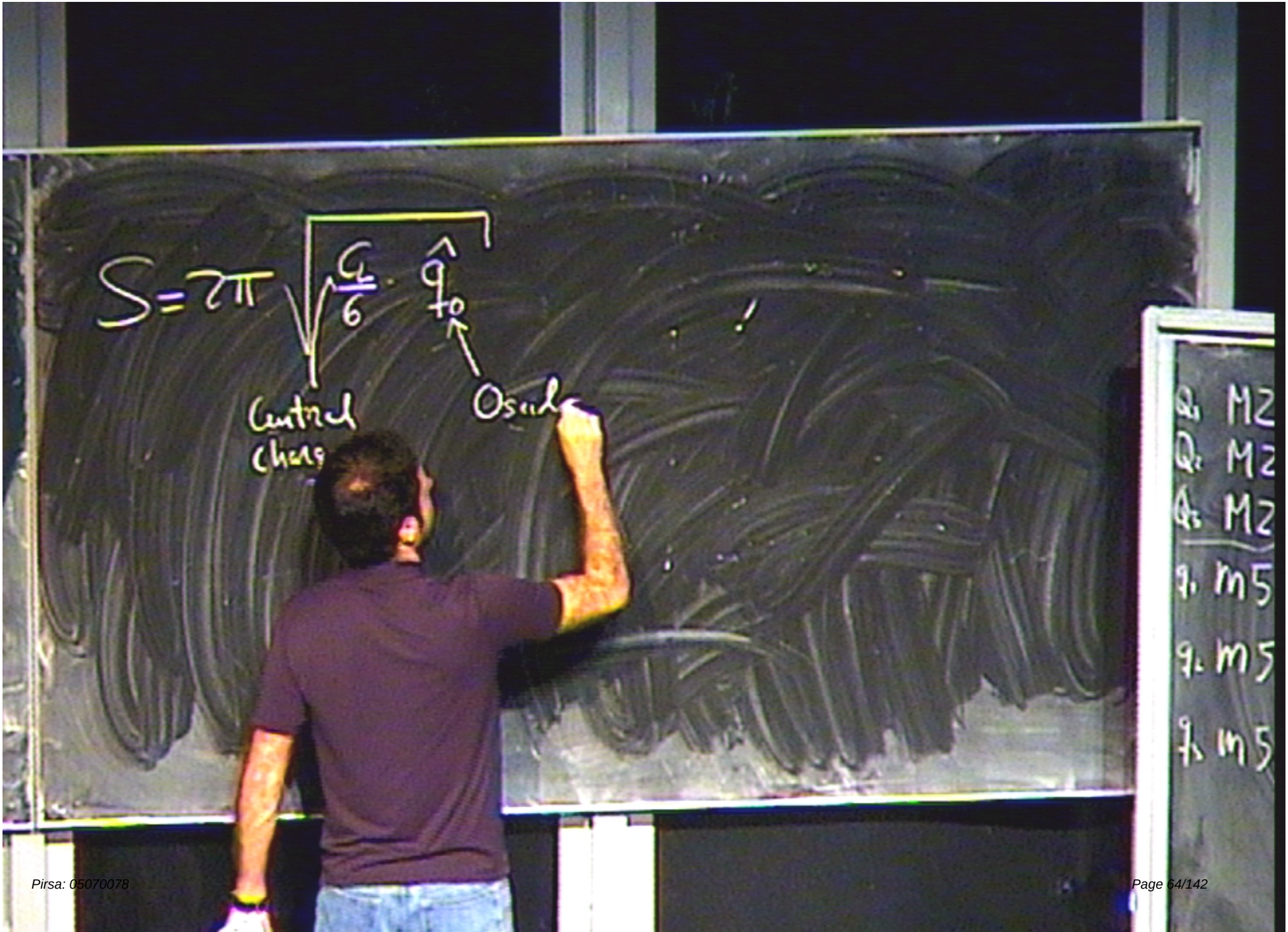
$\Downarrow t \to 0$

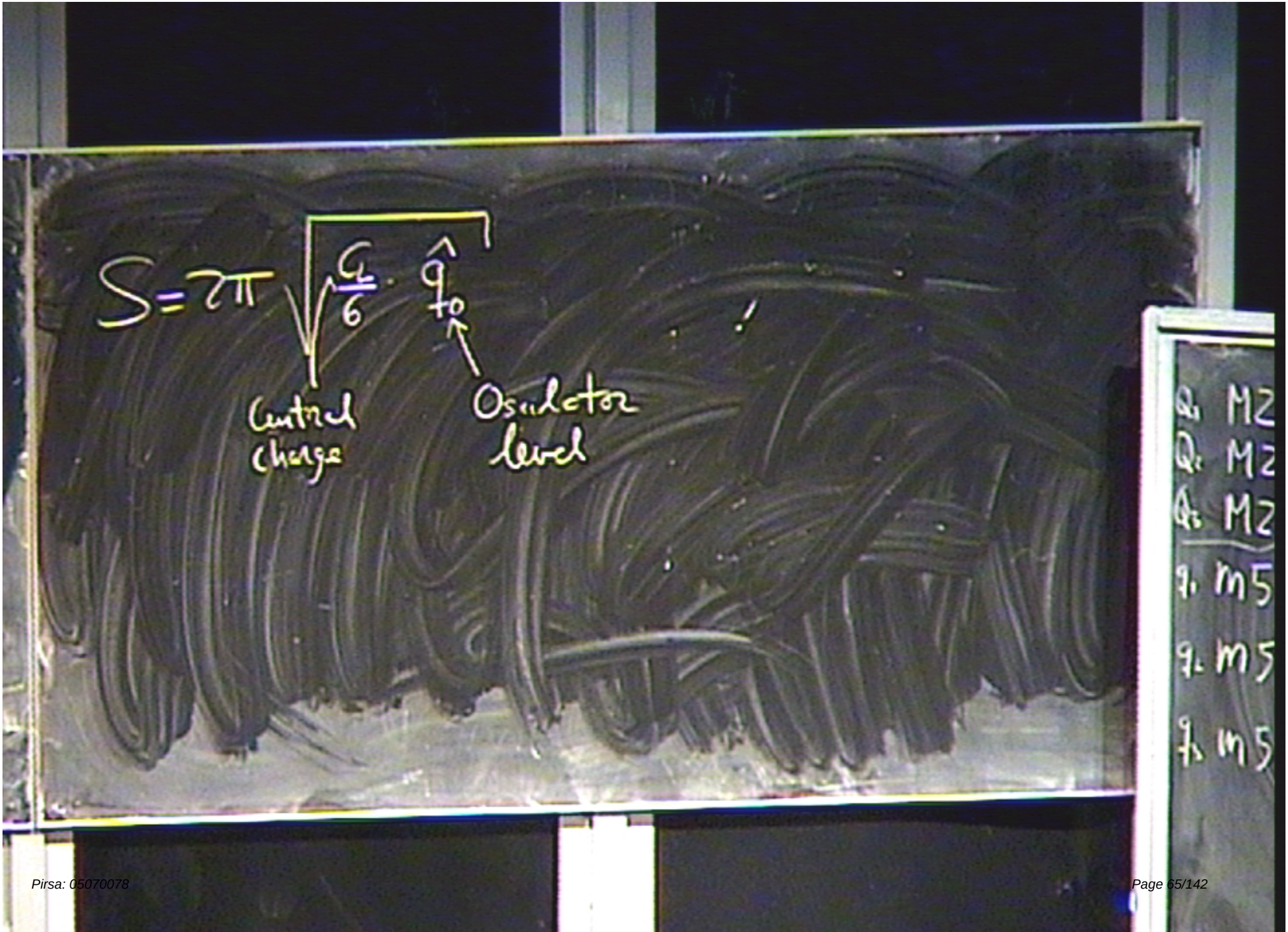
(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$

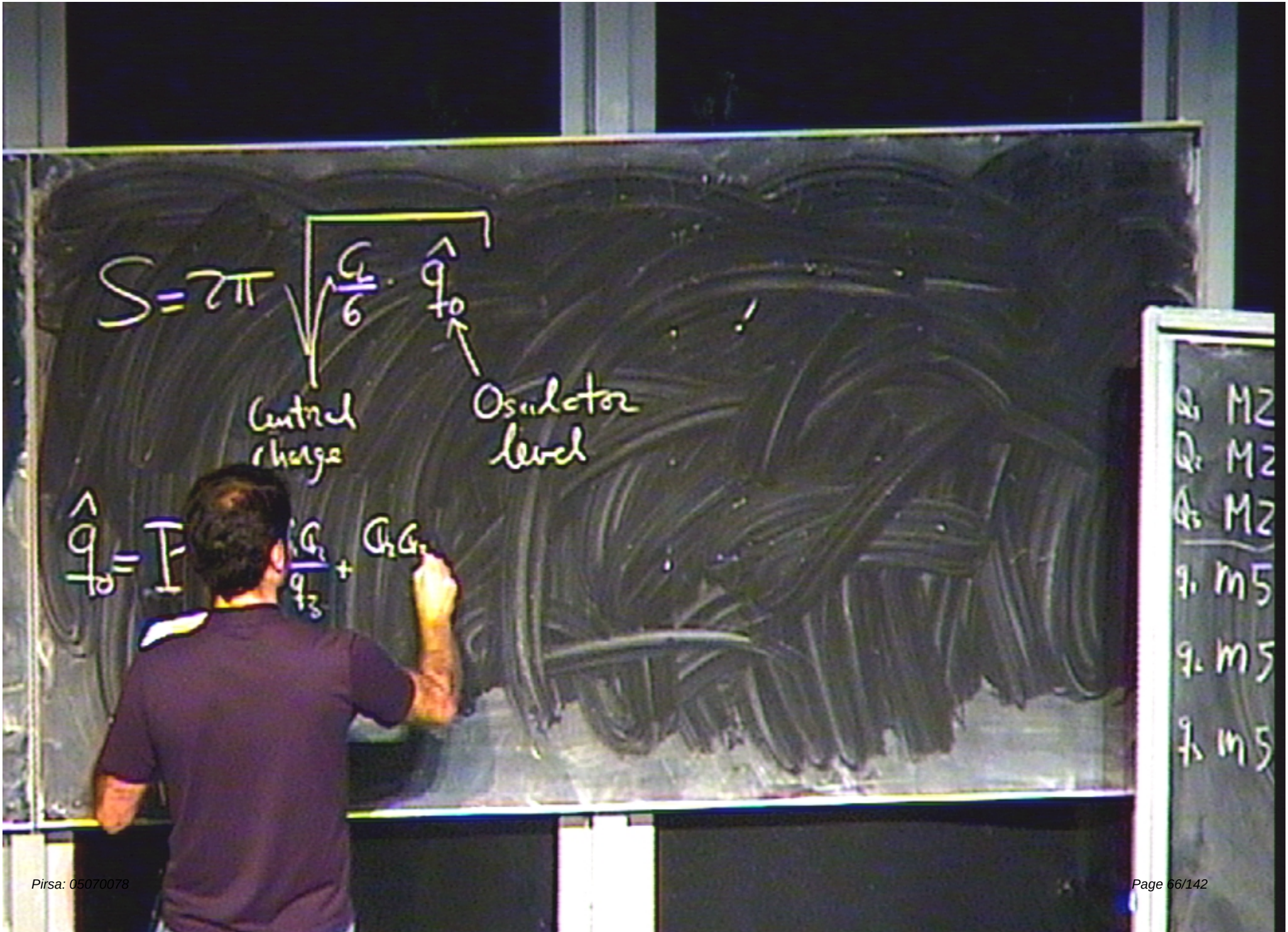

$S = 2\pi\sqrt{\frac{c}{6}\cdot\hat{q}_0}$
q_1 MZ
q_2 MZ
q_3 MZ
q_1 m5
q_2 m5
q_3 m5

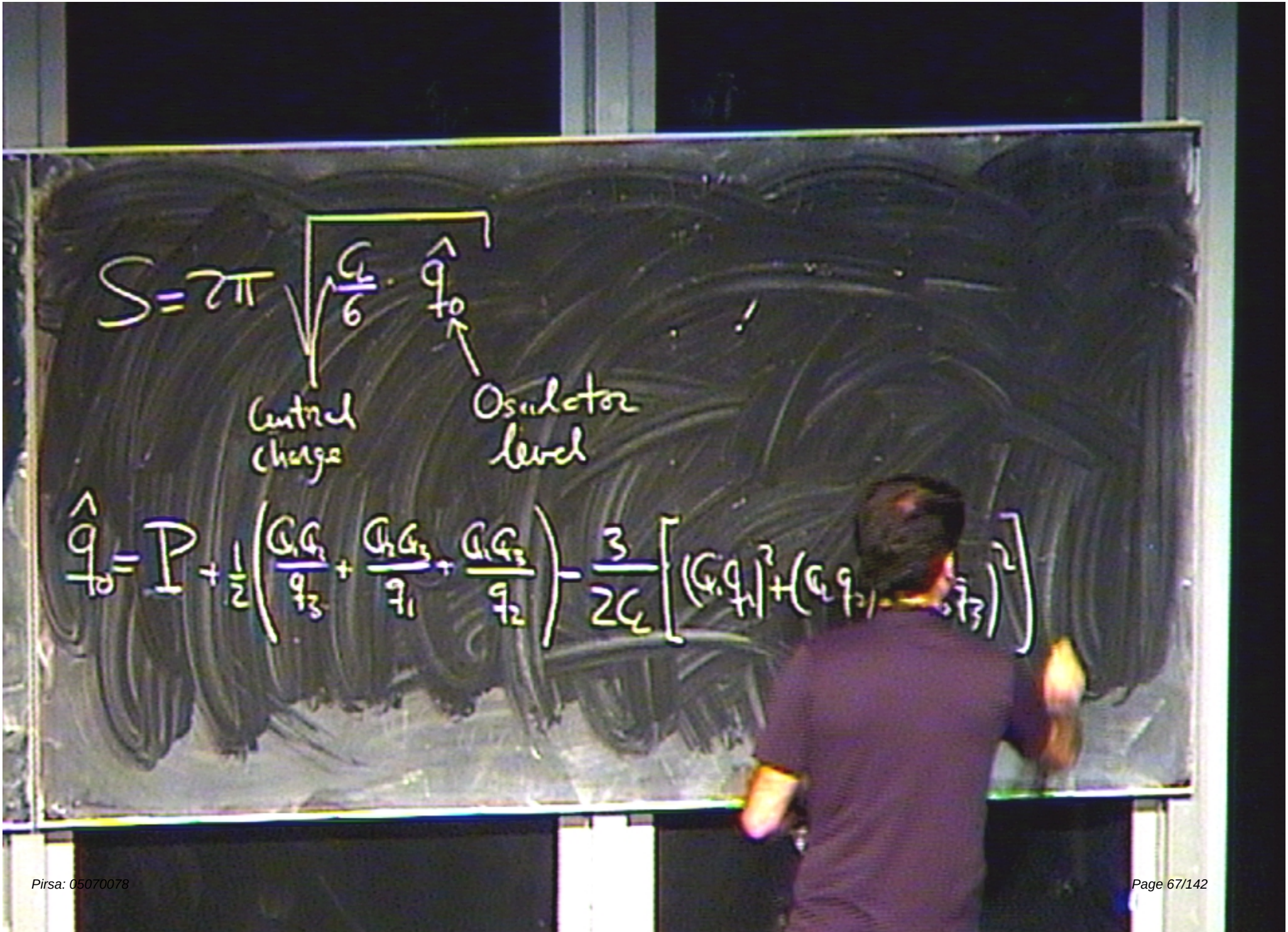

$S = 2\pi\sqrt{\frac{c}{6}\cdot\hat{q}_0}$
Q1 M2
Q2 M2
Q3 M2
q1 m5
q2 m5
q3 m5


$S = 2\pi\sqrt{\frac{c}{6}\cdot\hat{q}_0}$
q_1 m2
q_2 m2
q_3 m2
q_1 m5
q_2 m5
q_3 m5


$S = 2\pi \sqrt{\frac{c}{6} \cdot \hat{q}_0}$
Q1 MZ
Q2 MZ
Q3 MZ
q1 m5
q2 m5
q3 m5


$S = 2\pi \sqrt{\frac{c}{6} \cdot \hat{q}_0}$
Central charge
Oscillator level
Q_1 M2
Q_2 M2
Q_3 M2
q_1 m5
q_2 m5
q_3 m5


$S = 2\pi \sqrt{\frac{C_1}{6} \cdot \hat{q}_0}$
Central charge
Oscillator level
$\hat{q}_0 = I$
$\frac{C_1}{q_3} + C_1 C_2$
Q1 M2
Q2 M2
Q3 M2
q1 m5
q2 m5
q3 m5


$S = 2\pi \sqrt{\frac{C}{6} \cdot \hat{q}_0}$
Central charge
Oscillator level
$\hat{q}_0 = P + \frac{1}{2}\left(\frac{C_1 C_2}{q_3} + \frac{C_2 C_3}{q_1} + \frac{C_1 C_3}{q_2}\right) - \frac{3}{2C}\left[(C_1 q_1)^2 + (C_2 q_2 - C_3 q_3)^2\right]$

$$S = 2\pi \sqrt{\frac{C_4}{6} \cdot \hat{q}_{t_0}}$$

Central charge

Oscillator level

$$\hat{q}_{t_0} = P + \frac{1}{2}\left(\frac{C_1 C_4}{q_3} + \frac{C_2 C_3}{q_1} + \frac{C_3 C_4}{q_2}\right) - \frac{3}{2C_4}\left[(C_1 q_1)^2 + (C_2 q_2)^2 + (C_3 q_3)^2\right] + \frac{C_4}{24}$$

M-th. $T^6 \times S^L \times \mathbb{R}^{1,3}$

M5
(0,2) in D=6







Heim 4-cycle.

$\Downarrow t \to 0$

(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$

M-th. $T^6 \times S^1 \times \mathbb{R}^{1,3}$

M5
(0,2) in D=6



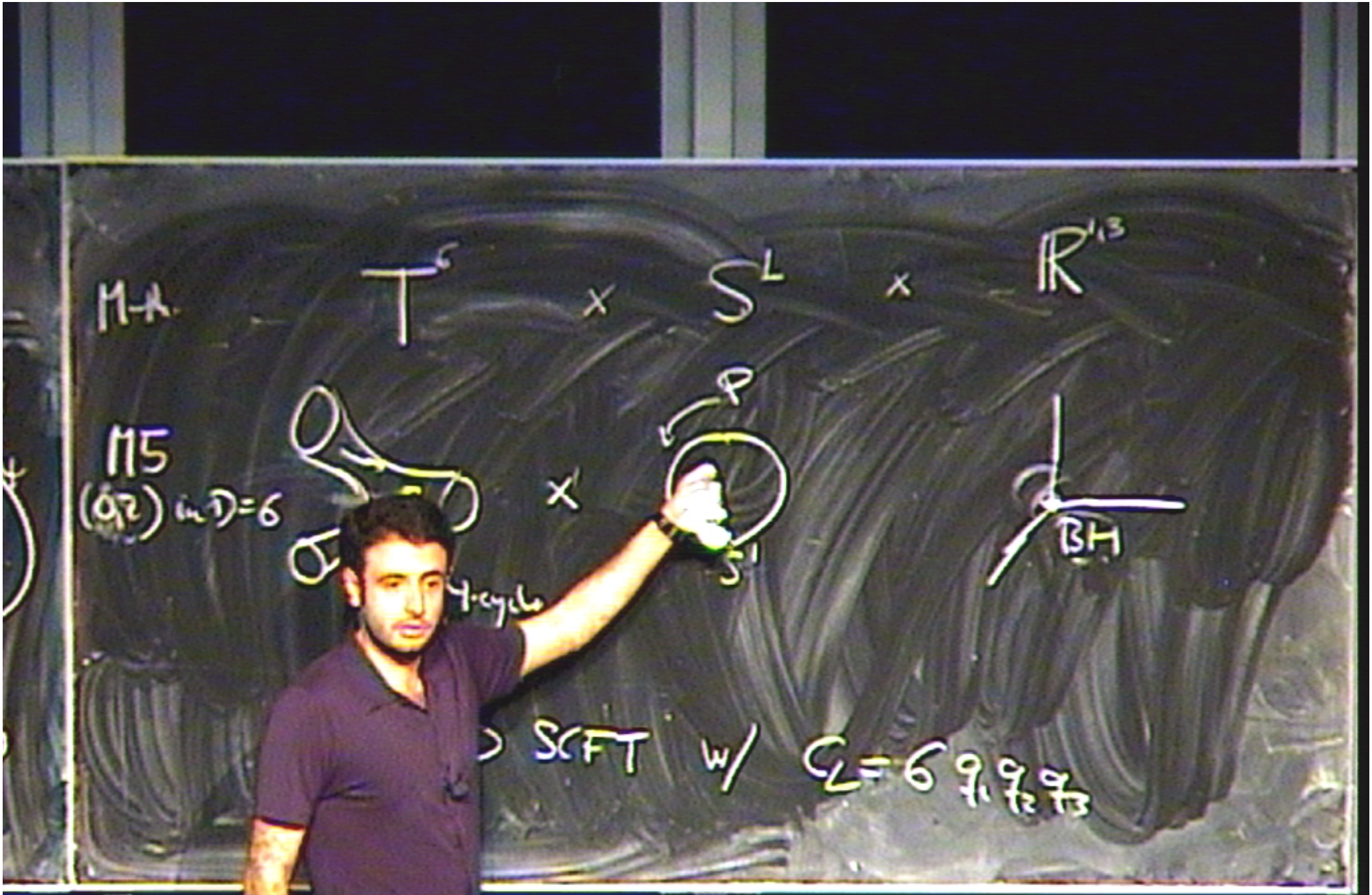
×

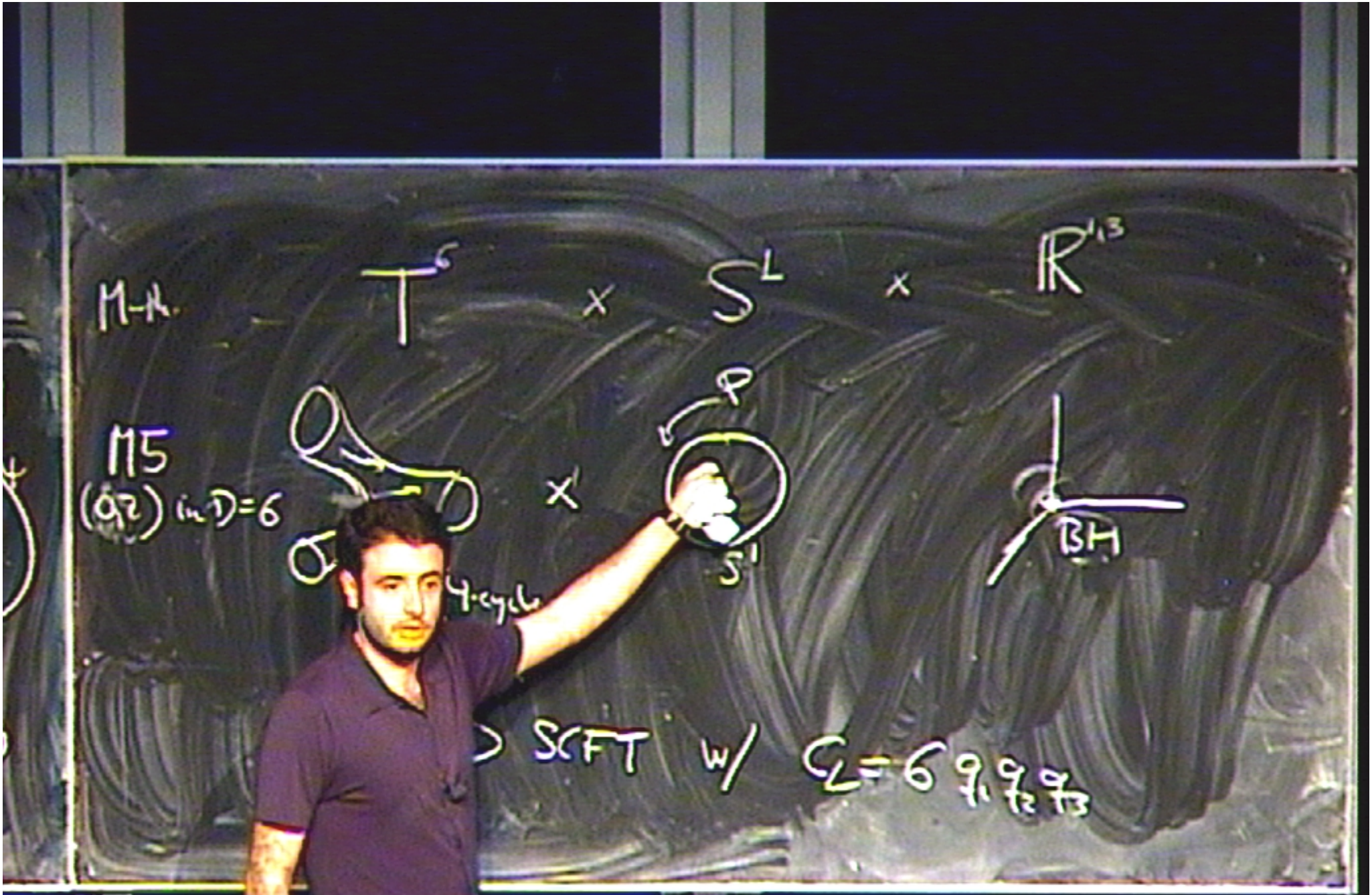




Heim 4-cycle

(0,4) 2D FT w/ $c_L = 6\,9_1 9_2 9_3$


M-th
T^6
x
S^L
x
$\mathbb{R}^{13}$
M5
(0,2) in D=6
x
P
S^1
4-cycle
BH
SCFT w/ $c_L = 6\,9\,9\,9$


M-th.
T^6 x S^L x $\mathbb{R}^{1,3}$
M5
(0,2) in D=6
x
P
S^1
4-cycle
BH
> SCFT w/ $c_L = 6\,q_1 q_2 q_3$

$$S = 2\pi \sqrt{\frac{C_L}{6} \cdot \hat{q}_{to}}$$

Control charge

Oscillator level

$$\hat{q}_{to} = P + \underbrace{\frac{1}{2}\left(\frac{C_1 C_2}{q_3} + \frac{C_2 C_3}{q_1} + \frac{C_1 C_3}{q_2}\right) - \frac{3}{2C_L}\left[(C_1 q_1)^2 + (C_2 q_2)^2 + (C_3 q_3)^2\right]}_{\text{MZ-induced shift}} + \underbrace{\frac{C_L}{24}}_{\text{zero-point shift}}$$

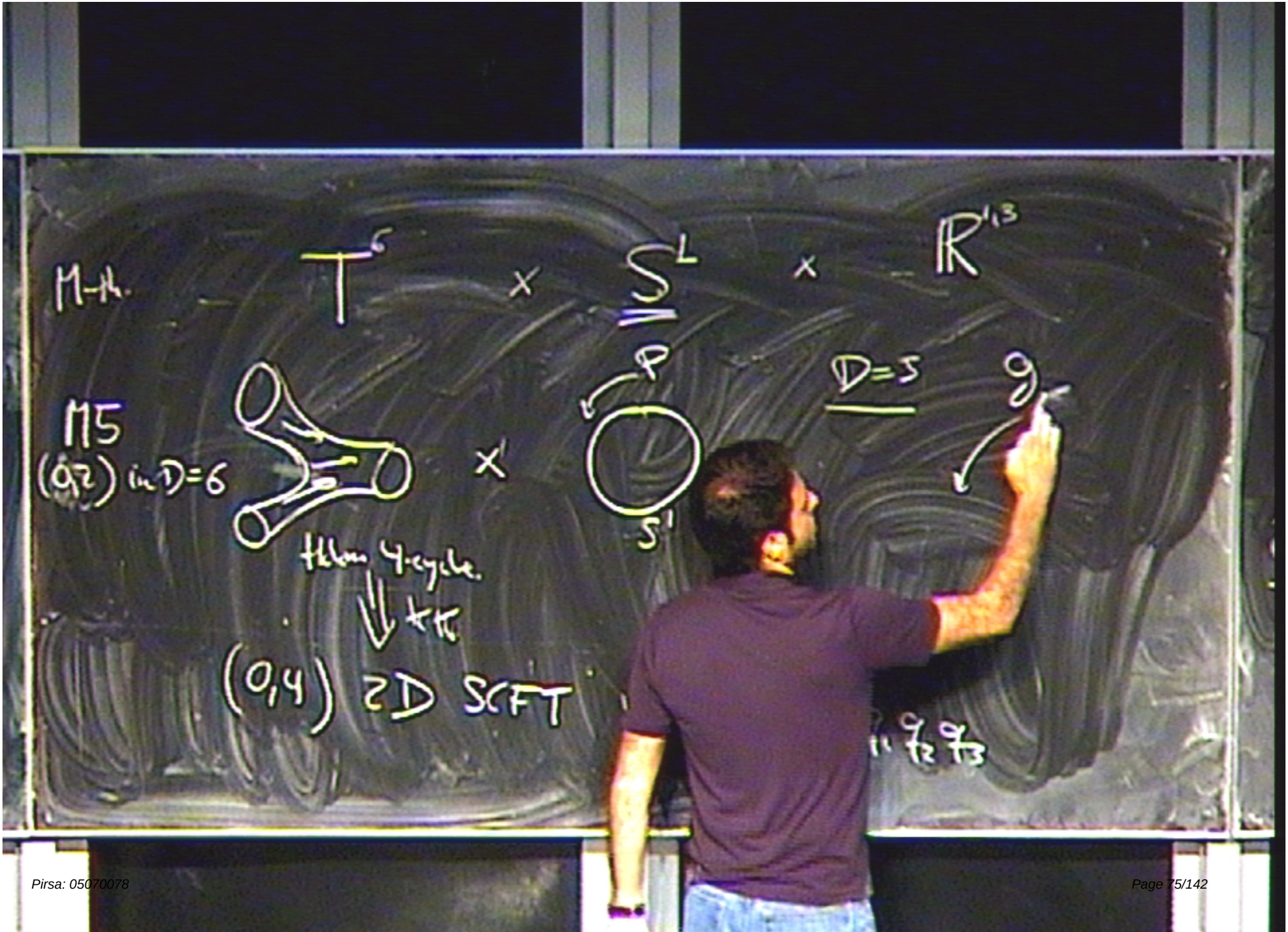
M-th. $T^6 \times S^1 \times \mathbb{R}^{1,3}$

M5 $(0,2)$ in $D=6$ $\times$  $\times$ 

$\underline{D=5}$ $g_{\mu\nu}$

Heterotic 4-cycle

$(0,4)$ 2D w/ $C_L = 6\,9_1 9_2 9_3$


M-th.
T^6
×
S^L
×
$\mathbb{R}^{1,3}$
M5
(0,2) in D=6
×
P
S^1
D=5
q
$q_2 q_3$
Klein 4-cycle.
(0,4) 2D SCFT

M-th. $T^6 \times S^L \times \mathbb{R}^{1,3}$

11-5

(0,2) in D=6



$\times$



D=5

$g_{\mu\nu}$



g_{11}, g_{45}, g_{53}

Holom 4-cycle.

$\Downarrow$ KK

(0,4) 2D SCFT w/ $C = 6 q_1 q_2 q_3$

M-th. $T^6 \times S^1 \times \mathbb{R}^{1,3}$

115 (0,2) in D=6



$\times$



D=5

$g_{\mu\nu}$



g_{i1}, g_{i5}, g_{53}

A_i

Klebanov-Witten 4-cycle.

$\Downarrow$ KK

(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$

M-th. $T^6 \times S^L \times \mathbb{R}^{1,3}$

115
(0,2) in D=6



$\times$



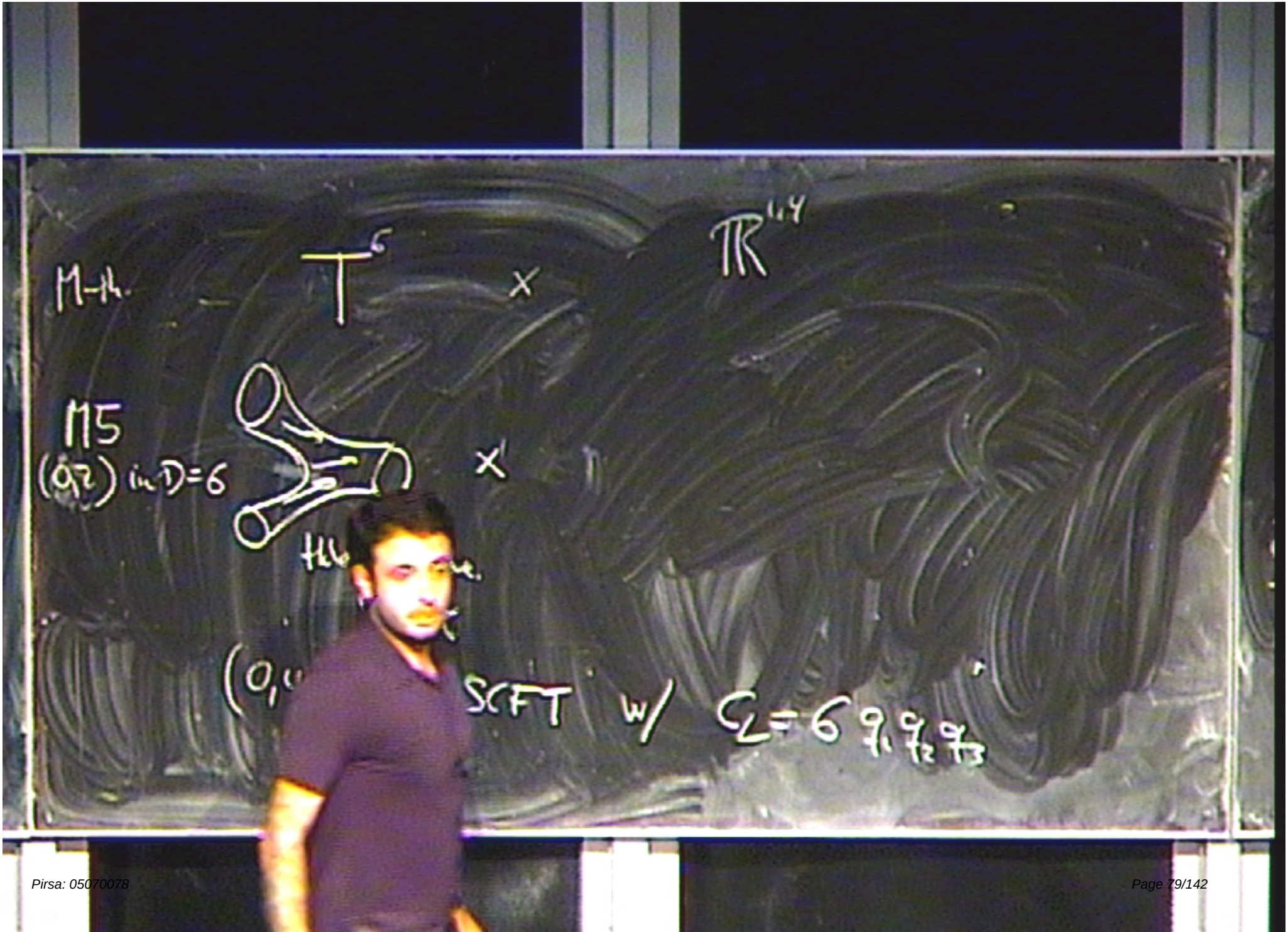
$\times$



Calabi-Yau 4-cycle.

$\Downarrow$ t'H

(0,4) 2D SCFT w/ $c_L = 6\,9_1 9_2 9_3$


M-th
T^6
x
$\mathbb{R}^{1,4}$
115
(0,2) in D=6
x'
SCFT w/ $c_L = 6\,9_1 9_2 9_3$

M-th. T^6 × $\mathbb{R}^{1,4}$

115

(92) in D=6

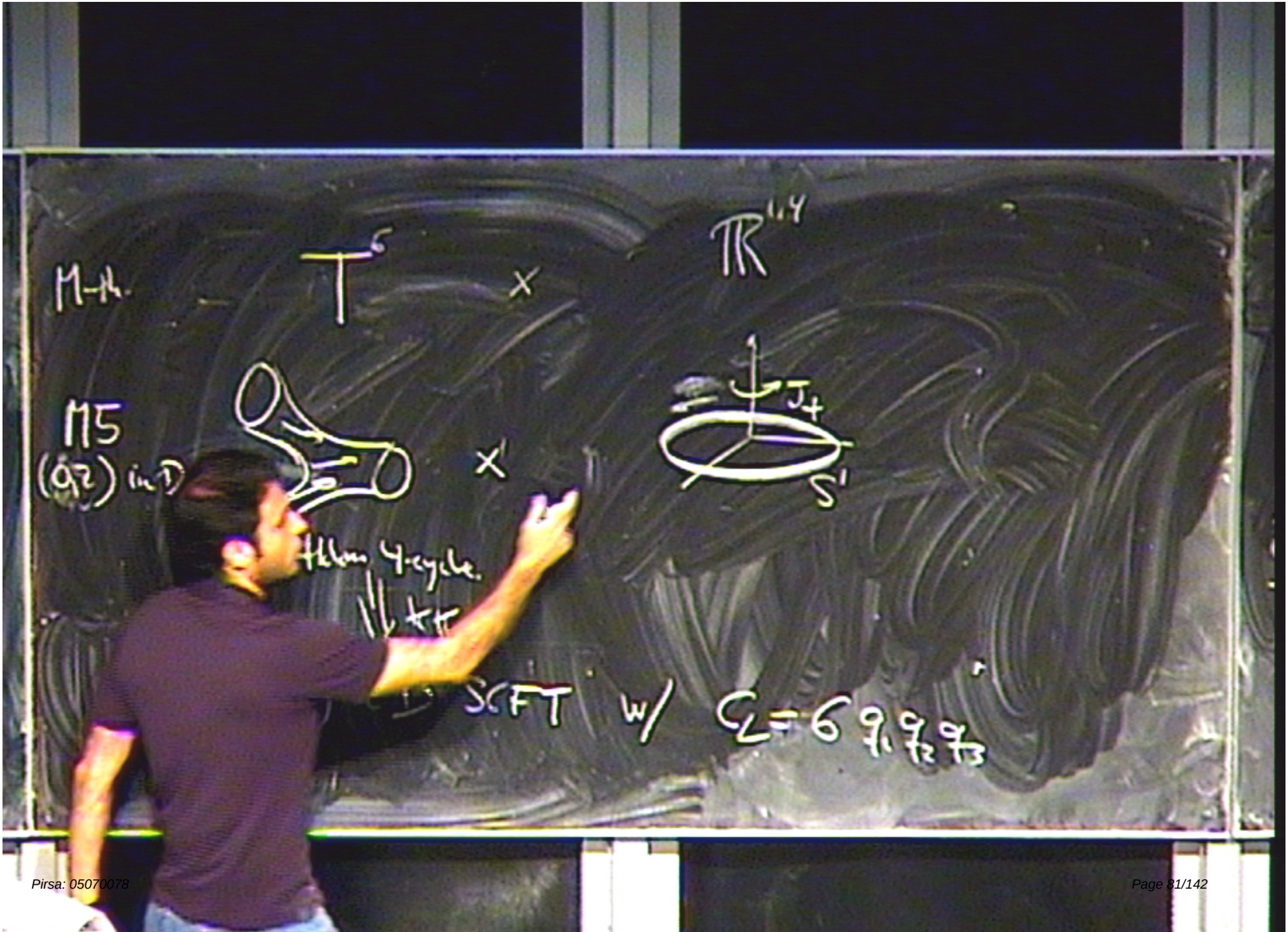


× $\mathbb{R}$

fibers 4-cycle.

$\Downarrow t \to 0$

(0,4) 2D SCFT w/ $c_L = 6 \cdot 92$


M-th.
T^6
x
$\mathbb{R}^{1,4}$
M5
(9 2) in T
x'
J_+
S^1
Hellow 4-cycle.
SCFT w/ $c_L = 6 q_1 q_2 q_3$

M-th. T^6 × $\mathbb{R}^{1,4}$

11S
(9,2) in D=6



×



tklam 4-cycle.

$\Downarrow t \to 0$

(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$

M-th. T^6 × $\mathbb{R}^{1,4}$

M5 on $(\mathbb{R}^2)$ in D=6 × 



$P = -J_+$

Tchain 4-cycle.

$\Downarrow$ tft

(0,4) 2D SCFT w/ $c_L = 6\,q_1 q_2 q_3$

M-th. T^6 × $\mathbb{R}^{1,4}$

M5 (0,2) in D=6 × 

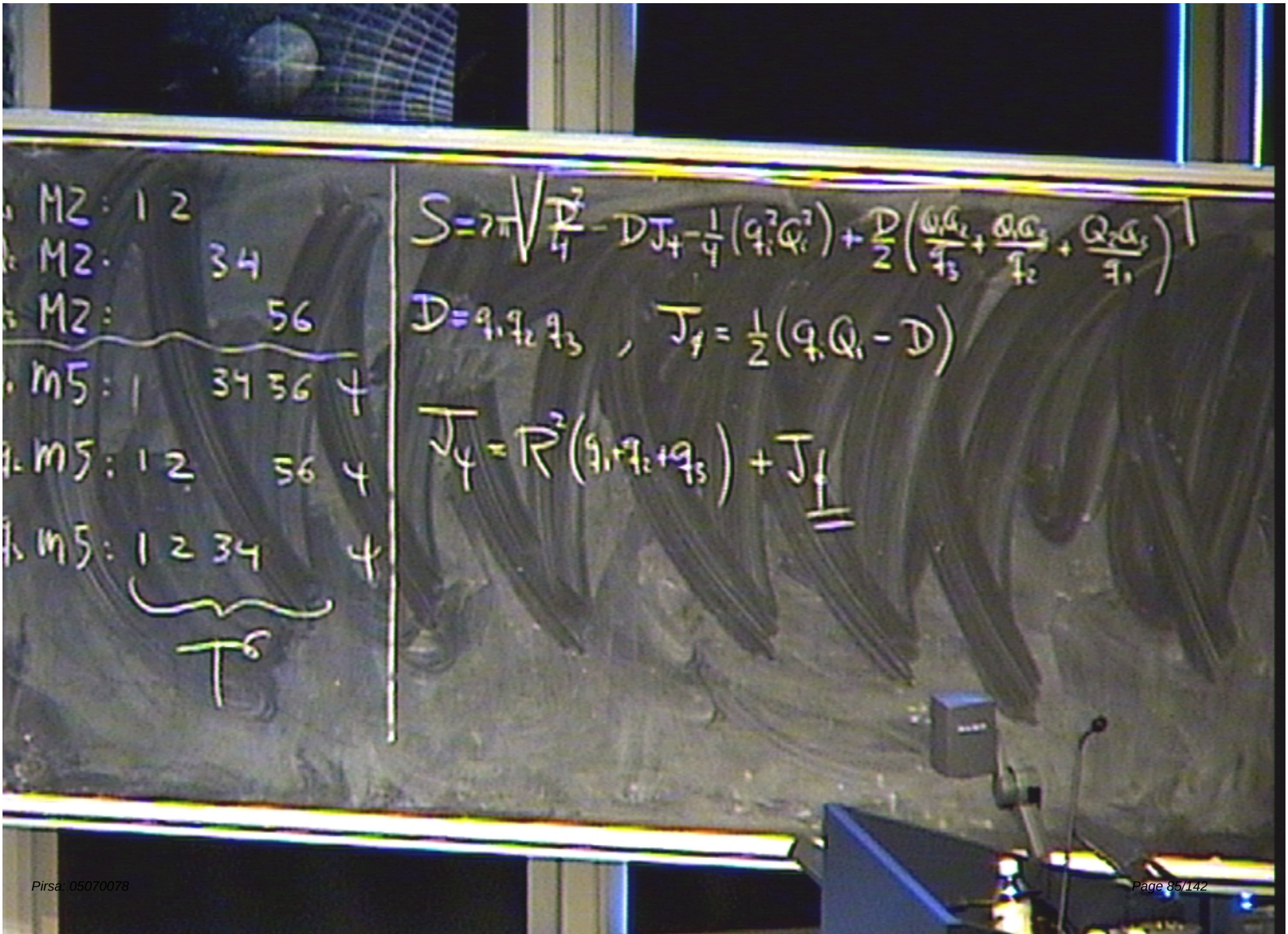


$P = -J_+$

take 4-cycle.

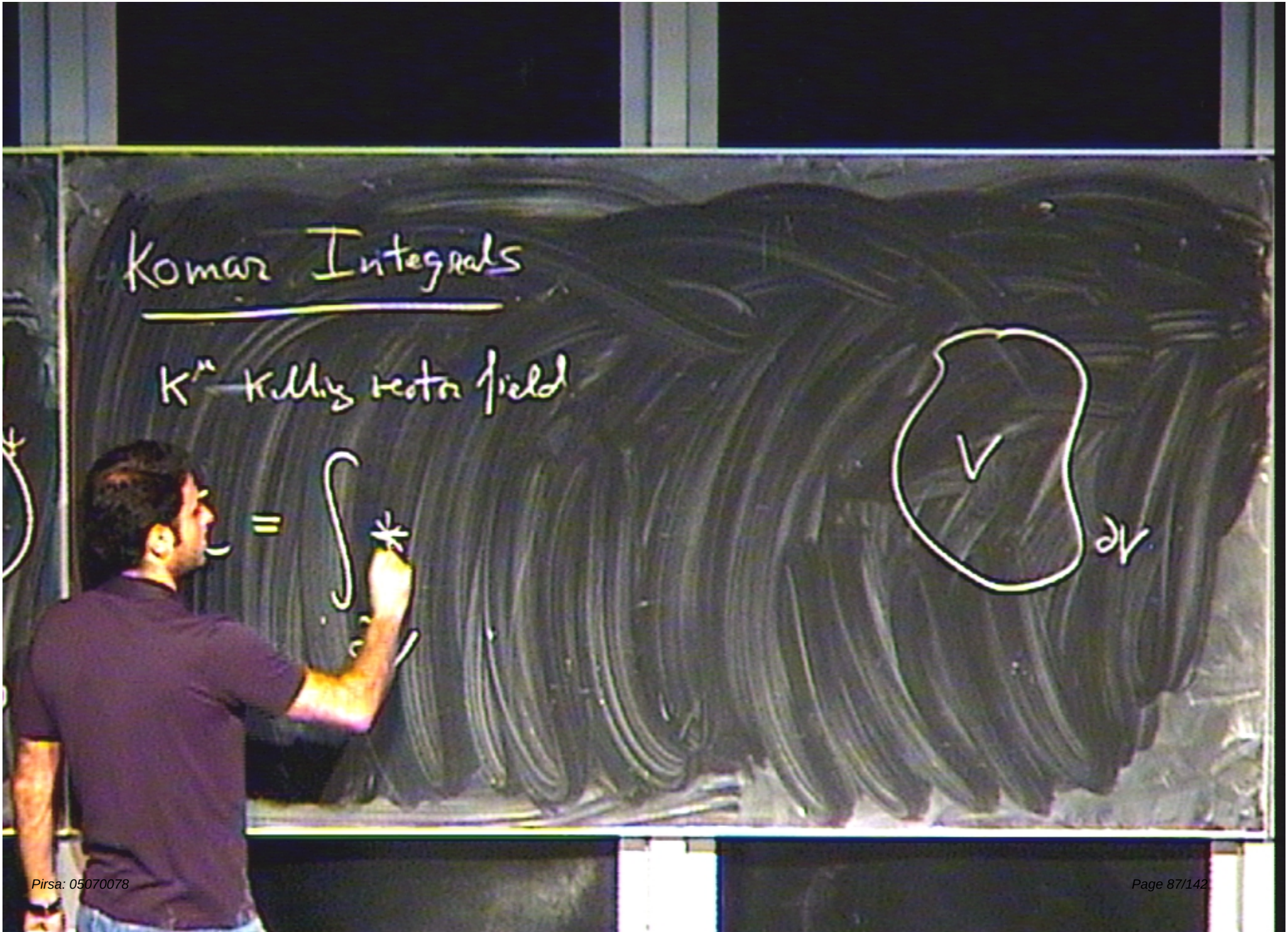
$\Downarrow$ t'H

(0,4) 2D SCFT w/ $c_L = 6 q_1 q_2 q_3$


M2 : 1 2
M2 : 3 4
M2 : 5 6
m5 : 1 3 5 6 4
m5 : 1 2 5 6 4
m5 : 1 2 3 4 4
T^6
S = 2π √(R^2/4 − D J_4 − 1/4 (q_1^2 Q_1^2)) + D/2 (Q_1 q_1/q_3 + Q_2 q_2/q_3 + Q_3 q_3/q_1)
D = q_1 q_2 q_3 , J_4 = 1/2 (q_1 Q_1 − D)
J_4 = R^2 (q_1 + q_2 + q_3) + J_1

Komar Integrals

k


Komar Integrals
K^μ Killing vector field
$\mathcal{L} = \int *$
V
dV

Komar Integrals

k^μ Killing vector field

$$K = \int_{\partial V} *dk$$



Komar Integrals

K^μ Killing vector field

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$

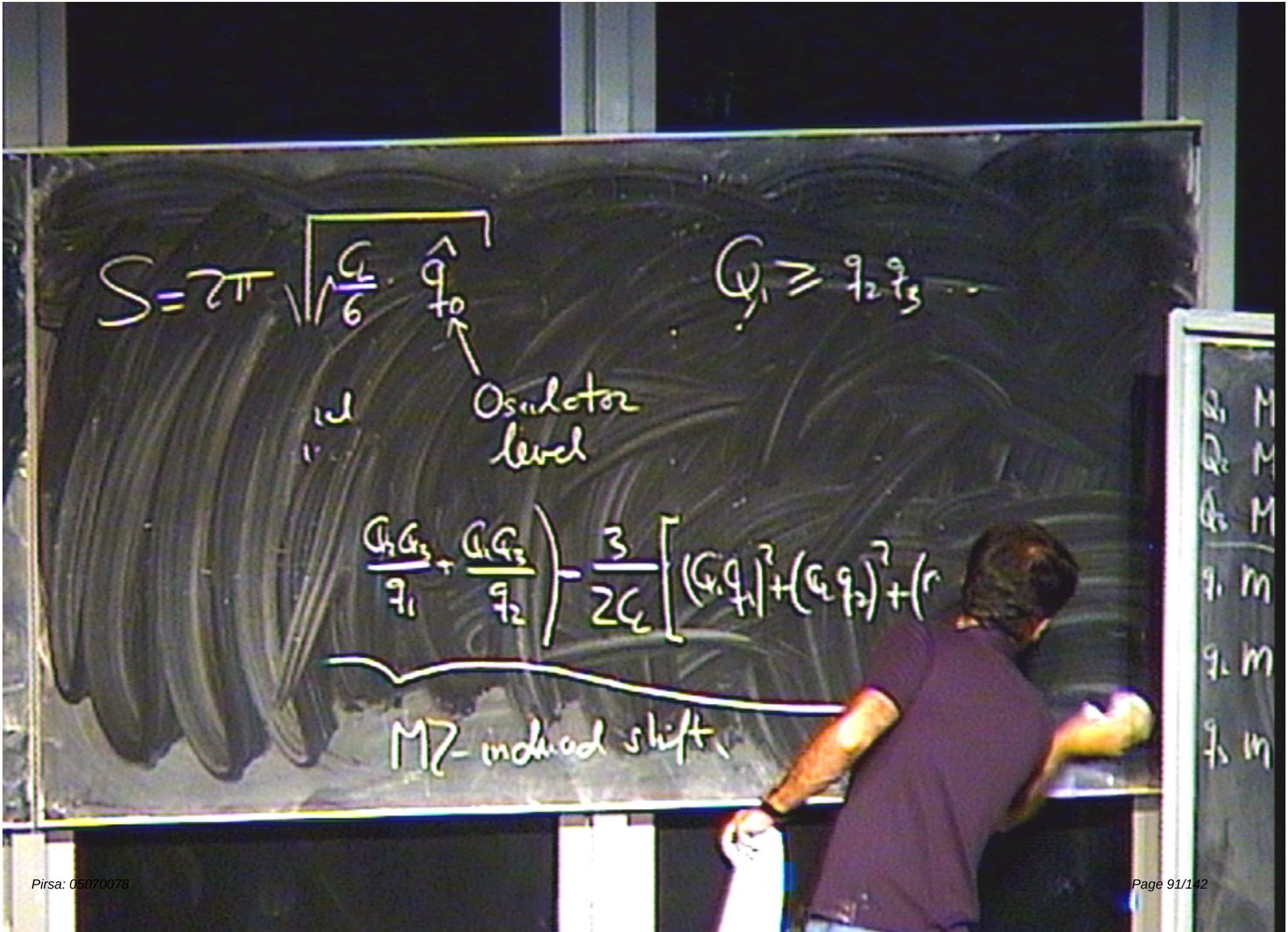


Komar Integrals

K^μ Killing vector field

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$




$S = 2\pi \sqrt{\frac{C}{6} \cdot \hat{q}_0}$
$C_{ij} \geq q_2 q_3 \ldots$
Oscillator level
$\frac{C_1 C_3}{q_1} + \frac{C_1 C_2}{q_2}$
$- \frac{3}{2C} [(C_1 q_1)^2 + (C_1 q_2)^2 + (C$
M7-induced shift
Q_1 M
Q_2 M
Q_3 M
q_1 m
q_2 m
q_3 m


q_1 M
q_2 M
q_3 M
q_1 m
q_2 m
q_3 m

For BR:

S^3_∞



At infinity:

$$\int_{S^3_\infty}$$

Q_1 M
Q_2 M
Q_3 M

q_1 m
q_2 m
q_3 m

For BR:

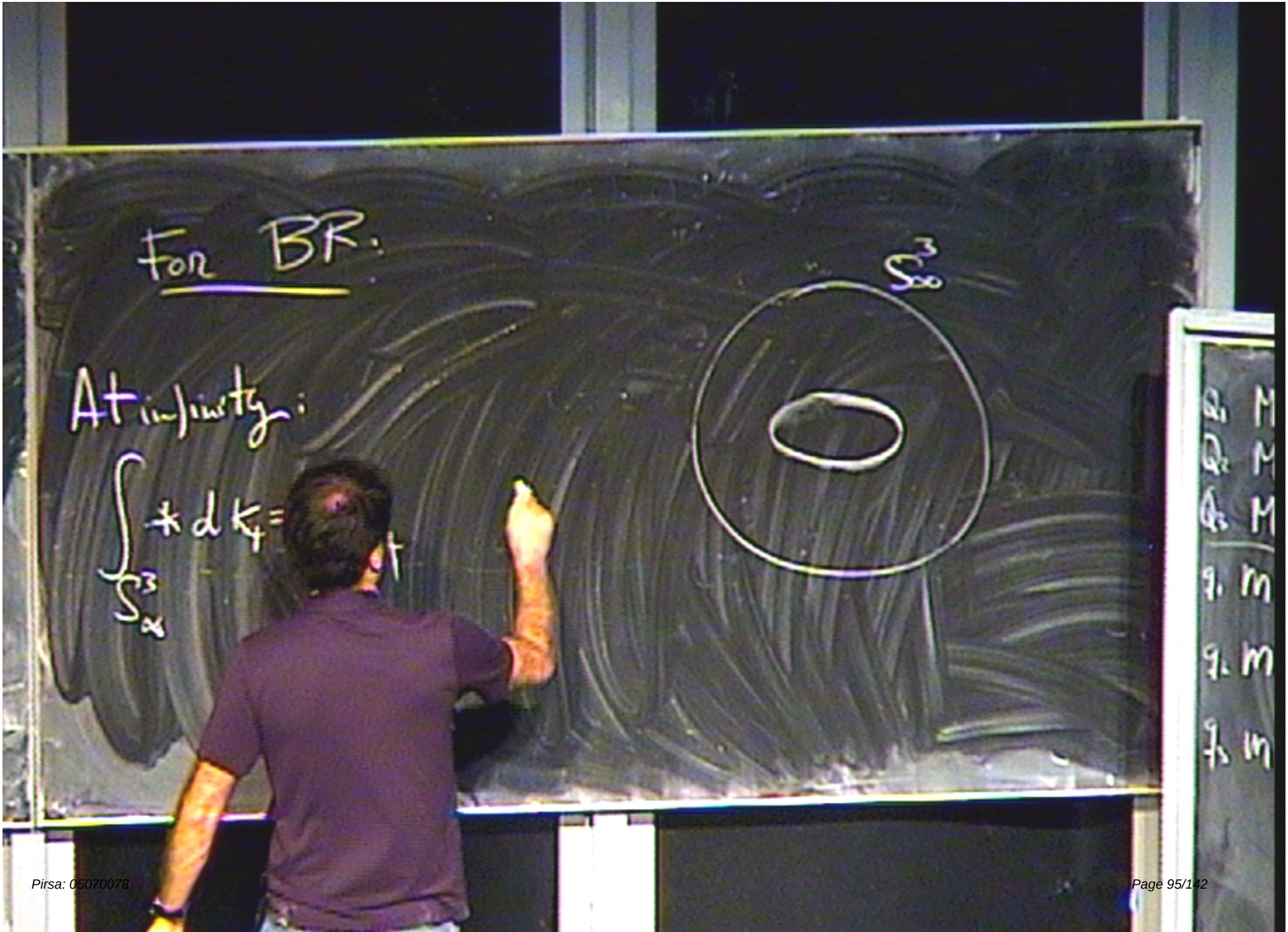


At infinity:

$$\int_{S^3_\infty} *dk_4 = -J_4$$

Q_1 M
Q_2 M
Q_3 M

q_1 m
q_2 m
q_3 m

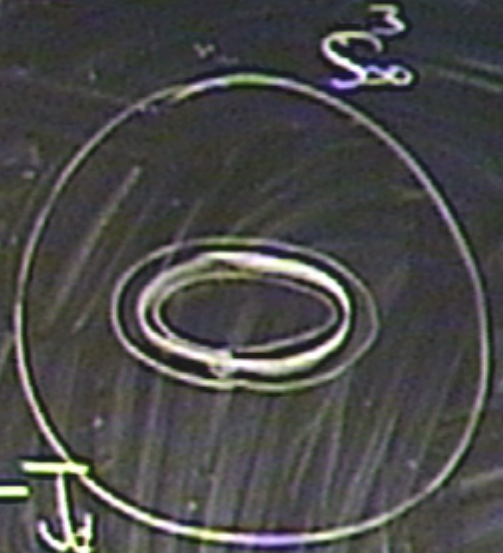

For BR:
S^3_∞
At (in)finity:
$\int_{S^3_\infty} * dK_4 =$
Q₁ M
Q₂ M
Q₃ M
q₁ m
q₂ m
q₃ m

For BR:

At infinity:

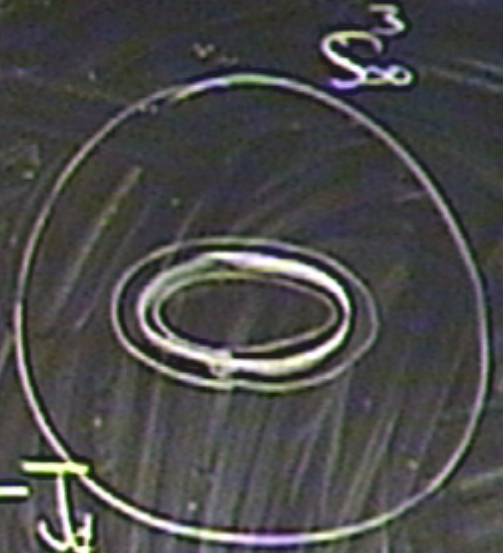
$$\int_{S^3_\infty} *dk_I = -J_I \,, \qquad \int_{S^3_\infty} *dk_I = -J_I$$

$$\int_{S^1 \times S^2_{thn}} *dk_I$$



Q_1 M
Q_2 M
Q_3 M
q_1 m
q_2 m
q_3 m

For BR:

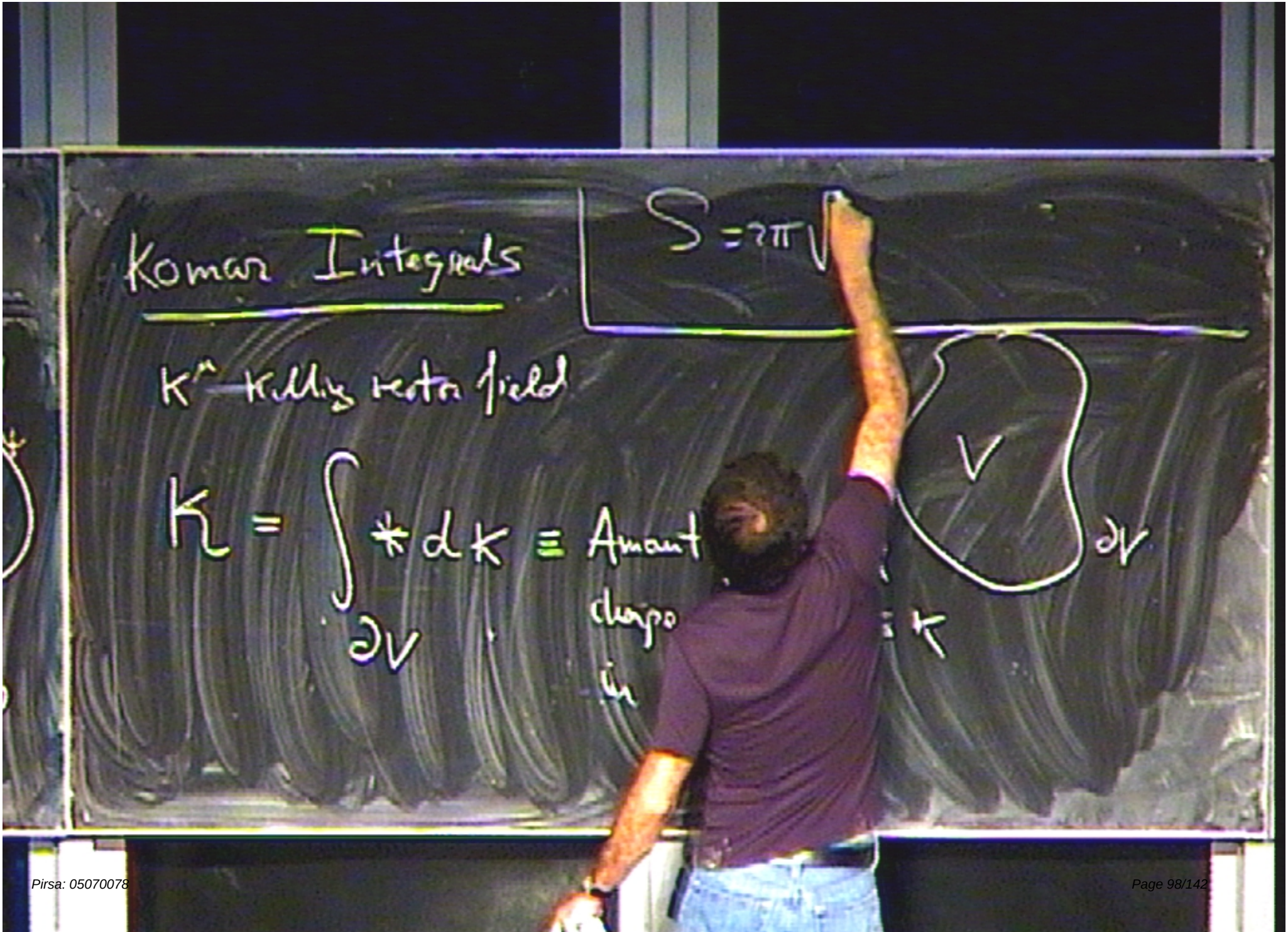


At infinity:

$$\int_{S^3_\alpha} *dk_4 = -J_4 \,, \qquad \int_{S^3_\alpha} *dk_4 = -J_4$$

$$\int_{S^1 \times S^2_{thn}} *dk_4 = \hat{q}_0 \,,$$

Q_1 M
Q_2 M
Q_3 M
q_1 m
q_2 m
q_3 m


Komar Integrals
S = 2π
k^ Killing vector field
K = ∫ *dk ≡ Amount
∂V
V
∂V
K

Komar Integrals

$$S = 2\pi\sqrt{\frac{q}{6}\hat{q}_0}$$

K^μ Killing vector field

$$\mathcal{K} = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



Komar Integrals

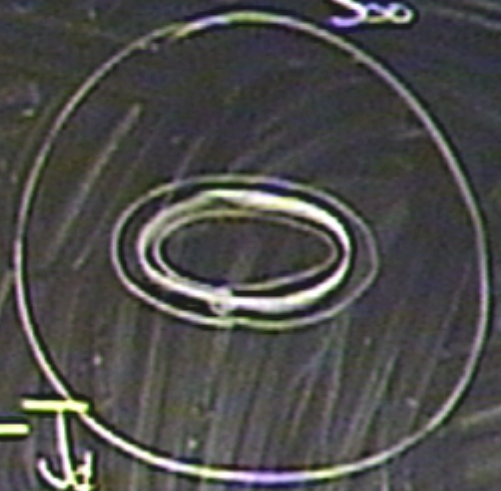
$$S = 2\pi\sqrt{\frac{q}{\hat{q}}\frac{q}{\hat{q}_0}}$$

k^μ Killing vector field

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



For BR:



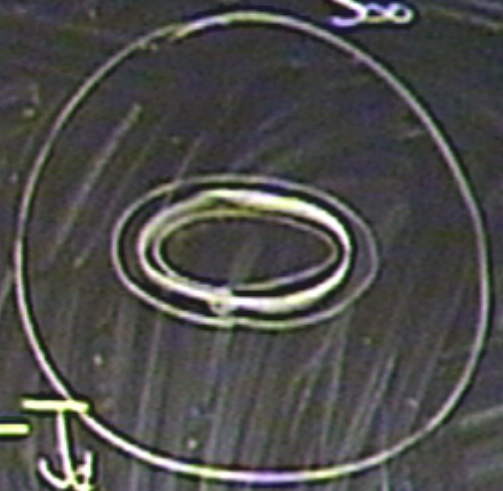
At infinity:

$$\int_{S^3_\infty} *dK_4 = -J_4 \,, \qquad \int_{S^3_\infty} *dK_4 = -J_4$$

$$\int_{S^1 \times S^2_{thn}} *dK_4 = \hat{q}_0 \,,$$

q_1 M
q_2 M
q_3 M
q_1 m
q_2 m
q_3 m

For BR:



At infinity:

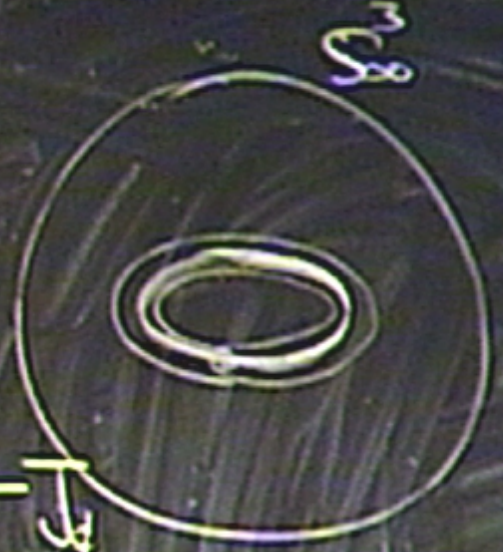
$$\int_{S^3_\infty} *dk_4 = -J_4 = P, \qquad \int_{S^3_\infty} *dk_4 = -J_4$$

$$\int_{S^1 \times S^2_{thn}} *dk_4 = \hat{q}_0$$

Q_1 M
Q_2 M
Q_3 M

q_1 m
q_2 m
q_3 m

For BR:



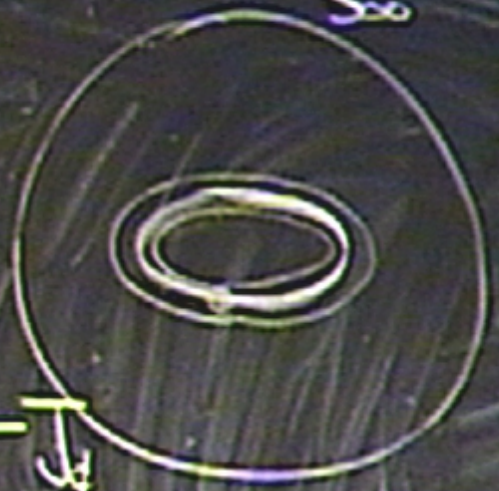
At infinity:

$$\int_{S^3_\infty} *dk_4 = -J_4 = P, \qquad \int_{S^3_\infty} *dk_4 = -J_4$$

$$\int_{S^1 \times S^2_{th}} *dk_4 = \hat{q}_0, \qquad \int_{S^1 \times S^2_{th}} *dk_1 = 0$$

Q_1 M
Q_2 M
Q_3 M
q_1 m
q_2 m
q_3 m

For BR:



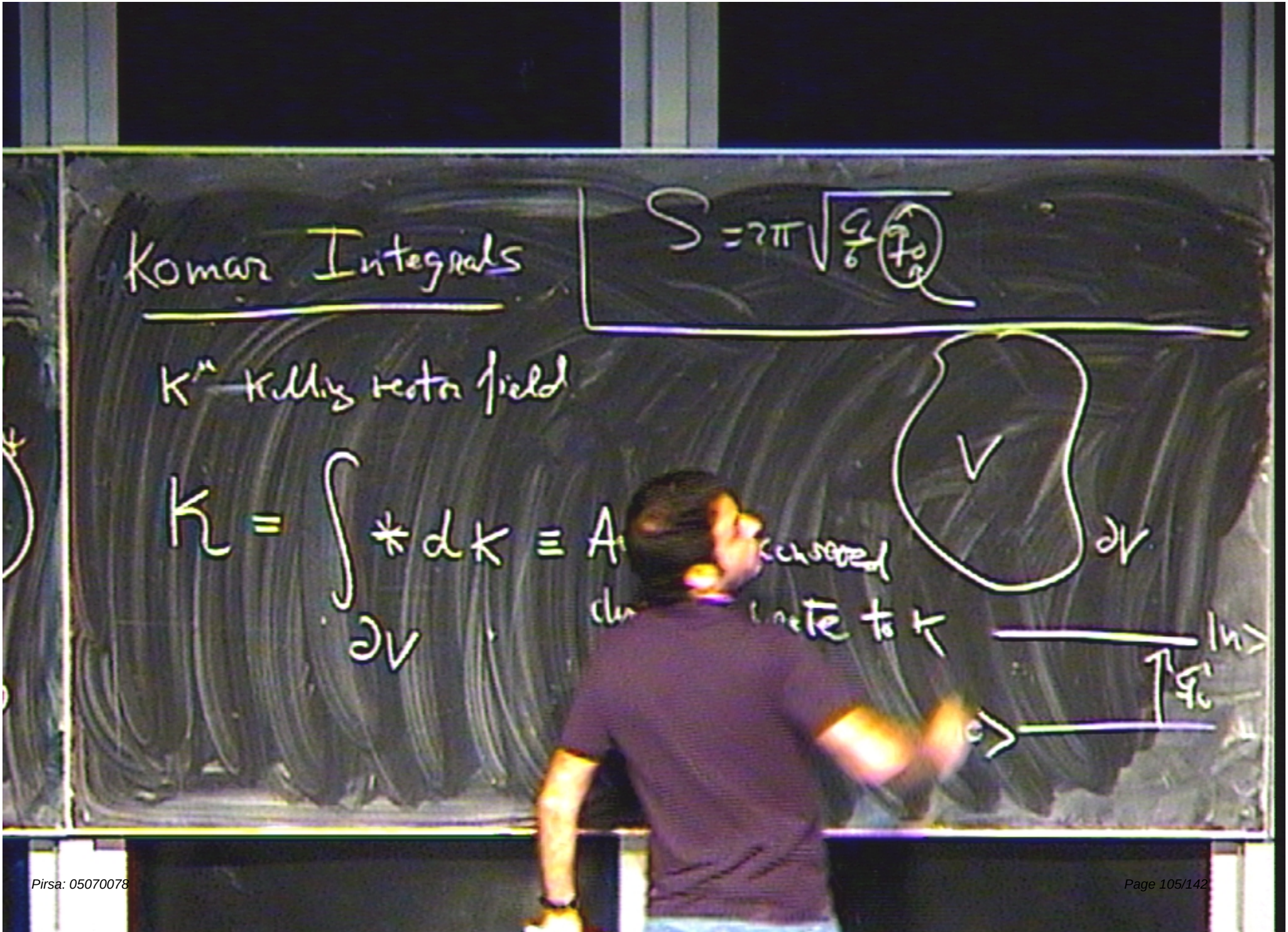
At infinity:

$$\int_{S^3_\infty} *dk_1 = -J_1 = P, \quad \int_{S^3_\infty} *dk_1 = -J_1$$

$$\int_{S^1 \times S^2_{th}} *dk_1 = \hat{q}_0, \quad \int_{S^1 \times S^2_{th}} *dk_1 = 0$$

Q_1 M
Q_2 M
Q_3 M

q_1 m
q_2 m
q_3 m

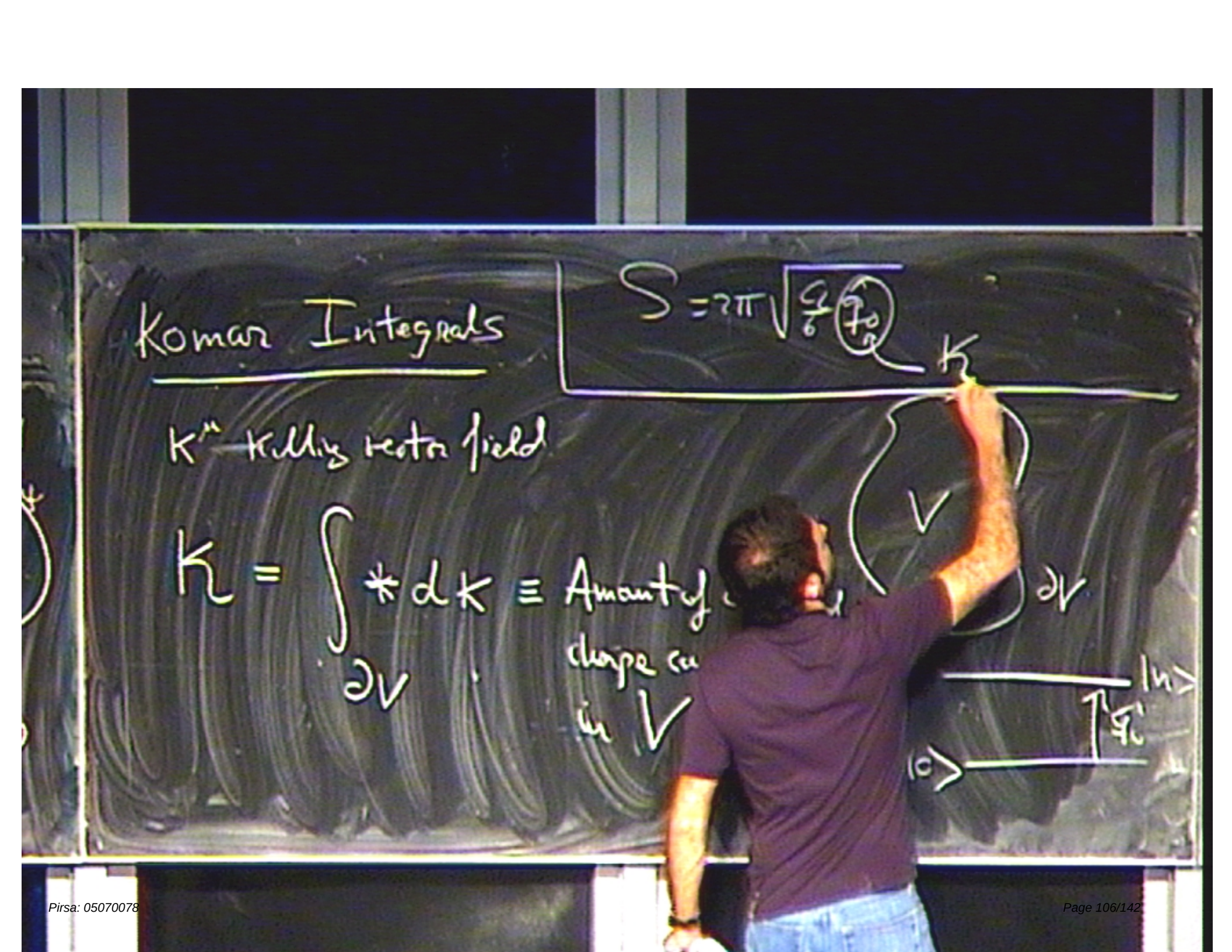

Komar Integrals
$S = 2\pi\sqrt{\frac{r}{b}\left(\frac{r_0}{b}\right)}$
K^μ Killing vector field
$K = \int_{\partial V} * dk \equiv A$
V
∂V
$|n\rangle$
$|\psi\rangle$

Komar Integrals

$$S = 2\pi\sqrt{\frac{q}{\ell}\left(\frac{T_0}{\ell}\right)}\,K$$

K^μ Killing vector field

$$K = \int_{\partial V} *dk \equiv \text{Amount of charge contained in } V$$

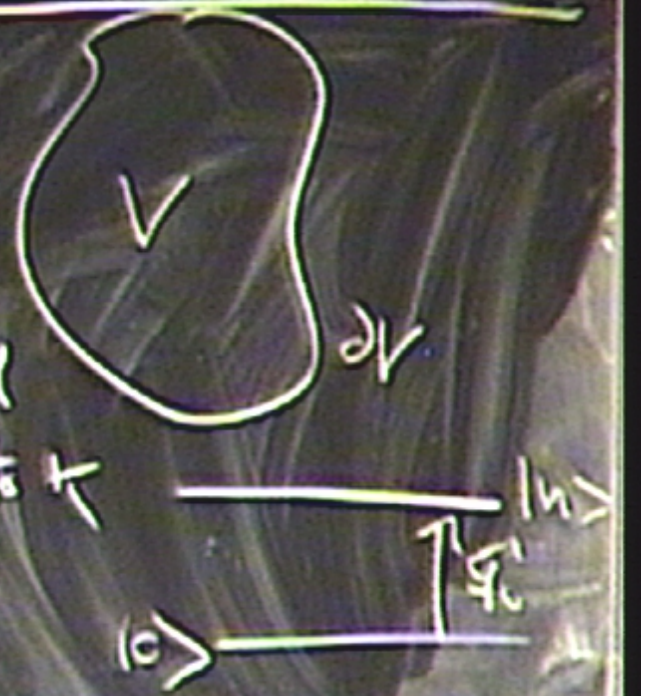


Komar Integrals

$$S = 2\pi \sqrt{\frac{g}{g_{tt}}}\, T_0 \qquad K_{\mu\nu}$$

K^μ Killing vector field

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



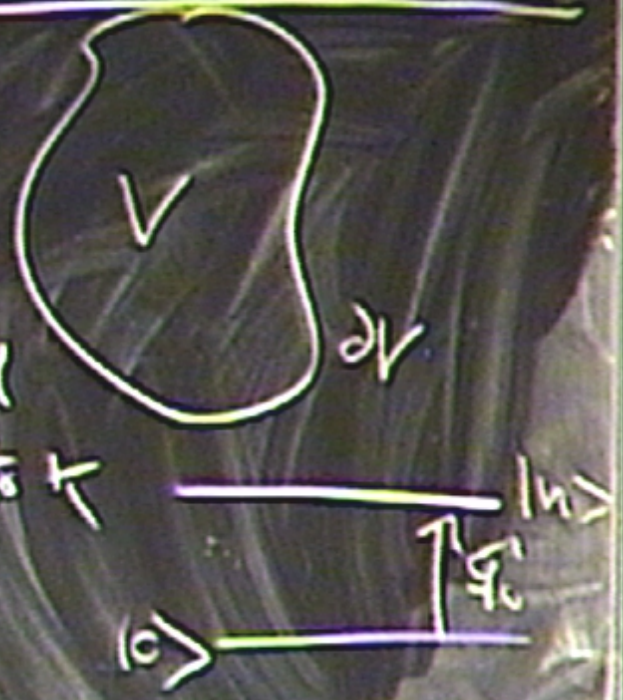
Komar Integrals

$$S = 2\pi \sqrt{\frac{\zeta}{\sigma}\left(\frac{T_0}{\kappa}\right)}\,\kappa_{H^0}$$

K^μ Killing vector field

$\zeta =$

$K = \int_{\partial V} {}^{*}k \equiv$ Amount of conserved charge conjugate to K in V



Komar Integrals

$$S = 2\pi \sqrt{\frac{c}{6}\left(T_0 - \frac{Q}{2}\right)}\, K_{\text{min}}$$

K^μ Killing vector field

$$c = \frac{3 R_{AdS}}{2 G_{3}}$$

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



$|0\rangle$

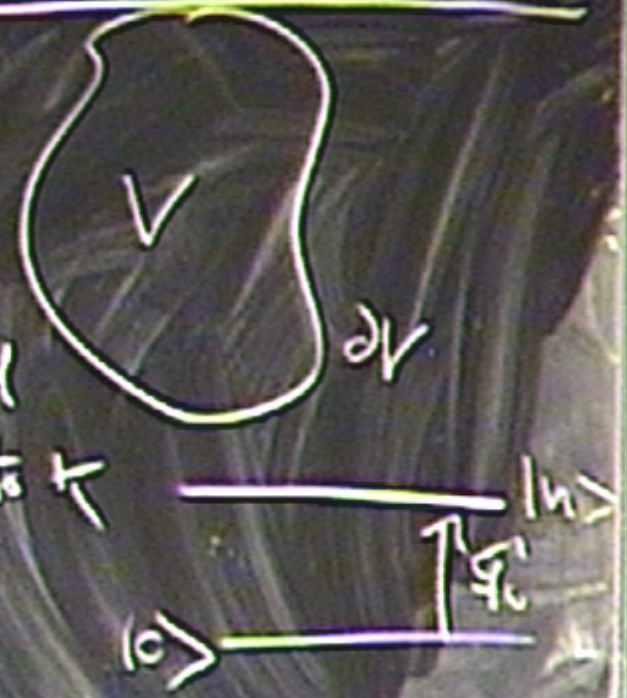
Komar Integrals

$$S = 2\pi \sqrt{\frac{C}{6}\left(T_0 - \frac{C}{24}\right)} \; K_{III}$$

K^μ — Killing vector field

$$C = \frac{3 R_{AdS_3}}{2 G_{(3)}}$$

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



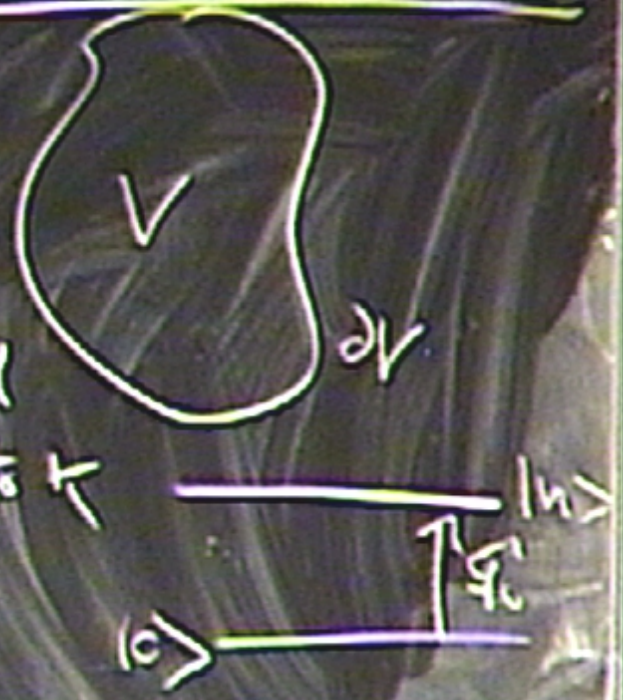
Komar Integrals

$$S = 2\pi \sqrt{\frac{Q}{\zeta}\left(\frac{T_0}{2}\right)} - K_{BH}$$

K^μ Killing vector field

$$\zeta = \frac{3 R_{AdS}}{2 G_{(3)}}$$

$$K = \int_{\partial V} *dK \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



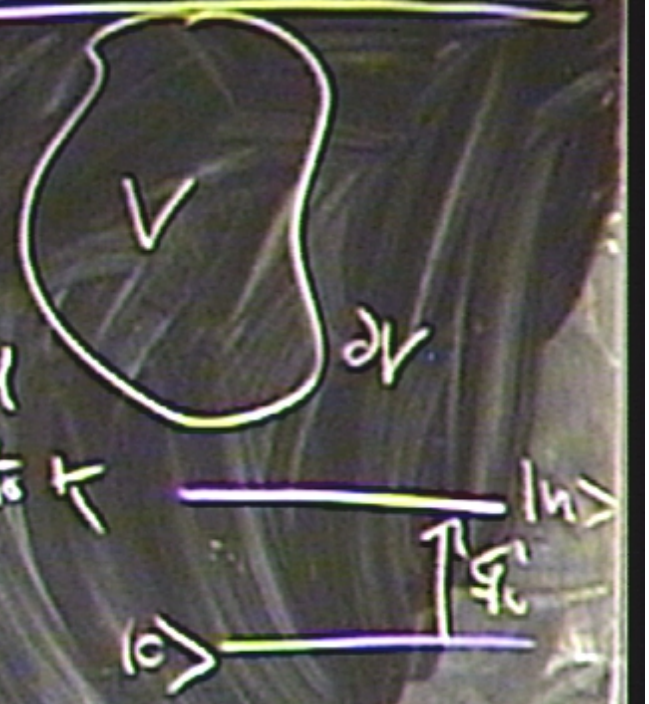
Komar Integrals

$$S = 2\pi \sqrt{\frac{c}{6}\left(T_0 - \frac{c}{24}\right)}\, K_{\text{min}}$$

K^m — Killing vector field

$$c = \frac{3 R_{AdS}}{2 G_3}$$

$$K = \int_{\partial V} *dk \equiv \text{Amount of conserved charge conjugate to } K \text{ in } V$$



For BR:

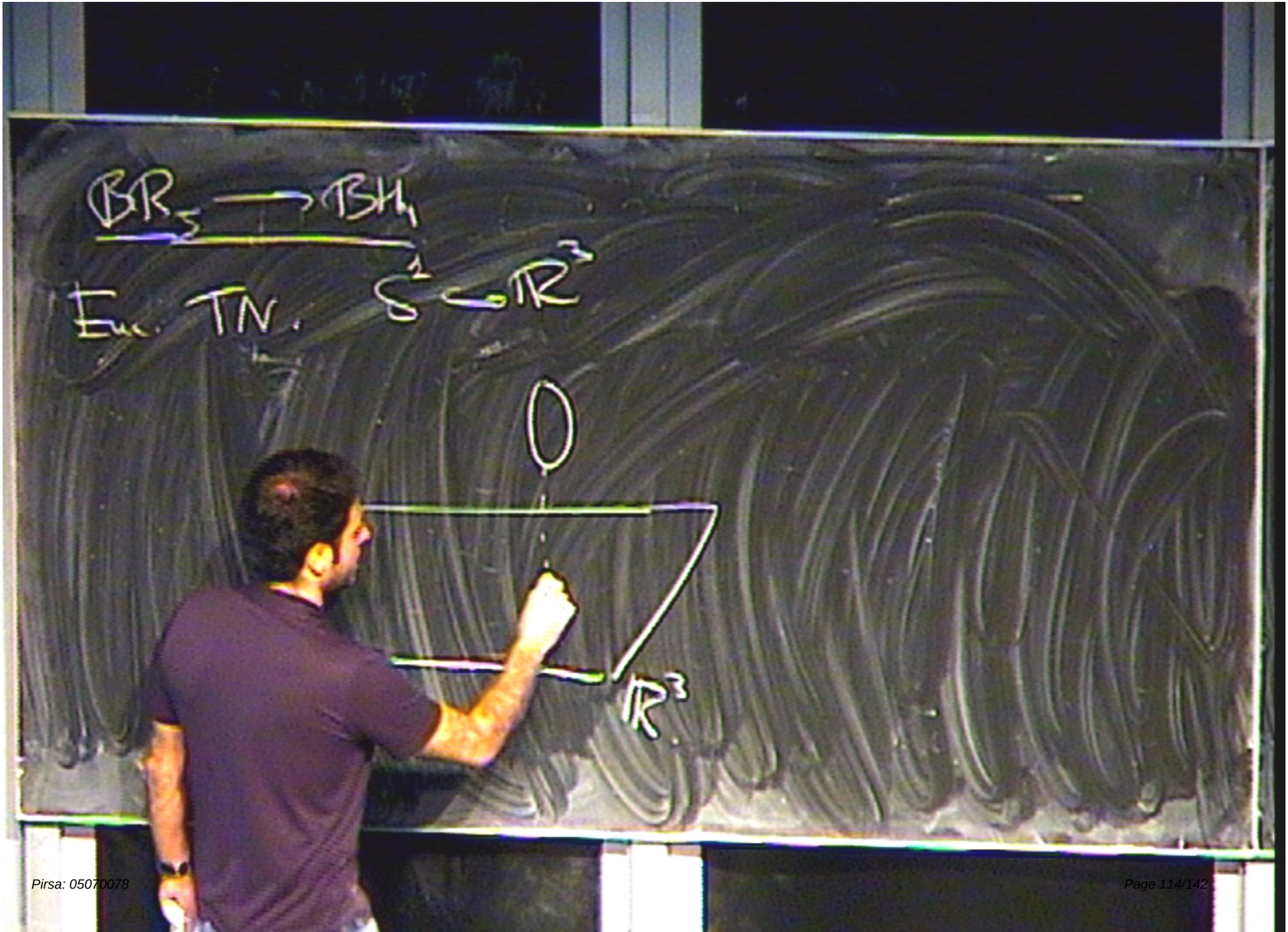
$$q = \int_{S^2} F$$

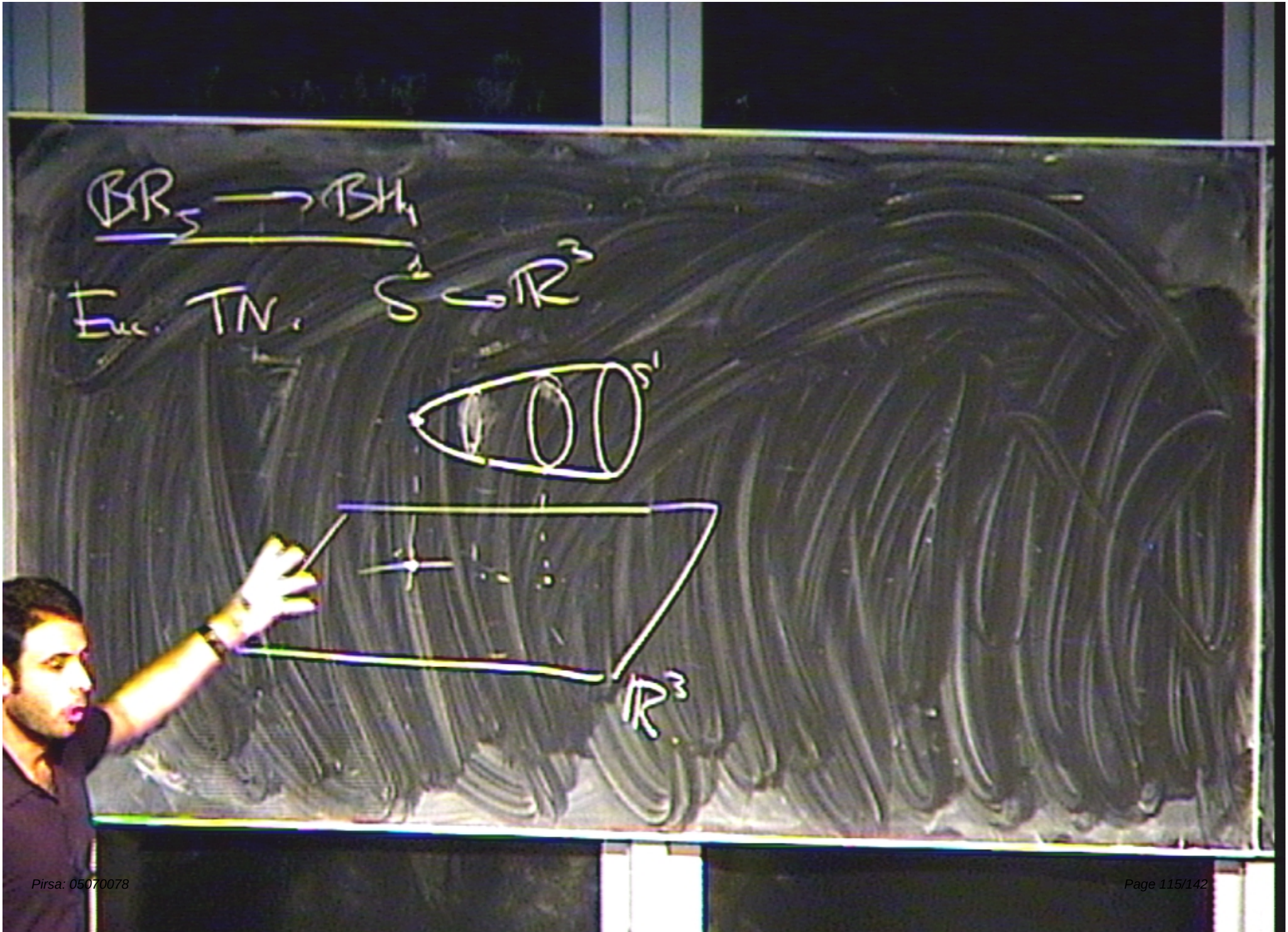
At infinity:

$$\int_{S^3_\infty} *dk_1 = -J_1 = P, \qquad \int_{S^3_\infty} *dk_1 = -\tilde{\psi}_1$$

$$\int_{S^2_\infty} *dk_1 = \hat{q}_0, \qquad \int_{S^1 \times S^2_\infty} *dk_1 = 0$$

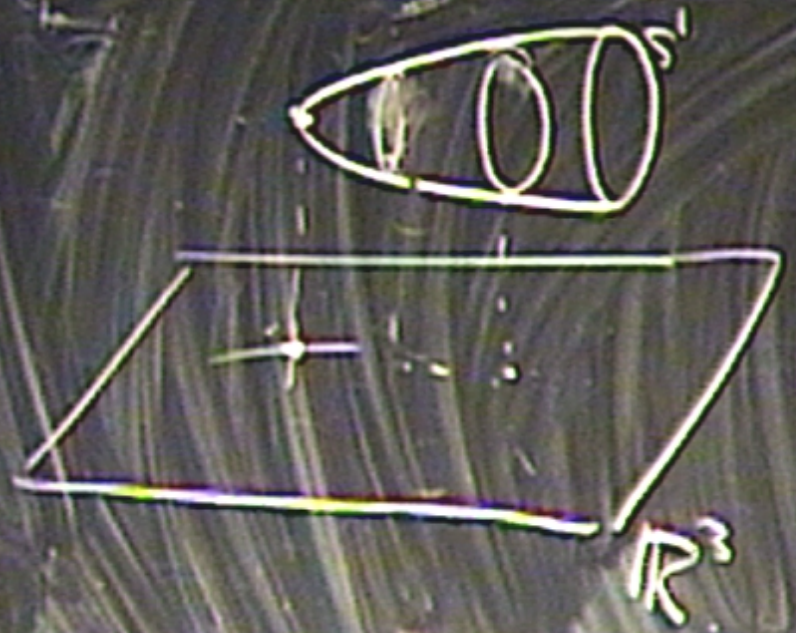



$BR_3 \longrightarrow BH_4$
Ec. TN.
$S^2 \subset \mathbb{R}^3$
0
$\mathbb{R}^3$


BR5 → BH4
Euc. TN. S1 ⊂ R3
S1
R3

$BR_3 \longrightarrow BH_4$

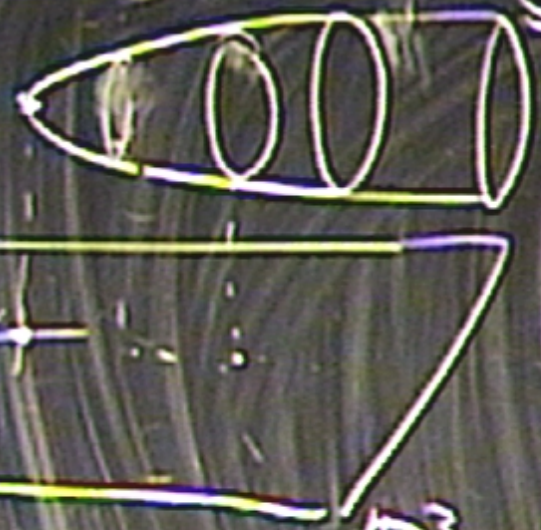
Euc. TN. $S^1 \subset \mathbb{R}^3$ Tqplog $TN_4 = \mathbb{R}^4$



$BR_5 \longrightarrow BH_4$

Euc. TN_4 $S^1 \hookrightarrow \mathbb{R}^3$

Topolog. $TN_4 = \mathbb{R}^4$



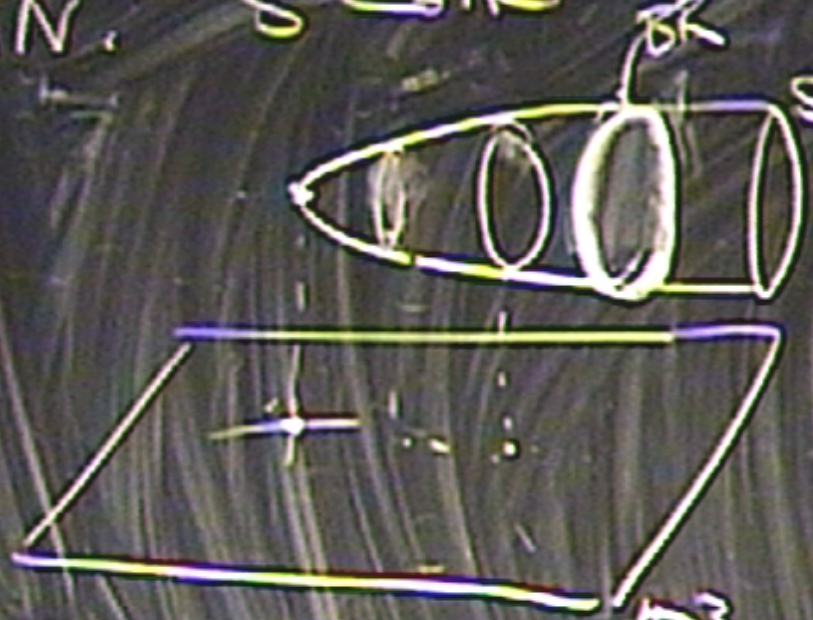
At $r \to \infty$ ($\mathbb{R}^3$)

$TN_4 \approx \mathbb{R}^3 \times S^1$

$BR_3 \longrightarrow BH_4$

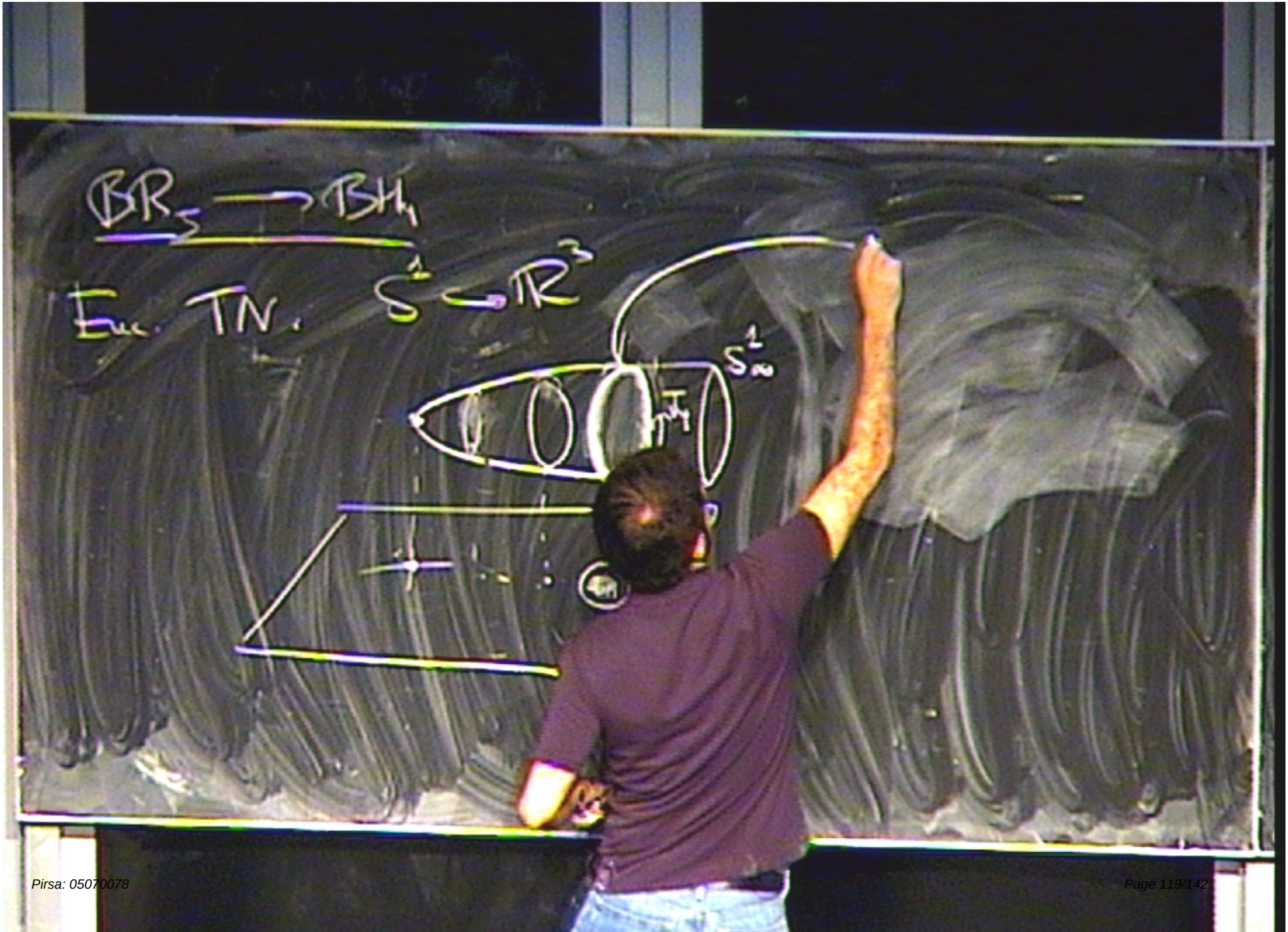
Euc. TN. $S^1 \hookrightarrow \mathbb{R}^3$

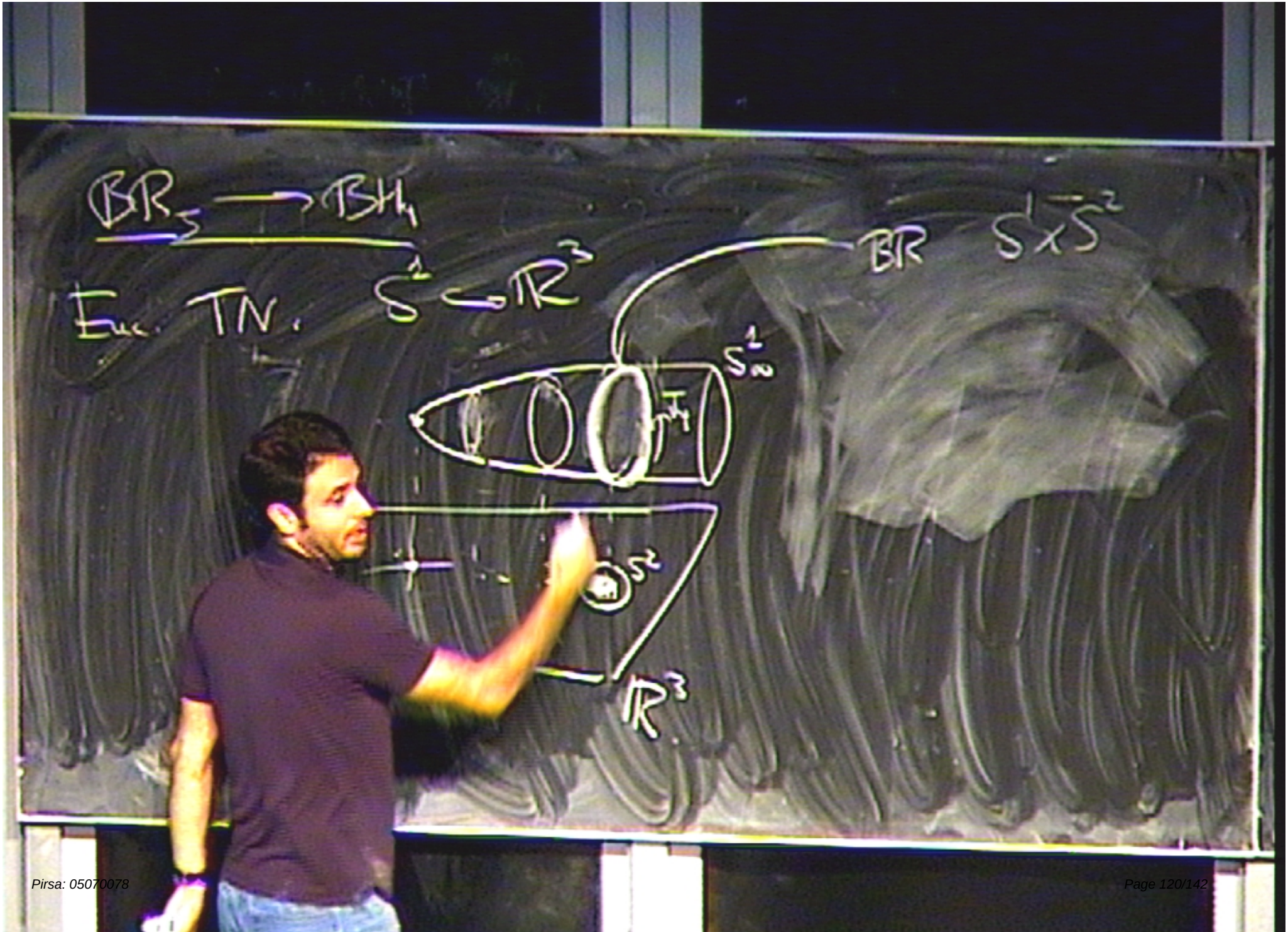
Topolog. $TN_4 = \mathbb{R}^4$

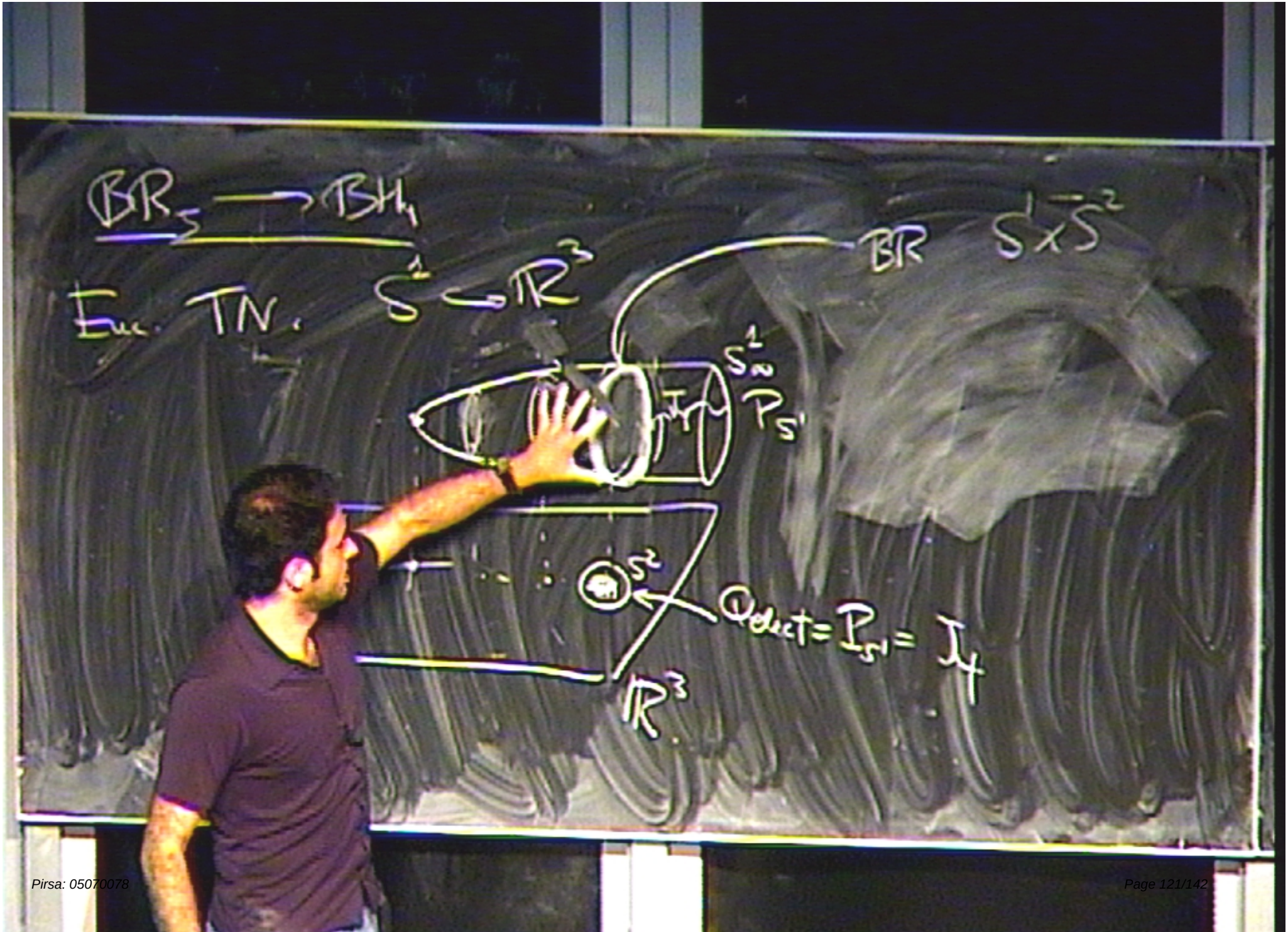


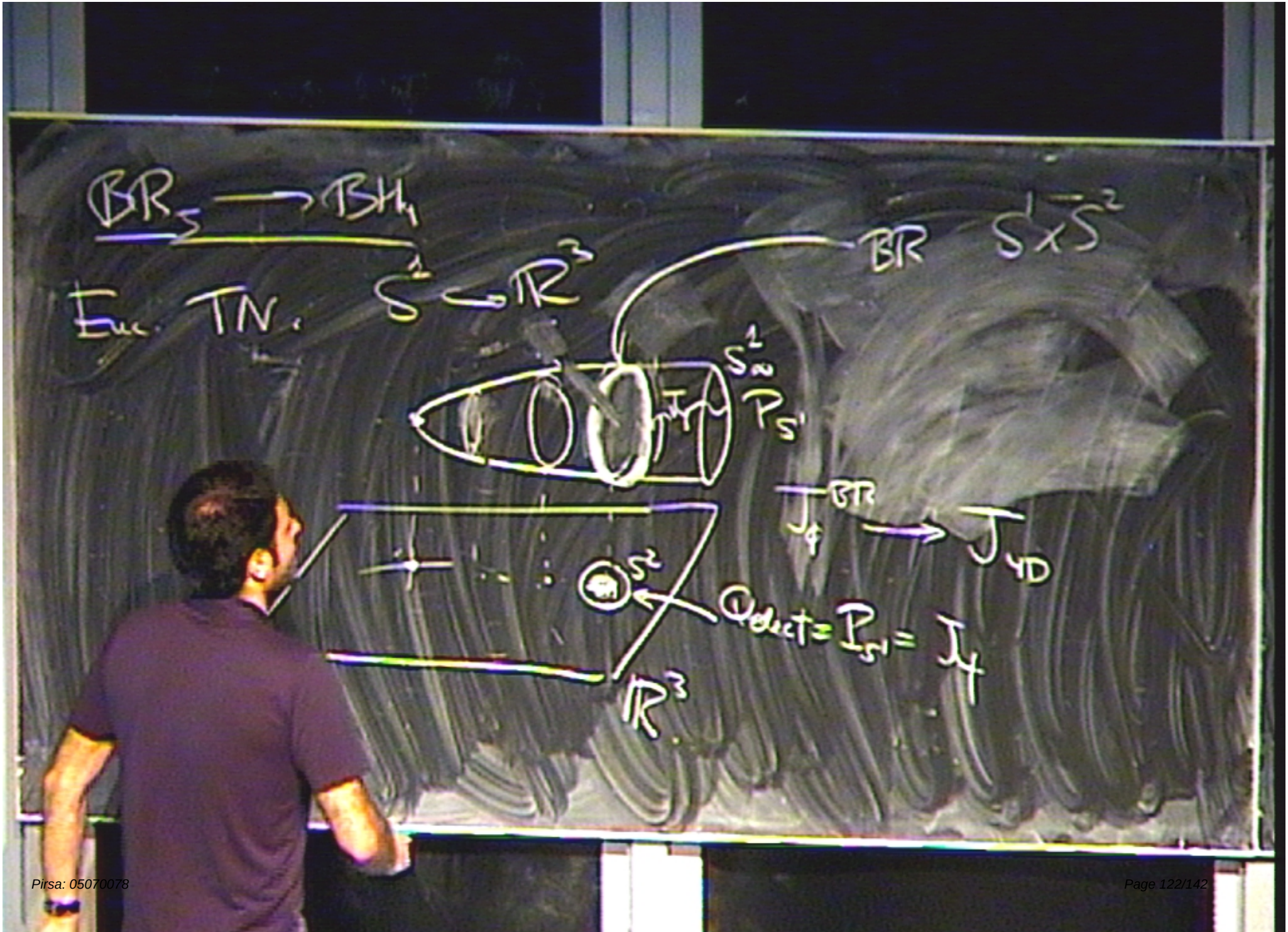
At $r \to \infty$ ($\mathbb{R}^3$)

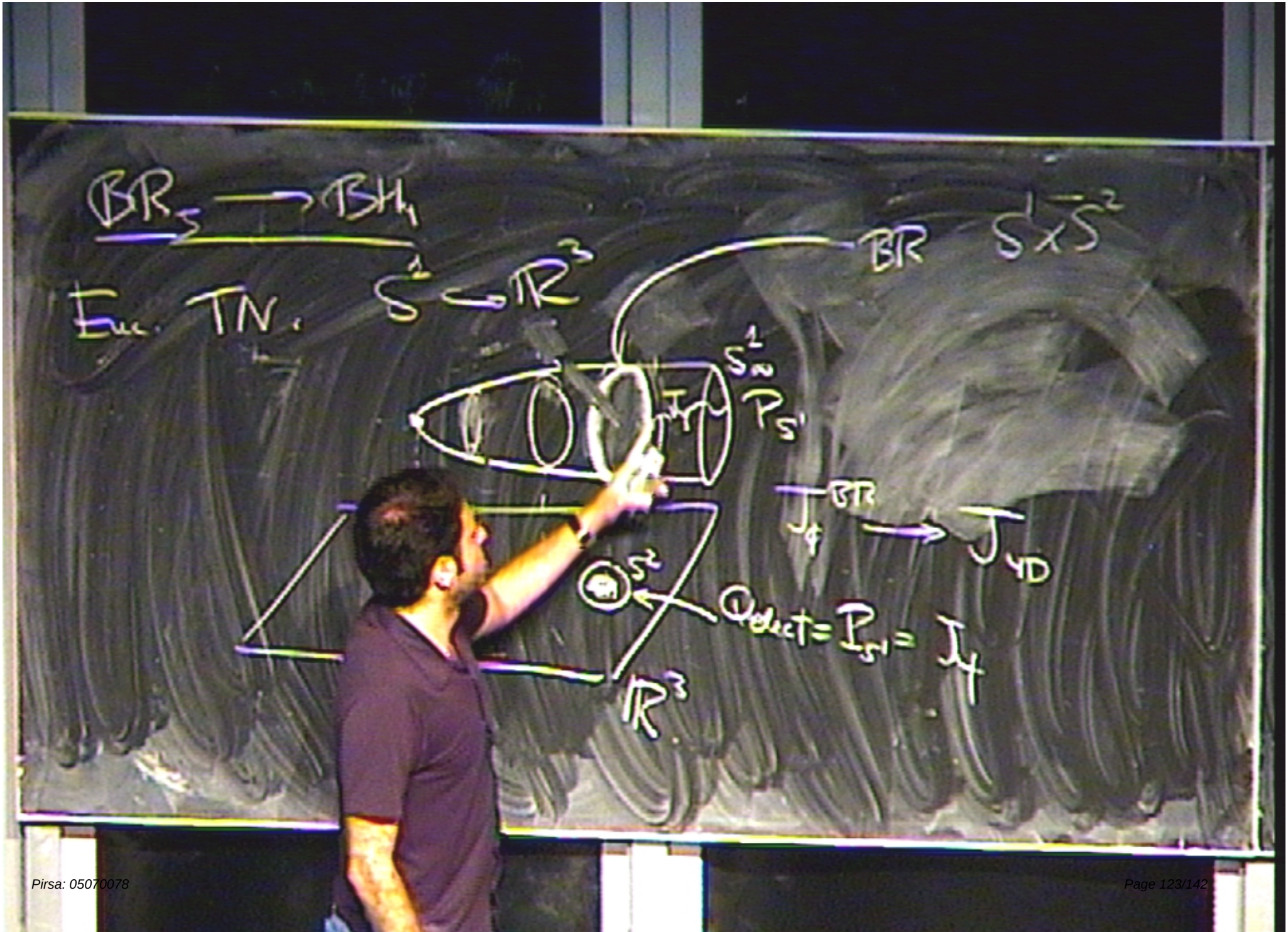
$TN_4 \approx \mathbb{R}^3 \times S^1$

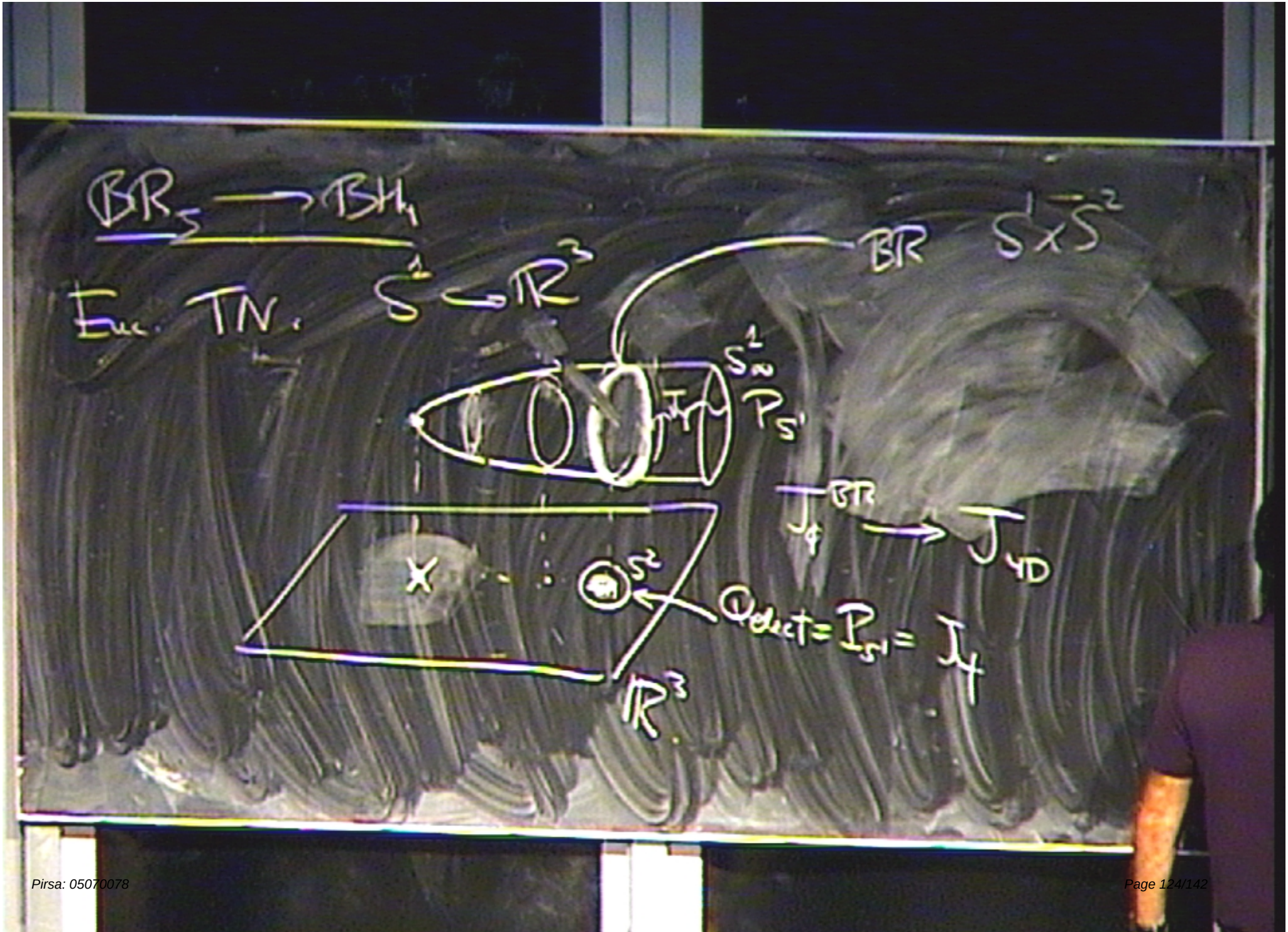

BR5 → BH4
Euc. TN. S1 ⊂ R3
S1∞

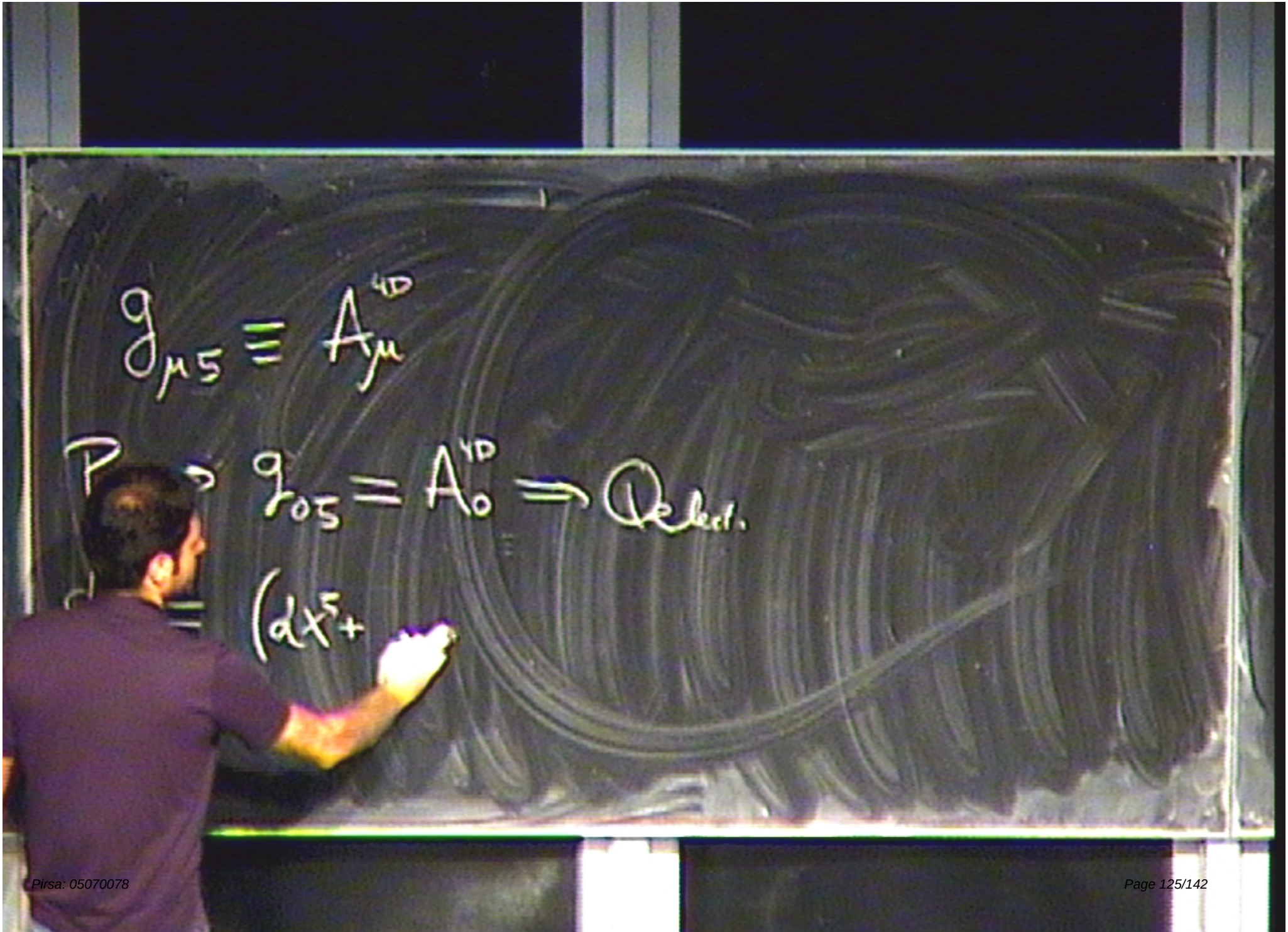

BR5 → BH4
Euc. TN.
S1 ↪ R3
BR
S1 × S2
S1∞
S2
R3


BR5 → BH4
Euc. TN. S1 ↪ R3
BR S1 × S2
S1∞
PS1
S2
Qdual = PS1 = J4
R3


BR$_5$ → BH$_4$
Euc. TN. $S^1 \subset R^3$
BR $S^1 \times S^2$
S^1_∞
P_{S^1}
J_4^{BR}
J_{4D}
S^2
$Q_{duct} = P_{S^1} = J_4$
R^3


BR5 → BH4
Euc. TN. S1 ↪ R3
BR S1 × S2
S1N
PS1
BR
J4
JHD
S2
Qdual = PS1 = J4
R3


BR5 → BH4
Euc. TN.
S1 ⊂ R3
BR
S1 × S2
S1∞
Ps1
JBR4
JHD
S2
Qdual = Ps1 = J4
R3


$g_{\mu 5} \equiv A_\mu^{4D}$
$g_{05} = A_0^{4D} \Rightarrow Q_{el.}$
$= (dx^5 +$

$$g_{\mu 5} \equiv A_\mu^{4D}$$

$$P_{S^1} \Rightarrow g_{05} \equiv A_0^{4D} \Rightarrow \text{Q}_{\text{elect.}}$$

$$ds^2_{(5)} = \left(dx^5 + C_\mu dx^\mu\right)^2 + \cdots \simeq \left(dx^5 + C_\mu dx^\mu \cdots\right)^2 \Rightarrow g_{\mu 5} = \;?$$

$g_{\mu 5}$ ↑ Graviphoton

$$g_{\mu 5} \equiv A_\mu^{4D}$$

$$P_5 \Rightarrow g_{05} = A_0^{4D} \Rightarrow \text{Q elect.}$$

$$ds^2_{(5)} \equiv \left(dx^5 + C_\mu dx^\mu\right)^2 + \cdots \simeq \left(dx^5 + C_\mu dx^\mu \cdots\right)^2 \Rightarrow g_{\mu 5} = A_\mu =$$

$+ \cdots$

$g_{\mu 5}$ ↑ spacelike

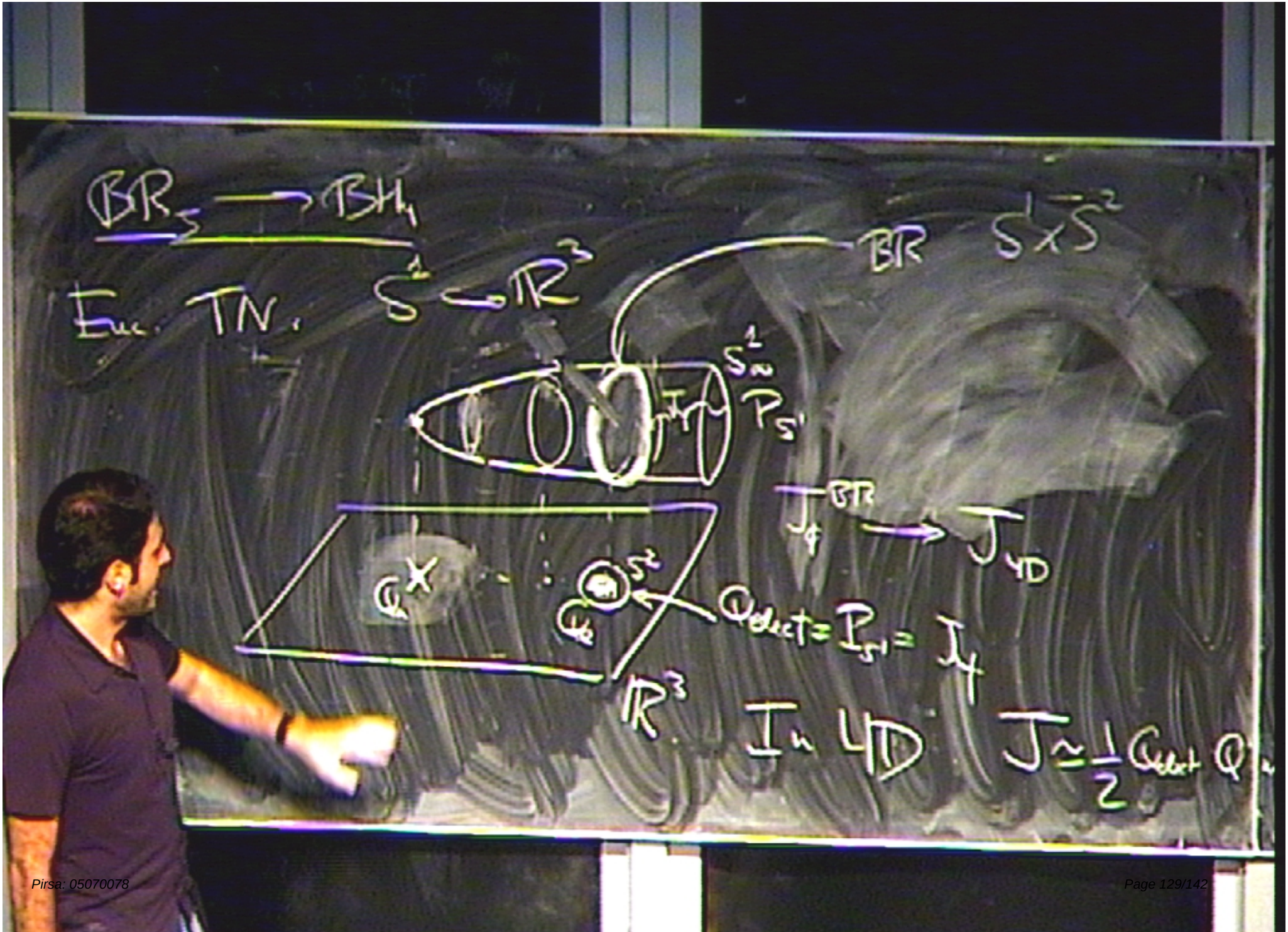
$g_{\mu 5} \equiv A_\mu^{4D}$

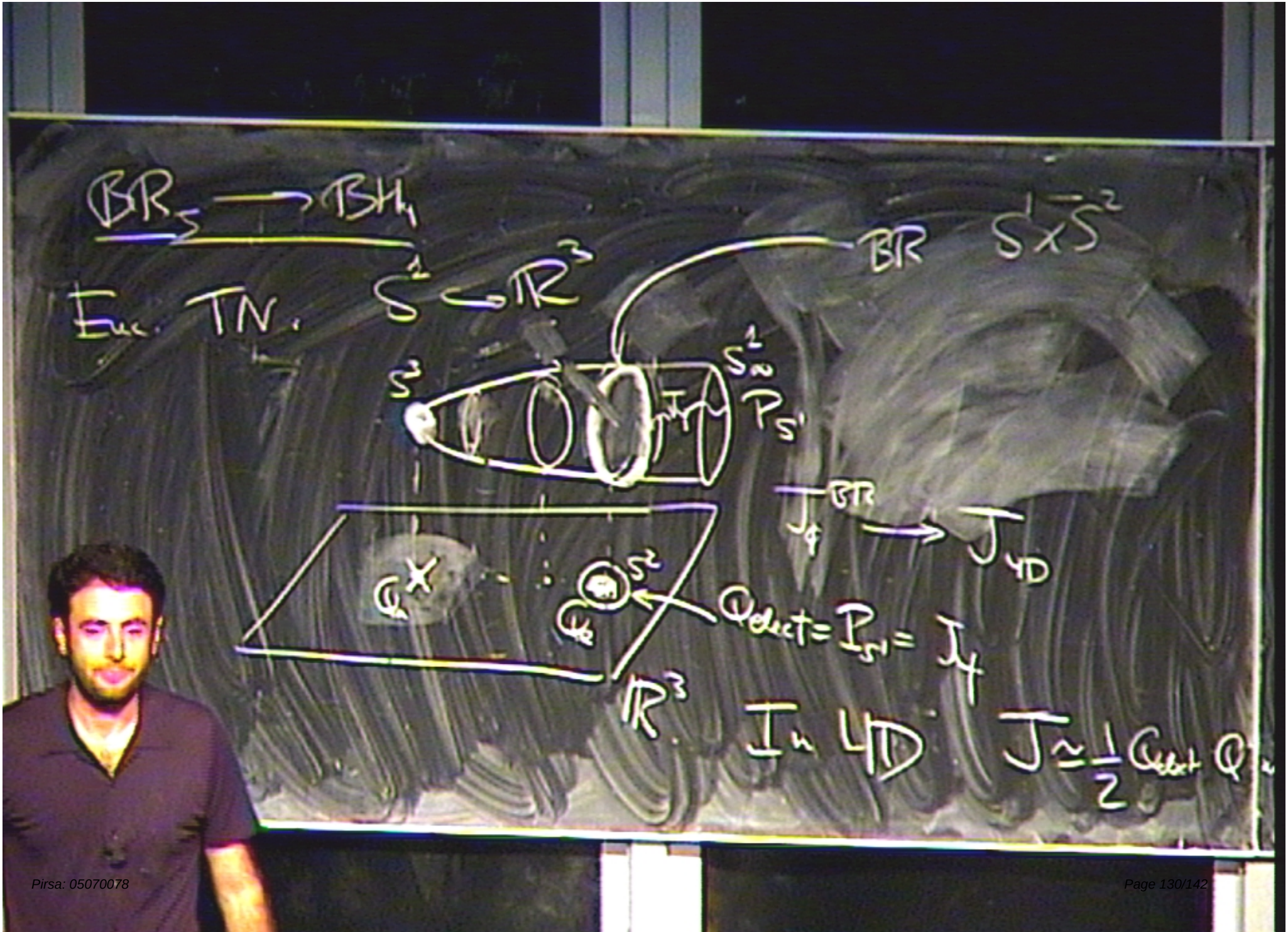
$P_5 \Rightarrow g_{05} = A_0^{4D} \Rightarrow$ Q_el.

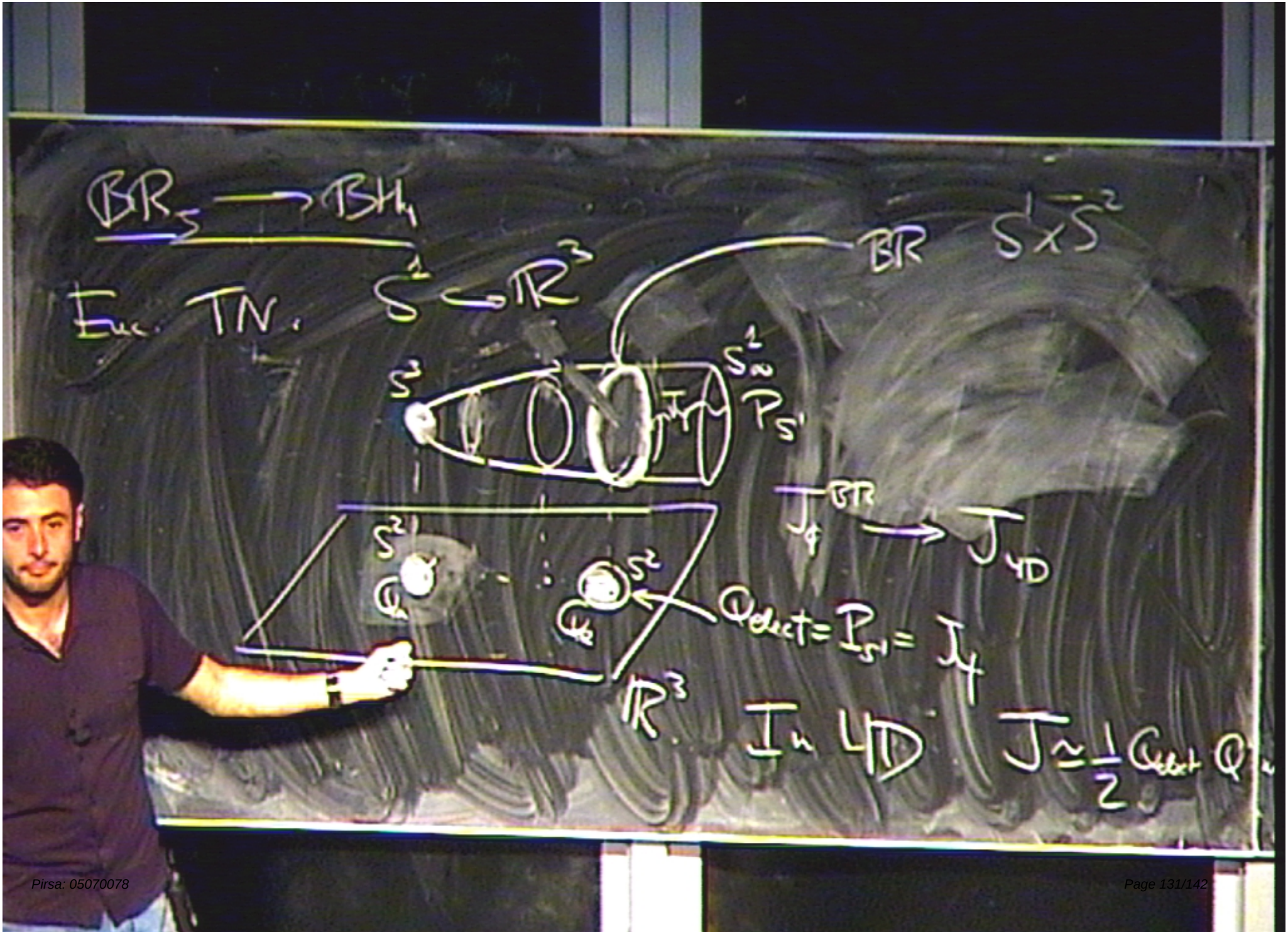
$ds_{(1)}^2 = \left(dx^5 + C_\mu dx^\mu\right)^2 + \cdots \simeq \left(dx^5 + C_\mu dx^\mu \cdots\right)^2 \Rightarrow g_{\mu 5} = A_\mu^{(1)} \Rightarrow$ Q_mag.

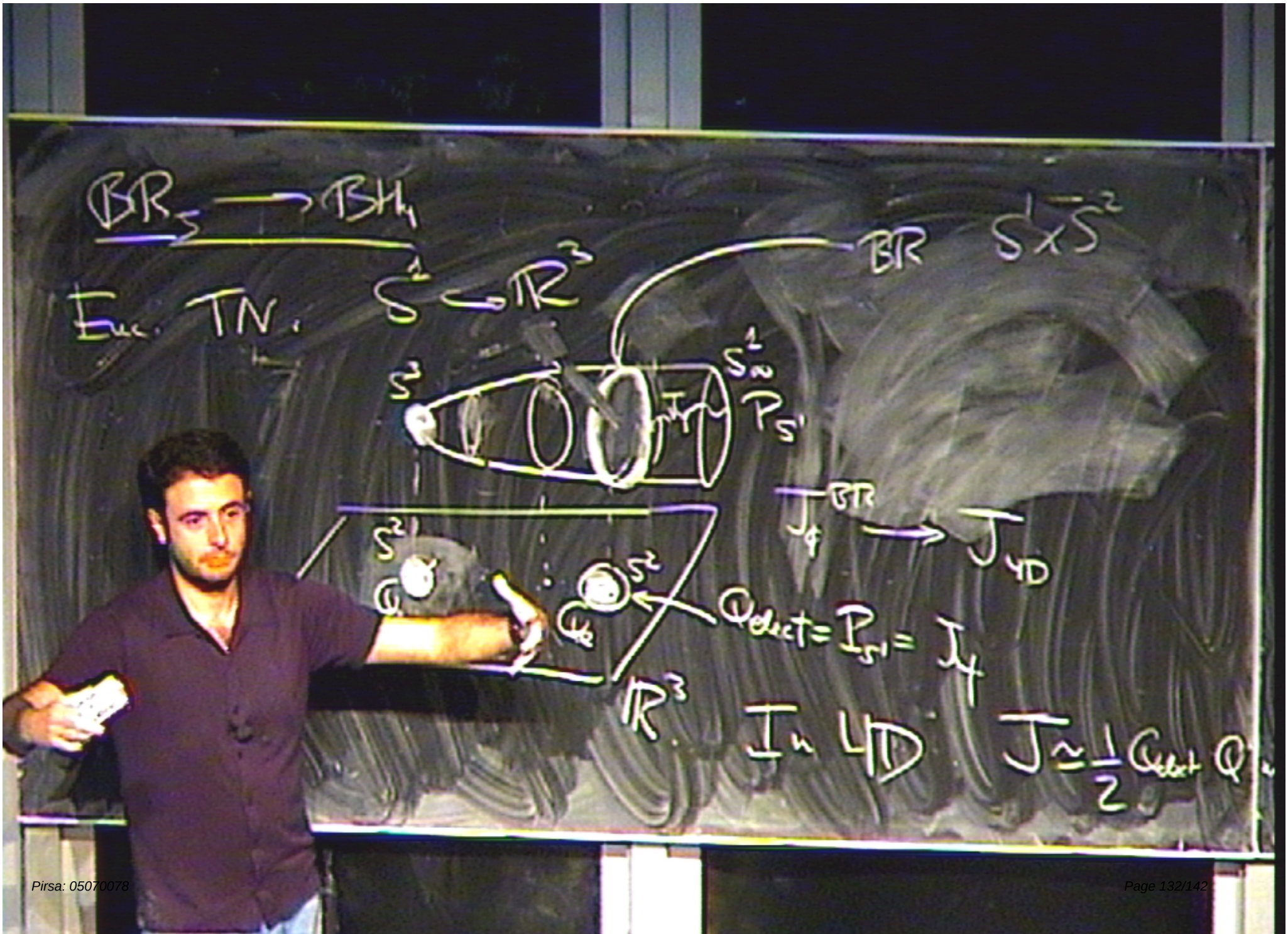
$Q_{(1)} + \cdots$

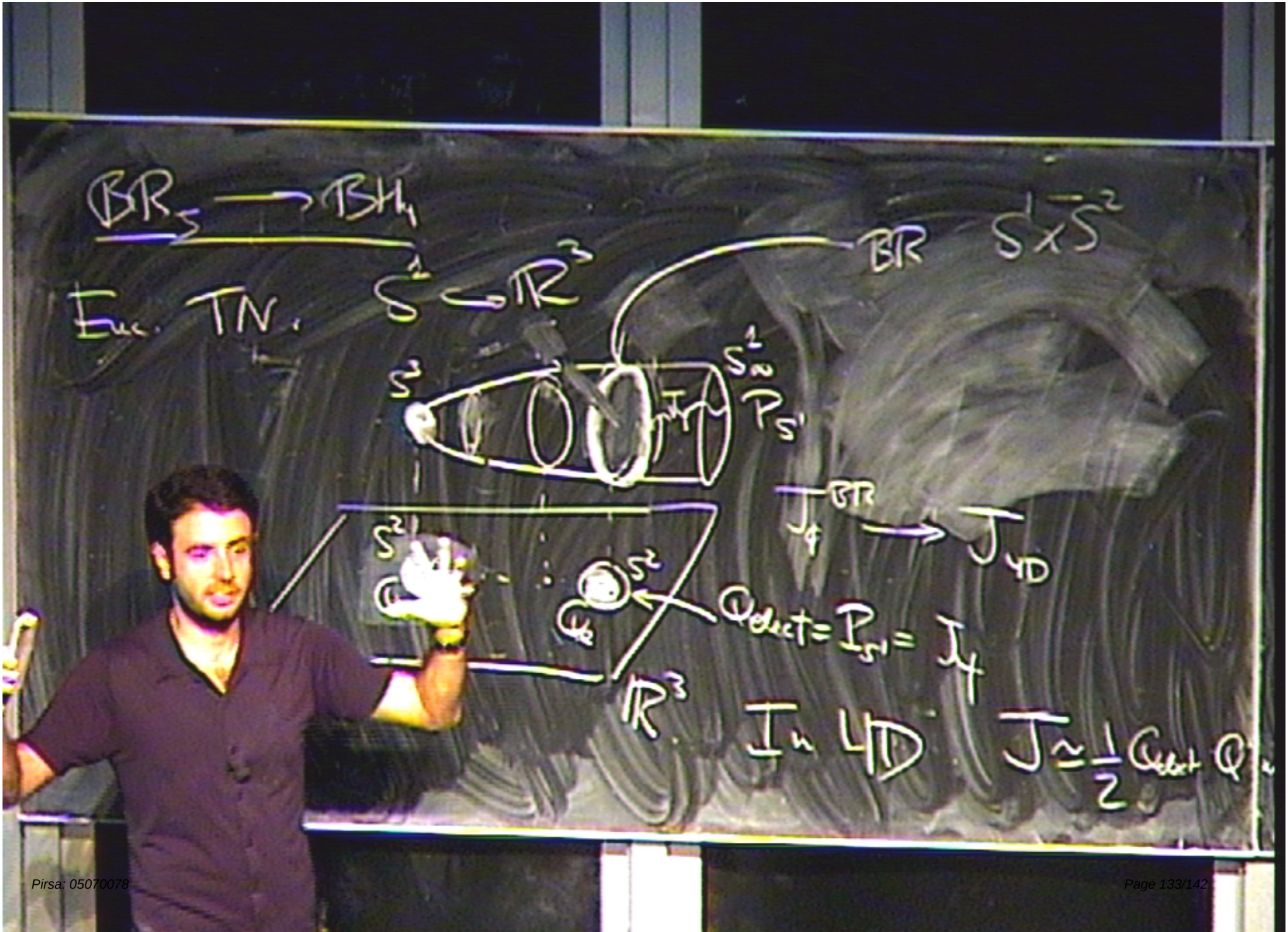
$g_{\mu 5}$ ↑ spectator

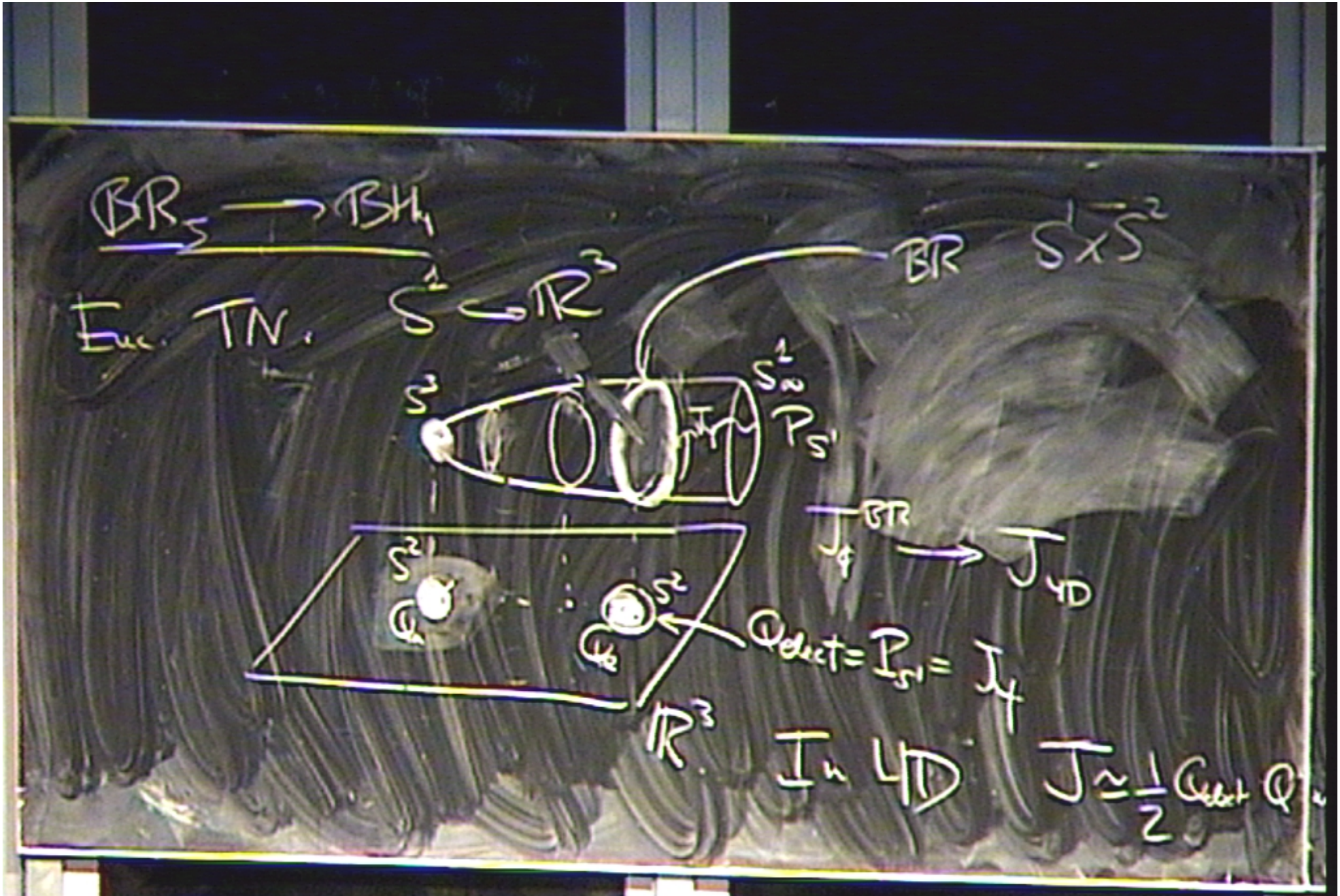

BR5 → BH4
Euc. TN. S1 ↪ R3
BR S1 × S2
R3
In 4D


BR$_5$ → BH$_4$
Euc. TN.
$S^1 \subset \mathbb{R}^3$
BR
$S^1 \times S^2$
S^2
S^1_∞
P_{S^1}
J_4^{BR}
J_{4D}
$Q_{ext} = P_{S^1} = J_4$
$\mathbb{R}^3$
In 4D
$J \simeq \frac{1}{2} Q_{ext}$


BR$_5$ → BH$_4$
Euc. TN.
$S^1 \subset \mathbb{R}^3$
BR
$S^1 \times S^2$
S^2
S^1_∞
P_{S^1}
J_4^{BR}
J_{4D}
S^2
S^2
$Q_{deact} = P_{S^1} = J_4$
$\mathbb{R}^3$
In 4D
$J \simeq \frac{1}{2} Q_{deact} Q$


BR3 → BH4
Euc. TN.
S1 ⊂ R3
BR
S1 × S2
S2
S1∞
PS1
JBR4
JHD
S2
S2
Qe
QeJect = PS1 = J4
R3
In HD
J ≃ 1/2 QeJect Q


BR$_5$ → BH$_4$
Euc. TN. $S^1 \subset R^3$
BR $S^1 \times S^2$
S^2
S^2_∞
P_{S^1}
J_4^{BR}
J_{4D}
S^2
S^2
$Q_{Bdact} = P_{S^1} = J_4$
R^3
In 4D
$J \simeq \frac{1}{2} Q_{Bdact} Q$

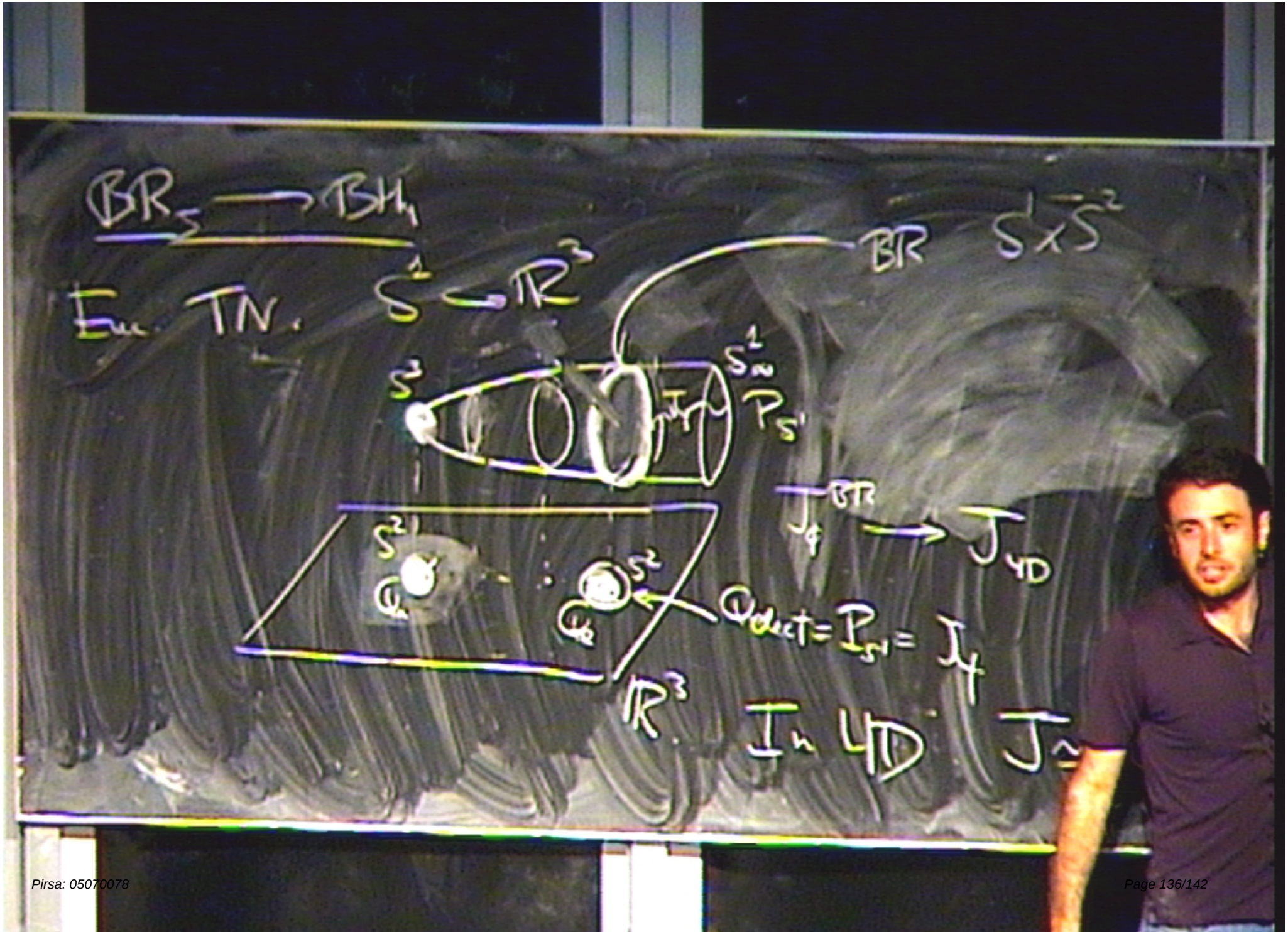

BR$_5$ → BH$_4$
Euc. TN. $S^1 \subset \mathbb{R}^3$
BR $S^1 \times S^2$
S^2
S^1_∞
P_{S^1}
J_4^{BR}
J_{4D}
S^2
S^2
$Q_{ebact} = P_{S^1} = J_4$
$\mathbb{R}^3$
In 4D
$J \simeq \frac{1}{2} Q_{ebact} Q$

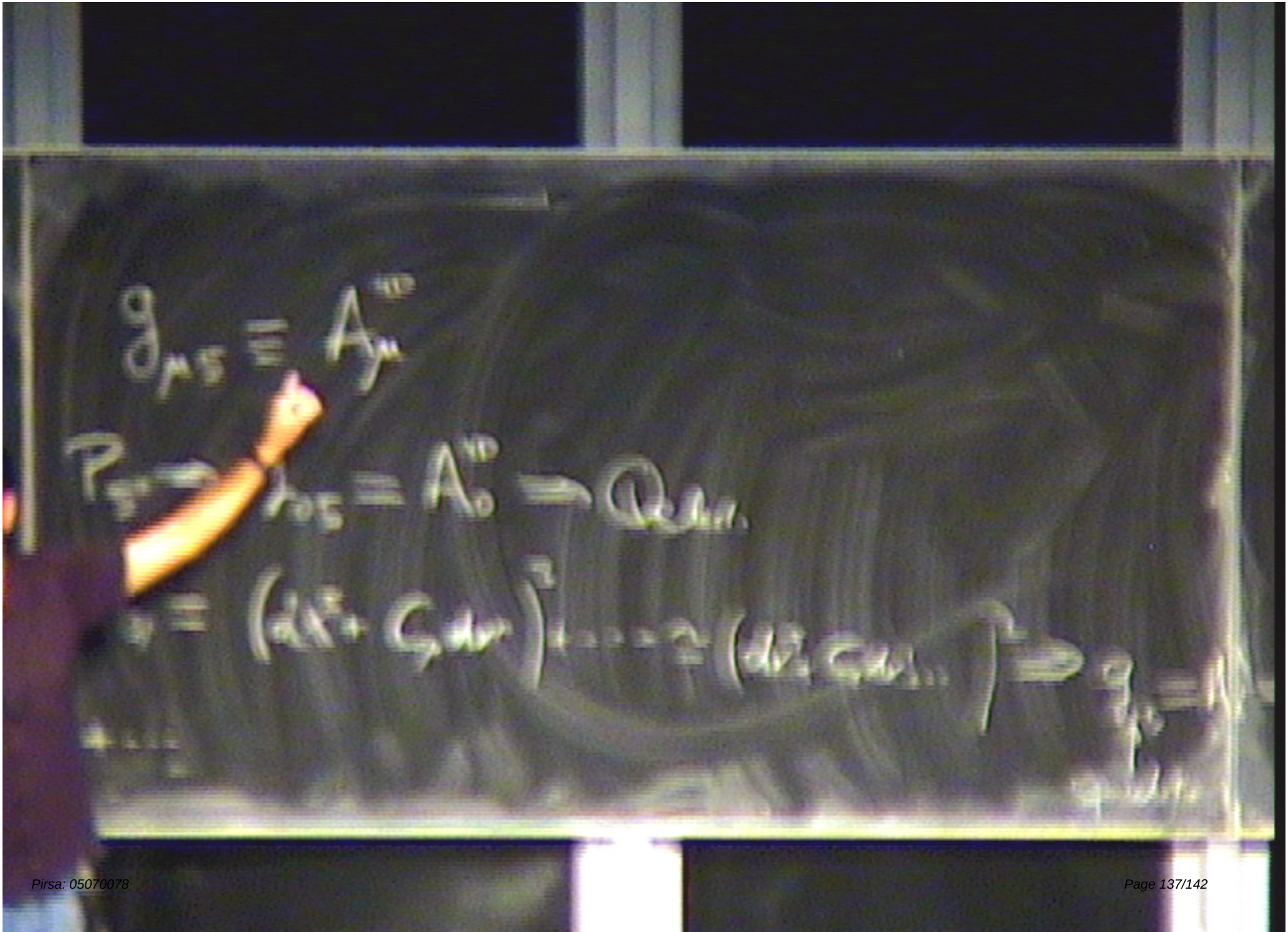
$Q_i \equiv Q$

$q_i = q$

$A_i \Longrightarrow$ Qhorg.

Q_1 M
Q_2 M
Q_3 M
q_1 m
q_2 m
q_3 m


BR5 → BH4
Euc. TN. S1 → R3
BR S1 × S2
S2
S1∞
PS1
BR
Jq → JYD
S2
S2
Qduct = PS1 = Jq
R3
In 4D
J≈



$g_{\mu 5} \equiv A_\mu^{4D}$

$P_{S^1} \Rightarrow g_{05} \equiv A_0^{4D} \Rightarrow$ Q elect.

$ds^2 = \left(dx^5 + C_\mu dx^\mu\right)^2 + \cdots \simeq \left(dx^5 + C_\mu dx^\mu \cdots\right)^2 \Rightarrow g_{\mu 5} = A_\mu =$

$+ \cdots$

$g_{\mu 5}$ ↑ Spacelike

$g_{\mu 5} \equiv A_\mu^{4D}$ $\qquad$ $A_m^5 \rightarrow A_\mu^{1\,4D}$

$P_{5'} \Rightarrow g_{05} \equiv A_0^{4D} \Rightarrow Q_{elect.}$

$ds^2_{(1)} \equiv \left(dx^5 + C_\mu dx^\mu\right)^2 + \cdots \simeq \left(dx^5 + C_\mu dx^\mu \cdots\right)^2 \Rightarrow g_{55} \equiv A$

$+ Q' A_\mu + \cdots$

g_{55} ↑ Spacelike

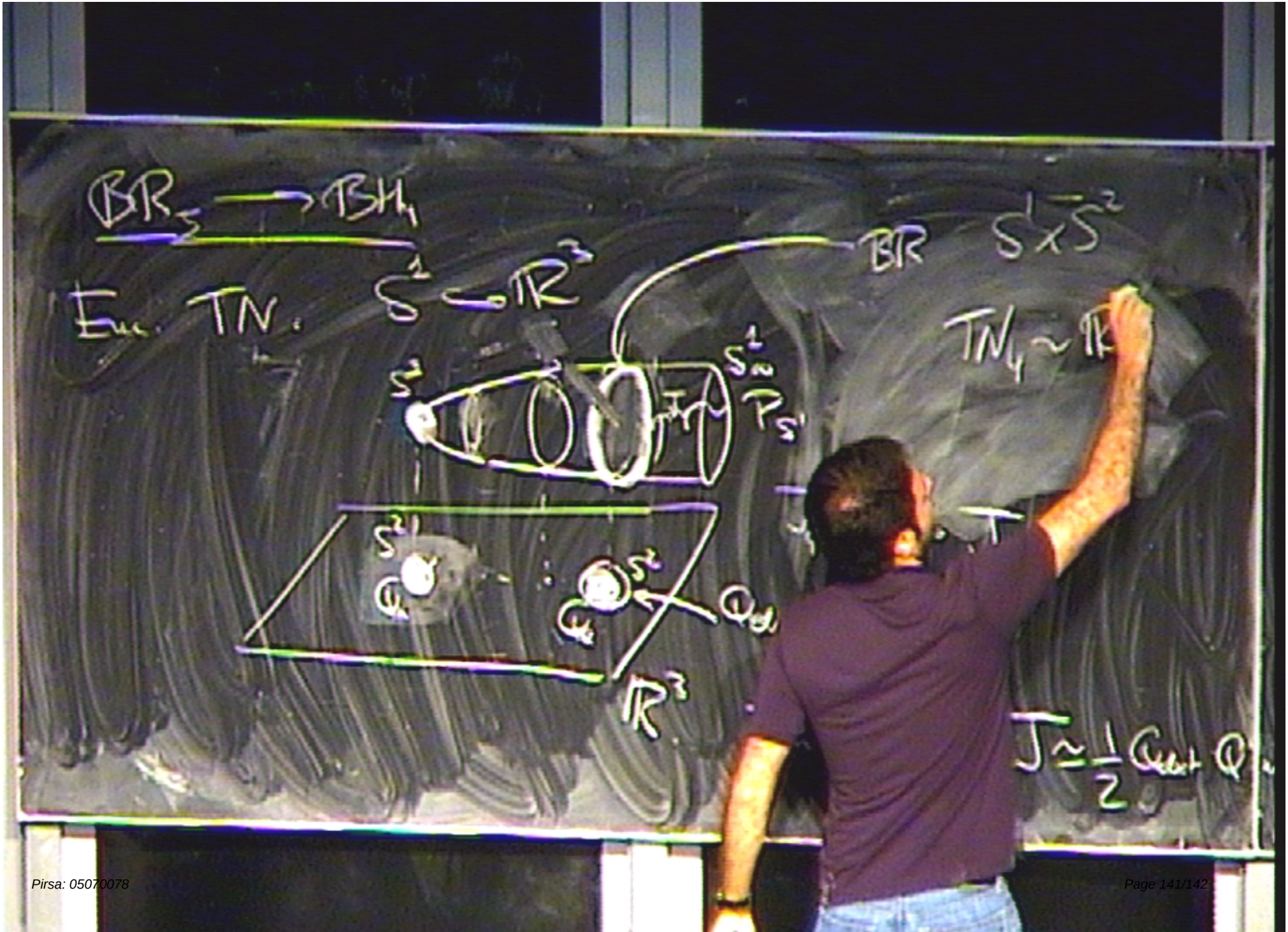
$Q_i \equiv Q$

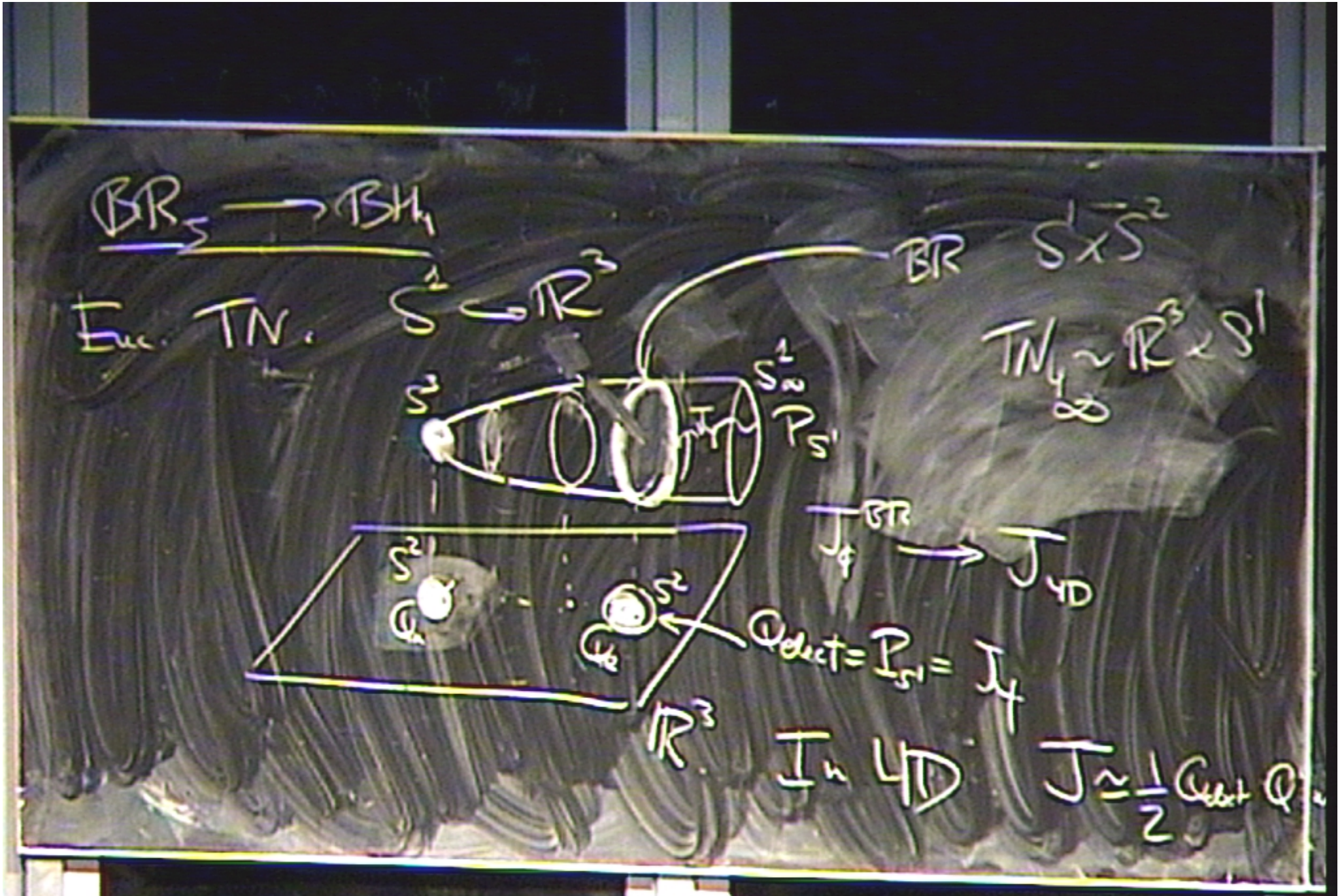
$q_i = q$

$AF \sim \mathbb{R}^4$

$A_i \longrightarrow Q_{neg.}$

Q_i M
Q_i M
Q_i M
q_i m
q_i m
q_i m


BR
BH
Euc. TN.
BR
TN


$BR_5 \longrightarrow BH_4$
Euc. TN. $S^1 \hookrightarrow R^3$
BR $S^1 \times S^2$
$TN_4 \underset{\infty}{\sim} R^3 \times S^1$
S^2
S^1_∞
P_{S^1}
$J_4^{BR} \longrightarrow J_{4D}$
S^2
S^2
$Q_{Euct} = P_{S^1} = J_4$
R^3
In 4D
$J \simeq \frac{1}{2} Q_{Euct} Q$