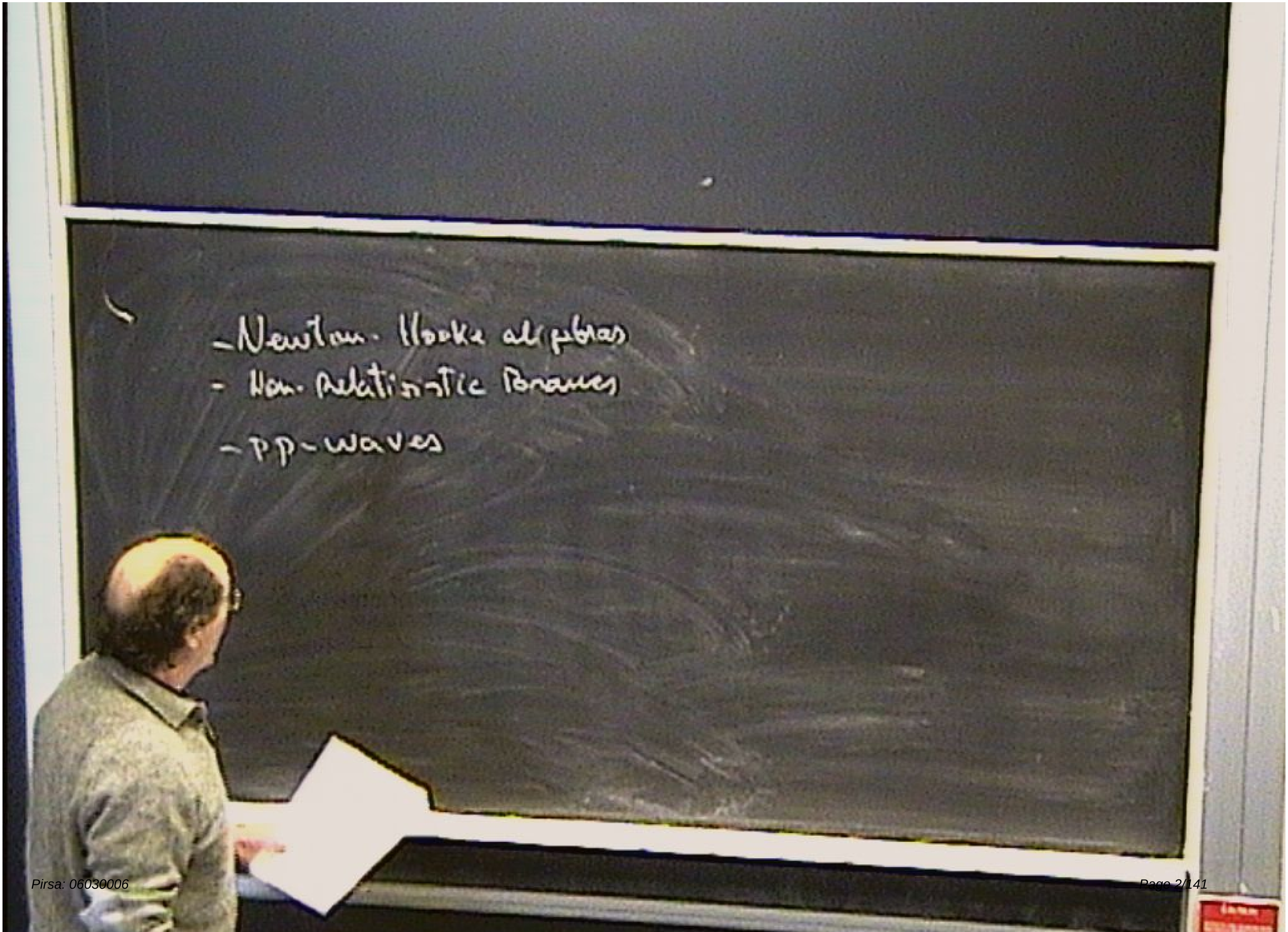
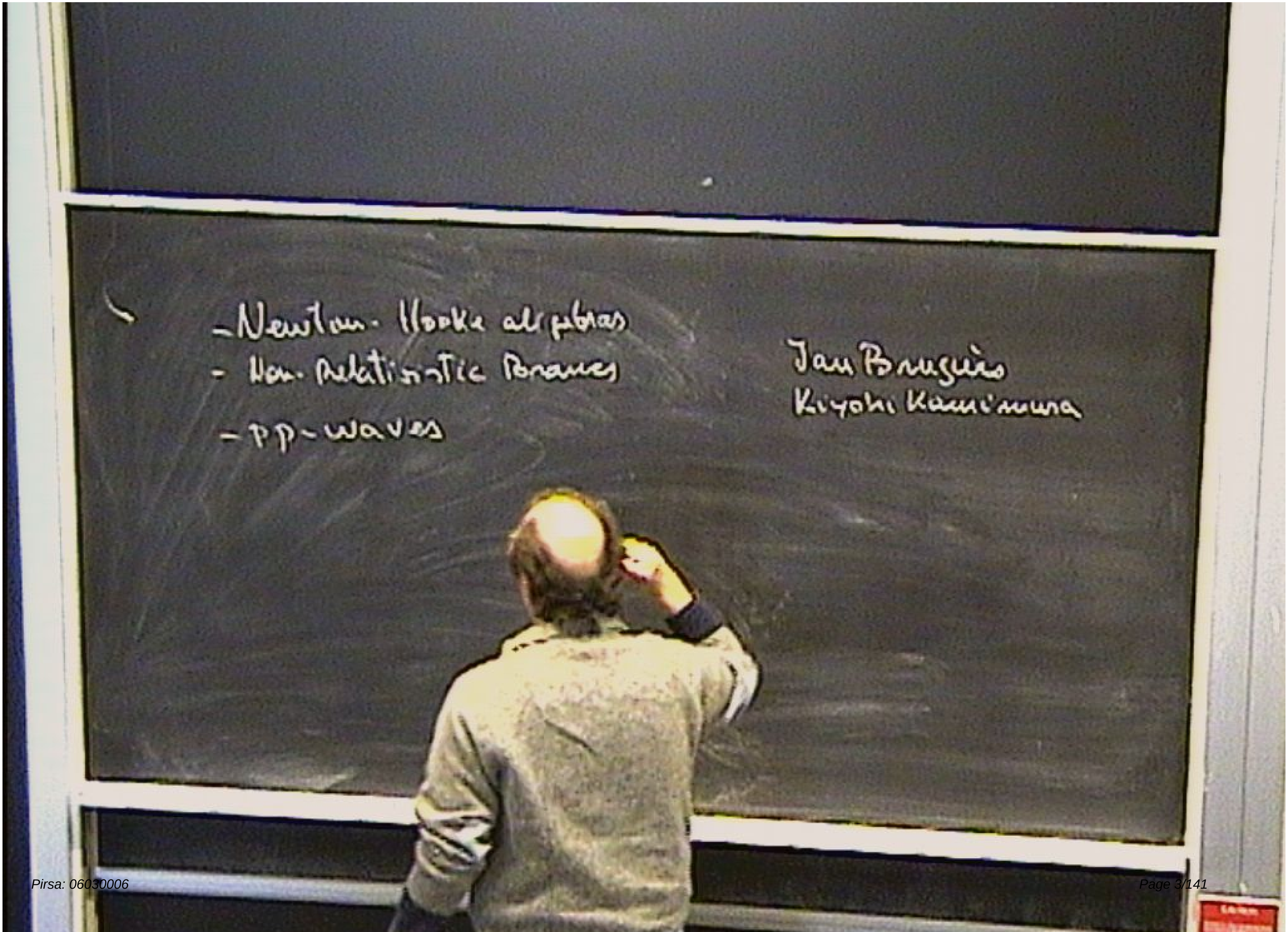
Title: Newton-Hooke algebras, non-relativistic branes and generalized pp-wave metrics

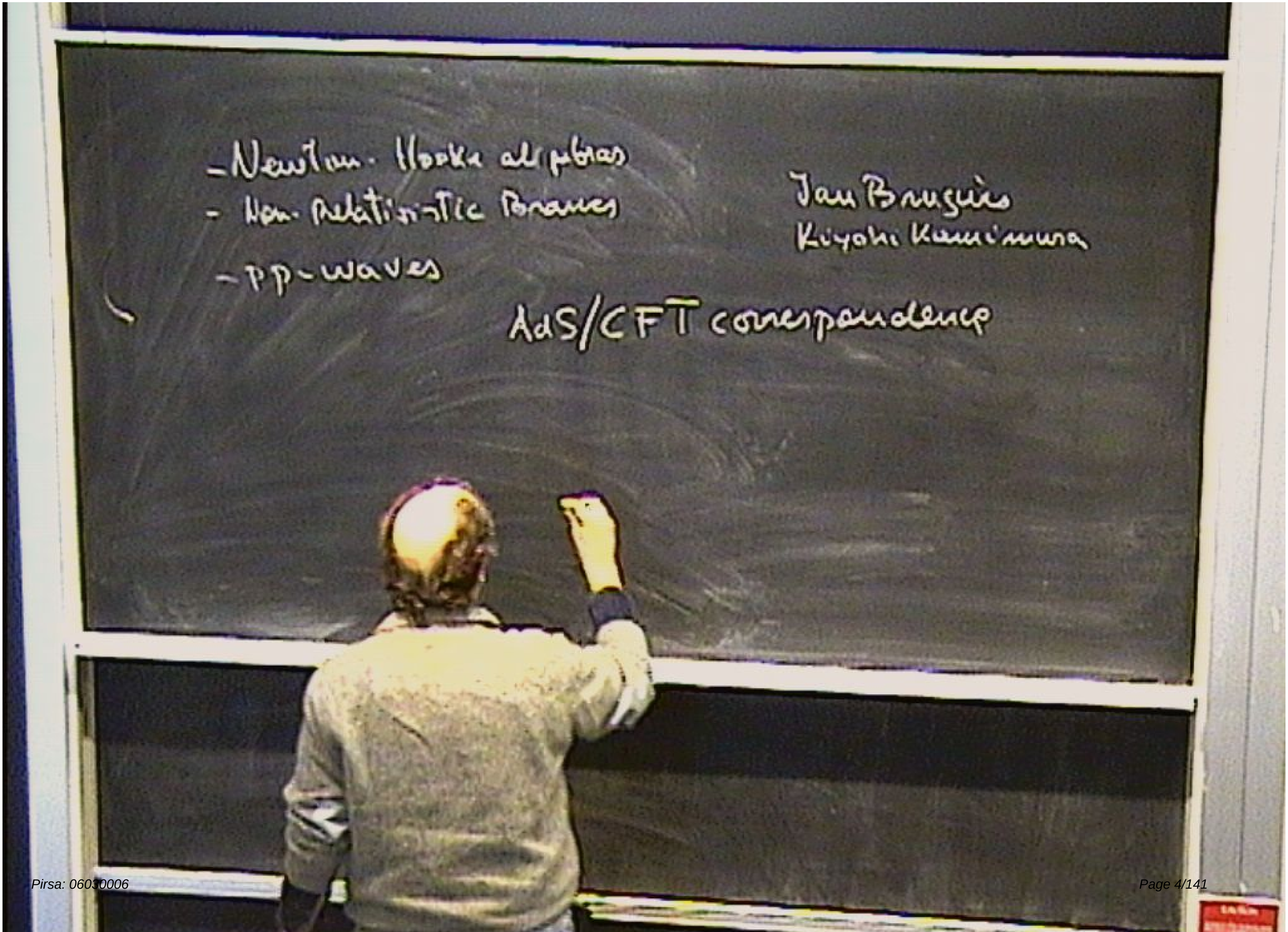
Date: Mar 07, 2006 02:00 PM

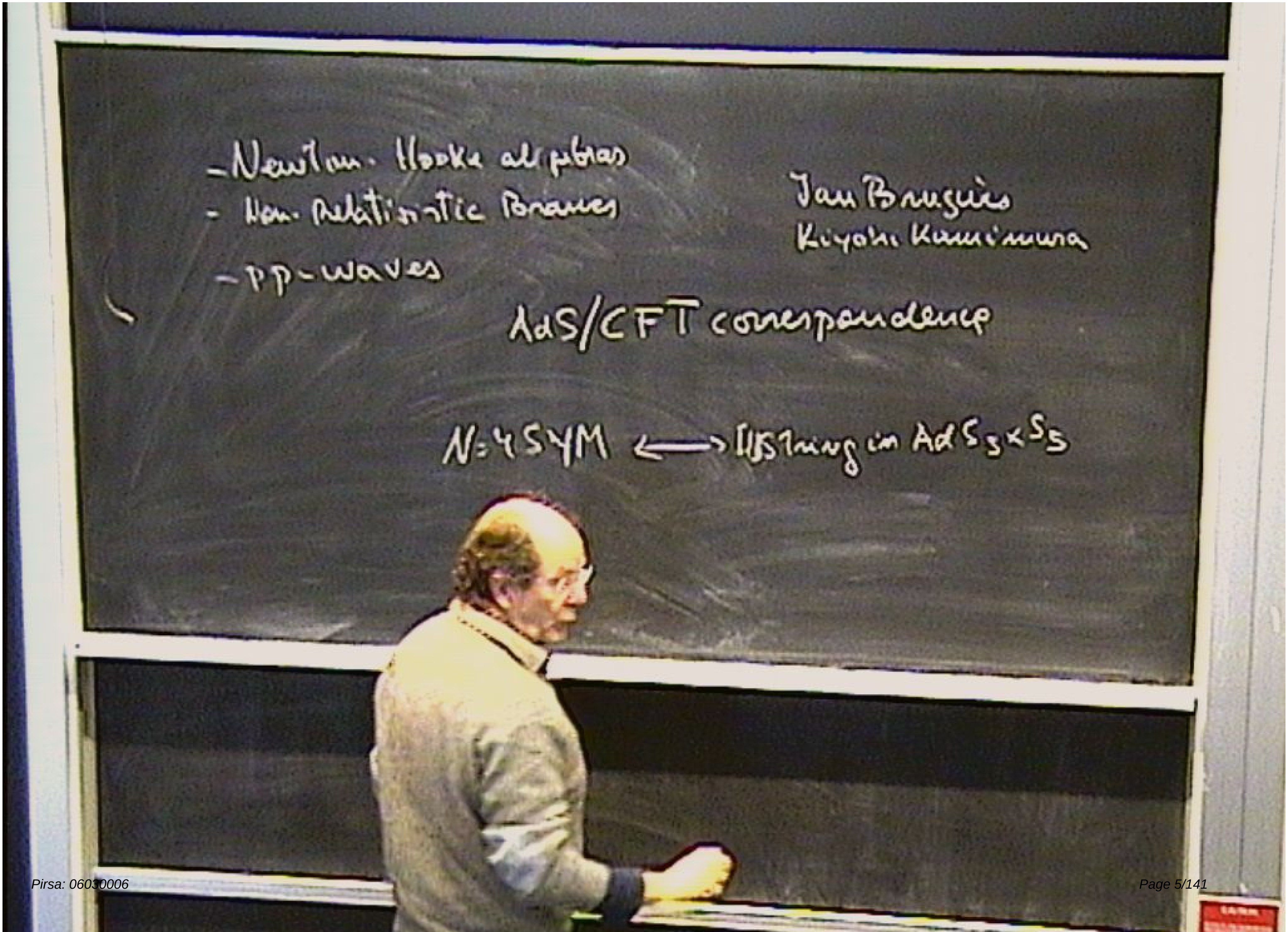
URL: http://pirsa.org/06030006

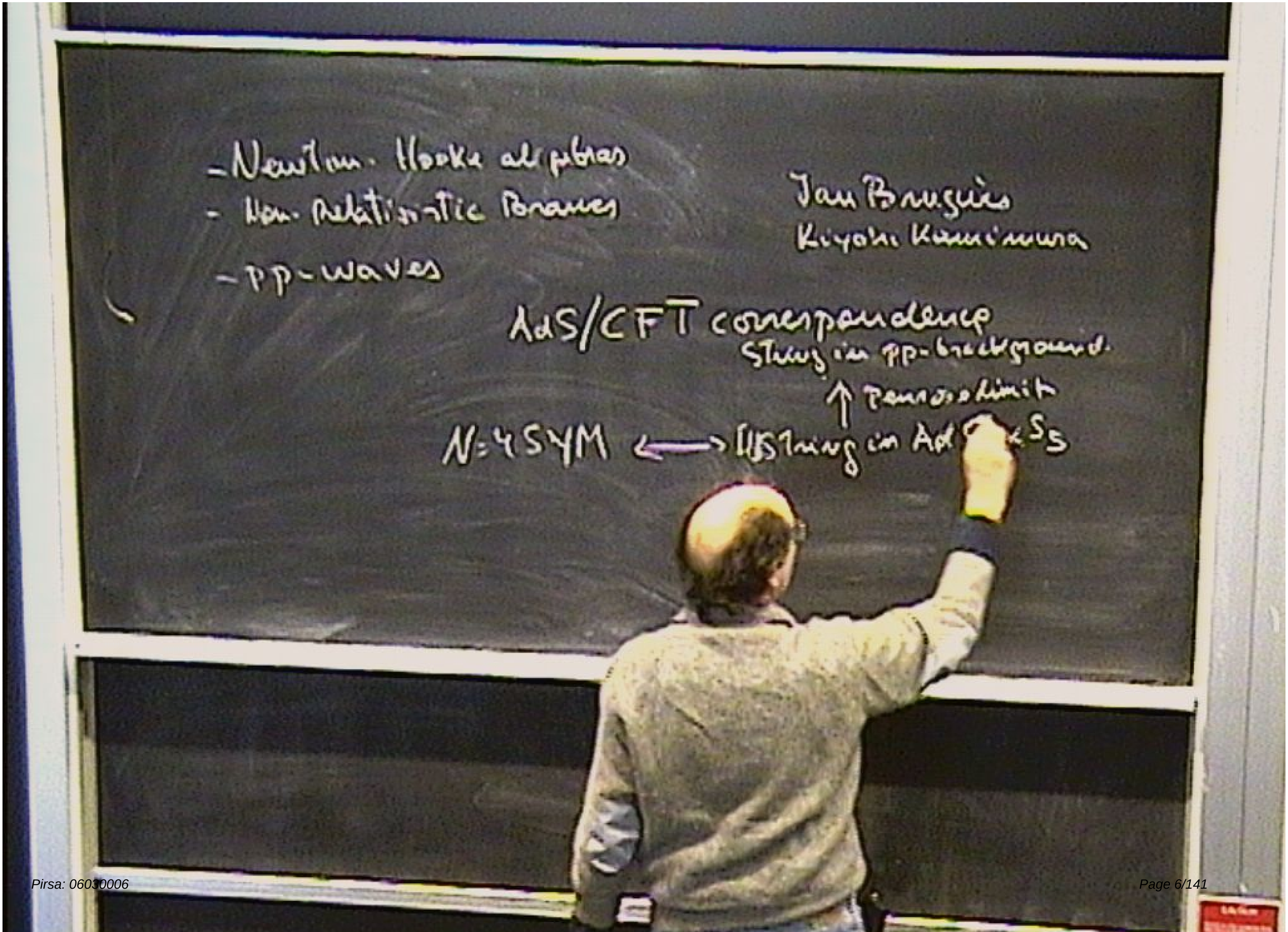
Abstract:


- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves

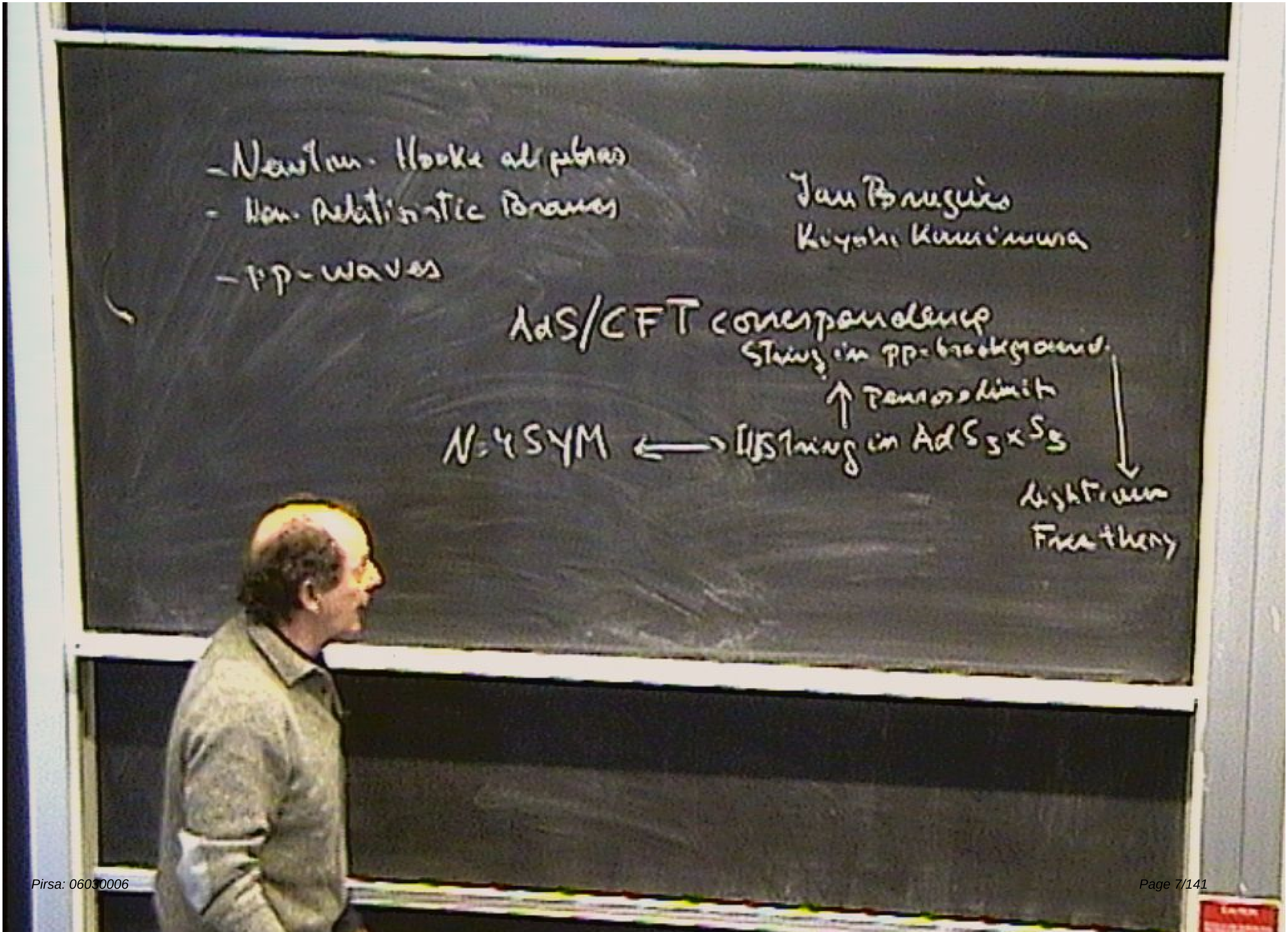

- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura


- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence

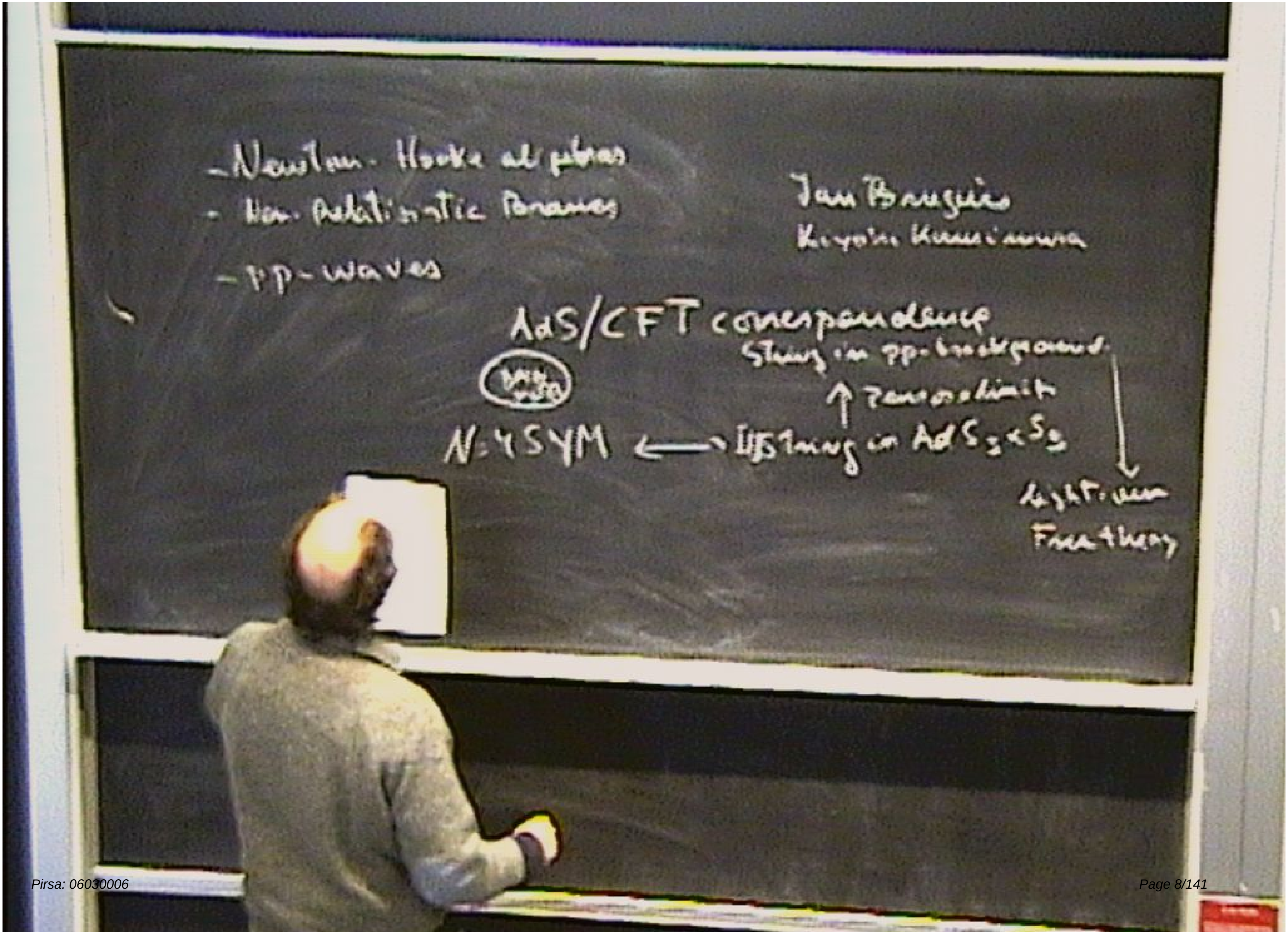

- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
N=4 SYM ⟷ IIB String in AdS5×S5

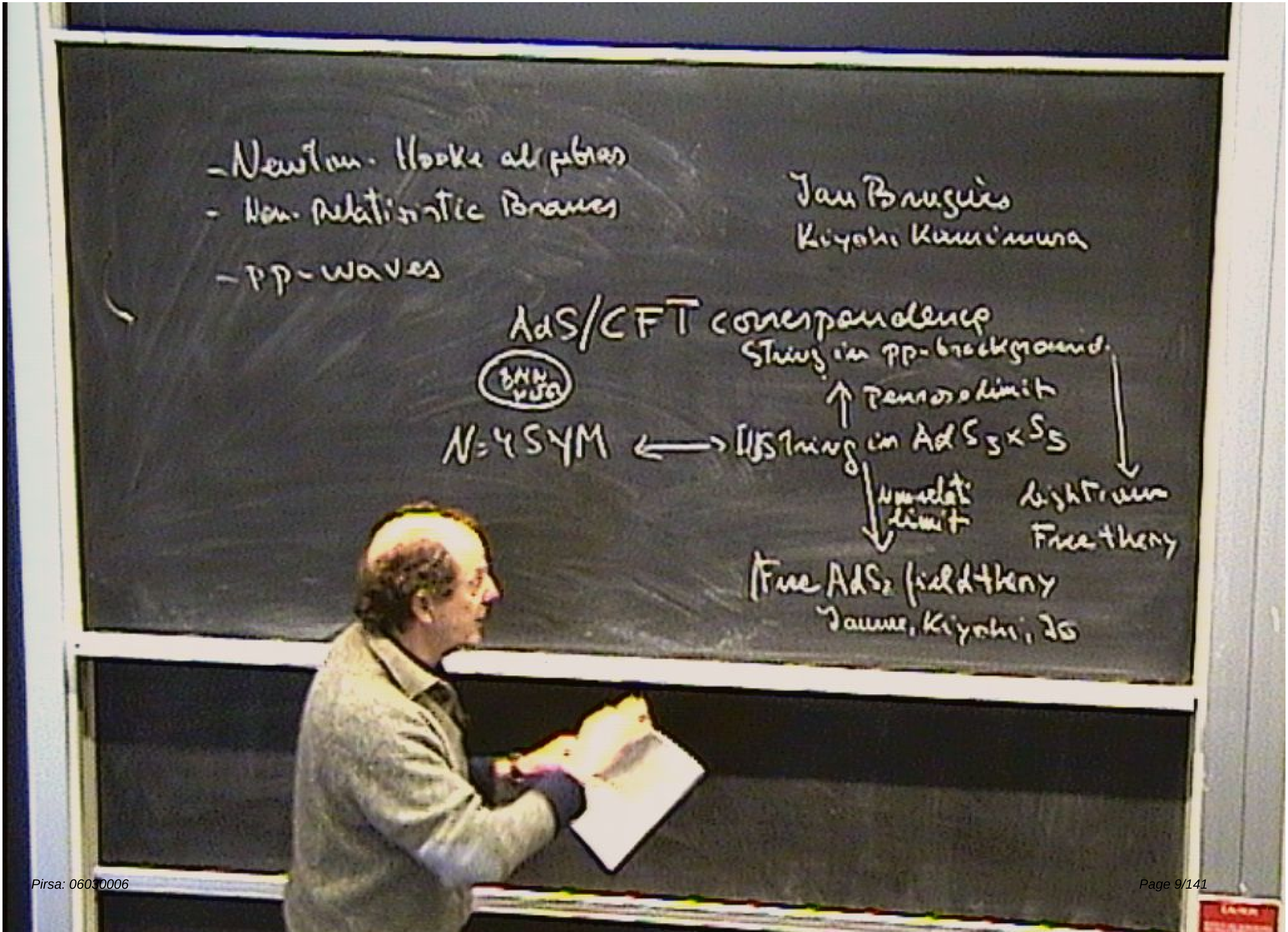


- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background.
↑ Penrose limit
N=4 SYM ⟷ IIB String in Ad × S5

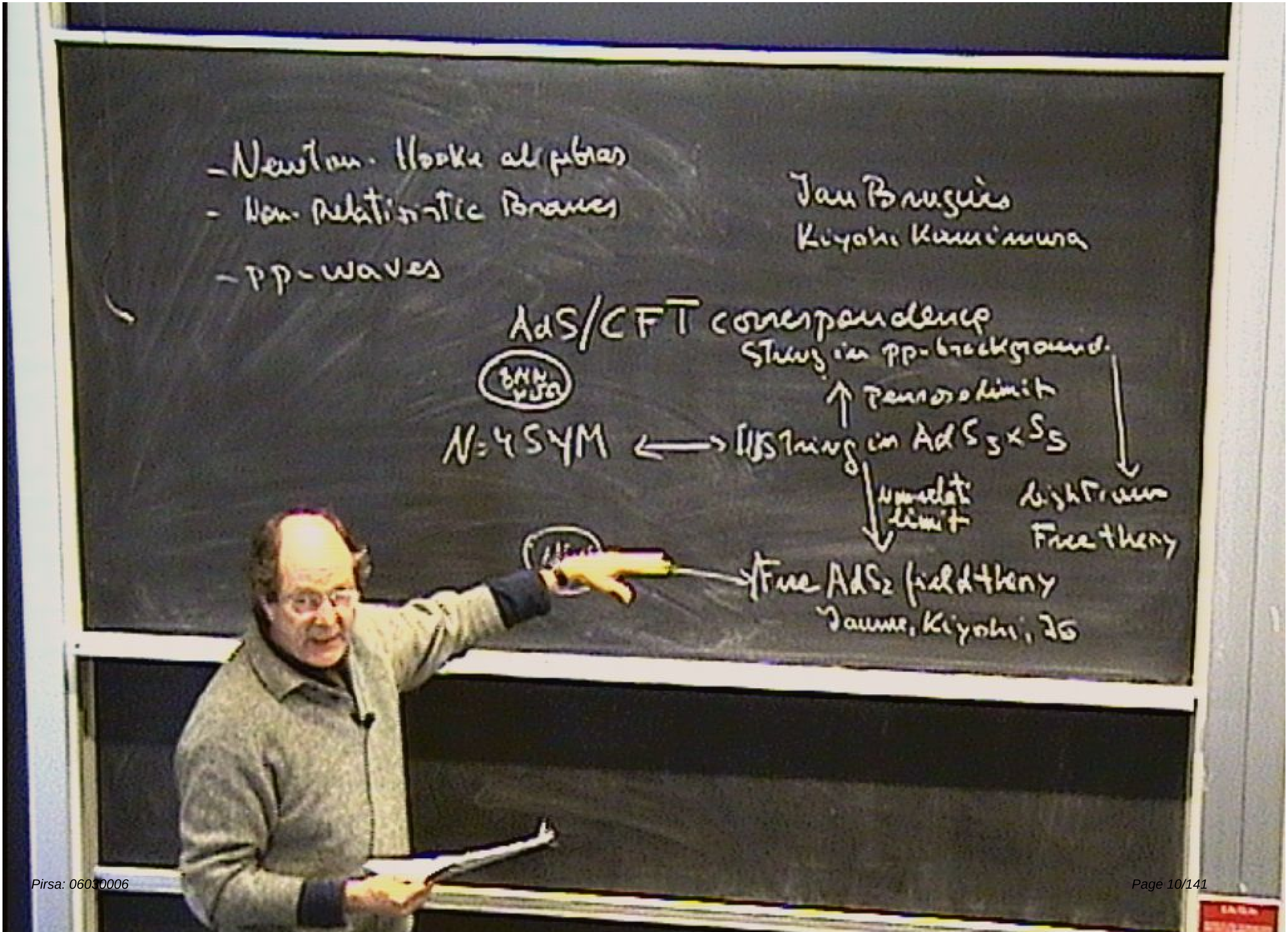


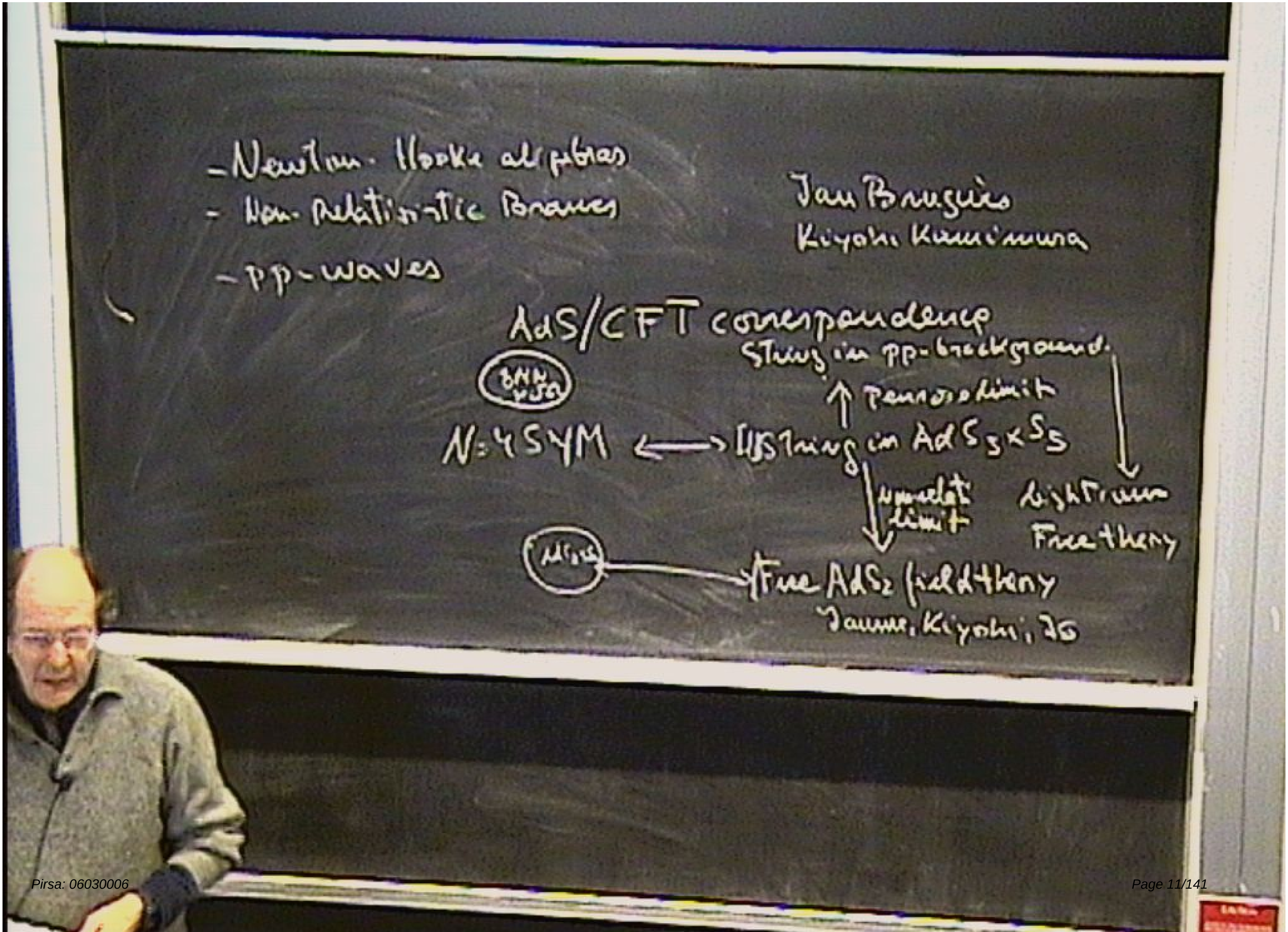
- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
Light cone
Free theory

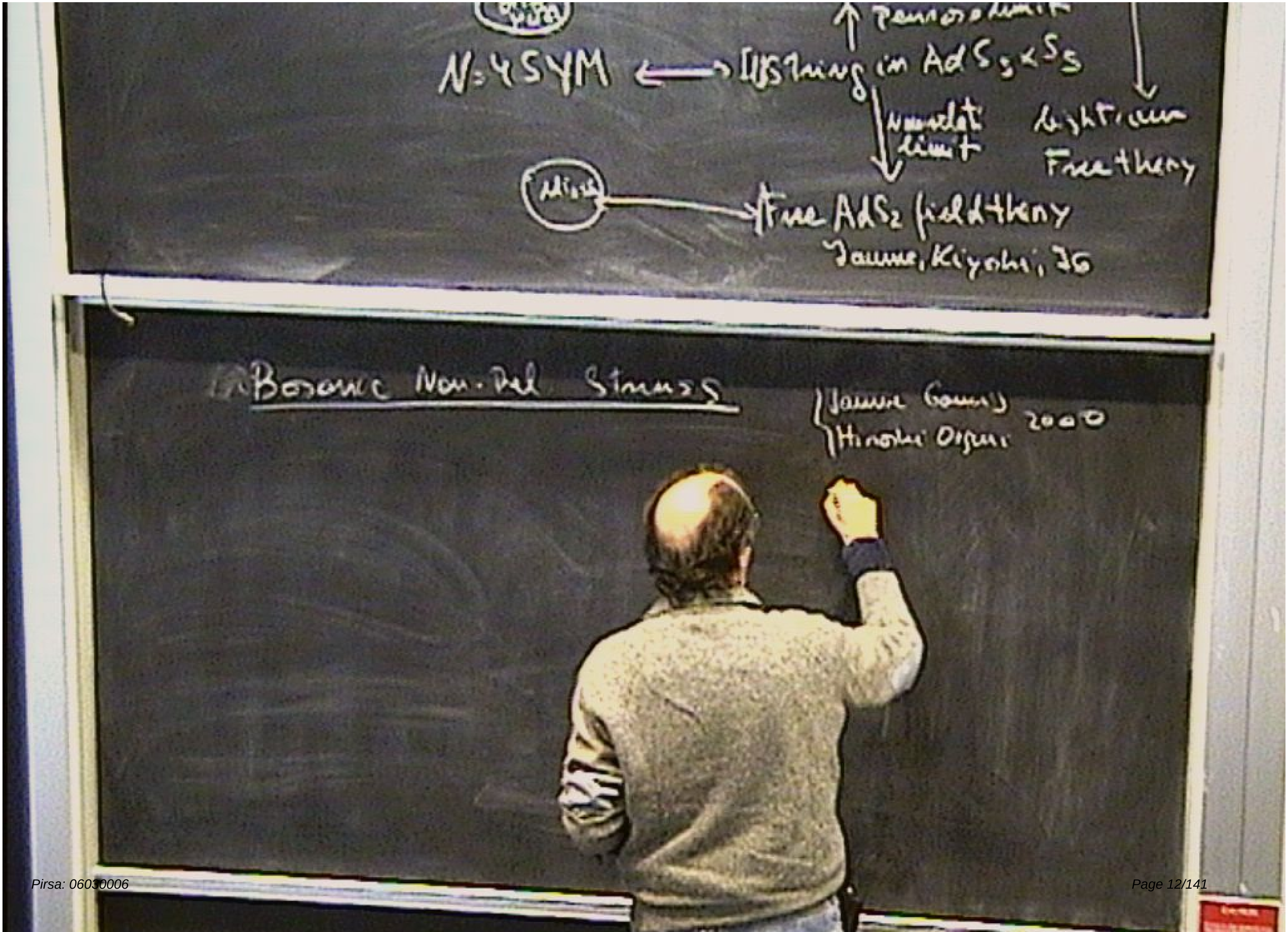

- Newton - Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
Light cone
Free theory

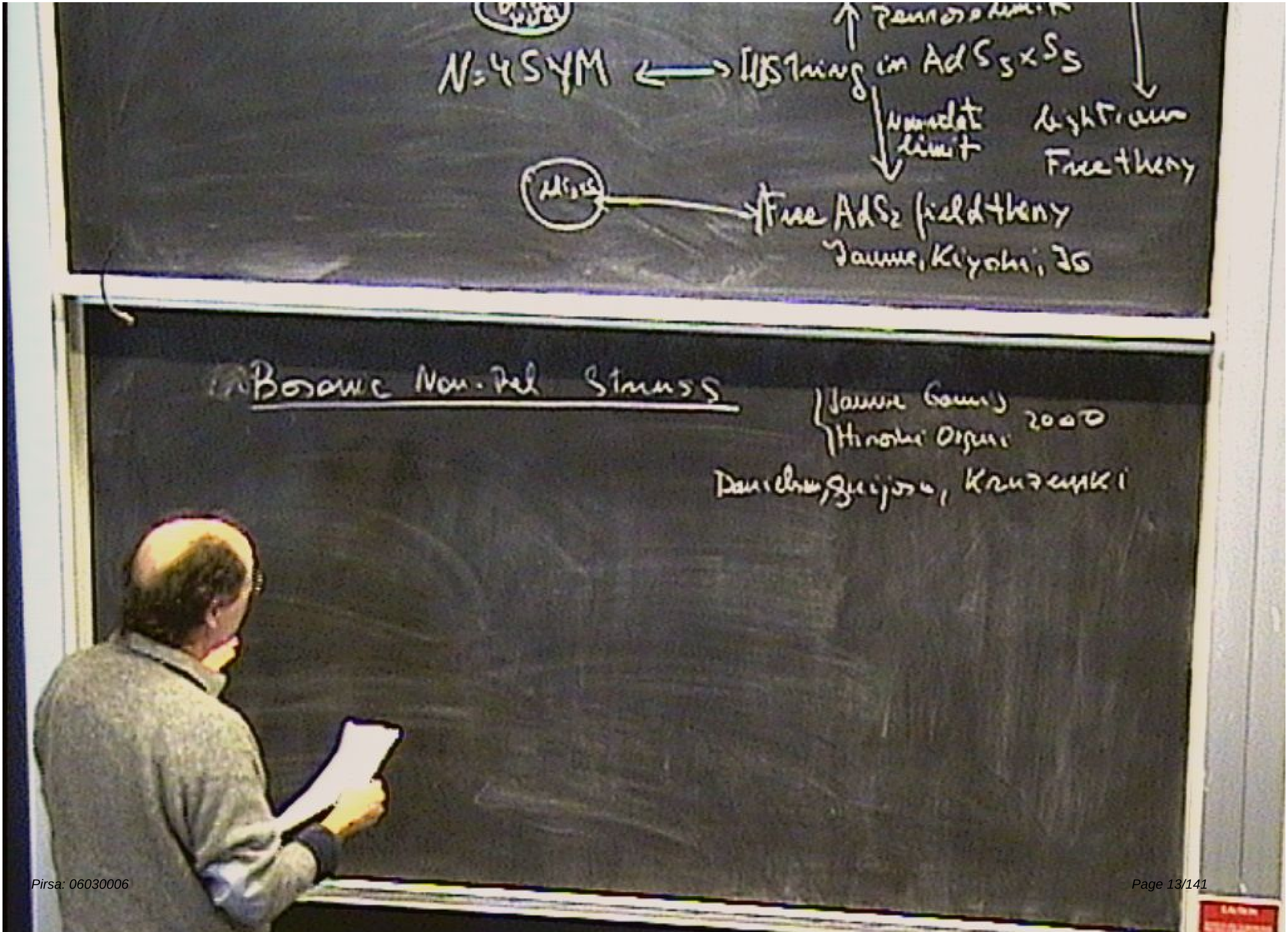


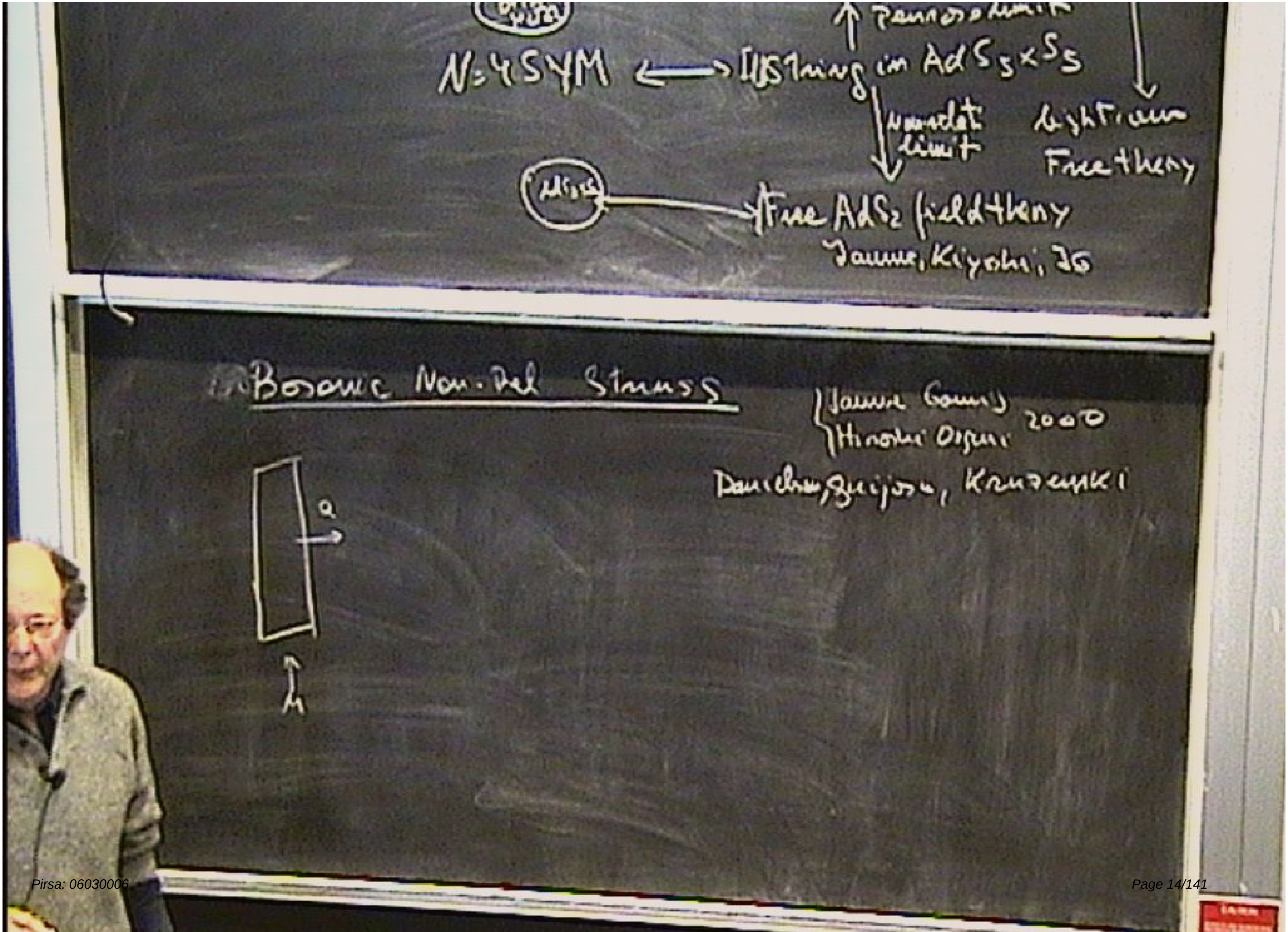
- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
Free theory
Free AdS2 field theory


- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
nonrelat. limit
lightcone
Free theory
Free AdS2 field theory
Jaume, Kiyoshi, JG


- Newton-Hooke algebras
- Non-Relativistic Branes
- pp-waves
Jan Brugues
Kiyoshi Kamimura
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
nonrelat. limit
Light cone
Free theory
Free AdS2 field theory
Jaume, Kiyoshi, JG


N=4 SYM
in AdS5×S5
Free AdS2 field theory
Bosonic Non-Rel Strings
Jaume Gomis
Hirosi Ooguri
2000


N=4 SYM
IIB String in AdS5×S5
Free AdS2 field theory
Free theory
Bosonic Non-Rel Strings
Gomis
Ooguri 2000


N=4 SYM
IIB String in AdS5×S5
limit
Free theory
Free AdS2 field theory
Bosonic Non-Rel Strings
Gomis
Ooguri
2000
Danielsson, Guijosa, Kruczenski

Penrose limit

$\mathcal{N}=4$ SYM $\longleftrightarrow$ IIB String in $AdS_5 \times S_5$

Nonrelat. limit

Light-cone Free theory

AdS2 $\longrightarrow$ Free AdS_2 field theory

Gomis, Kiyoshi, ...

Bosonic Non-Rel Strings

Gomis Gomis
Hirosi Ooguri 2000

Danielsson, Guijosa, Kruczenski

$$\begin{cases} X^{\mu} = \omega x^{n} \\ T_p = \tilde{T}_p \omega^{1-p} \end{cases}$$

$\uparrow$ Penrose limit

$\mathcal{N}=4$ SYM $\longleftrightarrow$ IIB String in $AdS_5 \times S_5$

nonrel. limit $\downarrow$ Light-cone Free theory

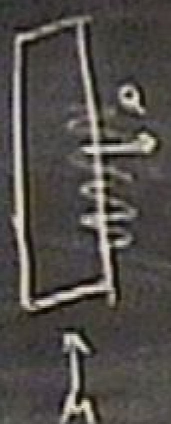
Free AdS_2 field theory

Gomis, Kiyoshi, JG

Bosonic Non-Rel Strings

{Gomis Gomis 2000
{Hiroshi Ooguri

Danielsson, Guijosa, Kruczenski



$$\begin{cases} X^\mu = \omega x^\mu \\ T_p = \tilde{T}_p \omega^{1-p} \end{cases}$$

ω dimensionless

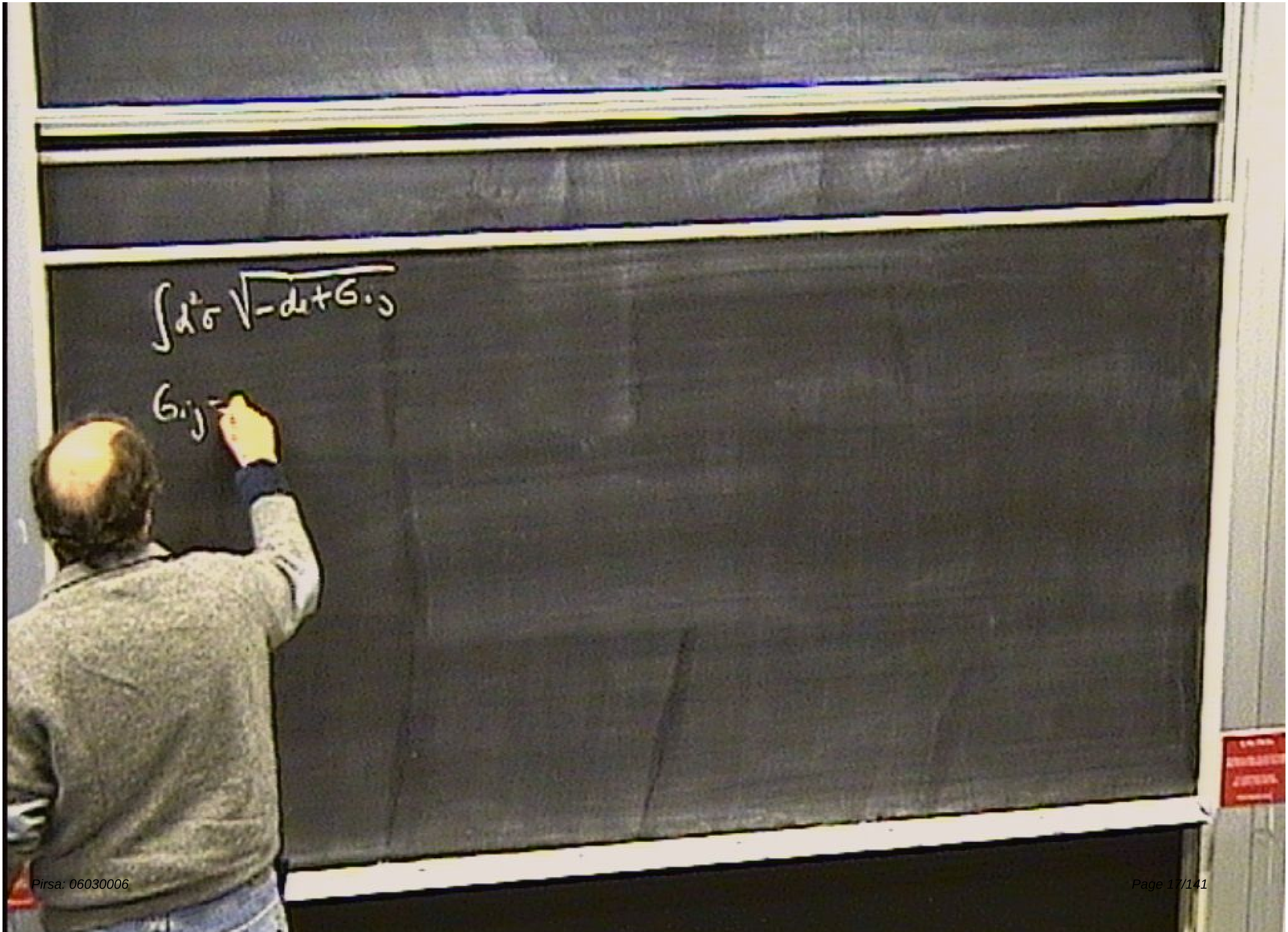
$\omega \to \infty$

$X^0 = \omega x^0$

$\omega \to 0$

Non-dynamical

non-transverse oscillations


$\int d^2\sigma \sqrt{-\det G_{ij}}$
$G_{ij} =$

$$\int d^2\sigma \sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X$$

Penrose limit

$\mathcal{N}=4$ SYM $\longleftrightarrow$ IIB String in $AdS_5 \times S_5$

Nonrelat. limit

lightcone Free theory

AdS_2 $\longrightarrow$ Free AdS_2 field theory

Jaume, Kiyoshi, JG

Bosonic Non-Rel Strings

Jaume Gomis, Hirosi Ooguri 2000

Danielsson, Guijosa, Kruczenski

$$\begin{cases} X^\mu = \omega x^\mu \\ T_p = \tilde{T}_p \, \omega^{1-p} \end{cases}$$

ω dimensionless

$\omega \to \infty$

(X^μ, X^9)

X^{11}

$X^0 = \omega x^0$

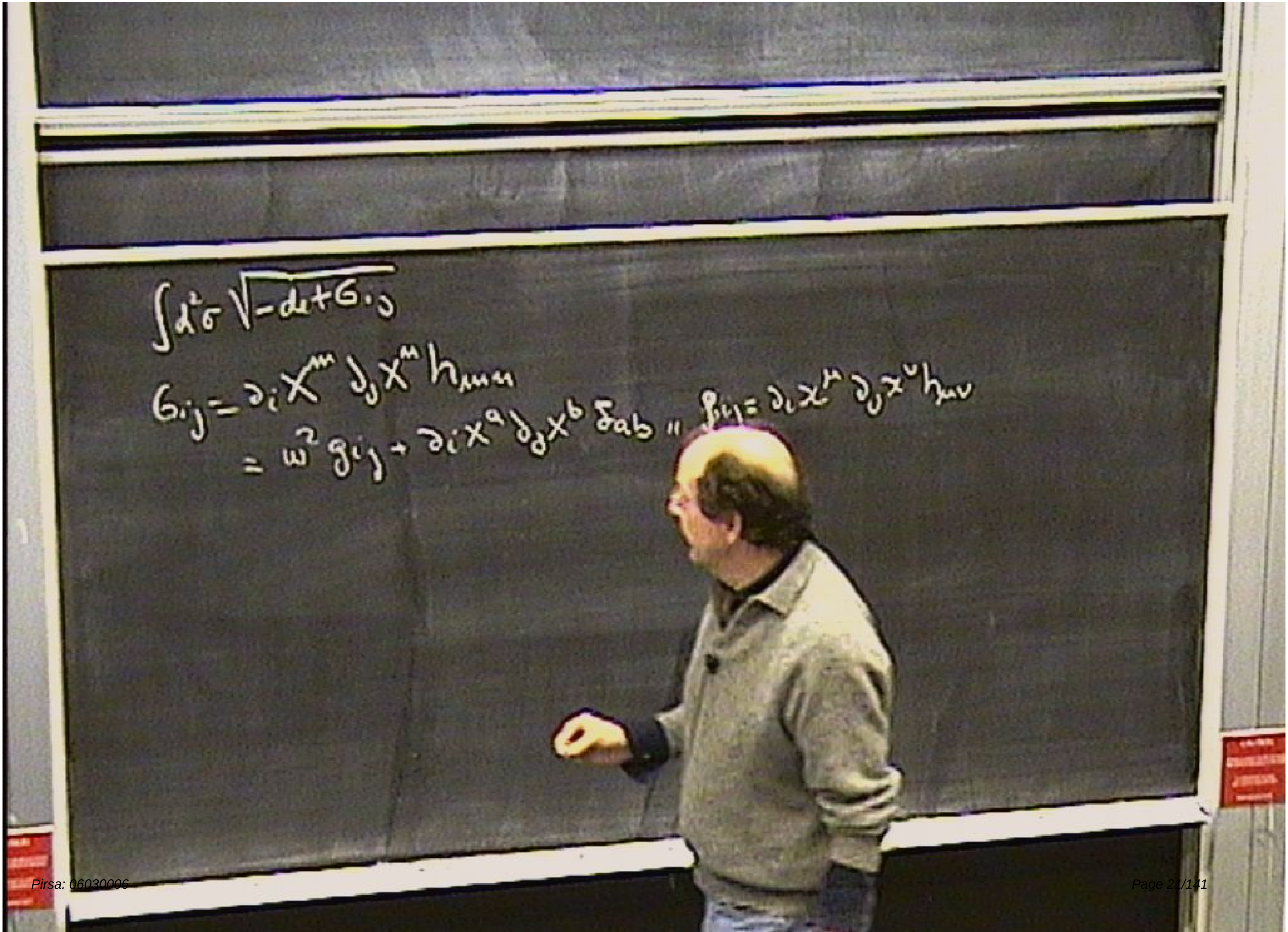
$\omega \to 0$

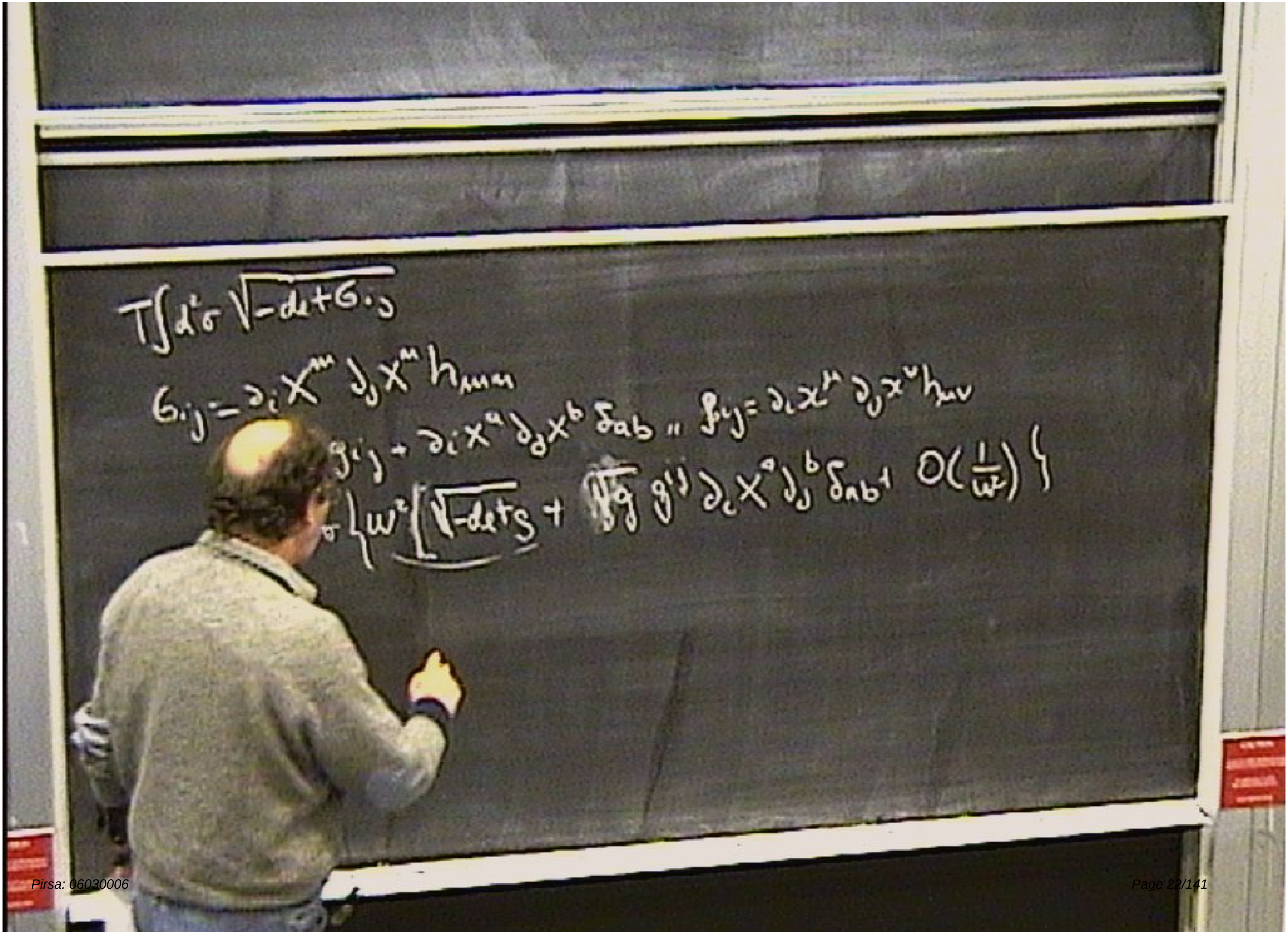
Non-dynamical

non-transverse oscillations

$$\int d^2\sigma \sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$$


$\int d^2\sigma \sqrt{-\det G_{ij}}$
$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$
$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$
$g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$



$T\int d^2\sigma \sqrt{-\det G_{ij}}$
$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$
$\partial_i X^a \partial_j X^b \delta_{ab}$,, $g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$
$g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$
$\{ w^2 [\sqrt{-\det g} + \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} + O(\frac{1}{w^2}) \}$

$$T\int d^2\sigma\,\sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$$

$$G_{ij} = \partial_i X^\mu \partial_j X^\nu h_{\mu\nu} + \partial_i X^a \partial_j X^b \delta_{ab} \qquad g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$$

$$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$$

$$= T\int d^2\sigma\,\Big\{\omega^2 \underbrace{\sqrt{-\det g}}_{\text{divergent}} + \sqrt{-g}\, g^{ij}\partial_i X^a \partial_j X^b \delta_{ab} + O\!\left(\frac{1}{\omega^2}\right)\Big\}$$

↑ Penrose limit

$\mathcal{N}=4$ SYM ⟷ IIB String in $AdS_5 \times S_5$

↓ nonrel. limit

light cone Free theory

(AdS₂) ⟶ Free AdS_2 field theory

Jaume, Kiyoshi, JG

Bosonic Non-Rel Strings

Jaume Gomis, Hirosi Ooguri 2000

Danielsson, Guijosa, Kruczenski

$$\begin{cases} X^\mu = \omega x^\mu \\ T_p = \tilde{T}_p \omega^{1-p} \end{cases}$$

ω dimensionless

$\omega \to \infty$

(X^μ, X^9, X^{M})

$X^0 = \omega x^0$

$\omega \to 0$

Non-dynamical

non-transverse oscillations

$$T\int d^2\sigma \sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X^M \partial_j X^N h_{MN}$$

$$= w^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab} \quad , \quad g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$$

$$= T\int d^2\sigma \left\{ w^2 \left[\underbrace{\sqrt{-\det g}}_{\text{divergent}} + \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} + O\left(\frac{1}{w^2}\right) \right\} \right.$$

$$T \int d^2\sigma \sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$$

$$= \partial_i x^a \partial_j x^b \delta_{ab} \quad g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$$

$$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$$

$$= T \int d^2\sigma \Big\{ \omega^2 \underbrace{\left[\sqrt{-\det g} \right.}_{\text{divergent}} + \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} + O\left(\frac{1}{\omega^2}\right) \Big\}$$

$$+ \int d^2\sigma \; B^*$$

$T\int d^2\sigma \sqrt{-\det G_{ij}}$

$G_{ij} = \partial_i X^\mu \partial_j X^\nu h_{\mu\nu}$

$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$,, $g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$

$= T\int d^2\sigma \left\{ \omega^2 \left[\underbrace{\cancel{\sqrt{-\det g}}}_{\text{divergent}} + \sqrt{-g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} + O\left(\frac{1}{\omega^2}\right) \right\} \right.$

$+ \int d^2\sigma\, B^{\mu\nu}$,, $H = dB = 0$

$$T\int d^2\sigma \sqrt{-\det G_{ij}}$$

$$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$$

$$= \partial_i X^a \partial_j X^b \delta_{ab} \quad ; \quad g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$$

$$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab} + O\left(\frac{1}{\omega^2}\right) \}$$

$$= T \int d^2\sigma \left\{ \omega^2 \underbrace{\left[\sqrt{-\det g} \right.}_{\text{divergent}} + \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} \right.$$

$$+ \int d^2\sigma\, B^{\mu\nu} \quad ; \quad H = dB = 0$$

$$B_{\mu\nu} = \epsilon_{\mu\nu} dx^\mu dx^\nu$$

$$= T \int d^2\sigma \left\{ w^2 \left[\underbrace{\cancel{\sqrt{-\det g}}}_{\text{divergent}} + \sqrt{g}\, g^{ij} \partial_i X \partial_j X \delta_{ab} + O\left(\tfrac{1}{w^2}\right) \right] \right\}$$

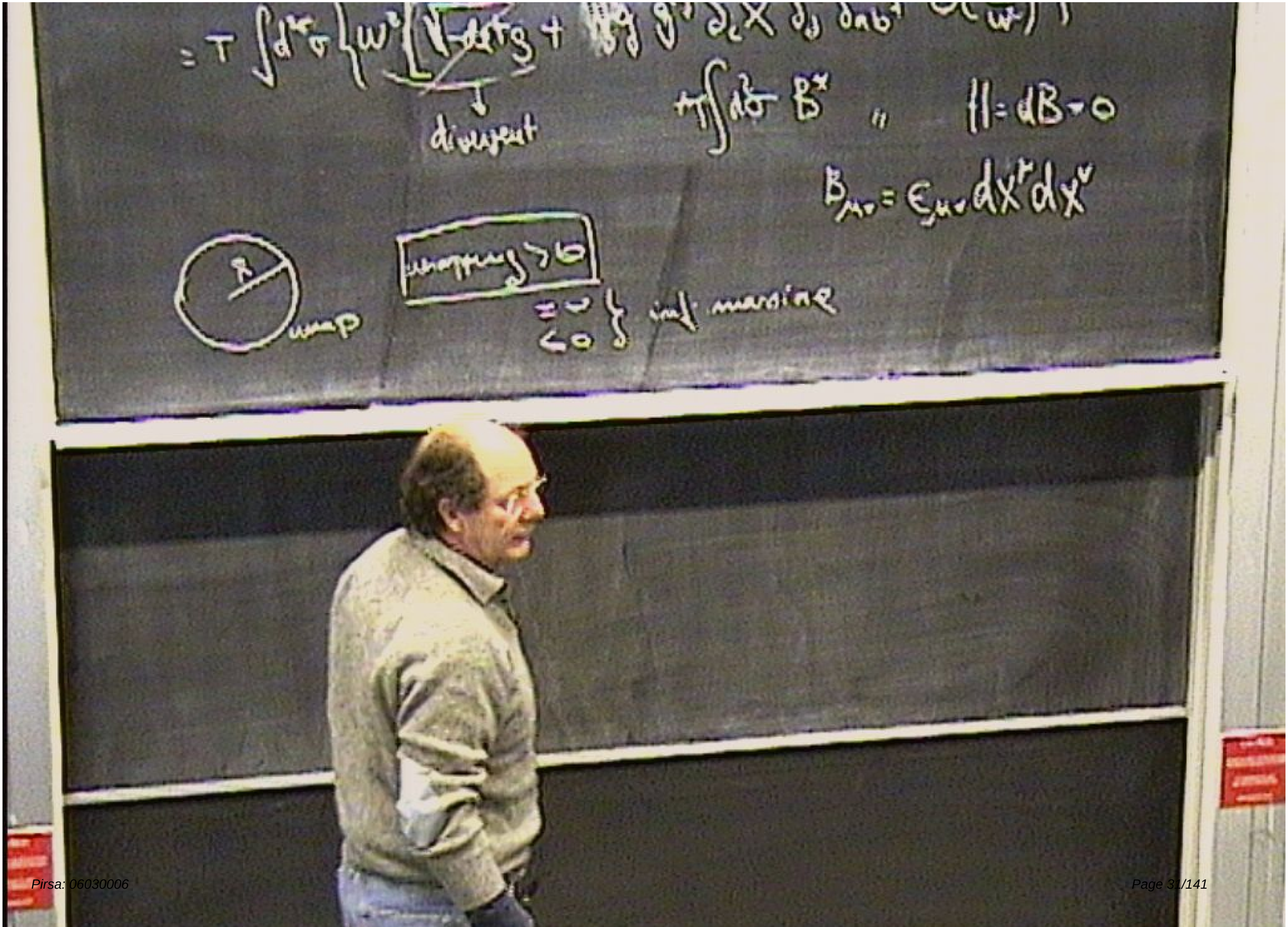
$$+ \int d^2\sigma\, B^{*} \quad '' \qquad H = dB = 0$$

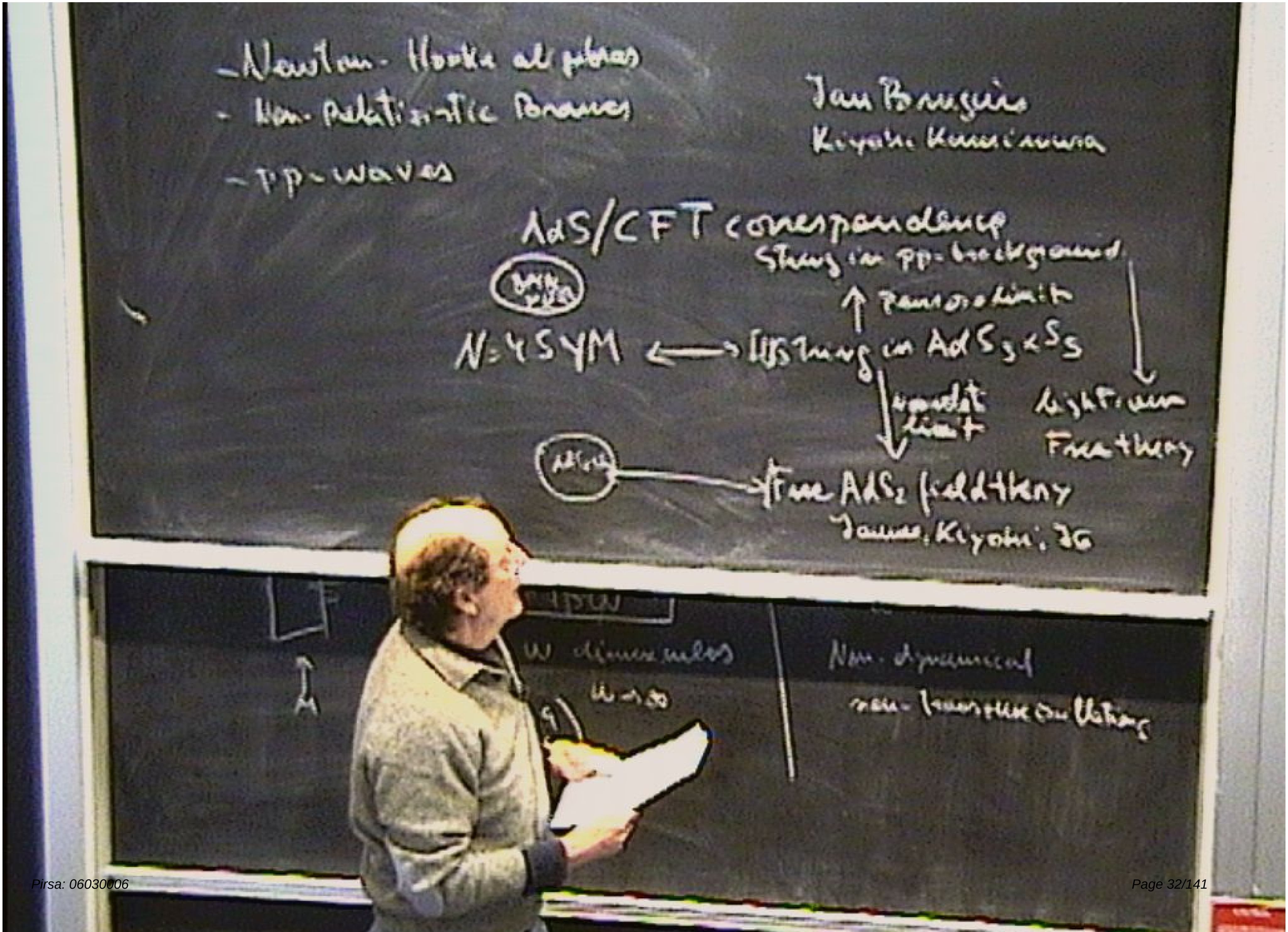
$$B_{\mu\nu} = \epsilon_{\mu\nu}\, dx^\mu dx^\nu$$

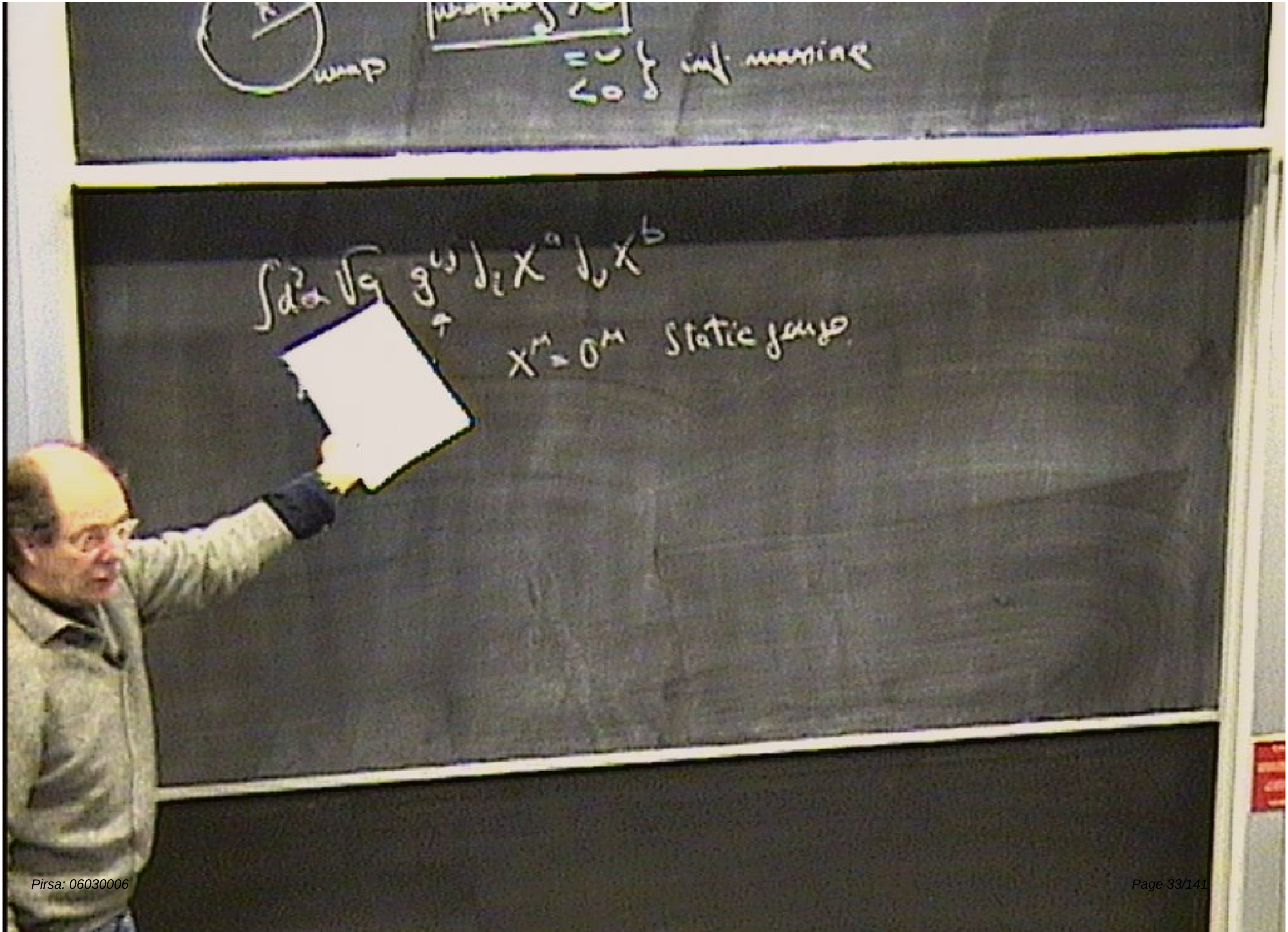
$$= T \int d^2\sigma \Big\{ w^2 \Big[\underbrace{\sqrt{-\det g}}_{\text{divergent}} + \sqrt{g}\, g^{ij} \partial_i X \partial_j X g_{ab} + O\Big(\frac{1}{w^2}\Big) \Big] \Big\}$$

$$+ \int d^2\sigma\, B^{*} \quad , \quad H = dB = 0$$

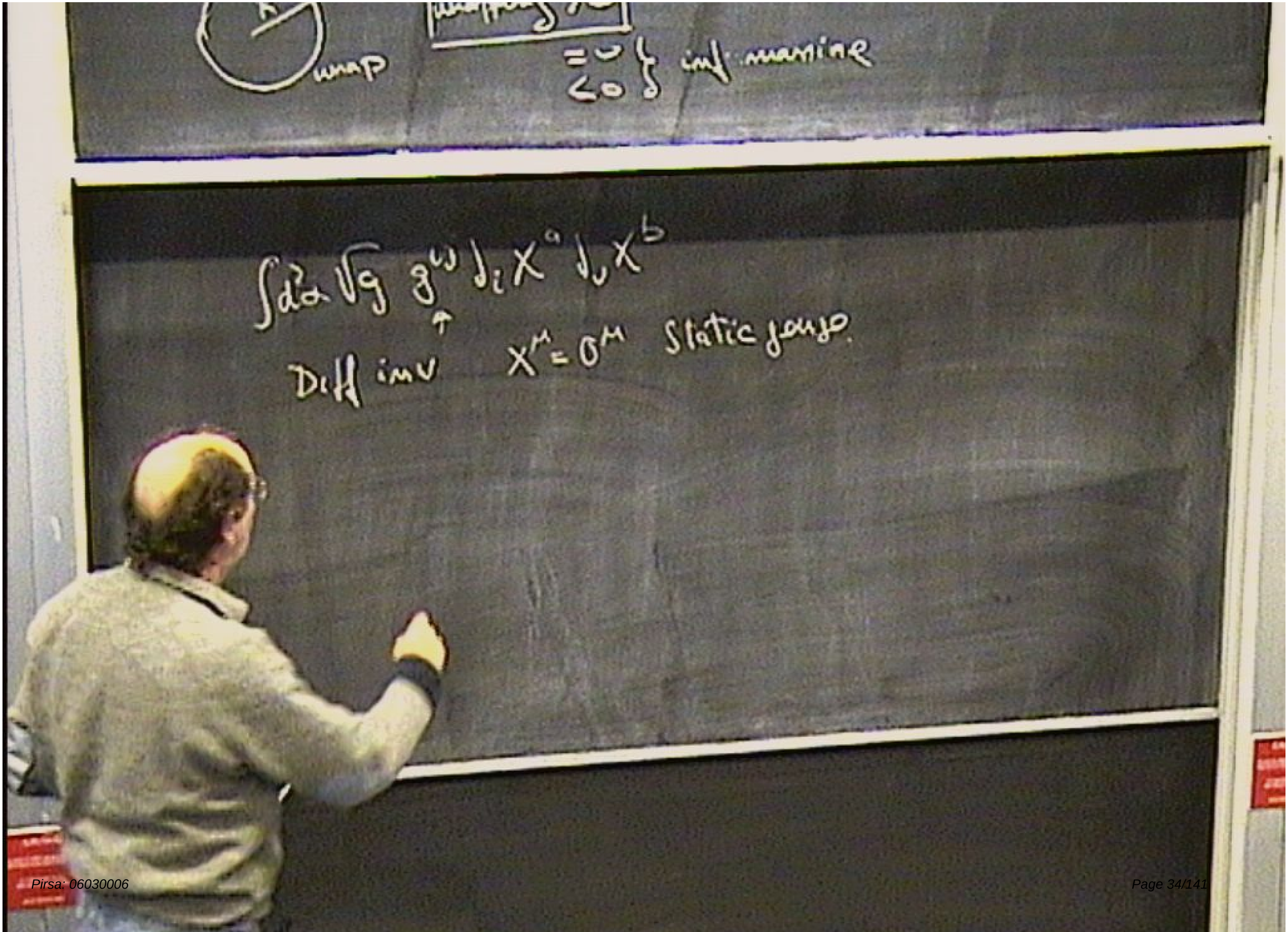
$$B_{\mu\nu} = \epsilon_{\mu\nu}\, dX^\mu dX^\nu$$


divergent
$B_{\mu\nu} = \epsilon_{\mu\nu} dX^\mu dX^\nu$
wrapping > 0
wrap


- Newton-Hooke algebras
- Non-relativistic branes
- pp-waves
AdS/CFT correspondence
String in pp-background
Penrose limit
N=4 SYM
IIB String in AdS5×S5
light cone
Free theory
Free AdS2 field theory
Jaume, Kiyoshi, JG
Non-dynamical



$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$
$X^\mu = \sigma^\mu$ static gauge


wrap
$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$
Diff inv
$X^\mu = \sigma^\mu$ Static gauge

wrap

$\left.\begin{array}{l} = 0 \\ < 0 \end{array}\right\}$ inf massive

$$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$$

Diff inv $\quad X^\mu = \sigma^\mu \quad$ Static gauge.

$$\int d^2x\, h^{ij} \partial_i X^a \partial_j X^b \delta_{ab}$$

nonrelat. limit

Lightcone Free theory

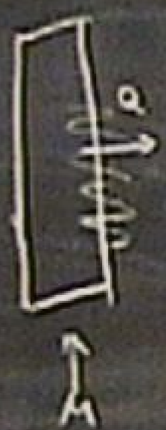
AdS_5 → Free AdS_2 field theory

Jaume, Kiyoshi, Jo

Bosonic Non-Rel Strings

Jaume Gomis, Hirosi Ooguri 2000

Danielsson, Guijosa, Kruczenski



$$X^\mu = \omega x^\mu$$

$$\boxed{T_p = \tilde{T}_p\, \omega^{1-p}}$$

ω dimensionless

$\omega \to \infty$

$$(X^\mu, X^9) \quad X^m$$

$$X^0 = \omega x^0$$

$\omega \to 0$

Non-dynamical

non-transverse oscillations

$$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$$

Diff inv $\quad X^\mu = \sigma^\mu$ static gauge.

$$\int d^2x\, h^{ij} \partial_i X^a \partial_j X^b \delta_{ab}$$

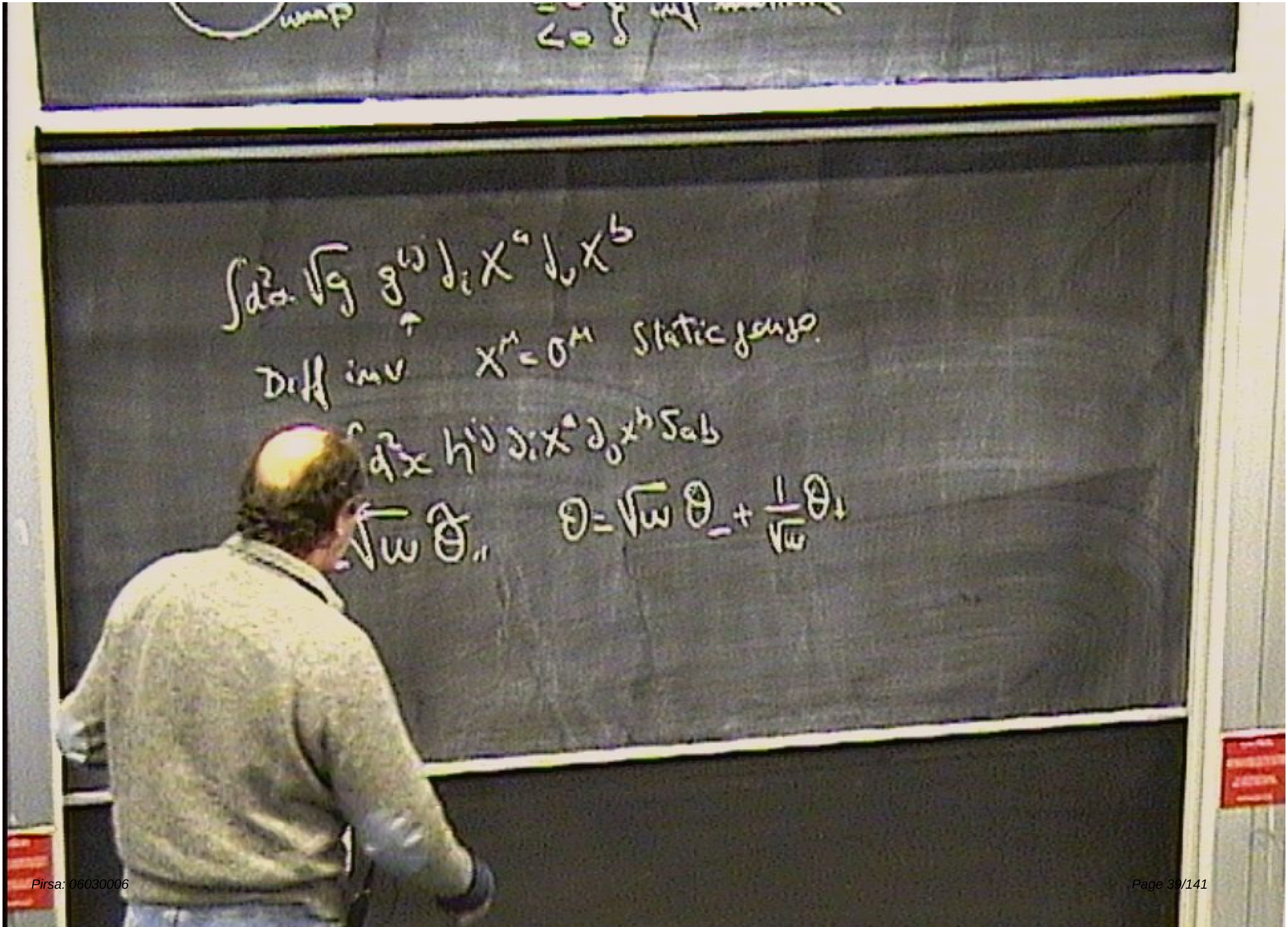
$\theta =$

$$\int d^2\sigma \sqrt{g}\, g^{ij}\, \partial_i X^a \partial_j X^b$$

Diff inv. $X^\mu = \sigma^\mu$ Static gauge.

$$\int d^2x\, h^{ij}\, \partial_i X^a \partial_j X^b \delta_{ab}$$

$$\theta = \sqrt{\omega}\, \tilde{\theta}$$


$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$
Diff inv $X^\mu = \sigma^\mu$ static gauge
$\int d^2x\, h^{ij} \partial_i x^a \partial_j x^b \delta_{ab}$
$\sqrt{w}\, \theta_{\parallel}$ $\theta = \sqrt{w}\, \theta_- + \frac{1}{\sqrt{w}} \theta_+$

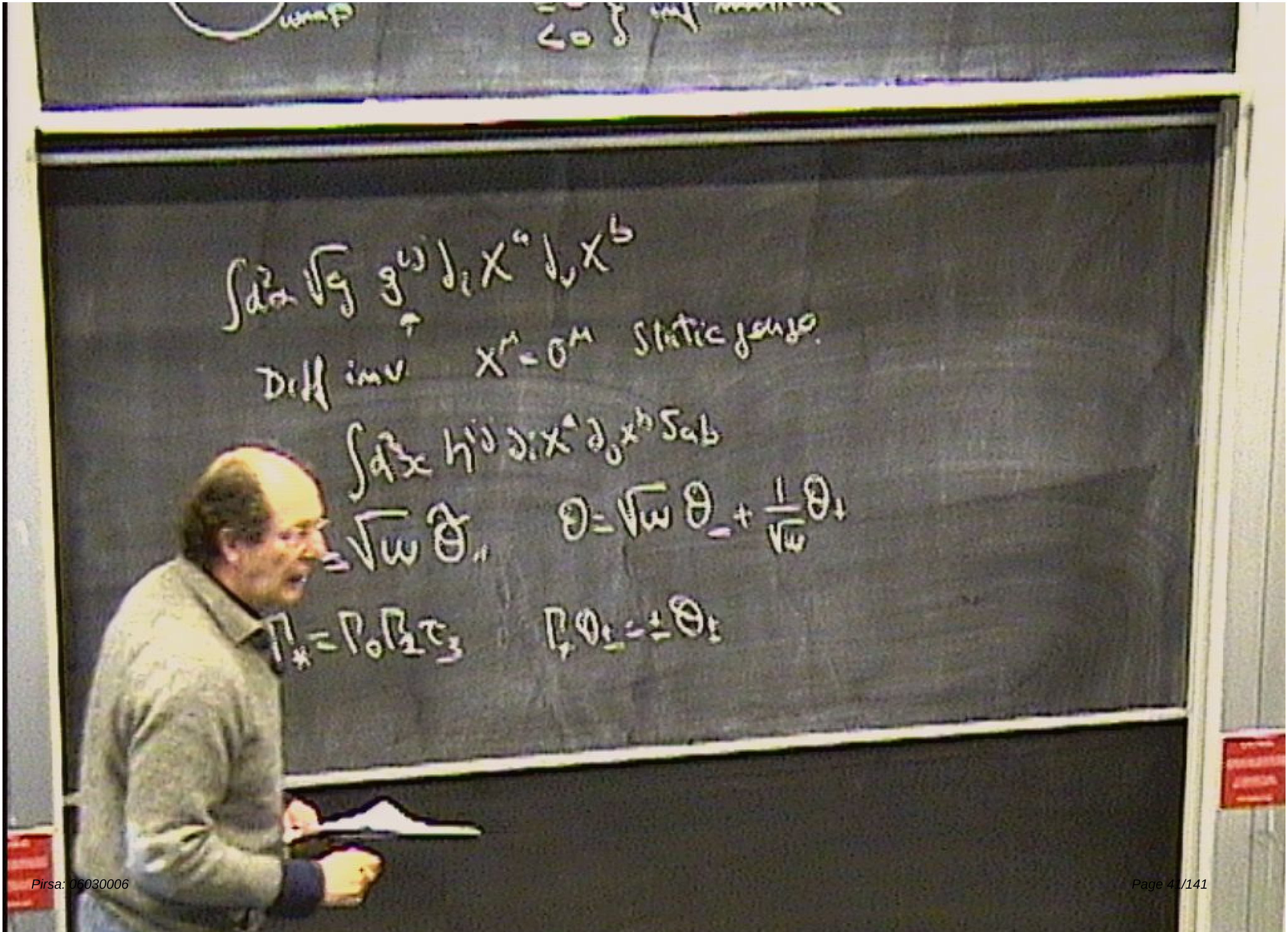
$$\int d^2\sigma \sqrt{g}\, g^{ij}\, \partial_i X^a \partial_j X^b$$

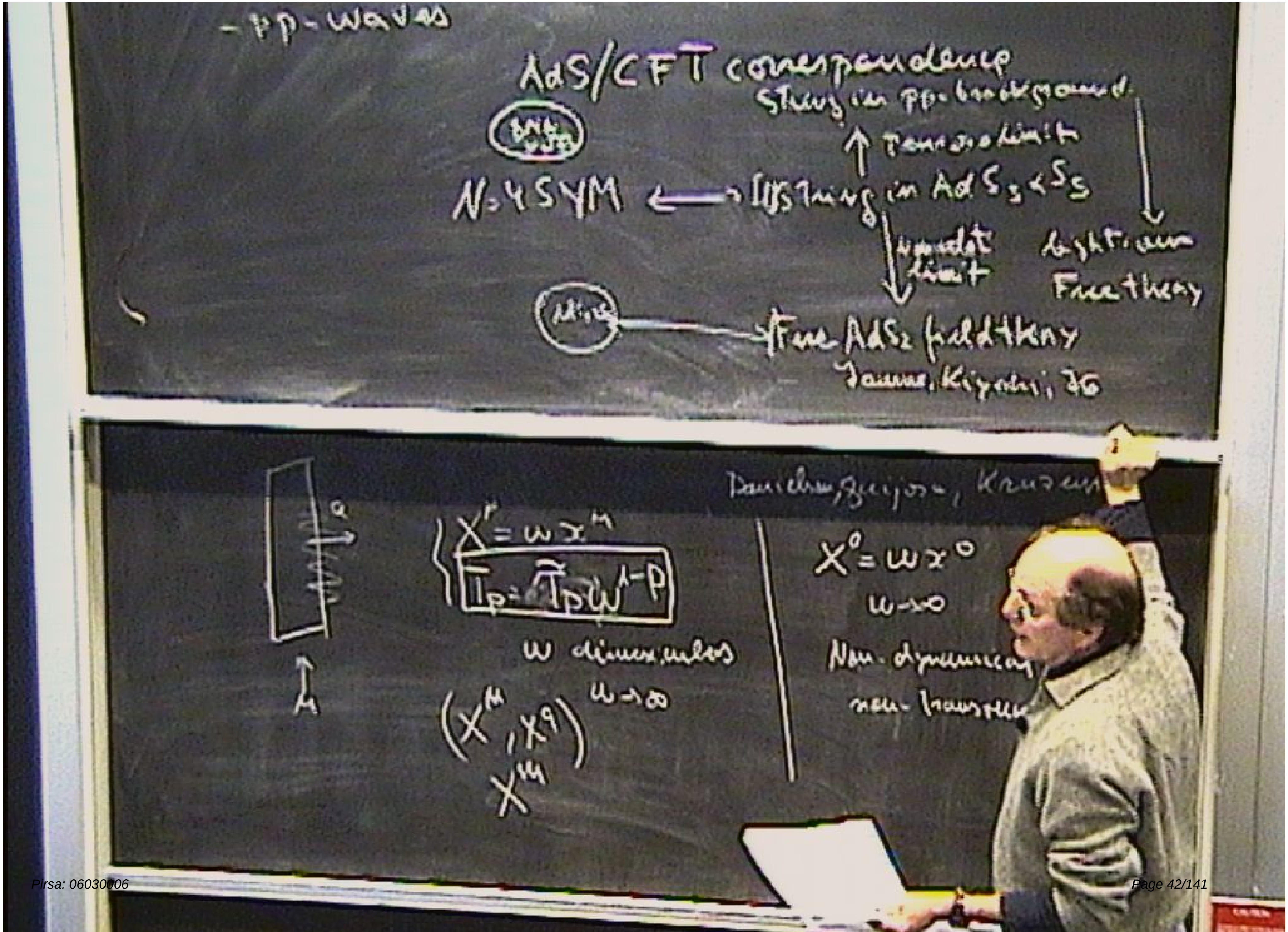
Diff inv. $\quad X^\mu = \sigma^\mu$ Static gauge.

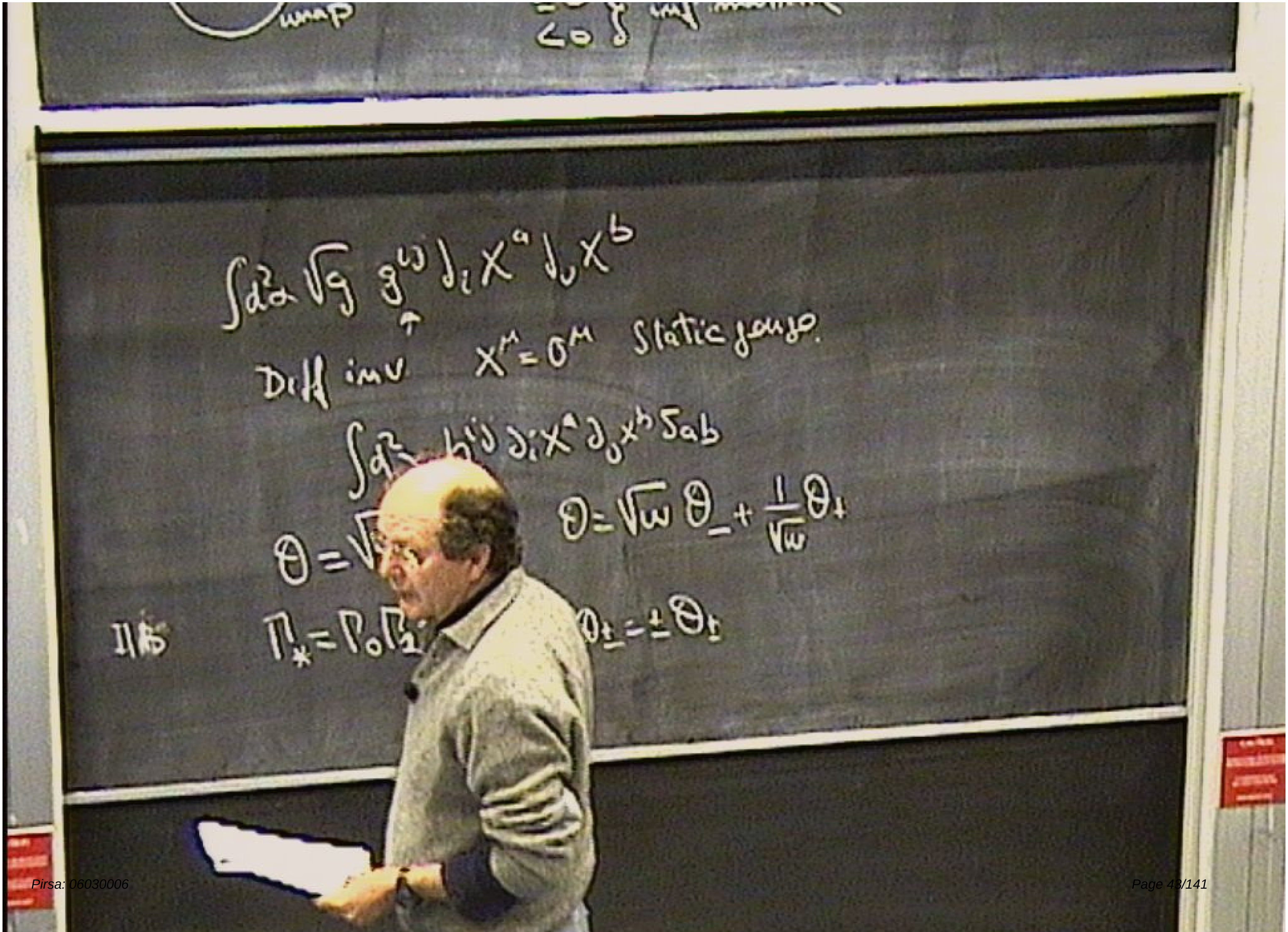
$$\int d^2x\, h^{ij}\, \partial_i X^a \partial_j X^b\, \delta_{ab}$$

$$\theta = \sqrt{w}\,\theta_{\parallel} \qquad \theta = \sqrt{w}\,\theta_- + \frac{1}{\sqrt{w}}\theta_+$$

Π_*


wrap
<0
∫d²σ √g g^{ij} ∂_i X^a ∂_j X^b
Diff inv   X^μ = σ^μ   static gauge
∫d³x h^{ij} ∂_i X^a ∂_j X^b δ_ab
= √ω θ_+   θ = √ω θ_- + (1/√ω) θ_+
Γ_* = Γ_0 Γ_2 τ_3   Γ_* θ_± = ± θ_±


- pp-waves
AdS/CFT correspondence
String in pp-background
N=4 SYM
IIB String in AdS5×S5
Free AdS5 field theory
Free theory
ω dimensionless
X0 = ω x0
Non-dynamical


∫d²σ √g g^{ij} ∂_i X^a ∂_j X^b
Diff inv
X^μ = σ^μ static gauge.
∫d²σ h^{ij} ∂_i X^a ∂_j X^b δ_ab
θ = √ω θ_- + 1/√ω θ_+
IIB
Γ_* = Γ_0 Γ_2
θ_± = ± θ_±

<0 {

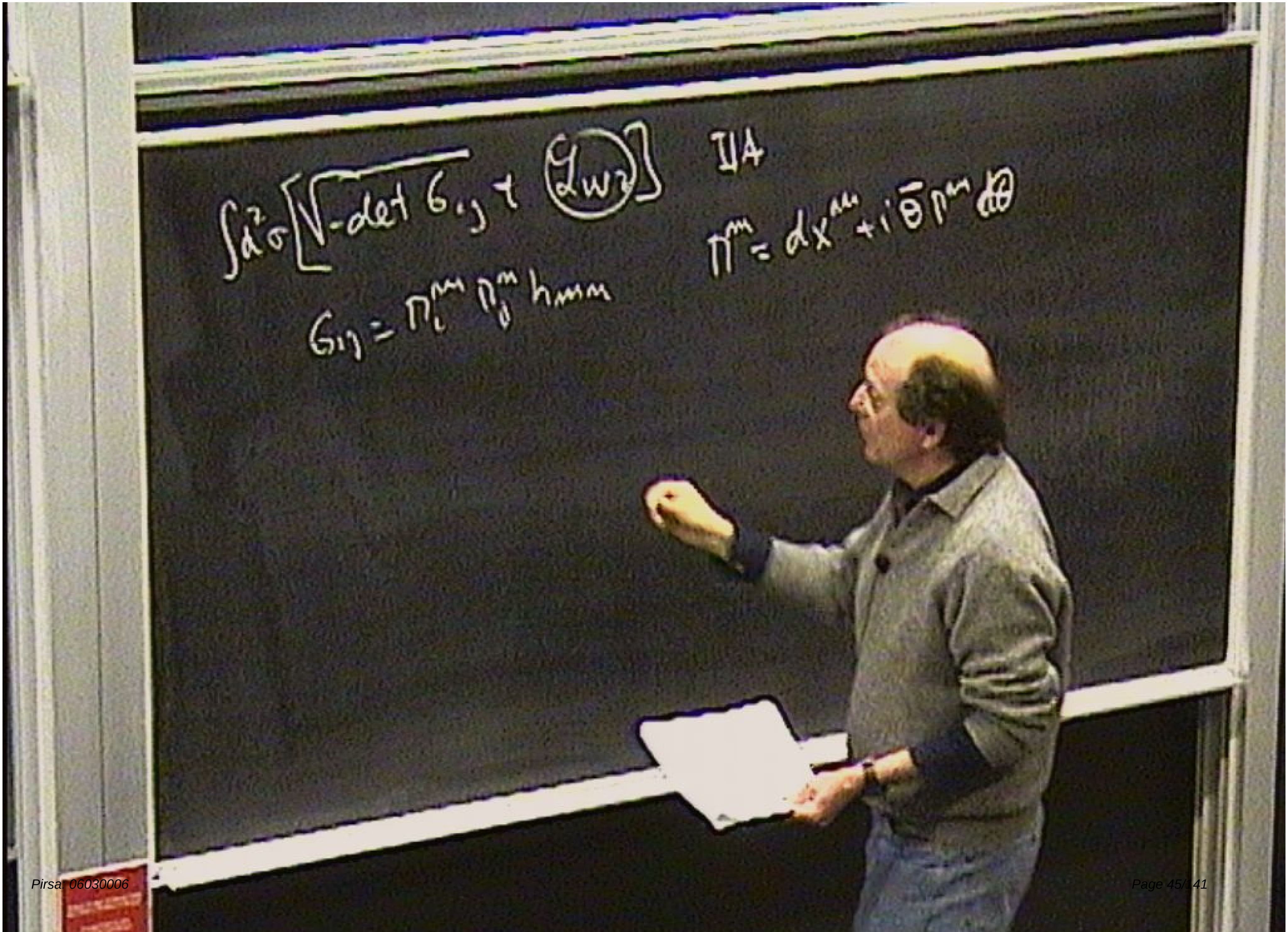
$\int d^2\sigma \sqrt{g}\, g^{ij} \partial_i X^a \partial_j X^b$

Diff inv. $\quad X^\mu = \sigma^\mu$ Static gauge.

$\int d^2x\, \eta^{ij} \partial_i X^a \partial_j X^b \delta_{ab}$

$\theta = \sqrt{\omega}\, \theta_{\parallel} \qquad \theta = \sqrt{\omega}\, \theta_- + \frac{1}{\sqrt{\omega}} \theta_+$

IIB $\qquad \Gamma_* = \Gamma_0 \Gamma_1 \tau_3 \qquad \Gamma_* \theta_\pm = \pm \theta_\pm$



$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + L_{WZ}\right]$
IIA
$\Pi^m = dx^m + i\bar{\theta}\Gamma^m d\theta$
$G_{ij} = \Pi_i^m \Pi_j^n h_{mn}$

$$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + \mathcal{L}_{WZ} \right] \quad \text{IIA}$$

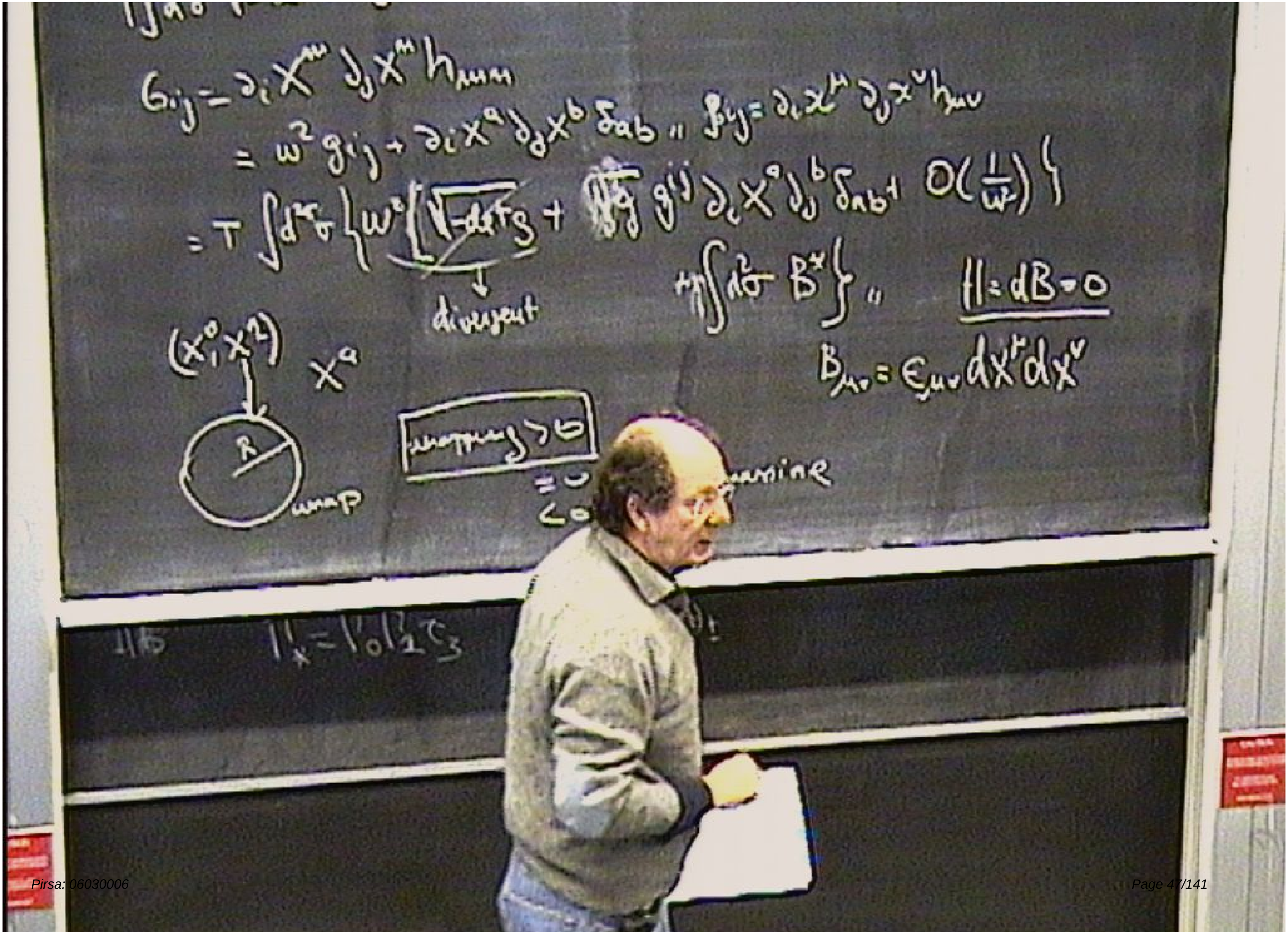
$$\Pi^m = dx^m + i\bar{\theta}\Gamma^m d\theta$$

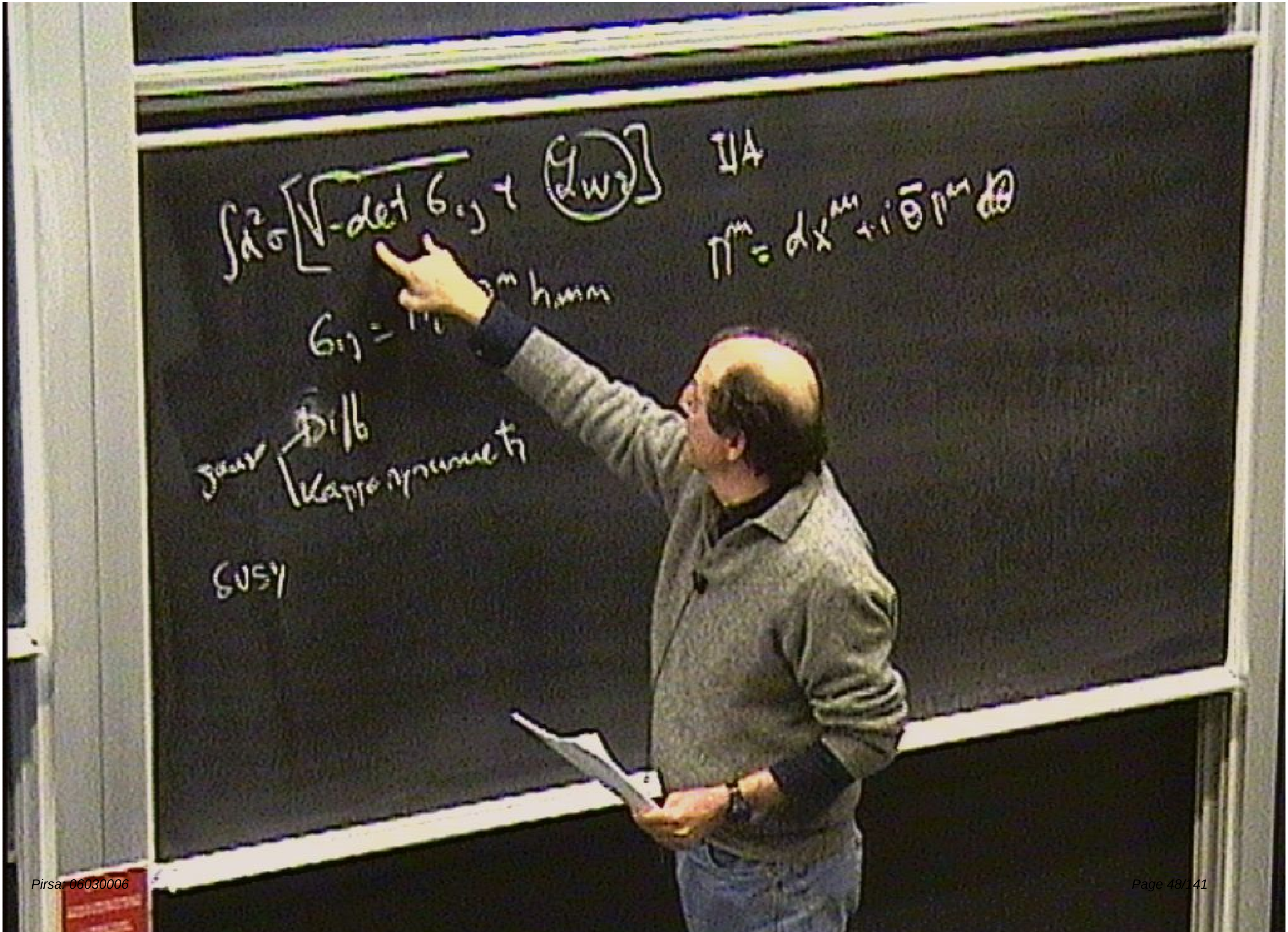
$$G_{ij} = \Pi_i^m \Pi_j^n h_{mn}$$

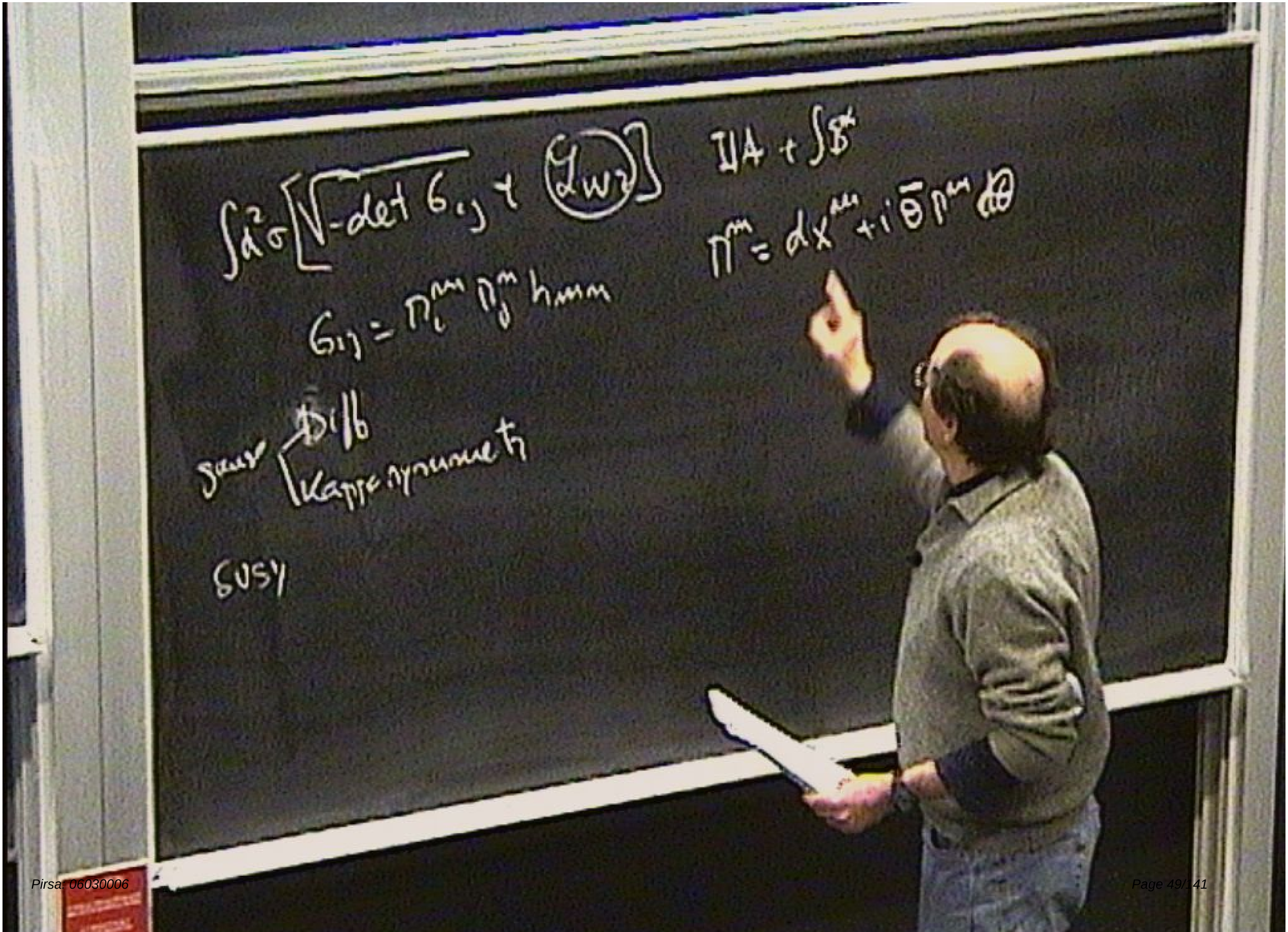
gauge Diff

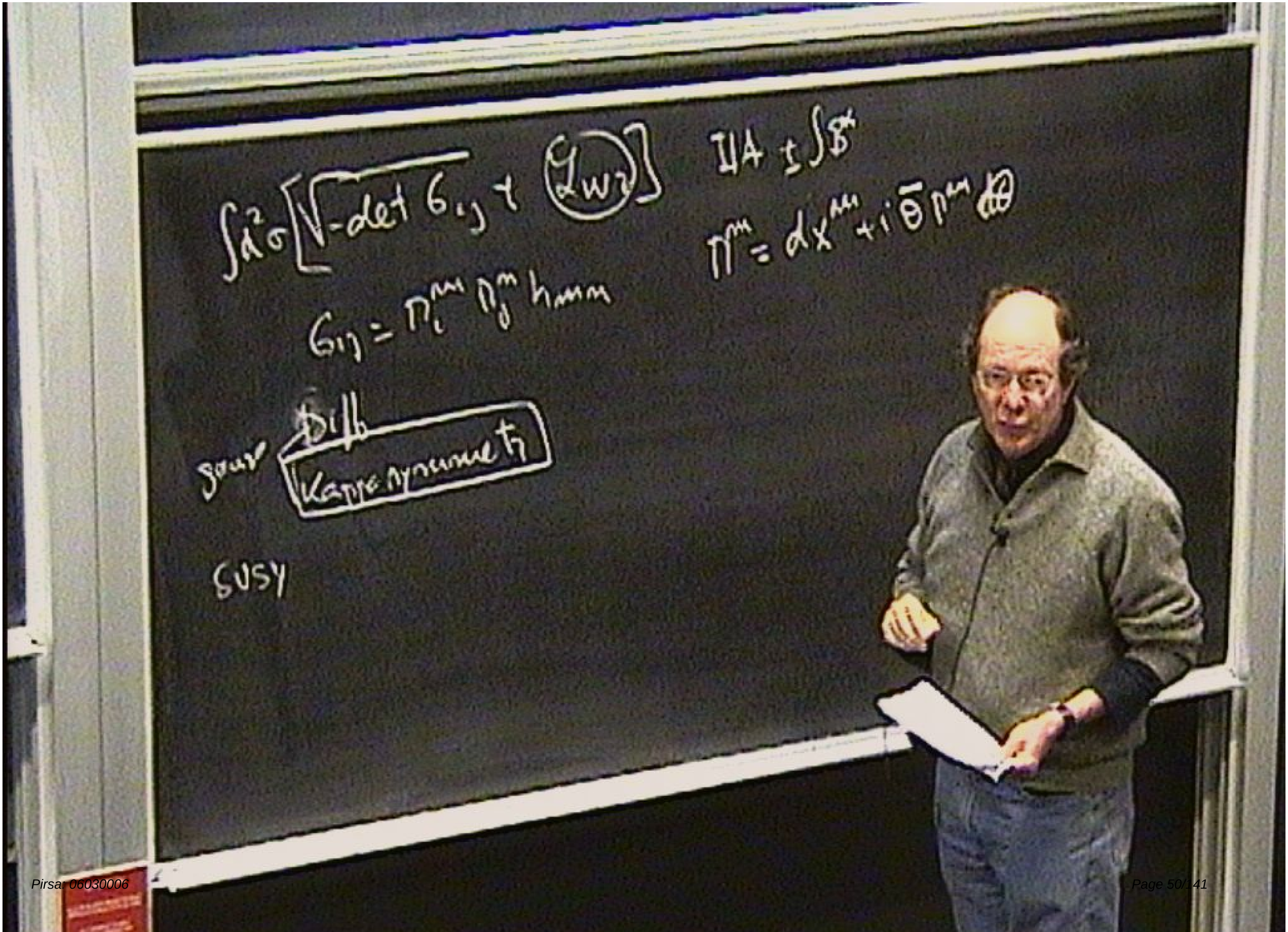
Kappa symmetry

SUSY


G_ij = ∂_i X^m ∂_j X^n h_mn
= w² g_ij + ∂_i X^a ∂_j X^b δ_ab
g_ij = ∂_i x^μ ∂_j x^ν h_μν
= T ∫d²σ {w² [√-det g + √g g^ij ∂_i X^a ∂_j X^b δ_ab + O(1/w²)}
divergent
∫d²σ B*}
H = dB = 0
B_μν = ε_μν dX^μ dX^ν
(X^0, X^1)
X^a
R
wrap
= 0
< 0
Γ_* = Γ_0 Γ_1 τ_3


$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + \int WZ \right]$
IIA
$\Pi^m = dX^m + i\bar{\theta}\Gamma^m d\theta$
$G_{ij} =$
Diff
gauge
Kappa symmetry
SUSY


IIA + ∫B
∫d²σ [√(-det G_ij) + L_WZ]
Π^m = dx^m + i θ̄ Γ^m dθ
G_ij = Π_i^m Π_j^n h_mn
Diff
gauge
Kappa symmetry
SUSY


$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + L_{WZ} \right]$
IIA $\pm$
$\Pi^\mu = dx^\mu + i\bar{\theta}\Gamma^\mu d\theta$
$G_{ij} = \Pi_i^\mu \Pi_j^\nu h_{\mu\nu}$
Diff
gauge
Kappa symmetry
SUSY

$G_{ij} = \partial_i X^m \partial_j X^n h_{mn}$

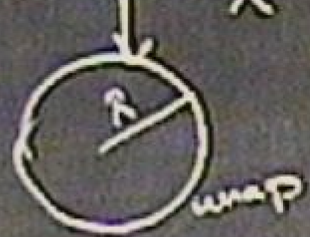
$= \omega^2 g_{ij} + \partial_i X^a \partial_j X^b \delta_{ab}$, $g_{ij} = \partial_i x^\mu \partial_j x^\nu h_{\mu\nu}$

$= T \int d^2\sigma \{ \omega^2 [\underbrace{\sqrt{-\det g}}_{\text{divergent}} + \sqrt{-g}\, g^{ij} \partial_i X^a \partial_j X^b \delta_{ab} + O(\frac{1}{\omega^2}) \}$

$+ \eta \int d^2\sigma\, B^* \}$, $H = dB = 0$

$B_{\mu\nu} = \epsilon_{\mu\nu} dx^\mu dx^\nu$

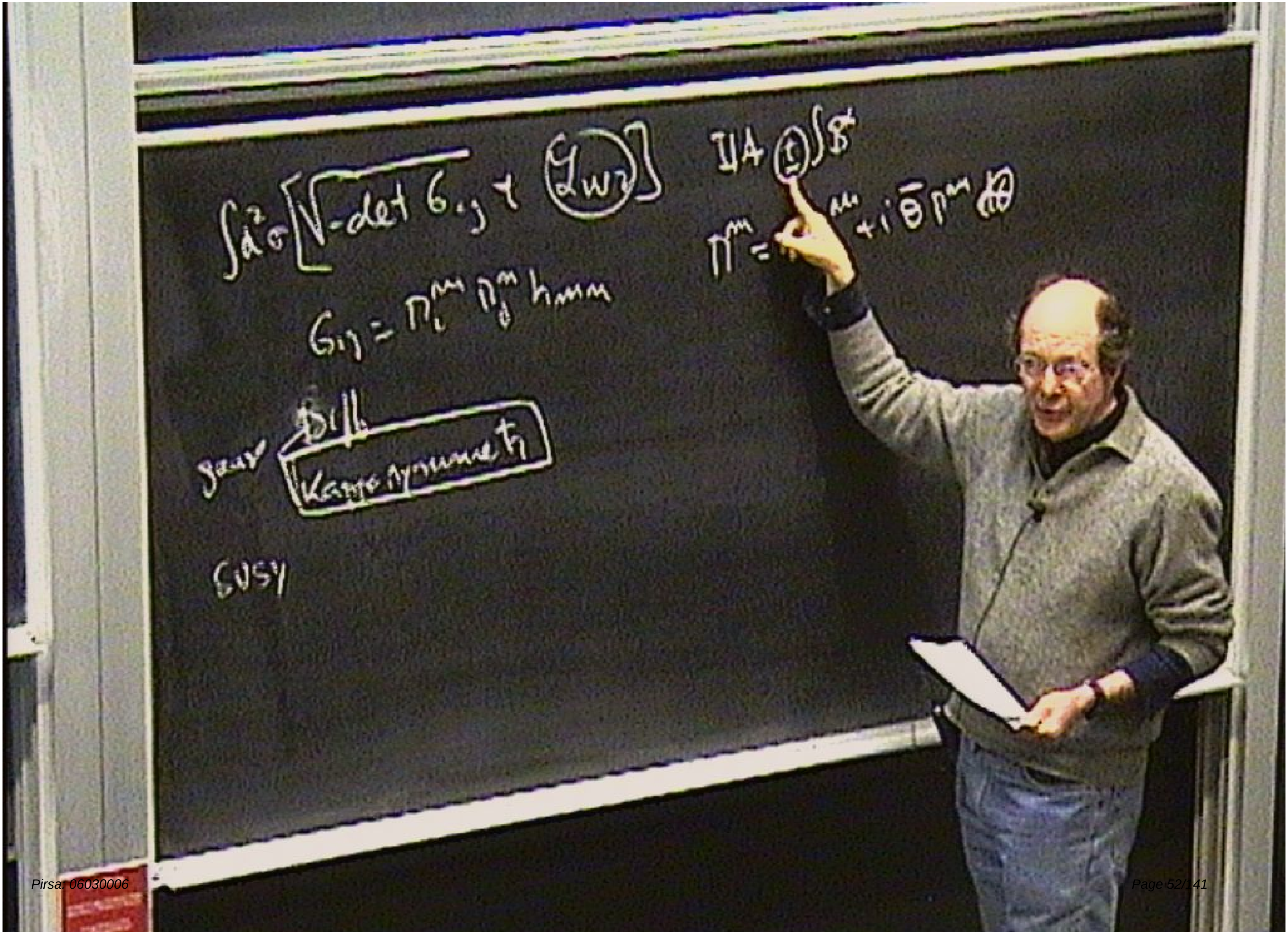
(x^0, x^1, x^2) $\quad X^a$



$\boxed{\text{winding} > 0}$

$= 0$, < 0 } inf. massive

IIB $\quad \Gamma_* = \Gamma_0 \Gamma_1 \sigma_3 \quad \Gamma_* \theta_\pm = \pm \theta_\pm$


IIA
SUSY
Kappa symmetry

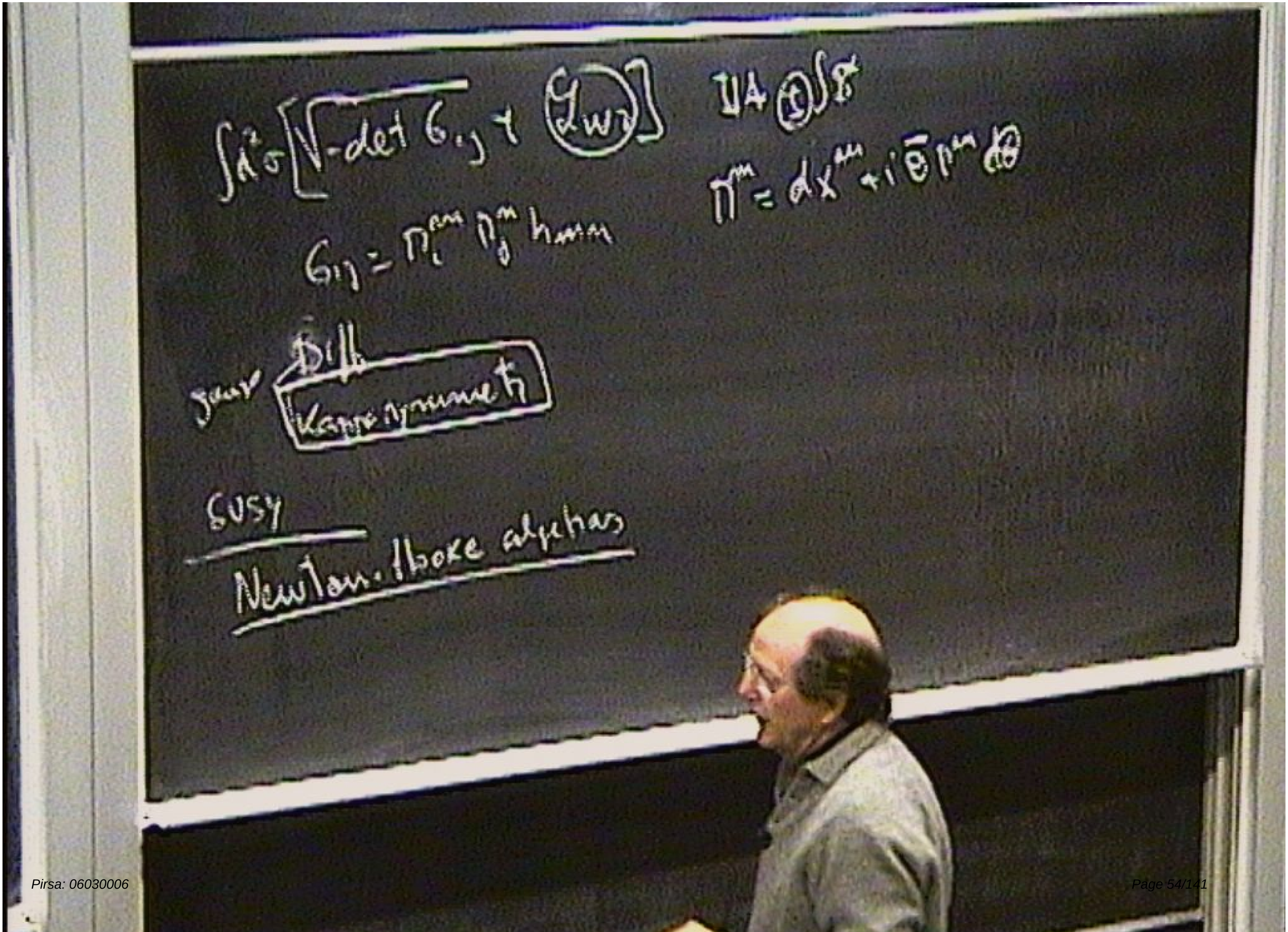
$G_{ij} = \ldots$

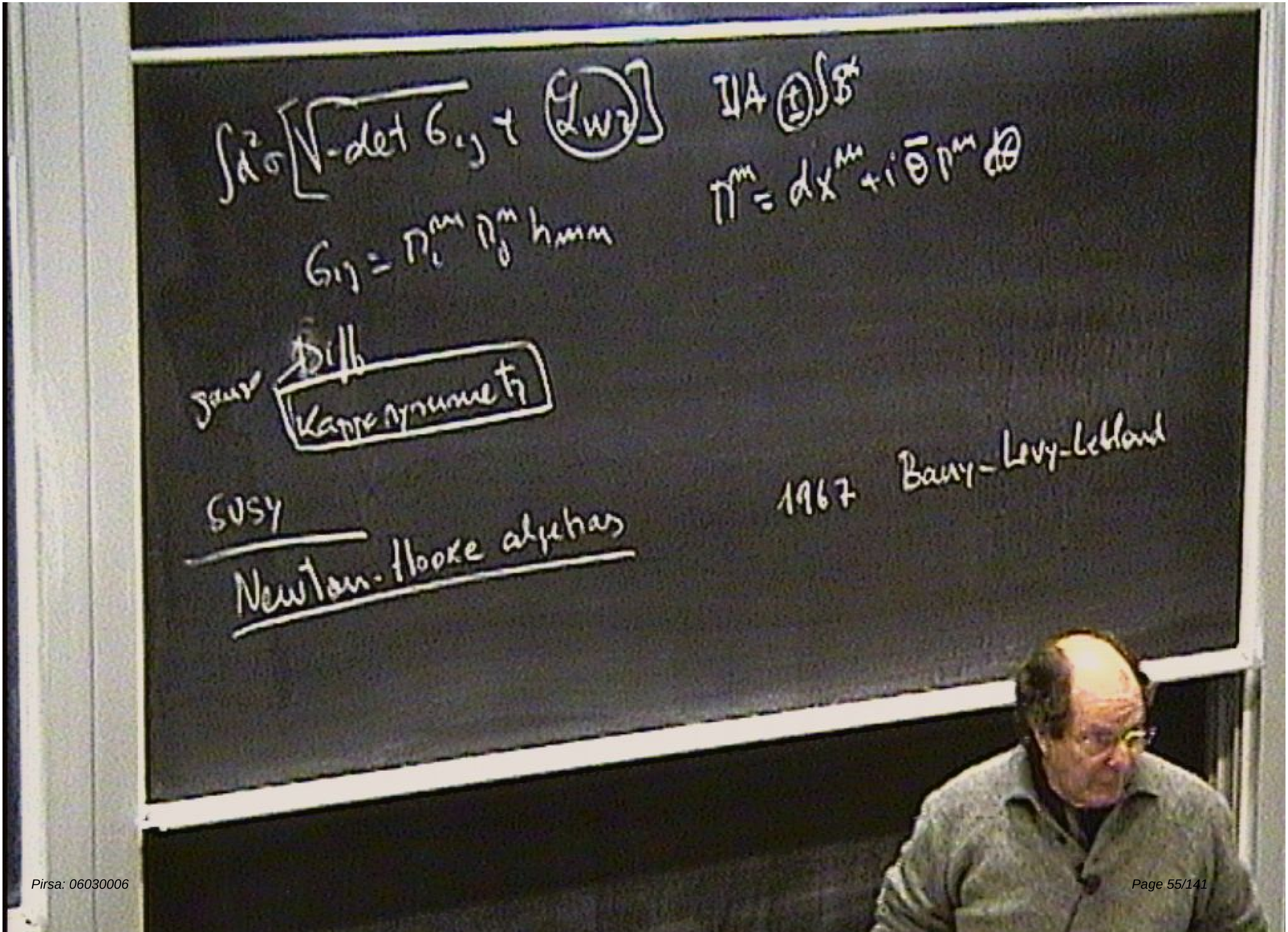
gauge Diff

$\boxed{\text{Gauge symmetry}}$

SUSY

Newton.


∫d²σ [√-det G_ij + L_WZ]
Π^m = dX^m + i θ̄ Γ^m dθ
G_ij = Π_i^m Π_j^n h_mn
gauge
Diff
Kappa symmetry
SUSY
Newton-Hooke algebras



∫d²σ [√-det G_ij + L_WZ]
IIA
Π^m = dx^m + i θ̄ Γ^m dθ
G_ij = Π_i^m Π_j^n h_mn
gauge
Diff
Kappa symmetry
SUSY
Newton-Hooke algebras
1967 Bacry-Levy-Leblond

$$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + \mathcal{L}_{WZ}\right]$$

IIA $\int \theta$

$$G_{ij} = \Pi_i^{\mu} \Pi_j^{m} h_{mn}$$

$$\Pi^m = dx^\mu + i\bar\theta\Gamma^m d\theta$$

gauge: Diff, $\boxed{\text{Kappa symmetry}}$

SUSY

Newton-Hooke algebras

1967 Bacry-Levy-Leblond

$$\psi'(x') = e^{ib}\psi(x)$$

$$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + \mathcal{L}_{WZ} \right] \qquad \text{IIA} \ \oplus \int \ldots$$

$$G_{ij} = \Pi_i^m \, \Pi_j^n \, h_{mn} \qquad \Pi^m = dx^m + i\bar{\theta}\Gamma^m d\theta$$

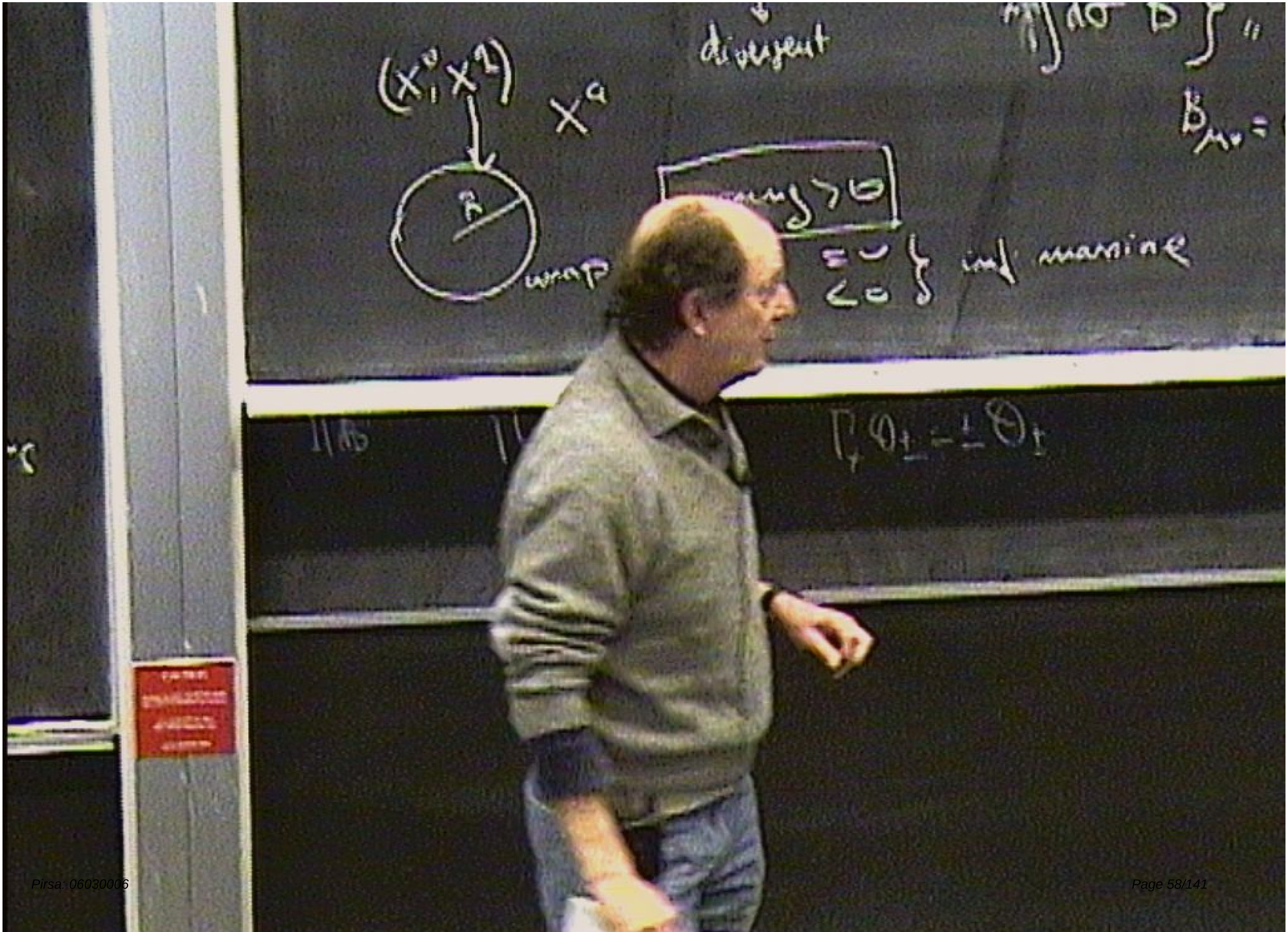
gauge: Diff, $\boxed{\text{Kappa symmetry}}$

SUSY

Newton-Hooke algebras

$$\psi'(x') = e^{i\varphi}\,\psi(x)$$

1967 Bacry–Levy-Leblond


divergent
wrap

$$\int d^2\sigma \left[\sqrt{-\det G_{ij}} + \mathcal{L}_{WZ} \right]$$

IIA

$$\Pi^m = dx^m + i\bar{\theta}\Gamma^m d\theta$$

$$G_{ij} = \Pi_i^m \Pi_j^n h_{mn}$$

gauge Diff

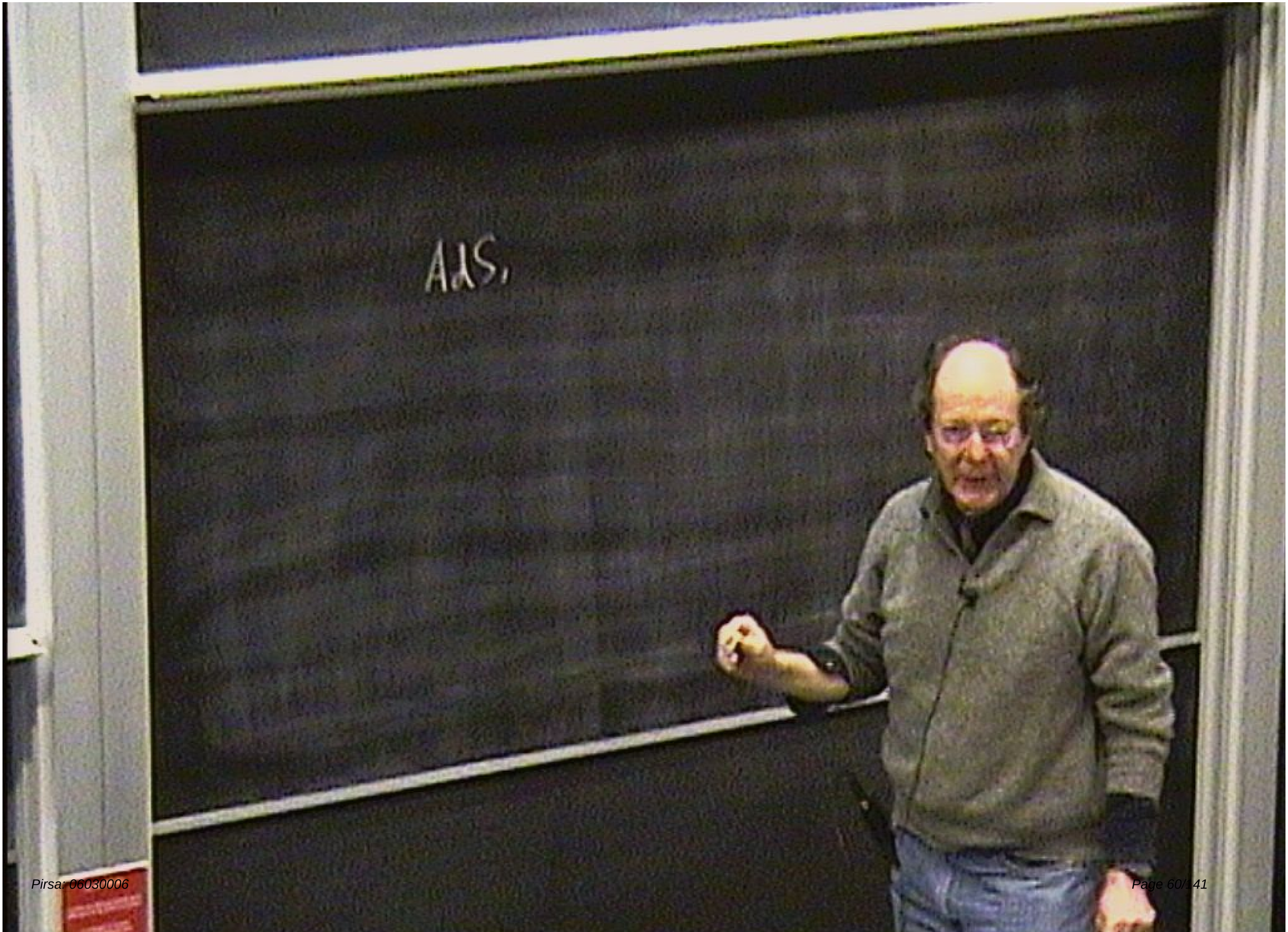
$\boxed{\text{Kappa-symmetry}}$

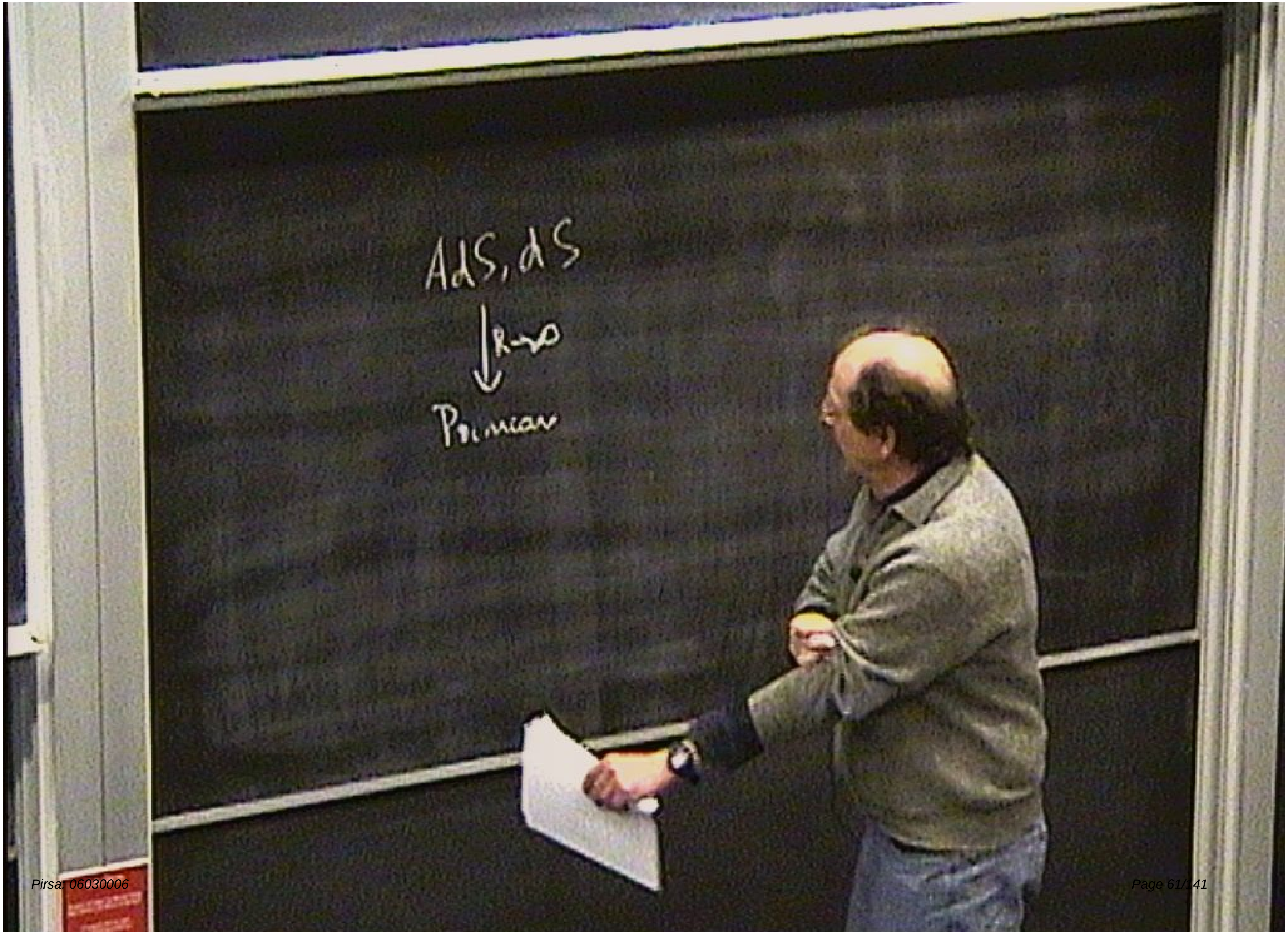
SUSY

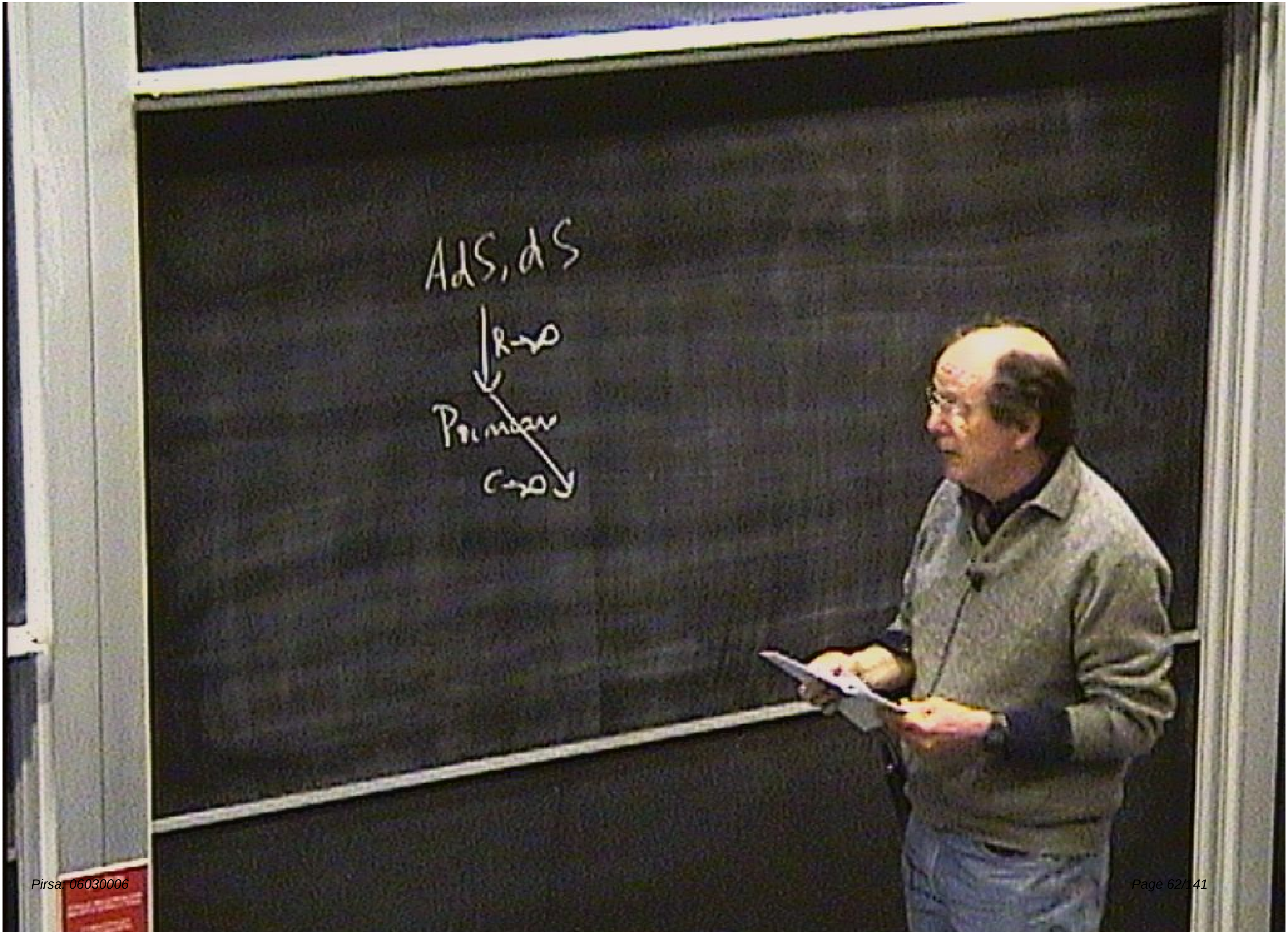
Newton-Hooke algebras

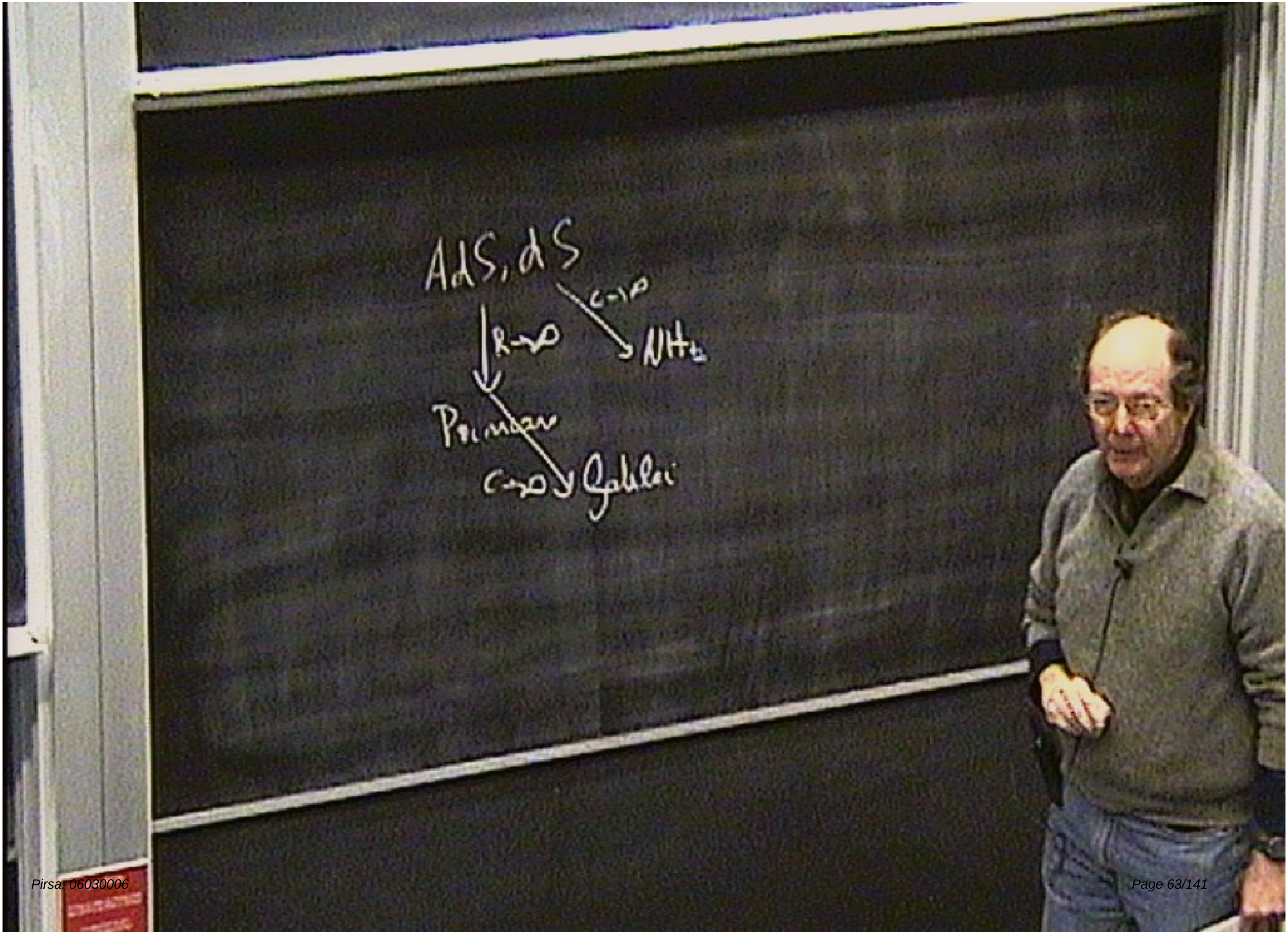
1967 Bacry-Levy-Leblond

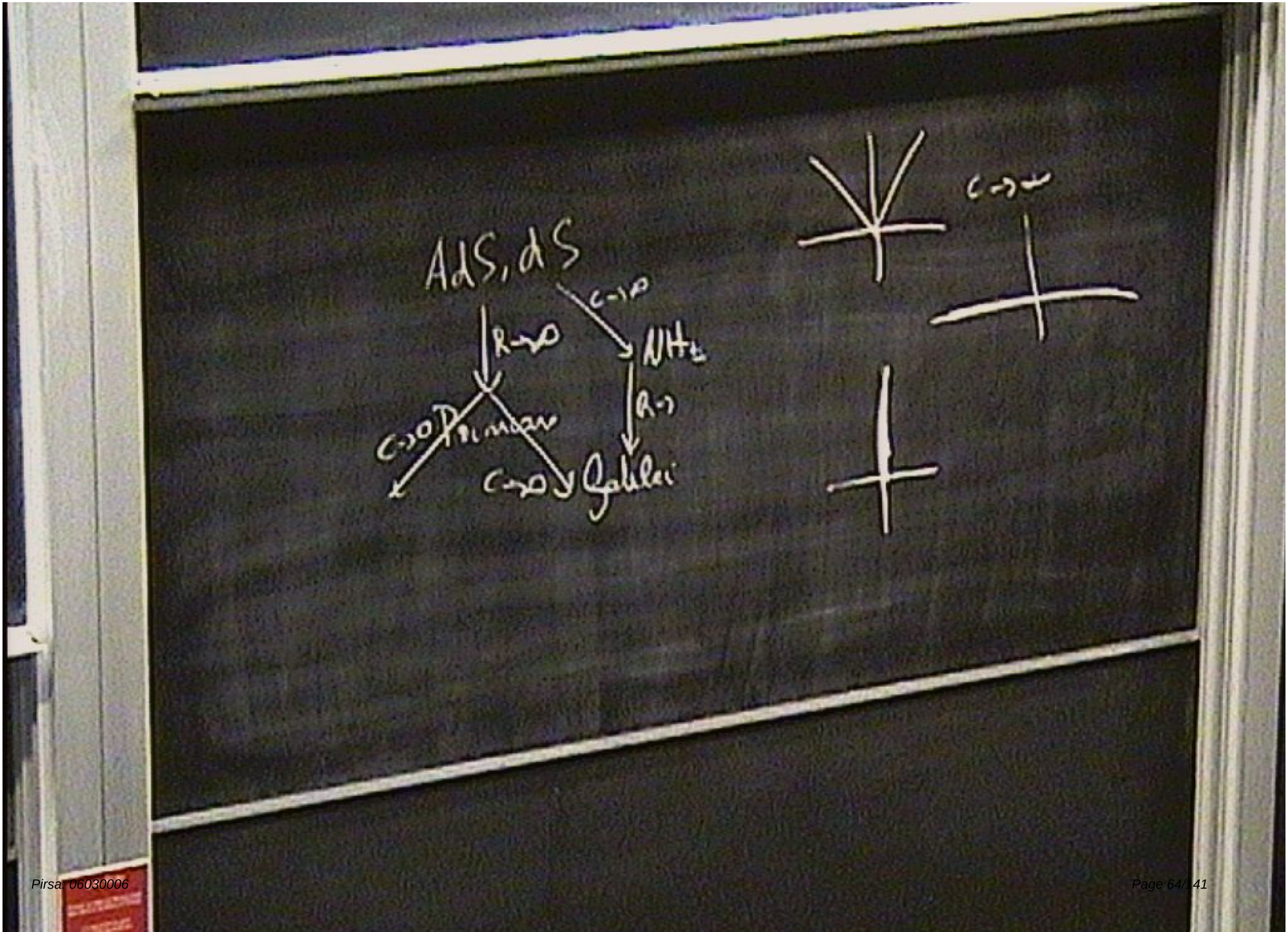
$$\psi'(x') = \cancel{e^{i\beta}}\,\psi(x)$$

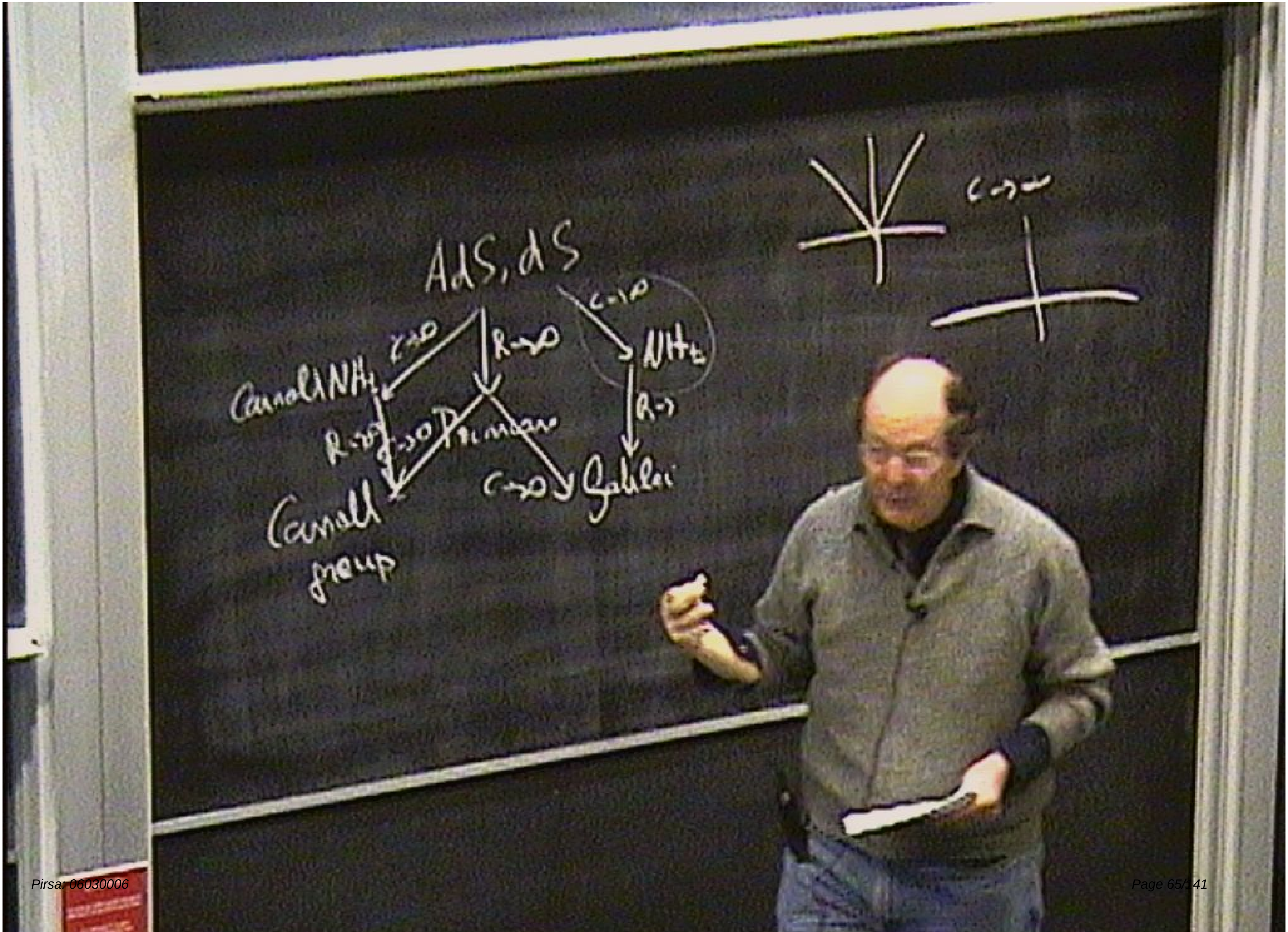

AdS,


AdS, dS
R→∞
Poincare


AdS, dS
R→∞
Poincare
c→∞


AdS, dS
R→∞
c→∞
NH
Poincaré
c→∞
Galilei


AdS, dS
Galilei


AdS, dS
Carroll group
Galilei

- Newton - Hooke at plorias
- Non-Relativistic Branes
- pp-waves

Jan Brugues
Kiyoshi Kamimura

AdS/CFT correspondence

Strings in pp-background

↑ penrose limit

$\mathcal{N}=4$ SYM ⟷ IIB String in $AdS_5 \times S_5$

non-relat limit

light-cone

Free theory

AdS₂ ⟷ Free AdS_2 field theory

Joaquim, Kiyoshi, JG

Bosonic Non-Rel Strings

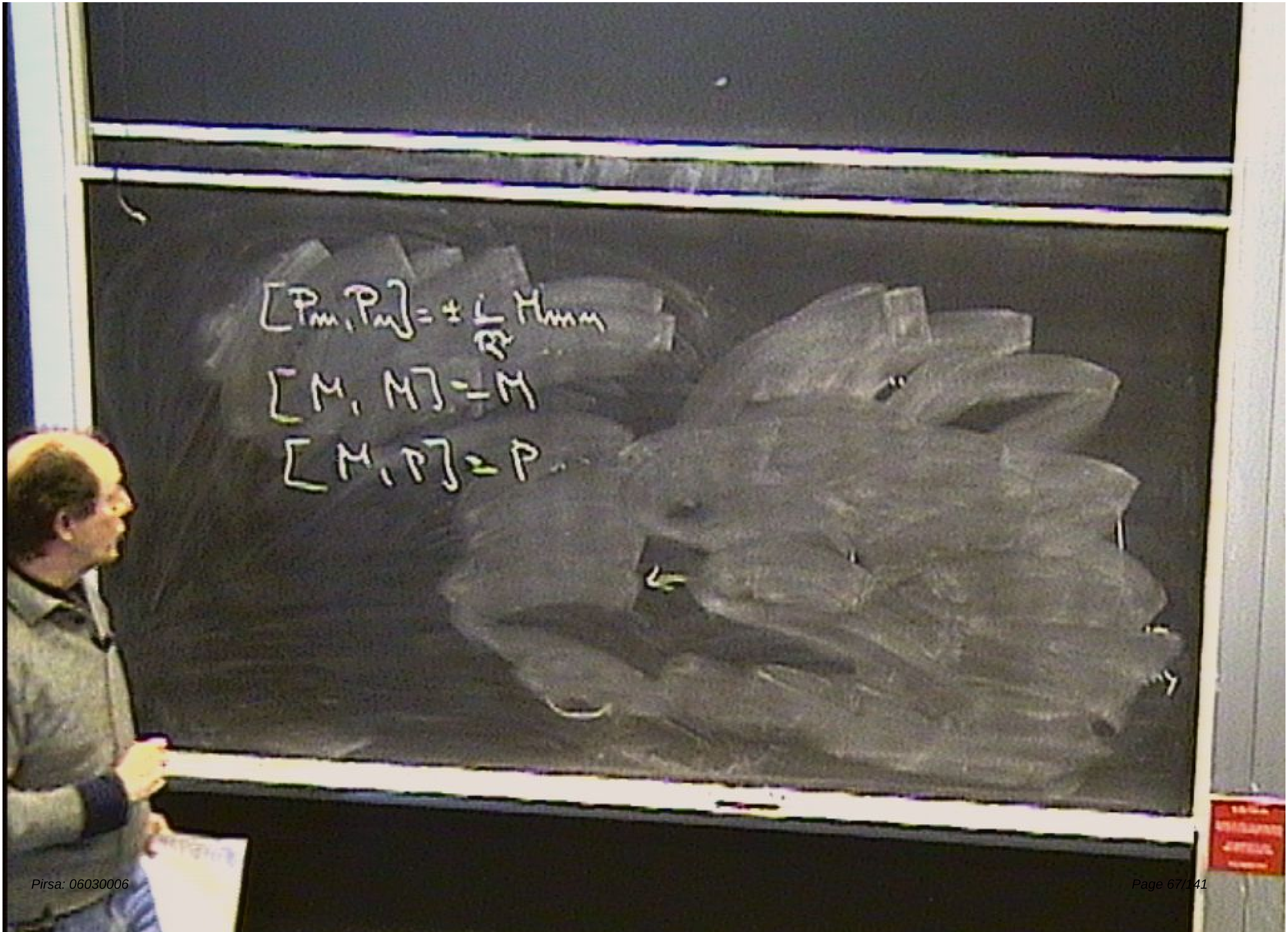
{Jaume Gomis
{Hirosi Ooguri 2000

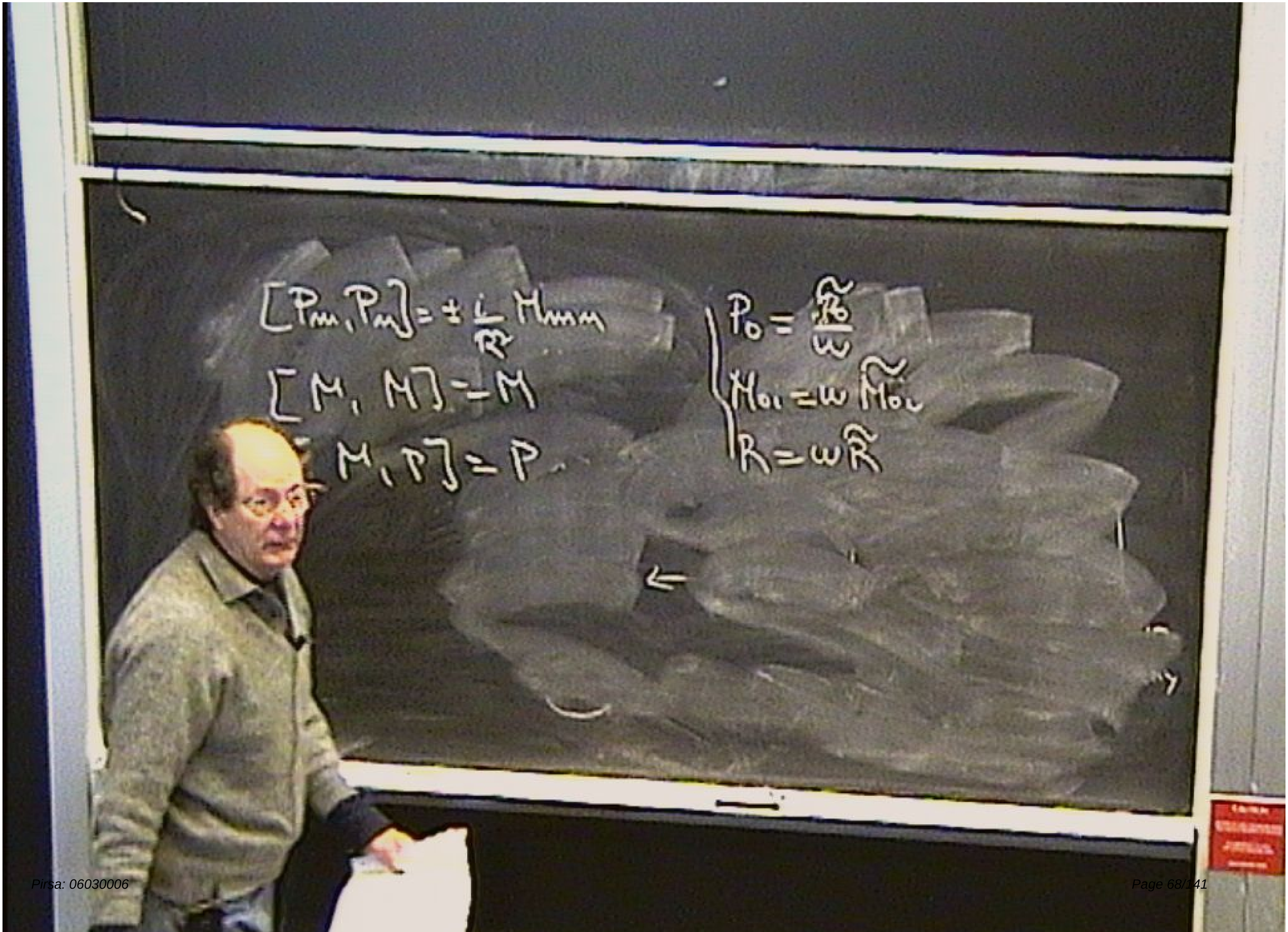
Danielsson, Guijosa, Kruczenski

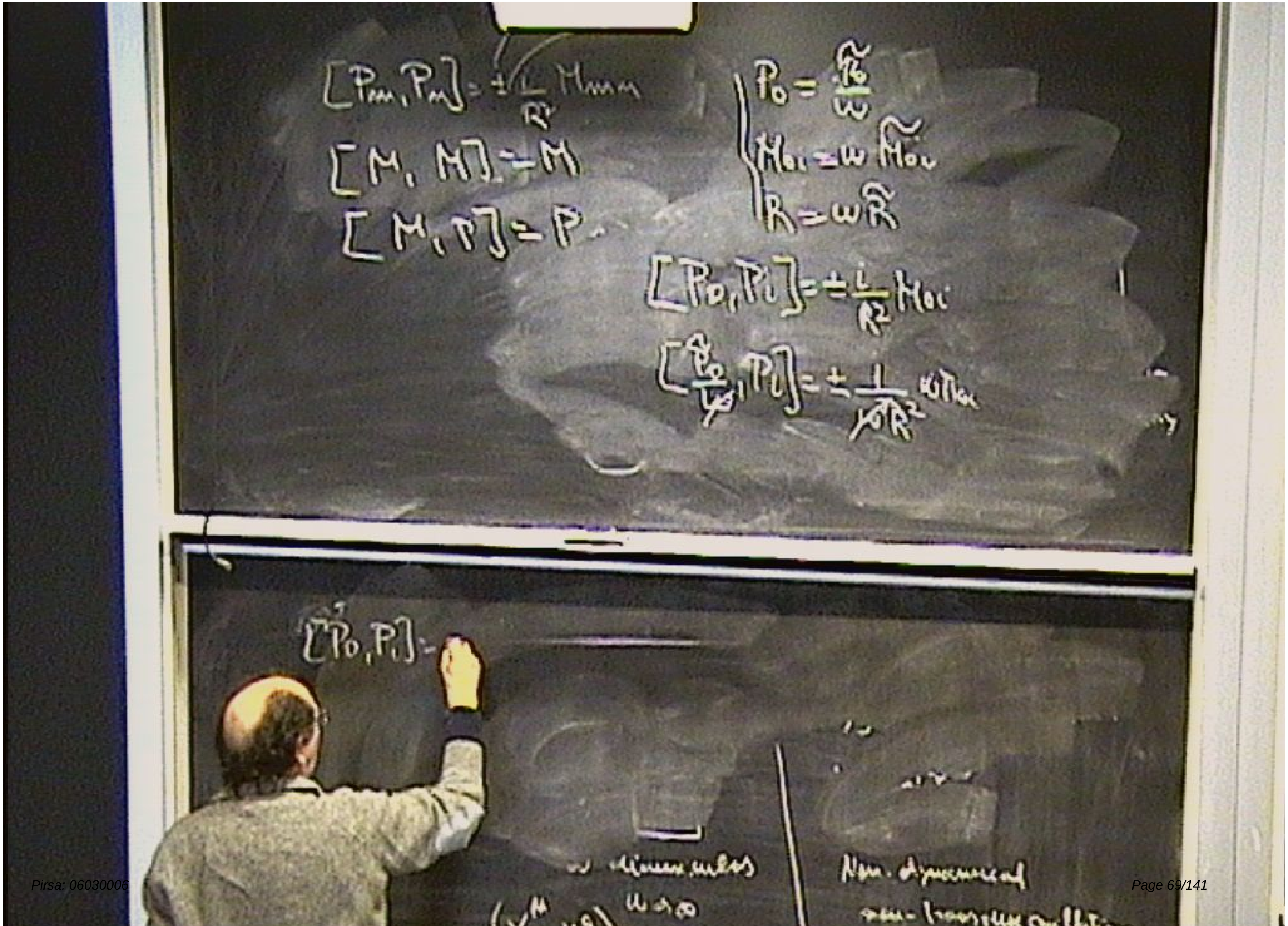
$\begin{cases} X^\mu = \omega x^\mu \\ \boxed{T_R = \hat{A} \,p\, \omega^{1-p}} \end{cases}$

$X^0 = \omega x^0$

$\omega \to \infty$


$[P_m, P_n] = \pm \frac{1}{R^2} M_{mn}$
$[M, M] = M$
$[M, P] = P$


$[P_m, P_n] = \pm \frac{i}{R^2} M_{mn}$
$[M, M] \sim M$
$[M, P] = P$
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$R = \omega \tilde{R}$


$[P_m, P_n] = \pm \frac{i}{R^2} M_{mn}$
$[M, M] = M$
$[M, P] = P$
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$R = \omega \tilde{R}$
$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$
$[\frac{\tilde{P}_0}{\omega}, P_i] = \pm \frac{1}{\omega \tilde{R}^2} \omega \tilde{M}_{0i}$
$[\tilde{P}_0, P_i] =$
ω dimensionless
$\omega \to \infty$
Non-dynamical

$$[P_m, P_n] = \pm \frac{i}{R^2} M_{mn}$$

$$[M, M] = M$$

$$[M, P] = P$$

$$P_0 = \frac{\tilde{P}_0}{\omega}$$

$$M_{0i} = \omega \tilde{M}_{0i}$$

$$R = \omega \tilde{R}$$

$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

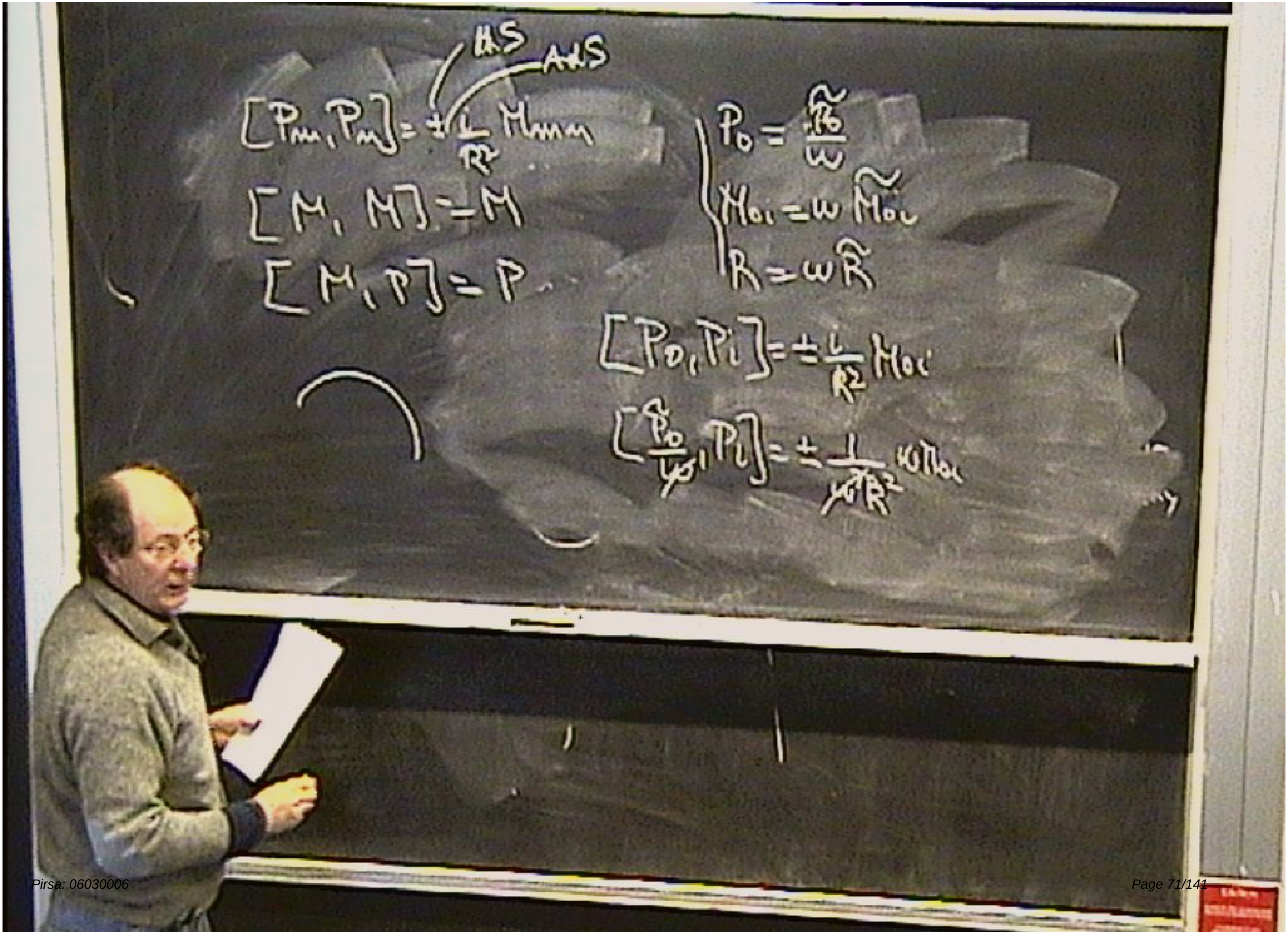
$$\left[\frac{\tilde{P}_0}{\cancel{\omega}}, P_i\right] = \pm \frac{1}{\cancel{\omega} \tilde{R}^2} \omega \tilde{M}_{0i}$$

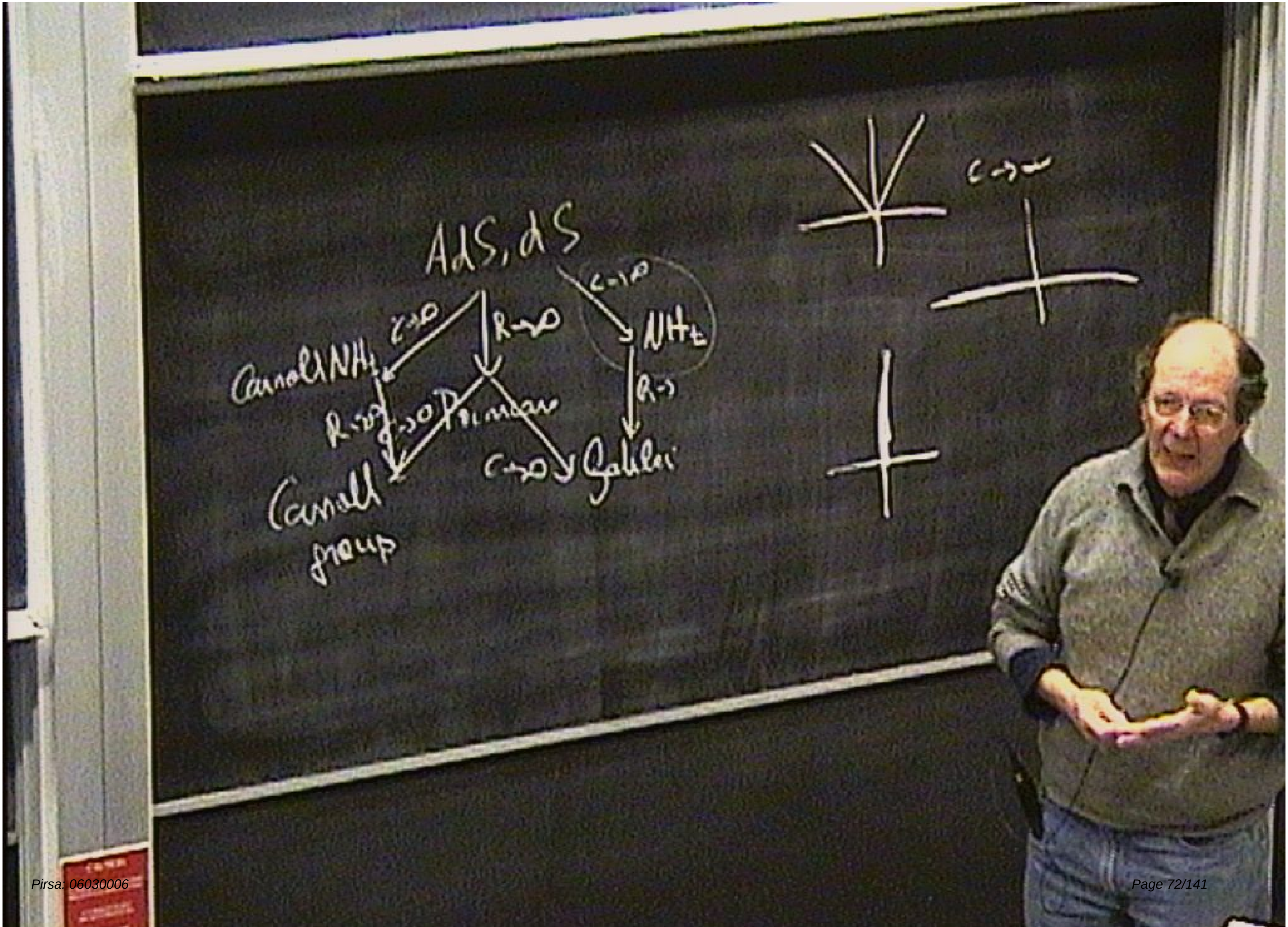
$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

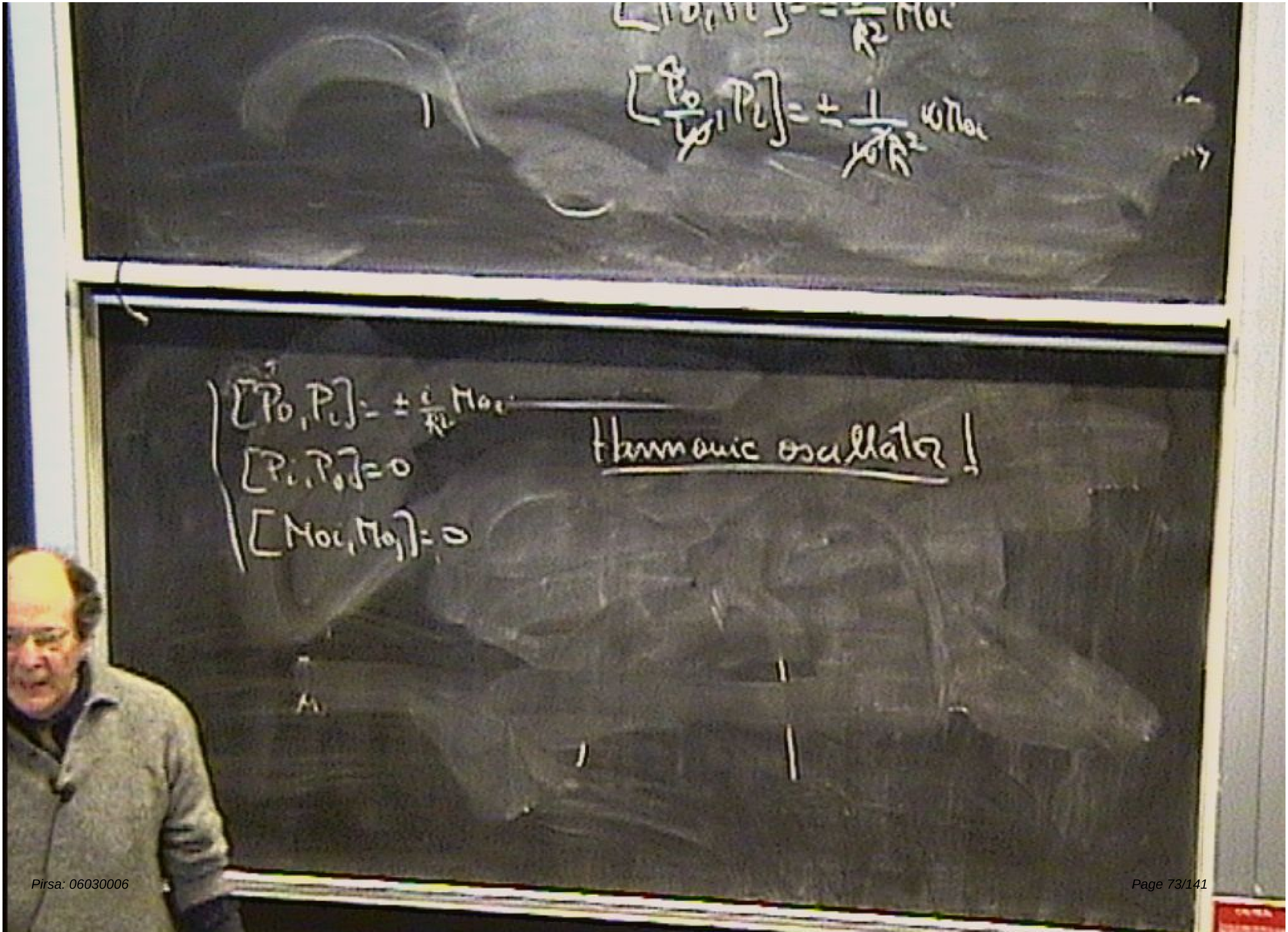
$$[P_i, P_j] = 0$$

$$[M_{0i}, M_{0j}] = 0$$

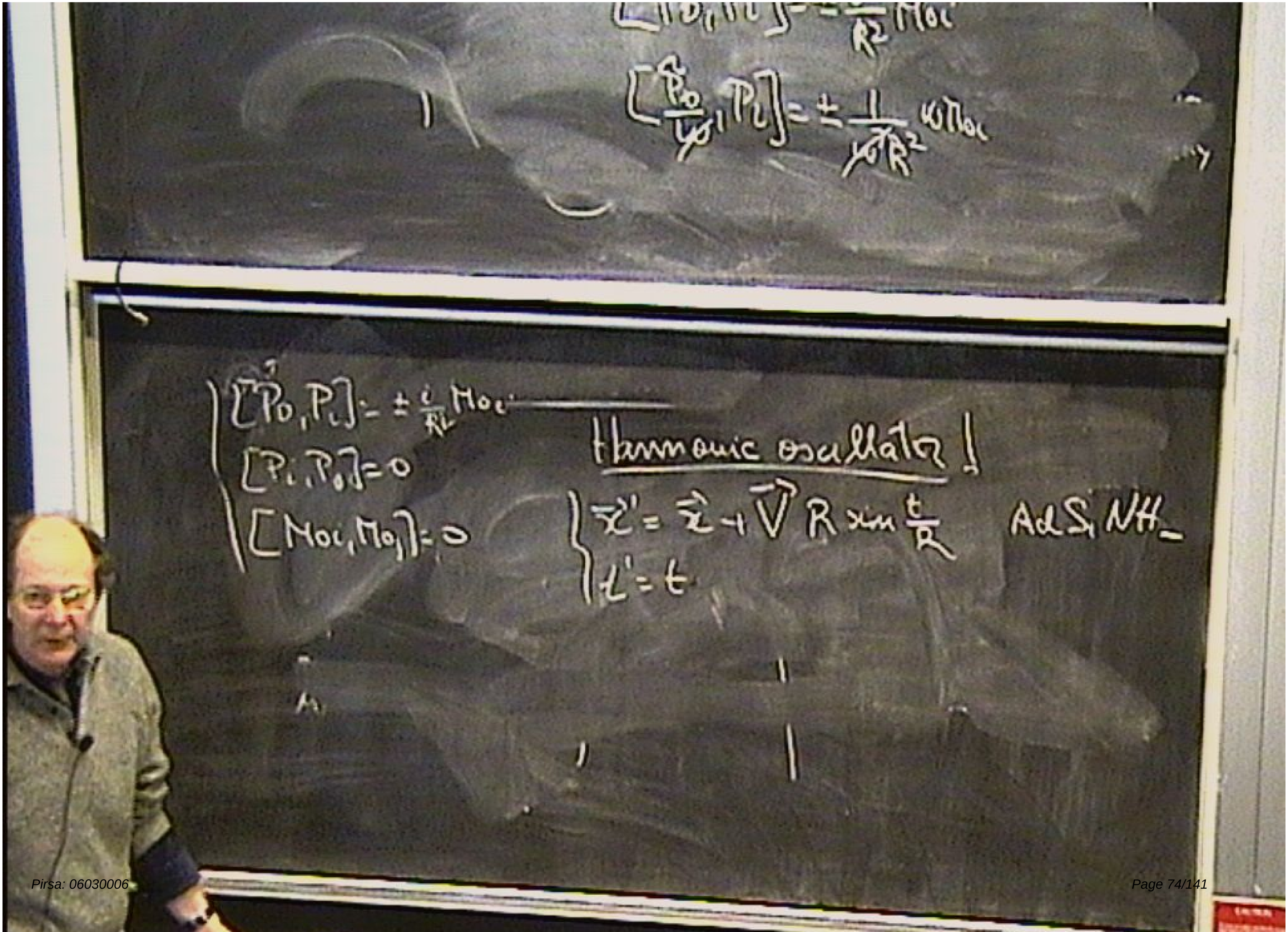
... dimensionless | Non-dynamical

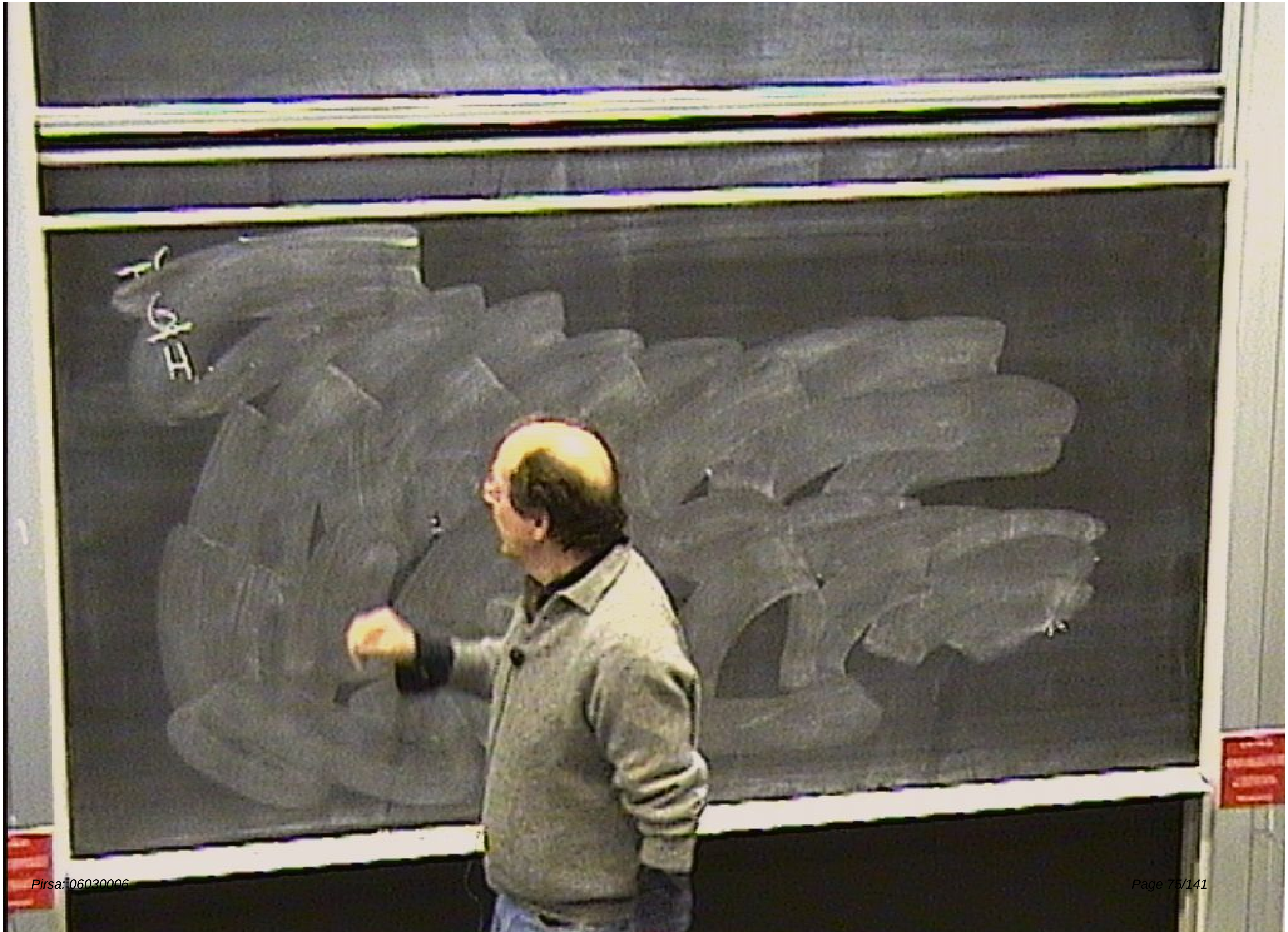

dS
AdS
$[P_m, P_n] = \pm \frac{1}{R^2} M_{mn}$
$[M, M] = M$
$[M, P] = P$
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$R = \omega \tilde{R}$
$[P_0, P_i] = \pm \frac{1}{R^2} M_{0i}$
$[\frac{P_0}{\omega}, P_i] = \pm \frac{1}{\omega R^2} \omega M_{0i}$

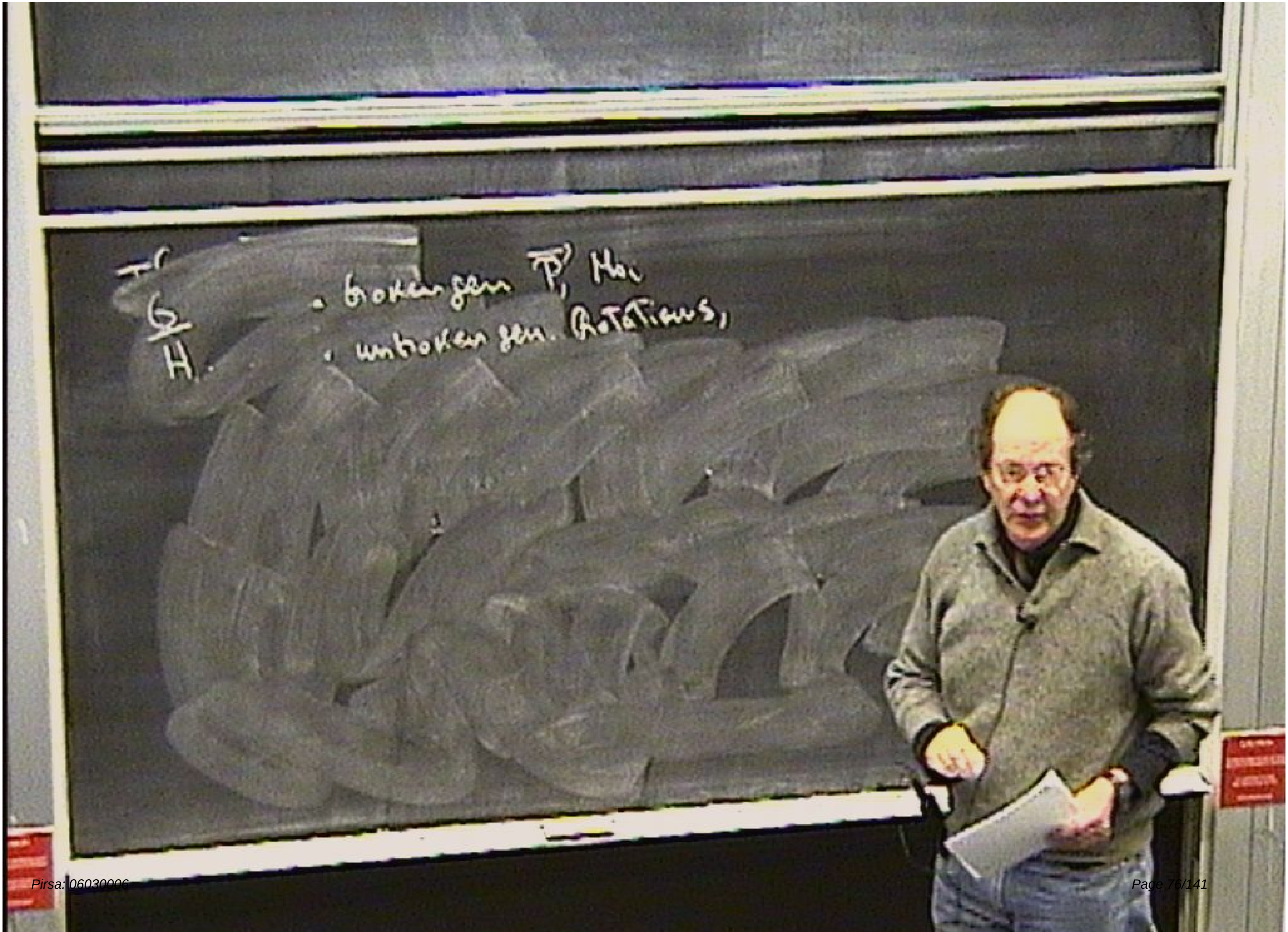

AdS, dS
R→∞
NH±
Poincaré
Galilei
Carroll group

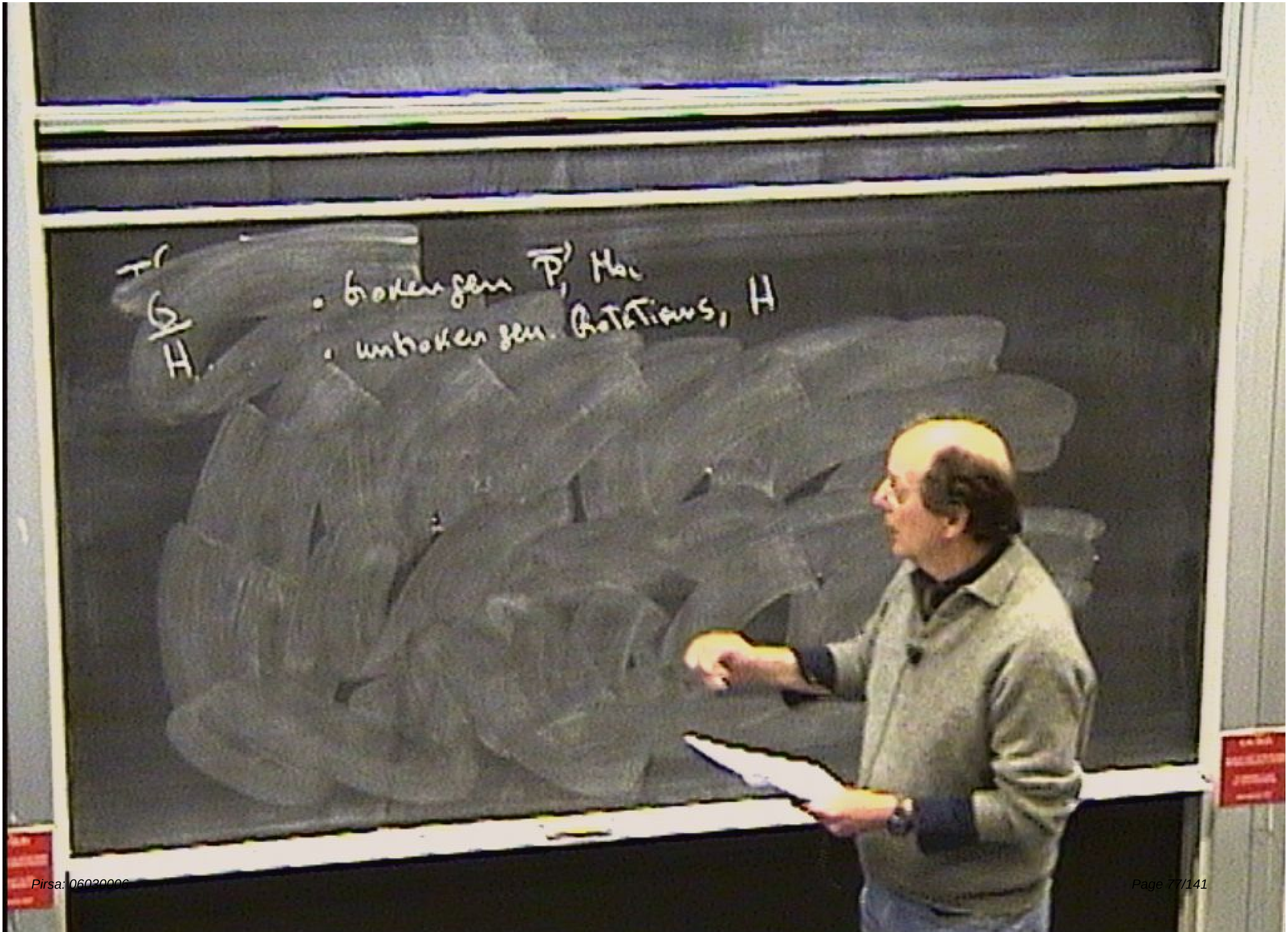


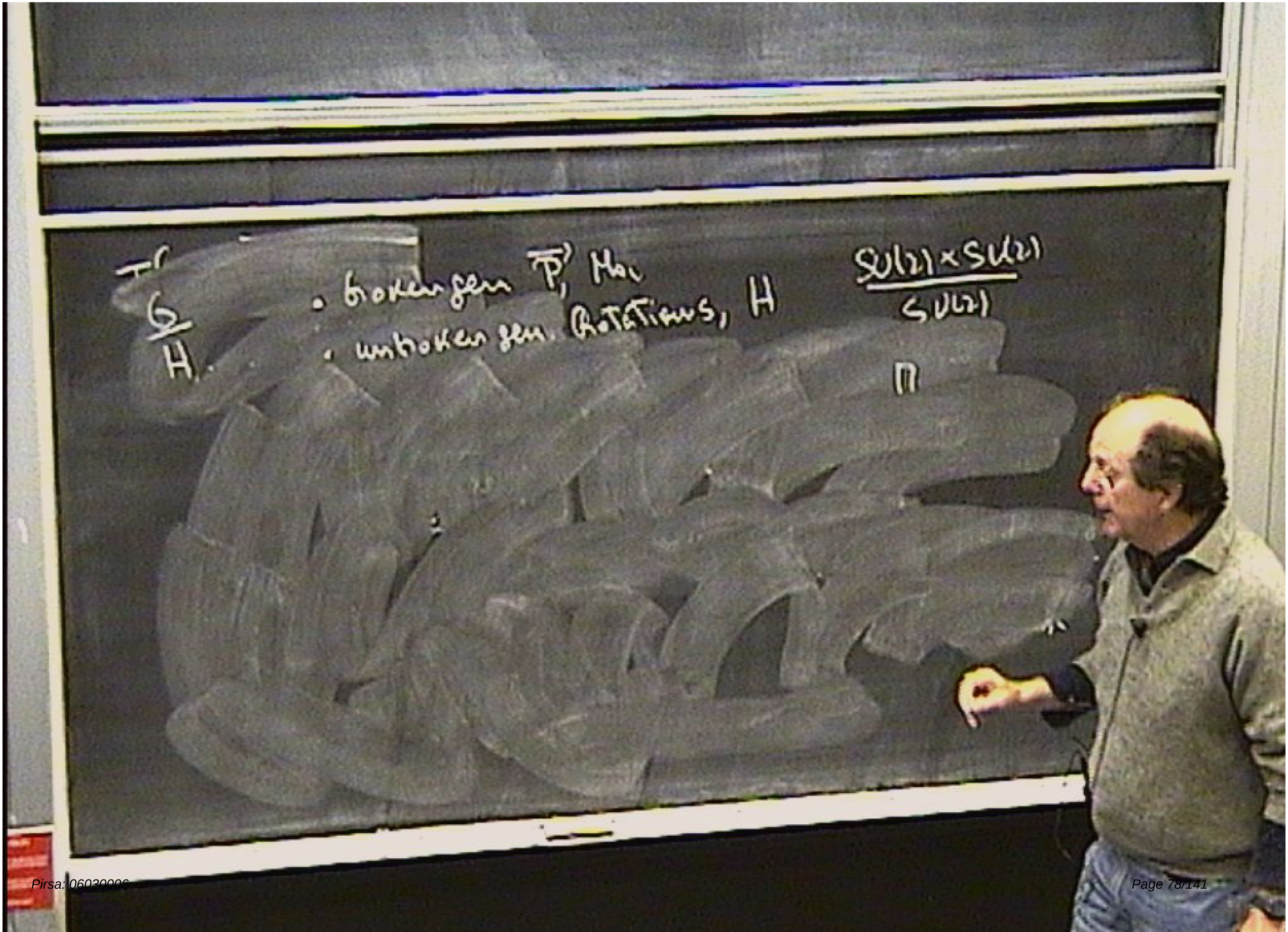
[P_0/ω, P_i] = ± 1/(ωR²) ω M_0i
[P_0, P_i] = ± i/R² M_0i
[P_i, P_0] = 0
[M_0i, M_0j] = 0
Harmonic oscillator !


$\left[\frac{P_0}{\omega}, P_i\right] = \pm \frac{1}{\omega R^2} M_{0i}$
$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$
$[P_i, P_j] = 0$
$[M_{0i}, M_{0j}] = 0$
Harmonic oscillator !
$\vec{x}' = \vec{x} + \vec{V} R \sin \frac{t}{R}$
AdS, NH_
$t' = t$




G
H
broken gen
unbroken gen. Rotations,


· broken gen
· unbroken gen. Rotations, H
G
H

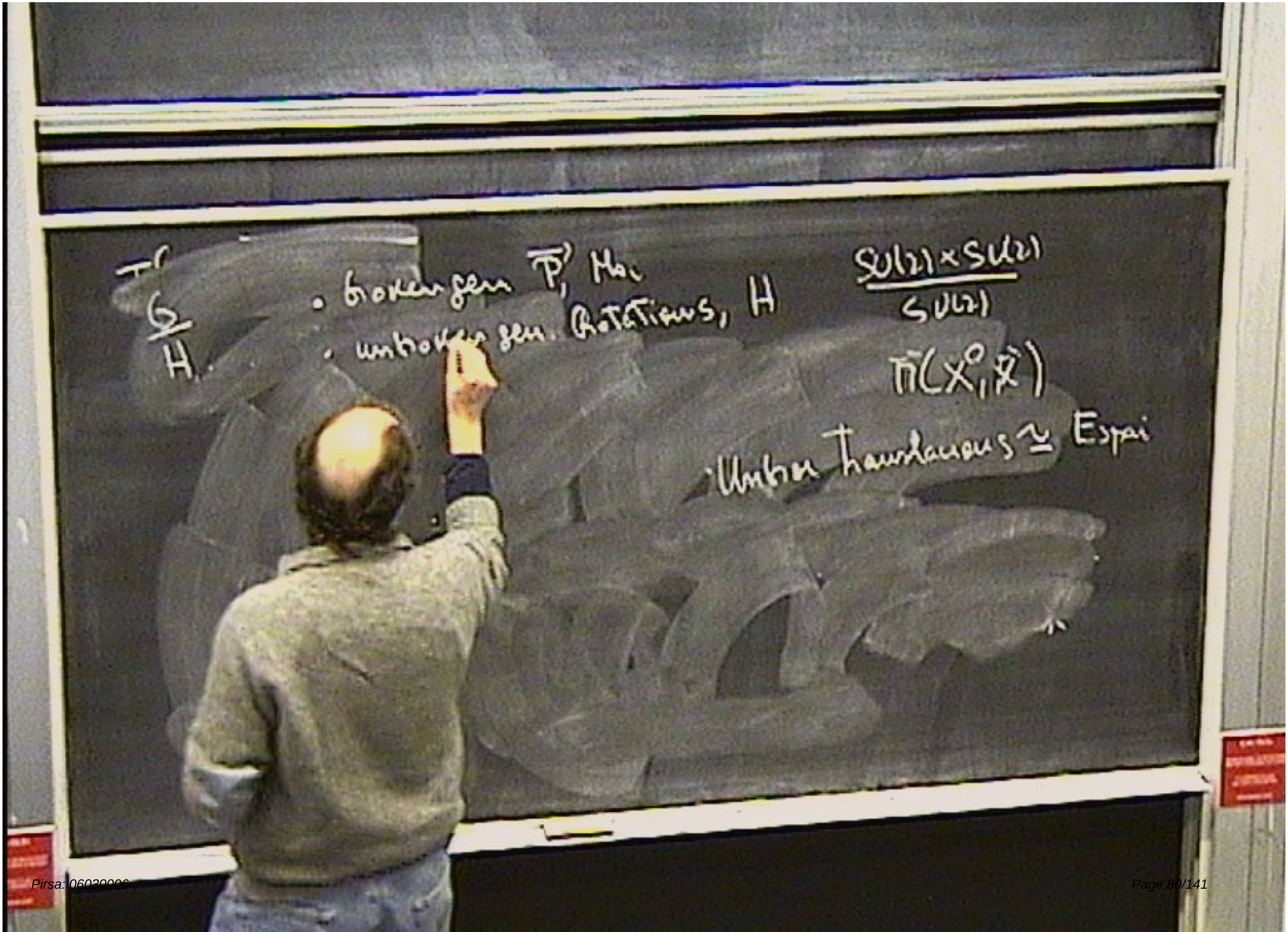

G
H
• broken gen P, M0i
• unbroken gen. Rotations, H
SU(2) × SU(2)
SU(2)
π

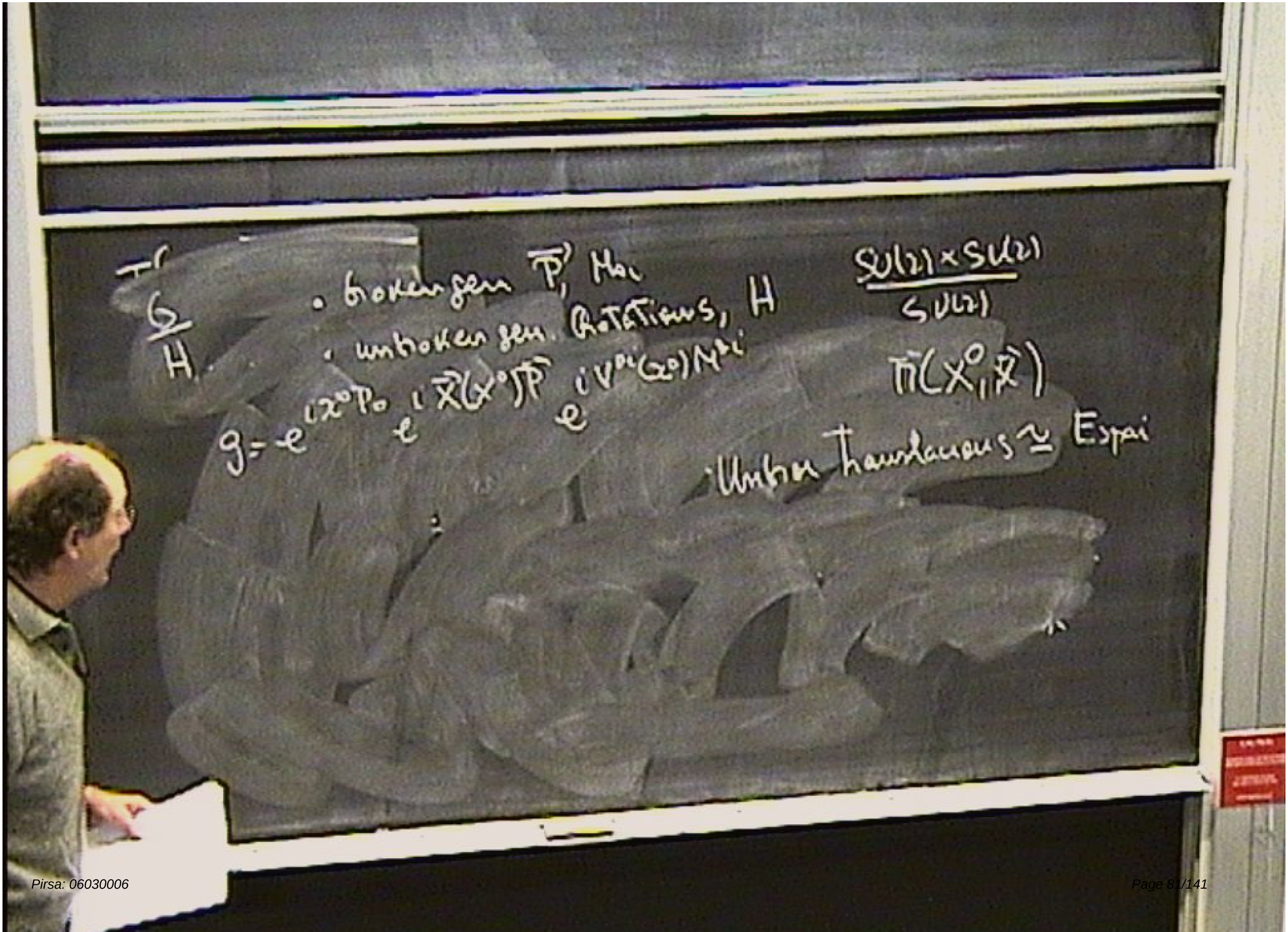
$\frac{G}{H}$

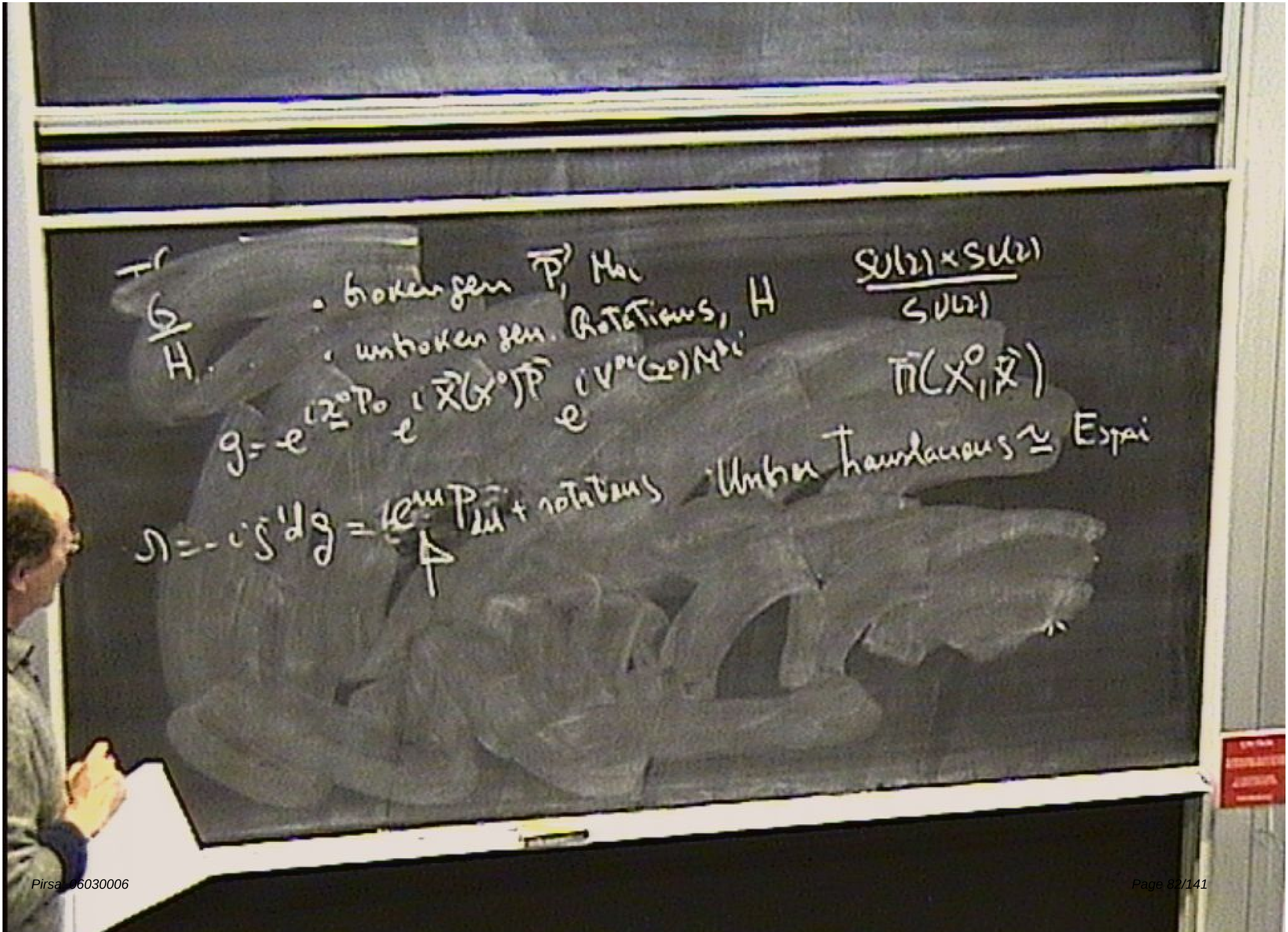
- broken gen $\vec{P}$, M_{0i}
- unbroken gen. Rotations, H

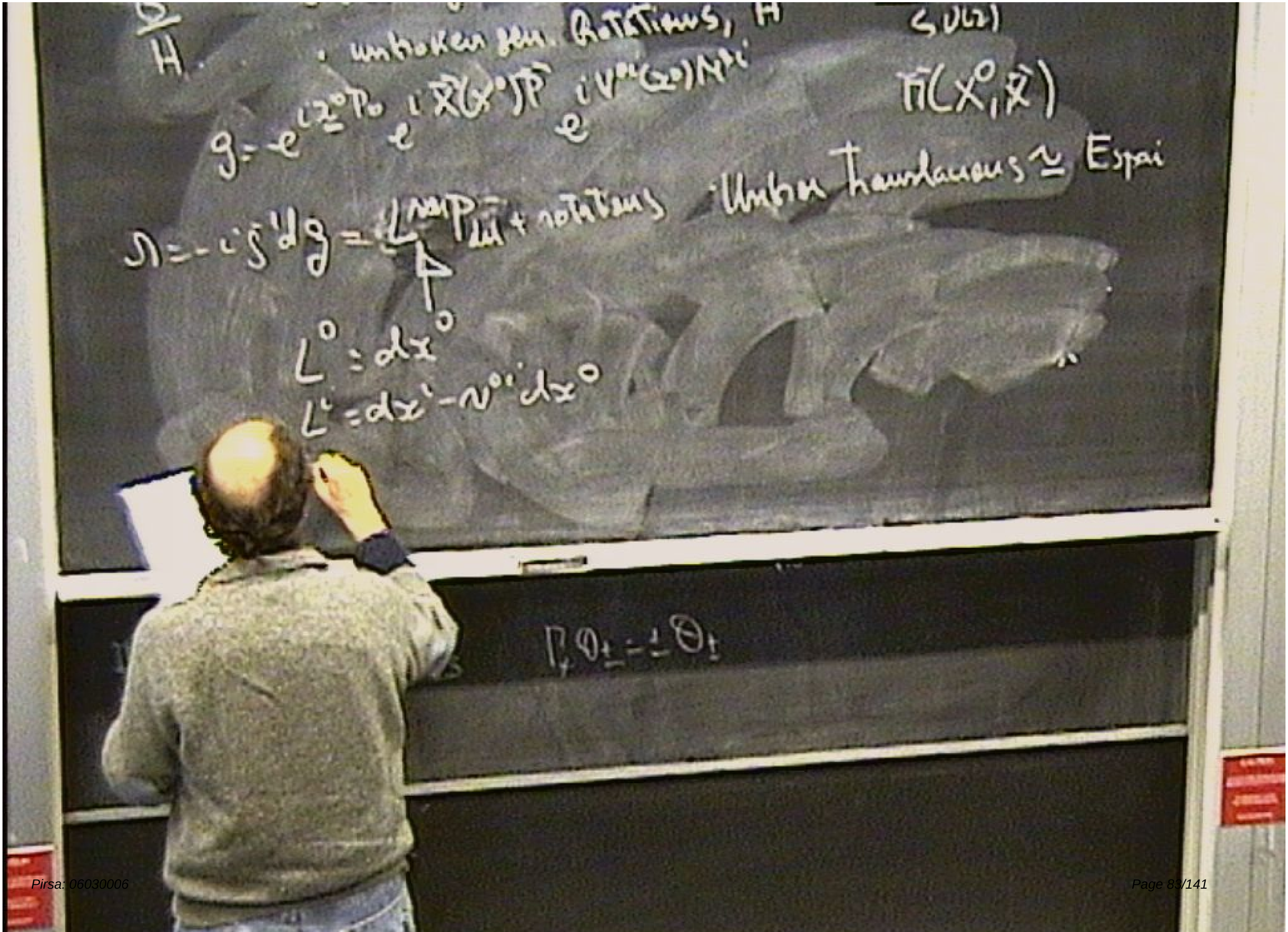
$$\frac{SU(2)\times SU(2)}{SU(2)}$$

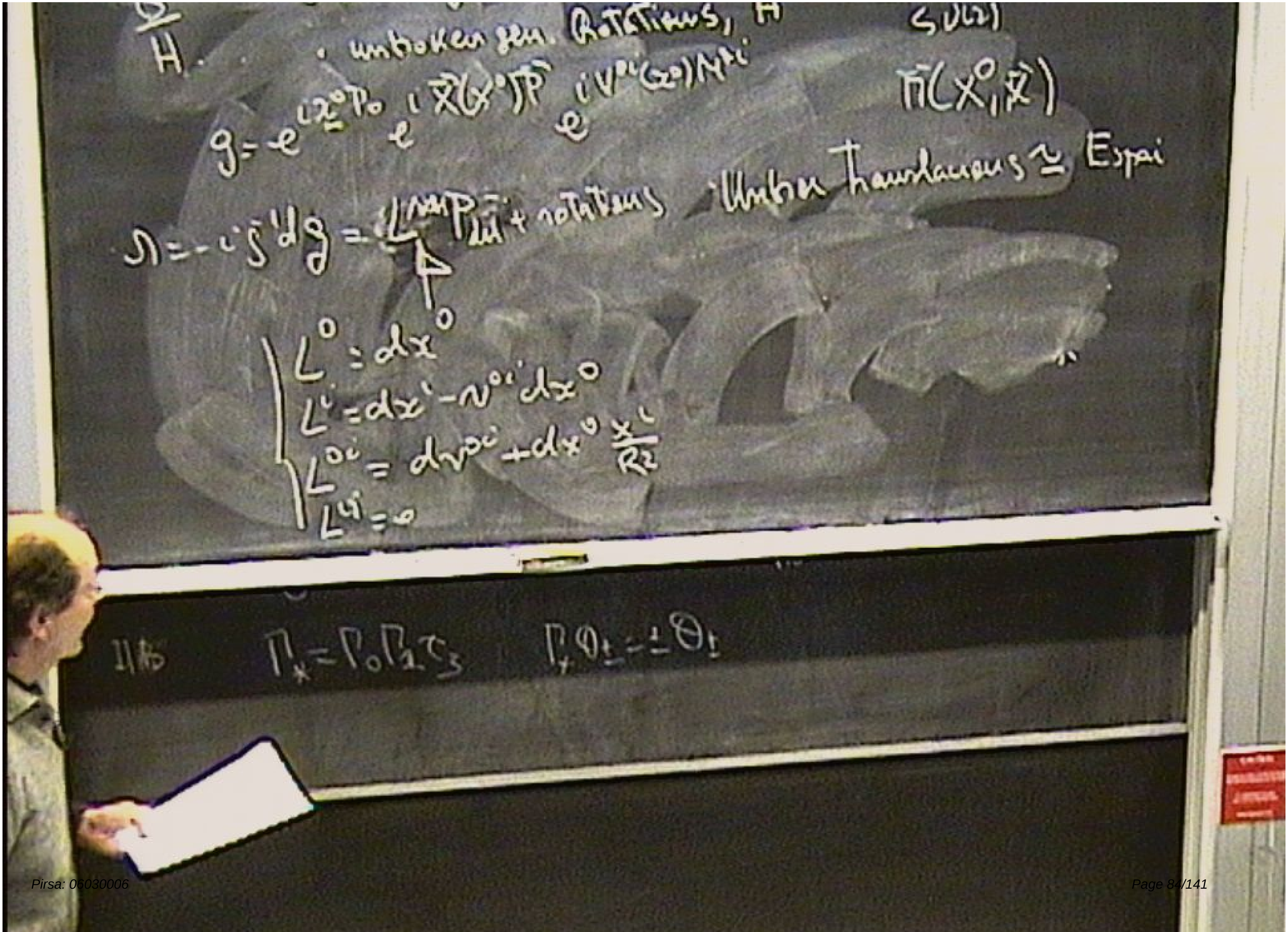
$$\pi(x^0, \vec{x})$$

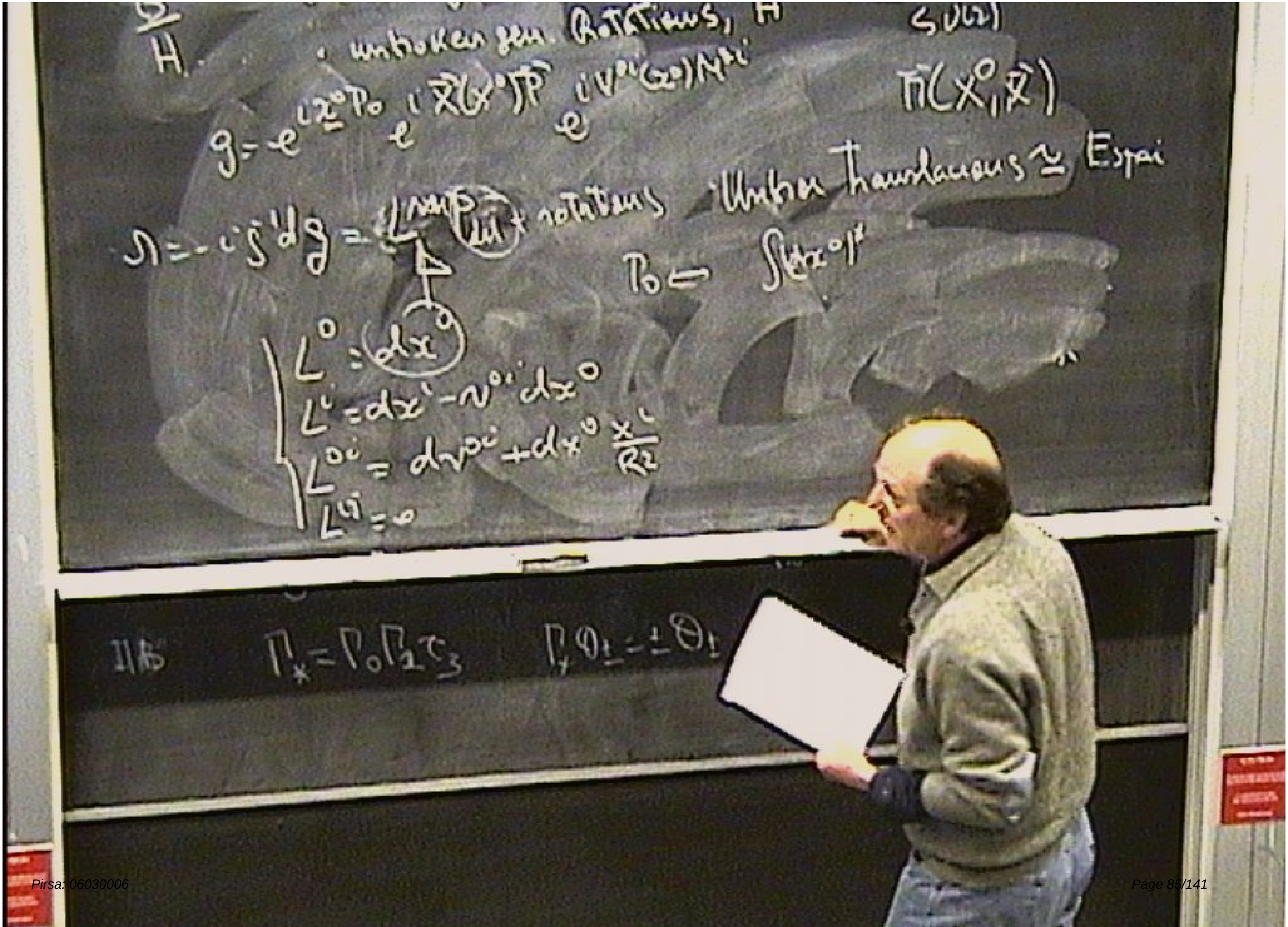

G/H
• broken gen $\vec{P}$, M_{0i}
• unbroken gen. Rotations, H
$\frac{SU(2)\times SU(2)}{SU(2)}$
$\pi(x^0, \vec{x})$
Unbroken translations ≃ Espai

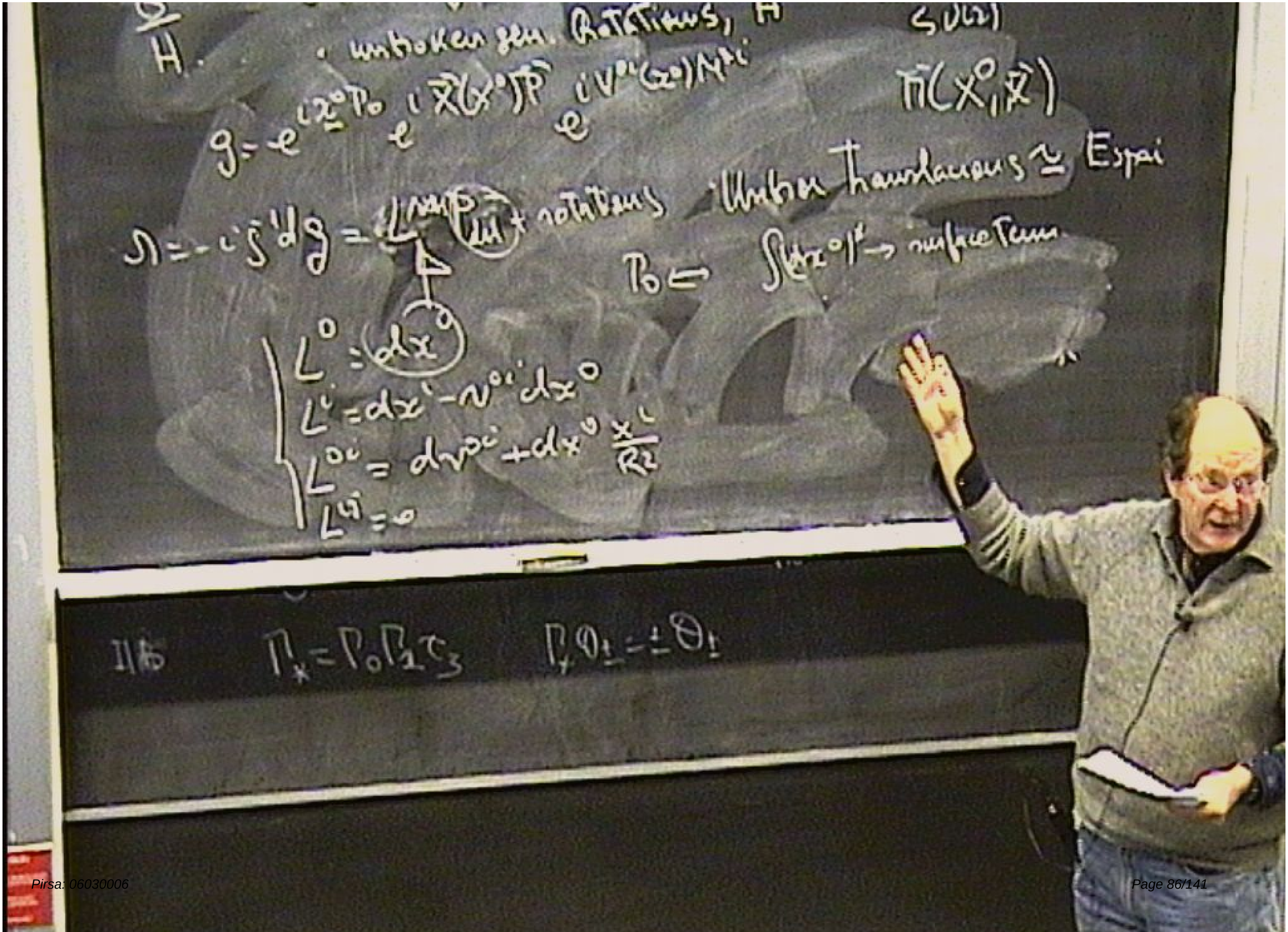

G/H
• broken gen P, Mai
• unbroken gen. Rotations, H
SU(2)×SU(2) / SU(2)
π(X⁰, x)
Unbroken translations ≃ Espai


G/H
• broken gen P⃗, Mai
• unbroken gen. Rotations, H
SU(2)×SU(2) / SU(2)
π(x°, x⃗)
g = e^{ix°P₀} e^{i x⃗(x°) P⃗} e^{i V^{μi}(x°) M^{μi}}
Unbroken translations ≃ Espai
Ω = -i g⁻¹dg = E^{μ} P_μ + rotations


unbroken gen. Rotations, H
SU(2)
Π(x⁰, x)
+ rotations
Unbroken Translations ≃ Espai
L⁰ = dx⁰
Lⁱ = dxⁱ - v⁰ⁱ dx⁰


unbroken gen. Rotations, H
+ rotations
Unbroken translations
L^0 = dx^0
L^i = dx^i - v^{0i} dx^0
L^{ij} = 0


unbroken gen. Rotations, H
SU(2)
Π(X⁰, X)
rotations
Unbroken translations
L⁰ = dx⁰
Lⁱ = dxⁱ − v⁰ⁱ dx⁰
L⁰ⁱ = dv⁰ⁱ + dx⁰ xⁱ/R²
Lⁱʲ = 0
IIB


unbroken gen. Rotations, H
rotations
surface Term

T

$\frac{G}{H}$

- broken gen $\vec{P}$, M_{0i}
- unbroken gen. Rotations, H

$\frac{SU(2)\times SU(2)}{SU(2)}$

$g = e^{i x^0 P_0}\, e^{i \vec{X}(x^0)\vec{P}}\, e^{i v^{0i}(x^0) M_{0i}}$

$\pi(X^0, \vec{X})$

Unbro Translations $\simeq$ Espai

$\Omega = -i g^{-1} dg = L^{\mu} P_{\mu} +$ rotations

$P_0 \leftarrow \int d^4x\, \partial^{\mu} \to$ surface Term

$L^0 = dx^0$

$L^i = dx^i - v^{0i} dx^0$

$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$

$L^{ij} = 0$

$\Omega_2 = L^i L^{0i}$

II B5 $\quad \Gamma_* = \Gamma_0 \Gamma_1 \tau_3 \quad \Gamma_* \Theta_{\pm} = \pm \Theta_{\pm}$

$\frac{G}{H}$

- broken gen $\vec{P}$, M_{0i}
- unbroken gen. Rotations, H

$$\frac{SU(2)\times SU(2)}{SU(2)}$$

$$\pi(x^0, \vec{x})$$

$$g = e^{i x^0 P_0} e^{i \vec{X}(x^0)\vec{P}} e^{i V^{0i}(x^0) M_{0i}}$$

Unbr. translations $\simeq$ Espai

$$\Omega = -i g^{-1} dg = L^{\text{nmp}} P_{nn} + \text{rotations}$$

$$P_0 \Leftarrow \int (dx^0)^t \rightarrow \text{surface Term}$$

$$\Omega_2 = L^i_1 L^{0i}, \quad d\Omega_2 = 0$$

$$\begin{cases} L^0 = dx^0 \\ L^i = dx^i - v^{0i} dx^0 \\ L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2} \\ L^{ij} = 0 \end{cases}$$

$$\Gamma_* = \Gamma_0 \Gamma_1 \tau_3 \qquad \Gamma_* \Theta_\pm = \pm \Theta_\pm$$

$\frac{G}{H}$

- broken gen $\vec{P}$, M_{0i}
- unbroken gen. Rotations, H

$$\frac{SU(2)\times SU(2)}{SU(2)}$$

$$\pi(X^0, \vec{X})$$

$$g = e^{i x^0 P_0}\, e^{i \vec{X}(x^0)\vec{P}}\, e^{i V^{0i}(x^0) M_{0i}}$$

Unbroken translations $\simeq$ Espai

$$\Omega = -i g^{-1} dg = L^{\text{nap}} P_{\text{nu}} + \text{rotations}$$

$P_0 \Leftarrow \int (dx^0)^t \rightarrow$ surface term

$$\begin{cases} L^0 = dx^0 \\ L^i = dx^i - v^{0i} dx^0 \\ L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2} \\ L^{ij} = 0 \end{cases}$$

$\Omega_2 = L^i_\wedge L^{0i}$, $\quad d\Omega_2 = 0$

$$\Omega_2 = d\left(-v^{0i} dx^i + dx^0 \frac{v^2}{2} + dx^0 \frac{\vec{x}^2}{R^2}\right)$$

$\Gamma_* = \Gamma_0 \Gamma_1 \tau_3 \qquad \Gamma_* \Theta_\pm = \pm \Theta_\pm$

$$\begin{cases} L^0 = dx^0 \\ L^i = dx^i - v^{0i}\,dx^0 \\ L^{0i} = dv^{0i} + dx^0\,\frac{x^i}{R^2} \\ L^{ij} = 0 \end{cases}$$

$$\Omega_2 = L^i \wedge L^{0i}, \quad d\Omega_2 = 0$$

$$\Omega_2 = d\Big(\underbrace{-v^{0i}\,dx^i + dx^0\,\frac{v^2}{2} + dx^0\,\frac{x^2}{R^2}}_{\Omega_2}\Big)$$

$H_2 \neq 0$ Eilenberg-Chevallier

$\frac{G}{H}$

- broken gen $\vec{P}$, H_0
- unbroken gen Rotations, H

$$\frac{SU(2)\times SU(2)}{SU(2)}$$

$$g = e^{i x^0 P_0}\, e^{i \vec{X}(x^0)\vec{P}}\, e^{i V^{0i}(x) M^{0i}}$$

$$\pi(x^0, \vec{x})$$

Unbroken Translations $\simeq$ Espai

$$\Omega = -i g^{-1} dg = L^{\mu} P_{\mu} + \text{rotations}$$

$P_0 \Leftrightarrow \int dx^0 \,\partial^{\mu} \to$ surface term

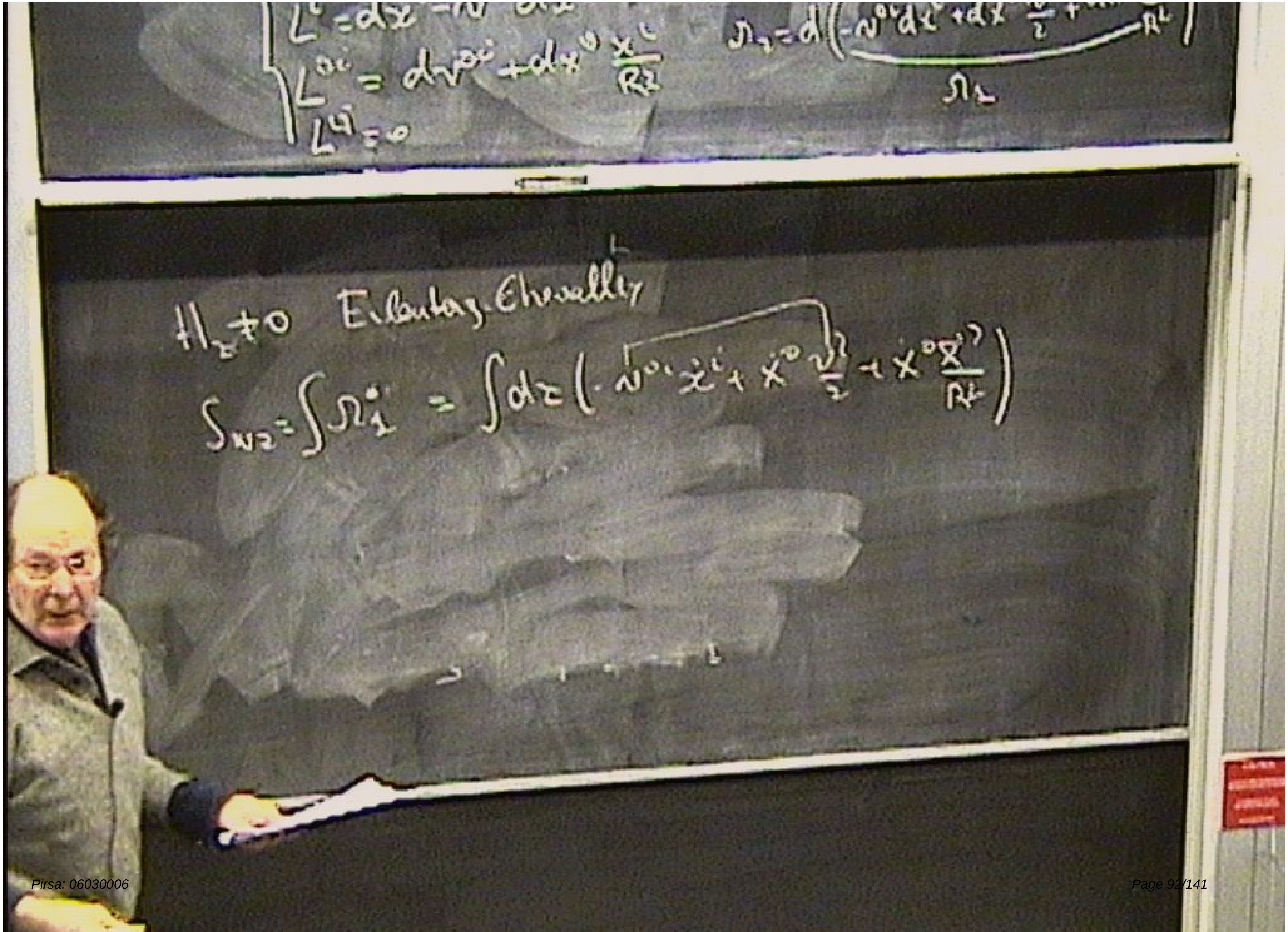
$$\begin{cases} L^0 = dx^0 \\ L^i = dx^i - v^{0i} dx^0 \\ L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2} \\ L^{ij} = 0 \end{cases}$$

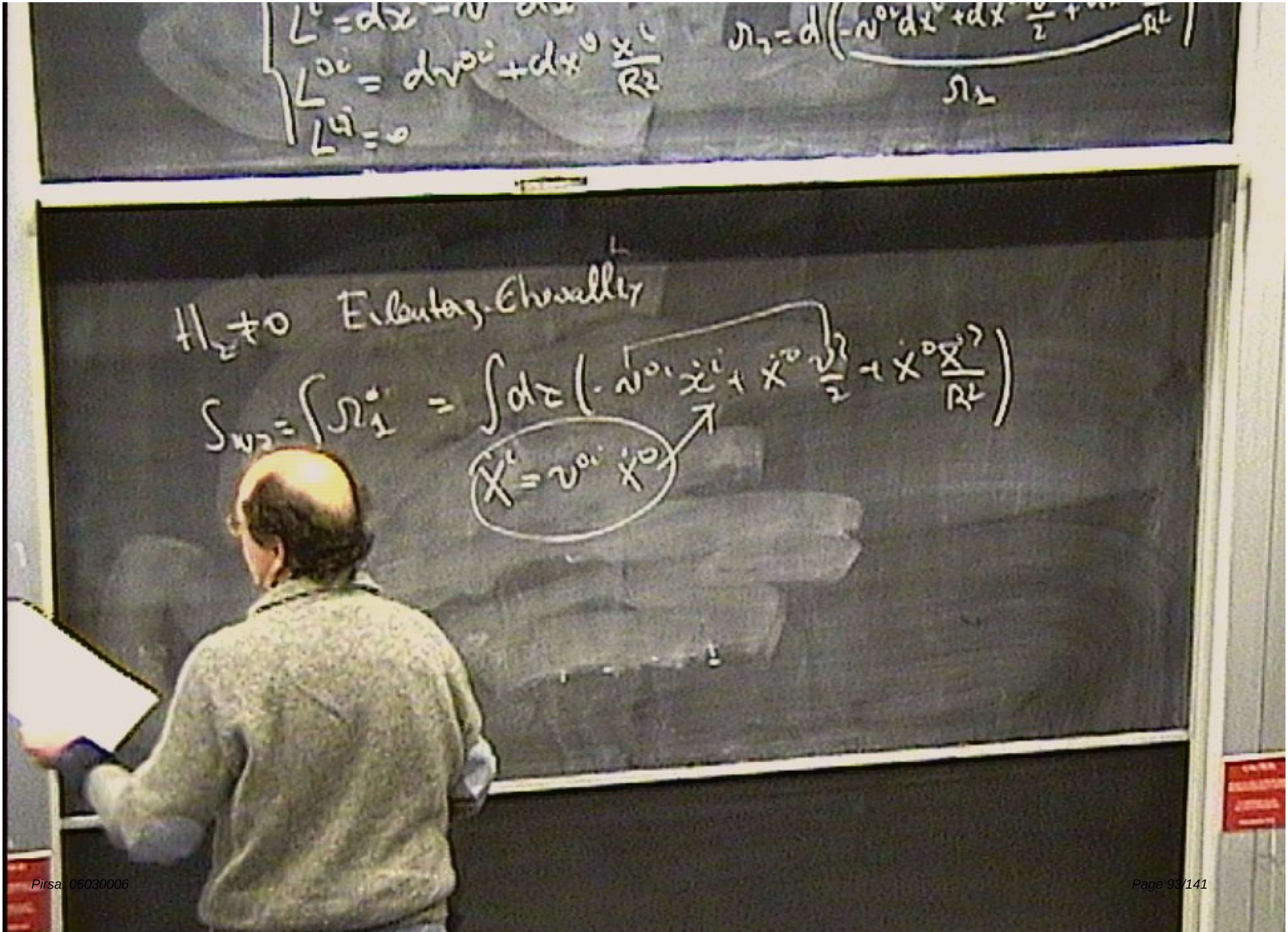
$\Omega_2 = L^i \wedge L^{0i}$, $\quad d\Omega_2 = 0$

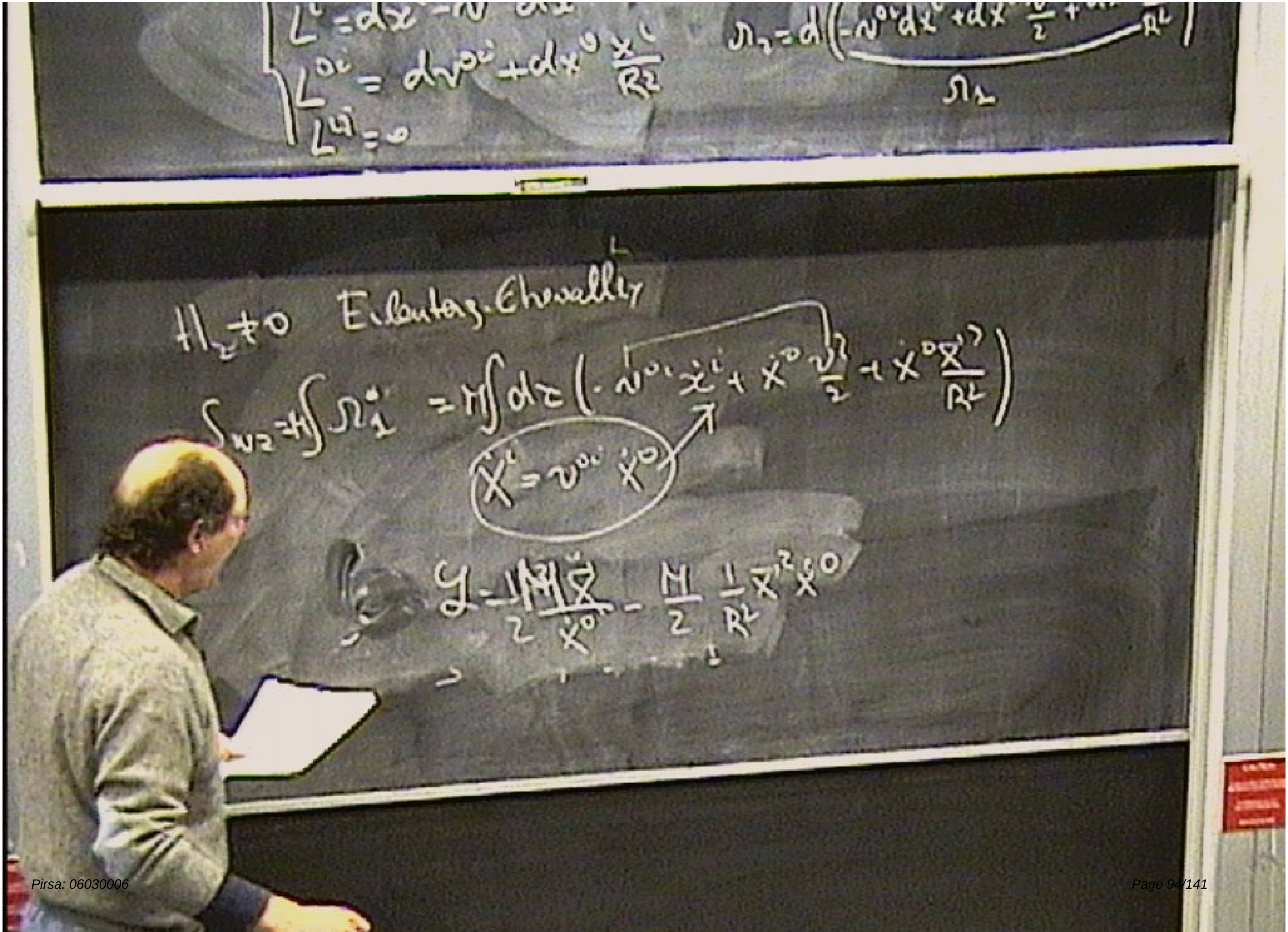
$$\Omega_2 = d\Big(\underbrace{-v^{0i} dx^i + dx^0 \frac{v^2}{2} + dx^0 \frac{\vec{x}^2}{R^2}}_{\Omega_2}\Big)$$

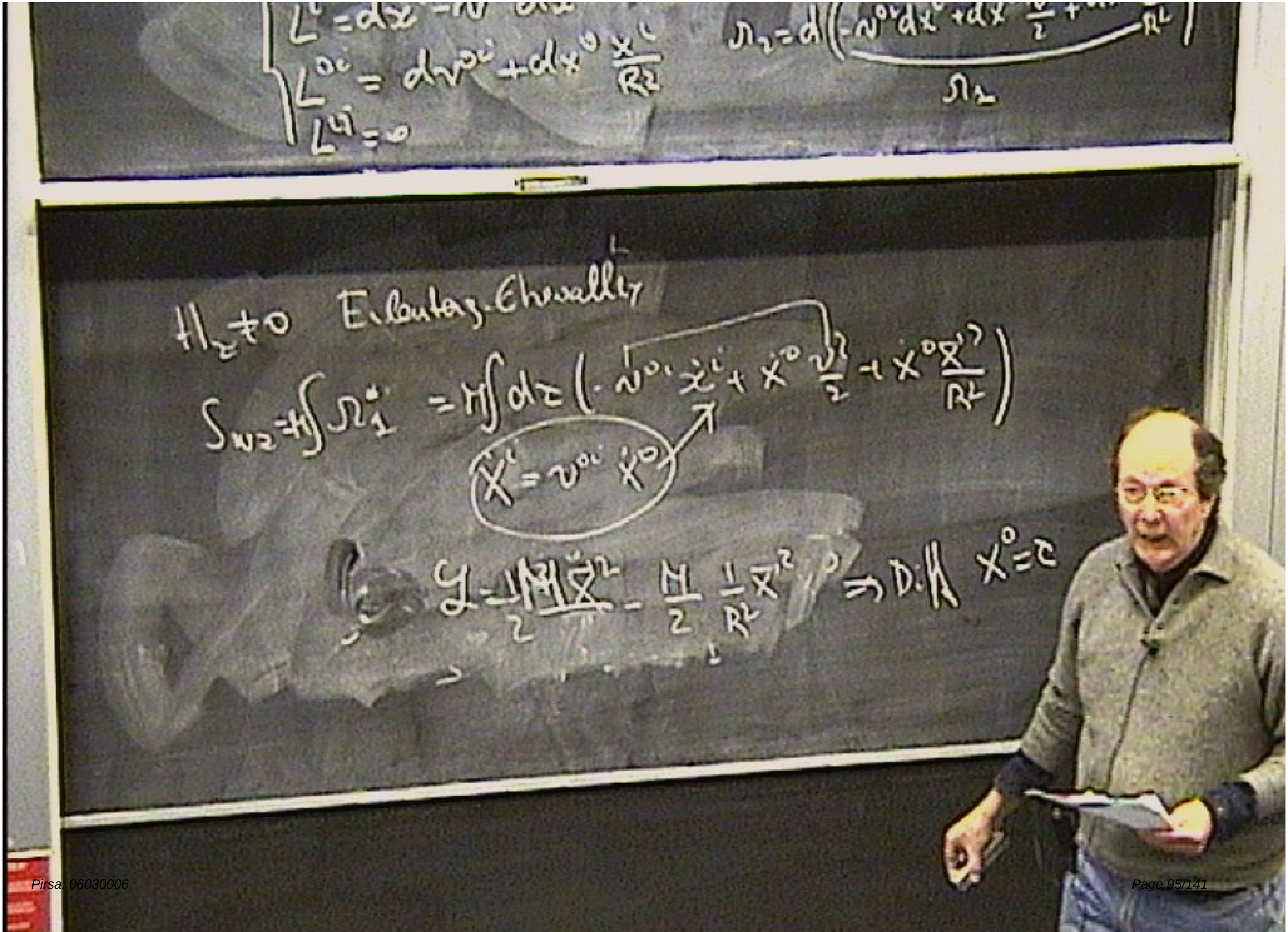
$H_2 \neq 0$ Eilenberg-Chevalley

$$\int \Omega_2^0$$

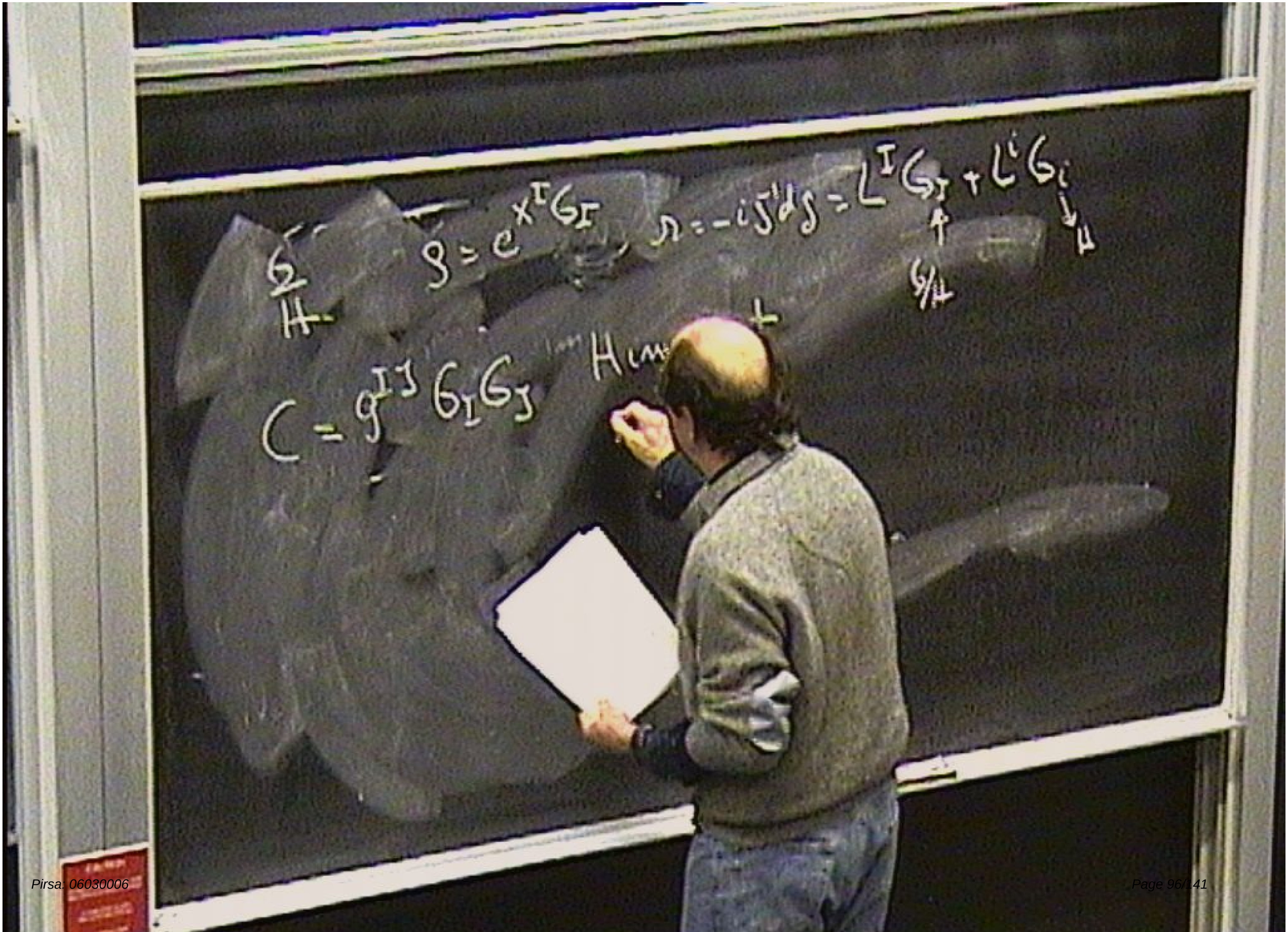

$L^{0i} = d\nu^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$\Omega_2 = d\left(-\nu^{0i} dx^i + dx^0 \frac{\nu^2}{2} + \dots\right)$
Ω_1
$H_2 \neq 0$ Eilenberg-Chevalley
$S_{WZ} = \int \Omega_1^0 = \int d\tau \left(-\nu^{0i} \dot{x}^i + \dot{x}^0 \frac{\nu^2}{2} + \dot{x}^0 \frac{x^2}{R^2} \right)$

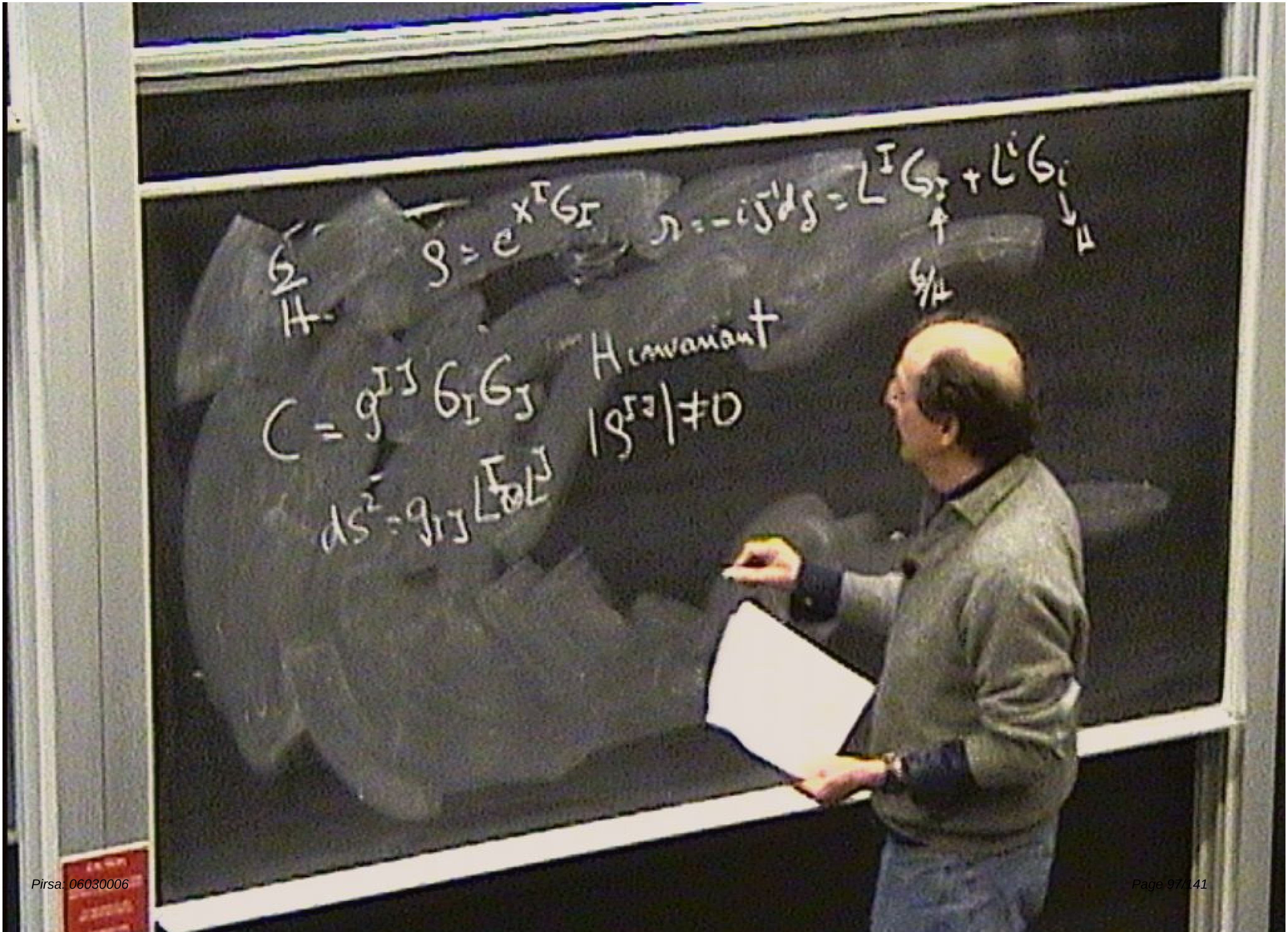

$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$\Omega_2 = d\left(-v^{0i}dx^i + dx^0 \frac{v^2}{2} + \dots\right)$
Ω_1
$H_2 \neq 0$ Eilenberg-Chevalley
$S_{NR} = \int \Omega_1^{0} = \int d\tau \left(-v^{0i}\dot{x}^i + \dot{x}^0 \frac{v^2}{2} + \dot{x}^0 \frac{x^2}{R^2} \right)$
$\dot{x}^i = v^{0i}\dot{x}^0$

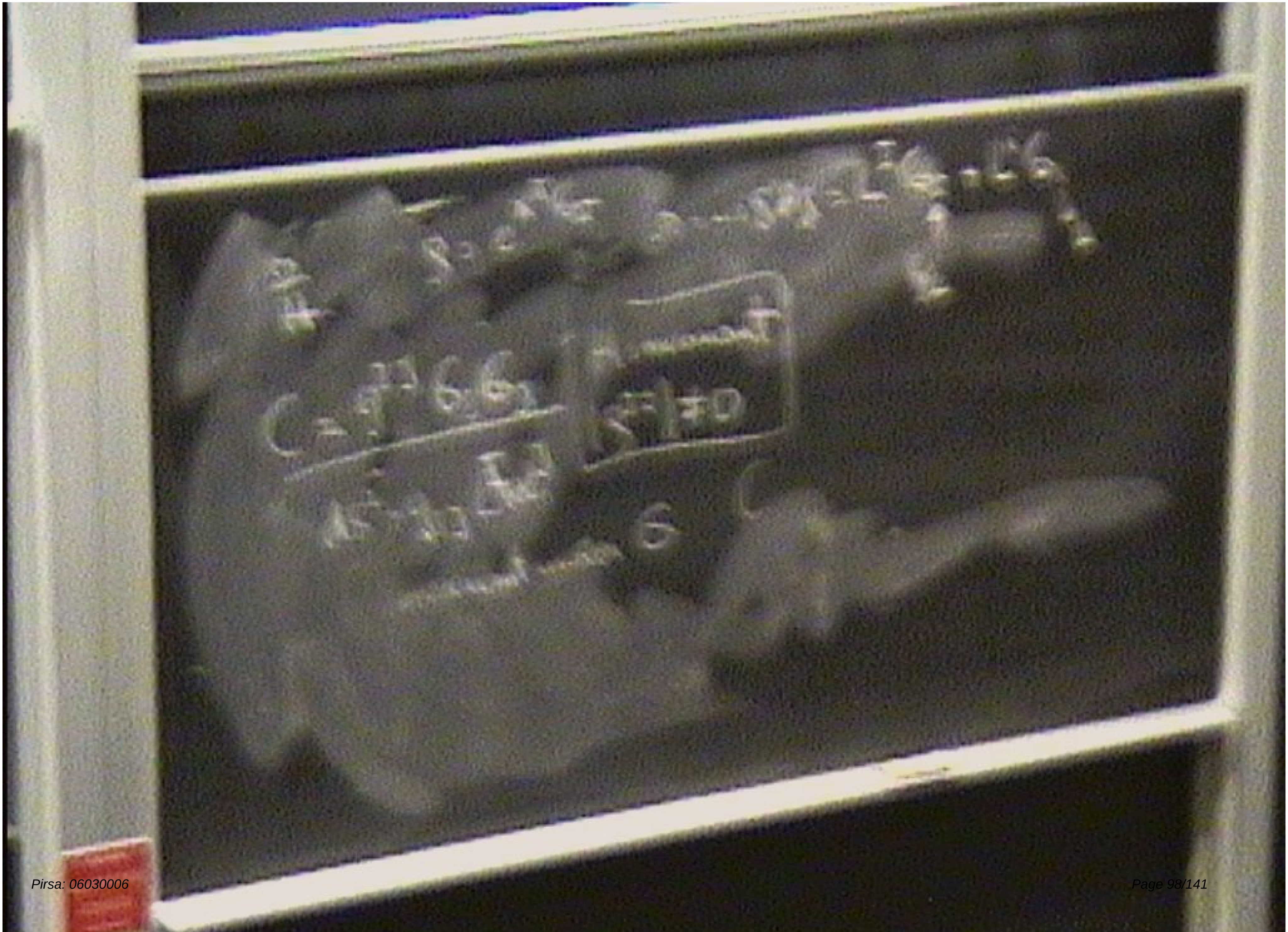

$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$\Omega_2 = d(-v^{0i} dx^i + dx^0 \frac{v^2}{2} + \ldots)$
Ω_1
$H_2 \neq 0$ Eilenberg-Chevalley
$S_{WZ} = M \int \Omega_1^0 = M \int d\tau \left(-v^{0i} \dot{x}^i + \dot{x}^0 \frac{v^2}{2} + \dot{x}^0 \frac{x^2}{R^2} \right)$
$\dot{x}^i = v^{0i} \dot{x}^0$
$\mathcal{L} = \frac{1}{2} M \frac{\dot{x}^2}{\dot{x}^0} - \frac{M}{2} \frac{1}{R^2} x^2 \dot{x}^0$



$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$\Omega_2 = d\left(-v^{0i}dx^i + dx^0 \frac{v^2}{2} + \ldots \frac{x^2}{R^2}\right)$
$H_2 \neq 0$ Eilenberg-Chevalley
$S_{WZ} = M\int \Omega_1^{0i} = M\int d\tau\left(-v^{0i}\dot{x}^i + \dot{x}^0\frac{v^2}{2} + \dot{x}^0\frac{x^2}{R^2}\right)$
$\dot{x}^i = v^{0i}\dot{x}^0$
$\mathcal{L} = \frac{1}{2}M\dot{x}^2 - \frac{M}{2}\frac{1}{R^2}x^2 \Rightarrow$ Diff $x^0 = \tau$


$\frac{G}{H}$
$g = e^{x^I G_I}$
$\Omega = -i g^{-1} dg = L^I G_I + L^i G_i$
G/H
$C = g^{IJ} G_I G_J$


$g = e^{x^I G_I}$
$\Omega = -i g^{-1} dg = L^I G_I + L^i G_i$
G/H
$C = g^{IJ} G_I G_J$
H invariant
$|g^{IJ}| \neq 0$
$ds^2 = g_{IJ} L^I \otimes L^J$



G/H

$g = e^{x^I G_I}$ $\qquad \Omega = -i g^{-1} dg = L^I G_I + L^i G_i$

$G_I \downarrow G/H \qquad G_i \downarrow H$

$$C = g^{IJ} G_I G_J \qquad \boxed{\begin{array}{l} H \text{ invariant} \\ |g^{IJ}| \neq 0 \end{array}}$$

$$ds^2 = g_{IJ} L^I \otimes L^J$$

invariant under G $\qquad C$

$$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$$

$$L^{ij} = 0$$

$$\Omega_2 = d\left(\ldots\right)$$

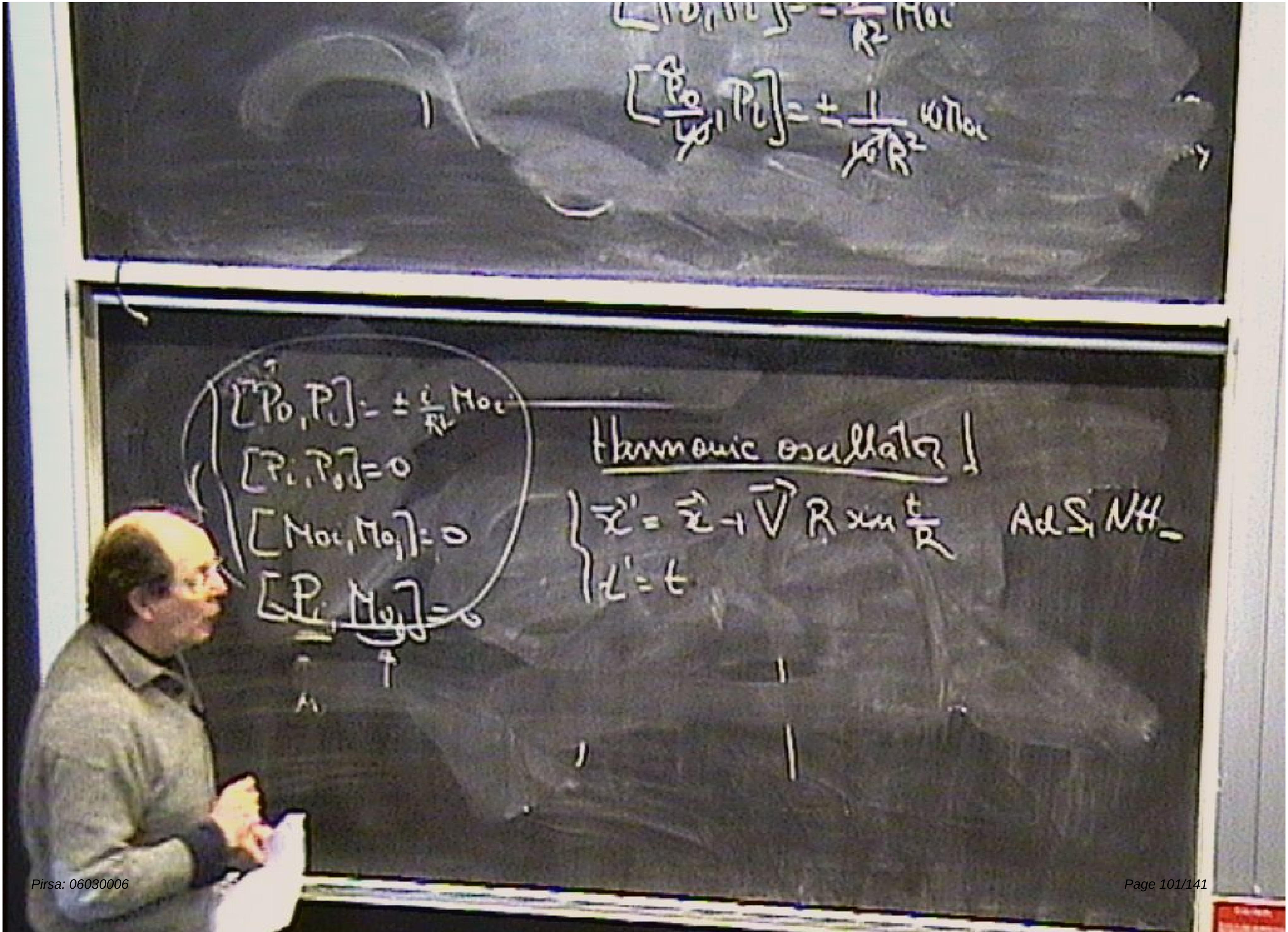
$$\Omega_2$$

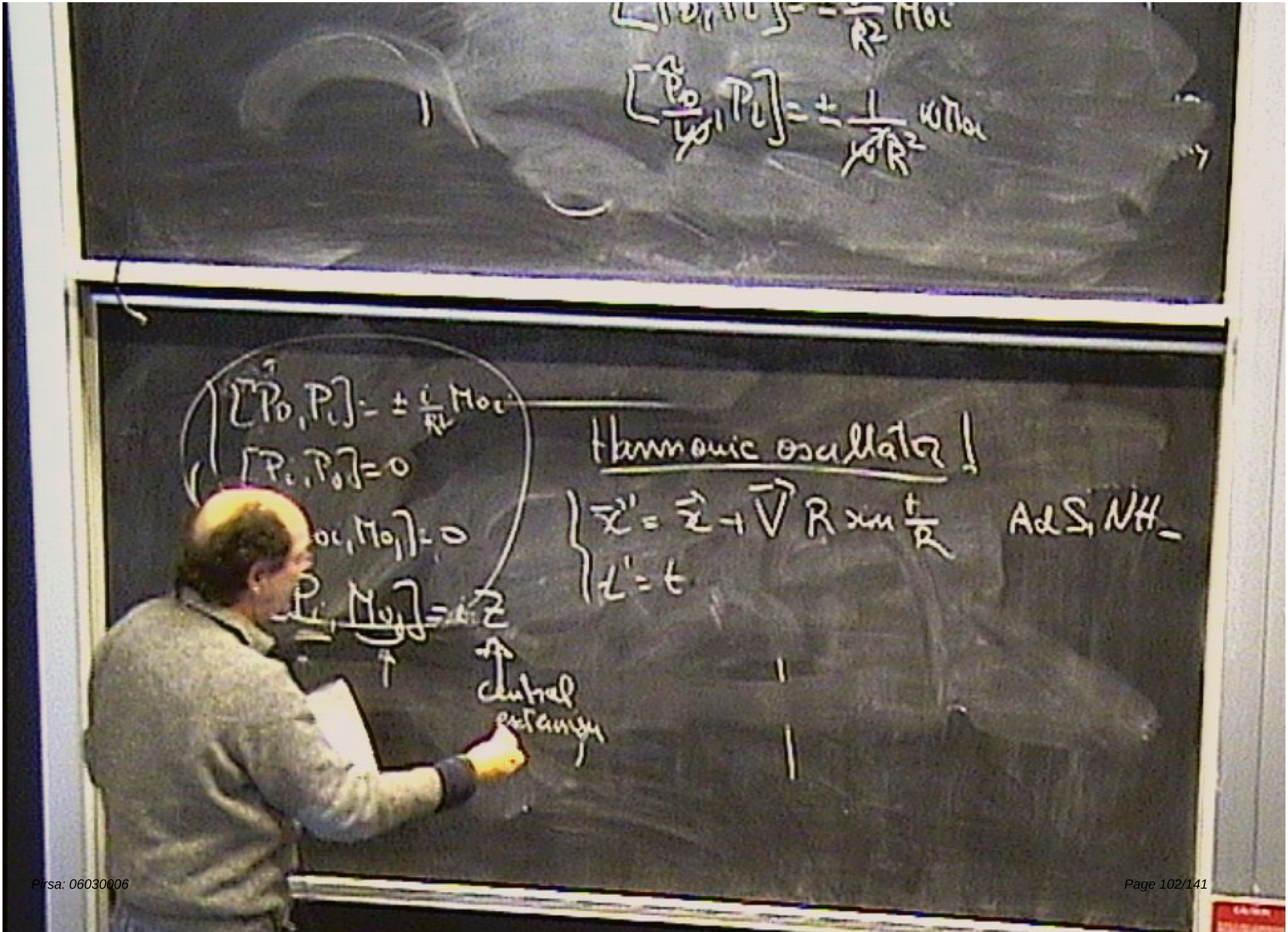
$\boxed{H_2 \neq 0}$ Eilenberg-Chevalley

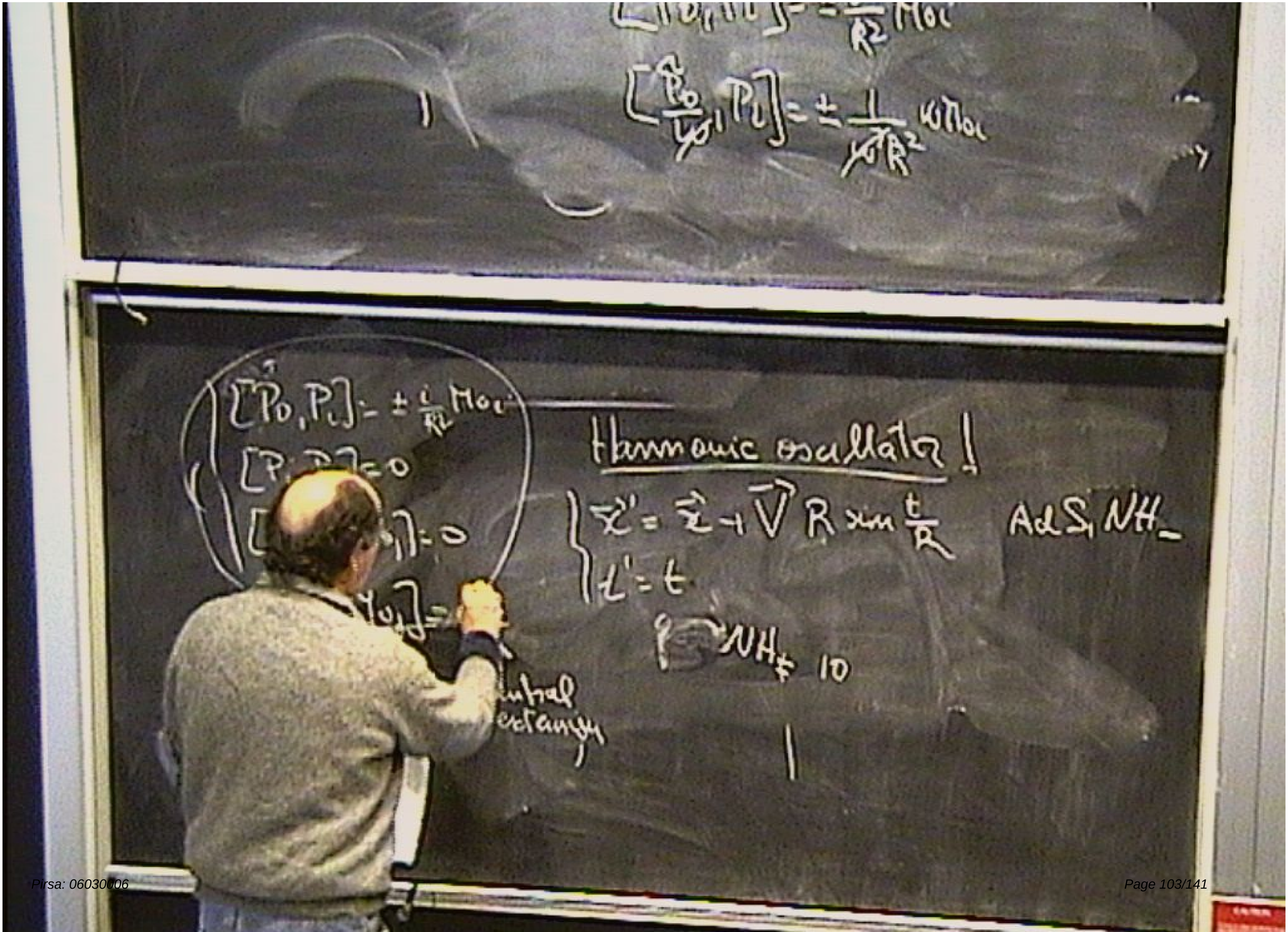
$$S_{WZ} = M \int \Omega_1^{0i} = M \int d\tau \left(\cdot\, v^{0i} \dot{x}^i + \dot{x}^0 \frac{v^2}{2} + \dot{x}^0 \frac{x^2}{R^2} \right)$$

$$\dot{x}^i = v^{0i} \dot{x}^0$$

$$\mathcal{L} = \frac{1}{2} M \dot{x}^2 - \frac{M}{2} \frac{1}{R^2} x^2 \Rightarrow \mathrm{Diff} \quad x^0 = \tau$$


$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$
$[P_i, P_0] = 0$
$[M_{0i}, M_{0j}] = 0$
$[P_i, M_{0j}] = 0$
Harmonic oscillator !
$\vec{x}' = \vec{x} + \vec{V} R \sin \frac{t}{R}$
$t' = t$
AdS, NH_-


[P_0, P_i] = ± i/R² M_0i
[P_i, P_0] = 0
Harmonic oscillator !
x' = x + V R sin t/R
t' = t
AdS, NH_
central
extension


Harmonic oscillator !
AdS, NH_
NH± 10

$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

$$\left[\frac{P_0}{\omega}, P_i\right] = \pm \frac{1}{\omega R^2} \omega M_{0i}$$

$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

$$[P_i, P_j] = 0$$

$$[M_{0i}, M_{0j}] = 0$$

$$[P_i, M_{0j}] = i Z$$

central extension

Harmonic oscillator!

$$\vec{x}' = \vec{x} + \vec{V} R \sin \frac{t}{R} \qquad AdS, NH_-$$

$$t' = t$$

$$Z \to c$$

$NH_\pm$ 10 11 e^{icZ}

$\frac{G}{H}$

$g = e^{x^I G_I}$

$\Omega = -i g^{-1} dg = L^I \underset{G/H}{G_I} + L^i \underset{H}{G_i}$

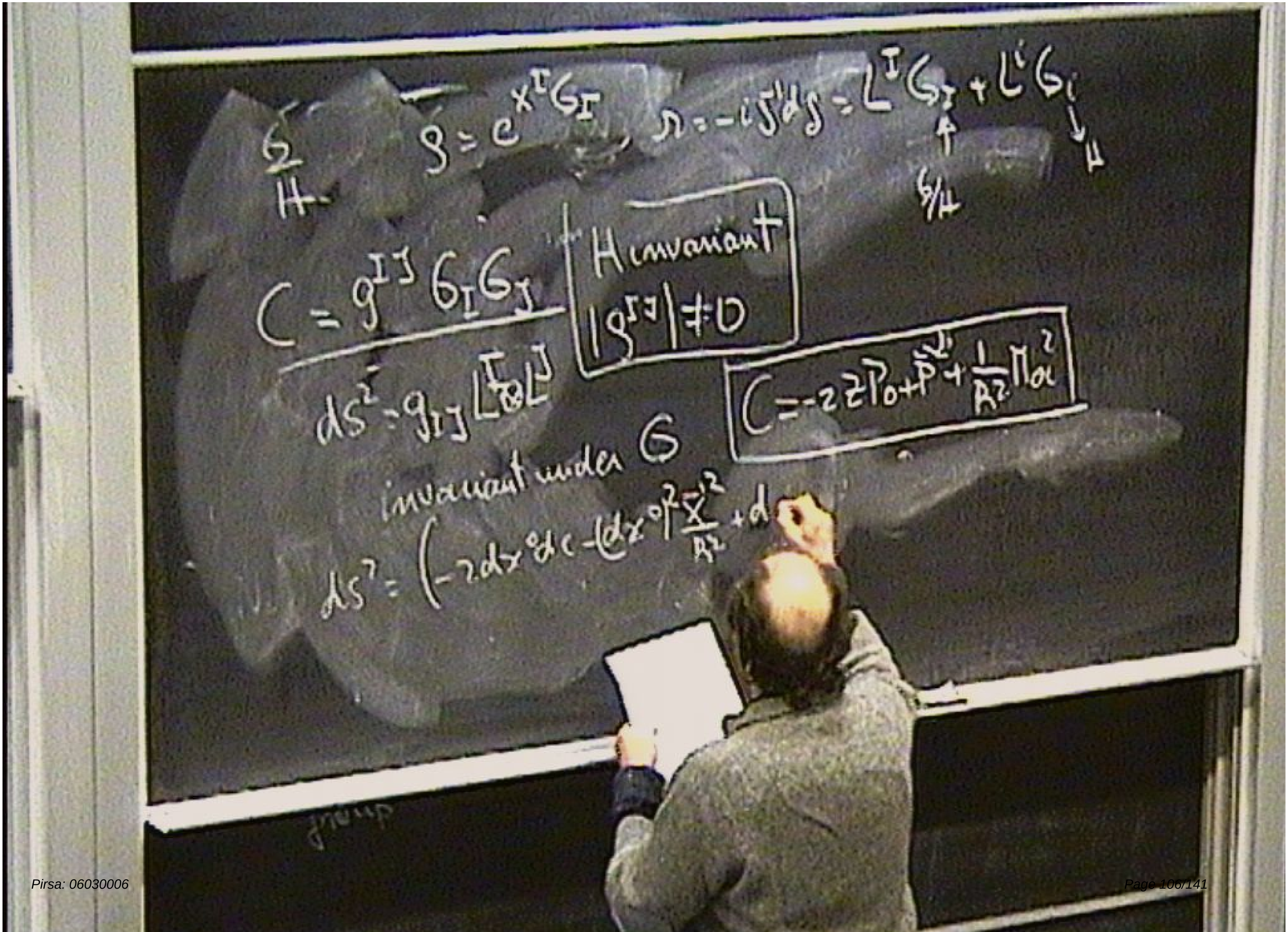
$C = g^{IJ} G_I G_J$

$\boxed{\begin{array}{l} H \text{ invariant} \\ |g^{IJ}| \neq 0 \end{array}}$

$ds^2 = g_{IJ} L^I \otimes L^J$

invariant under G

$\boxed{C = -2 Z P_\theta + \vec{P}^2 + \frac{1}{a^2} \Pi_\alpha^2}$


G/H
g = e^{x^I G_I}
Ω = -i g^{-1} dg = L^I G_I + L^i G_i
G/H
H
H invariant
|g^{IJ}| ≠ 0
C = g^{IJ} G_I G_J
ds^2 = g_{IJ} L^I ⊗ L^J
C = -2 ∂ P_0 + P^2 + 1/R^2 Π_α^2
invariant under G
ds^2 = (-2dx^0 dx - (dx^0)^2 x^2/R^2 + d

$\frac{G}{H}$ $\quad g = e^{x^I G_I}$ $\quad \Omega = -i g^{-1} dg = L^I G_I + L^i G_i$

$G/H \qquad H$

$C = g^{IJ} G_I G_J$ $\quad \boxed{\begin{array}{l} H \text{ invariant} \\ |g^{IJ}| \neq 0 \end{array}}$

$ds^2 = g_{IJ} L^I \otimes L^J$

invariant under G

$\boxed{C = -2 Z P_0 + \vec{P}^2 + \frac{1}{R^2} \Pi_\alpha^2}$

$$ds^2 = \left(-2dx^0 dc - (dx^0)^2 \frac{\vec{X}^2}{R^2} + (d\vec{X})^2\right) + \left(d(R n^{0\alpha}) + dx^0 \frac{Z^i}{R}\right)^2$$

pp wave . $\qquad$ sigma

$\frac{G}{H}$ $\quad g = e^{x^I G_I}$ $\quad \Omega = -i g^{-1} dg = L^I G_I + L^i G_i$

$G/H \qquad H$

$C = g^{IJ} G_I G_J$

H invariant

$|g^{IJ}| \neq 0$

$ds^2 = g_{IJ} L^I \otimes L^J$

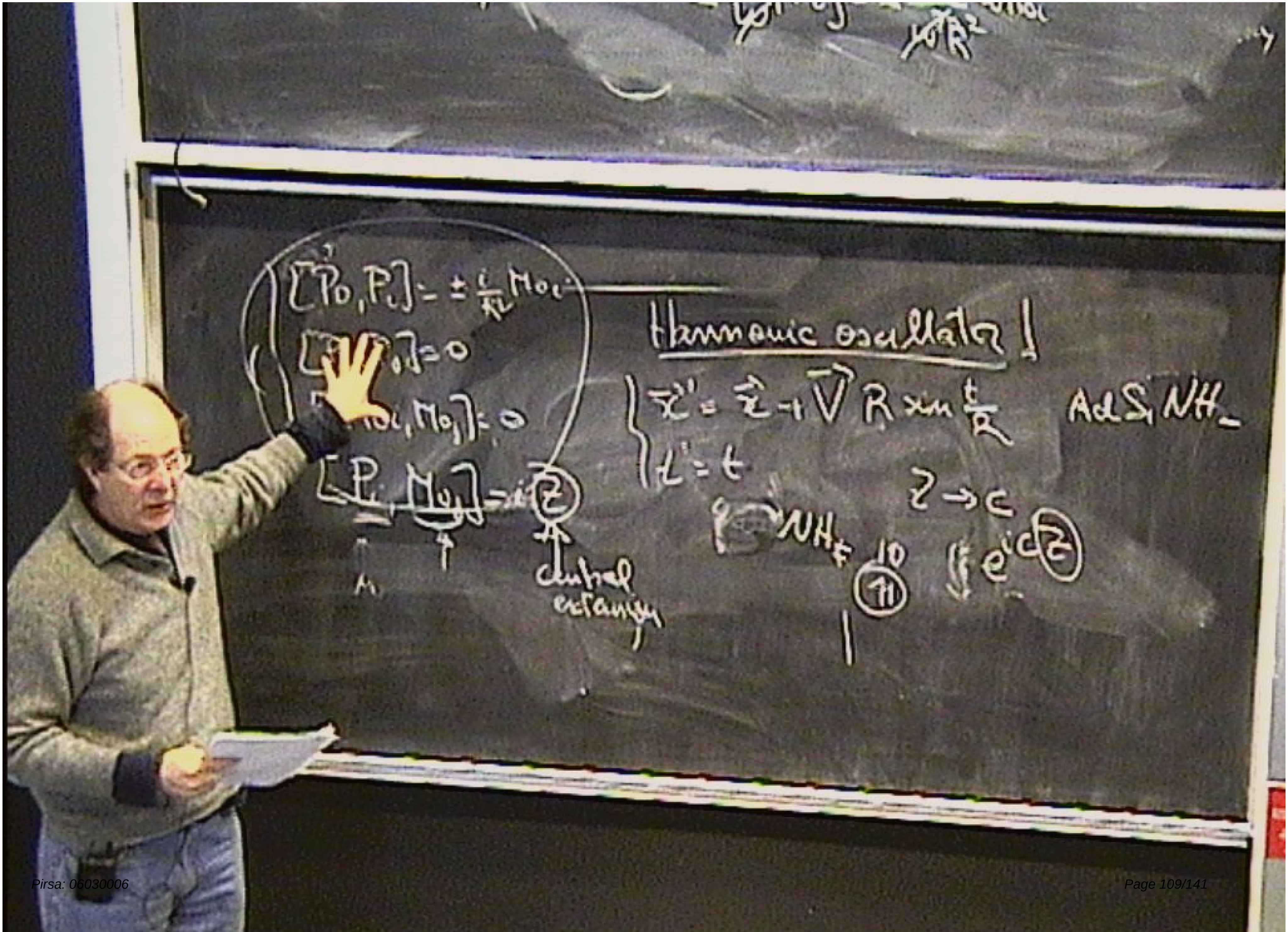
invariant under G

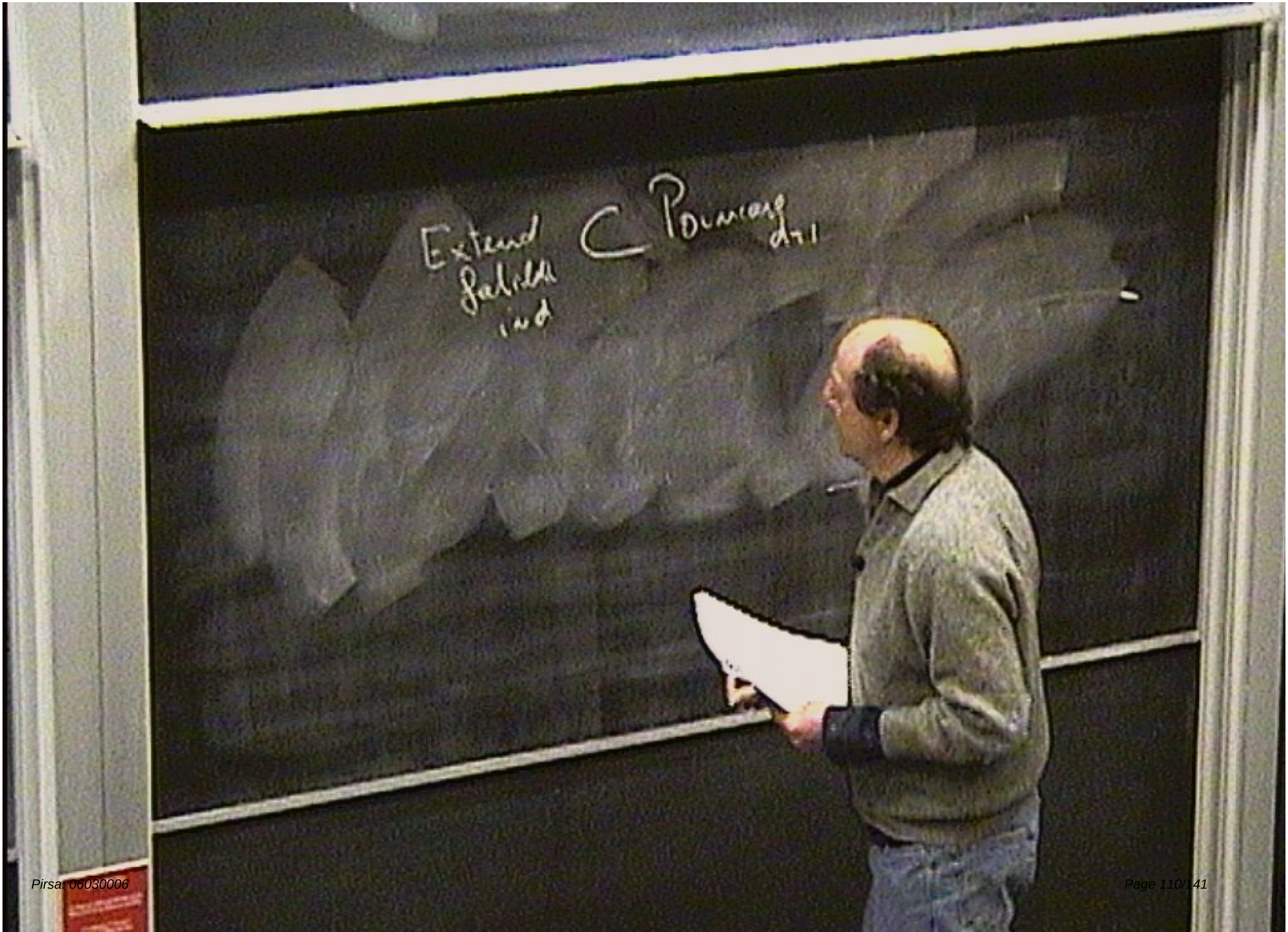
$C = -2 Z P_0 + \vec{P}^2 + \frac{1}{R^2} \Pi_a^2$

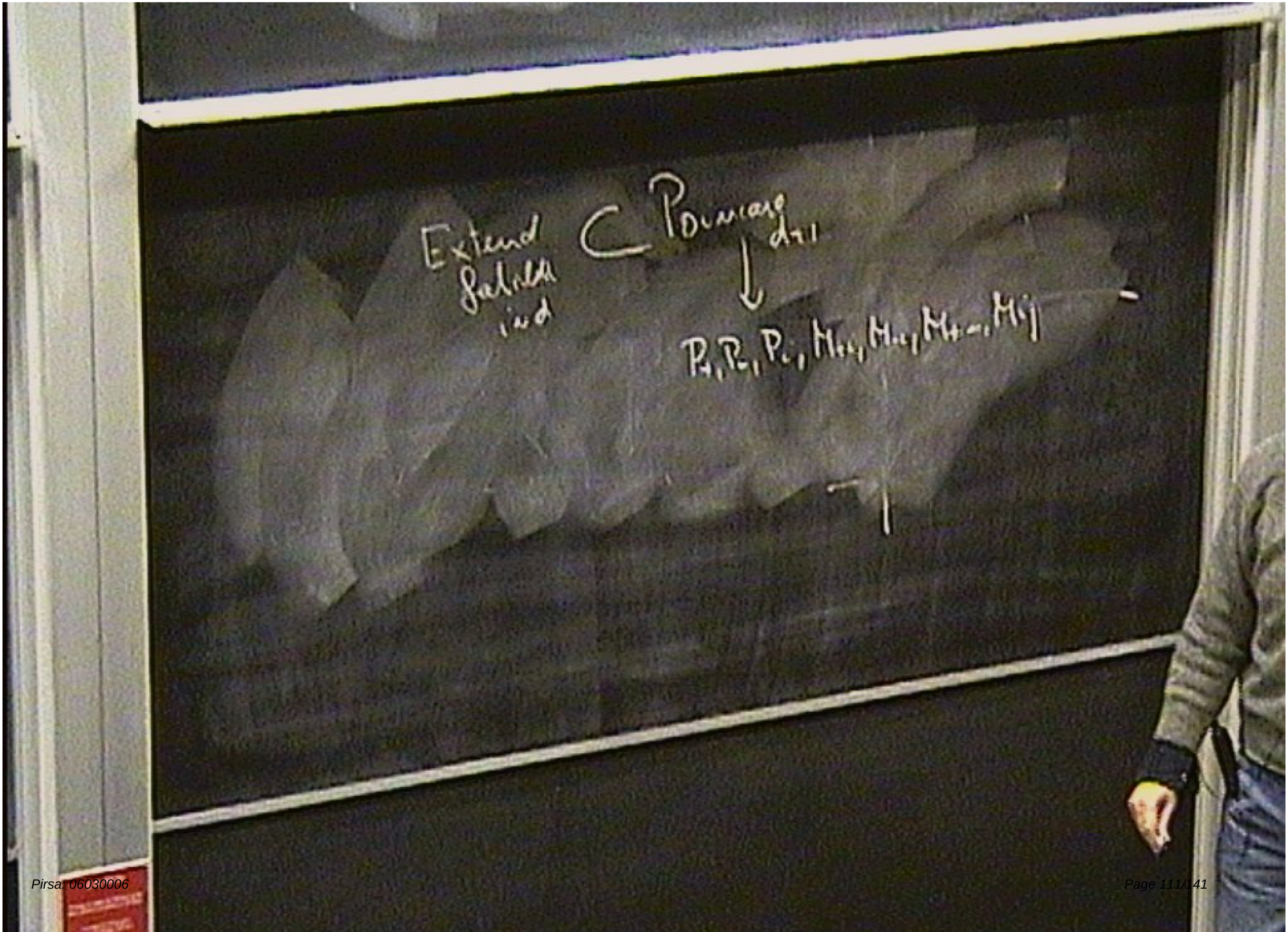
$x^i, R v^a$

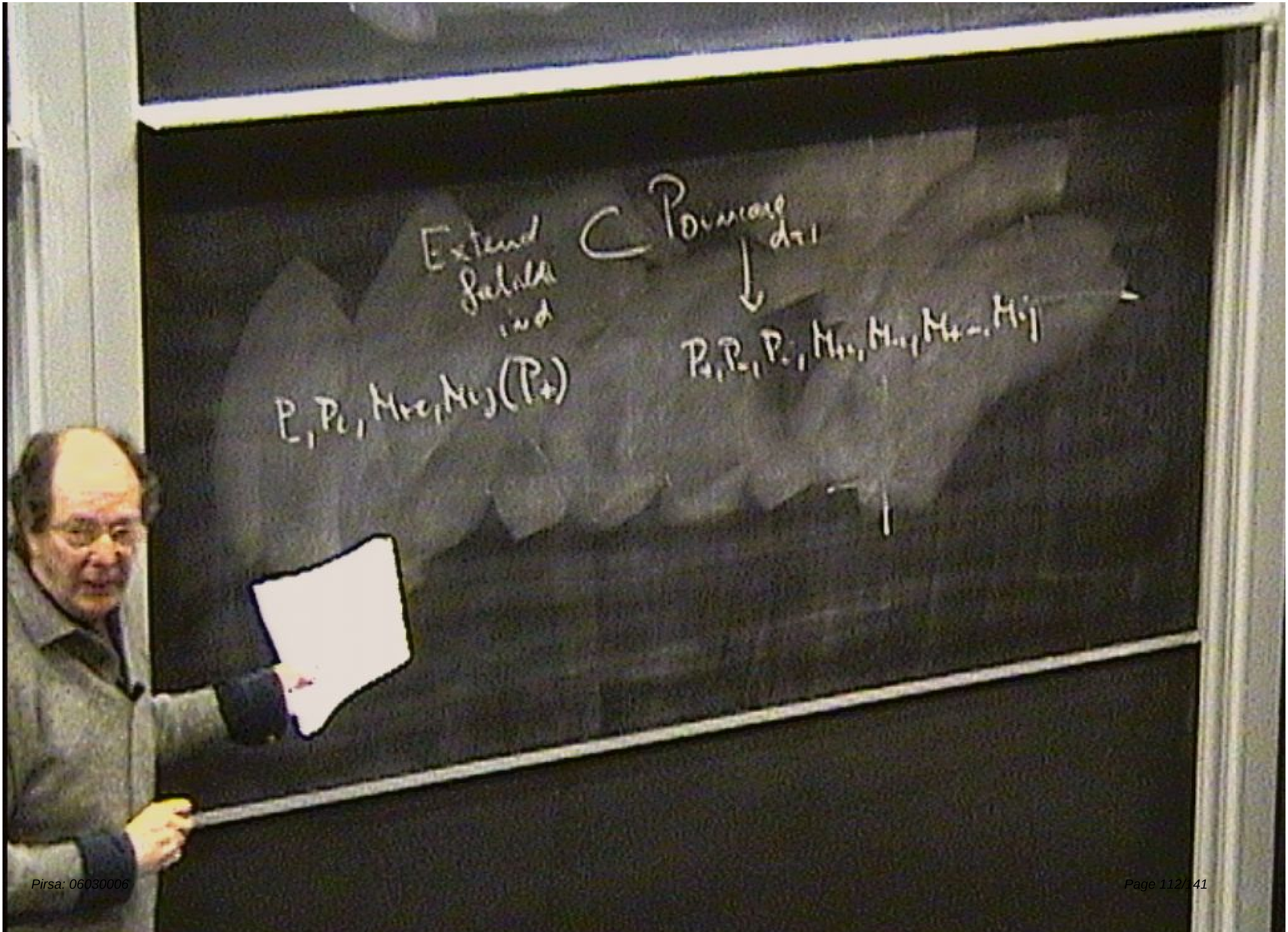
$$ds^2 = \underbrace{\left(-2dx^0 dc - (dx^0)^2 \frac{X^2}{R^2} + (dx^i)^2\right)}_{\text{pp wave}} + \underbrace{\left(d(R n^{0a}) + dx^0 \frac{X^i}{R}\right)^2}_{\text{system}}$$

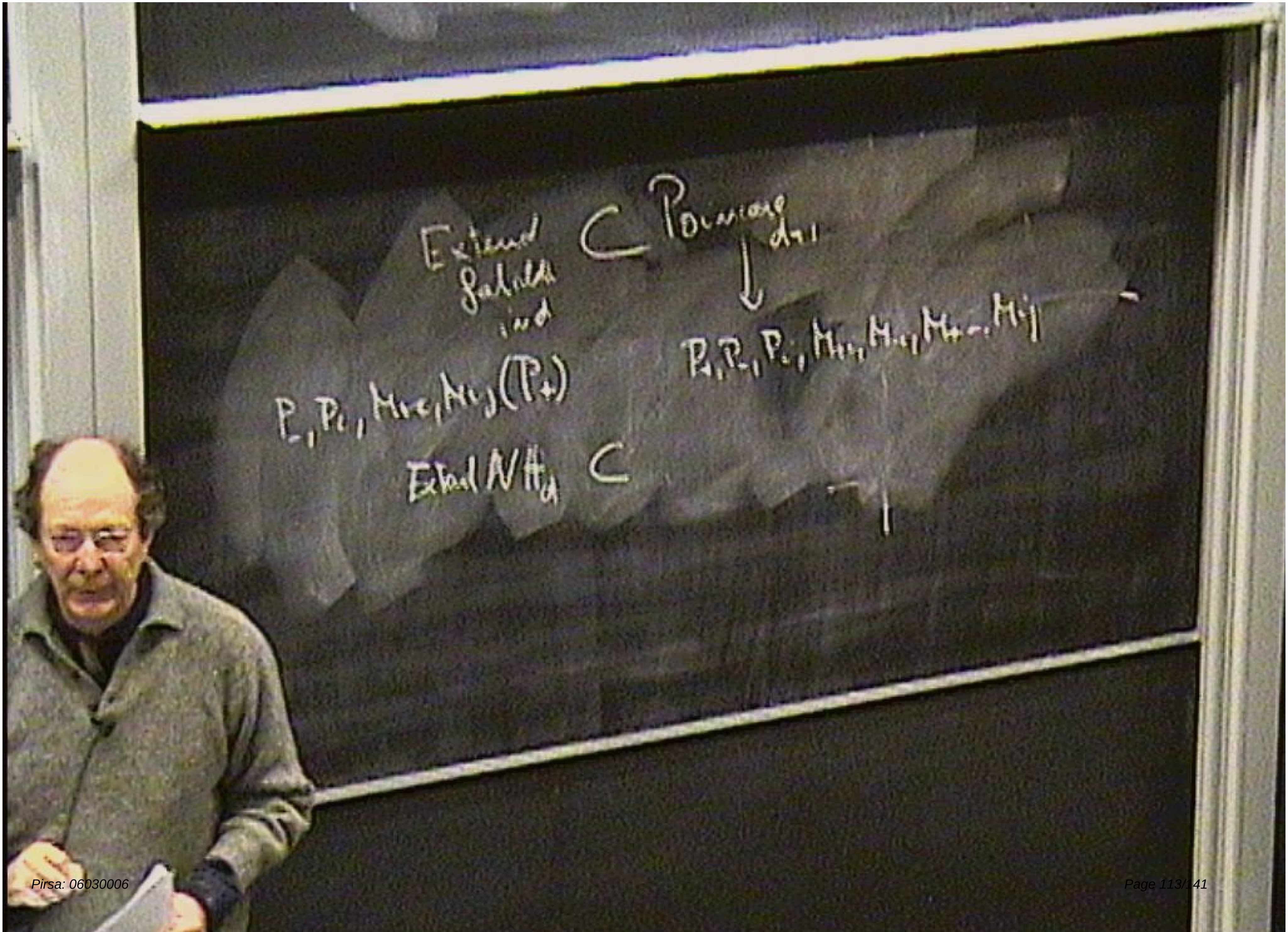
group

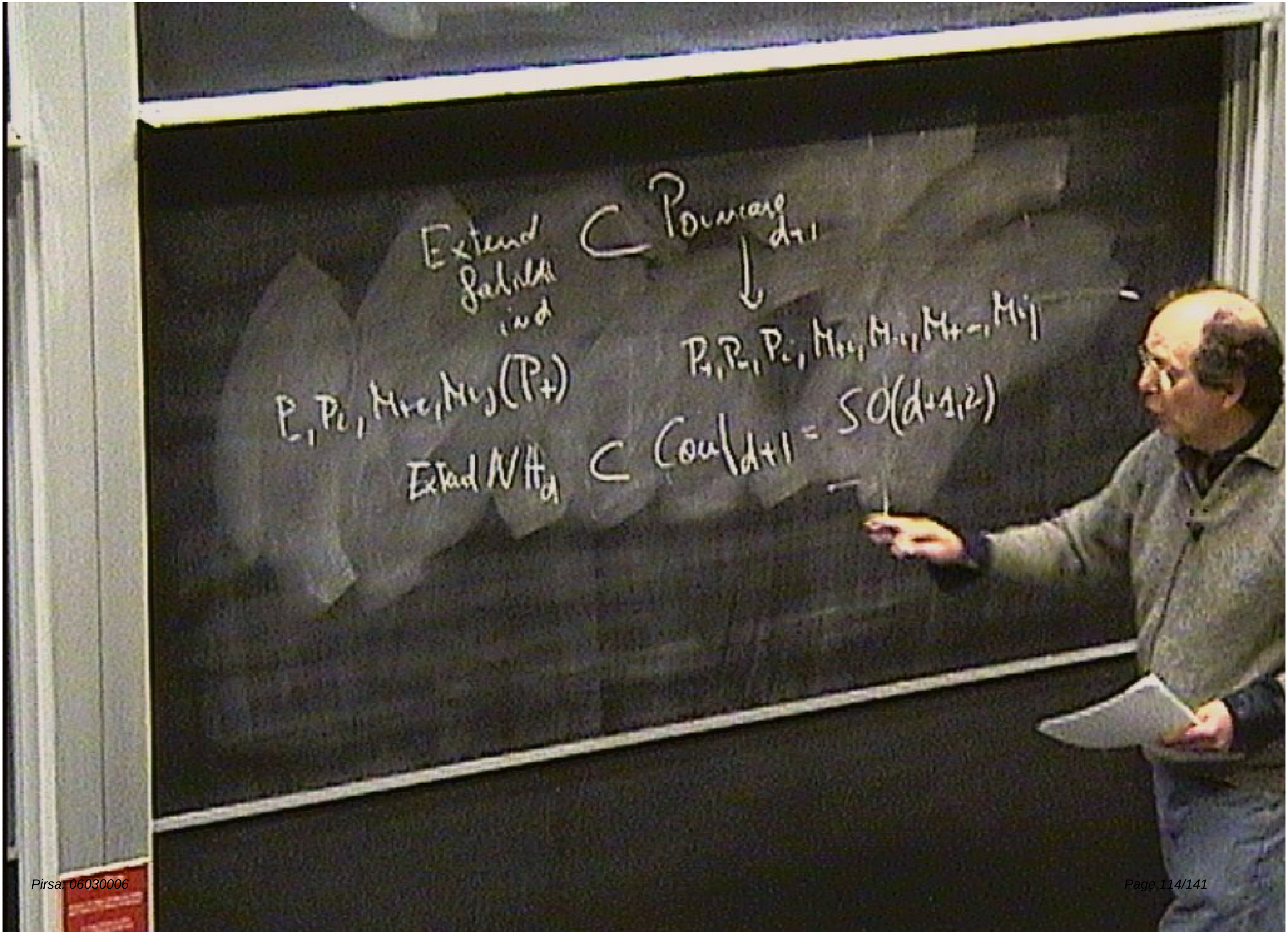

[P0, Pi] = ± i/R² M0i
[M0i, M0j] = 0
[Pi, M0j] = i z
central extension
Harmonic oscillator !
x' = x + V R sin t/R
t' = t
AdS, NH−
z → c
NH+
e^icz

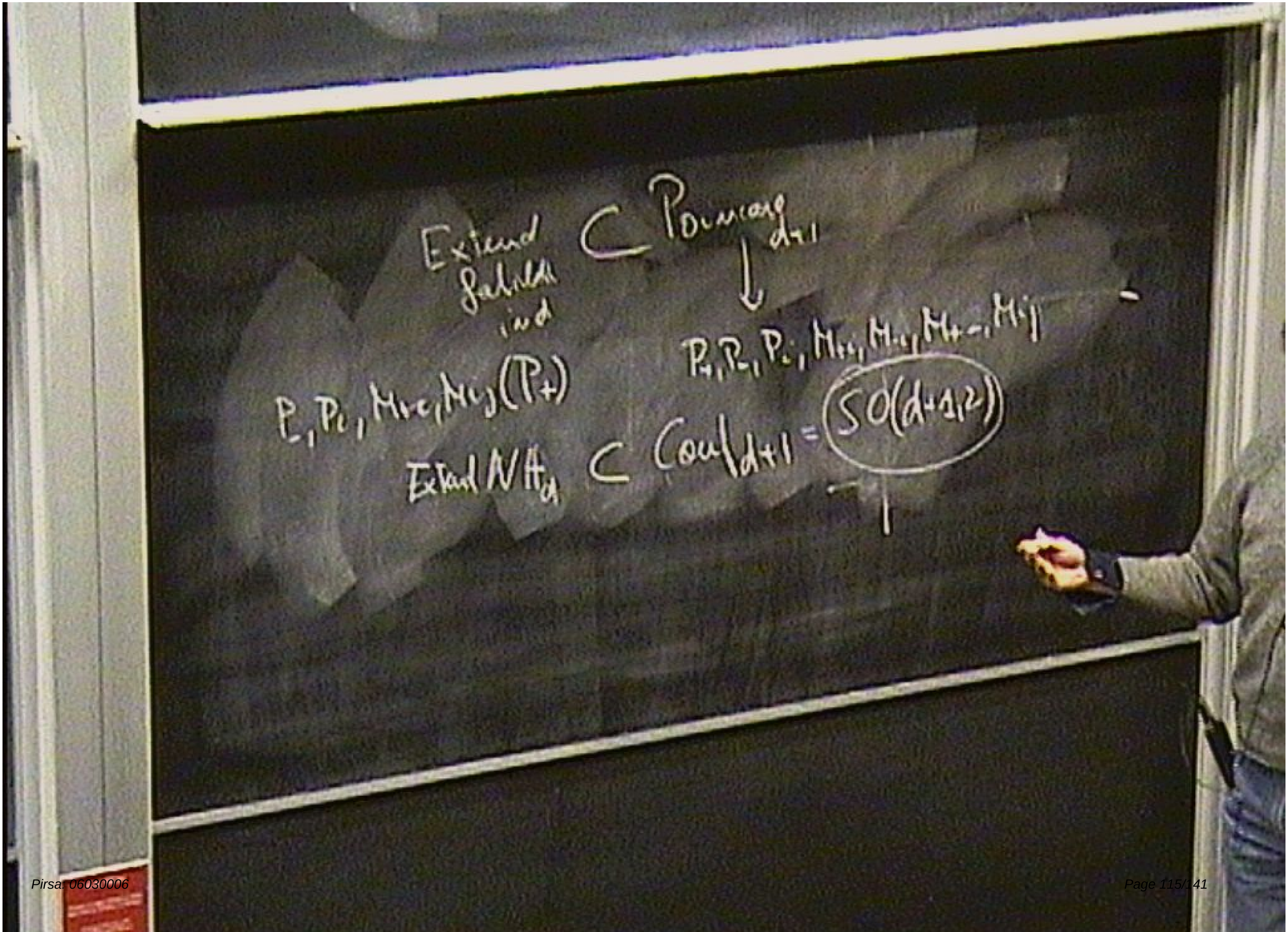

Extend
Poincare


Extend Galilean ind ⊂ Poincaré d+1
$P_+, P_-, P_i, M_{+-}, M_{+i}, M_{-i}, M_{ij}$


Extend
Poincare




Extend Galilei ind ⊂ Poincaré d+1
P+, P-, Pi, M+i, M-i, M+-, Mij
P-, Pi, M+i, Mij (P+)
Extend NHd ⊂ Conf|d+1 = SO(d+1,2)


Extend Galilean ⊂ Poincaré d+1
ind
P-, Pi, M+i, Mij (P+)
P+, P-, Pi, M+i, M-i, M+-, Mij
Extend NRd ⊂ Conf d+1 = SO(d+2,2)

Extend Galilean ind $\subset$ $\mathrm{Poincaré}_{d+1}$

$\downarrow$

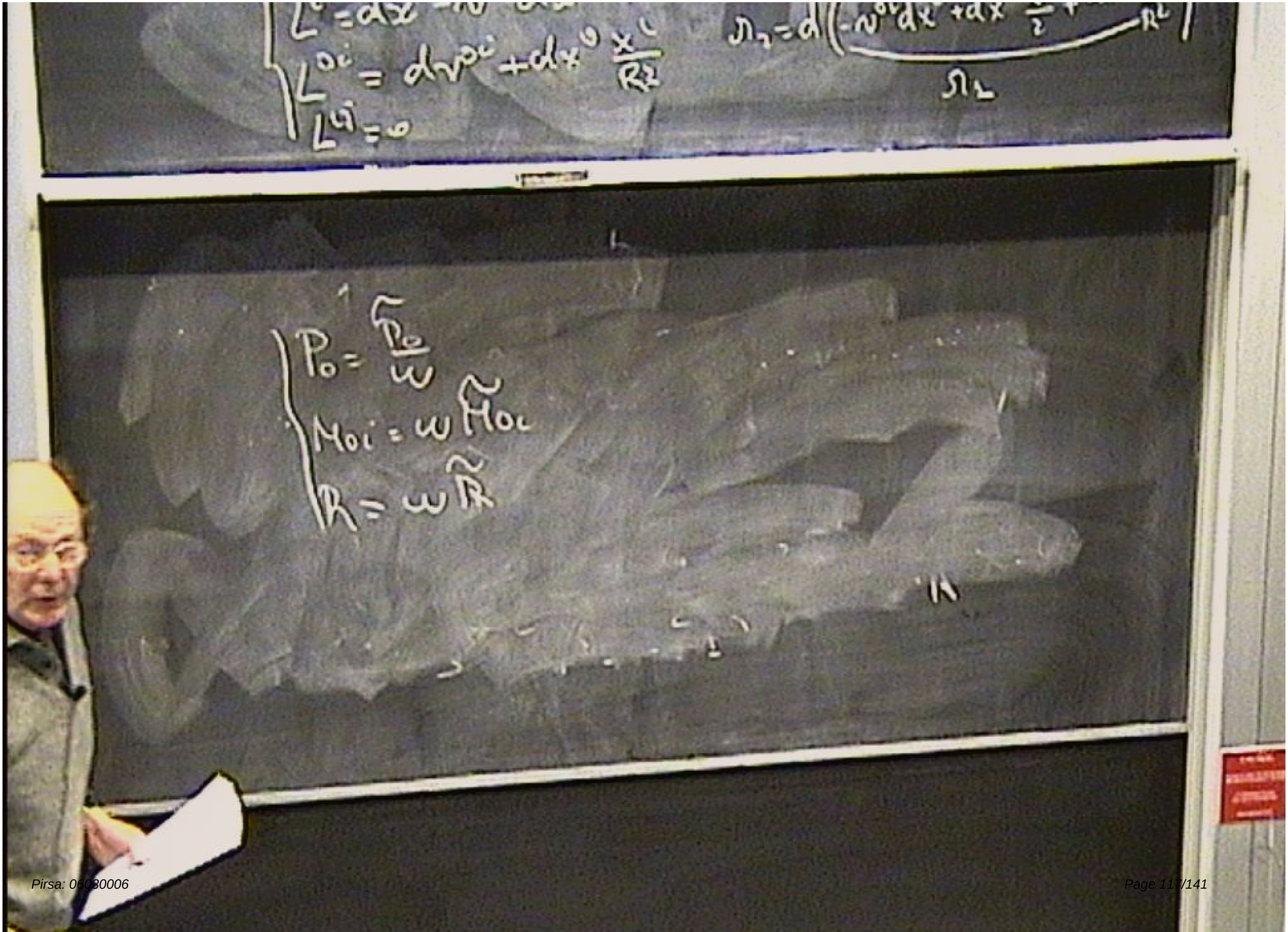
$P_+, P_-, P_i, M_{+i}, M_{-i}, M_{+-}, M_{ij}$

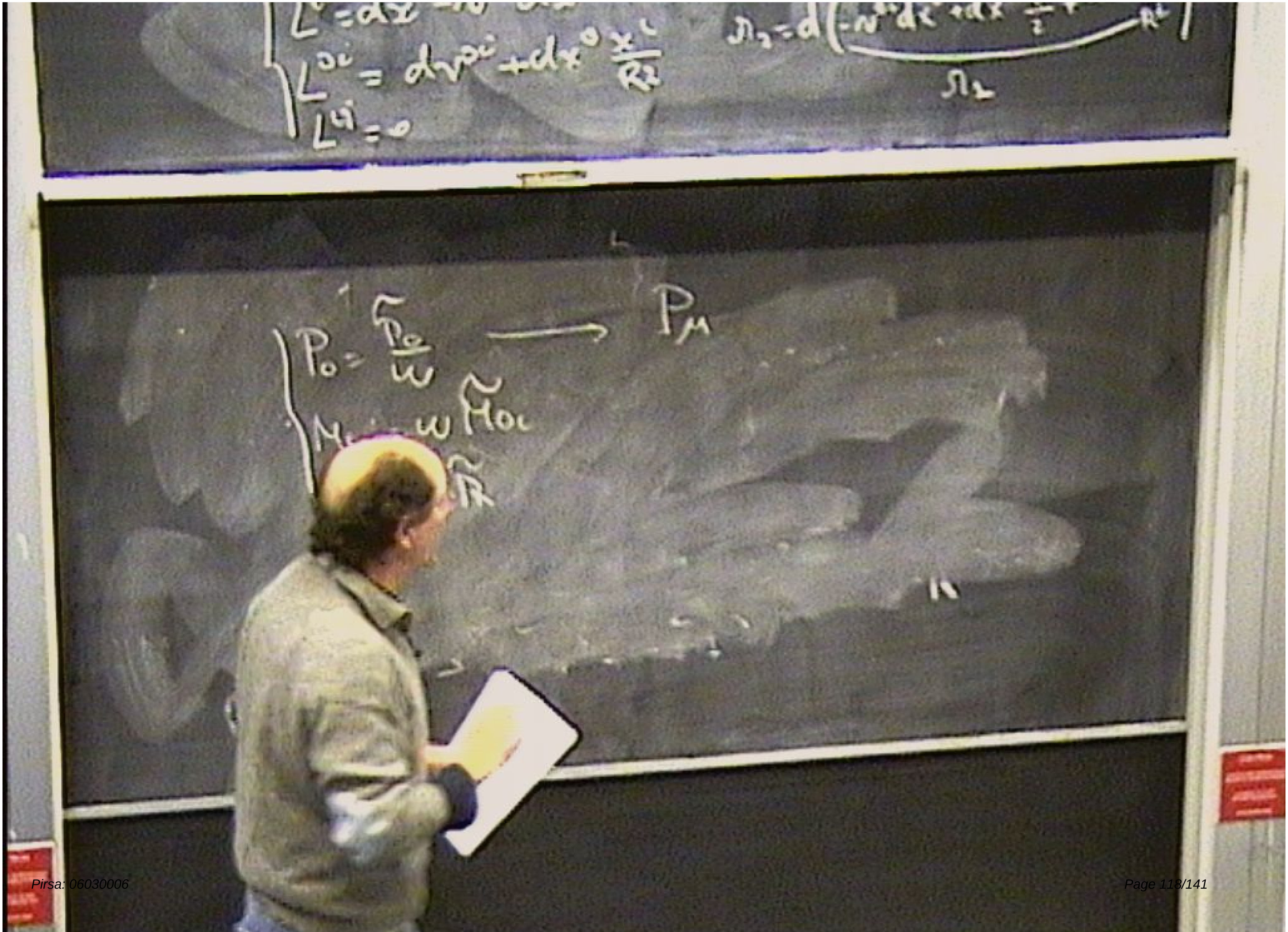
$P_-, P_i, M_{+i}, M_{ij} \, (P_+)$

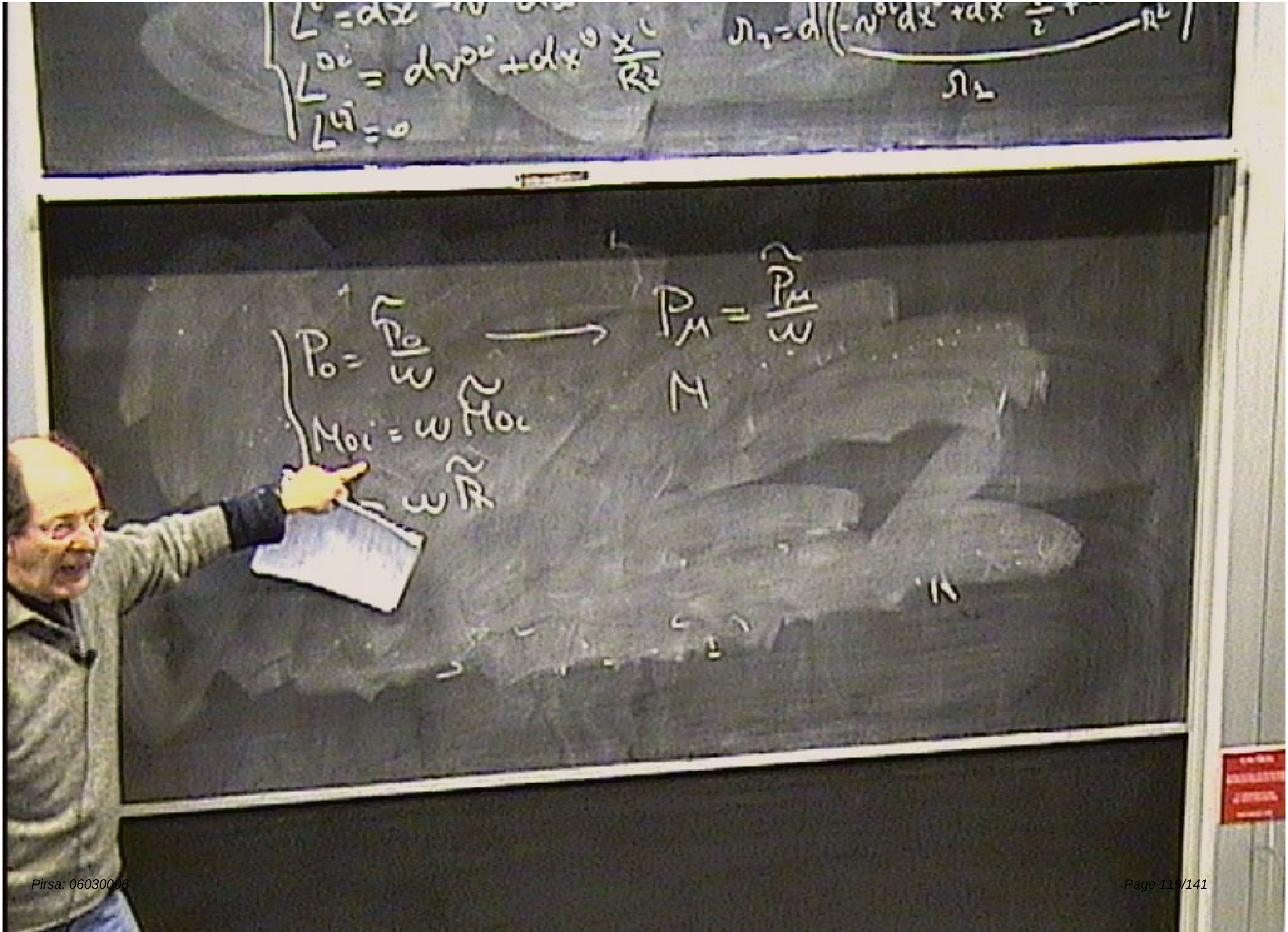
Extend NH_d $\subset$ $\mathrm{Conf}_{d+1} = SO(d+1,2)$

$- + + + + + - \mid \quad A_{\pm} = \dfrac{A_1 \pm A_0}{2}$

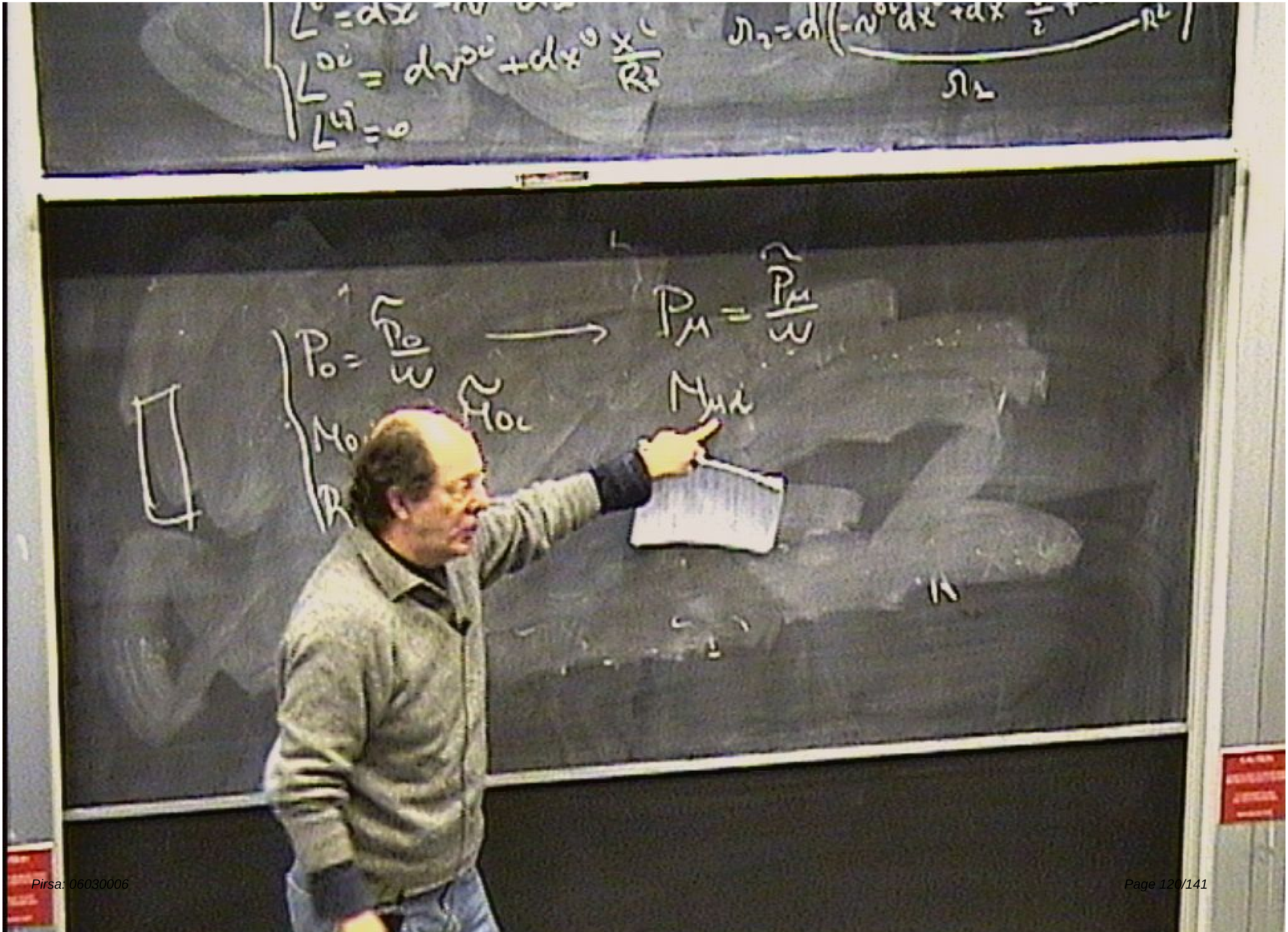
$A'_{\pm} = \dfrac{A_{d+1} \pm A_{d+2}}{2}$

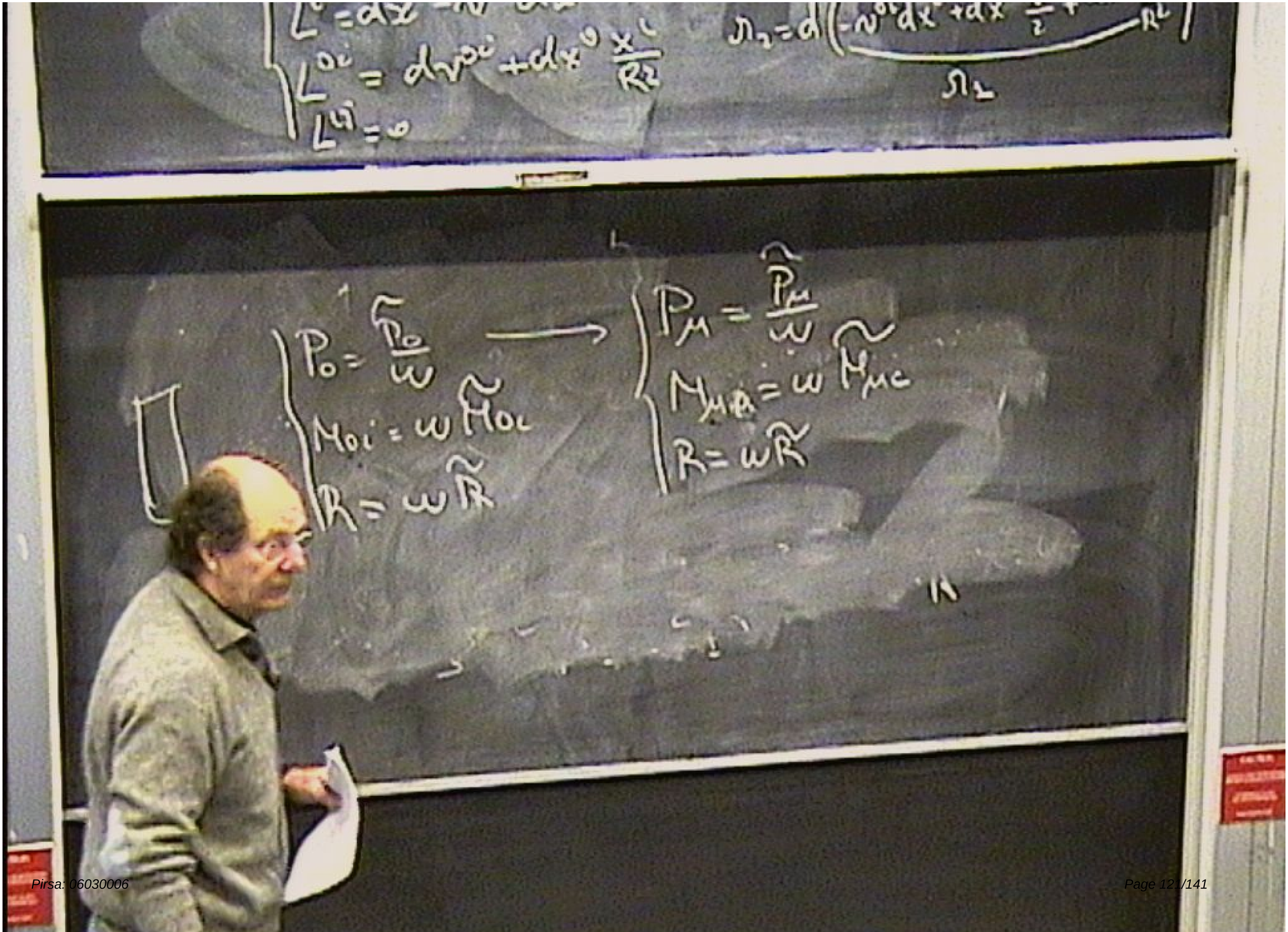

$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$\Omega_2 = d(-v^{0i} dx^i + dx^0 \ldots)$
Ω_2
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$R = \omega \tilde{R}$





$L^{0i} = d\omega^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{ij} = 0$
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$\omega \tilde{R}$
$P_\mu = \frac{\hat{P}_\mu}{\omega}$
M


P0 = P̂0 / w
Pμ = P̂μ / w
Mμi


L^{0i} = dv^{0i} + dx^0 x^i/R^2
L^{ij} = 0
Ω_2
P_0 = P̃_0/w
M_{0i} = w M̃_{0i}
R = w R̃
P_μ = P̃_μ/w
M_{μν} = w M̃_{μν}
R = w R̃

$$[M, M] = M$$

$$[M, P] = P$$

$$M_{0i} = \omega \tilde{M}_{0i}$$

$$R = \omega \tilde{R}$$

$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

$$\left[\frac{P_0}{\omega}, P_i\right] = \pm \frac{1}{\cancel{\omega} R^2} \omega \tilde{M}_{0i}$$

$$[P_0, P_i] = \pm \frac{i}{R^2} M_{0i}$$

$$[P_i, P_j] = 0$$

$$[M_{0i}, M_{0j}] = 0$$

$$[P_i, M_{0j}] = i Z$$

central extension

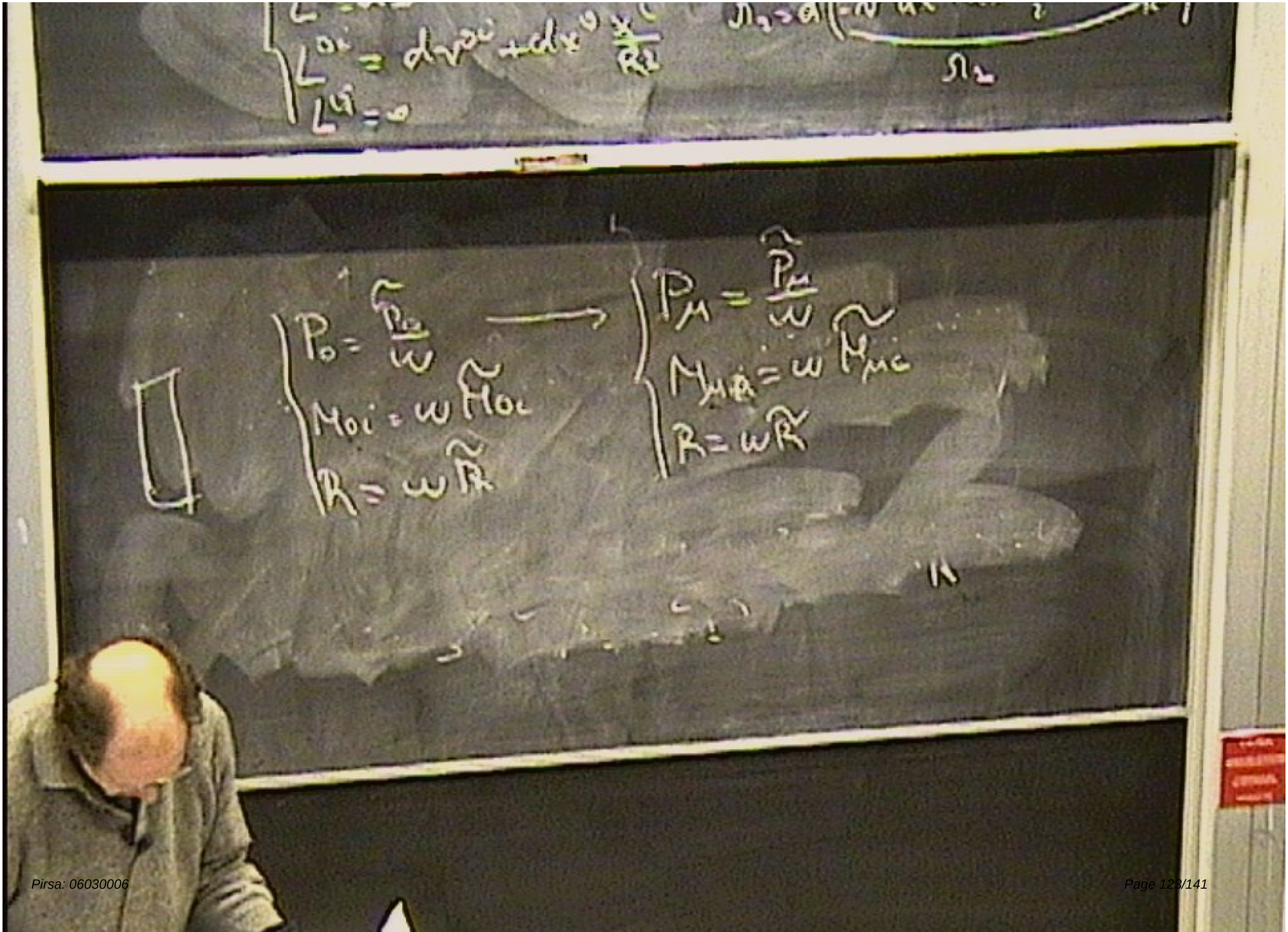
Harmonic oscillator!

$$\vec{x}' = \vec{x} + \vec{V} R \sin \frac{t}{R} \qquad AdS, NH_-$$

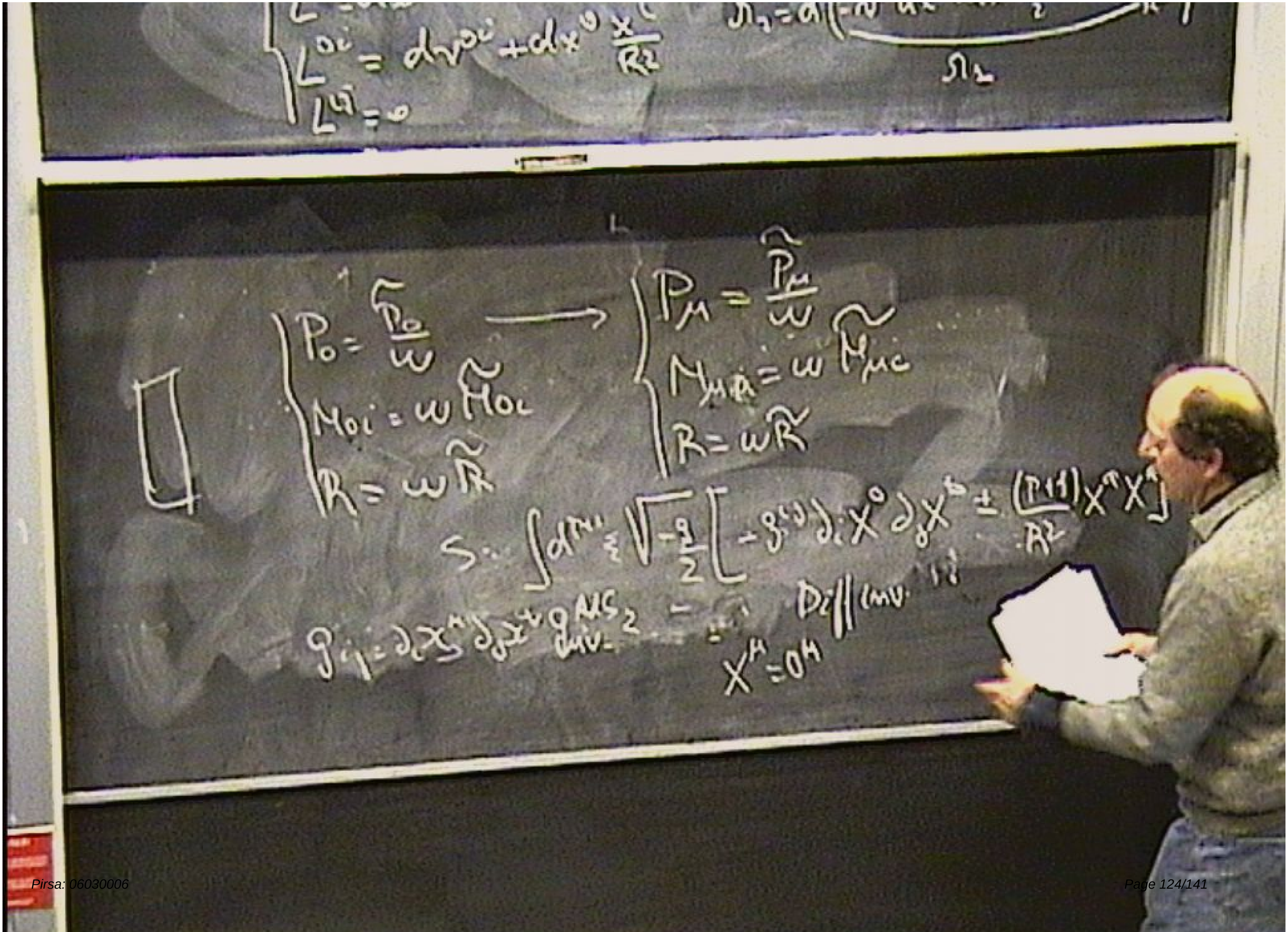
$$t' = t$$

$$Z \to c$$

NH_+ $\quad \frac{10}{11}$ $\quad e^{icZ}$



L^{0i} = dv^{0i} + dx^0 x^i/R^2
L^{ij} = 0
Ω_2
P_0 = P̃_0/w
M_{0i} = w M̃_{0i}
R = w R̃
P_μ = P̂_μ/w
M_{μν} = w M̃_{μν}
R = w R̃


Diff inv.

$$L^{0i} = d\varphi^{i} + dx^{0}\frac{x^{i}}{R^2}$$

$$L^{ij} = 0$$

Ω_2

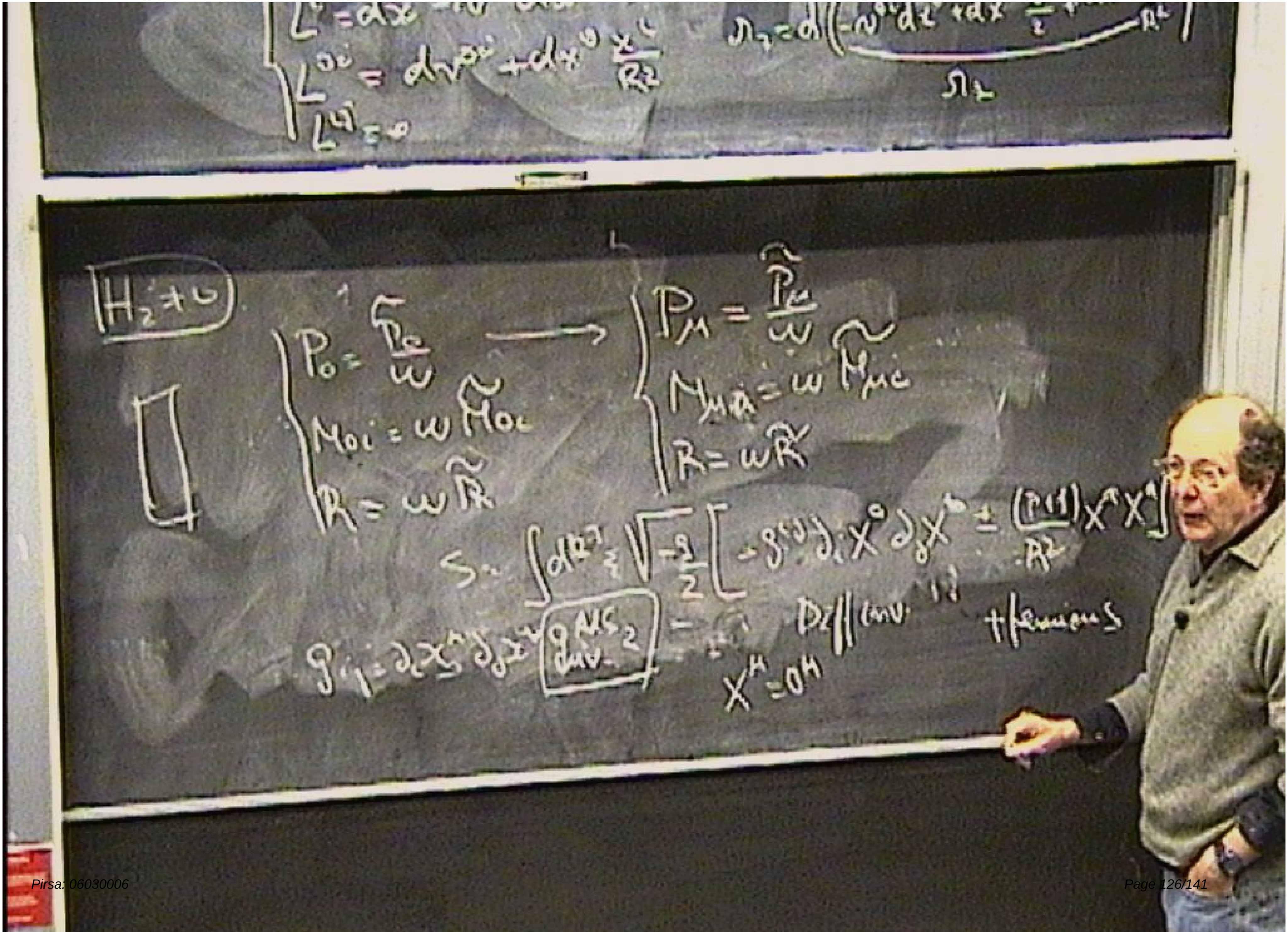
$\boxed{H_2 \neq 0}$

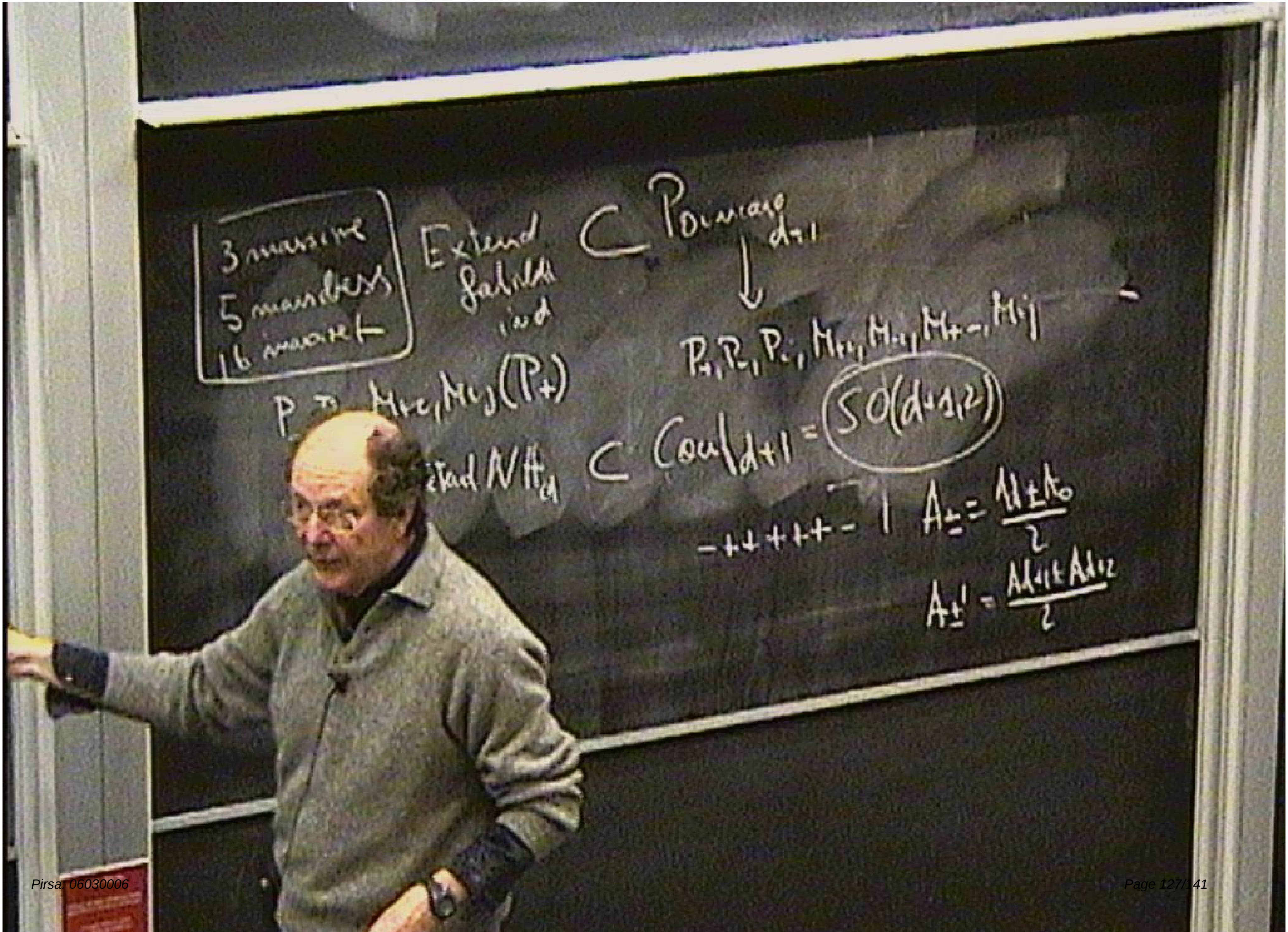
$$\begin{cases} P_0 = \frac{\tilde{P}_0}{w} \\ M_{0i} = w\,\tilde{M}_{0i} \\ R = w\tilde{R} \end{cases} \longrightarrow \begin{cases} P_\mu = \frac{\tilde{P}_\mu}{w} \\ M_{\mu\nu} = w\,\tilde{M}_{\mu\nu} \\ R = w\tilde{R} \end{cases}$$

$$S = \int d\sigma\, d\xi \sqrt{-\frac{g}{2}}\left[-g^{ij}\partial_i X^a \partial_j X^b \pm \frac{(p+1)}{R^2} X^a X^a\right]$$

$$g_{ij} = \partial_i x^\mu \partial_j x^\nu \boxed{g^{AdS_2}_{\mu\nu}}$$

$$X^\mu = 0^\mu$$


$L^{0i} = dv^{0i} + dx^0 \frac{x^i}{R^2}$
$L^{4} = 0$
Ω_2
$H_2 \neq 0$
$P_0 = \frac{\tilde{P}_0}{\omega}$
$M_{0i} = \omega \tilde{M}_{0i}$
$R = \omega \tilde{R}$
$P_\mu = \frac{\tilde{P}_\mu}{\omega}$
$M_{\mu a} = \omega \tilde{M}_{\mu a}$
$R = \omega \tilde{R}$
$S = \int d^2\xi \sqrt{-\frac{g}{2}} \left[-g^{ij} \partial_i X^a \partial_j X^b \pm \frac{(p+1)}{R^2} X^a X^a \right]$
$X^\mu = 0$
+ fermions


3 massive
Extend
Poincaré
SO(d+1,2)

$$L^0 = dx^0 - \omega^{0i} dx^i \ldots$$
$$L^{0i} = d\omega^{0i} + dx^0 \frac{x^i}{R^2}$$
$$L^{ij} = 0$$

$$\Omega_2 = d\Big(\underbrace{-\omega^{0i} dx^i + dx^0 \frac{x^2}{2} \ldots R^2}_{\Omega_2}\Big)$$

$H_2 \neq 0$

$$P_0 = \frac{\tilde{P}_0}{\omega} \longrightarrow P_\mu = \frac{\hat{P}_\mu}{\omega}$$
$$M_{0i} = \omega \tilde{M}_{0i} \qquad M_{\mu\nu} = \omega \tilde{M}_{\mu\nu}$$
$$R = \omega \tilde{R} \qquad R = \omega \tilde{R}$$

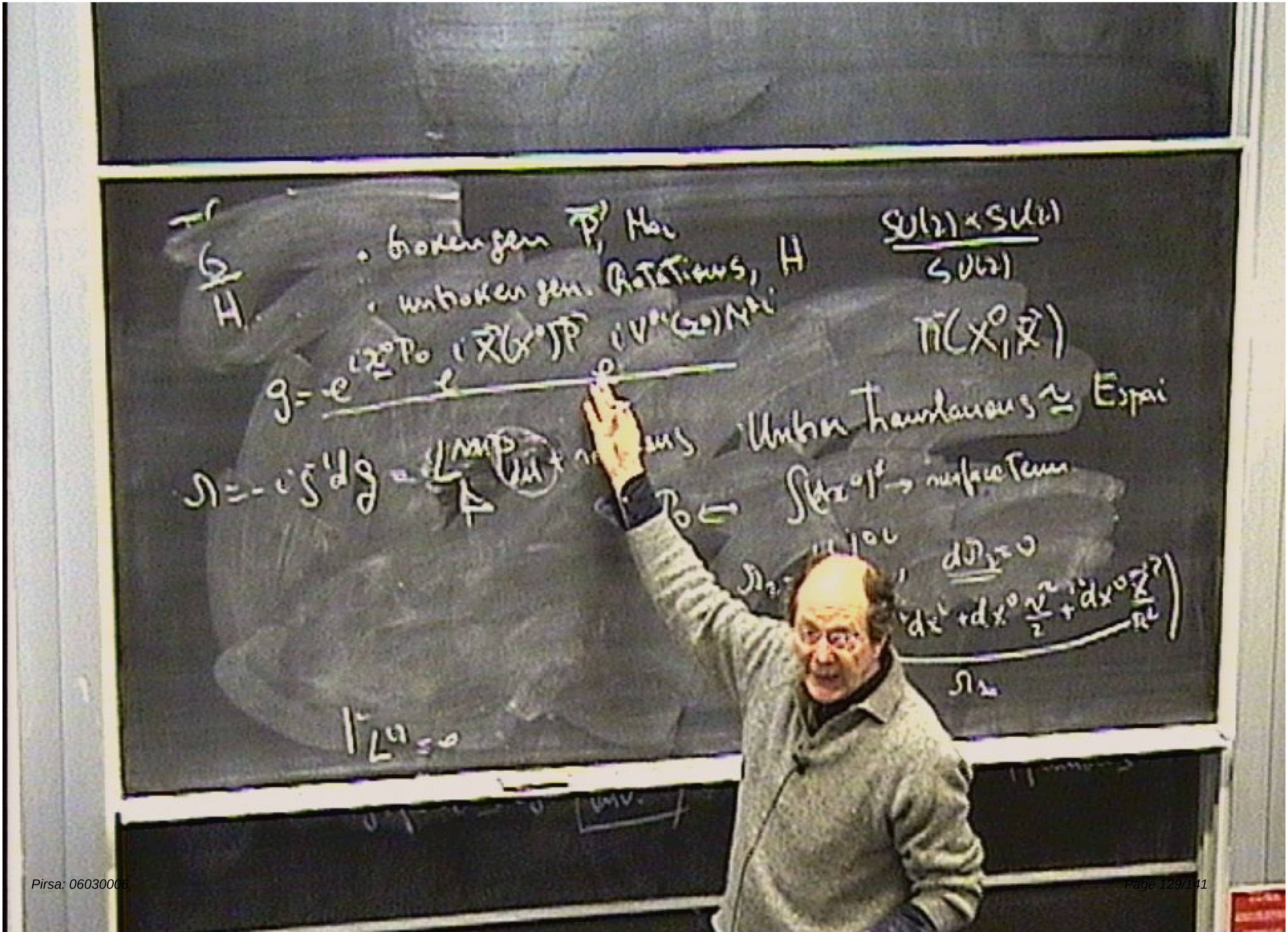
SUSY AdS_2

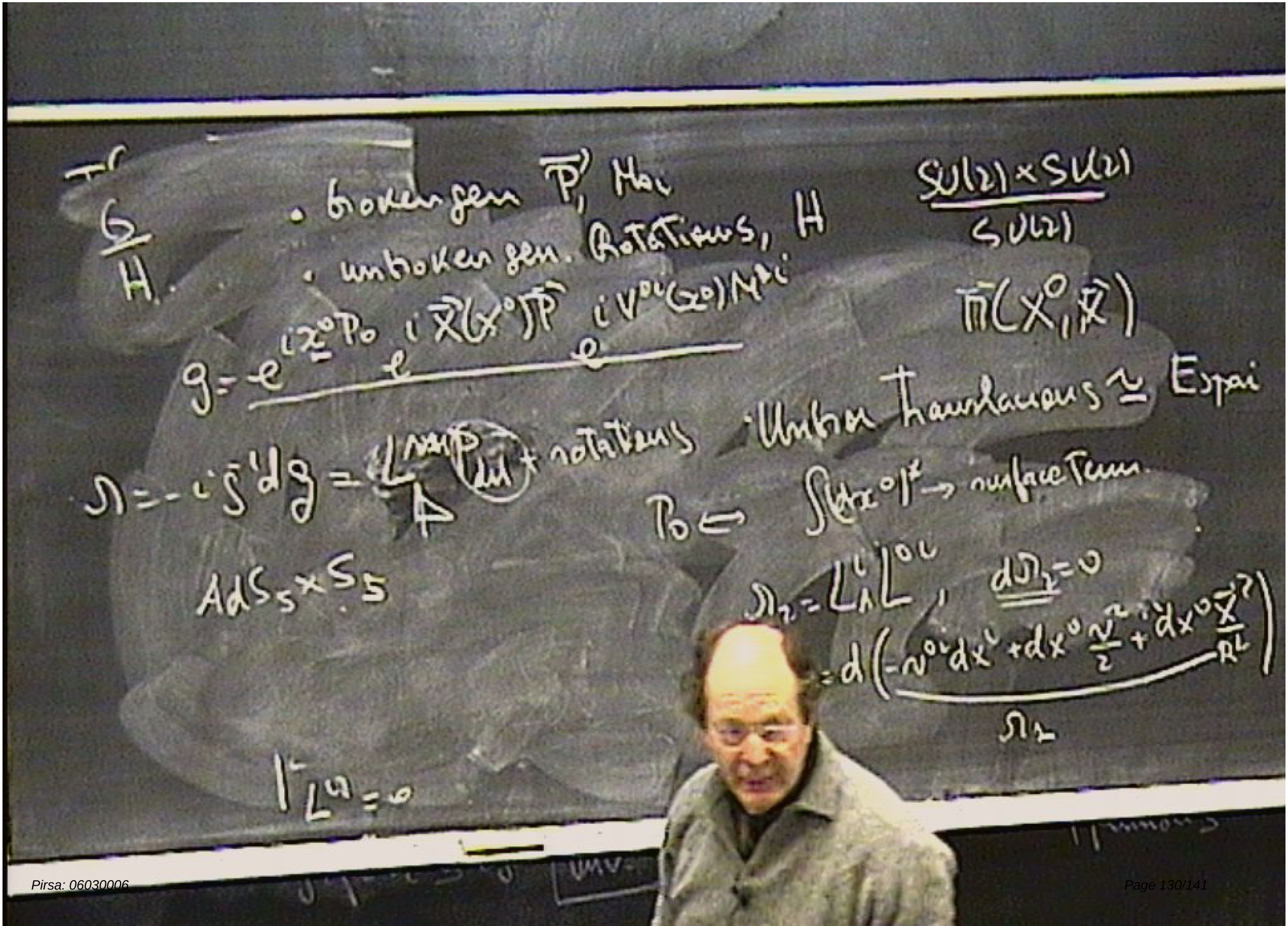
$$S \sim \int d^2\tau \sqrt{-\frac{g}{2}}\left[-g^{ij}\partial_i X^a \partial_j X^b \pm \frac{(P+1)}{R^2} X^a X^b\right]$$

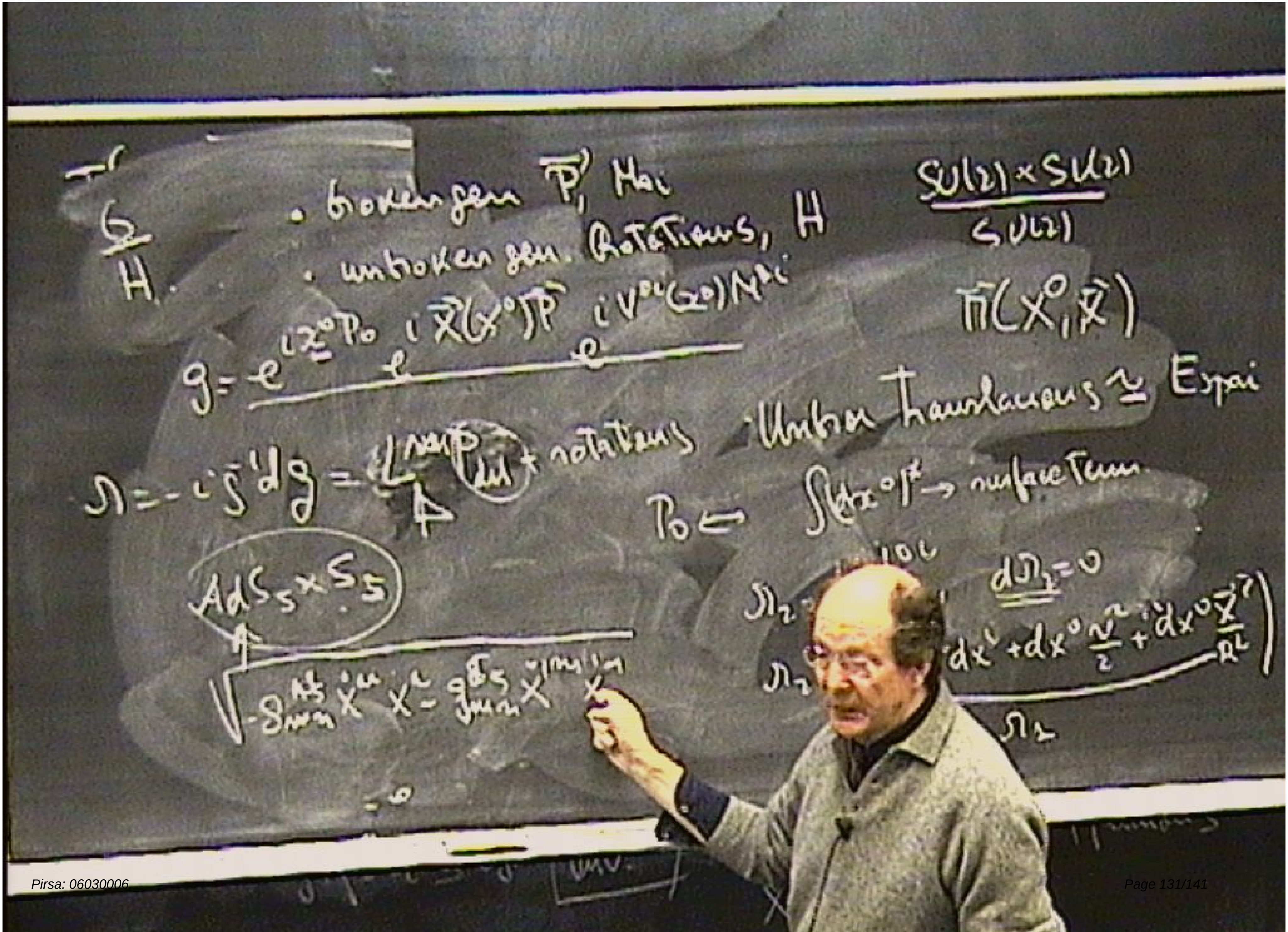
$$g_{ij} = \partial_i x^\mu \partial_j x^\nu \boxed{g^{AdS_2}_{\mu\nu}}$$

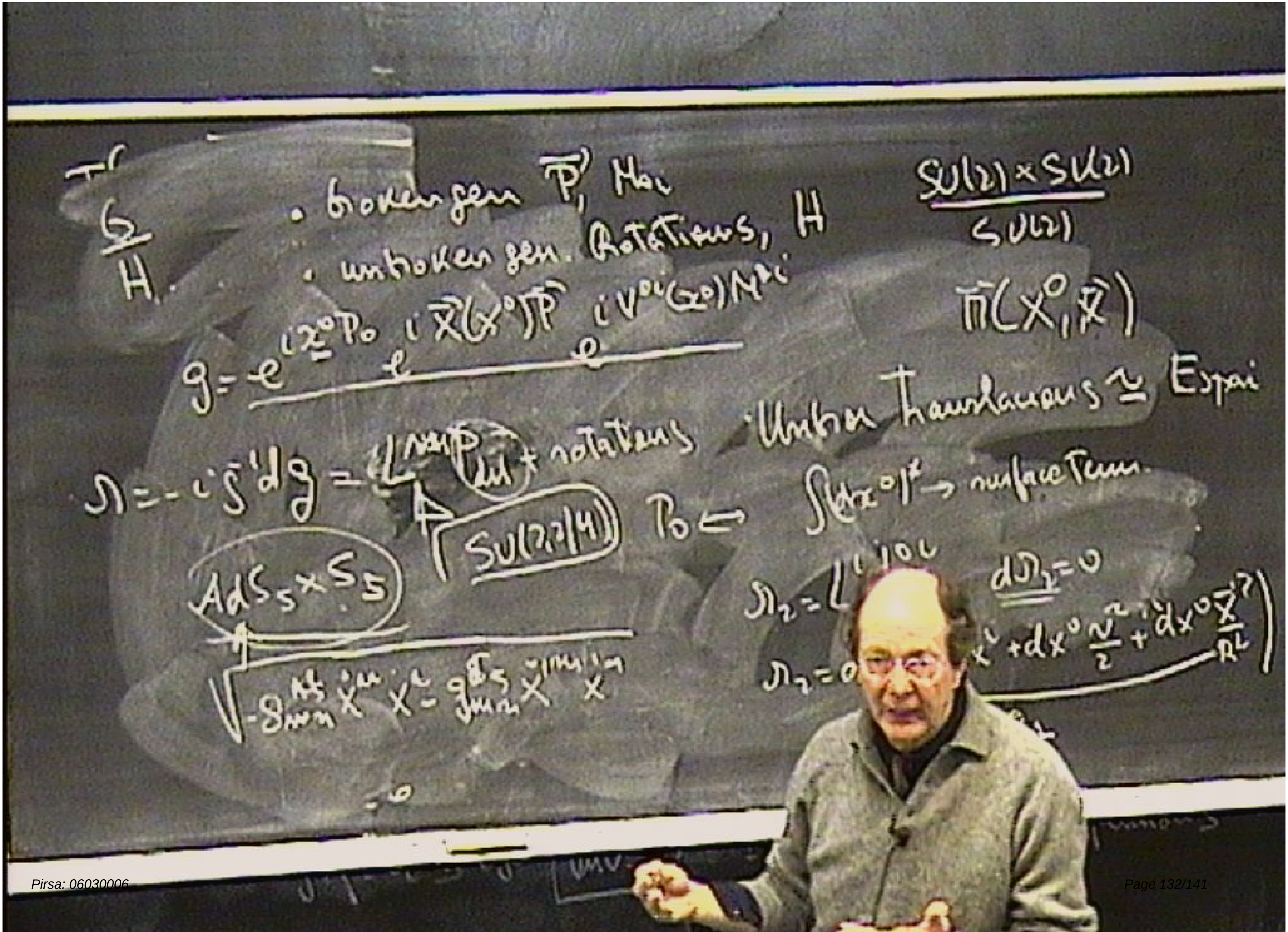
Diff inv. + fermions

$$X^\mu = 0^\mu$$


SU(2) × SU(2)
SU(2)
unbroken gen. Rotations, H
surface Term


G/H
· broken gen P, H
· unbroken gen. Rotations, H
SU(2) × SU(2) / SU(2)
rotations
surface term
AdS5 × S5


· broken gen
· unbroken gen. Rotations, H
SU(2) × SU(2)
SU(2)
+ rotations
surface term
AdS5 × S5



G/H
• broken gen P, M0i
• unbroken gen. Rotations, H
SU(2) × SU(2) / SU(2)
π(x0, x)
g = e^{ix0P0} e^{iX(x0)P} e^{iv0i(x0)M0i}
Unbr. translations
rotations
SU(2,2|4)
AdS5 × S5
surface term
dΩ2 = 0

$\frac{G}{H}$ • broken gen $\vec{P}$, M_{0i}

• unbroken gen. Rotations, H

$$g = e^{i x^0 P_0} e^{i \vec{X}(x^0)\vec{P}} e^{i V^{0i}(x^0) M^{0i}}$$

$$\Omega = -i g^{-1} dg = L^{\mu} P_{\mu} + \text{rotations}$$

AdS$_5 \times S_5$ $\quad$ $SU(2,2|4)$ $\quad$ $P_0 \Leftarrow$

$$\sqrt{-g^{AdS}_{mn} \dot{X}^m \dot{X}^n - g^{S_5}_{mn} \dot{X}^m \dot{X}^n}$$

$$\frac{SU(2) \times SU(2)}{SU(2)}$$

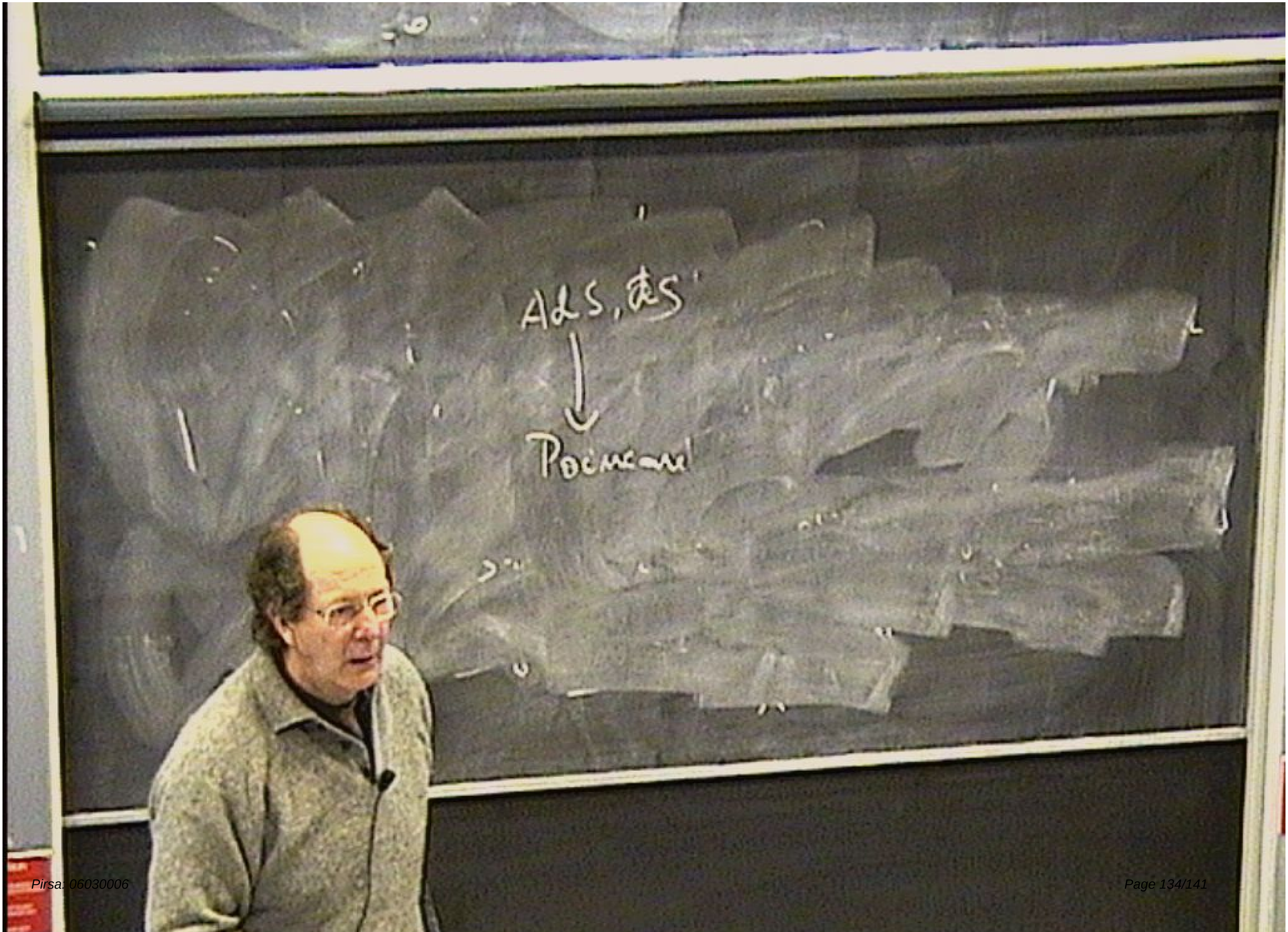
$\pi(X^0, \vec{x})$

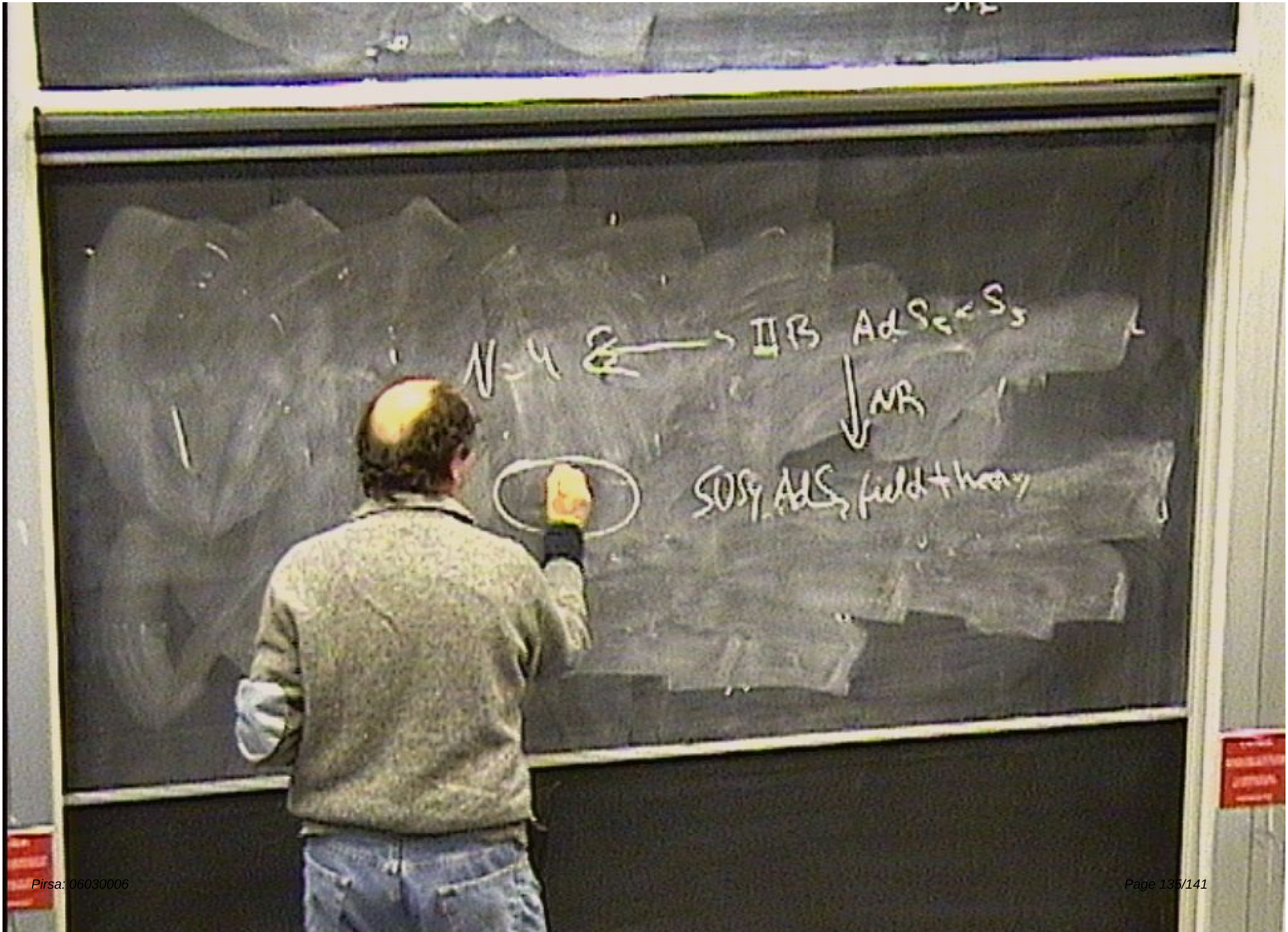
Unbroken translations $\simeq$ Espai

$\int (\partial x^0)^2 \rightarrow$ surface term

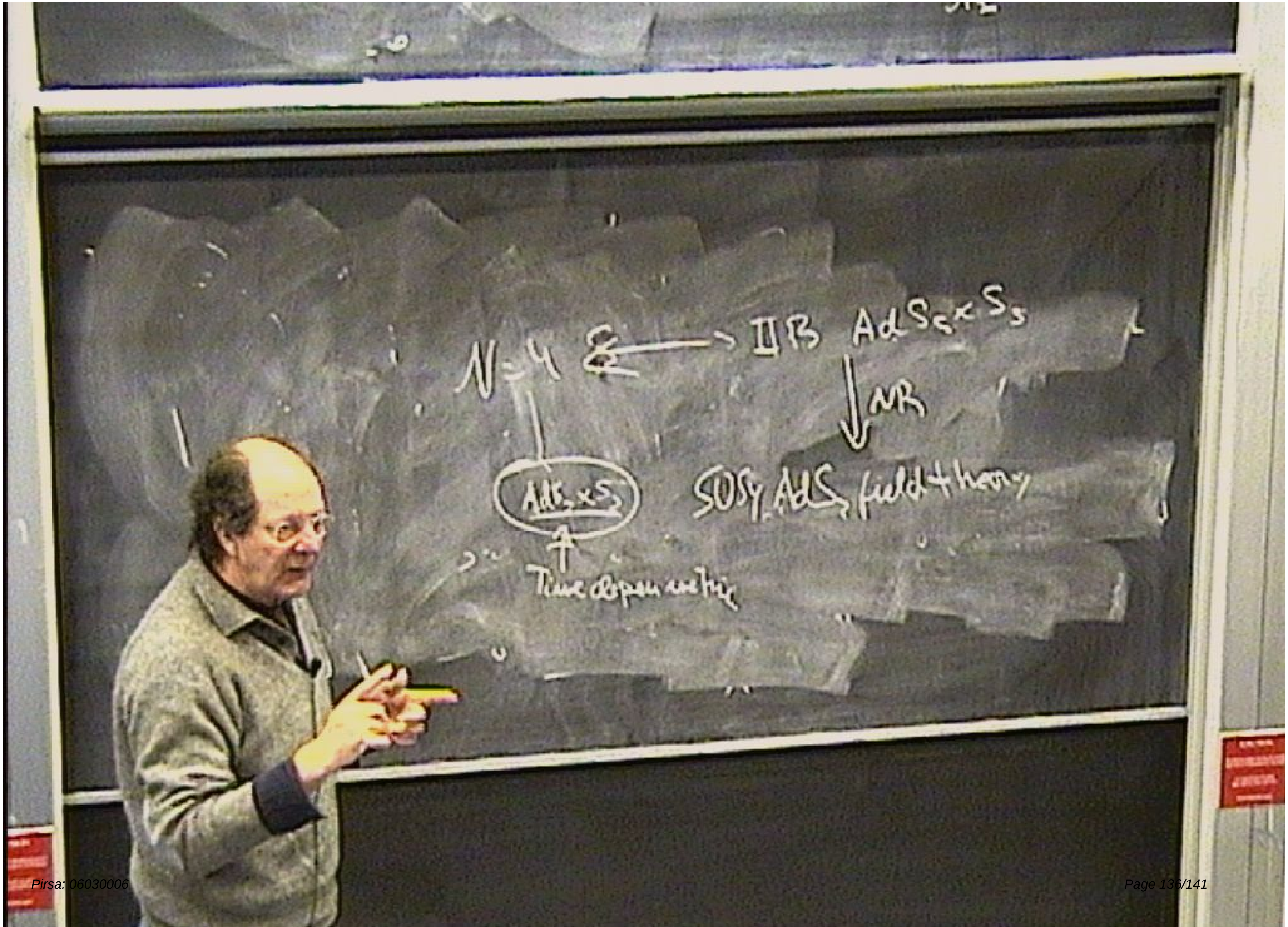
$\Omega_2 = L^i_\wedge L^{0i}$, $\quad d\Omega_2 = 0$

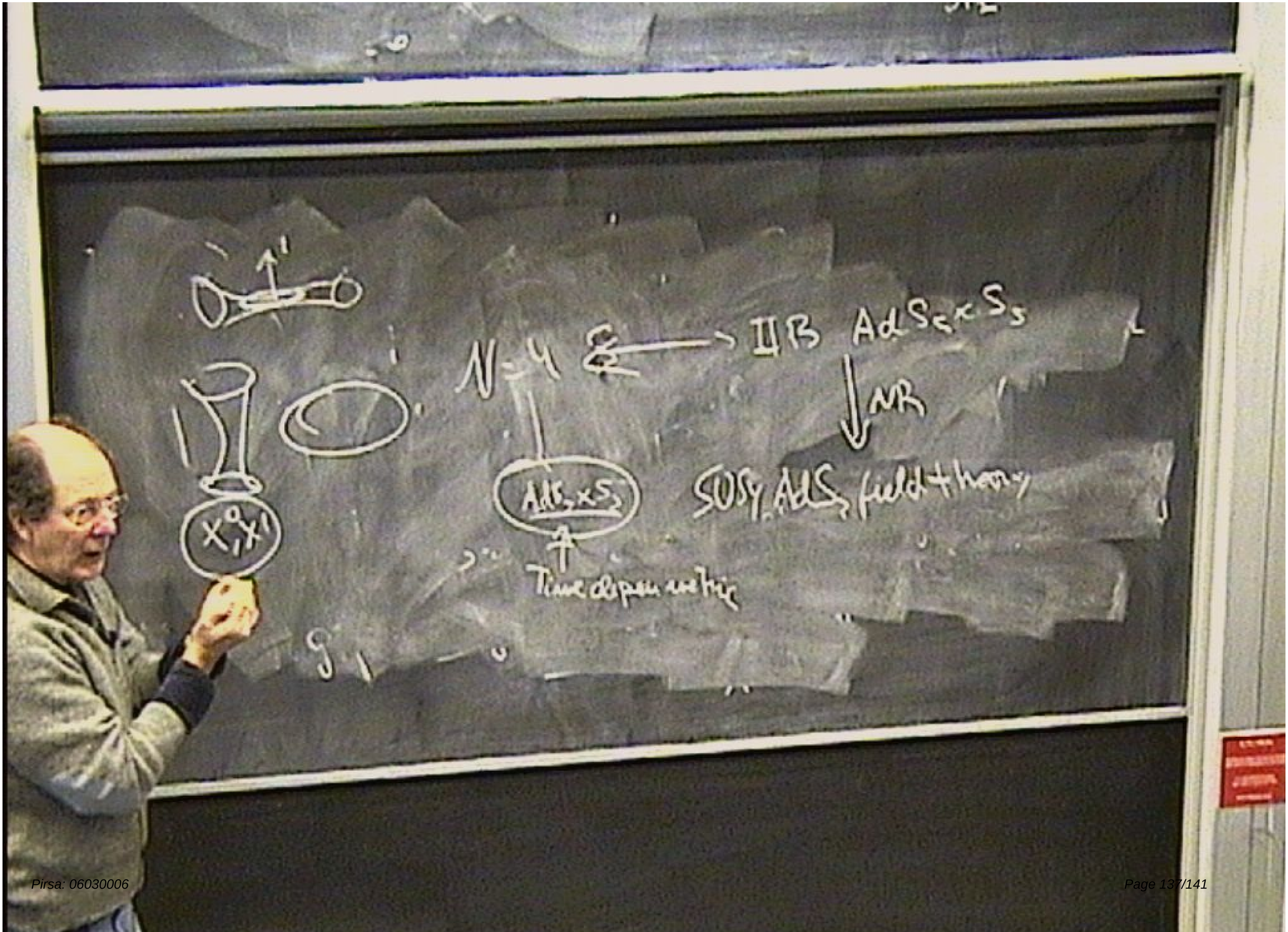
$$\Omega_2 = d\Big(\underbrace{-v^{0i} dx^i + dx^0 \frac{v^2}{2} + dx^0 \frac{\vec{X}^2}{R^2}}_{\Omega_1}\Big)$$

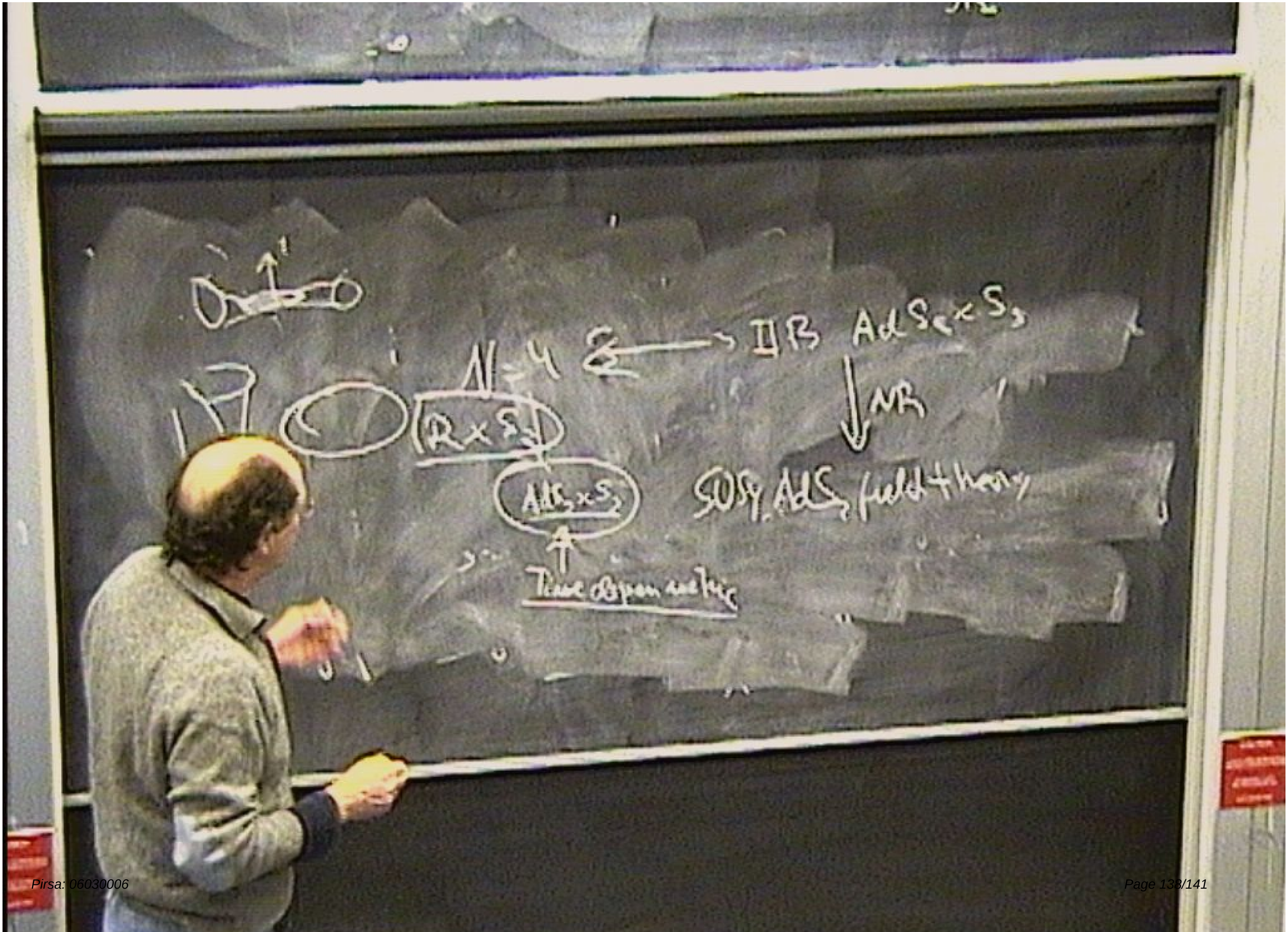

AdS, dS
Poincaré

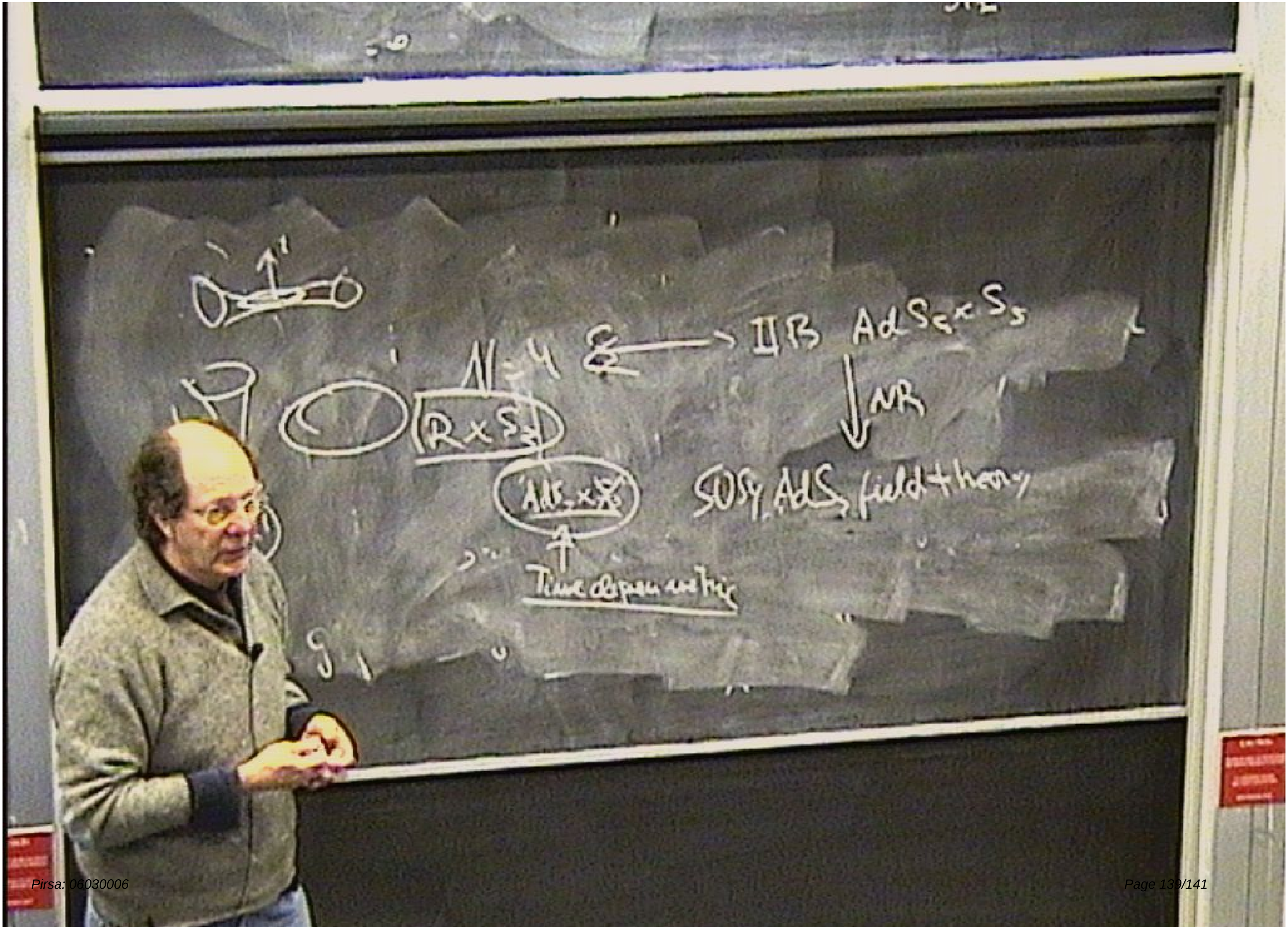


N=4 ⟷ IIB AdS5×S5
NR
SUSY AdS5 field theory

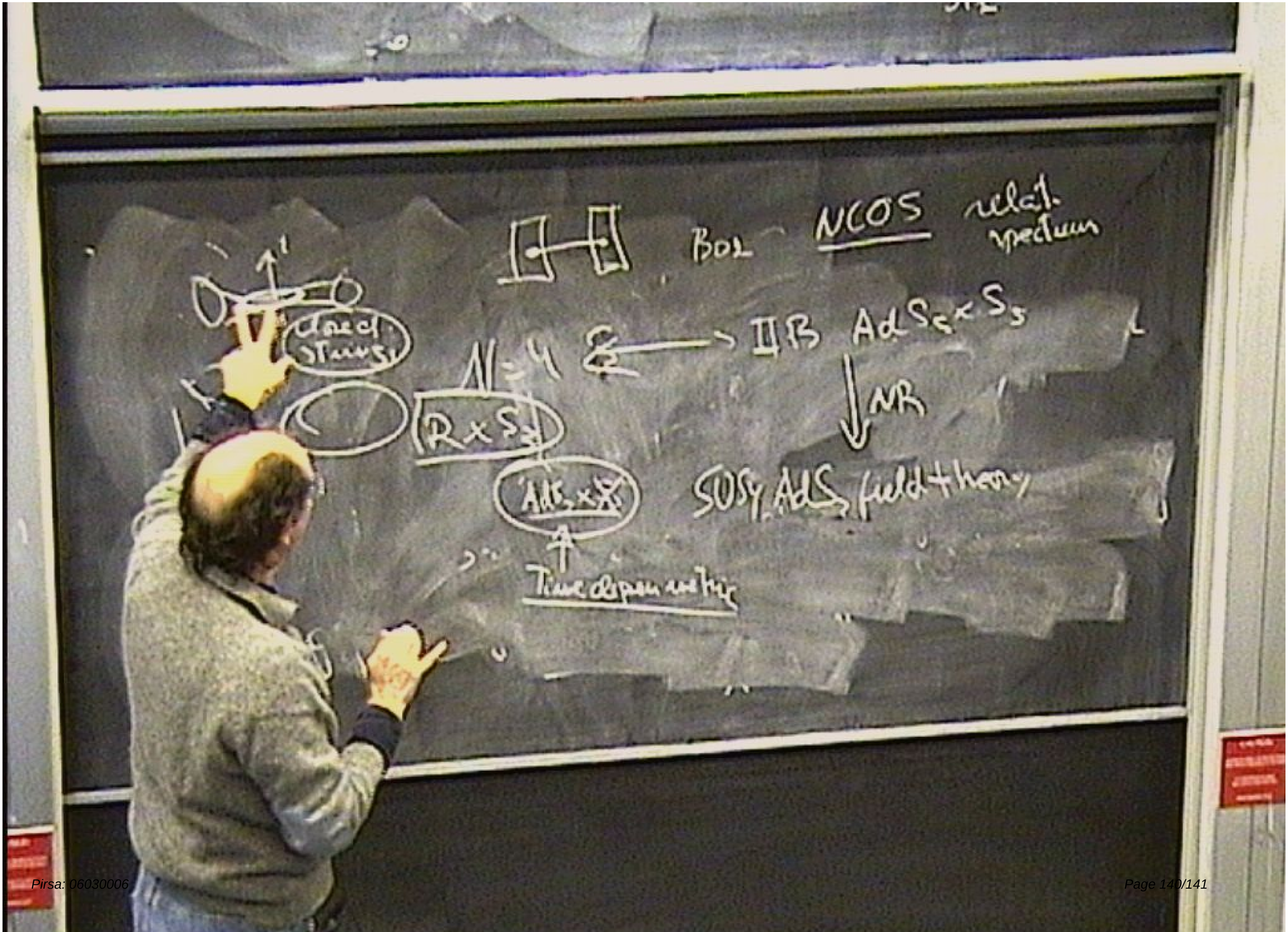

N=4
IIB AdS5×S5
NR
SUSY AdS2 field theory
AdS2×S2

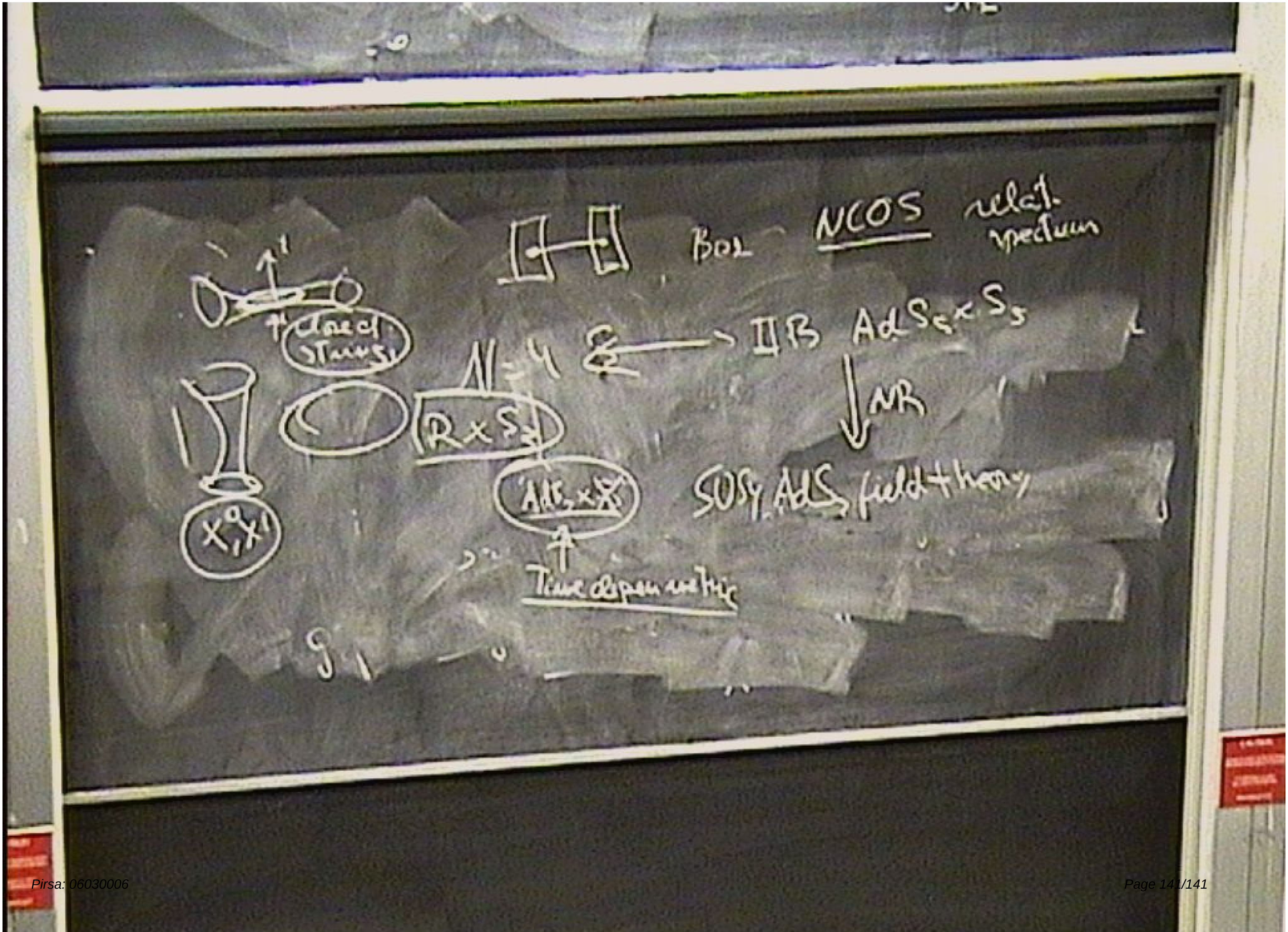

N=4
IIB AdS5×S5
NR
SUSY AdS2 field theory
AdS2×S2
Time dependent metric
X0, X1


N=4
IIB AdS5 × S5
NR
R × S3
SUSY AdS5 field theory



IIB AdS5 × S5
N = 4
NR
R × S3
SUSY AdS2 field theory


NCOS
Box
IIB AdS5 × S5
NR
SUSY AdS5 field theory
R × S3
Time dependent metric


NCOS
spectrum
closed strings
IIB AdS5 x S5
NR
R x S3
SUSY AdS5 field theory
Time dependent metric