Title: AdS/CFT and cosmological backgrounds

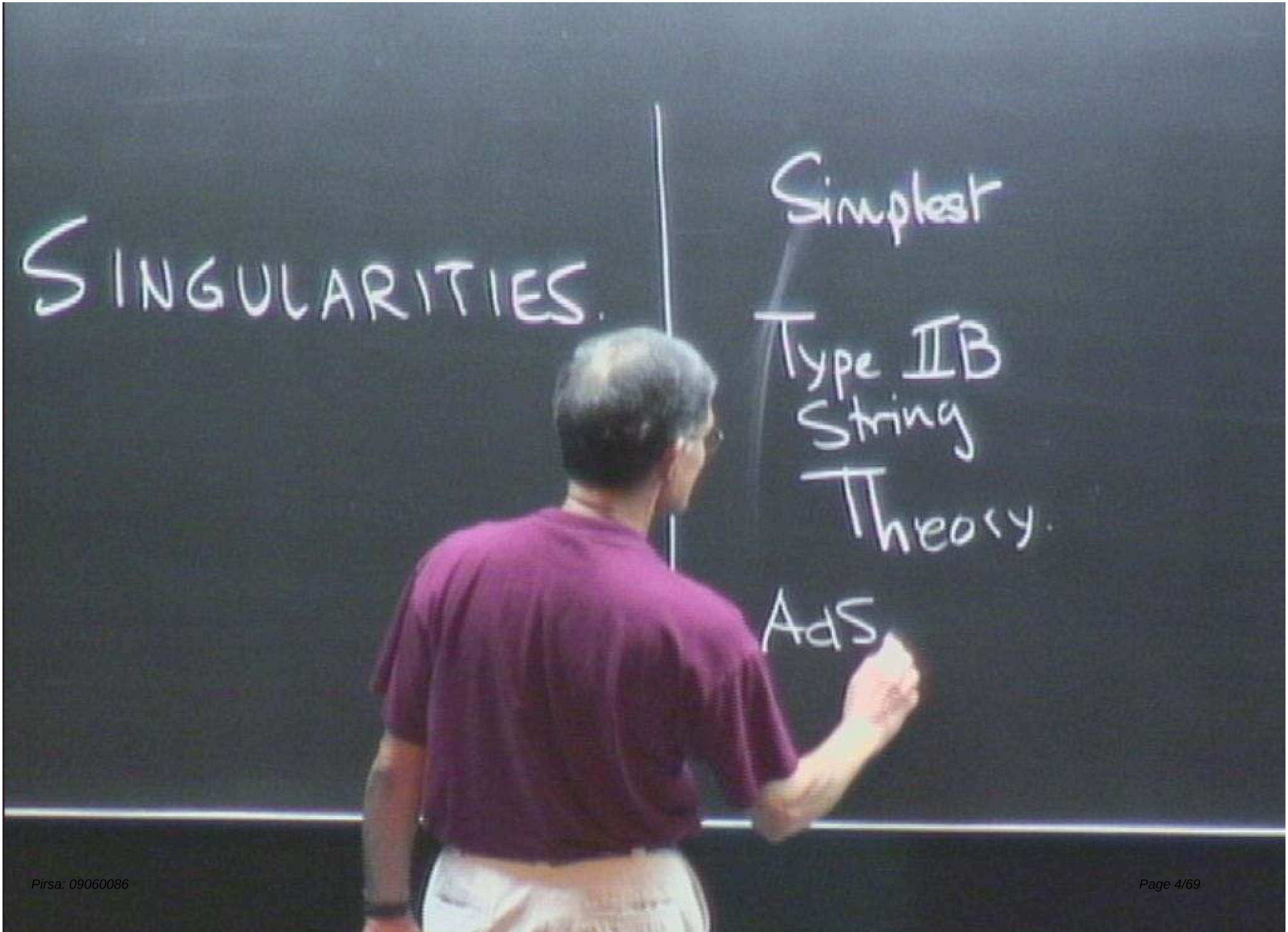
Date: Jun 30, 2009 02:00 PM

URL: http://pirsa.org/09060086

Abstract:

SINGULARITIES.

SINGULARITIES.


SINGULARITIES.
Simplest
Type IIB
String
Theory.
AdS

SINGULARITIES.

Simplest

Type IIB String Theory.

$AdS_5 \times S^5$

SINGULARITIES.

Simplest

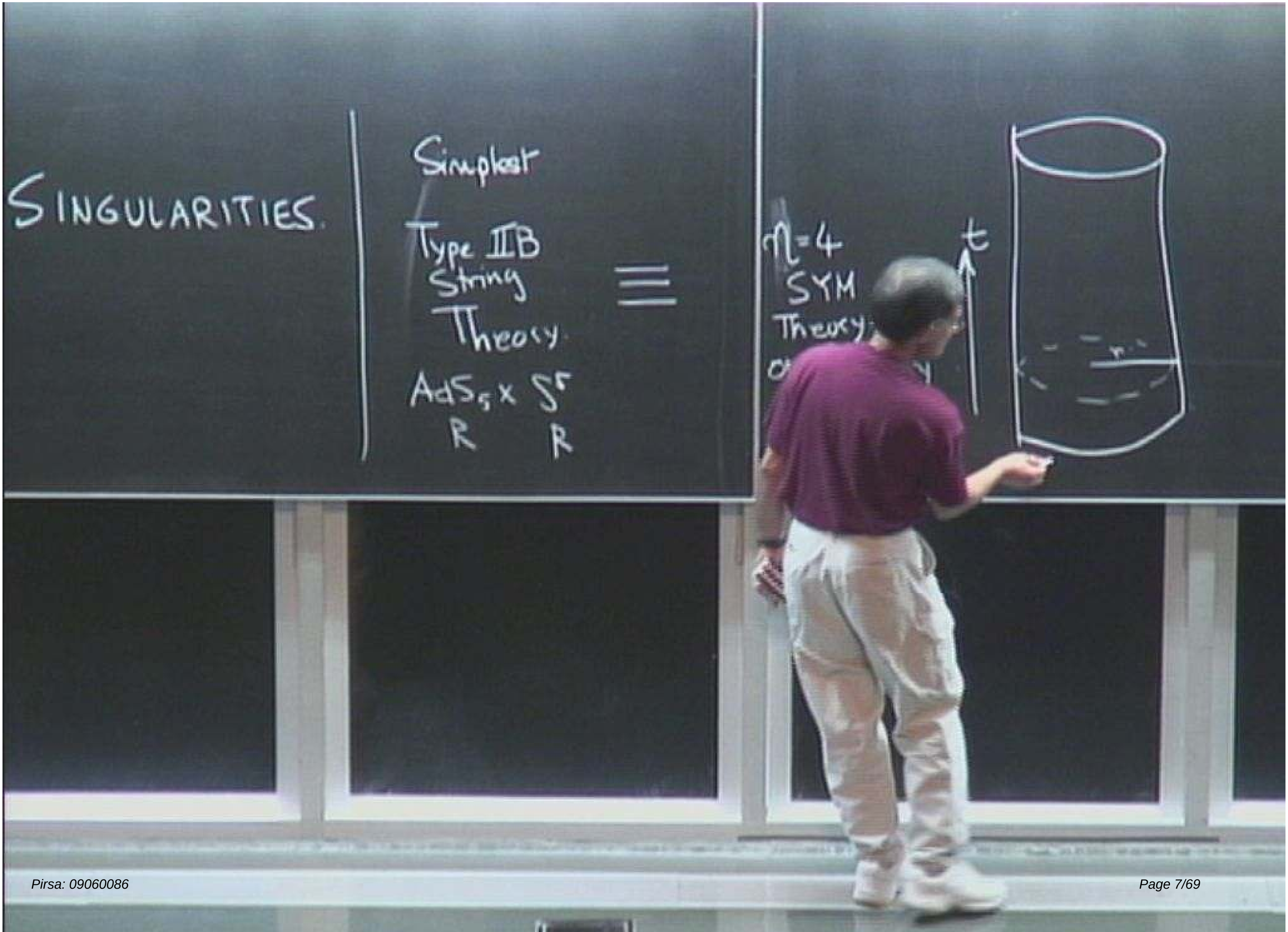
Type IIB String Theory.

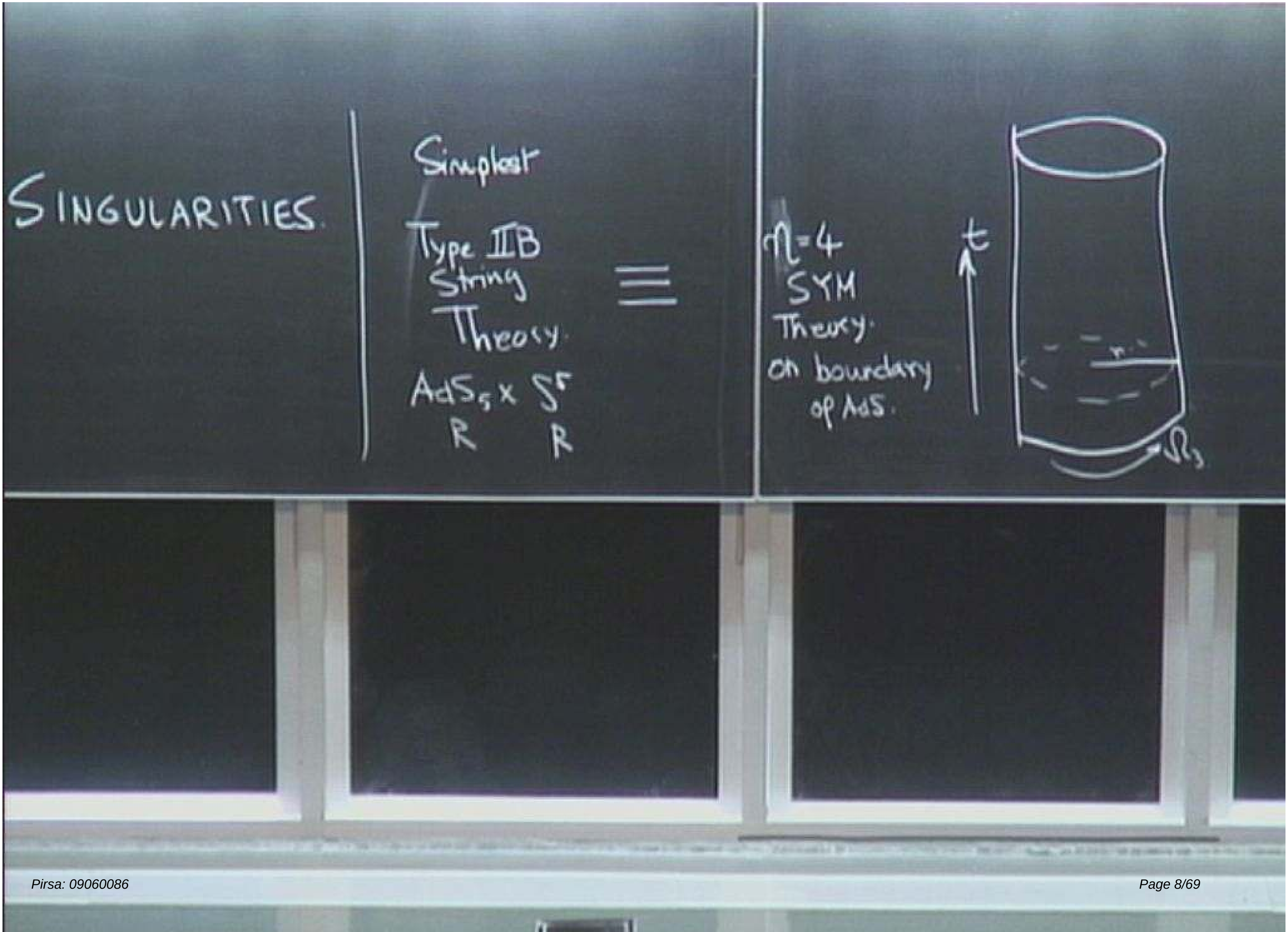
$AdS_5 \times S^5$

$R \quad R$

$\equiv$

$\mathcal{N}=4$ SYM Theory.

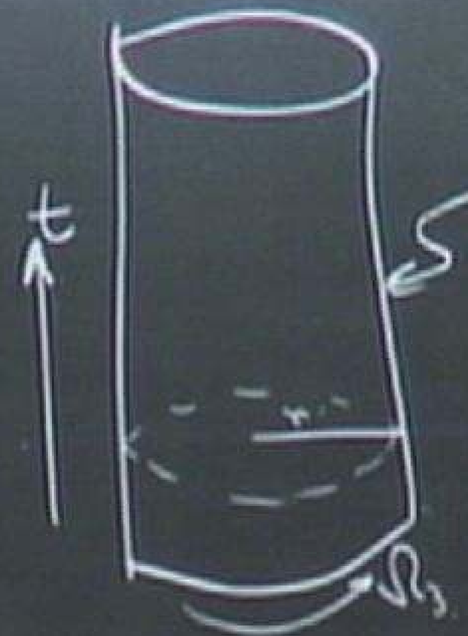

SINGULARITIES.
Simplest
Type IIB
String
Theory.
AdS5 x S5
R R
≡
N=4
SYM
Theory
t


SINGULARITIES.
Simplest
Type IIB
String
Theory.
$AdS_5 \times S^5$
R R
$\equiv$
$\mathcal{N}=4$
SYM
Theory.
on boundary
of AdS.
t
r
Ω_3

Simplest

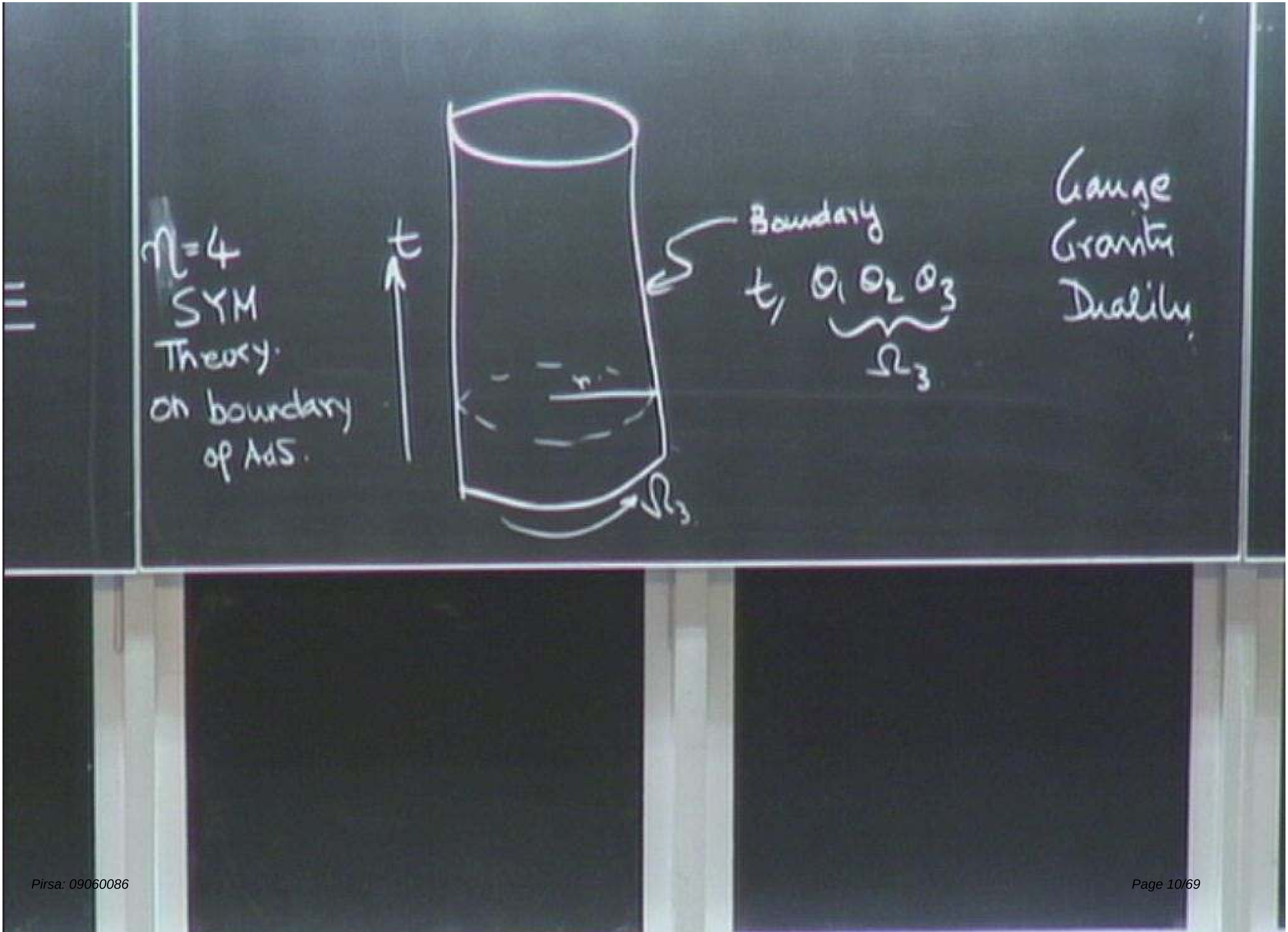
$$\left(\begin{array}{c} \text{Type IIB} \\ \text{String} \\ \text{Theory} \\ AdS_5 \times S^5 \\ R \qquad R \end{array} \right) \equiv$$

$\mathcal{N}=4$
SYM
Theory
on boundary
of AdS5.



Boundary

$t, \underbrace{O_1\, O_2\, O_3}_{\Omega_3}$


N=4
SYM
Theory.
on boundary
of AdS.
t
Boundary
t, θ1 θ2 θ3
Ω3
r
Ω3
Gauge
Gravity
Duality

SINGULARITIES.

g_s. l_s.

Simplest

(Type IIB String Theory.

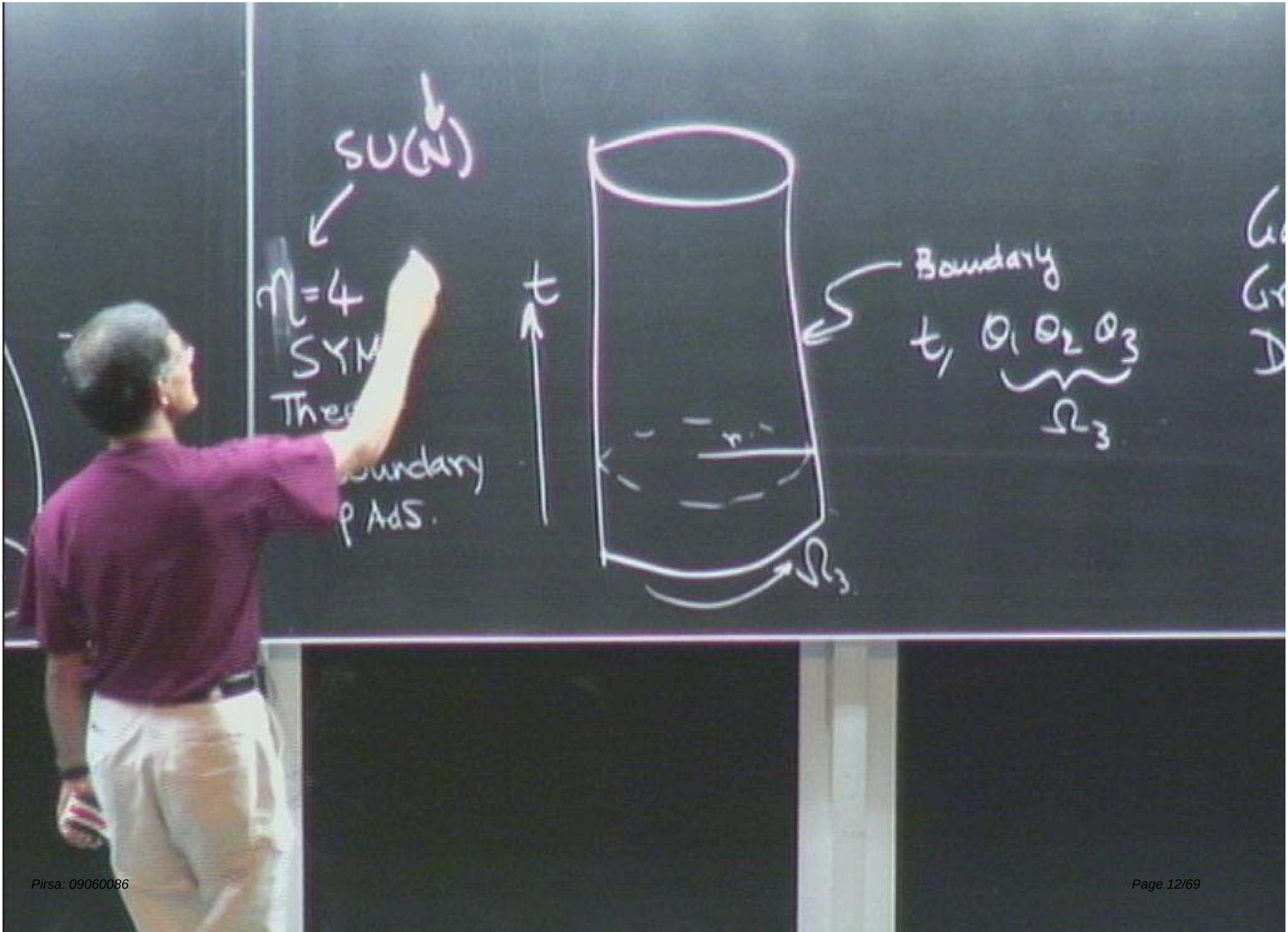
$AdS_5 \times S^5$

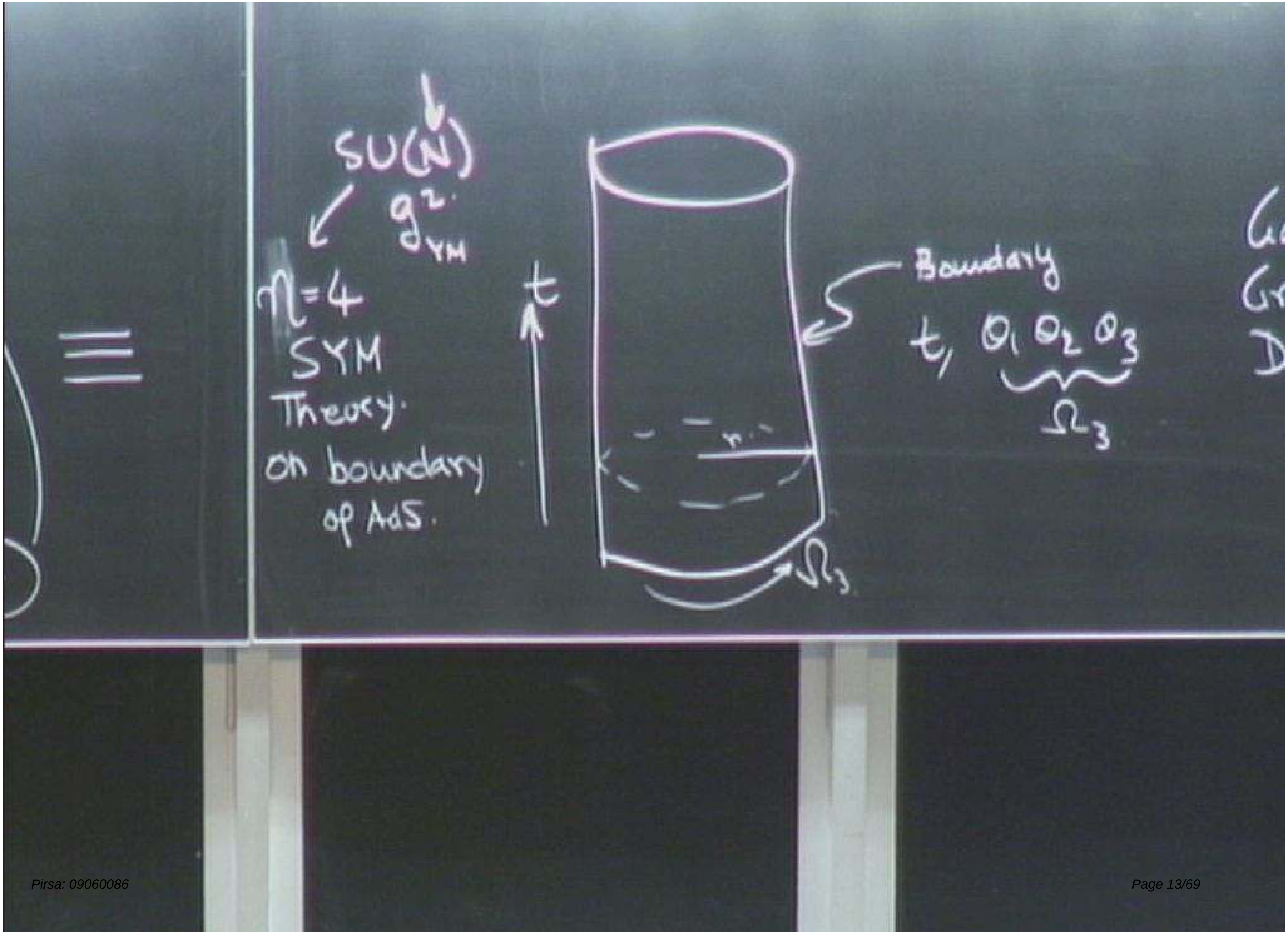
R R)

$\equiv$

$\mathcal{N}=4$ SYM Theory on bound

of AdS


SU(N)
$\mathcal{N}=4$
SYM
oundary
AdS.
t
Boundary
$t, \underbrace{O_1 \, O_2 \, O_3}_{\Omega_3}$
Ω_3


$SU(N)$
g^2_{YM}
$\mathcal{N}=4$
SYM
Theory.
on boundary
of AdS5.
t
Boundary
$t, \underbrace{O_1\ O_2\ O_3}_{\Omega_3}$
Ω_3

$\Omega_2 \, \Omega_3$

Ω_3

Gauge

Gravity

Duality

$$g_s = g_{YM}^2$$

$$\left(\frac{R}{l_s}\right) = 4\pi\left(g_{YM}^2 N\right)$$

$$g_s = g_{YM}^2$$

't Hooft large N limit

$$\left(\frac{R}{l_s}\right) = 4\pi(g_{YM}^2 N)$$

$N \gg 1$.

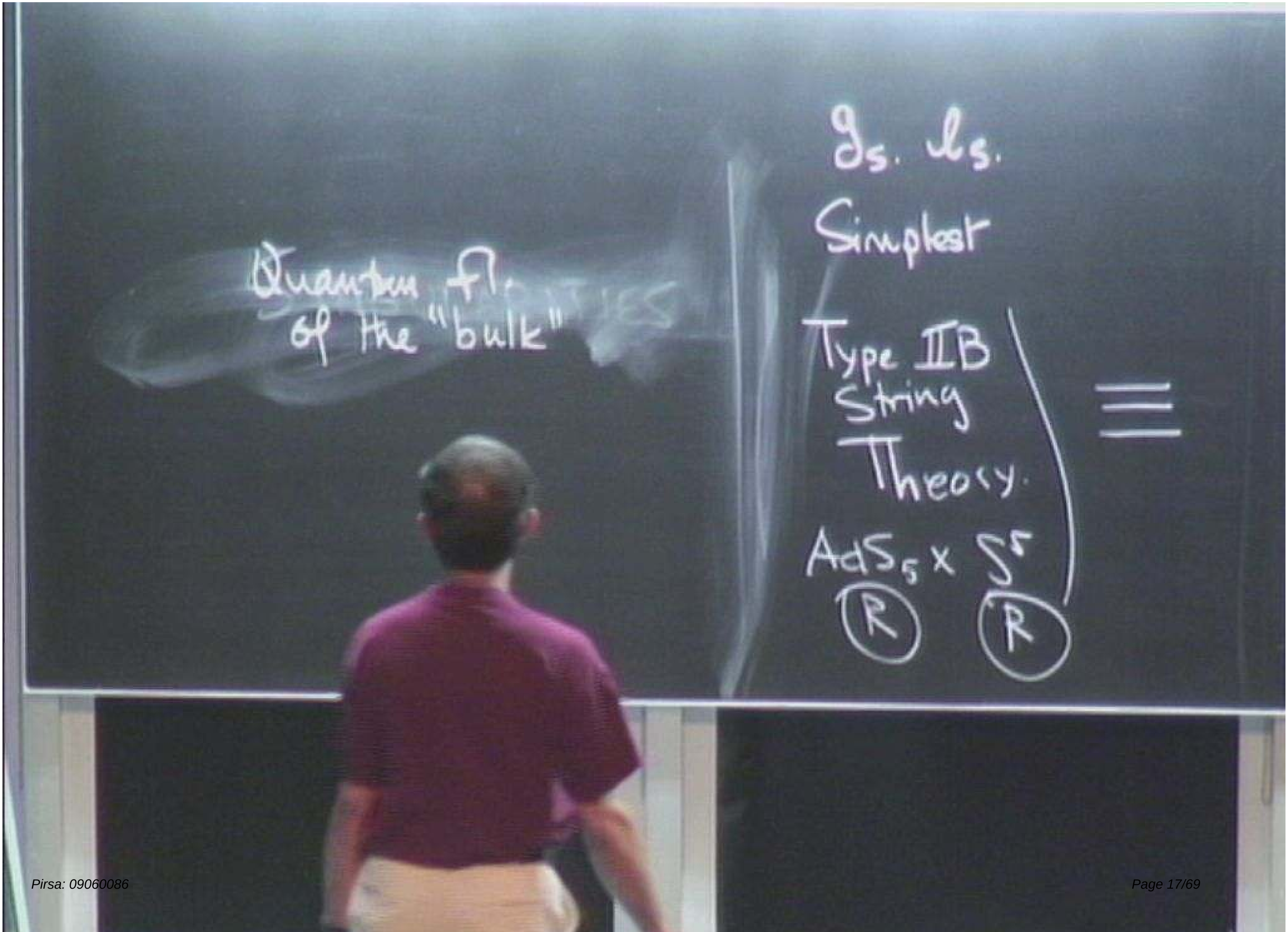
$$g_s = g_{YM}^2$$

$$\left(\frac{R}{l_s}\right) = 4\pi(g_{YM}^2 N)$$

't Hooft large N limit

$$N \gg 1$$

$$\lambda = g_{YM}^2 N \sim \text{fixed}$$


Quantum fl.
of the "bulk"
g_s. l_s.
Simplest
Type IIB
String
Theory.
$AdS_5 \times S^5$
R
R
≡

Quantum fl.
of the "bulk"

$\sim \frac{\lambda}{N}$

g_s. l_s.

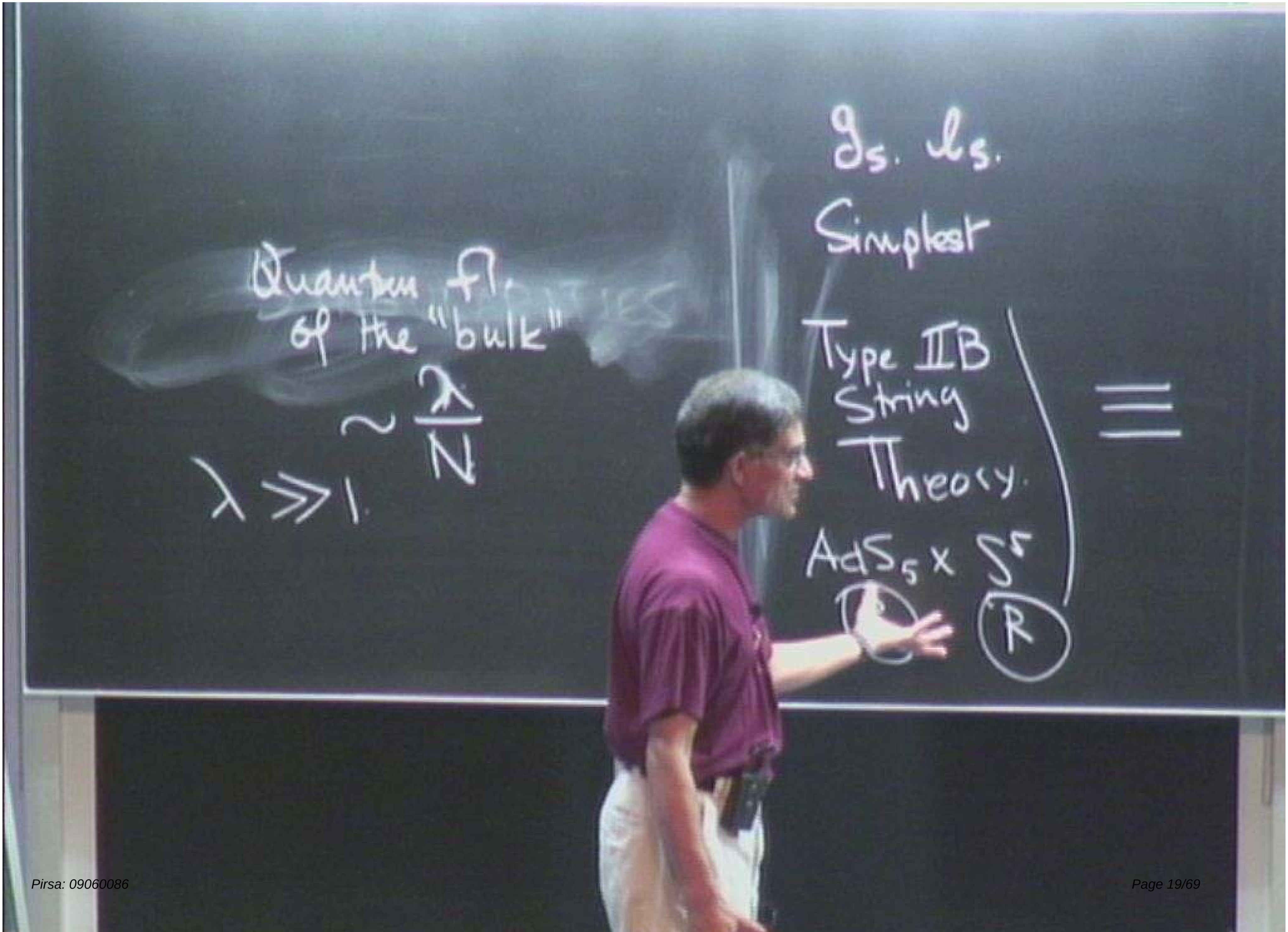
Simplest

Type IIB
String
Theory.

$AdS_5 \times S^5$

R R

$\equiv$


Quantum fl.
of the "bulk"
~ λ/N
λ ≫ 1.
gs. ls.
Simplest
Type IIB
String
Theory.
AdS5 x S5
R
≡

Quantum fl.
of the "bulk"

$$\sim \frac{\lambda}{N}$$

$\lambda \gg 1.$

$$\left(\frac{R}{l_s}\right) \gg 1.$$

$g_s.\ l_s.$

Simplest

Type IIB
String
Theory.

$\equiv$

$AdS_5 \times S^5$

$R \quad R$

g_s. l_s.

Simplest

Quantum fl.
of the "bulk"

$\sim \frac{\lambda}{N}$

$\lambda \gg 1$.

$\left(\frac{R}{l_s}\right) \gg 1$.

Normal space-time
Sugra.

Type IIB
String
Theory.

$AdS_5 \times S^5$

R R

$\equiv$

Quantum fl.
of the "bulk"

$$\sim \frac{\lambda}{N}$$

$$\lambda \gg 1. \quad \left(\frac{R}{l_s}\right) \gg 1.$$

Normal space-time
Sugra.

g_s. l_s.

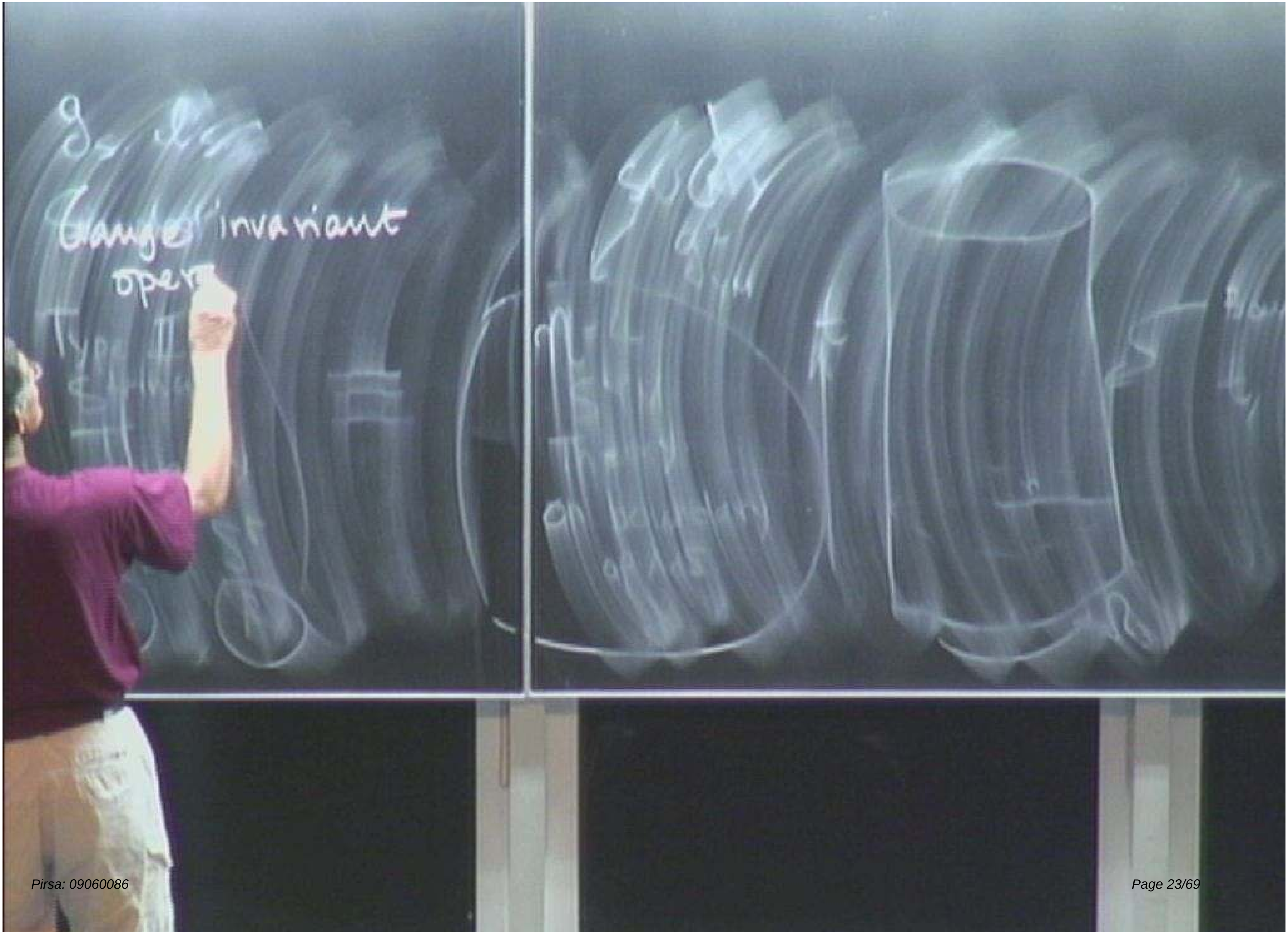
Simplest

Type IIB
String
Theory.

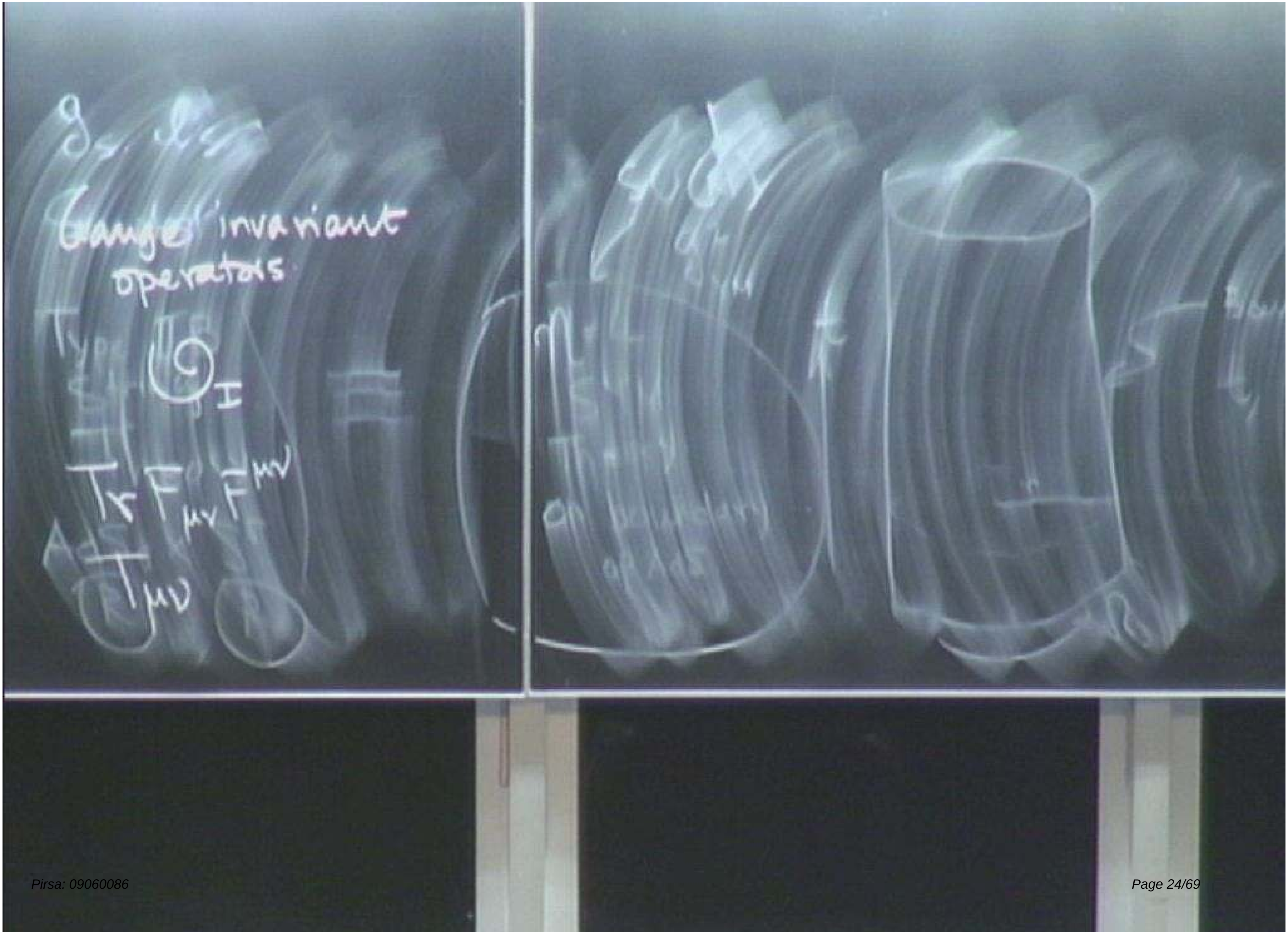
$AdS_5 \times S^5$

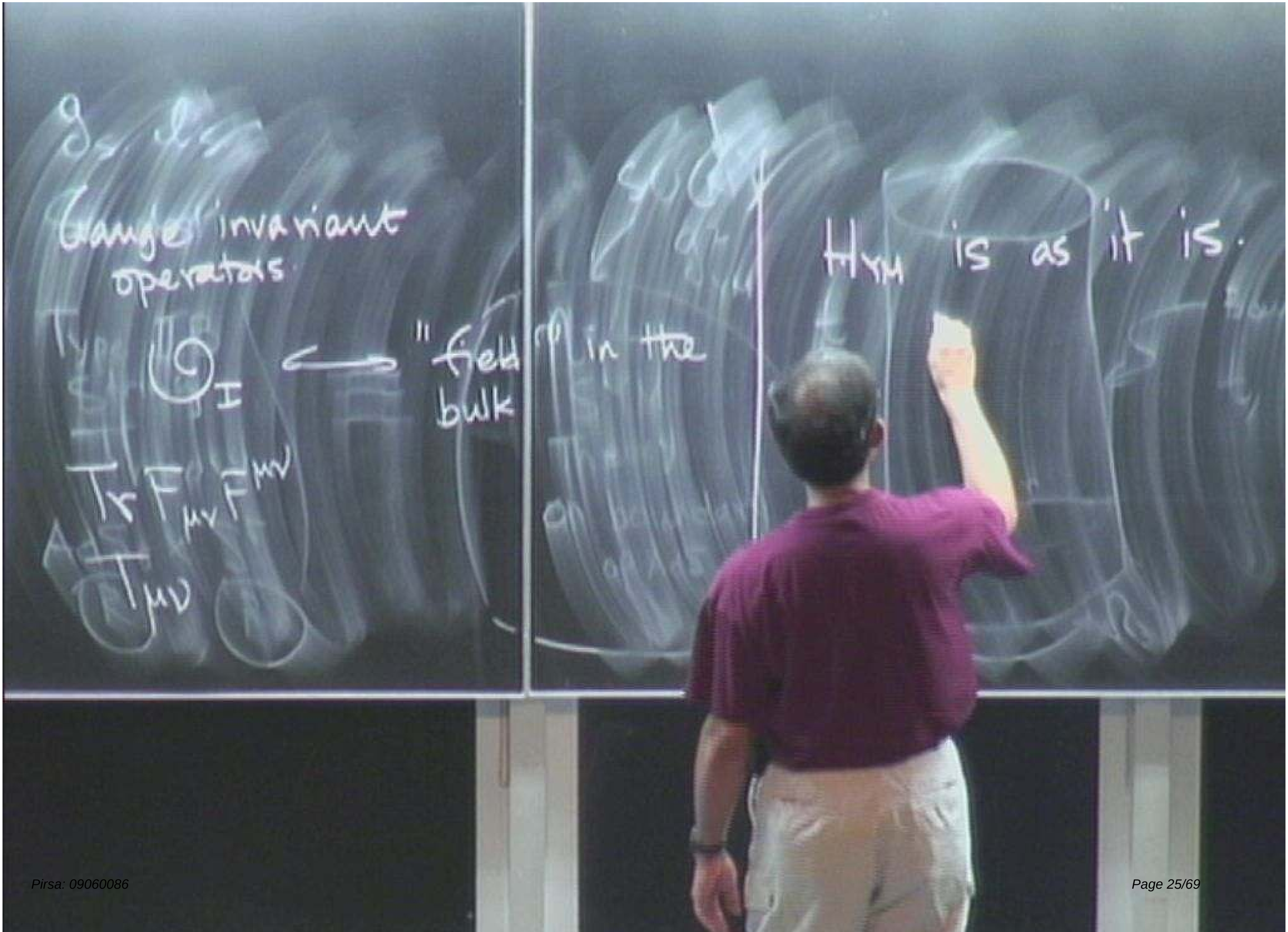
R R

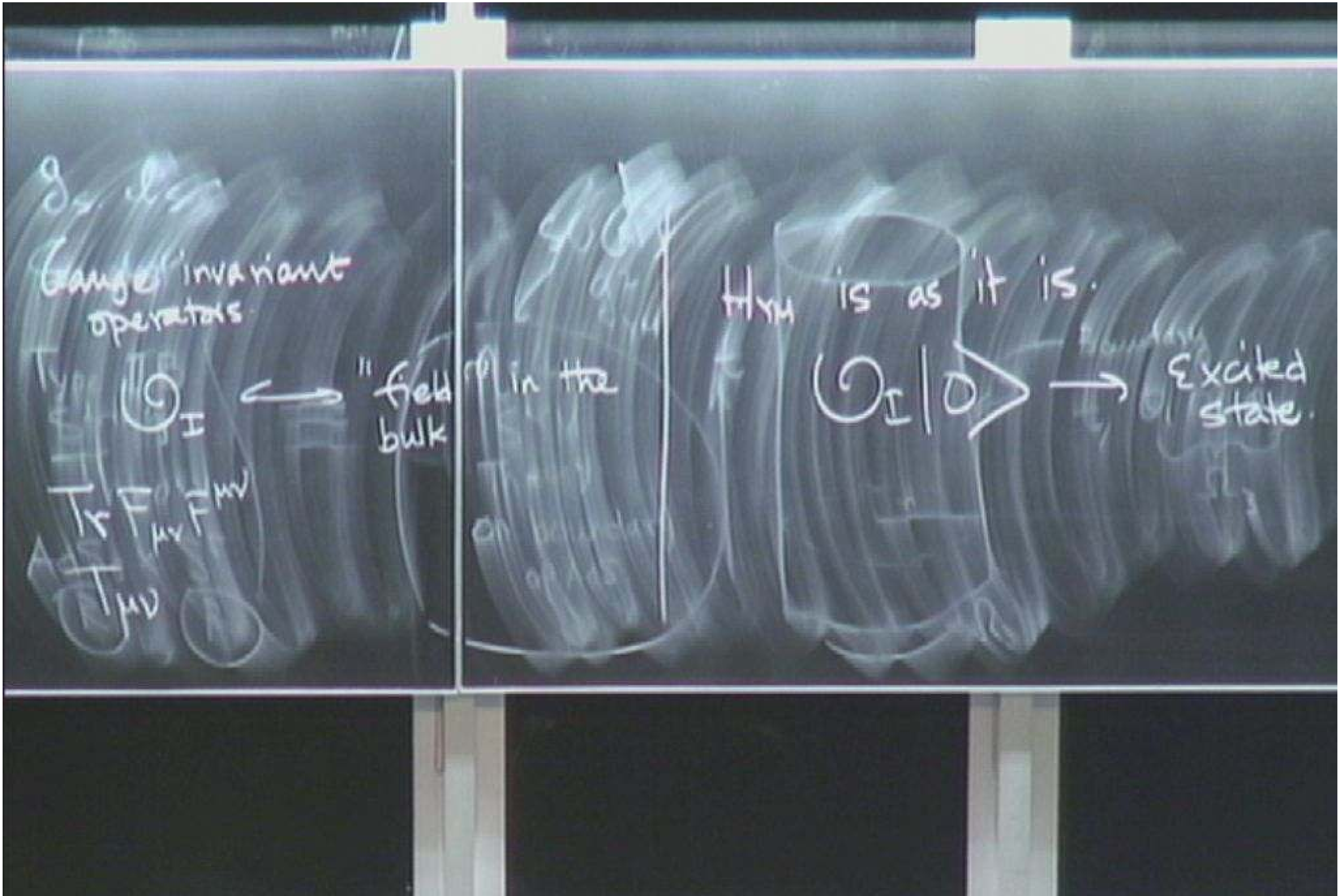
$\equiv$



Gauge invariant
oper


Gauge invariant
operators
$\mathrm{Tr}\, F_{\mu\nu} F^{\mu\nu}$
$T_{\mu\nu}$


Gauge invariant operators
$\mathcal{O}_I \longleftrightarrow$ "field" in the bulk
$\mathrm{Tr}\, F_{\mu\nu} F^{\mu\nu}$
$T_{\mu\nu}$
H_{YM} is as it is.


Gauge invariant operators
$\mathcal{O}_I \longleftrightarrow$ "field" in the bulk
$\mathrm{Tr}\, F_{\mu\nu} F^{\mu\nu}$
$T_{\mu\nu}$
H_{YM} is as it is.
$\mathcal{O}_I |0\rangle \longrightarrow$ Excited state.

Gauge invariant operators

$\mathcal{O}_I \longleftrightarrow$ "field" in the bulk

$\mathrm{Tr}\, F_{\mu\nu} F^{\mu\nu}$

$T_{\mu\nu}$

H_{YM} is as it is.

$\mathcal{O}_I |0\rangle \longrightarrow$ Excited state.

$S_{YM} \longrightarrow S_{YM} + \int g(x)\, \mathcal{O}_I(x)$

Gauge invariant operators

$\mathcal{O}_I \longleftrightarrow$ "field" in the bulk

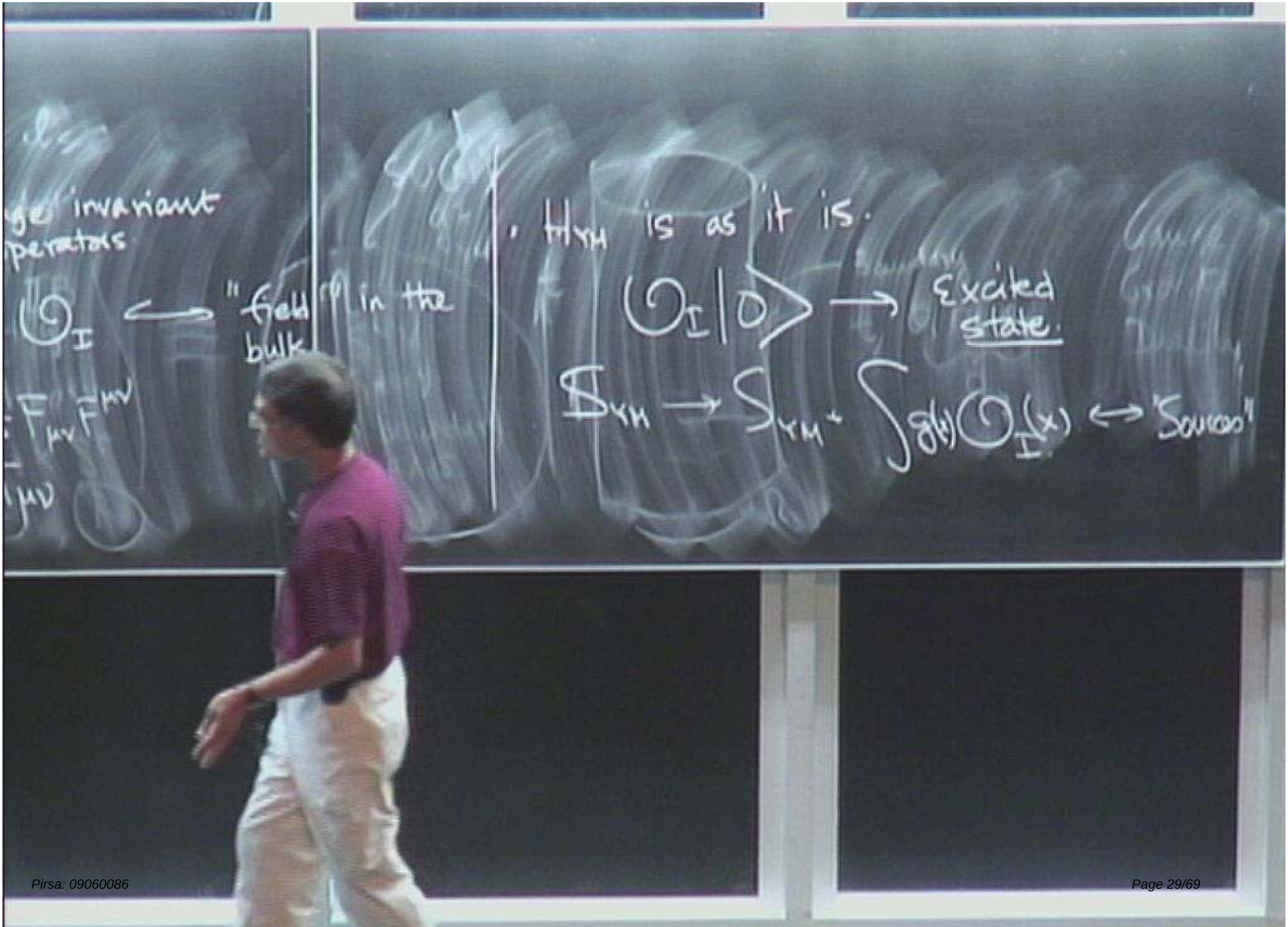
$\mathrm{Tr}\, F_{\mu\nu}F^{\mu\nu}$

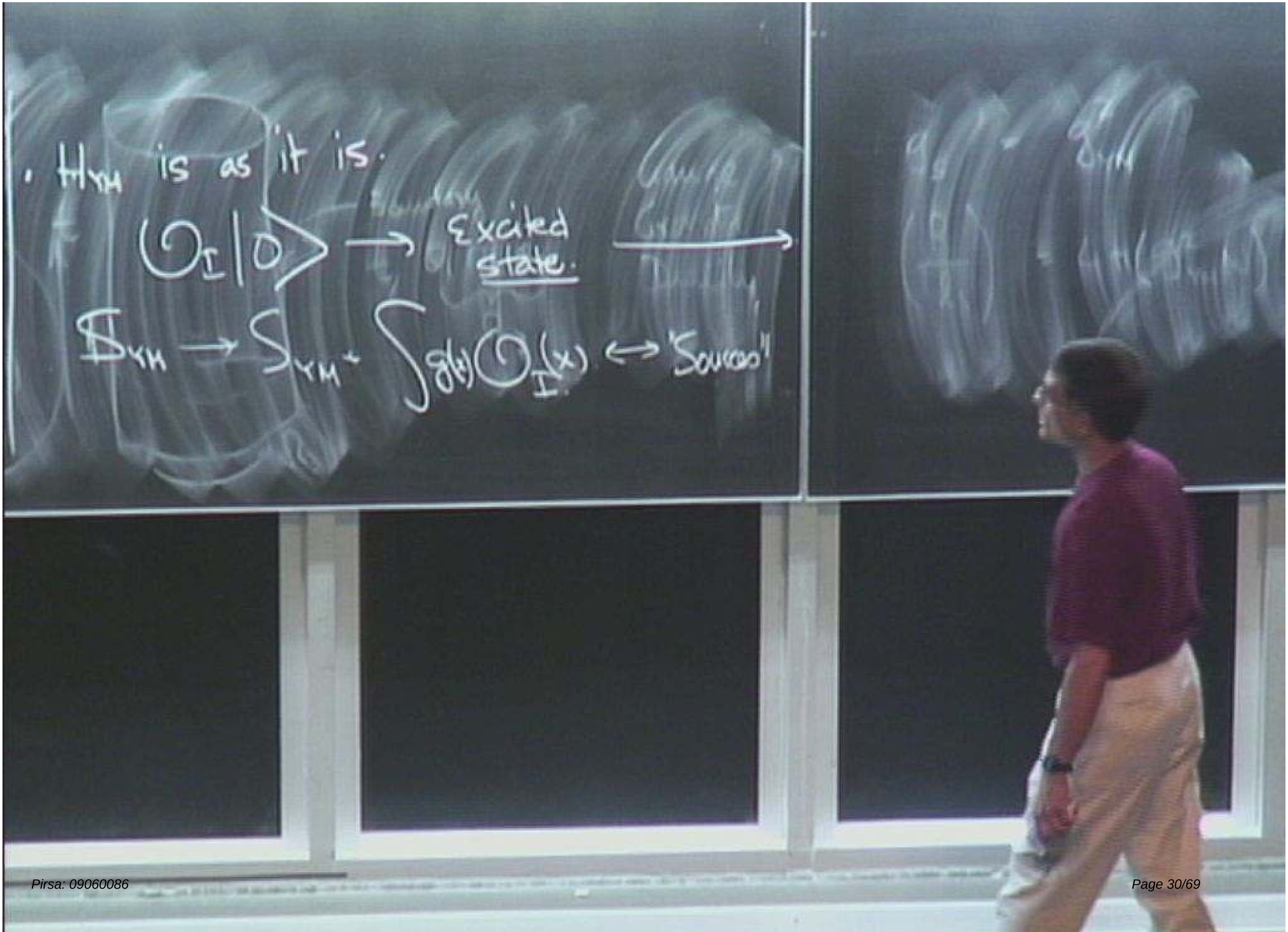
$T_{\mu\nu}$

H_{YM} is as it is.

$\mathcal{O}_I|0\rangle \longrightarrow$ Excited state.

$S_{YM} \longrightarrow S_{YM} + \int g(x)\,\mathcal{O}_I(x)$


invariant
"field" in the
bulk
$F_{\mu\nu}F^{\mu\nu}$
H_{YM} is as it is.
$O_I|0\rangle \longrightarrow$ Excited state.
$S_{YM} \longrightarrow S_{YM} + \int g(x) O_I(x) \leftrightarrow$ "Sources"


. H_{YM} is as it is.
$\mathcal{O}_I|0\rangle \longrightarrow$ Excited state.
$S_{YM} \longrightarrow S_{YM} + \int g(x)\,\mathcal{O}_I(x) \longleftrightarrow$ "Sources"

. H_{YM} is as it is.

$\langle \mathcal{O}_I | 0 \rangle \longrightarrow$ Excited state. $\longrightarrow$ normalizable deformation

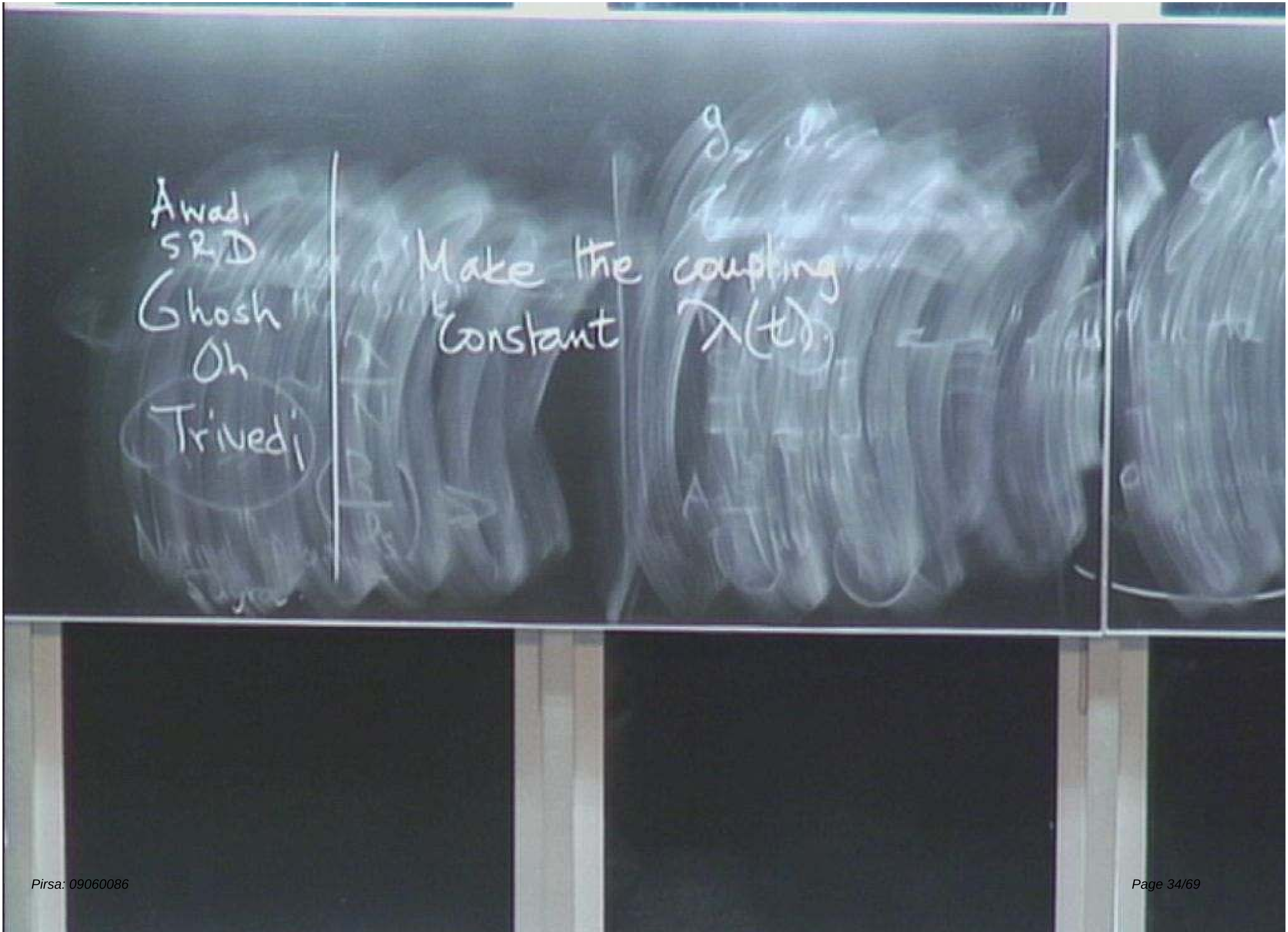
$S_{YM} \longrightarrow S_{YM} + \int g(x) \mathcal{O}_I(x) \longleftrightarrow$ "Source"

· H_{YM} is as it is.

$\mathcal{O}_I|0\rangle \longrightarrow$ Excited state. $\longrightarrow$ normalizable deformation

$S_{YM} \longrightarrow S_{YM} + \int g(x)\,\mathcal{O}_I(x) \longleftrightarrow$ "Sources" $\longrightarrow$ non-normalizable

Awadi
SR/D
Ghosh
Oh
Trivedi


Awad,
SR,D
Ghosh
Oh
Trivedi
Make the coupling
constant λ(t).

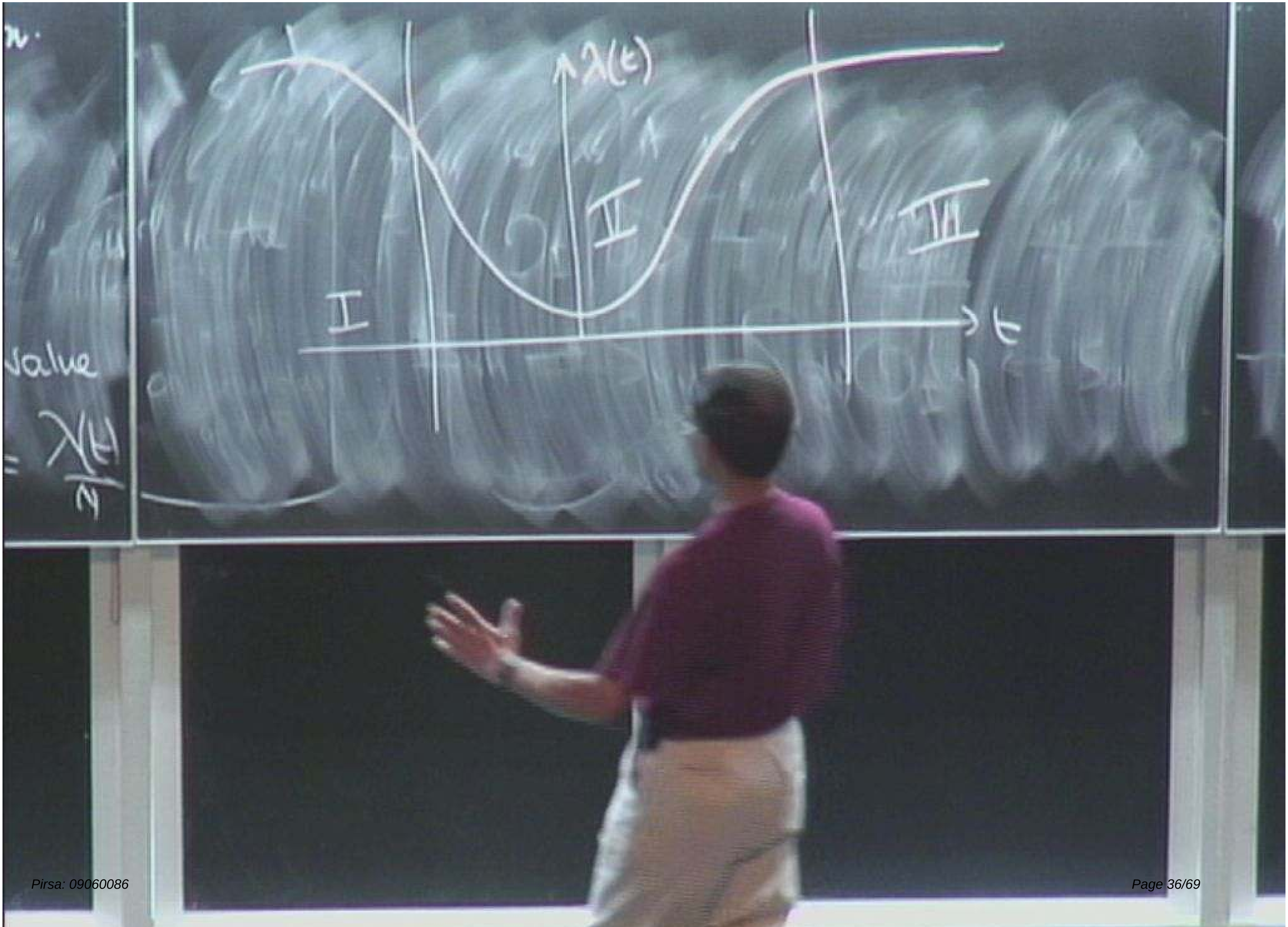
$\mathrm{Tr}\, F^2 \quad g_s \longrightarrow$ Dilaton.

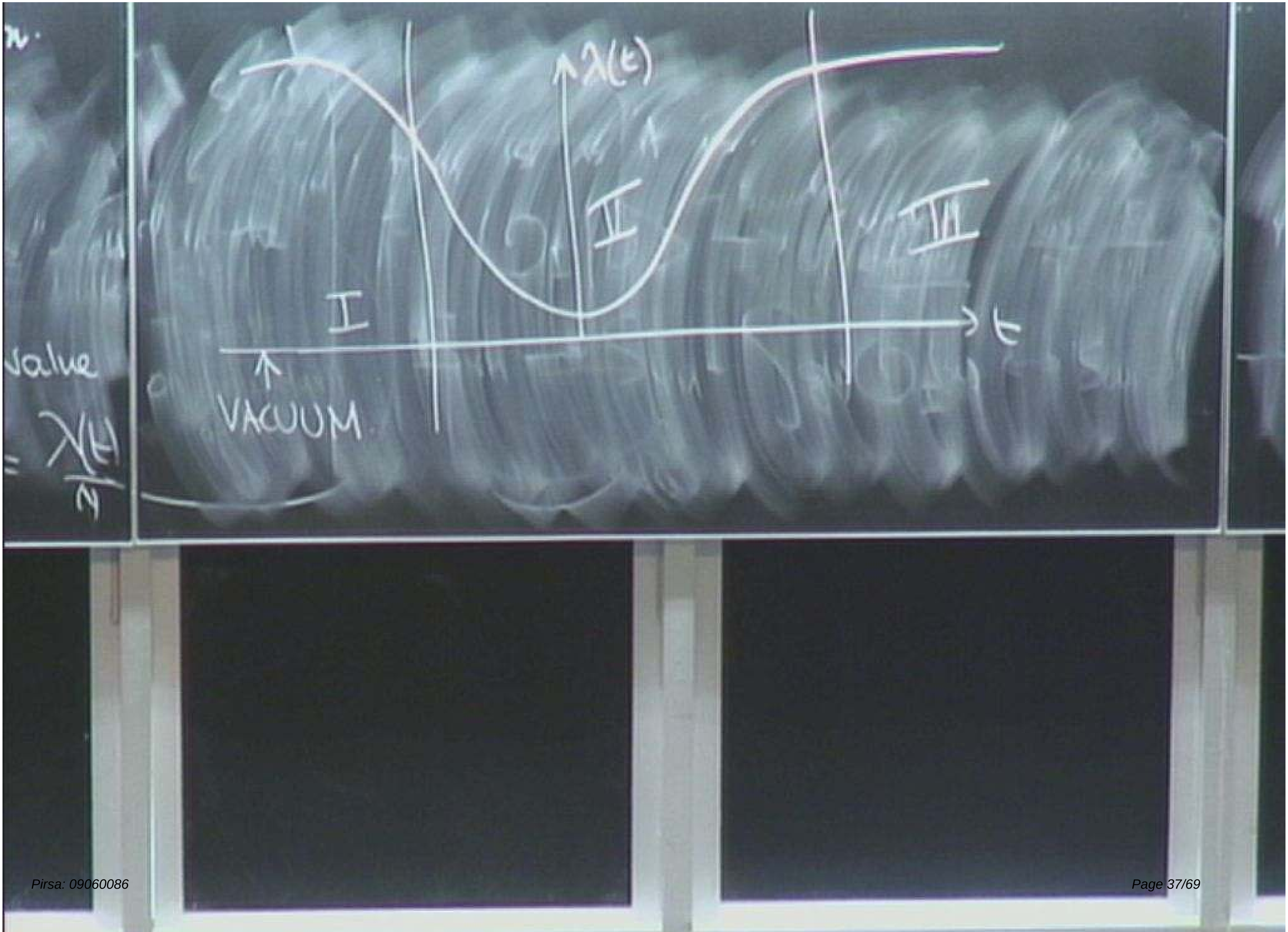
Awad,
SRD
Ghosh
Oh
Trivedi

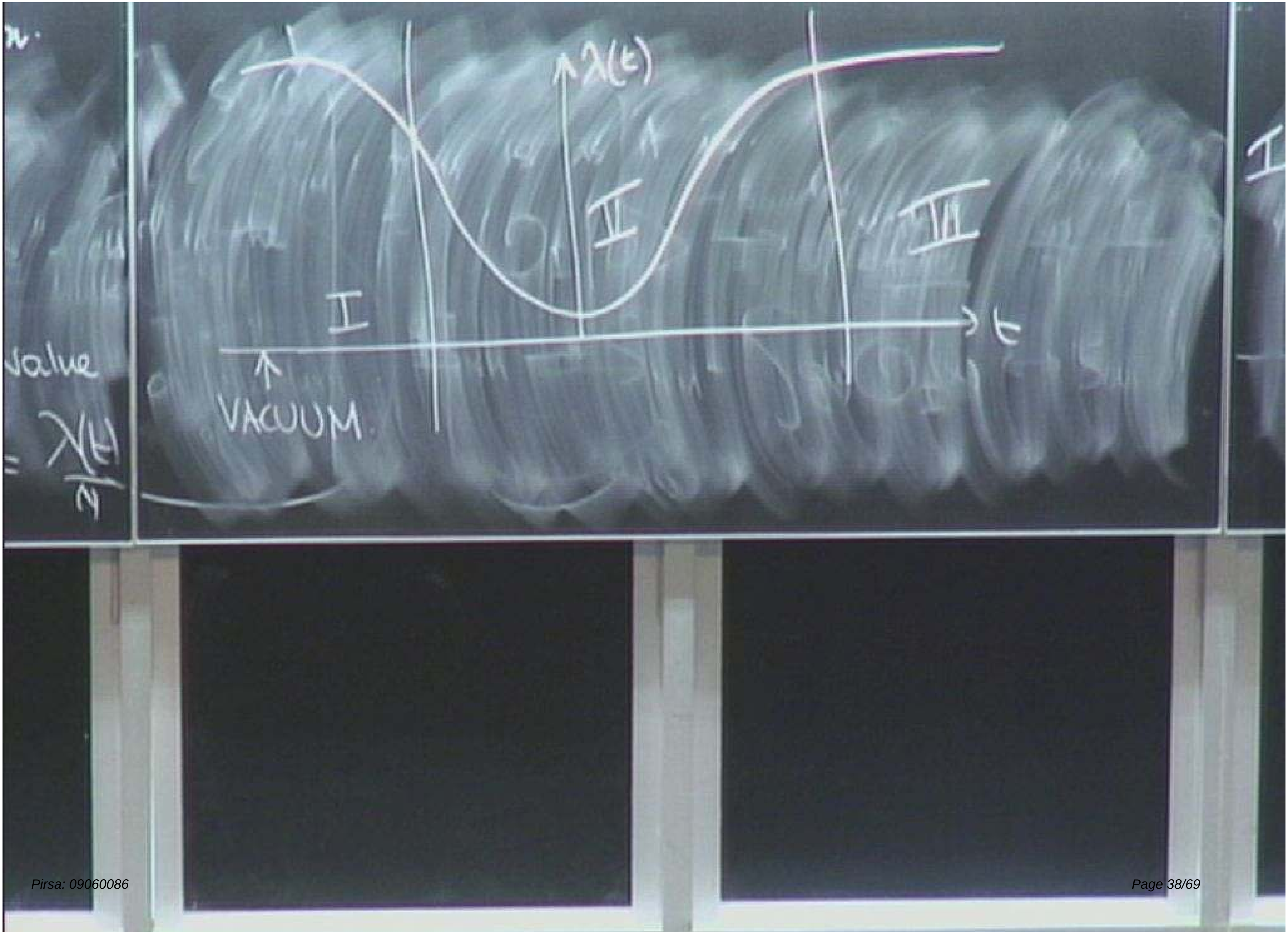
Make the coupling constant $\lambda(t)$.

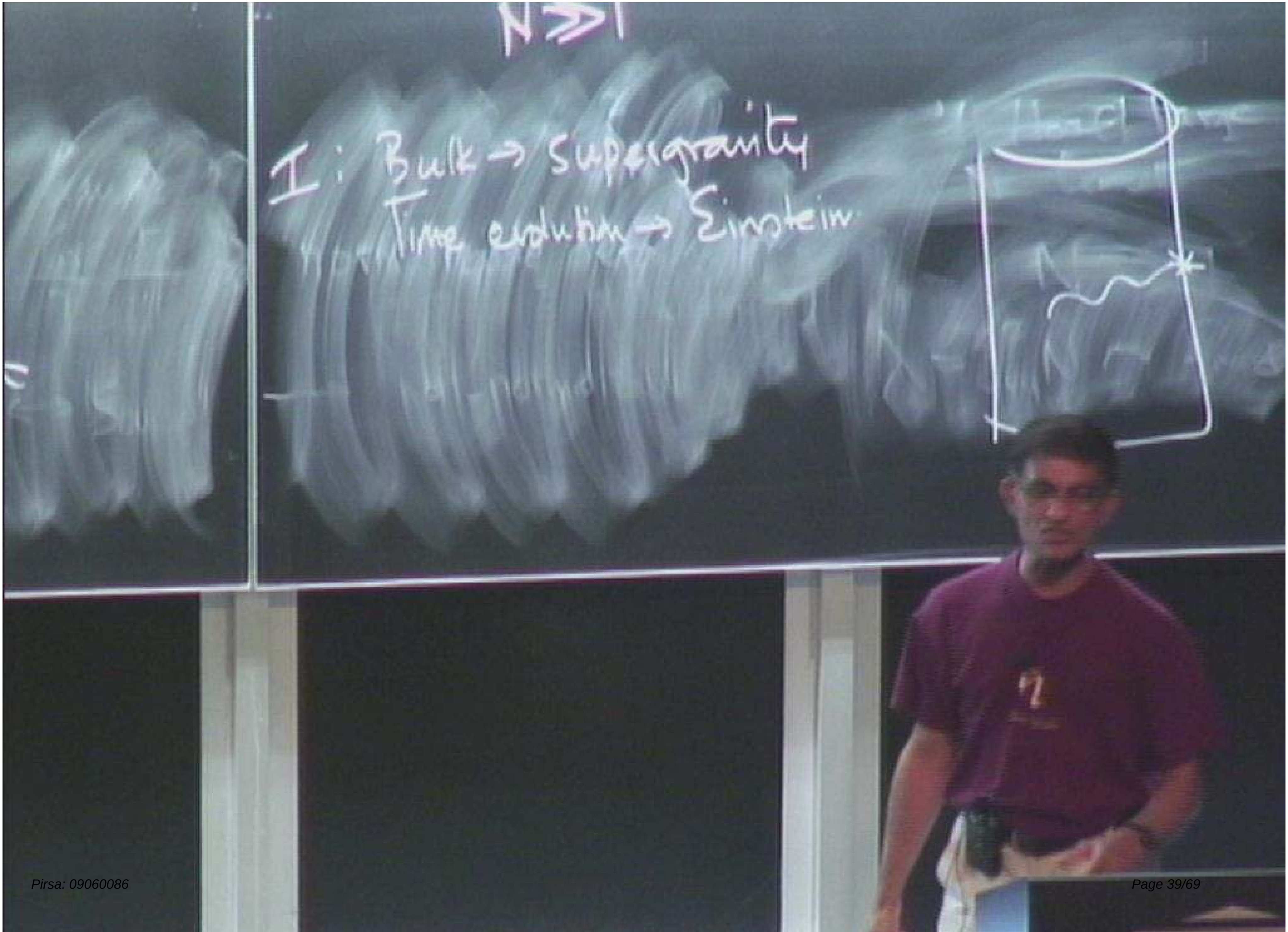
- Dilaton with boundary value $\Phi_0(t)$

$$e^{\Phi_0(t)} = \frac{\lambda(t)}{N}$$


value
λ(t)
I
II
III
t


λ(t)
I
II
III
t
VACUUM
value


λ(t)
I
II
III
t
VACUUM
value


N ≫ 1
I : Bulk → supergravity
Time evolution → Einstein

$N \geq 1$

I : Bulk → Supergravity

Time evolution → Einstein

$N \gg 1$

I : Bulk → supergravity
Time evolution → Einstein

II Curvatures become string scale

→ $\boxed{\text{Use the gauge theory}}$

$N \gg 1$

I : Bulk → Supergravity

Time evolution → Einstein

II Curvatures become string scale

→ $\boxed{\text{Use the gauge theory}}$

$\mathrm{Tr}\, F^2 g_S \to$ Dilaton.

Awad,
SRD
Ghosh
Oh
Trivedi

$\lambda(t)$ SLOWLY VARYING.

$R\partial_t \ll 1$ $\quad R = 1$ units $\quad \partial_t \sim \epsilon$

Evolve this for long time
so that $\lambda \lessapprox O(1)$.

I: Supergravity

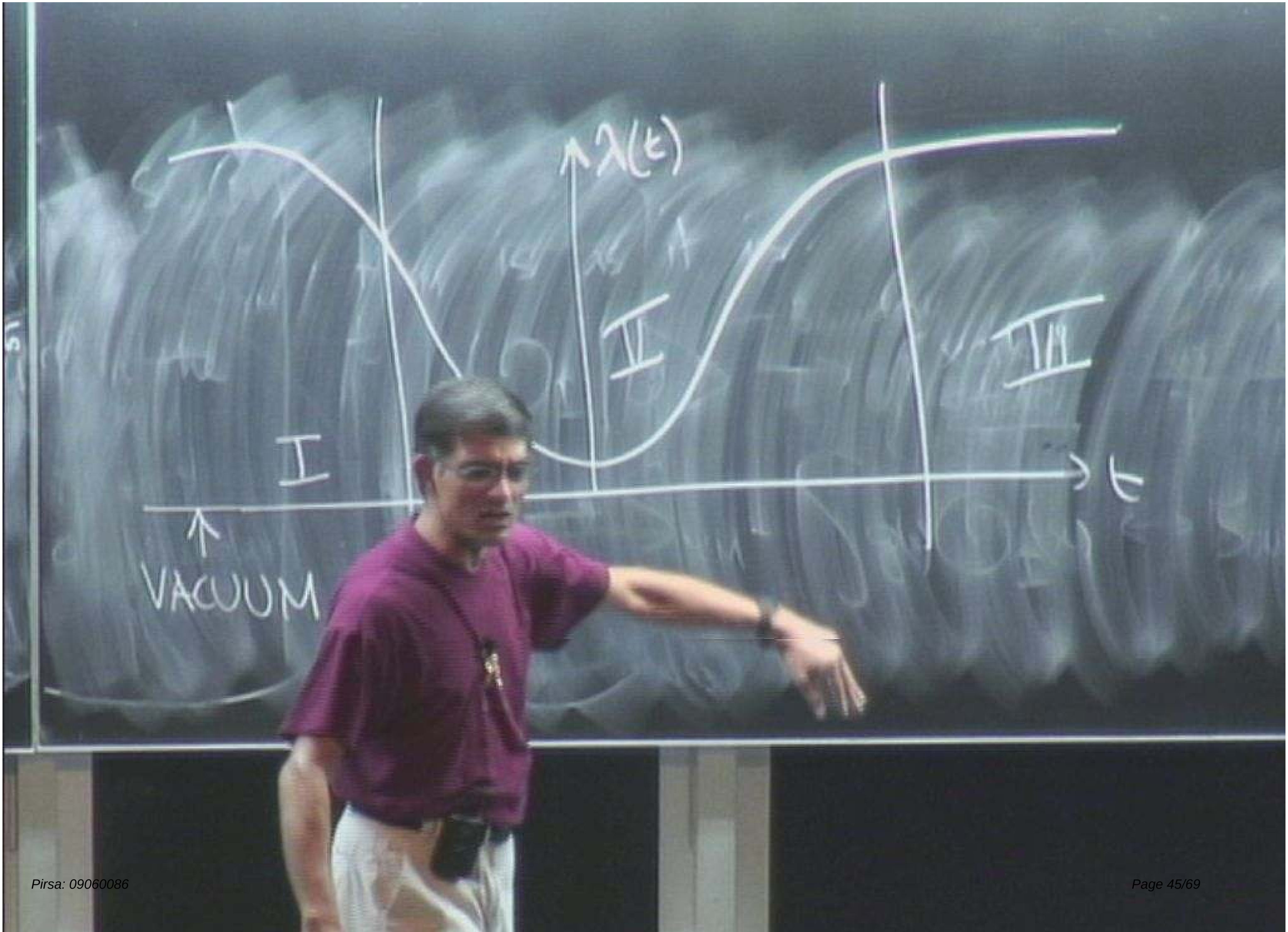
soln smooth

no horizons / BH

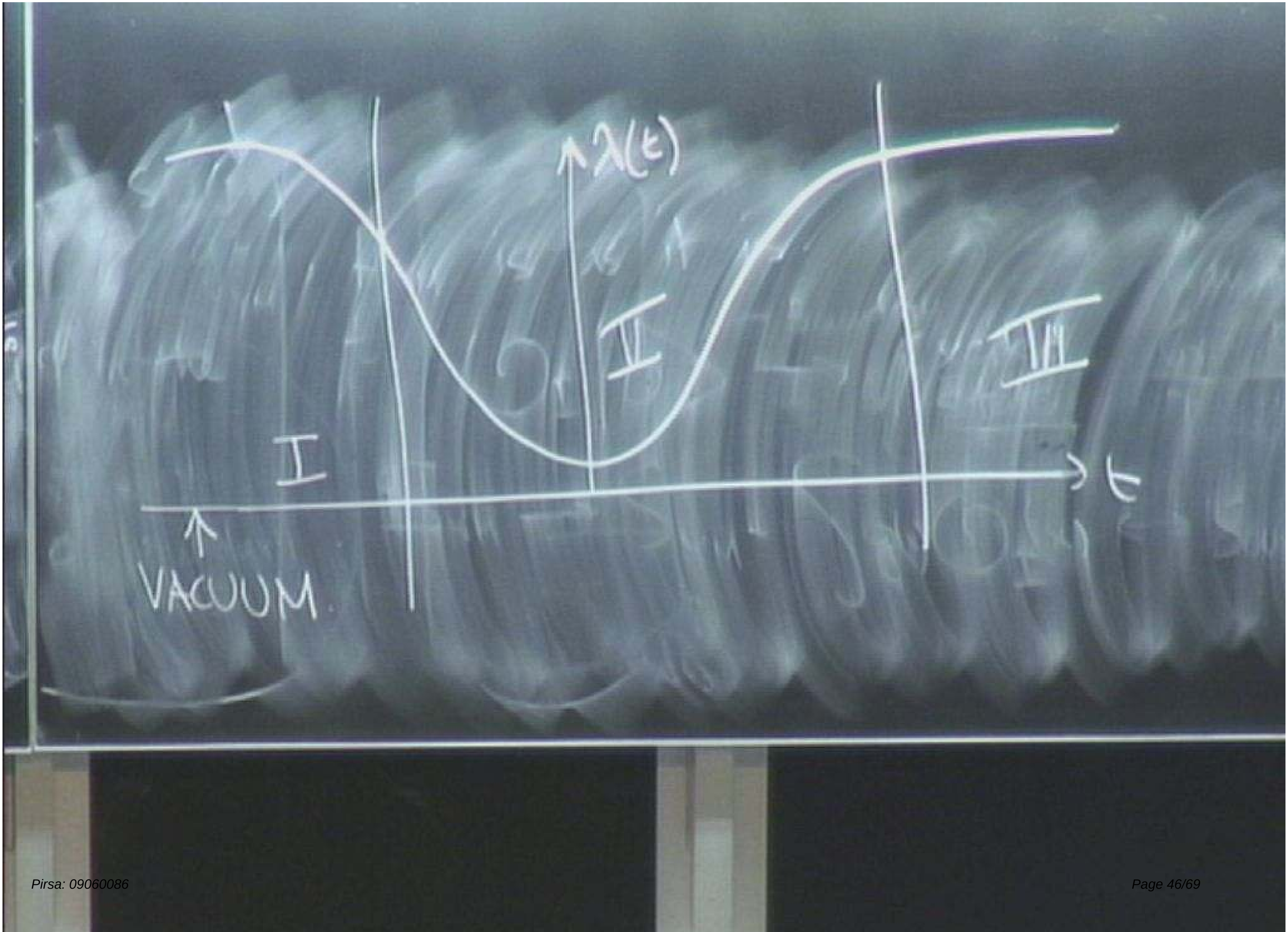
II Theory defined on S^3

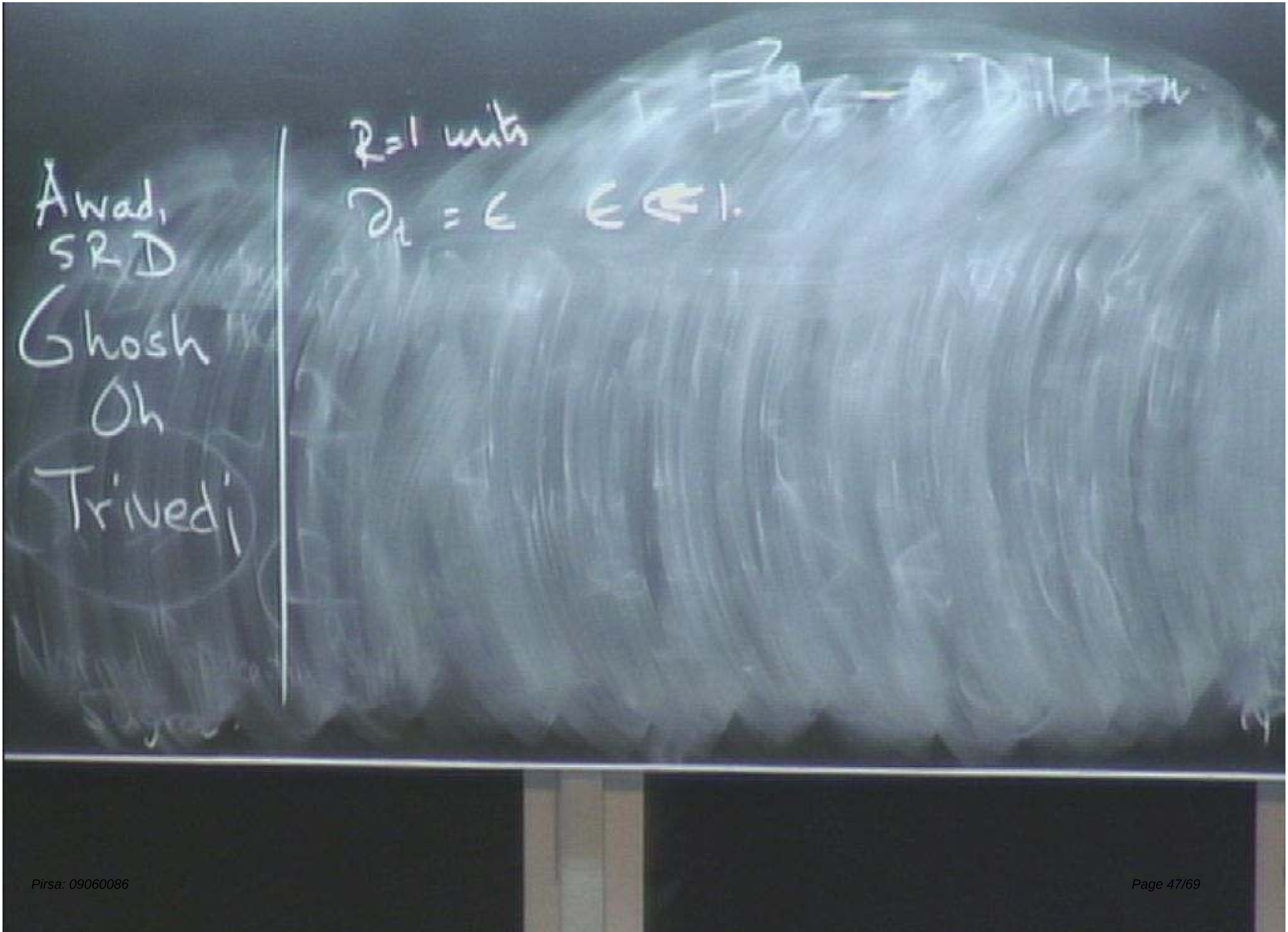
$\Rightarrow$ energy gap above ground state

$\longrightarrow$ Adiabatic Approx.



λ(t)
I
II
III
t
VACUUM


λ(t)
I
II
III
t
VACUUM


Awad,
SRD
Ghosh
Oh
Trivedi
R=1 units
$\partial_t = \epsilon \quad \epsilon \ll 1.$

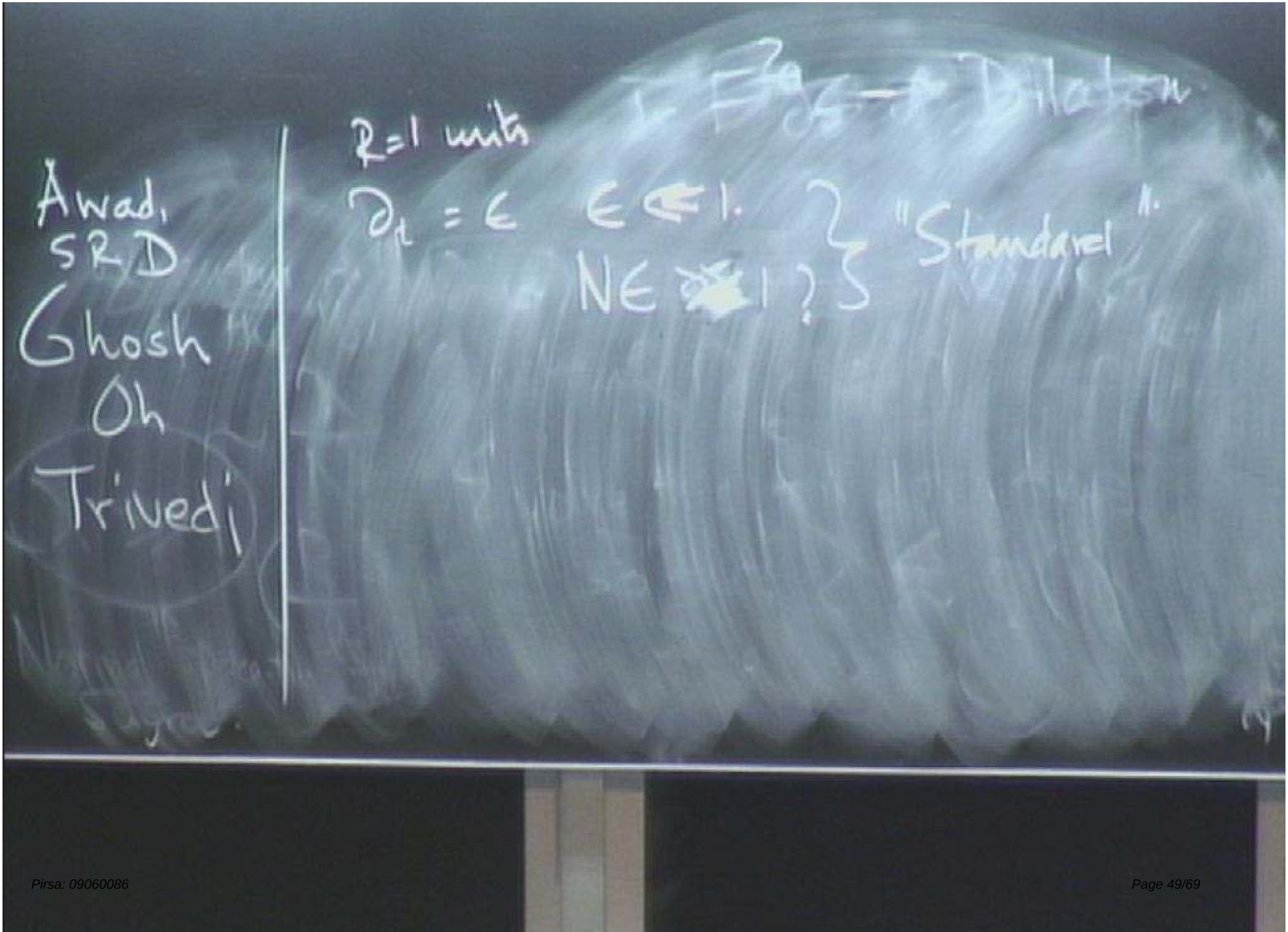
Awad,
SRD
Ghosh
Oh
Trivedi

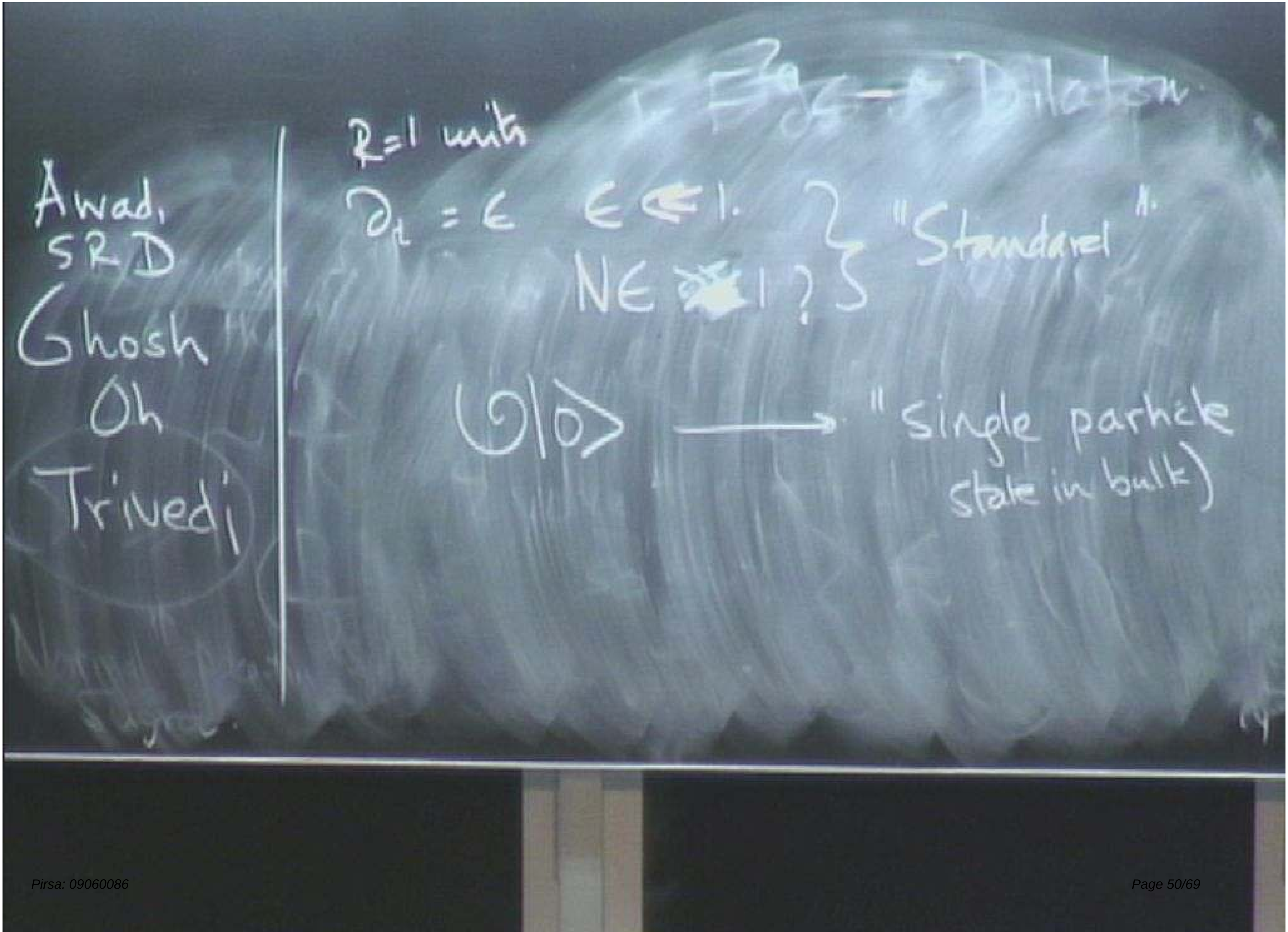
$R=1$ units

$\partial_t = \epsilon \quad \epsilon \lll 1.$

$N\epsilon \lll 1$

"Standard"


Awad, SRD
Ghosh
Oh
Trivedi
R=1 units
$\partial_t = \epsilon \quad \epsilon \ll 1.$
$N\epsilon$ 1 ?
"Standard"


Awad,
SRD
Ghosh
Oh
Trivedi
R=1 units
∂t = ε   ε ≪ 1.
Nε ≪ 1 ?
"Standard"
⟨0|0⟩ → "single particle
state in bulk)

Awad,
SRD
Ghosh
Oh
Trivedi

$R = 1$ units

$\partial_t = \epsilon \quad \epsilon \lll 1.$

$N\epsilon \;\; 1 \; ?$ } "Standard"

$\mathcal{O}|0\rangle \longrightarrow$ "single particle state in bulk)

$e^{\lambda(t)\mathcal{O}}|0\rangle$ Classical field

Awad,
SRD
Ghosh
Oh
Trivedi

$R=1$ units

$\partial_t = \epsilon \quad \epsilon \ll 1.$

$N\epsilon \ \ 1\ ?$ } "Standard"

$\mathcal{O}|0\rangle \longrightarrow$ "single particle state in bulk)

$e^{\lambda(t)\mathcal{O}}|0\rangle$ Classical field

Awad,
SRD
Ghosh
Oh
Trivedi

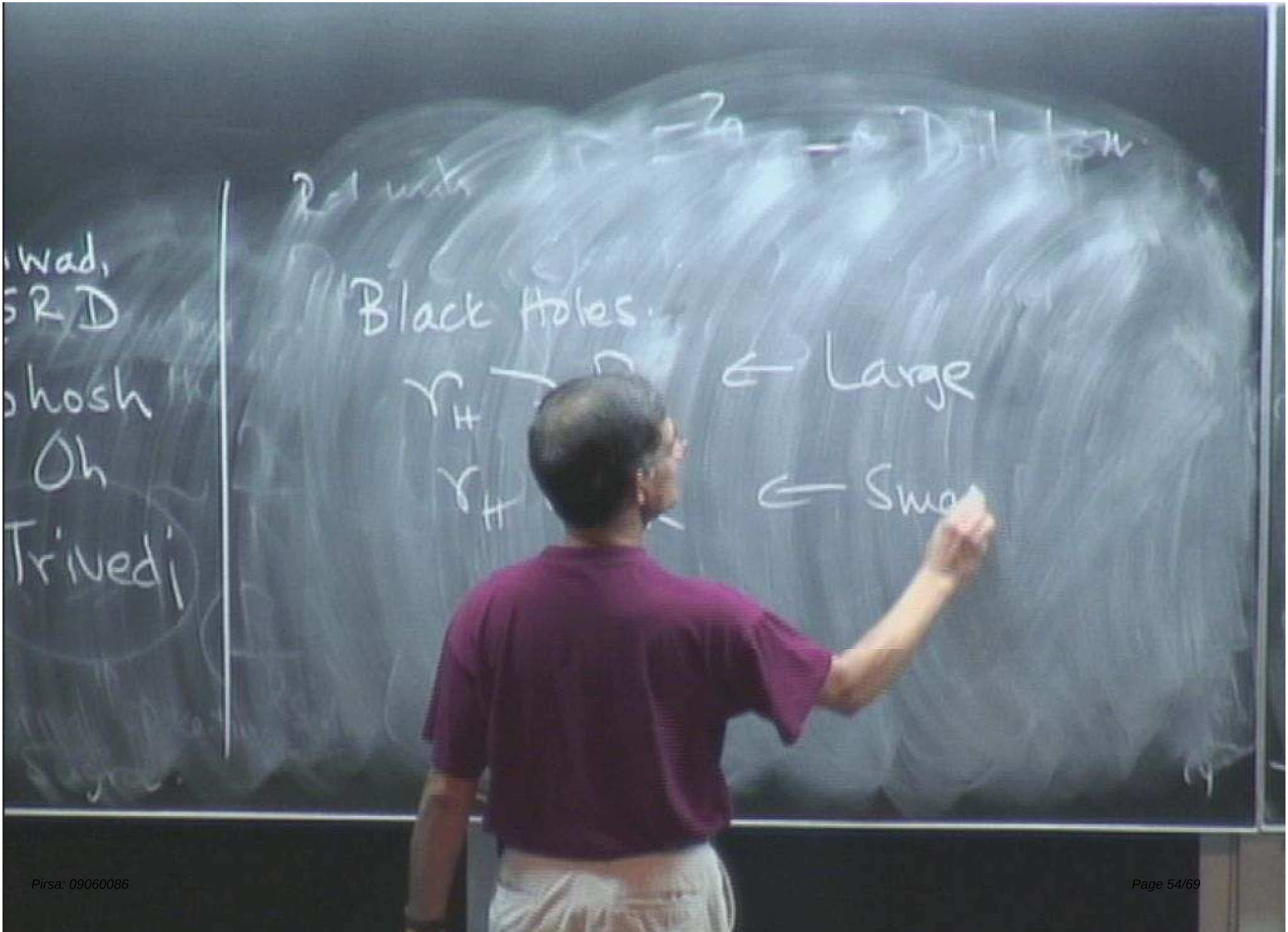
$R=1$ units

$\partial_t = \epsilon \quad \epsilon \ll 1.$

$N\epsilon \ll 1$? } "Standard"

$\mathcal{O}|0\rangle \longrightarrow$ "single particle state in bulk)

$e^{\lambda(t)\mathcal{O}}|0\rangle$ Classical field

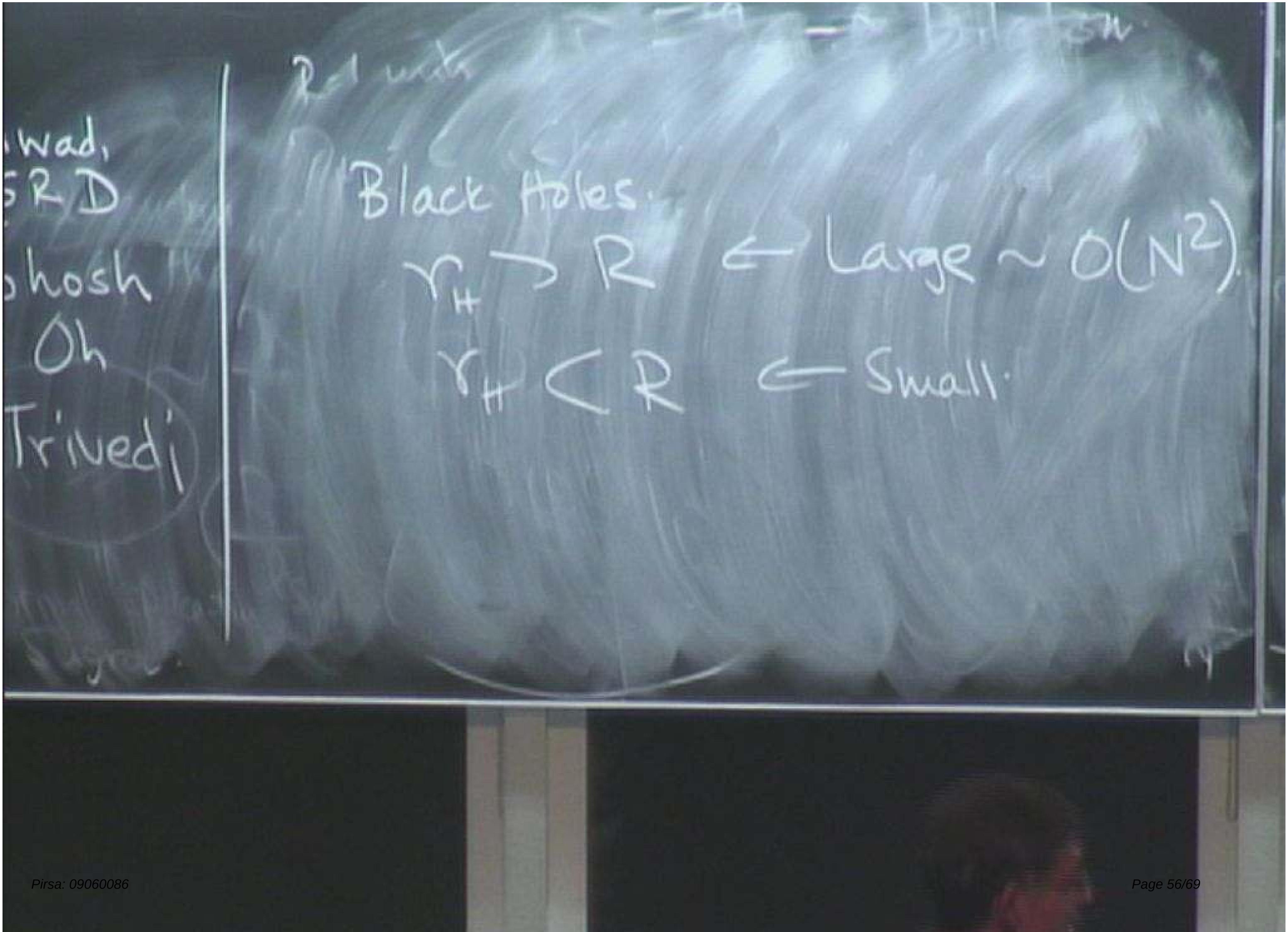

Black Holes.
Large
Oh
Trivedi

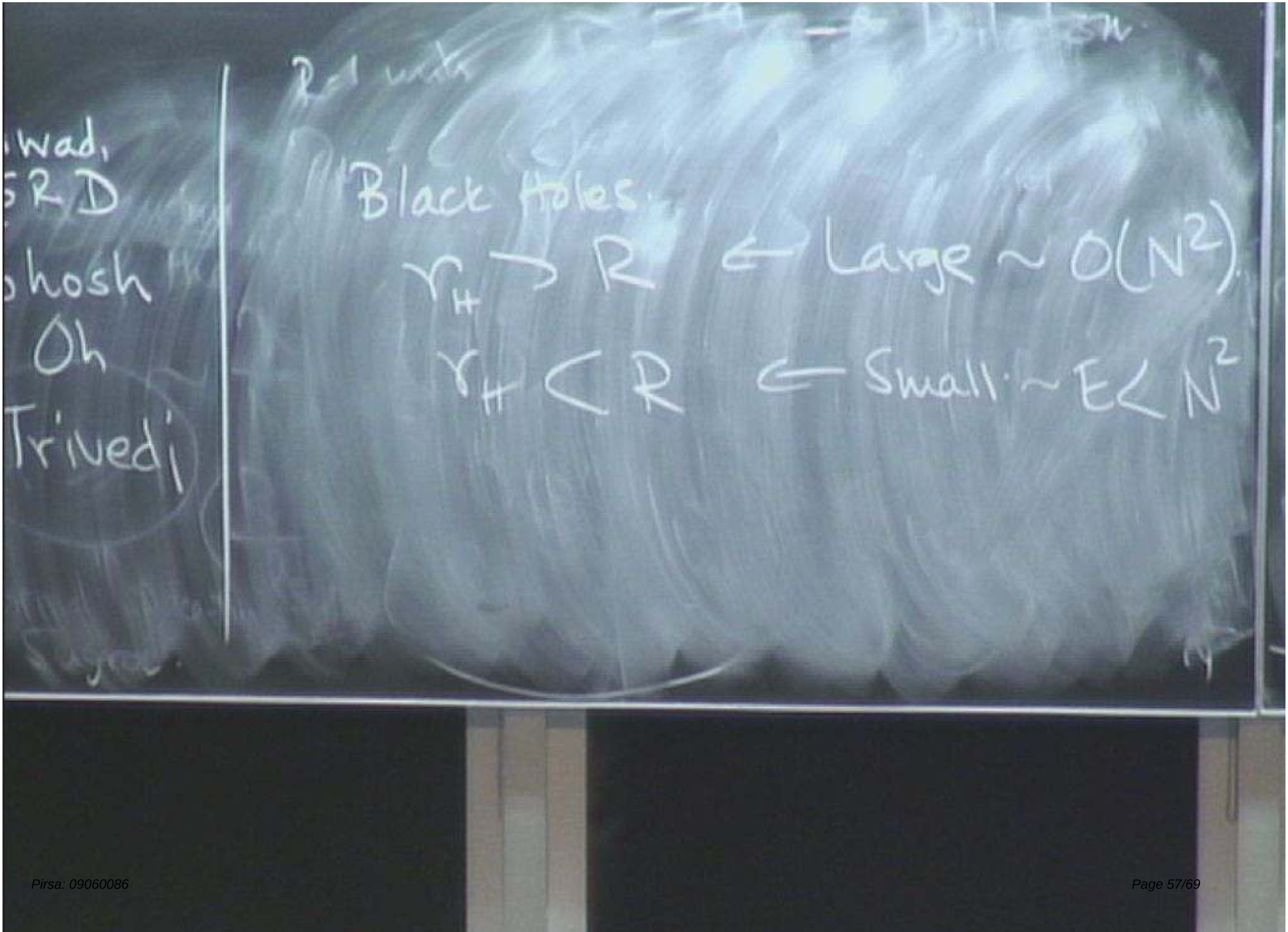
...wad,
...SRD
...hosh
Oh
Trivedi

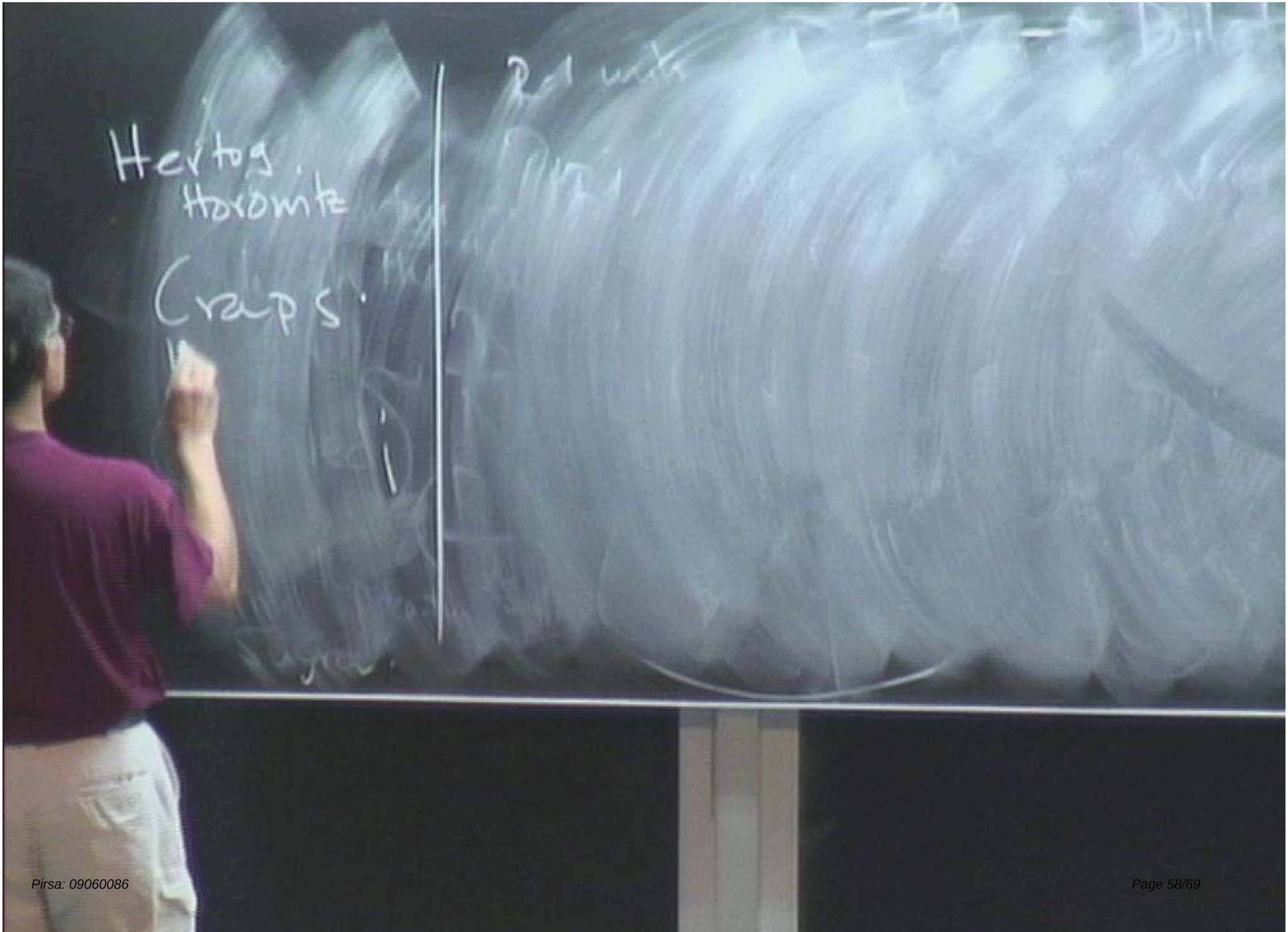
Black Holes.

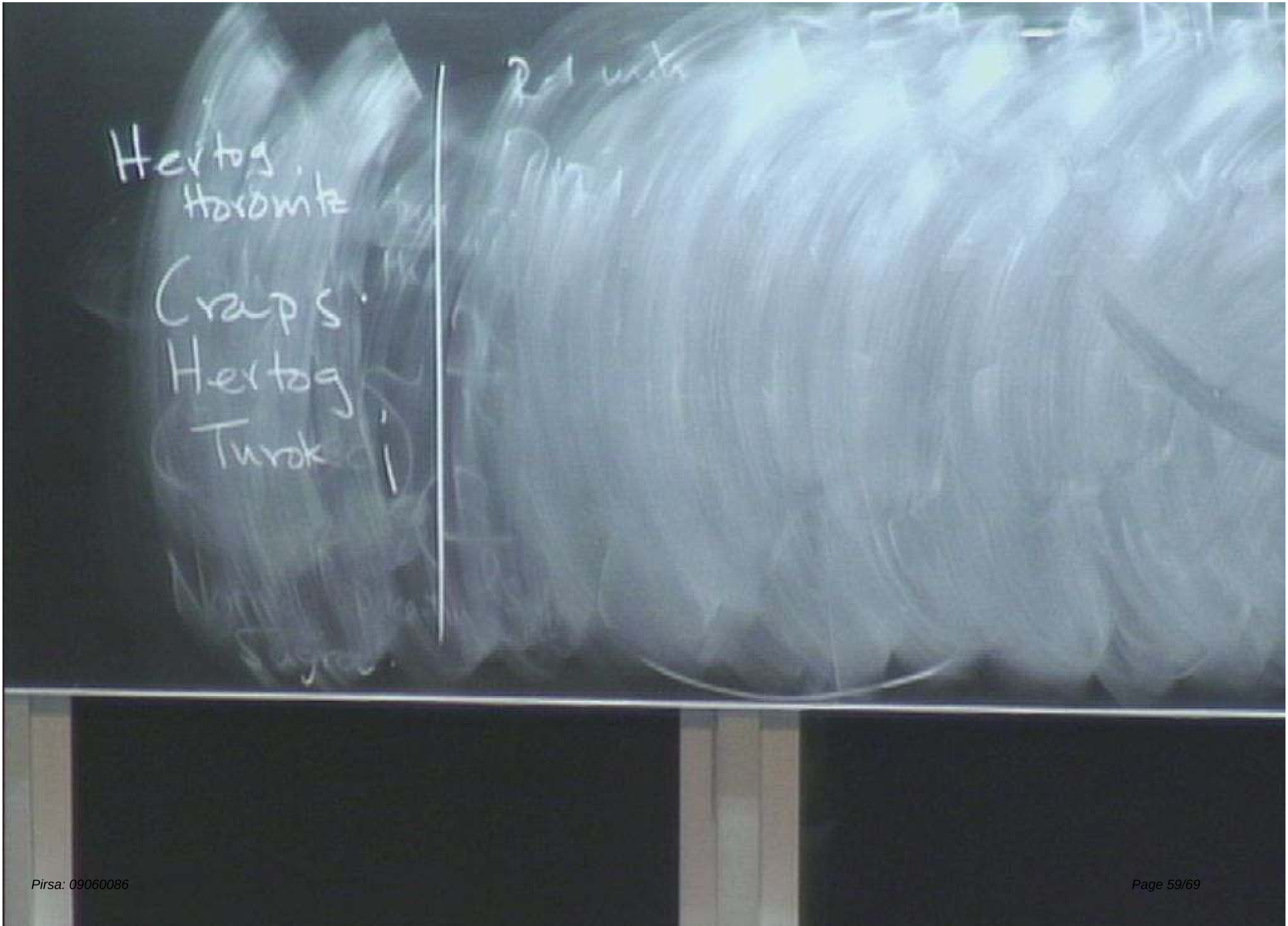
$r_H > R \leftarrow$ Large

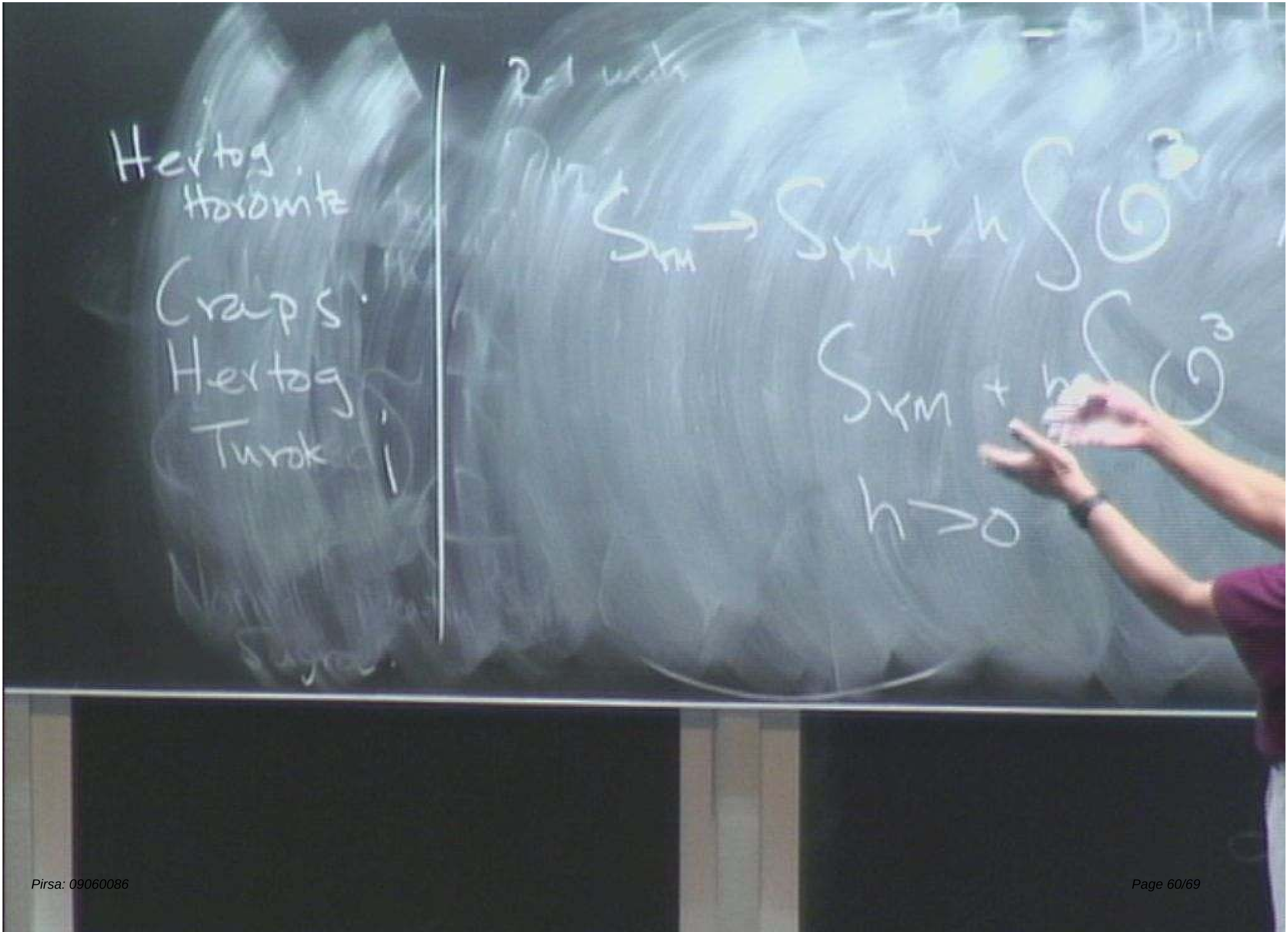
$r_H < R \leftarrow$ Small.


wad,
SRD
hosh
Oh
Trivedi
Black Holes.
r_H > R ← Large ~ O(N^2).
r_H < R ← Small.


Black Holes.
$r_H > R$ ← Large ~ $O(N^2)$.
$r_H < R$ ← Small ~ $E < N^2$
Oh
Trivedi


Hertog
Horowitz
Craps


Hertog,
Horowitz
Craps,
Hertog
Turok


Hertog
Horowitz
Craps
Hertog
Turok
$S_{YM} \to S_{YM} + h \int \phi^3$
$S_{YM} + h \int \phi^3$
$h > 0$

Hertog
Horowitz

Craps
Hertog
Turok

$S_{YM} \to S_{YM} + h\int \mathcal{O}^3$ AdS_5

$S_{YM} + h\int \mathcal{O}^3$ AdS_4

$h > 0$

I

VACUUM

Hertog, Horowitz

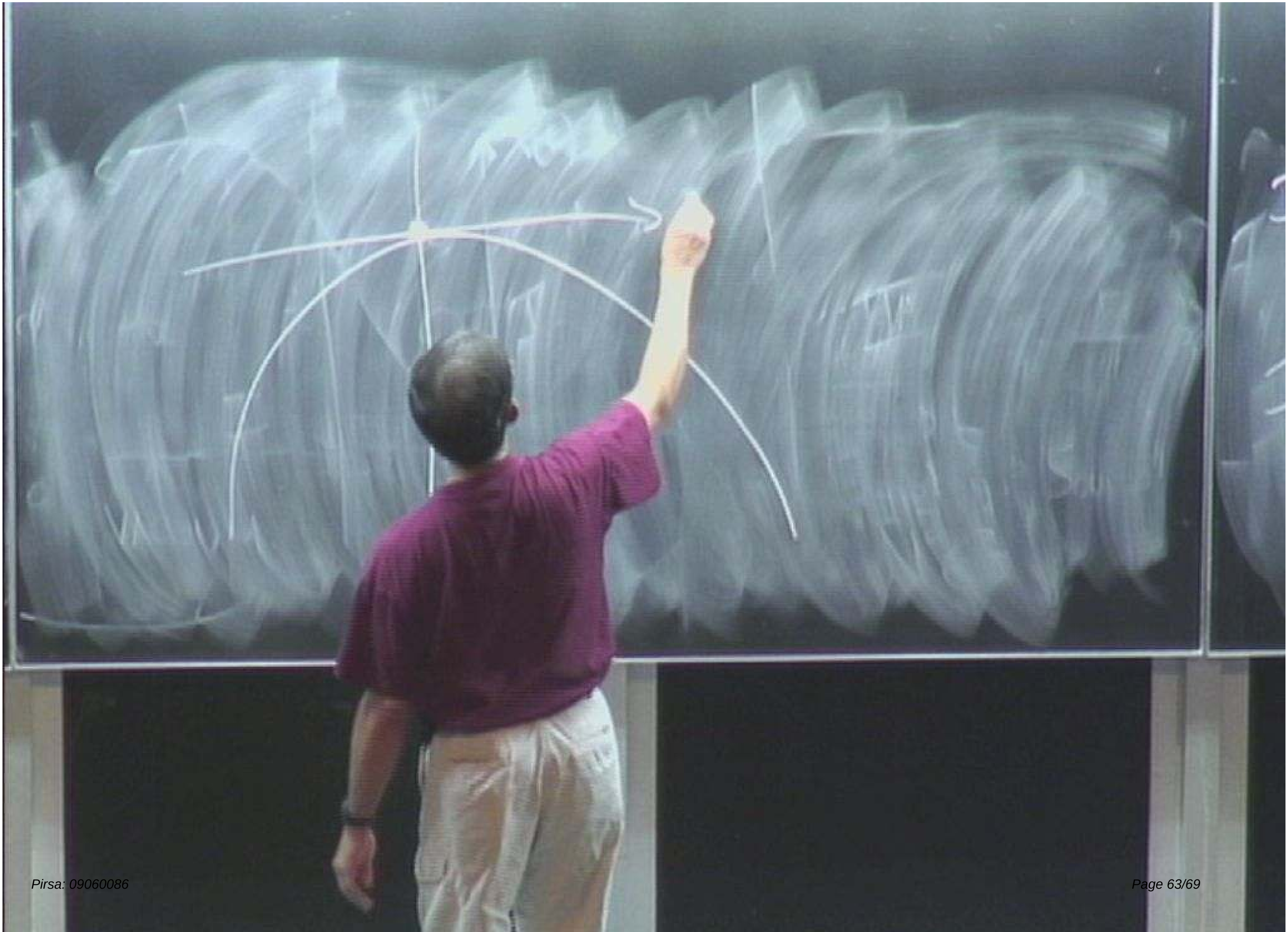
Craps, Hertog, Turok

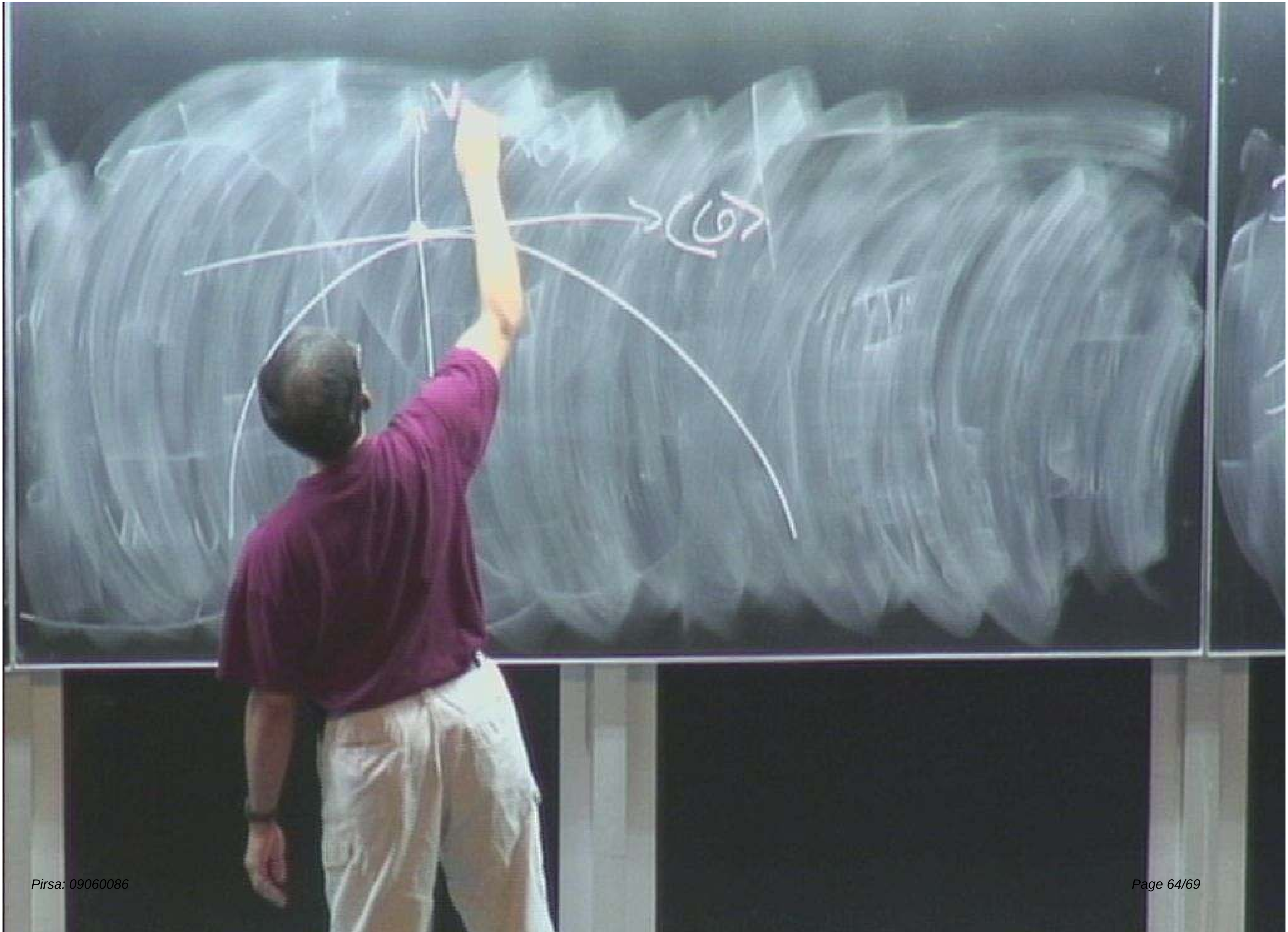
Rel with ... Dilaton

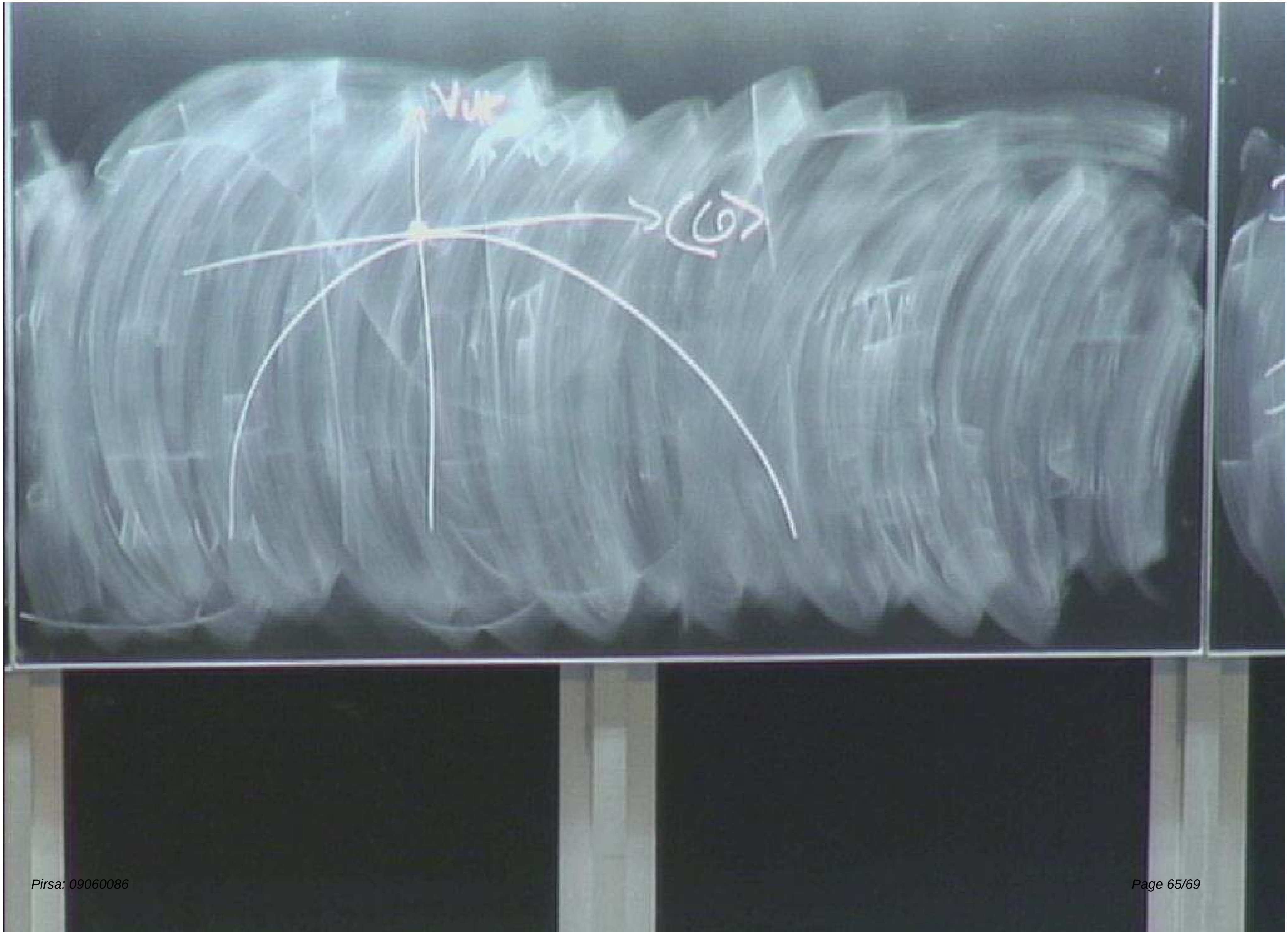
$$S_{YM} \to S_{YM} + h\int \mathcal{O} \qquad AdS_5$$

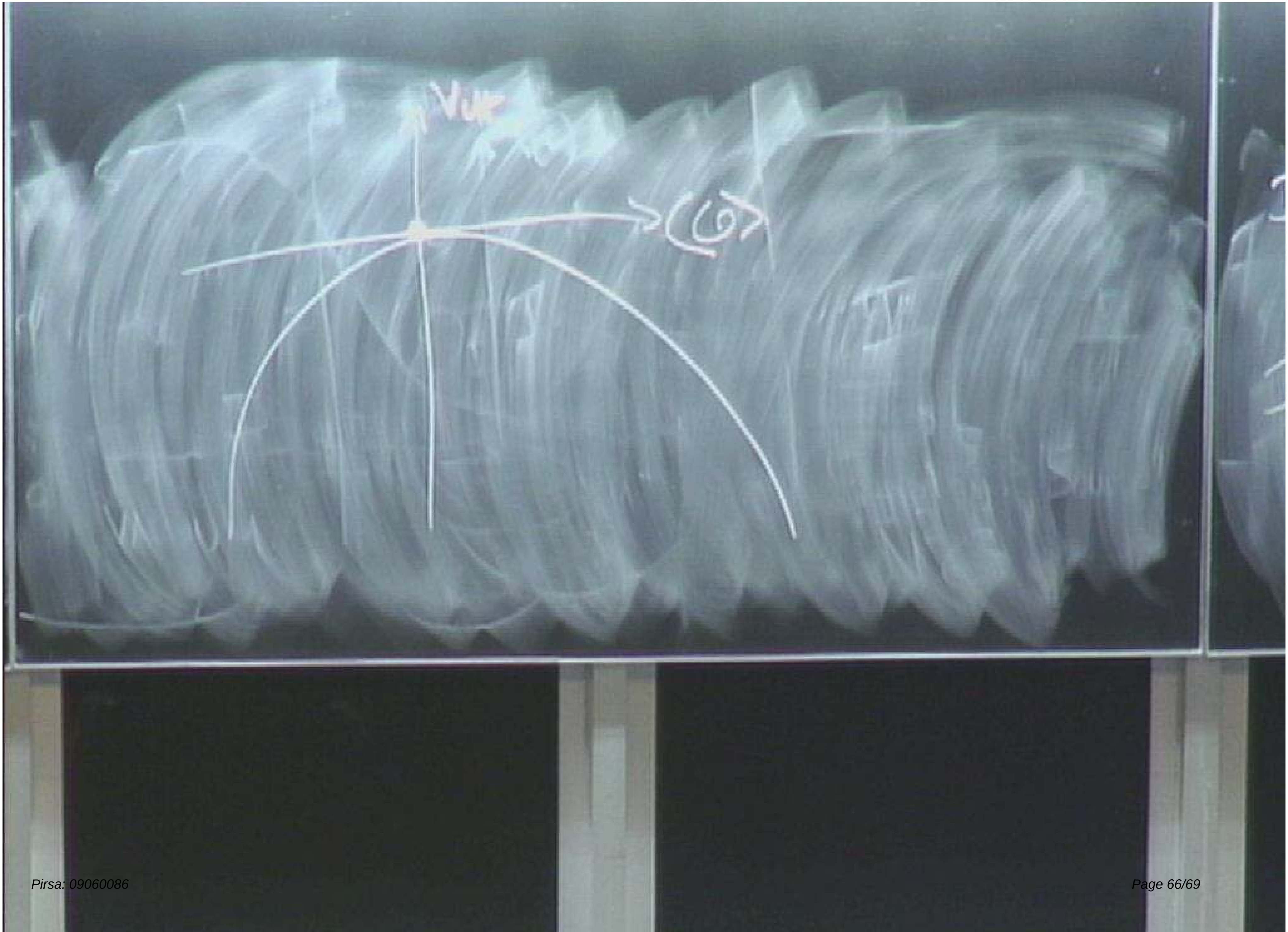
$$S_{YM} + h\int \mathcal{O}^3 \qquad AdS_4$$

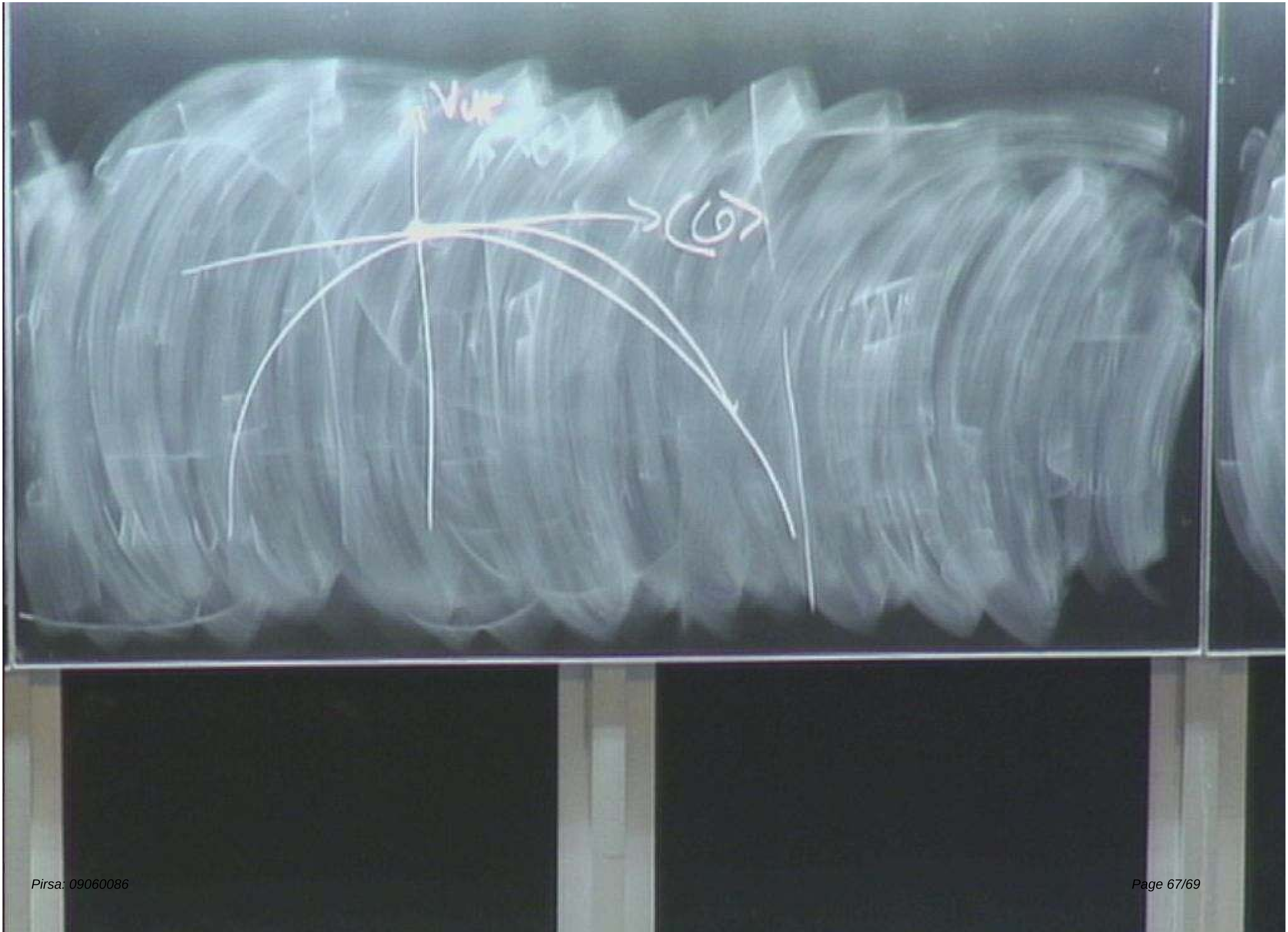
$$h > 0$$

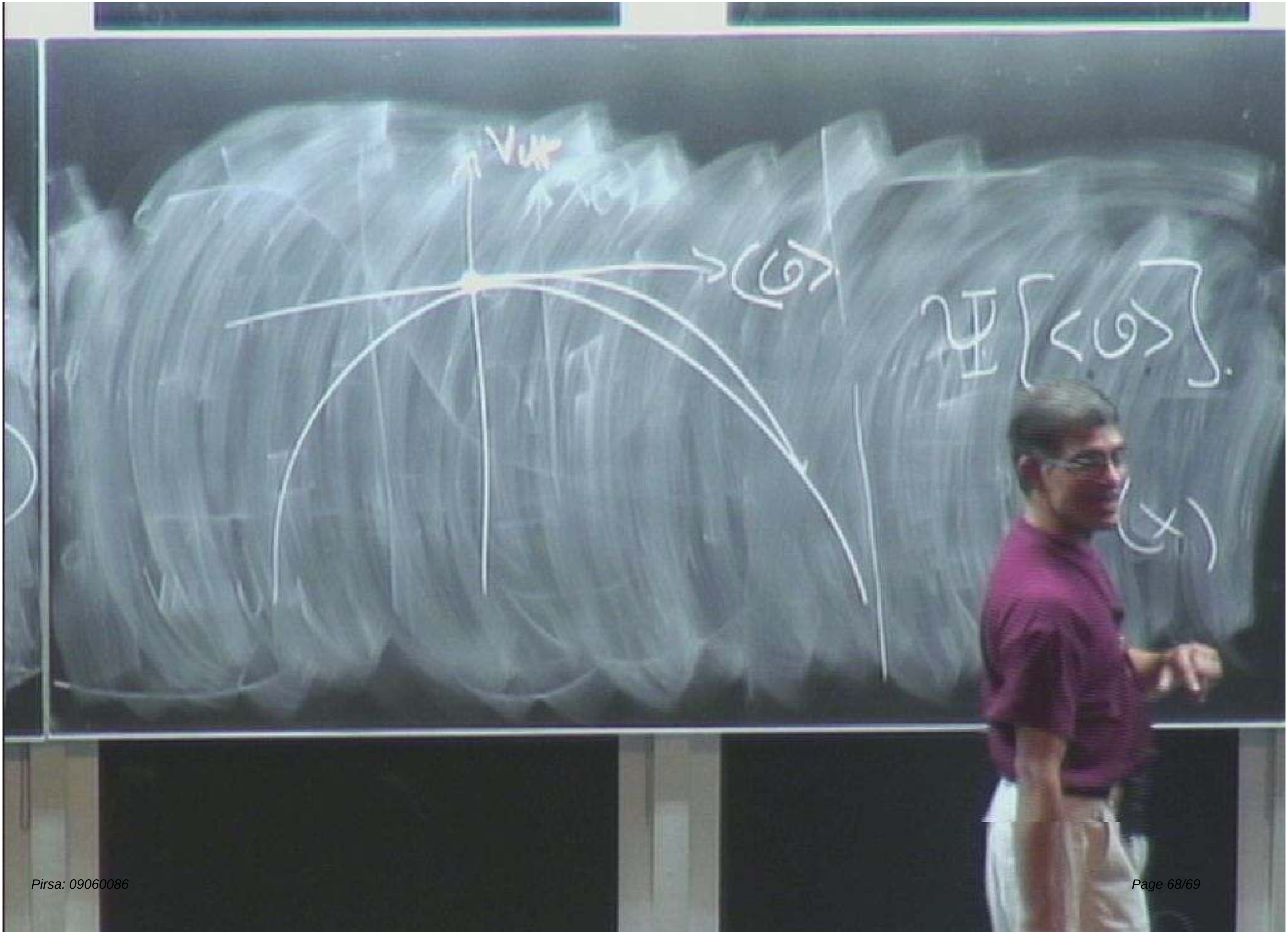


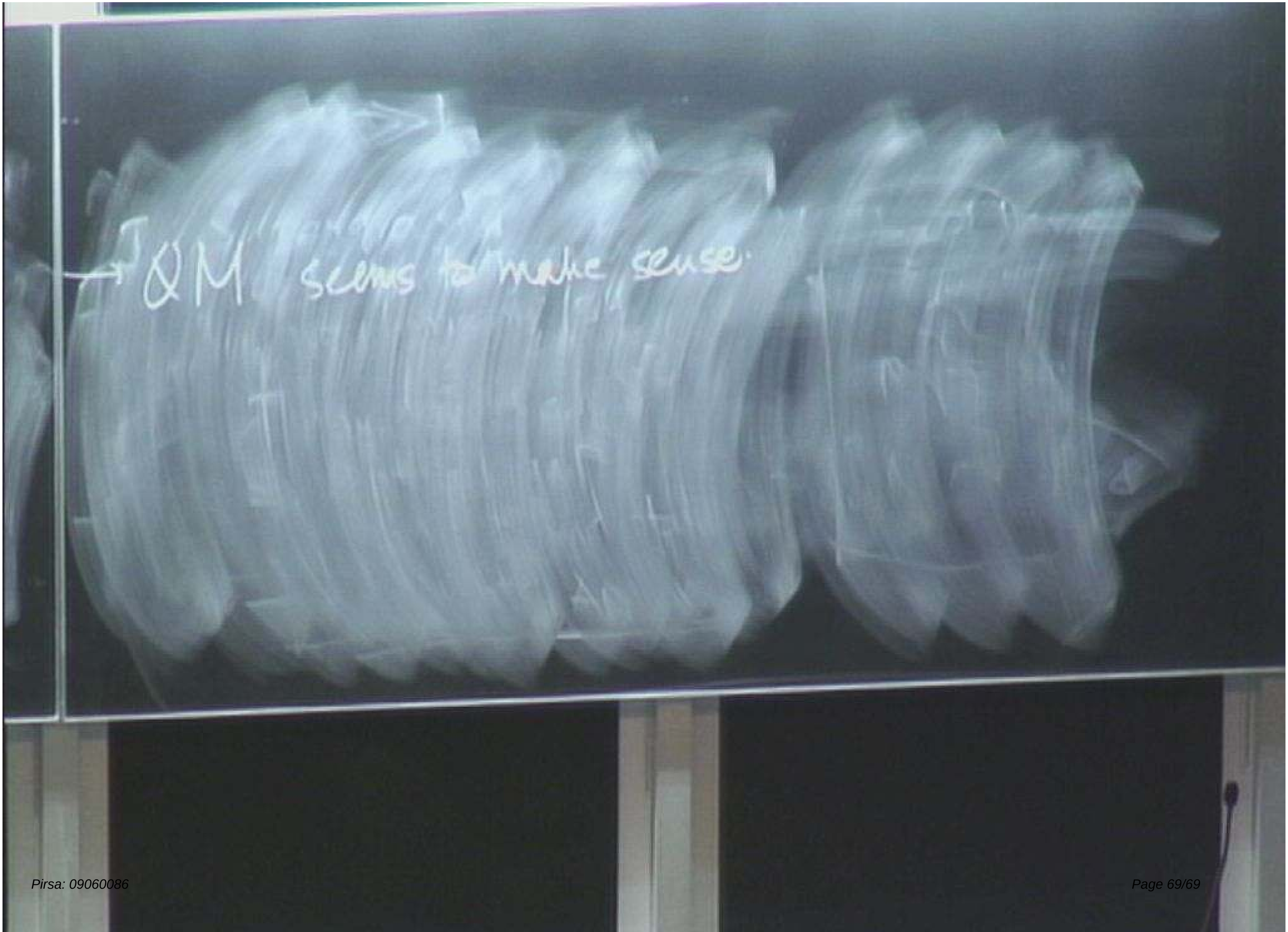

⟨σ⟩


⟨φ⟩






V_{eff}
$\langle\phi\rangle$
$\Psi[\langle\phi\rangle]$


QM seems to make sense.