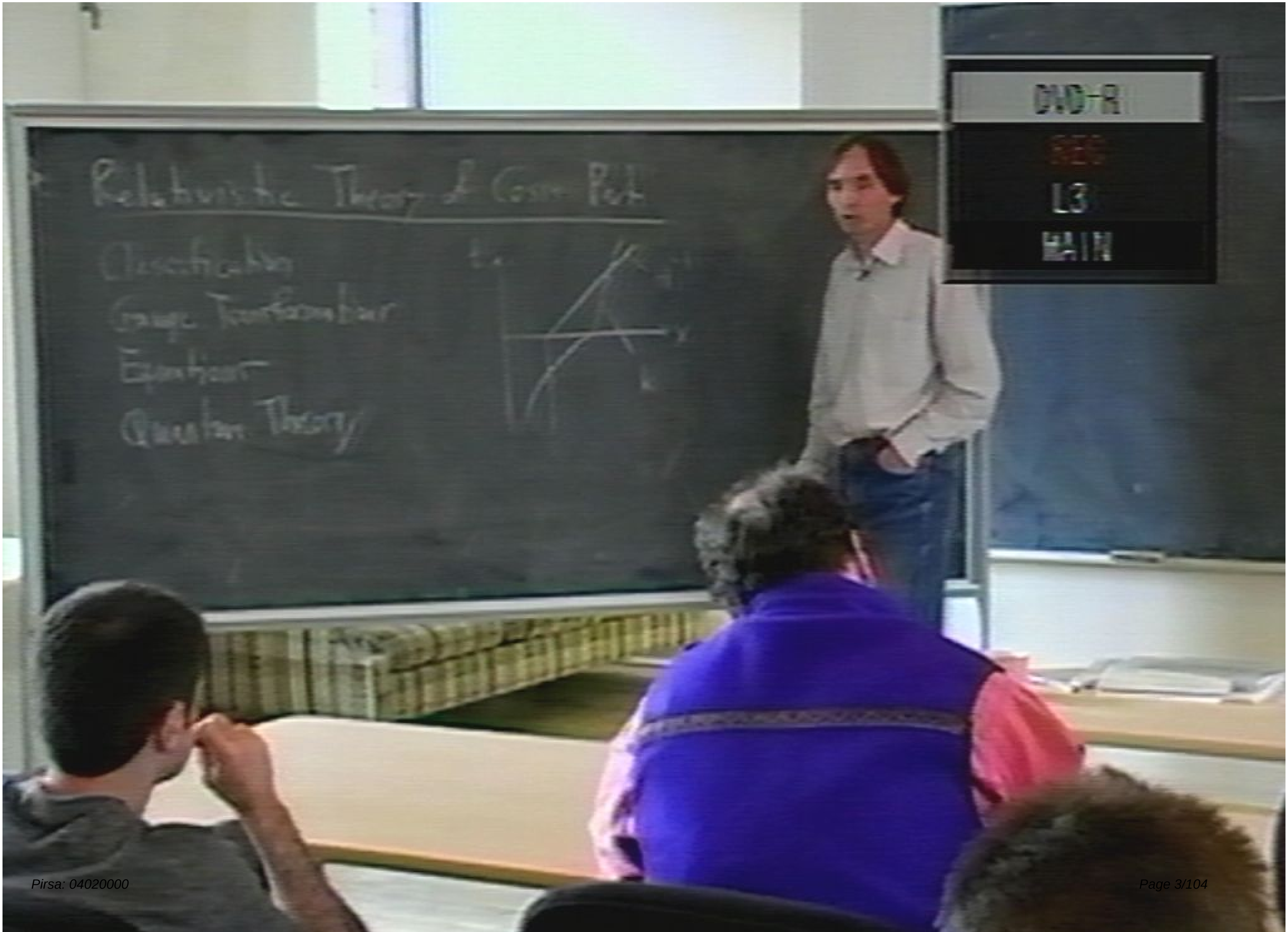
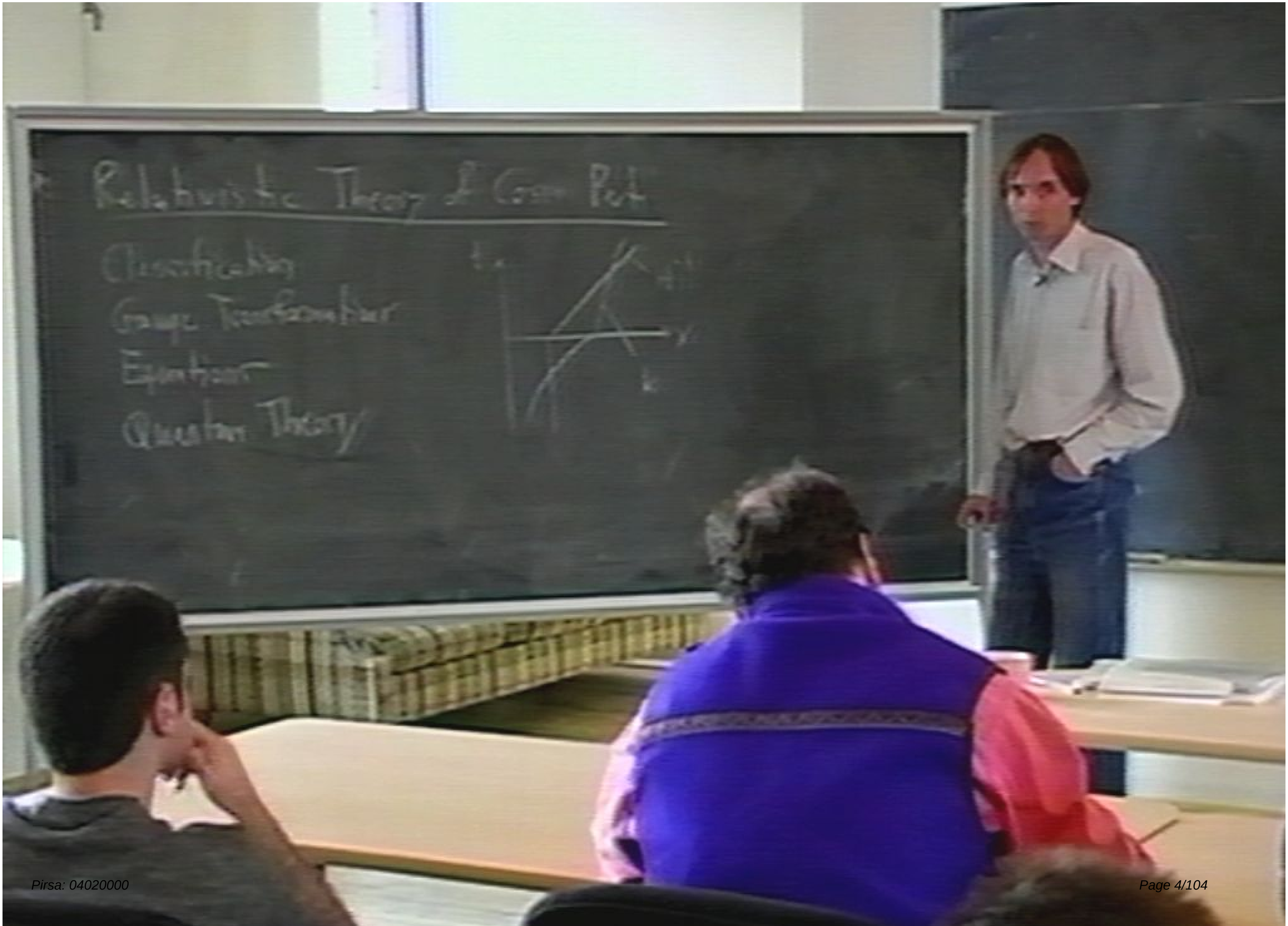
Title: Theory of Cosmological Perterbations - Final

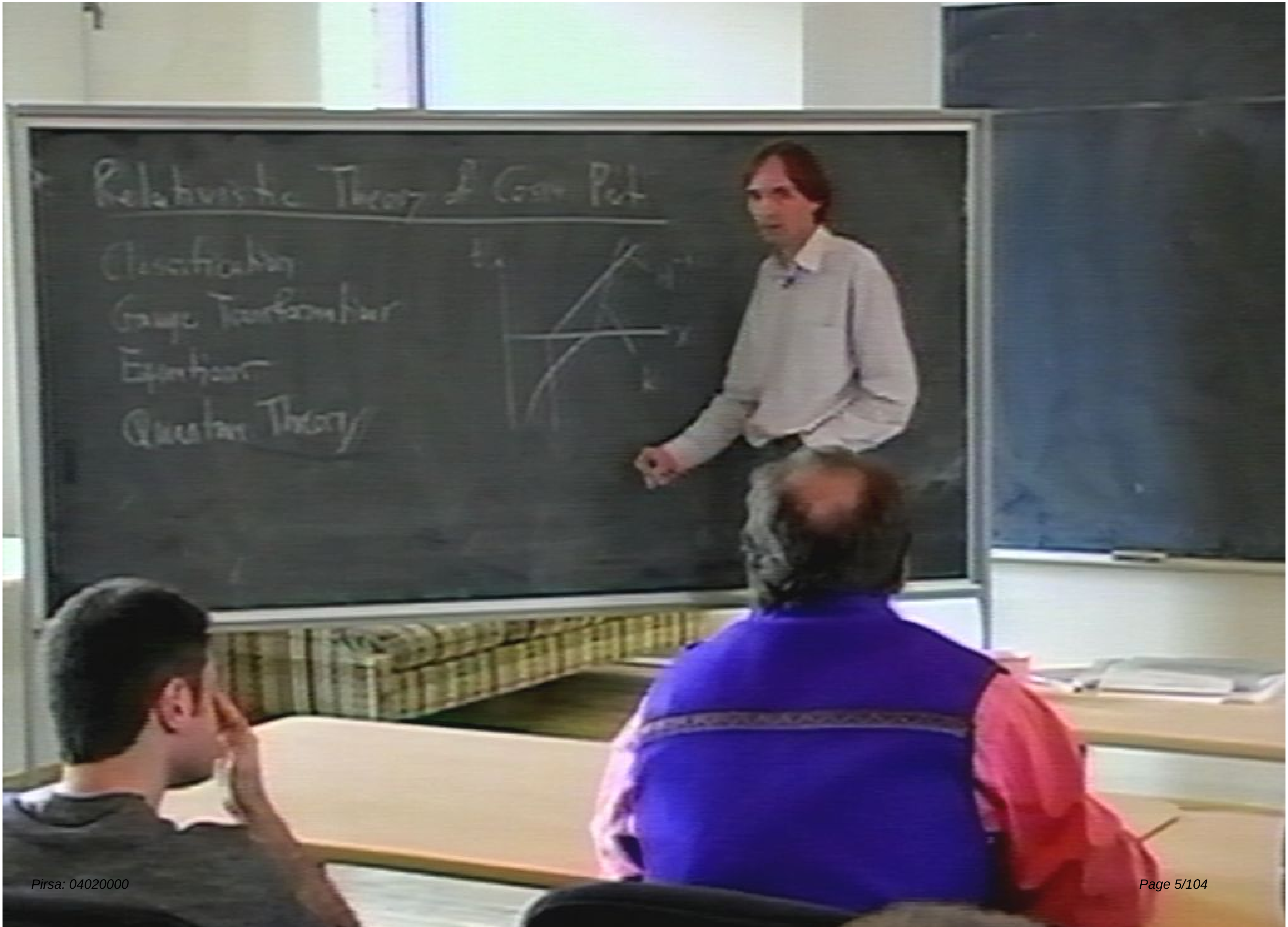
Date: Feb 20, 2004 03:30 PM

URL: http://pirsa.org/04020000

Abstract:


Relativistic Theory of Cosm Pert
Classification
Gauge Transformation
Equations
Quantum Theory
DVD-R
L3
MAIN


Classification
Gauge Transformation
Equations
Quantum Theory


Relativistic Theory of Cosm Pert
Classification
Gauge Transformation
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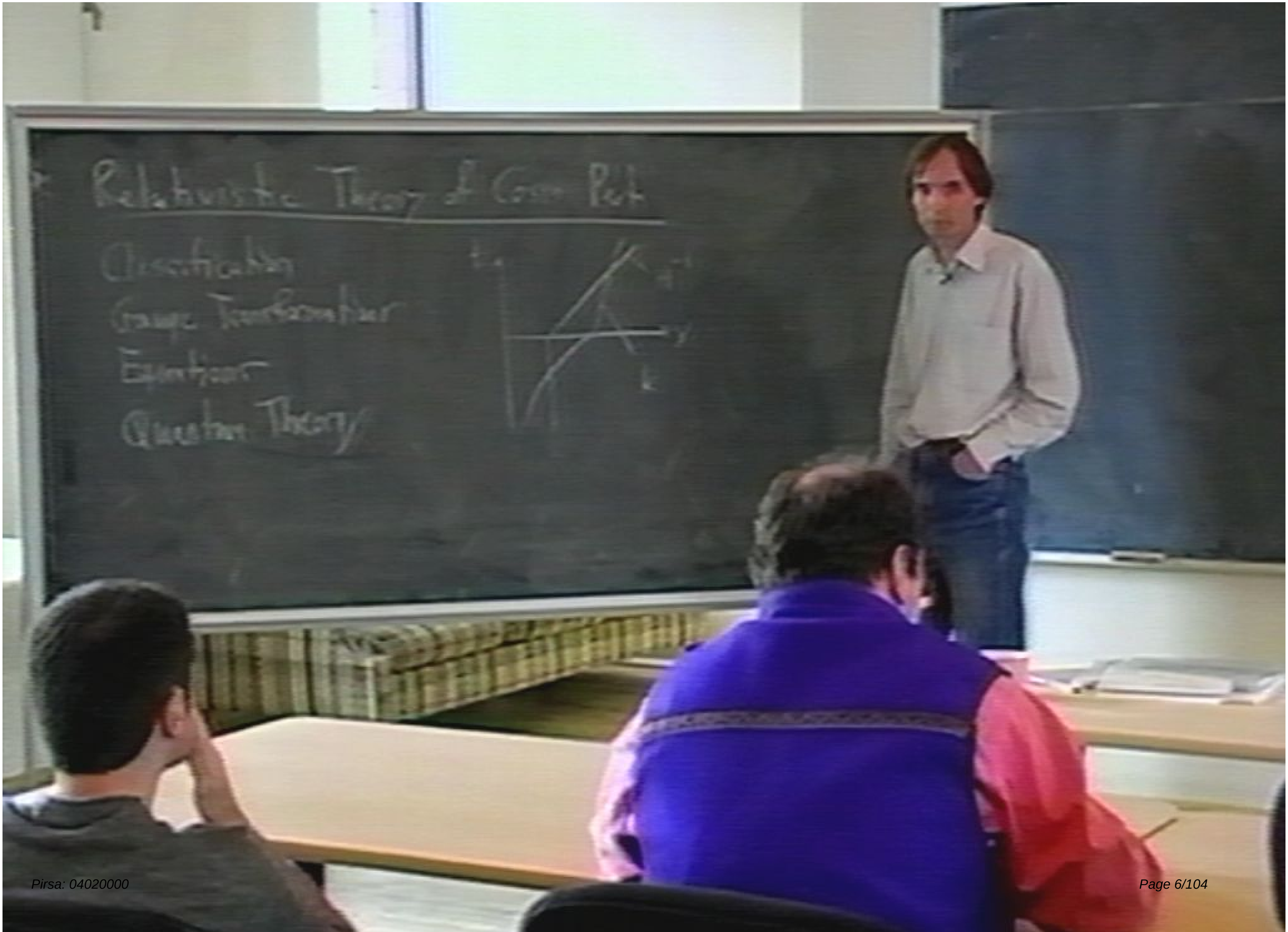
Quantum Theory


Relativistic Theory of Cosm Pert
Classification
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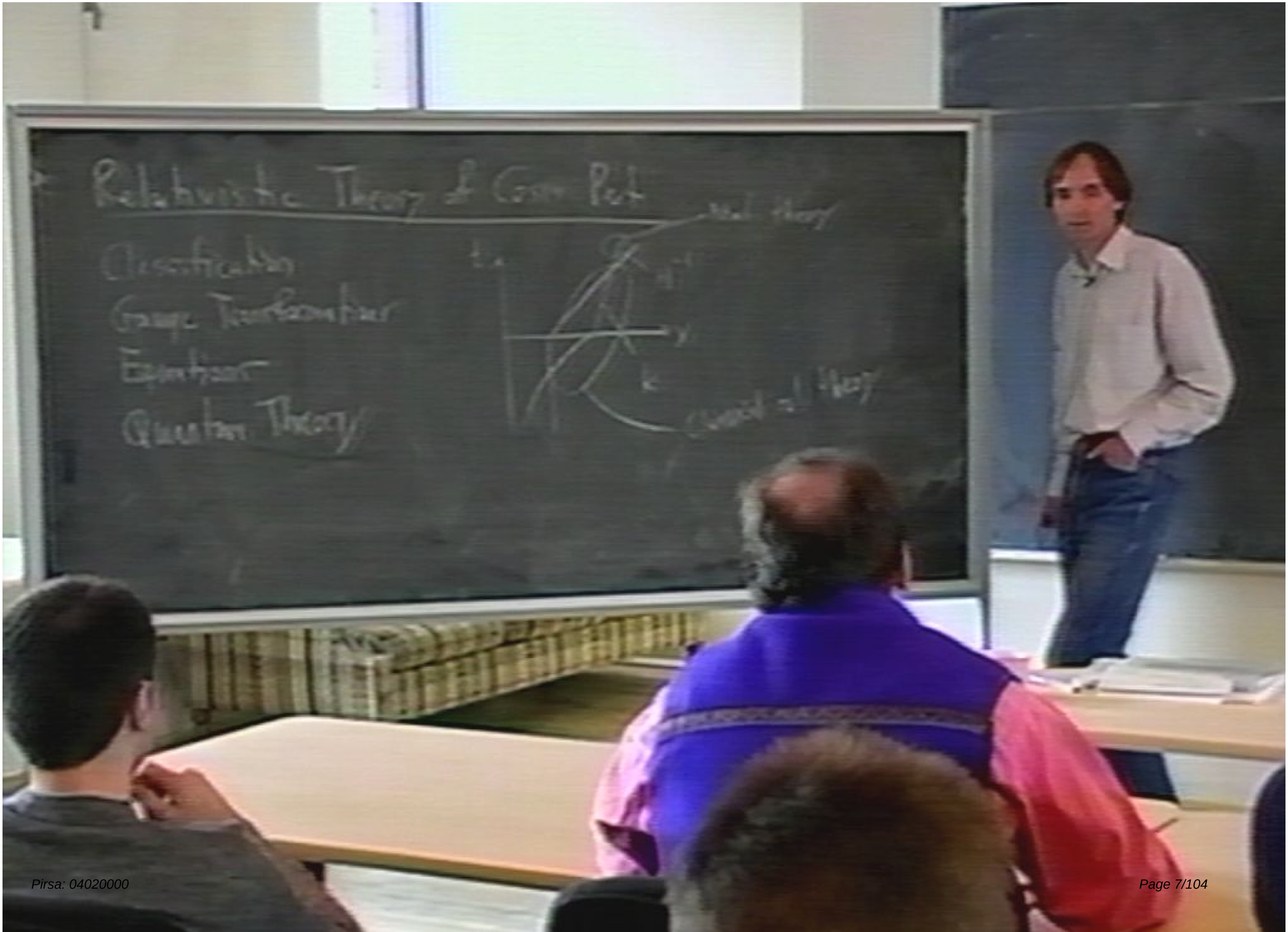
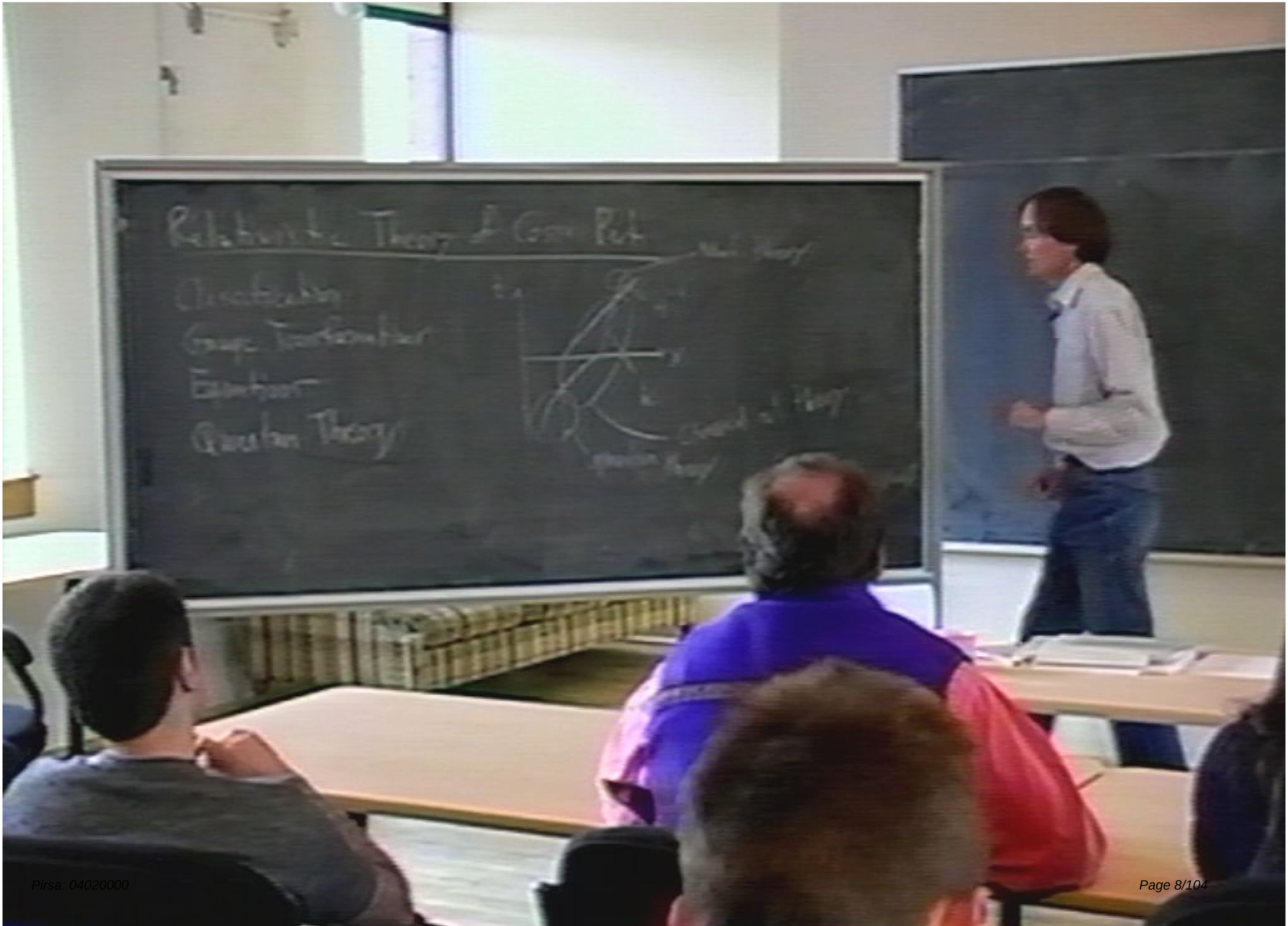
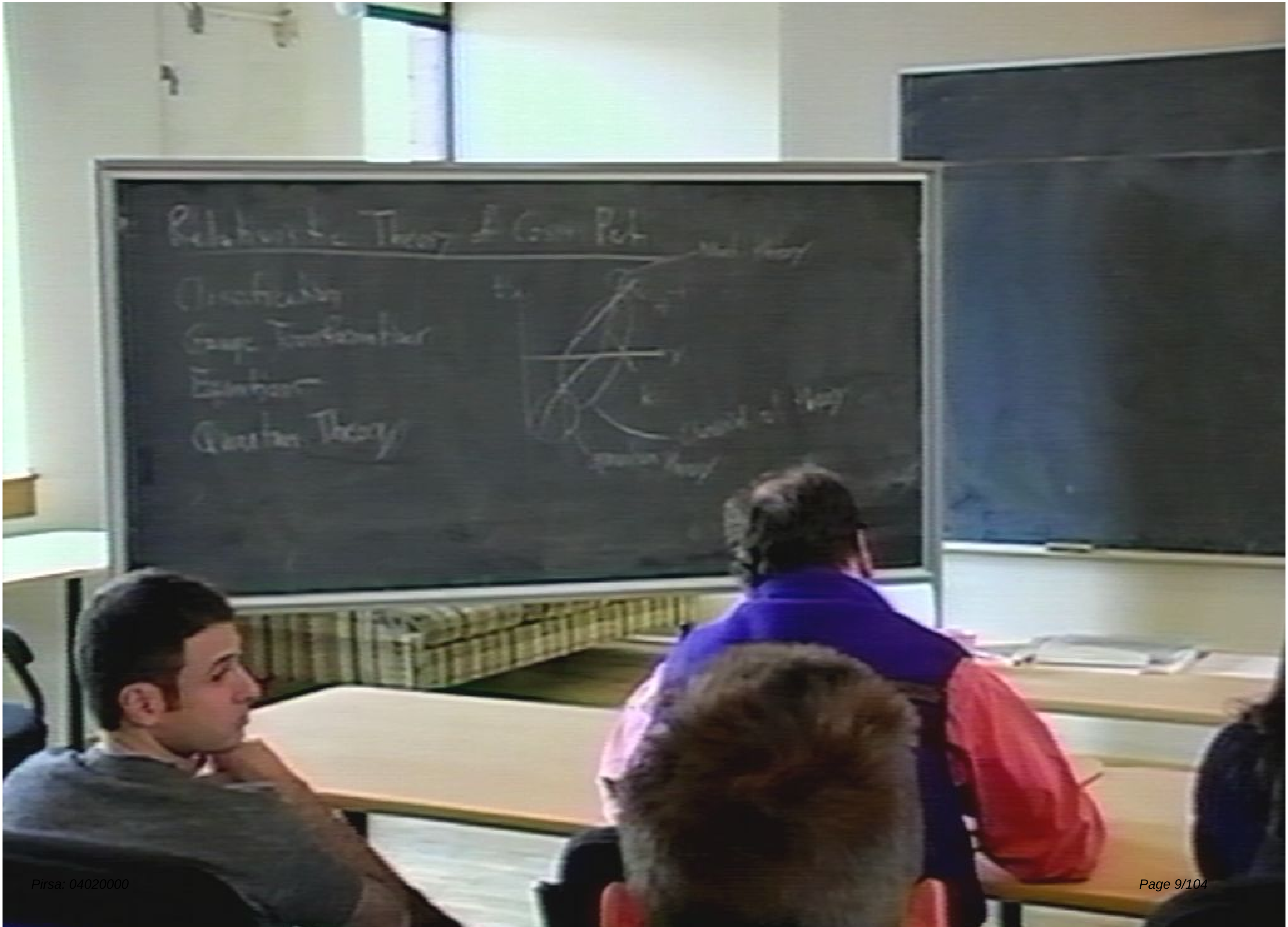
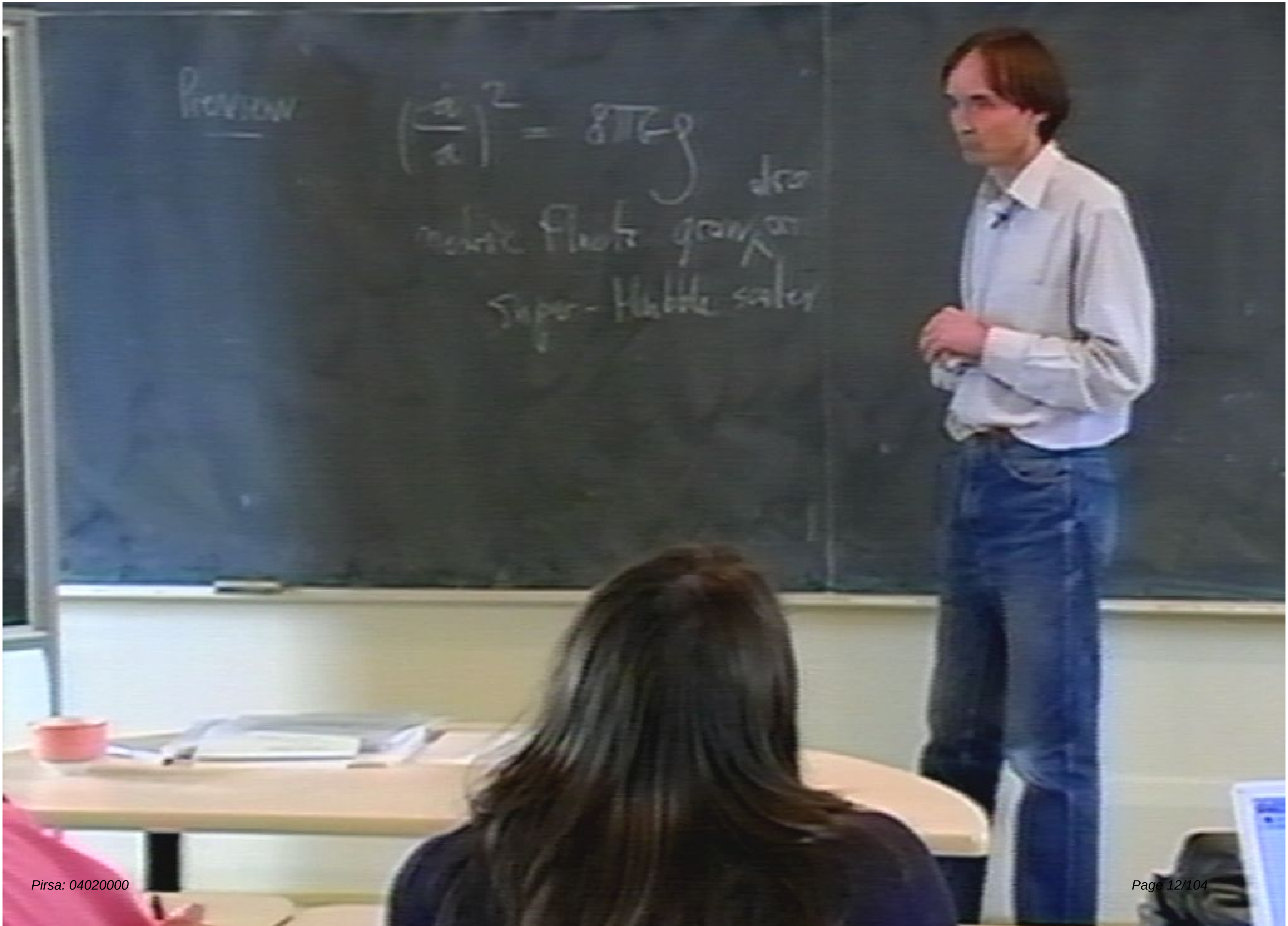
Quantum Theory

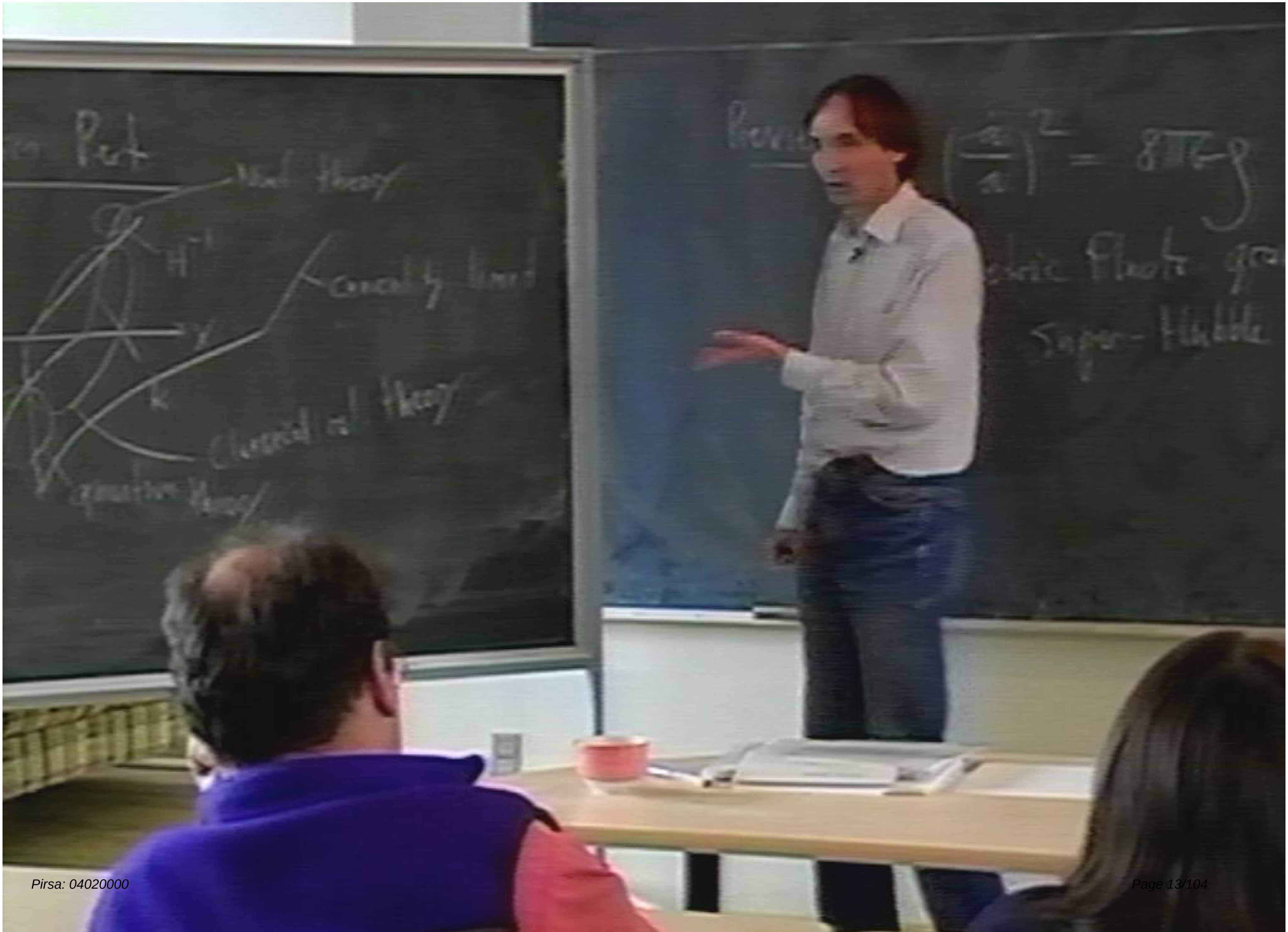

Classification
Gauge Transformation
Equations
Quantum Theory
Classical Theory

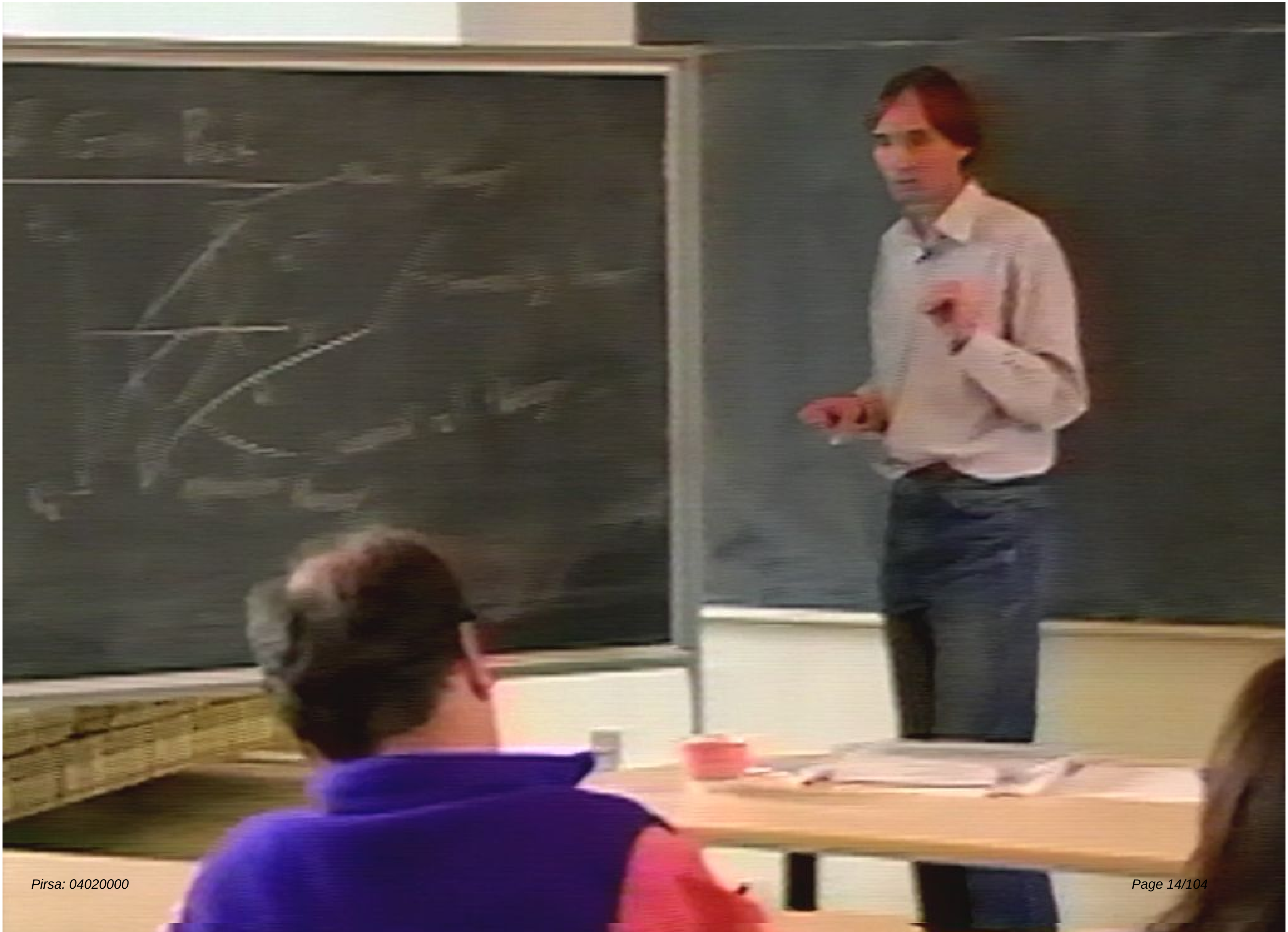

Quantum Theory

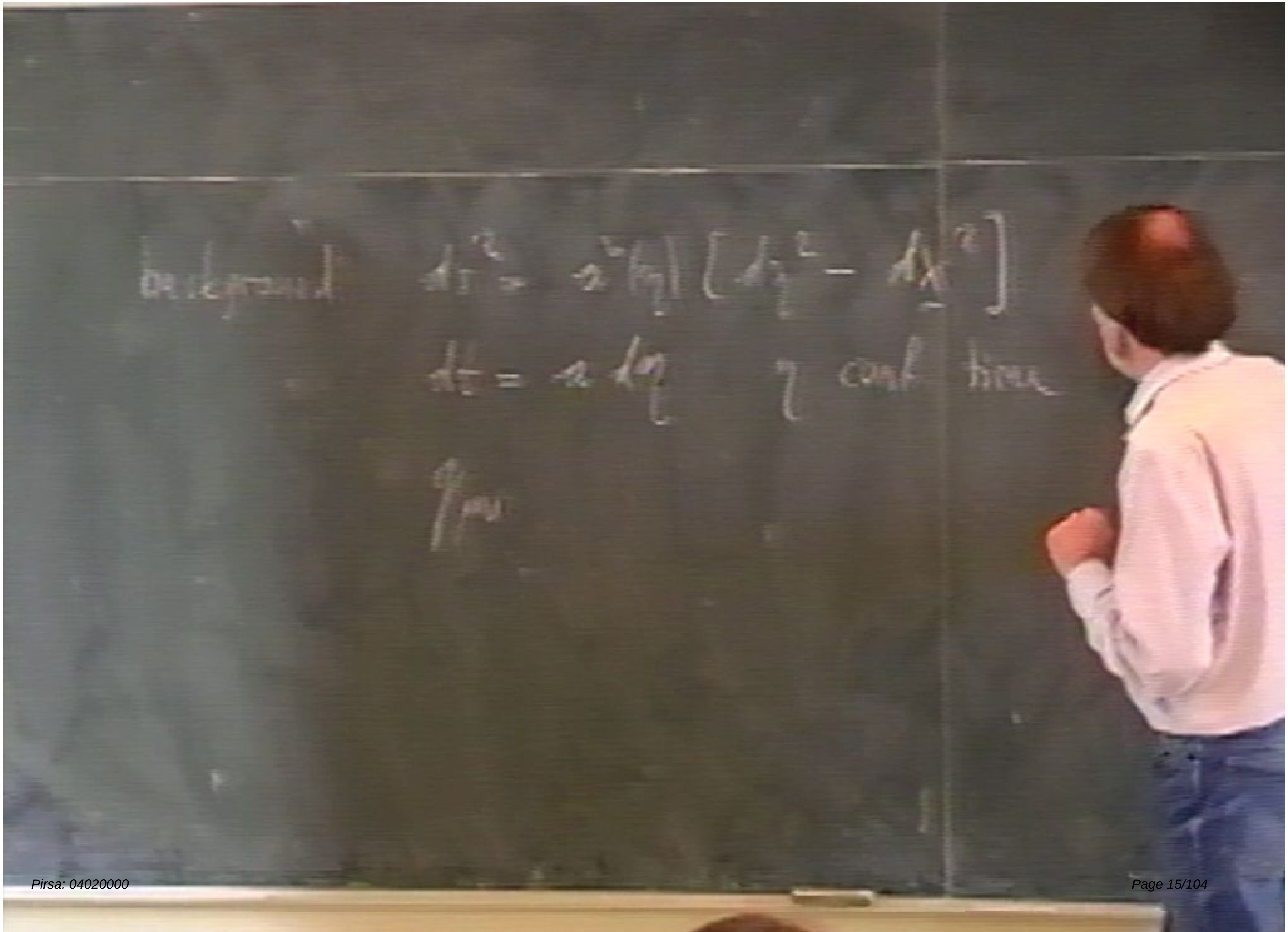



Preview
$\left(\frac{\dot{a}}{a}\right)^2 = 8\pi G\rho$
metric flucts grow on
super-Hubble scales







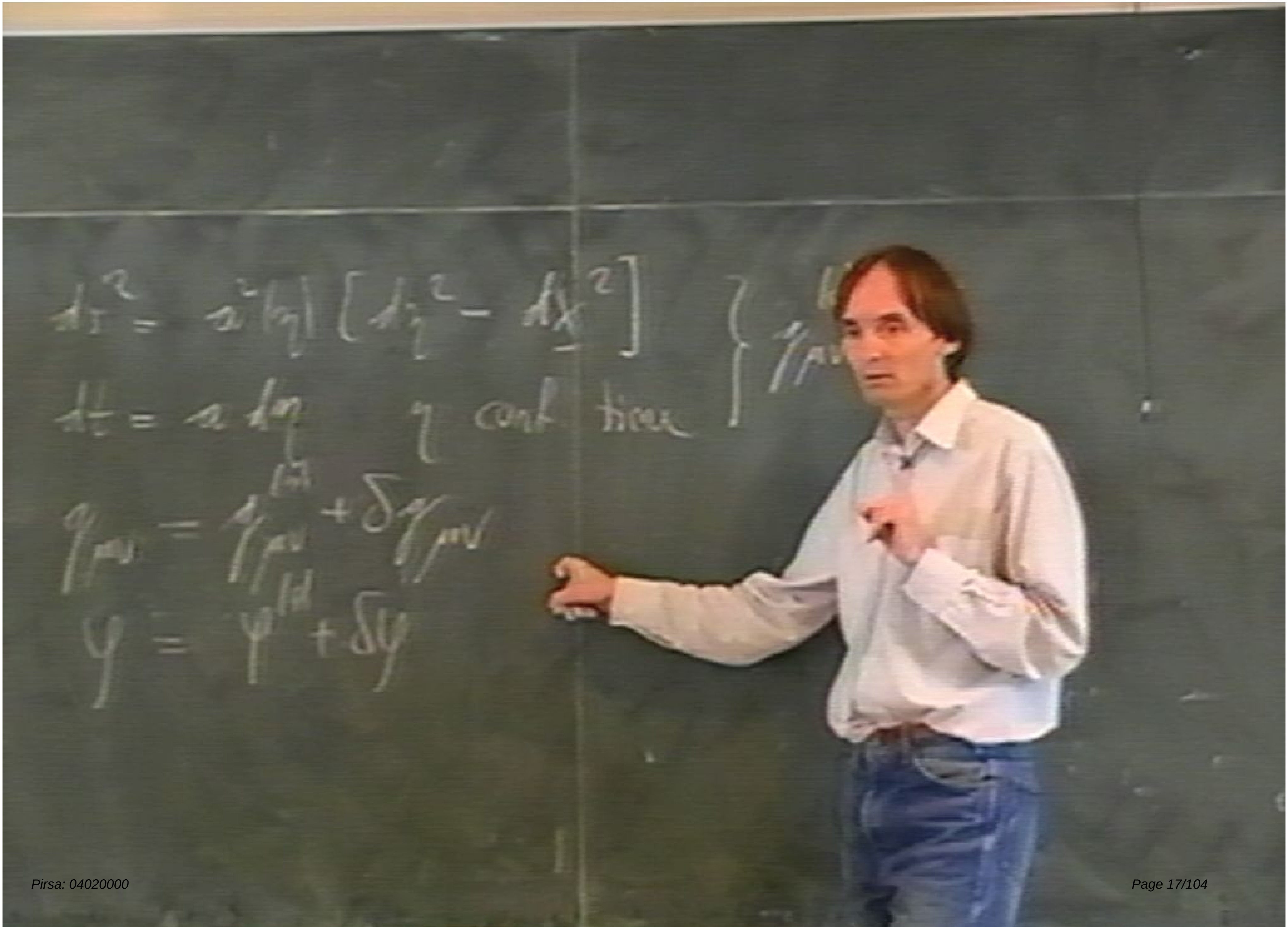

background: $ds^2 = a^2(\eta)\left[d\eta^2 - d\underline{x}^2\right]$
$dt = a\, d\eta$ η conf. time
$g_{\mu\nu}$

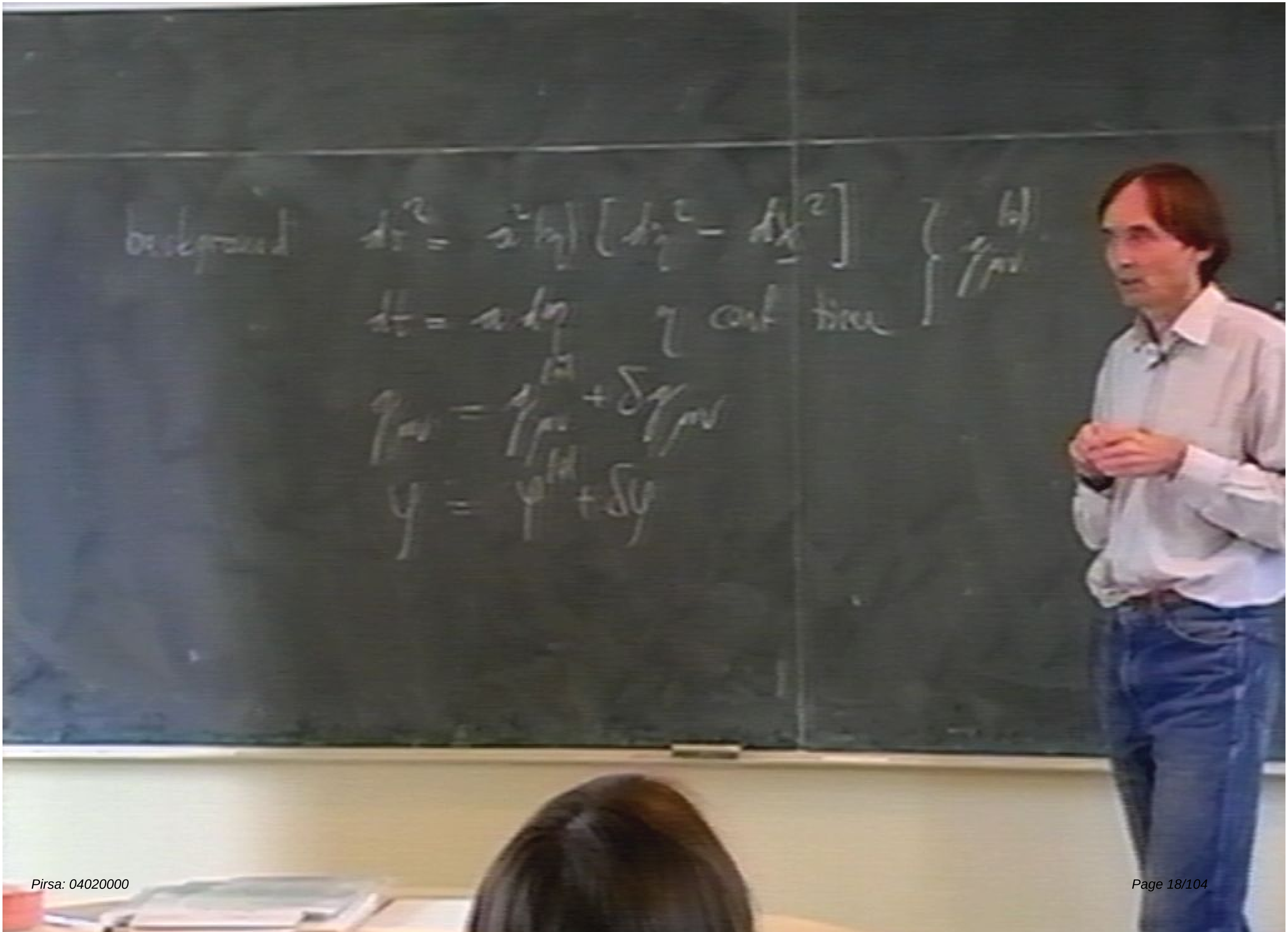
ground

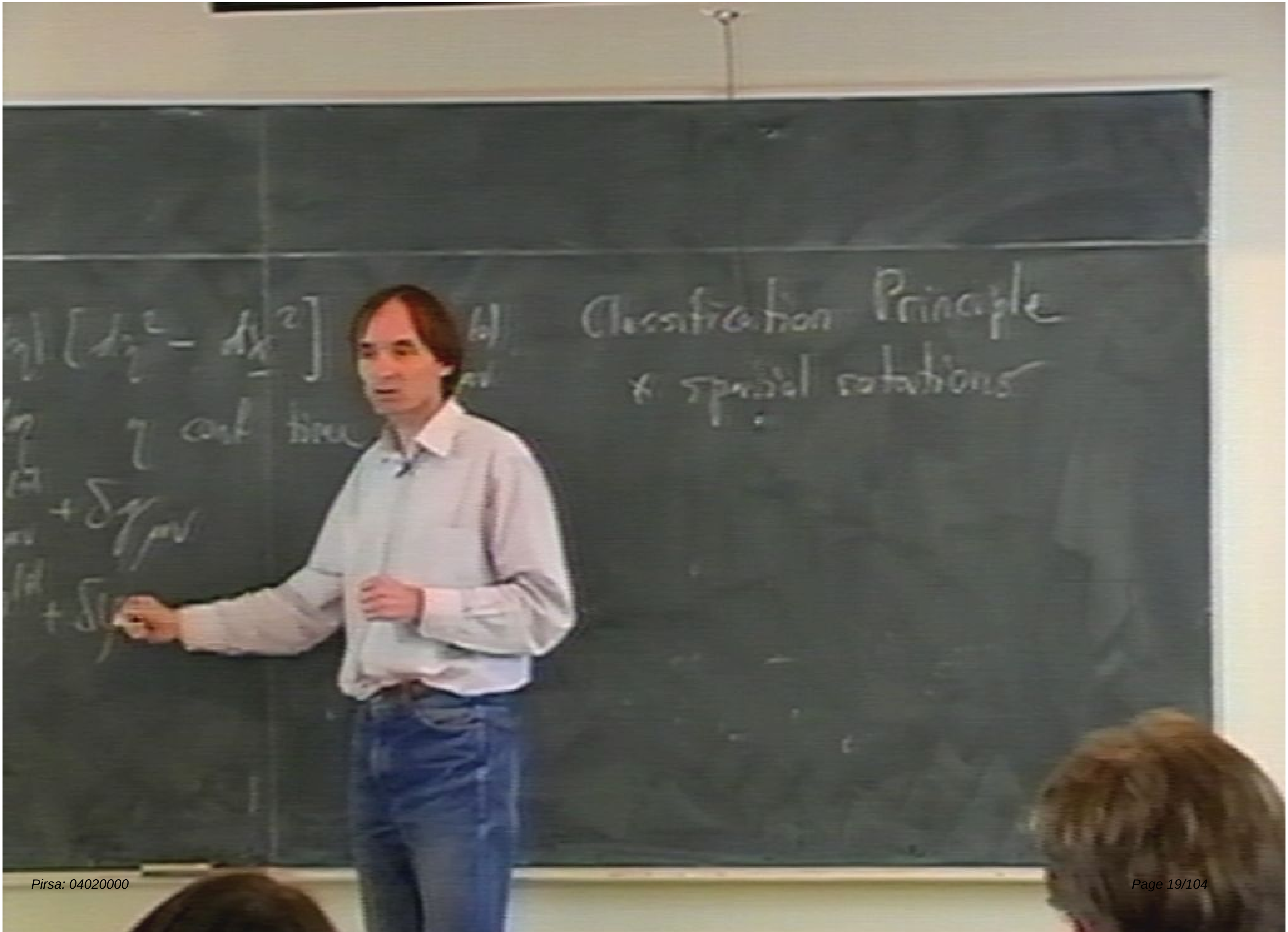
$$ds^2 = a^2(\eta)\left[d\eta^2 - d\underline{x}^2\right] \quad \Big\} \; g^{(0)}_{\mu\nu}$$

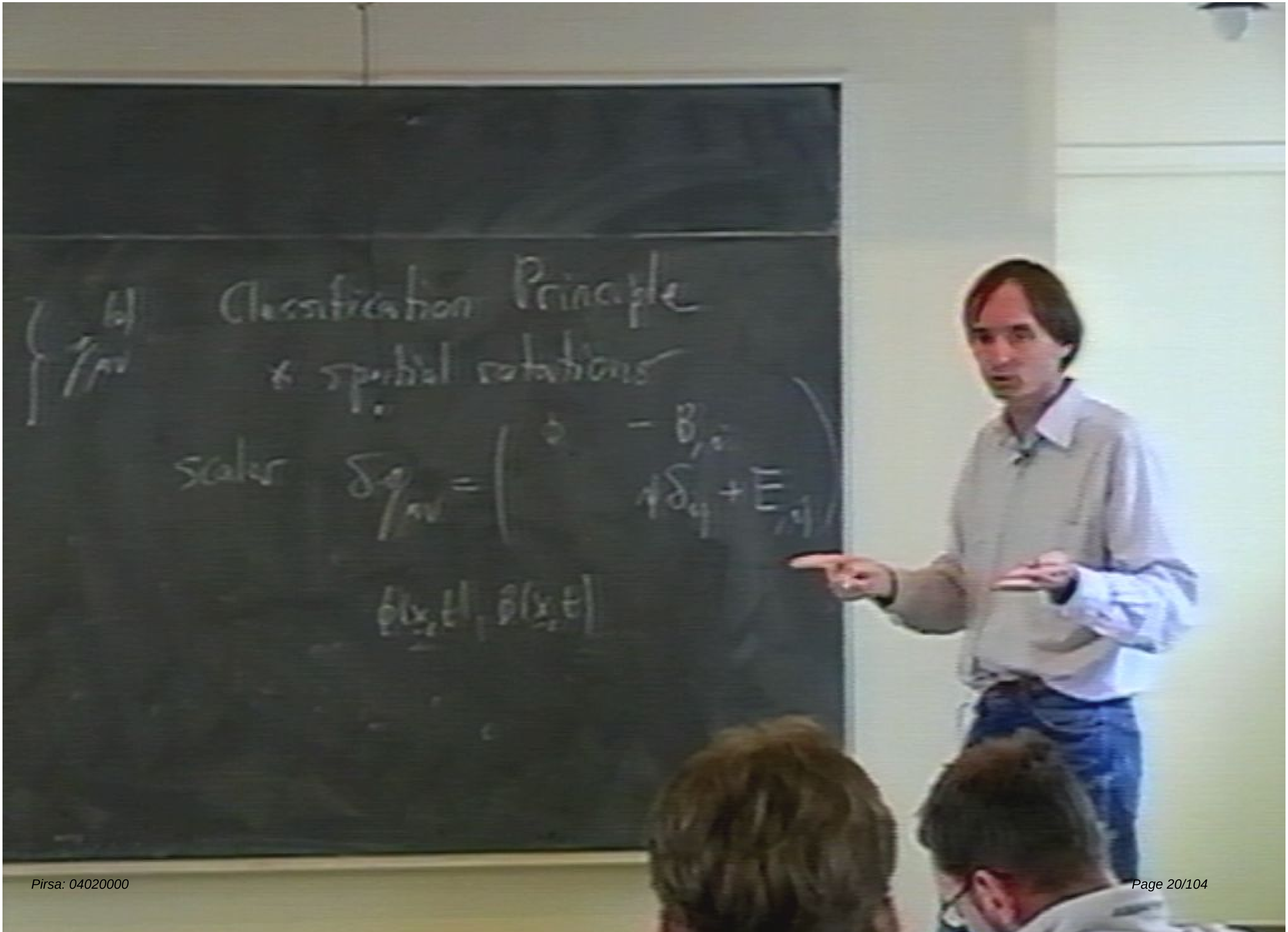
$$dt = a\, d\eta \qquad \eta \text{ conf time}$$

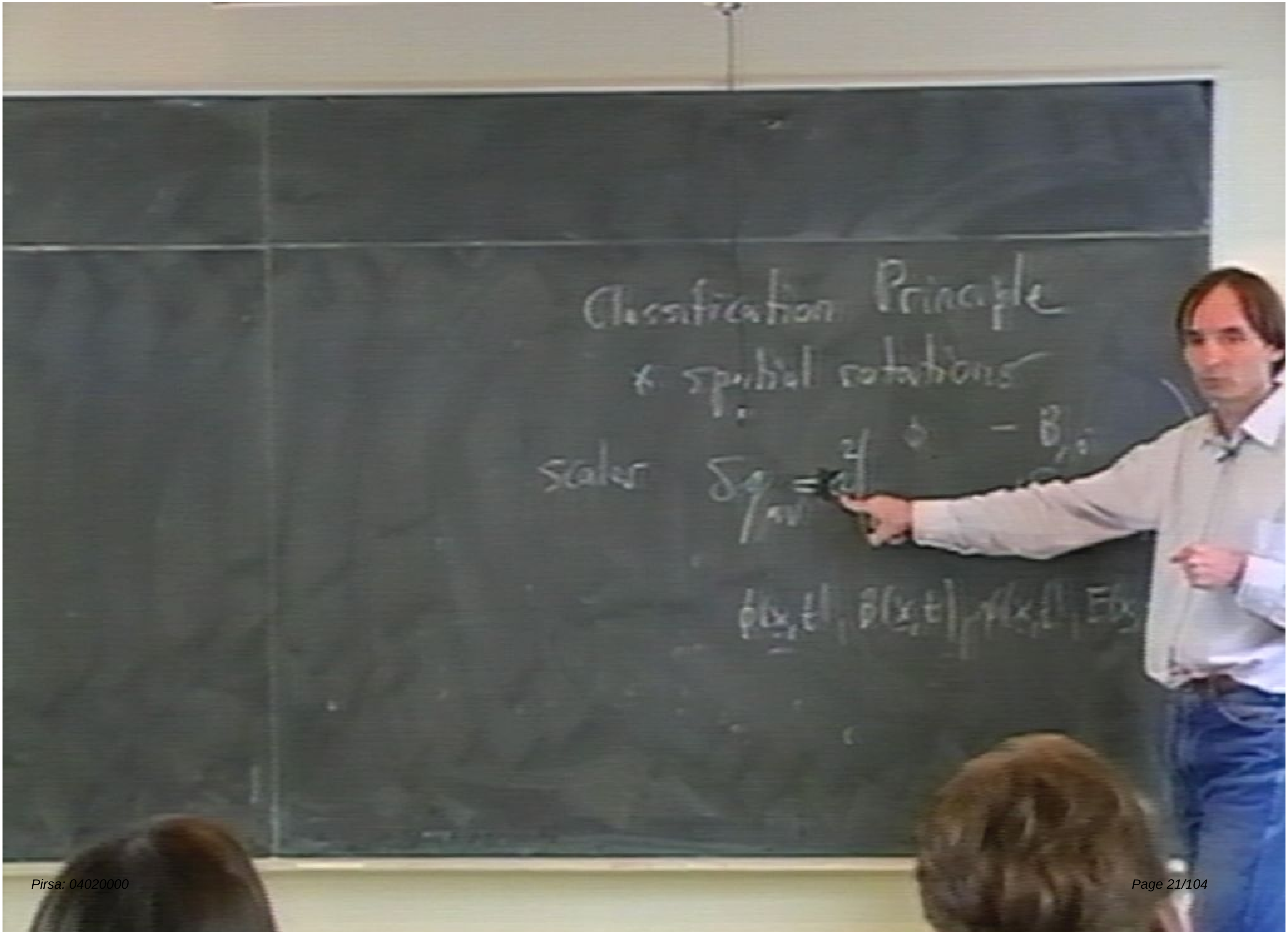
$$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$$

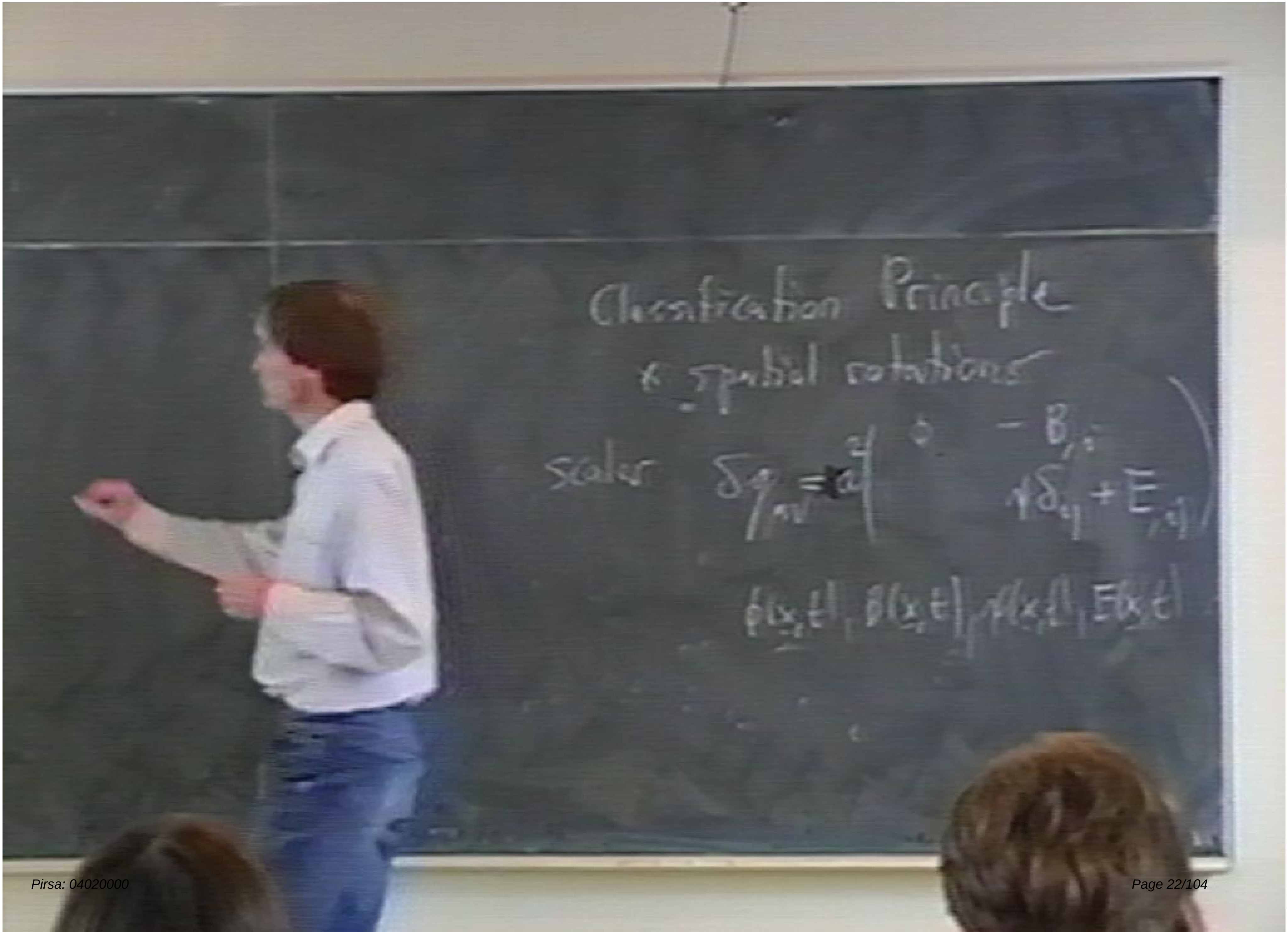

$d\tau^2 = a^2(\eta)\,[d\eta^2 - d\underline{x}^2]$
$dt = a\, d\eta$
η conf time
$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$
$\varphi = \varphi^{(0)} + \delta\varphi$


background $ds^2 = a^2(\eta)[d\eta^2 - d\underline{x}^2]$
$g^{(0)}_{\mu\nu}$
$dt = a\,d\eta$ η conf time
$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$
$\varphi = \varphi^{(0)} + \delta\varphi$


Classification Principle
& special solutions


Classification Principle
& spatial rotations
scalar

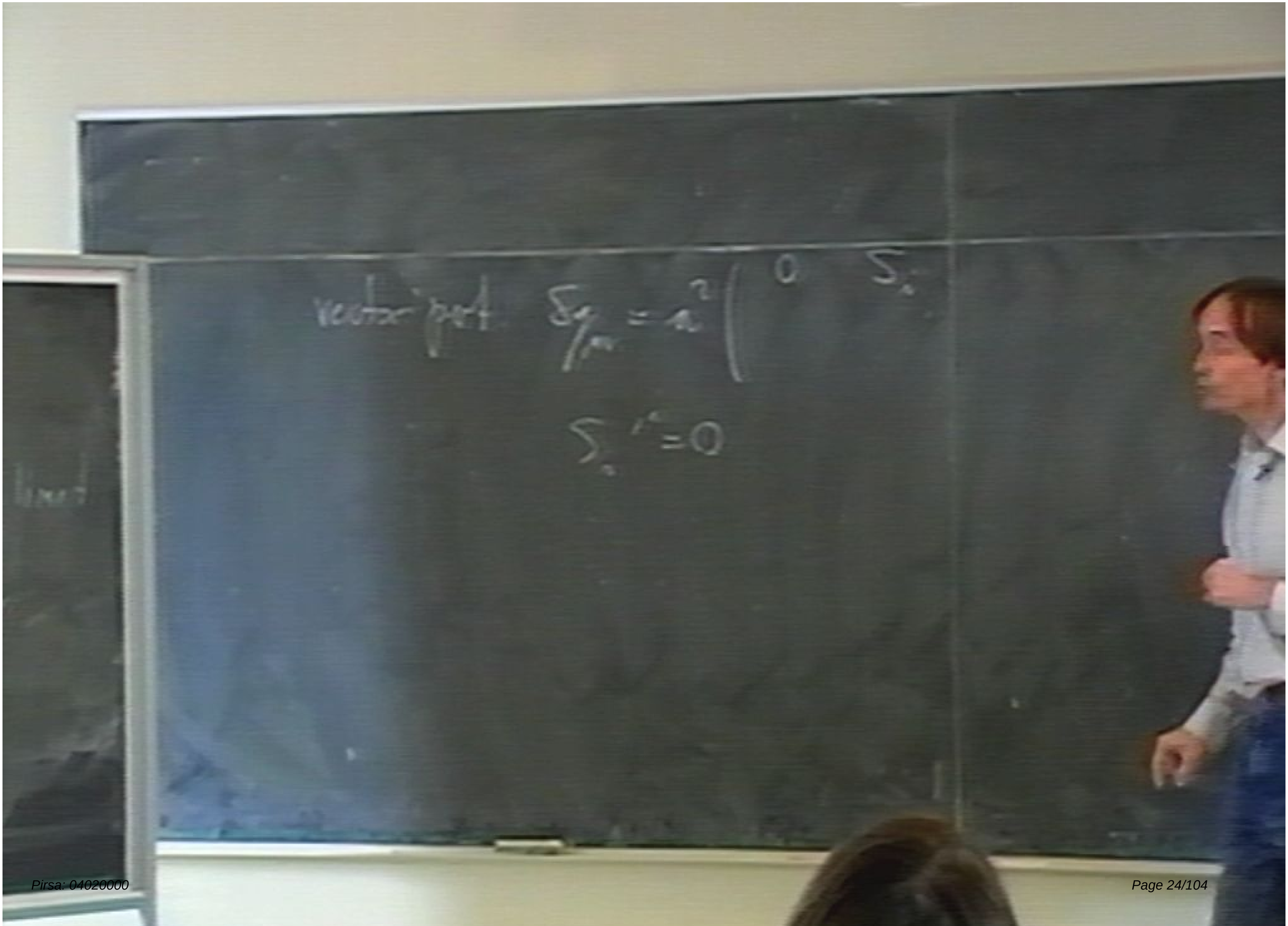

Classification Principle
& spatial rotations
scalar

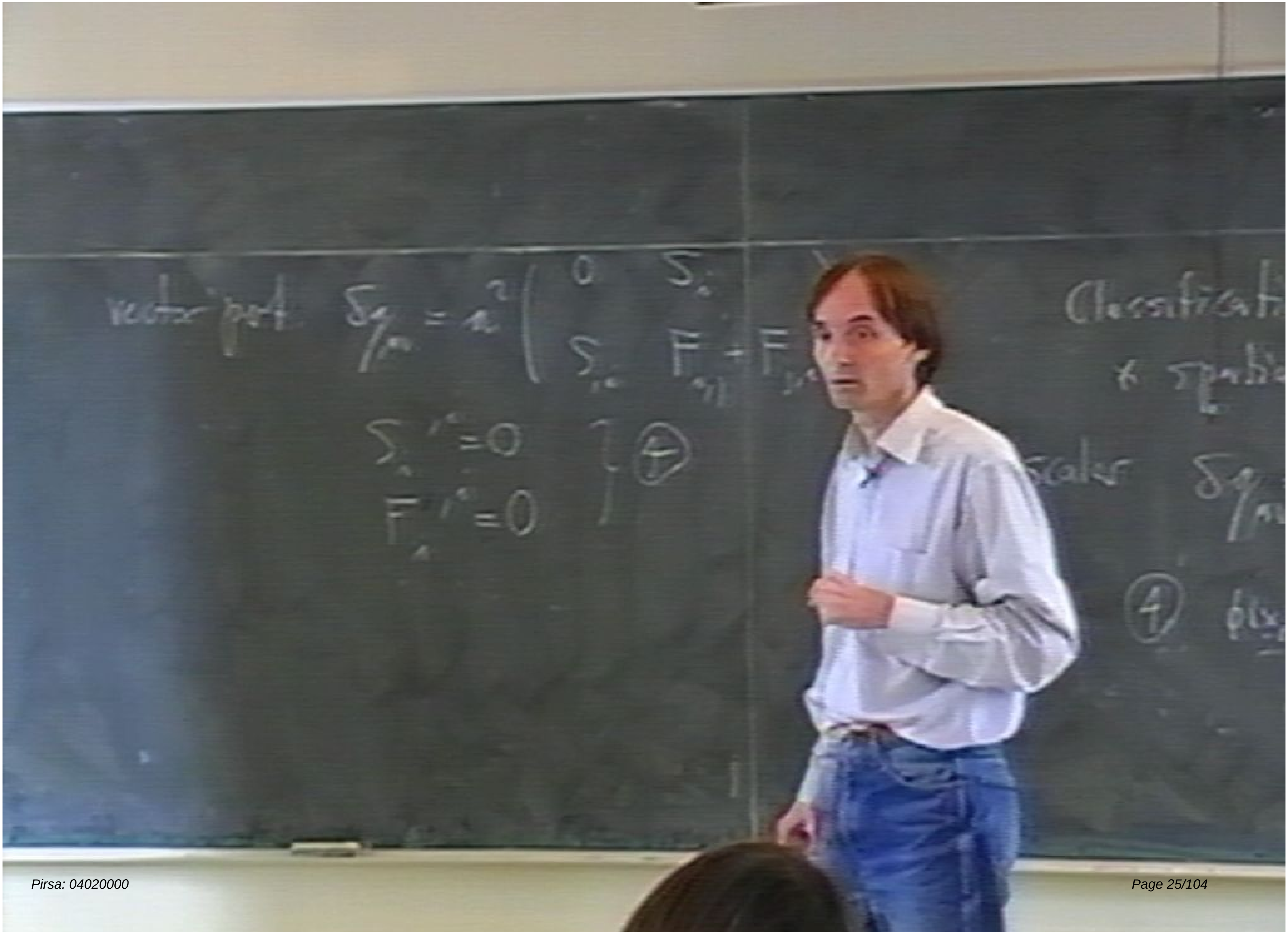

Classification Principle
spatial rotations
scalar

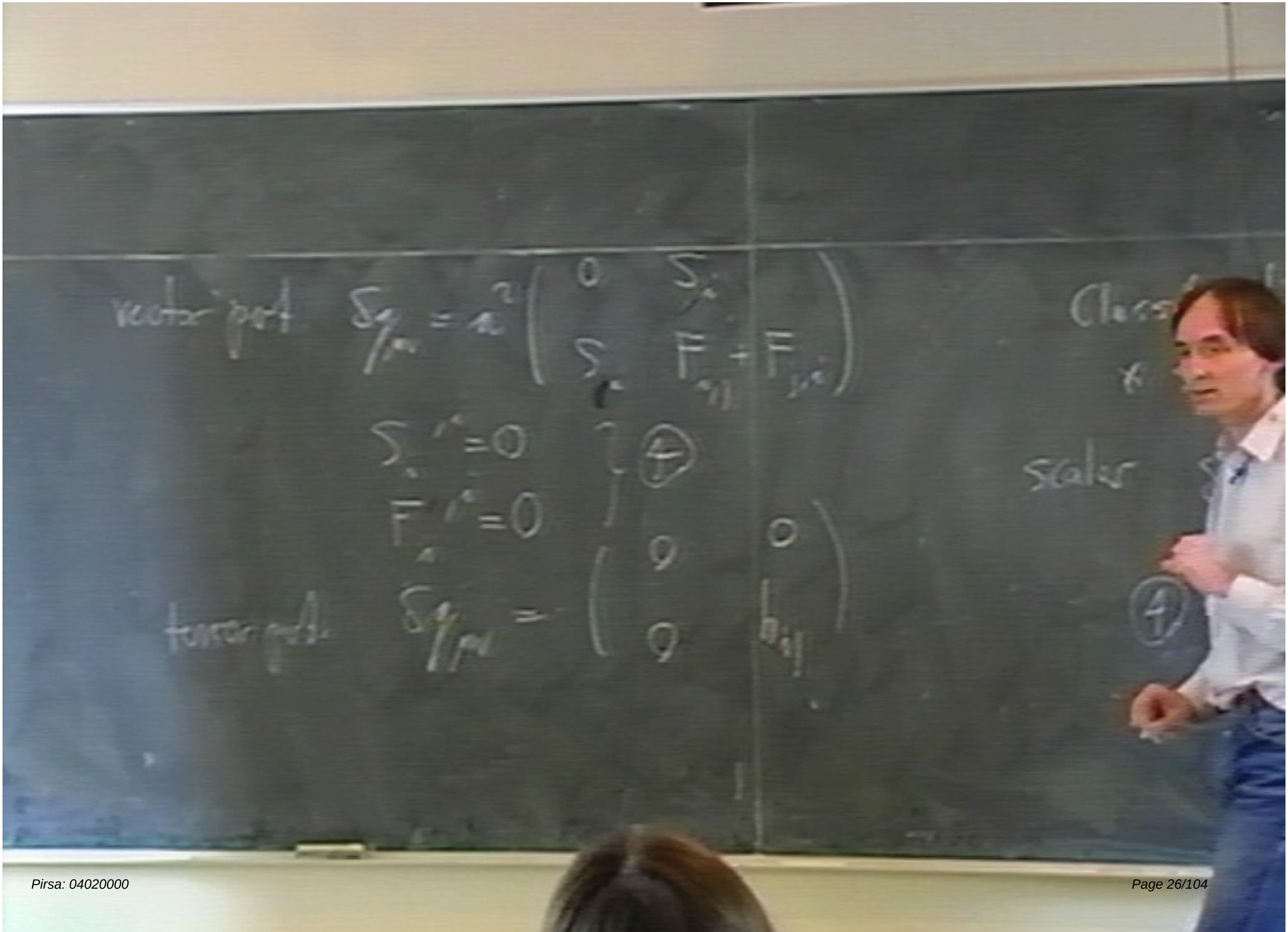
vector part. $\delta g_{\mu\nu} = a^2 \left(\begin{matrix} 0 \\ \end{matrix} \right.$

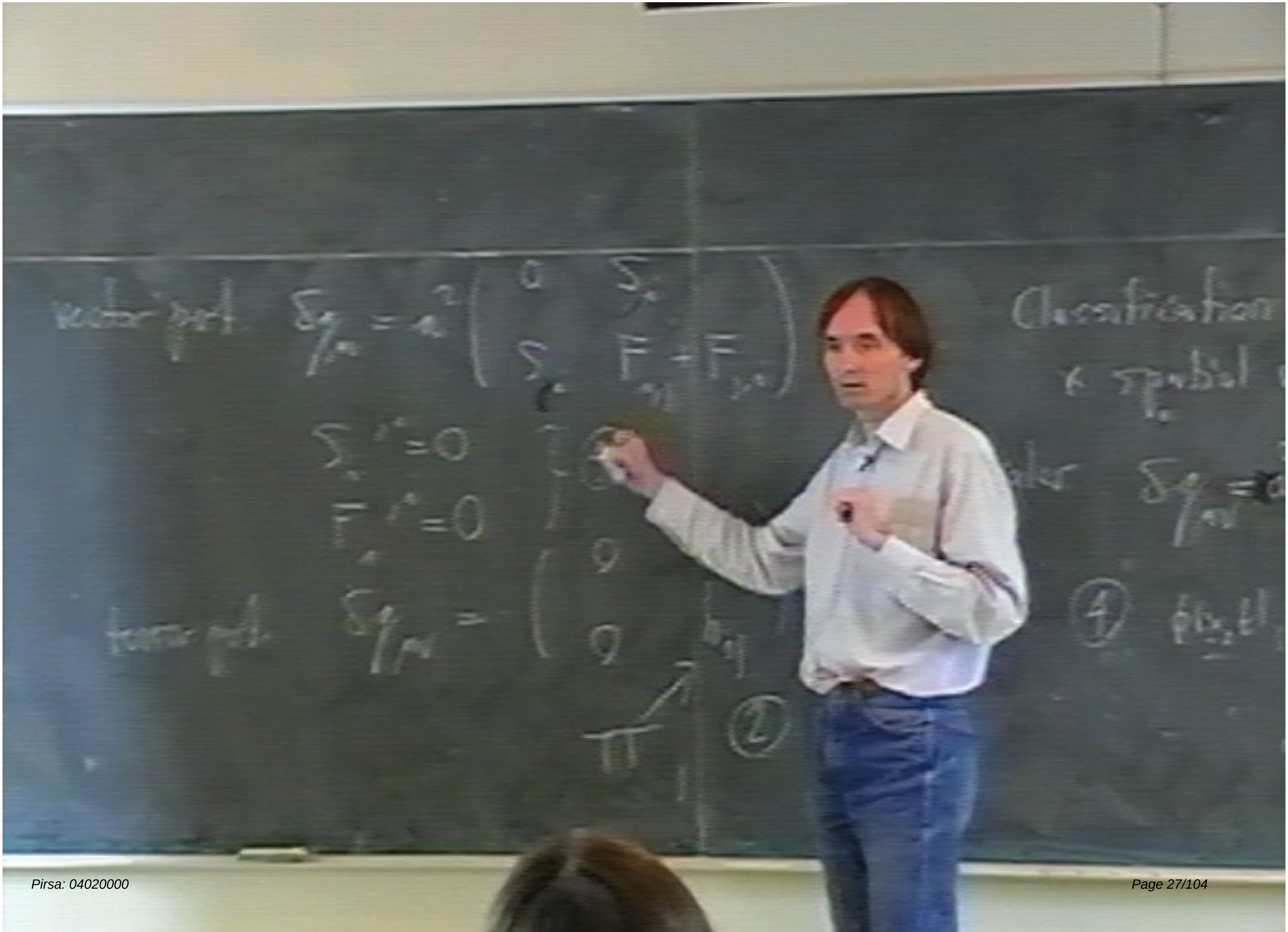
Clas

scalar

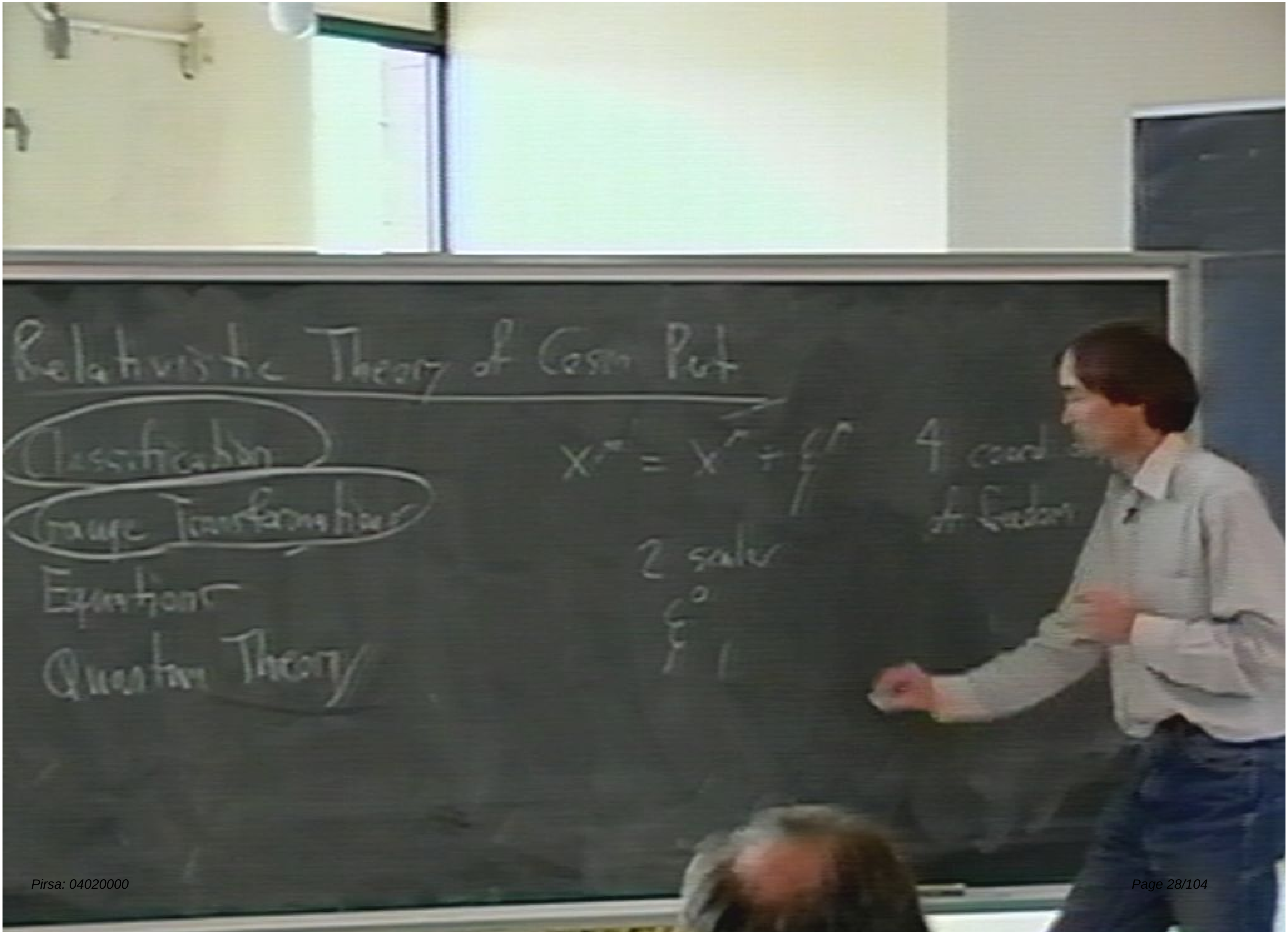

vector part. $\delta g_{\mu\nu} = a^2 \left(\begin{matrix} 0 & S_i \end{matrix} \right.$
$S_i{}^{,i} = 0$


vector part
Classificati
scalar


vector pert. $\delta g_{\mu\nu} = a^2 \begin{pmatrix} 0 & S_i \\ S_i & F_{i,j}+F_{j,i} \end{pmatrix}$
$S_i{}^{,i}=0$
$F_i{}^{,i}=0$
4
tensor pert. $\delta g_{\mu\nu} = \begin{pmatrix} 0 & 0 \\ 0 & h_{ij} \end{pmatrix}$
scalar
4



vector part
tensor part
Classification


Relativistic Theory of Cosm Pert
Classification
Gauge Transformations
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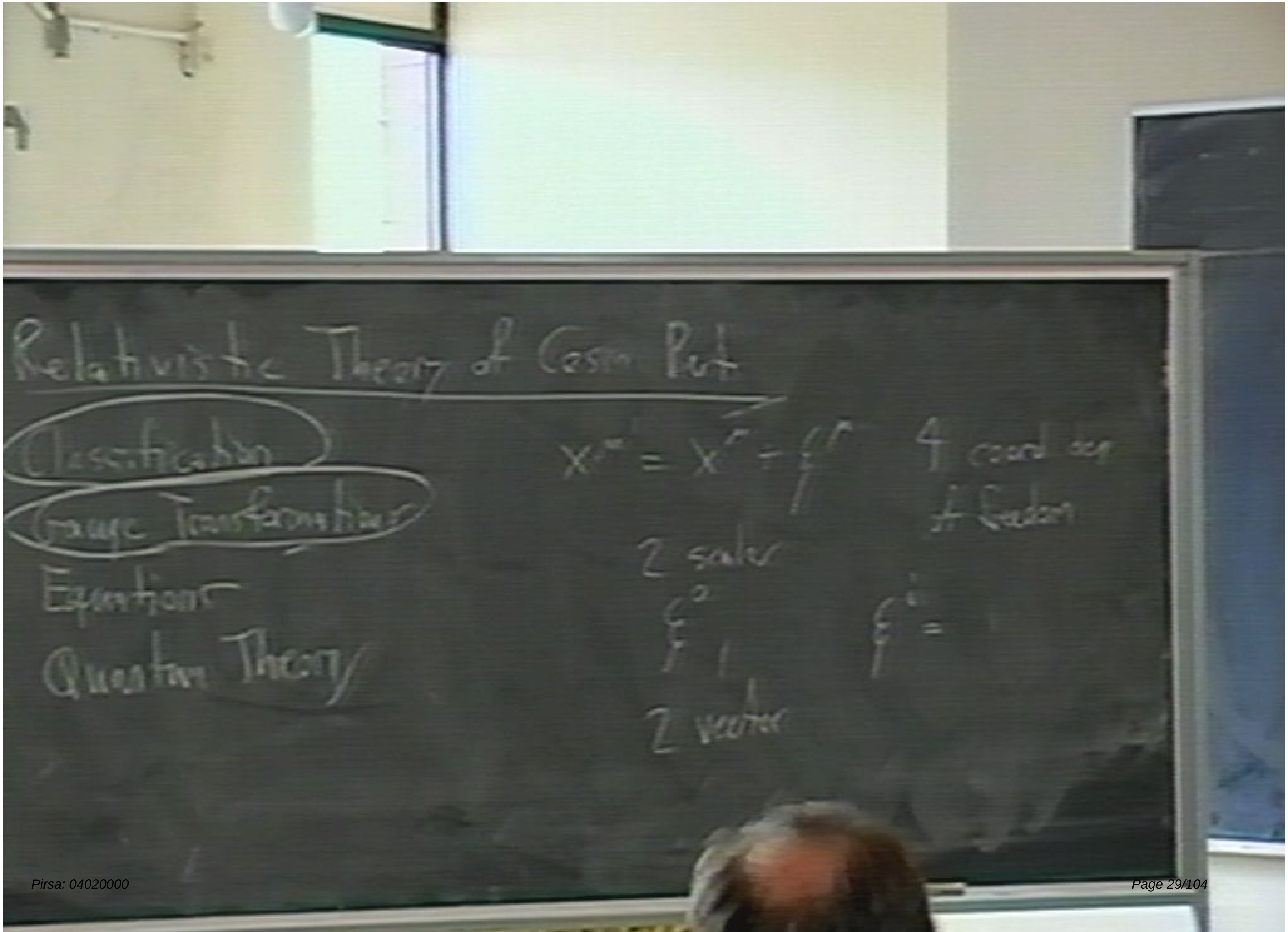
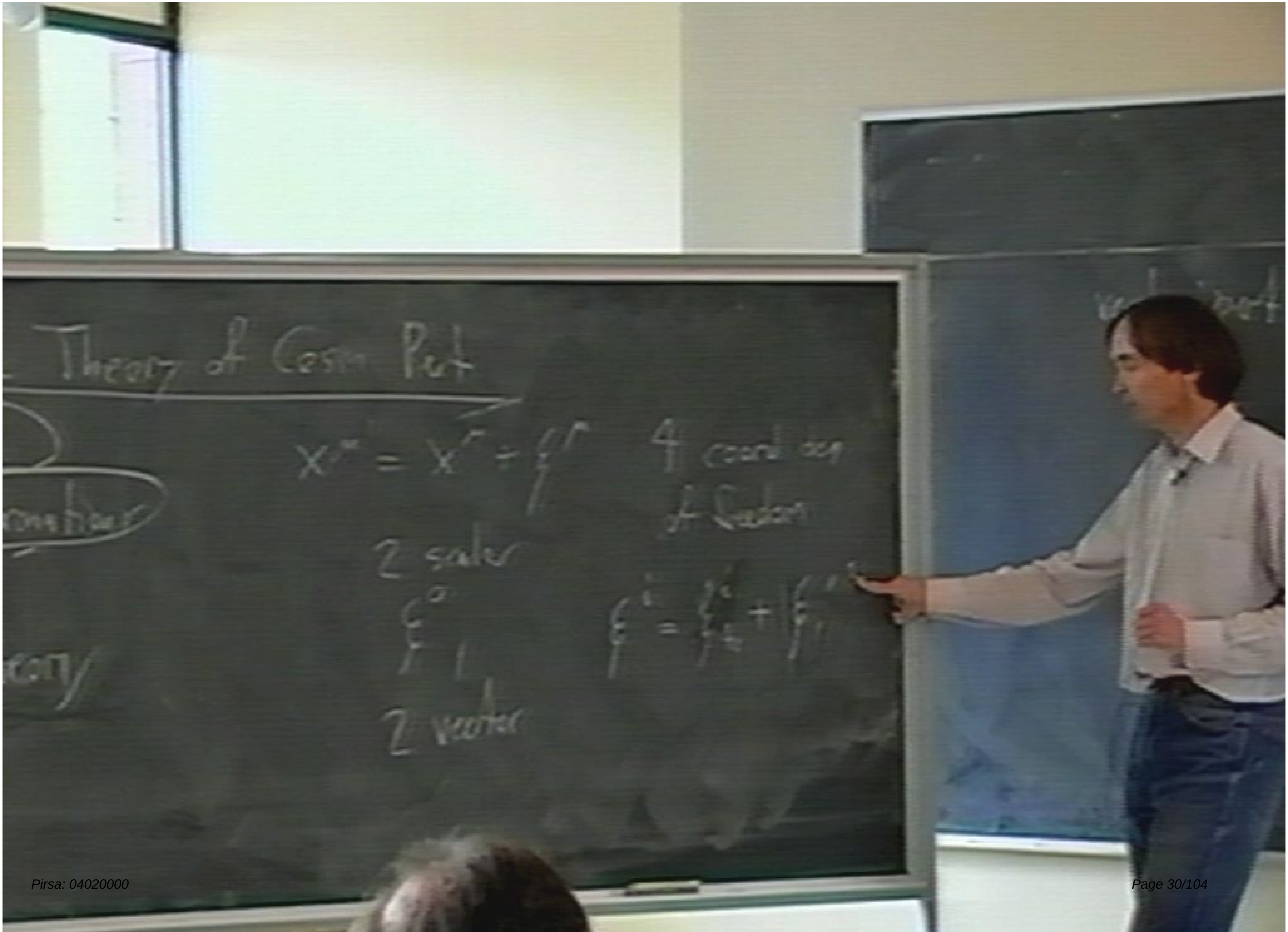
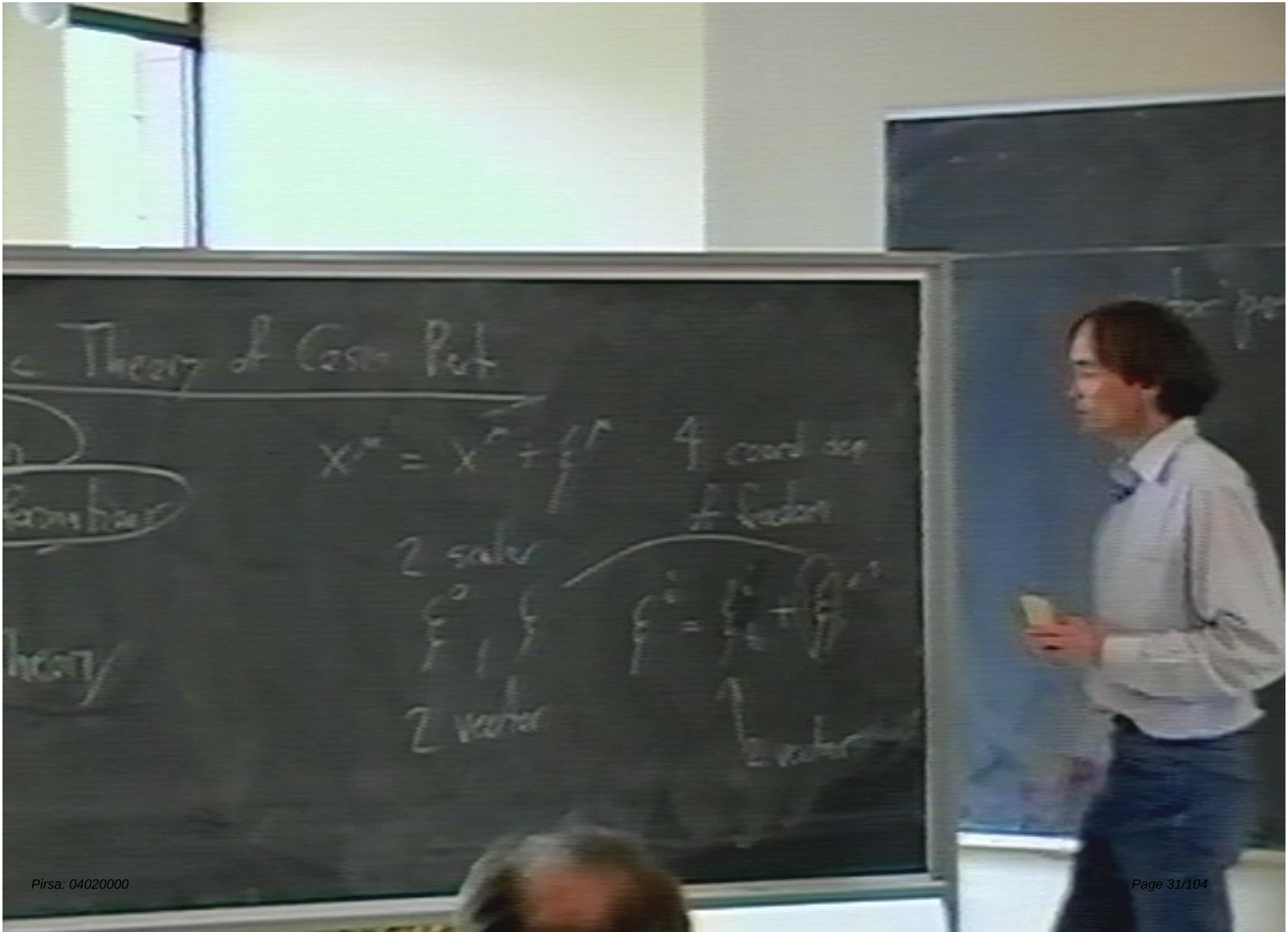
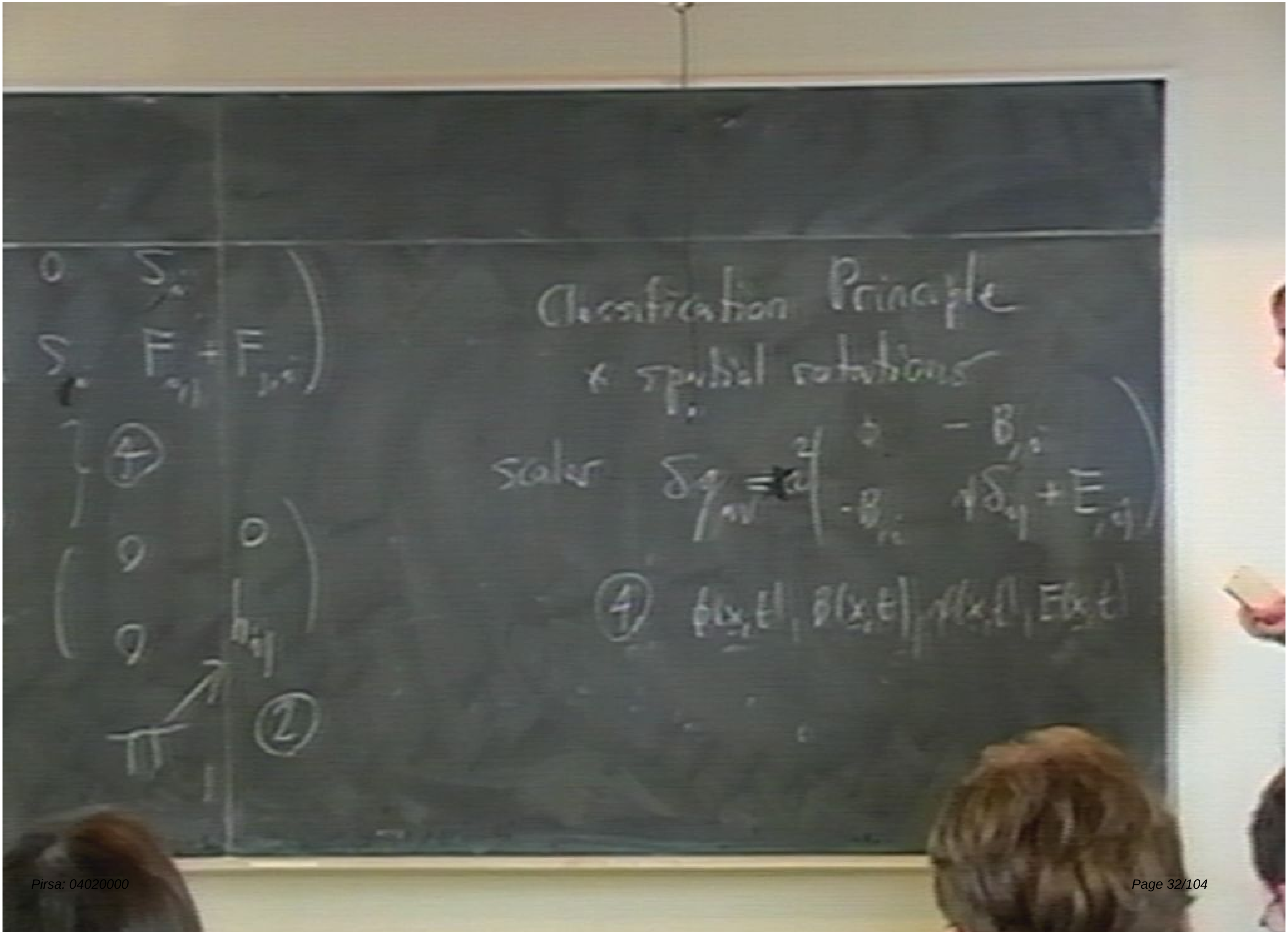
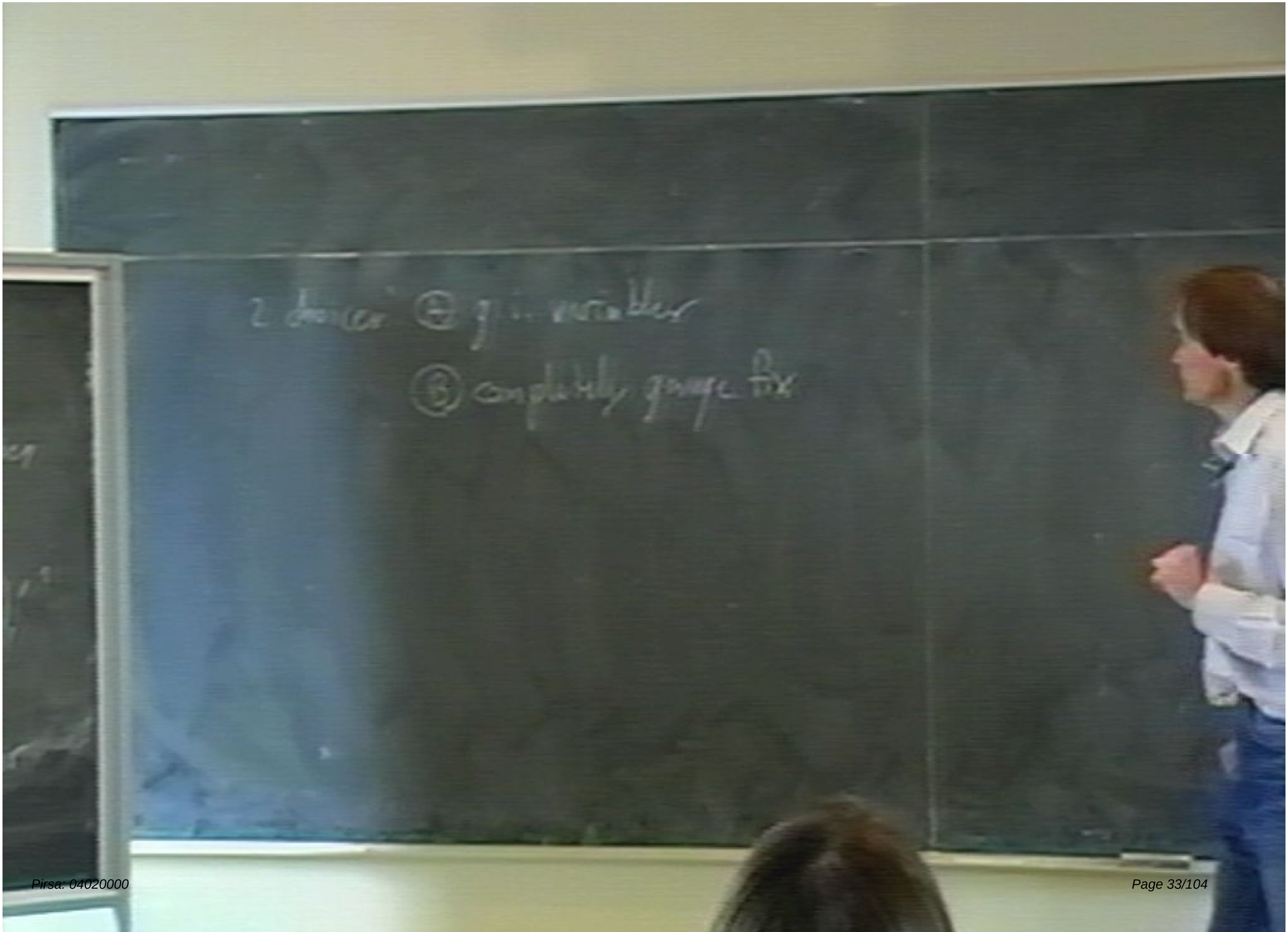
Quantum Theory
2 scalar

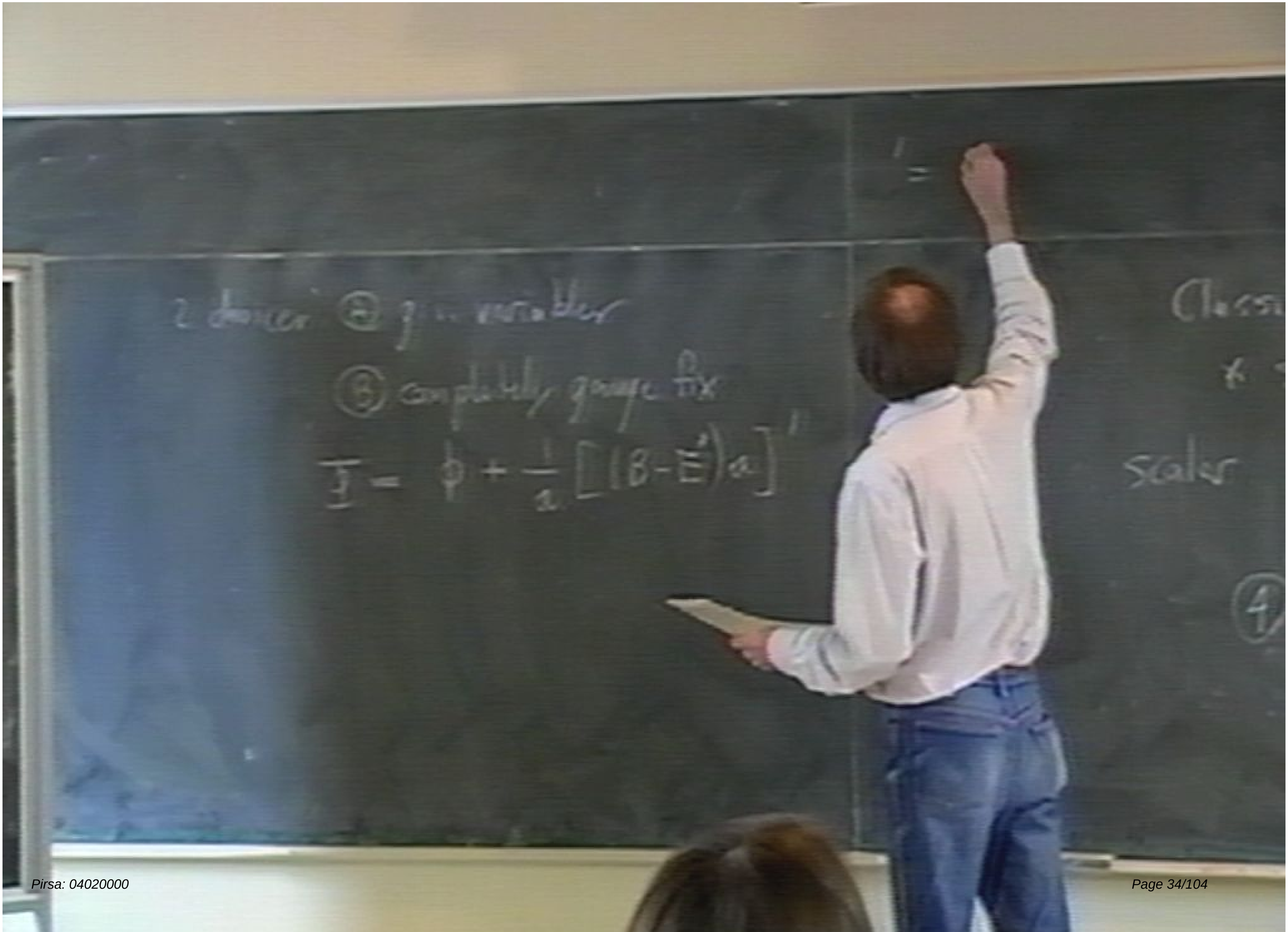

Relativistic Theory of Cosm Pert
Classification
Gauge Transformations
Equations
Quantum Theory
x'^μ = x^μ + ξ^μ
4 coord deg of freedom
2 scalar
ξ^0
2 vector

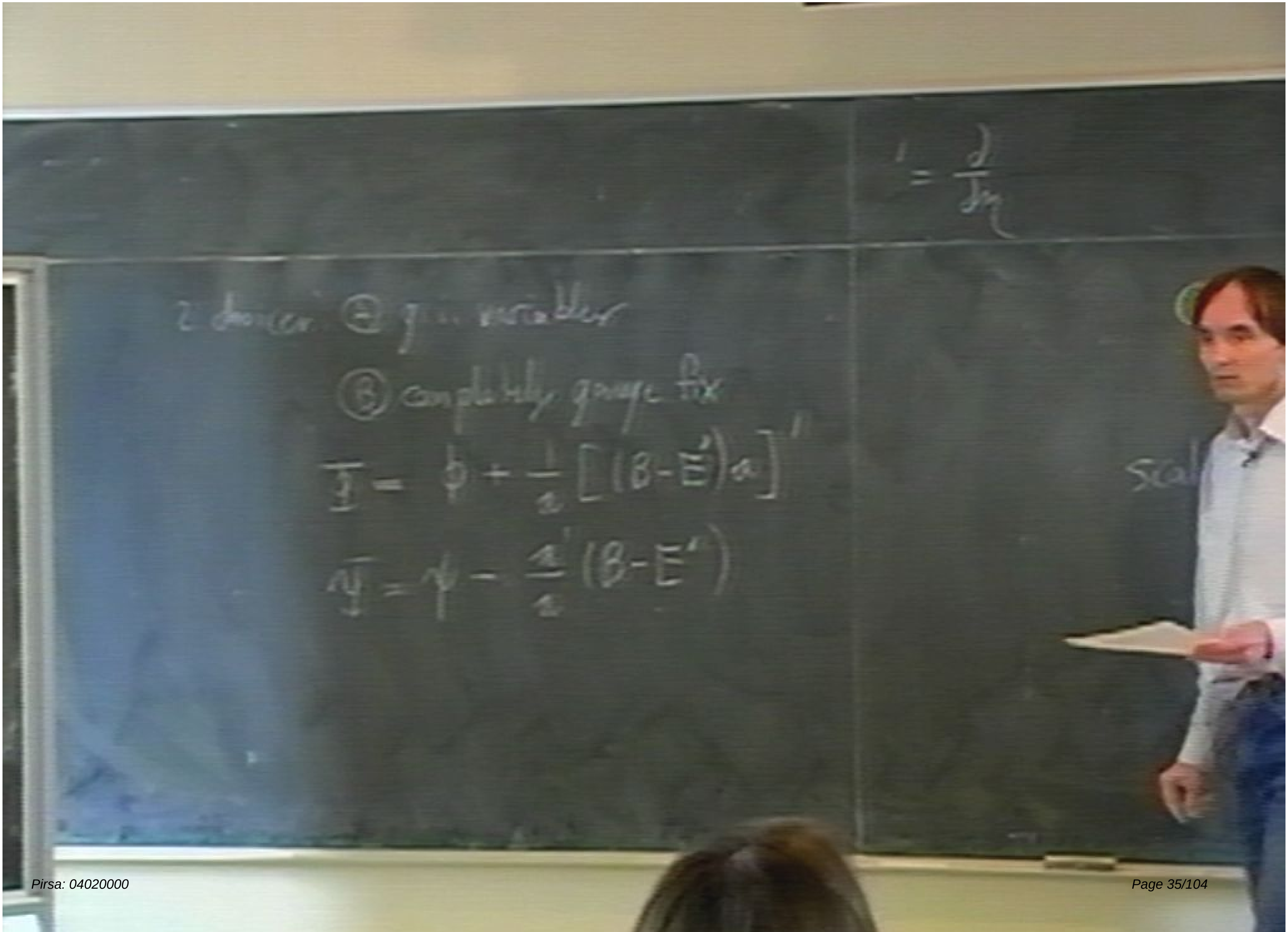

Theory of Cosm Pert
4 coord deg
of freedom
2 scaler
2 vector

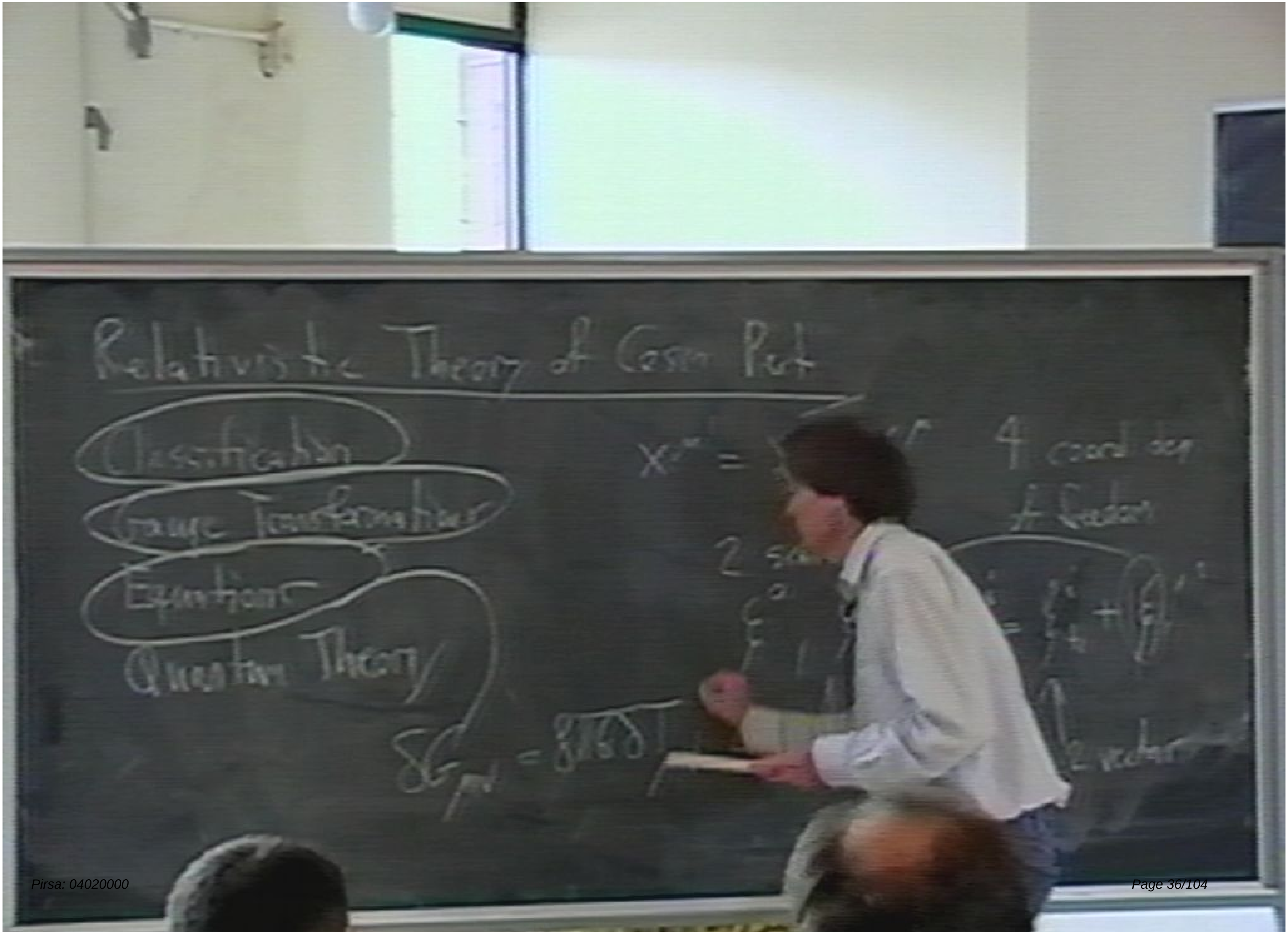

Theory of Cosm Pert
4 coord dep
2 scalar
2 vector

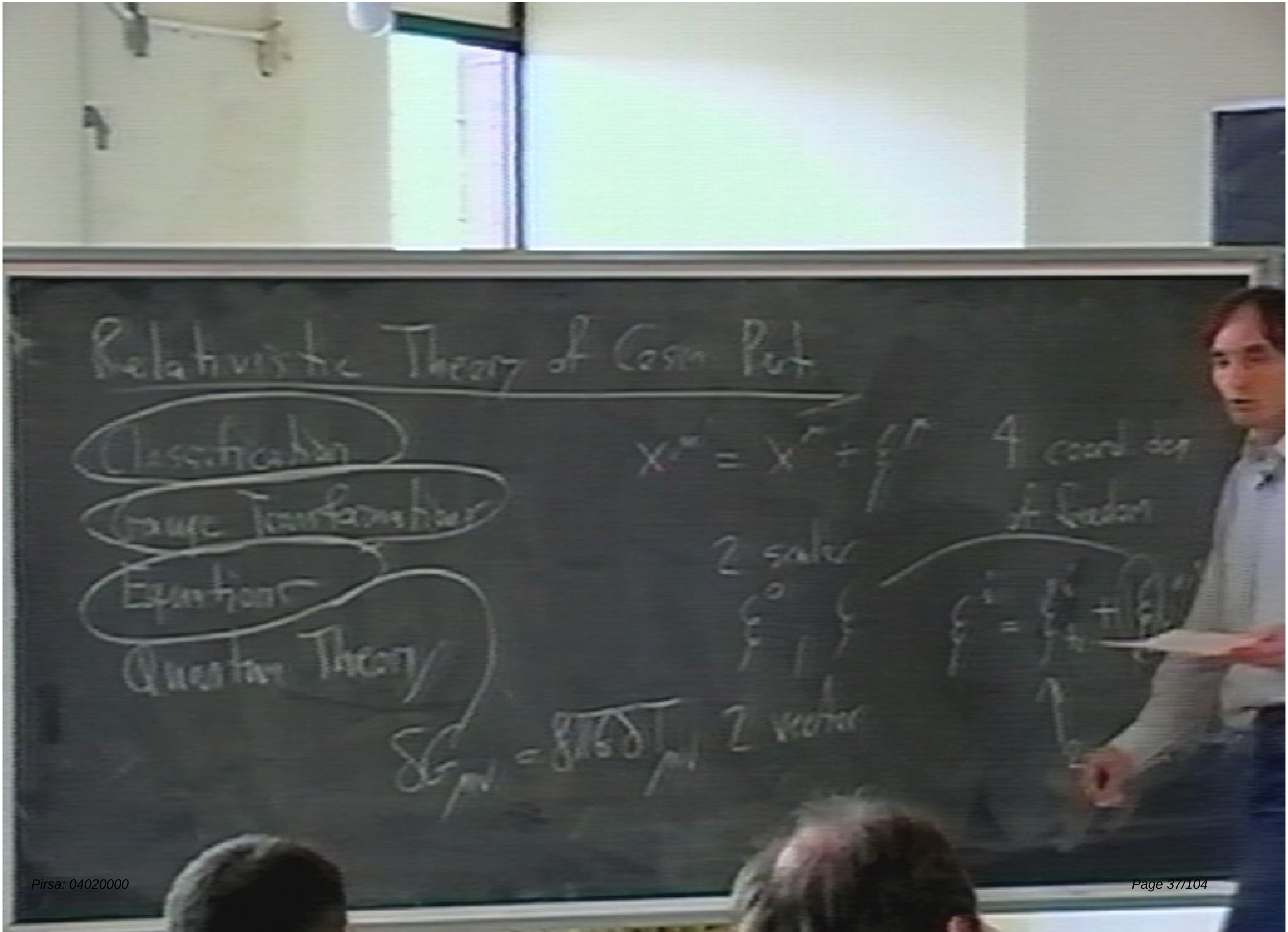

Classification Principle
spatial rotations
scalar


2 choices (a) g.i. variables
(b) completely gauge fix


2 choices (a) g.i. variables
(b) completely gauge fix
$\Phi = \phi + \frac{1}{a}[(B-E')a]'$
scalar


$' = \frac{\partial}{\partial \eta}$
2 choices (a) g.i. variables
(b) completely gauge fix
$\Phi = \phi + \frac{1}{a}\left[(B-E')a\right]'$
$\Psi = \psi - \frac{a'}{a}(B-E')$
scal


Relativistic Theory of Cosm Pert
Classification
Gauge Transformations
Equations
Quantum Theory
4 coord deg of freedom
2 vectors


Relativistic Theory of Cosm Pert
Classification
Gauge Transformations
Equations
Quantum Theory
4 coord deg of freedom
2 scalar
2 vector

$' = \frac{\partial}{\partial \eta}$

2 choices: ⓐ gi. variables

ⓑ completely gauge fix

$$\Phi = \phi + \frac{1}{a}\left[(B-E')a\right]'$$

$$\Psi = \psi - \frac{a'}{a}(B-E')$$

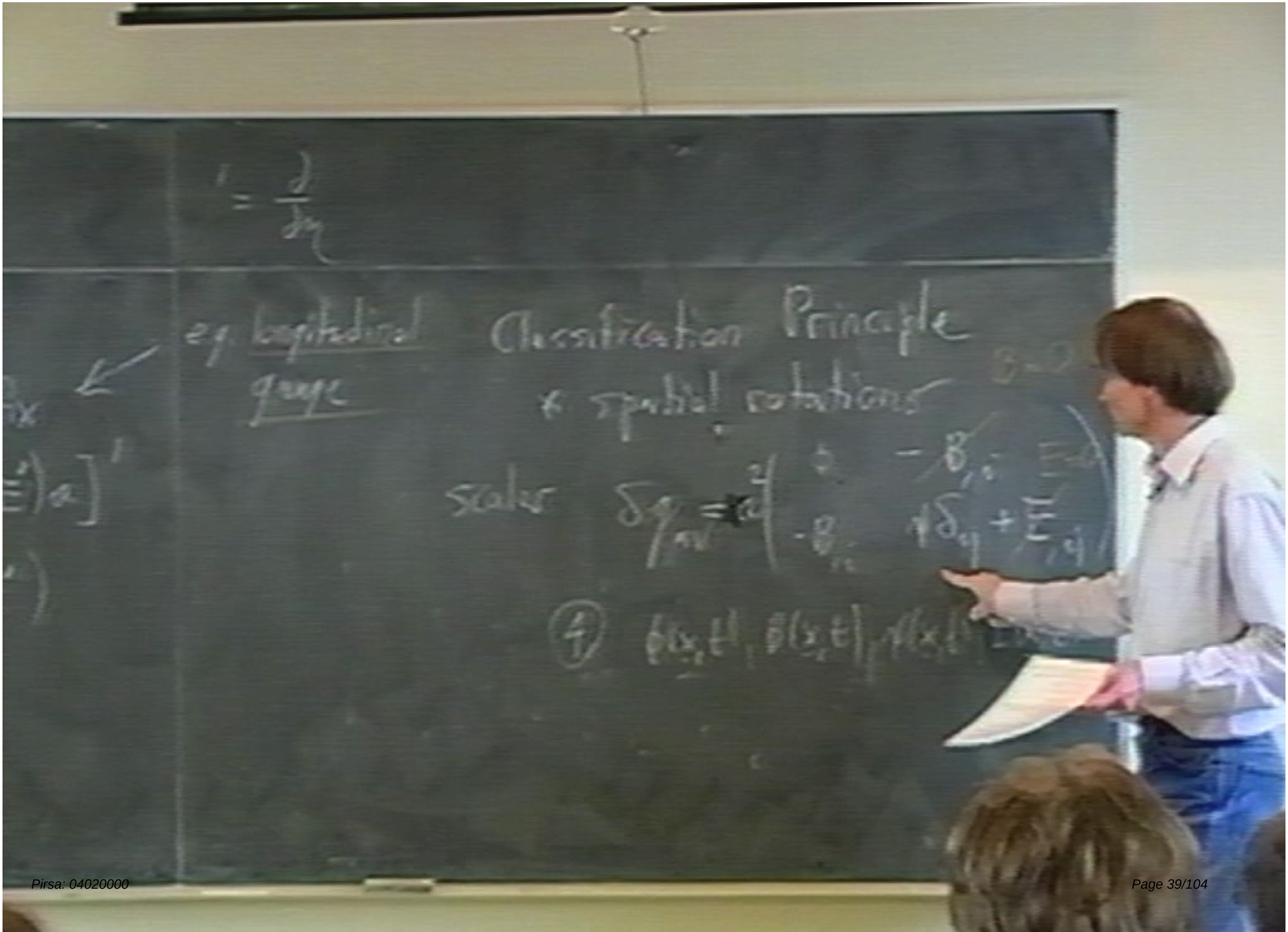
e.g. longitudinal gauge

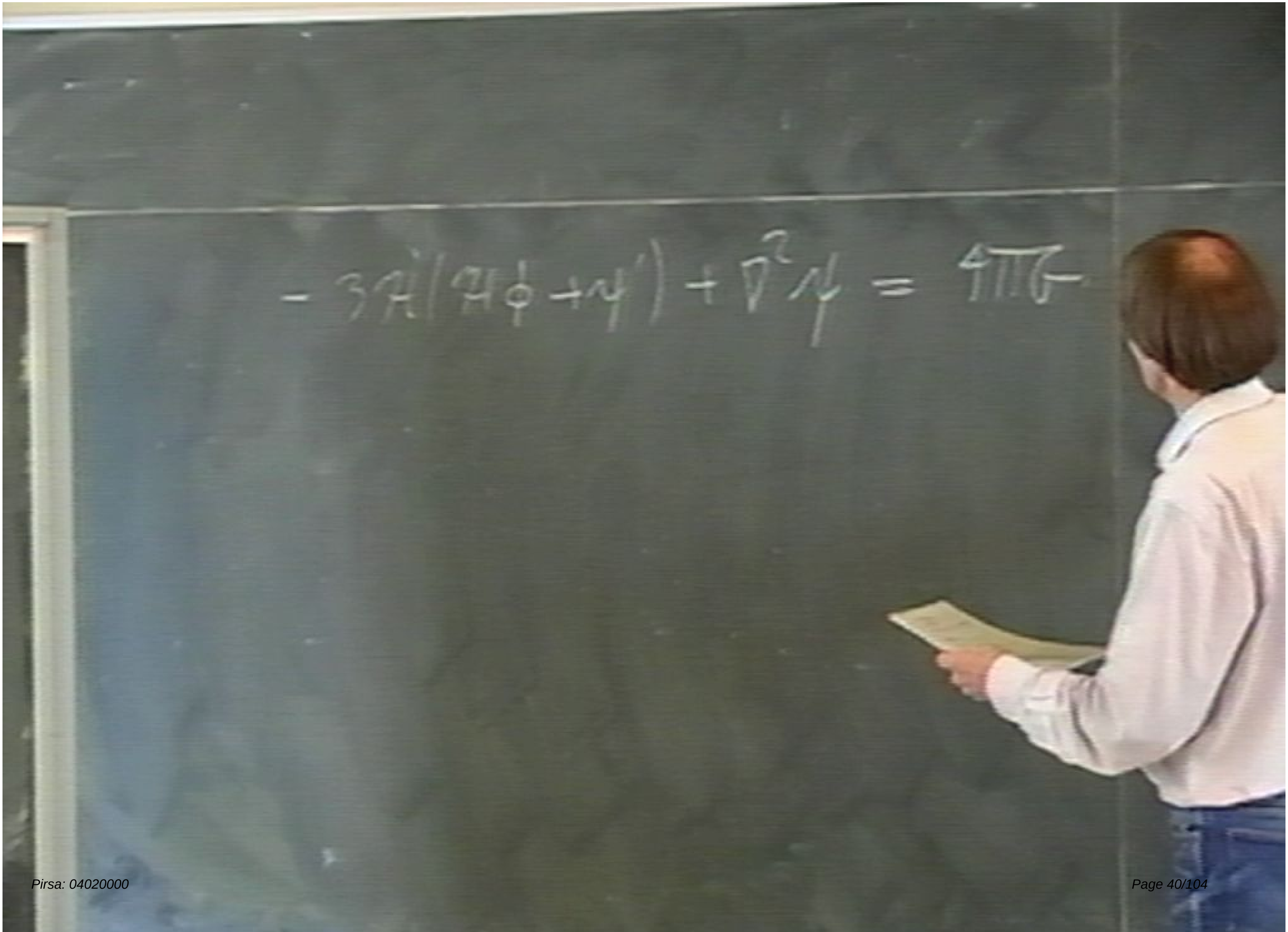
Classifica...

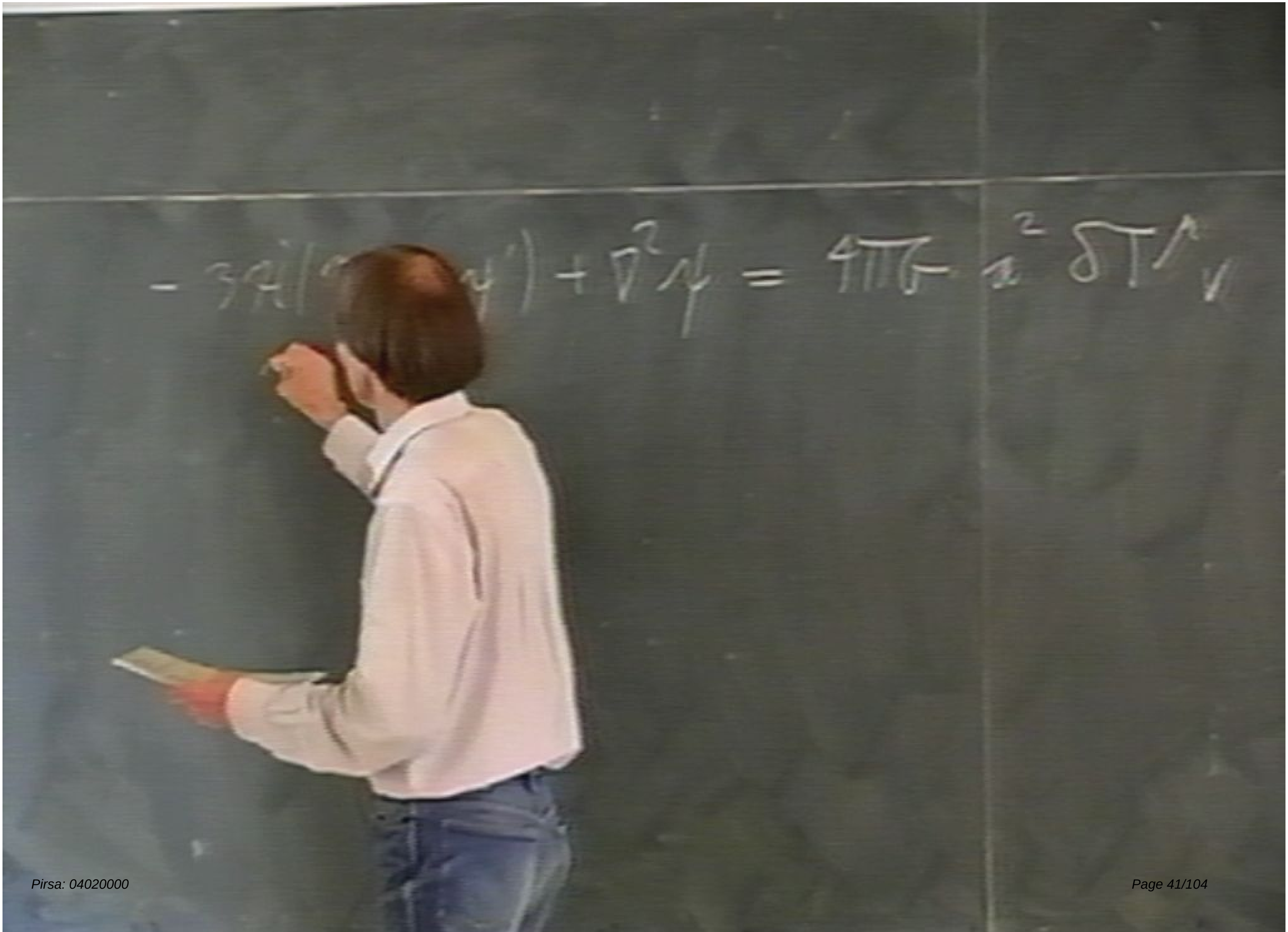
& spa...

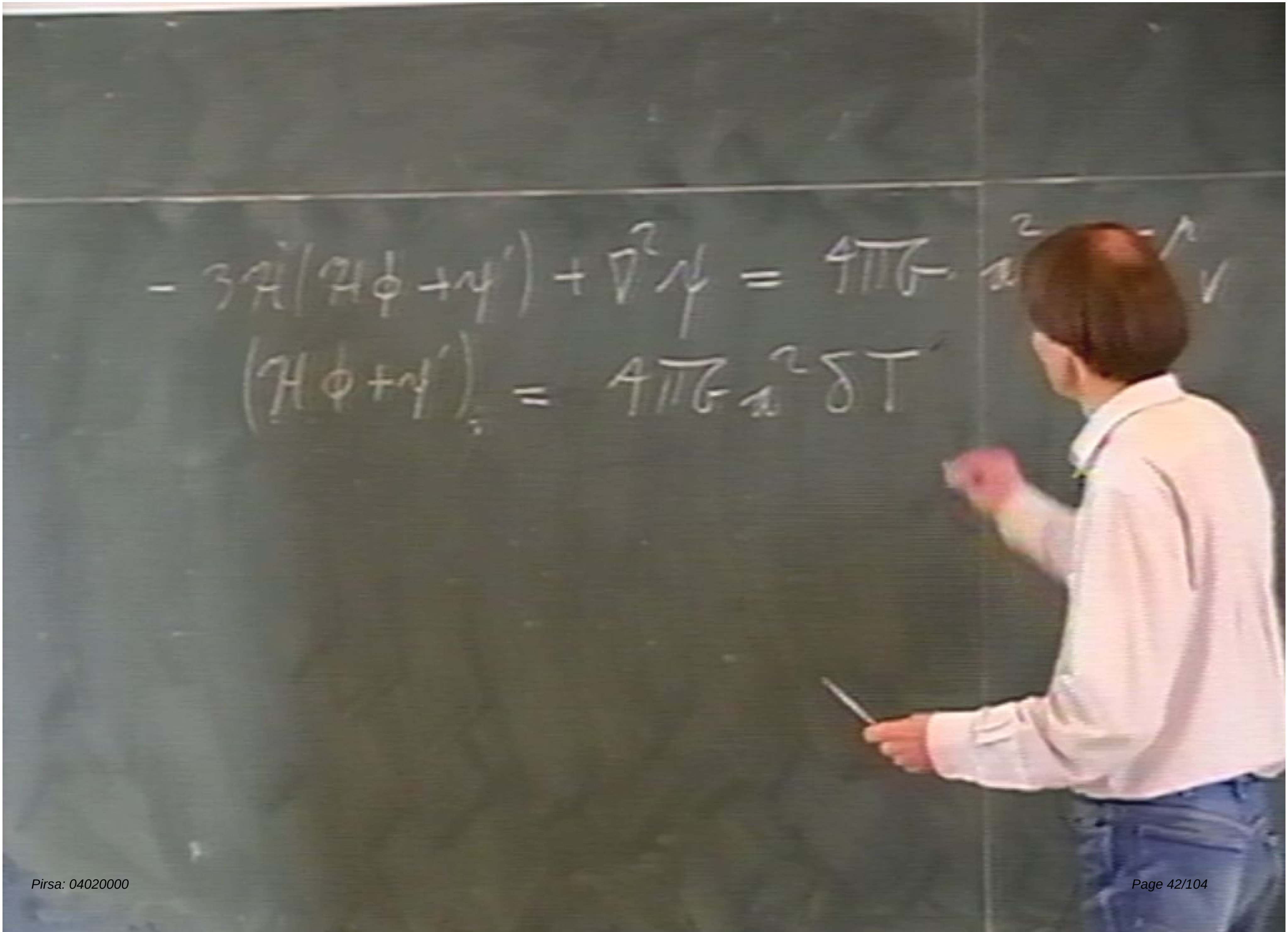
scalar δ...

④ ϕ...


e.g. longitudinal gauge
Classification Principle
× spatial rotations
scalar


$-3\mathcal{H}(\mathcal{H}\phi+\psi')+\nabla^2\psi = 4\pi G$




$-3\mathcal{H}'(\mathcal{H}\phi+\psi')+\nabla^2\psi = 4\pi G a^2$
$(\mathcal{H}\phi+\psi')_{,i} = 4\pi G a^2 \delta T$

$$-3\mathcal{H}(\mathcal{H}\phi+\psi') + \nabla^2\psi = 4\pi G\, a^2\, \delta T^{0}$$

$$(\mathcal{H}\phi+\psi')_{,i} = 4\pi G\, a^2\, \delta T^0_i$$

$$(2\mathcal{H}'+\mathcal{H}^2)\phi + \mathcal{H}\phi' + \psi'' + 2\mathcal{H}\psi'$$

$$3\mathcal{H}(\mathcal{H}\phi+\psi')+\nabla^2\psi = 4\pi G a^2 \delta T^{\mu}{}_{\nu}$$

$$(\mathcal{H}\phi+\psi')_{,i} = 4\pi G a^2 \delta T^{0}{}_{i}$$

$$(2\mathcal{H}'+\mathcal{H}^2)\phi+\mathcal{H}\phi'+\psi''+2\mathcal{H}\psi']\delta_{ij}$$

$$+\nabla^2\psi = 4\pi G\, a^2\, \delta T^0{}_0$$

$$= 4\pi G\, a^2\, \delta T^0{}_i$$

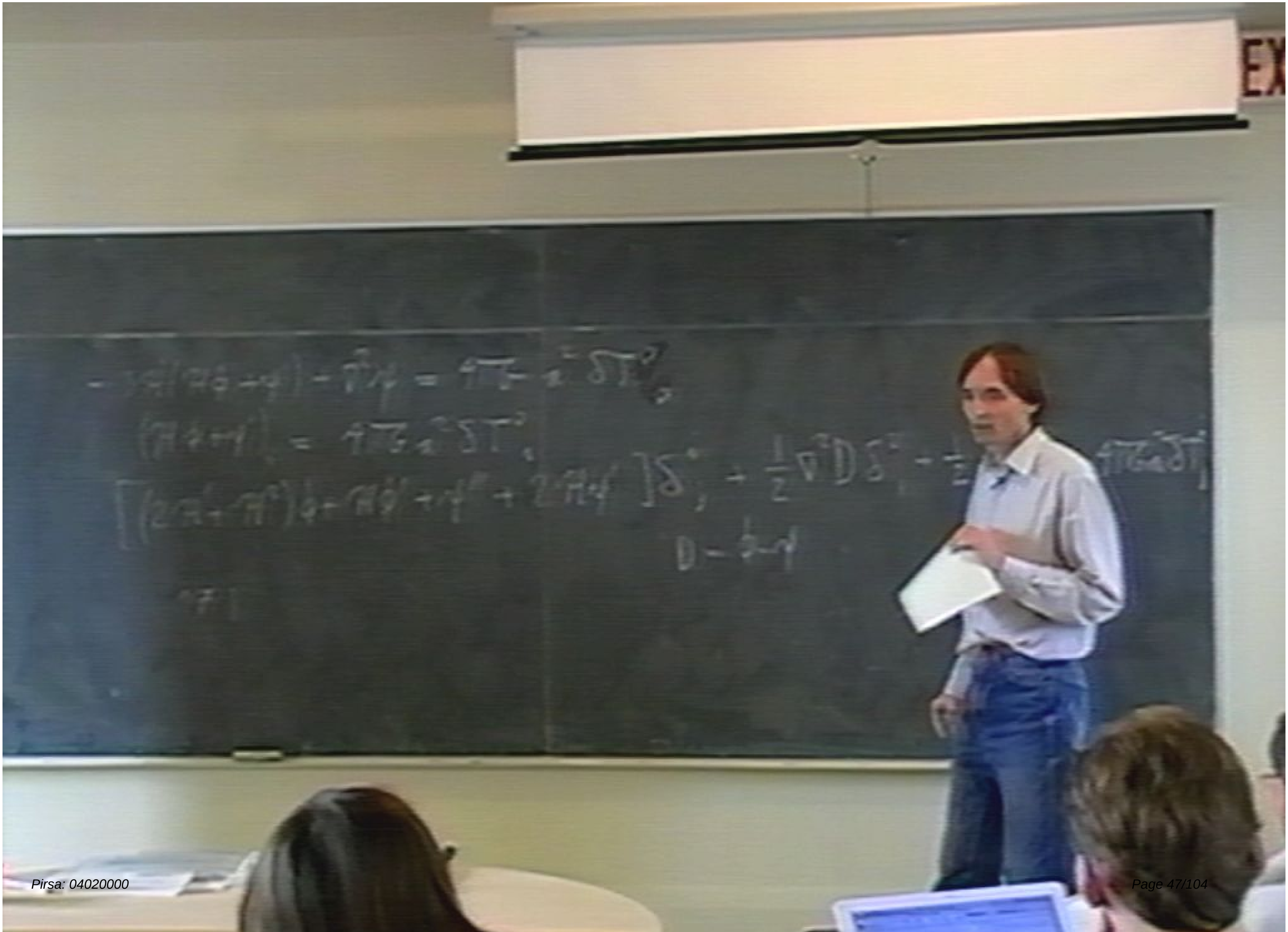
$$\phi + \mathcal{H}\phi' + \psi'' + 2\mathcal{H}\psi' \,]\, \delta^i{}_j + \frac{1}{2}\nabla^2 D$$

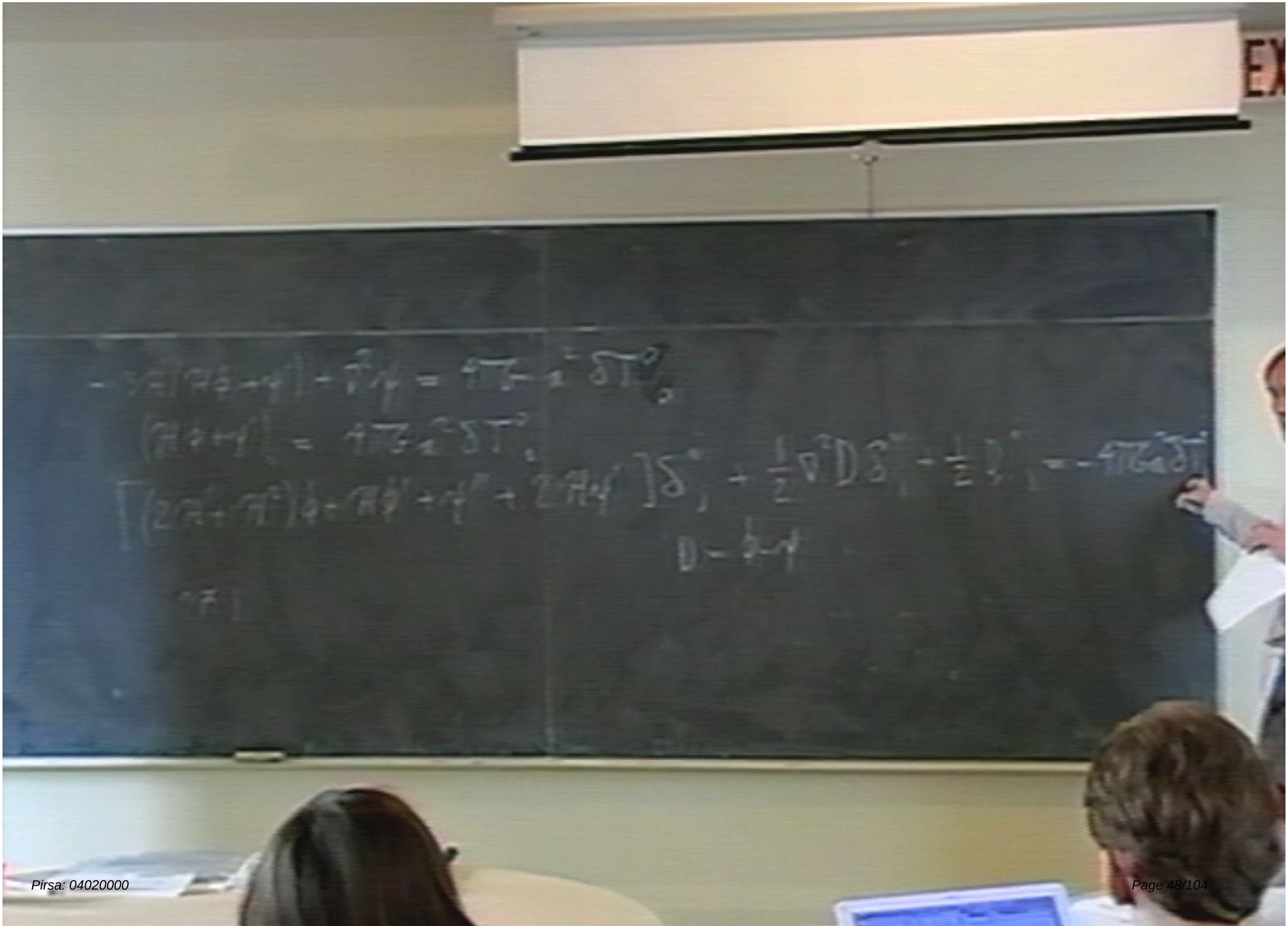
$$-3\mathcal{H}(\mathcal{H}\phi + \psi') + \nabla^2\psi = 4\pi G a^2 \delta T^0{}_0$$

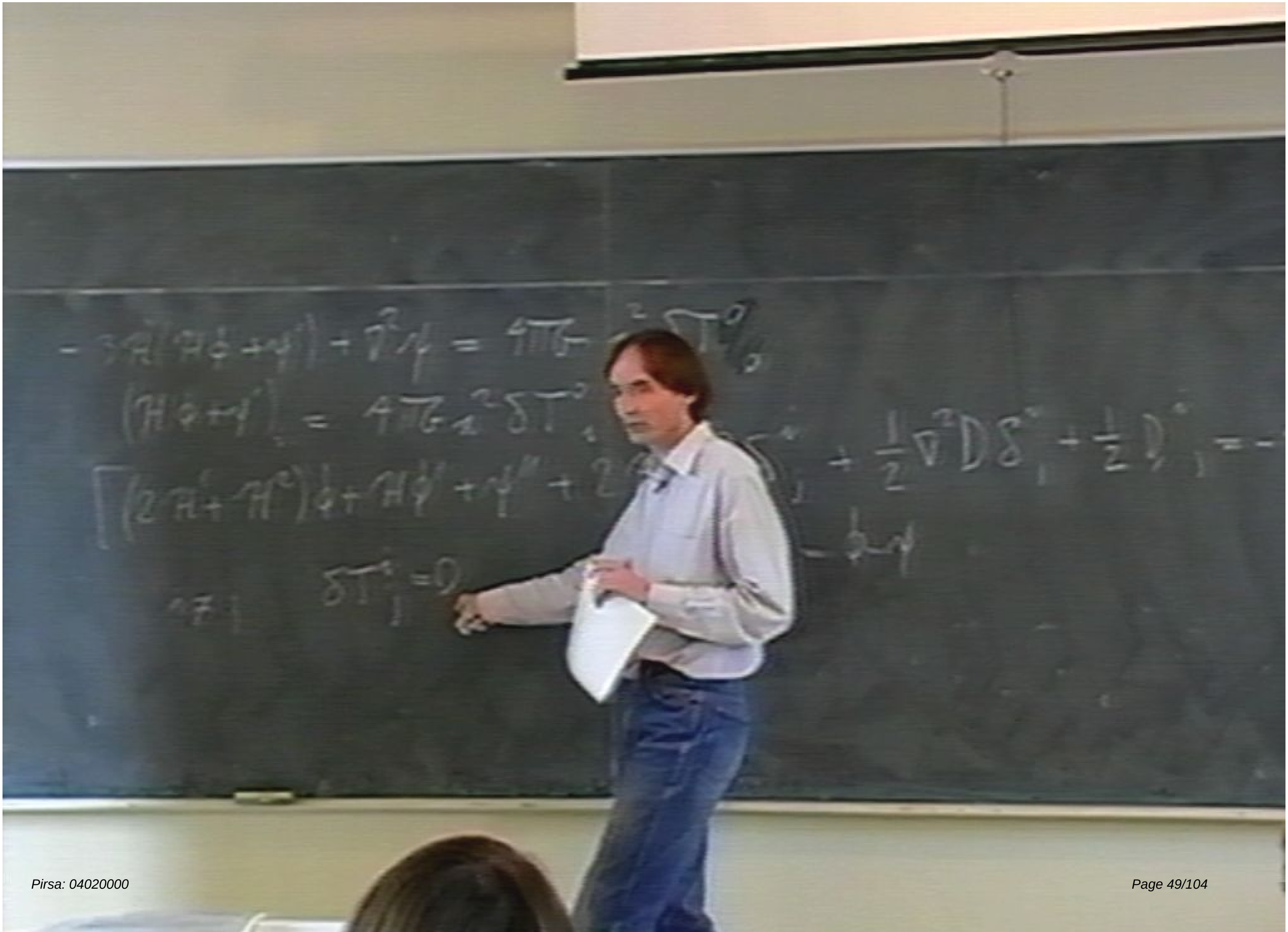
$$(\mathcal{H}\phi + \psi')_{,i} = 4\pi G a^2 \delta T^0{}_i$$

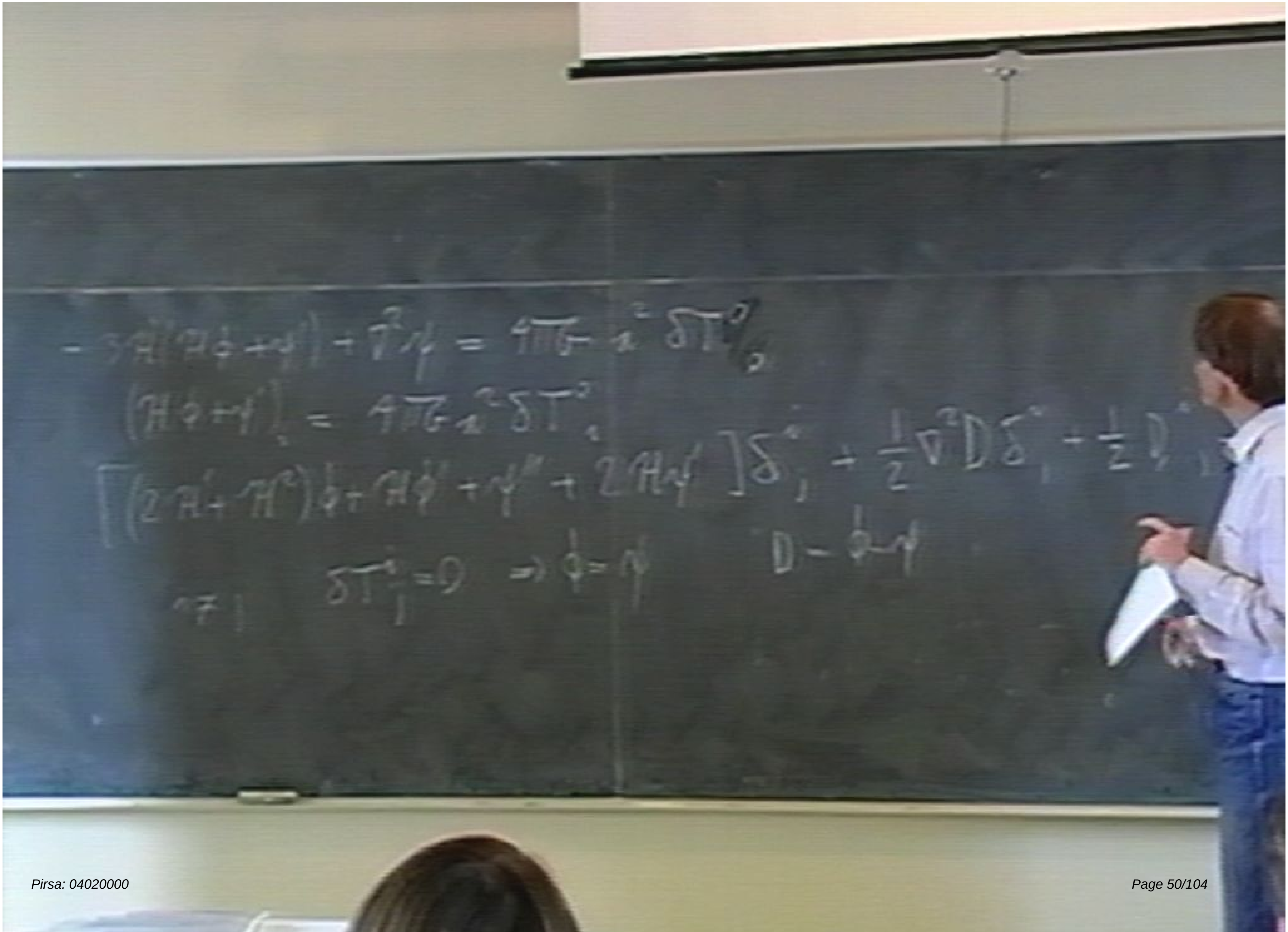
$$\left[(2\mathcal{H}' + \mathcal{H}^2)\phi + \mathcal{H}\phi' + \psi'' + 2\mathcal{H}\psi'\right]\delta^i{}_j + \frac{1}{2}\nabla^2 D\,\delta^i{}_j + \frac{1}{2}$$

$$D = \phi - \psi$$









$-3\mathcal{H}(\mathcal{H}\phi+\psi')+\nabla^2\psi = 4\pi G a^2 \delta T^0{}_0$
$(\mathcal{H}\phi+\psi')_{,i} = 4\pi G a^2 \delta T^0{}_i$
$[(2\mathcal{H}'+\mathcal{H}^2)\phi+\mathcal{H}\phi'+\psi''+2\mathcal{H}\psi']\delta^i{}_j + \frac{1}{2}\nabla^2 D\,\delta^i{}_j + \frac{1}{2} D$
$\delta T^i{}_j = 0 \Rightarrow \phi = \psi$
$D = \phi - \psi$

$$(\mathcal{H}\phi' + \psi') + \nabla^2\psi = 4\pi G a^2 \delta T^0_0$$

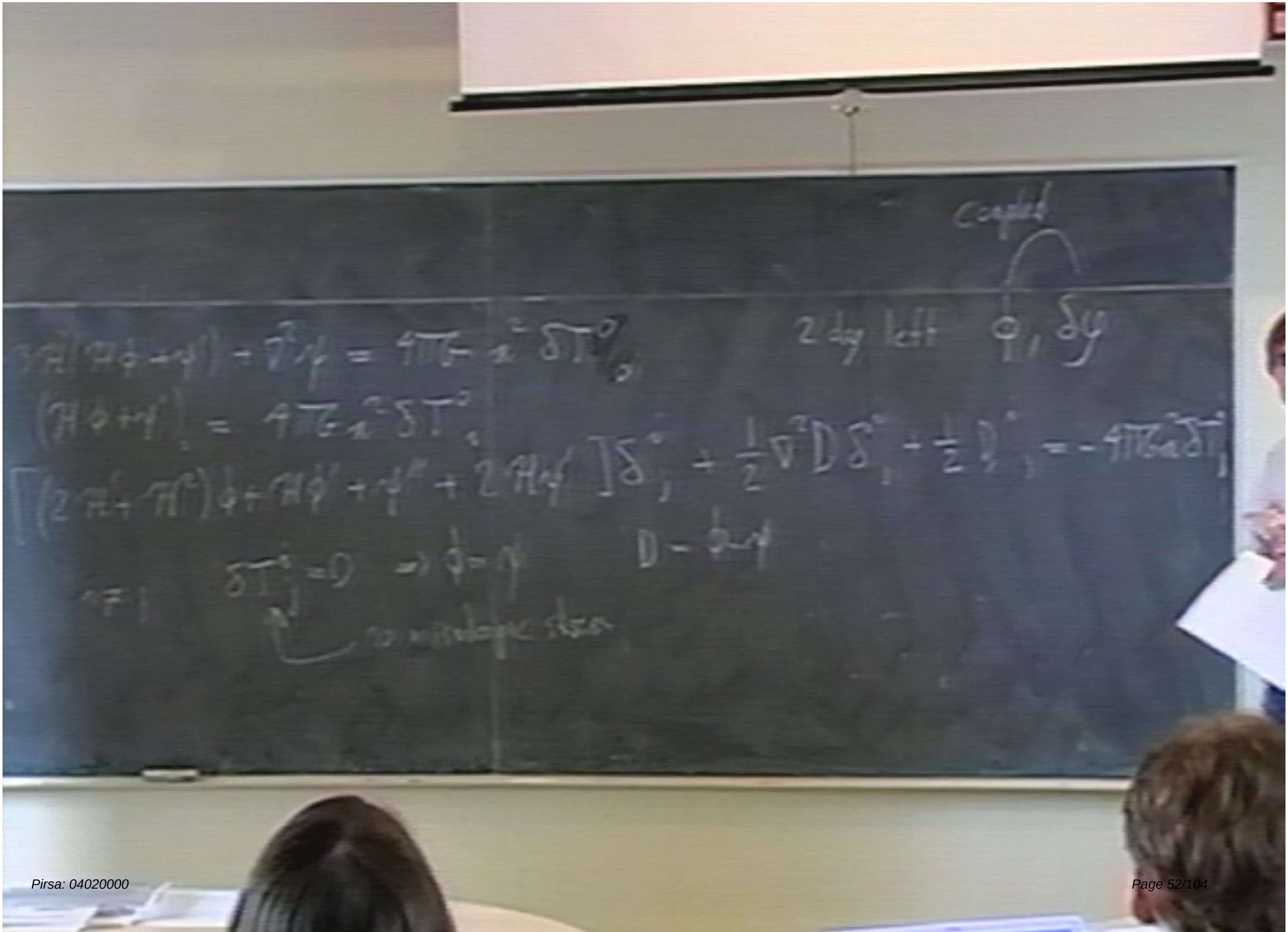
2 dof left $\phi, \delta\varphi$

$$(\mathcal{H}\phi + \psi')_{,i} = 4\pi G a^2 \delta T^0_i$$

$$\left[(2\mathcal{H}' + \mathcal{H}^2)\phi + \mathcal{H}\phi' + \psi'' + 2\mathcal{H}\psi'\right]\delta^i_j + \frac{1}{2}\nabla^2 D\,\delta^i_j - \frac{1}{2}D^{,i}_{,j} = -4\pi G a^2 \delta T^i_j$$

$i \neq j$ $\quad \delta T^i_j = 0 \Rightarrow \phi = \psi$ $\qquad D = \phi - \psi$

no anisotropic stress


coupled

combination $\quad \phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \right.$

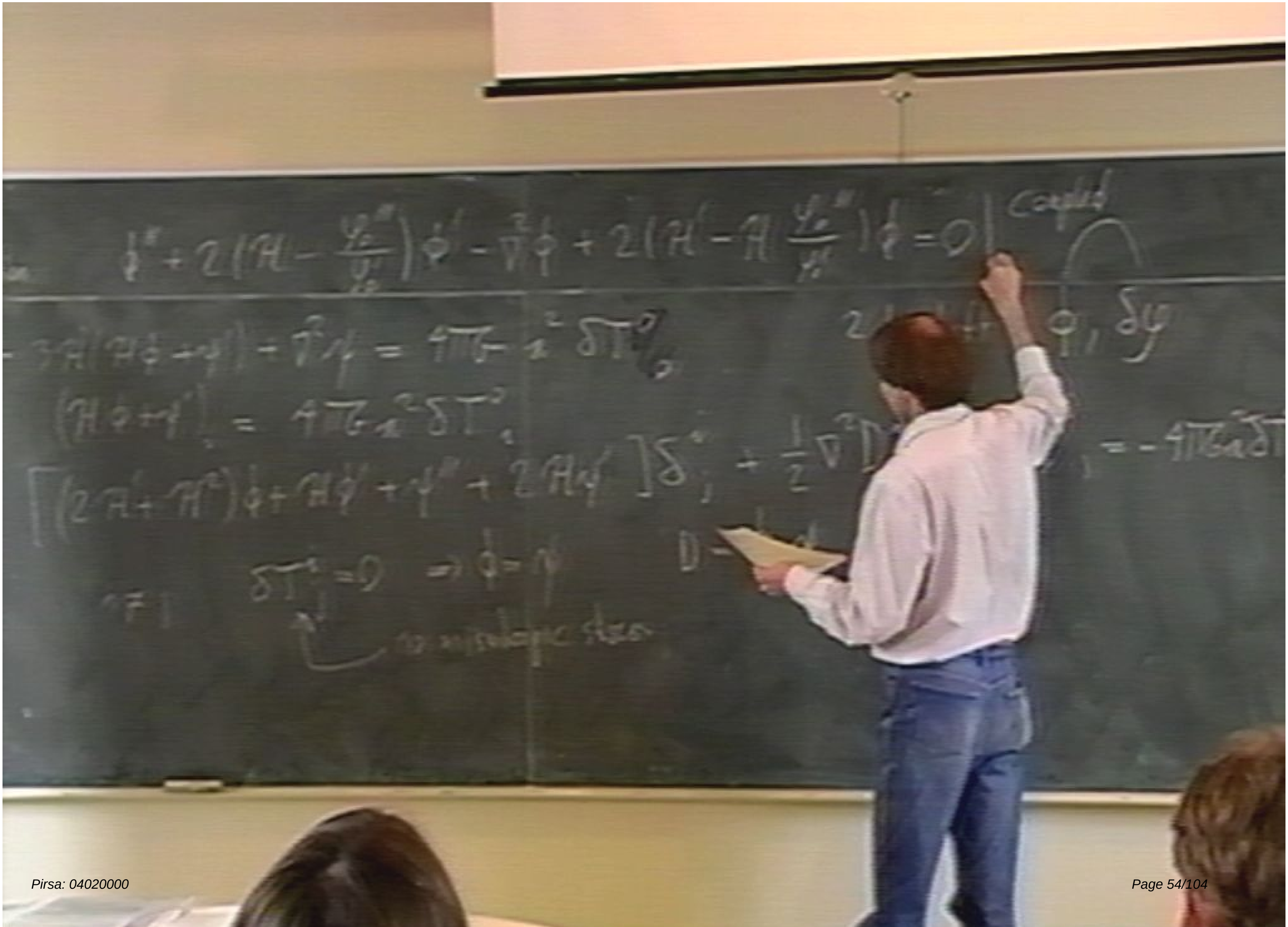
$$-3\mathcal{H}(\mathcal{H}\phi + \psi') + \nabla^2\psi = 4\pi G a^2 \delta T^0_0$$

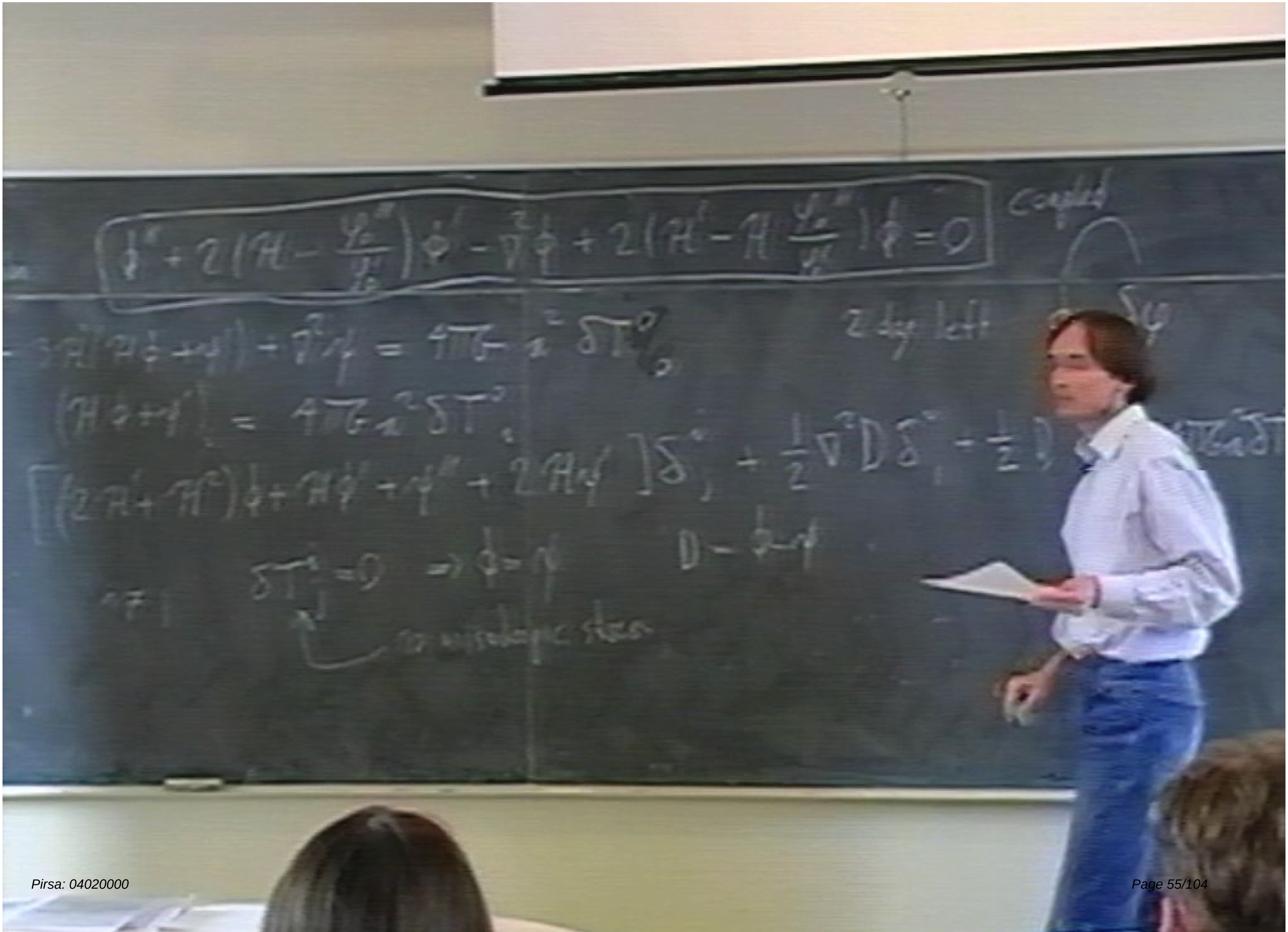
$$(\mathcal{H}\phi + \psi')_{,i} = 4\pi G a^2 \delta T^0_i$$

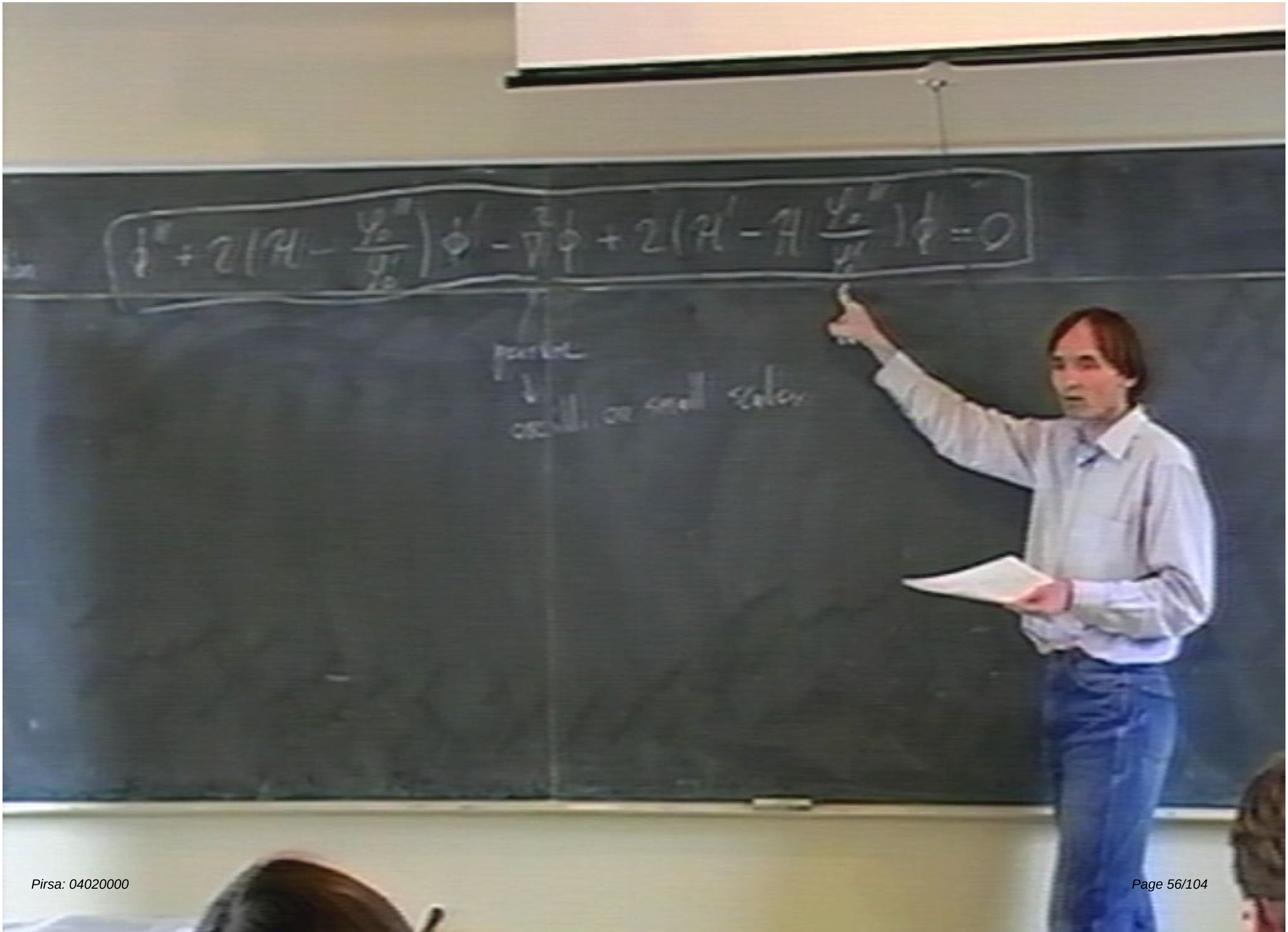
$$\left[(2\mathcal{H}' + \mathcal{H}^2)\phi + \mathcal{H}\phi' + \psi'' + 2\mathcal{H}\psi'\right]\delta^i_j$$

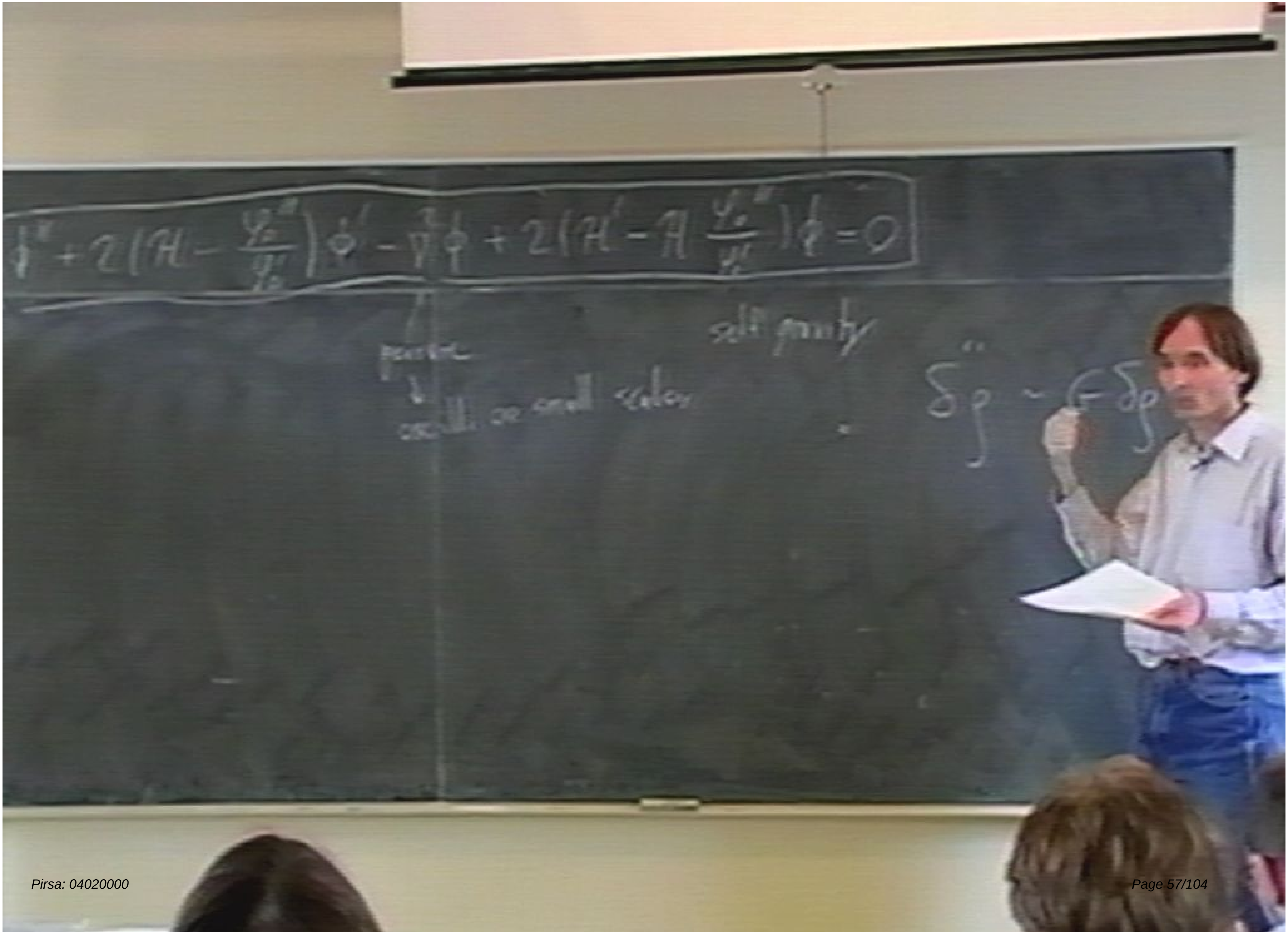
$i \neq j \qquad \delta T^i_j = 0 \quad \Rightarrow \phi = \psi$

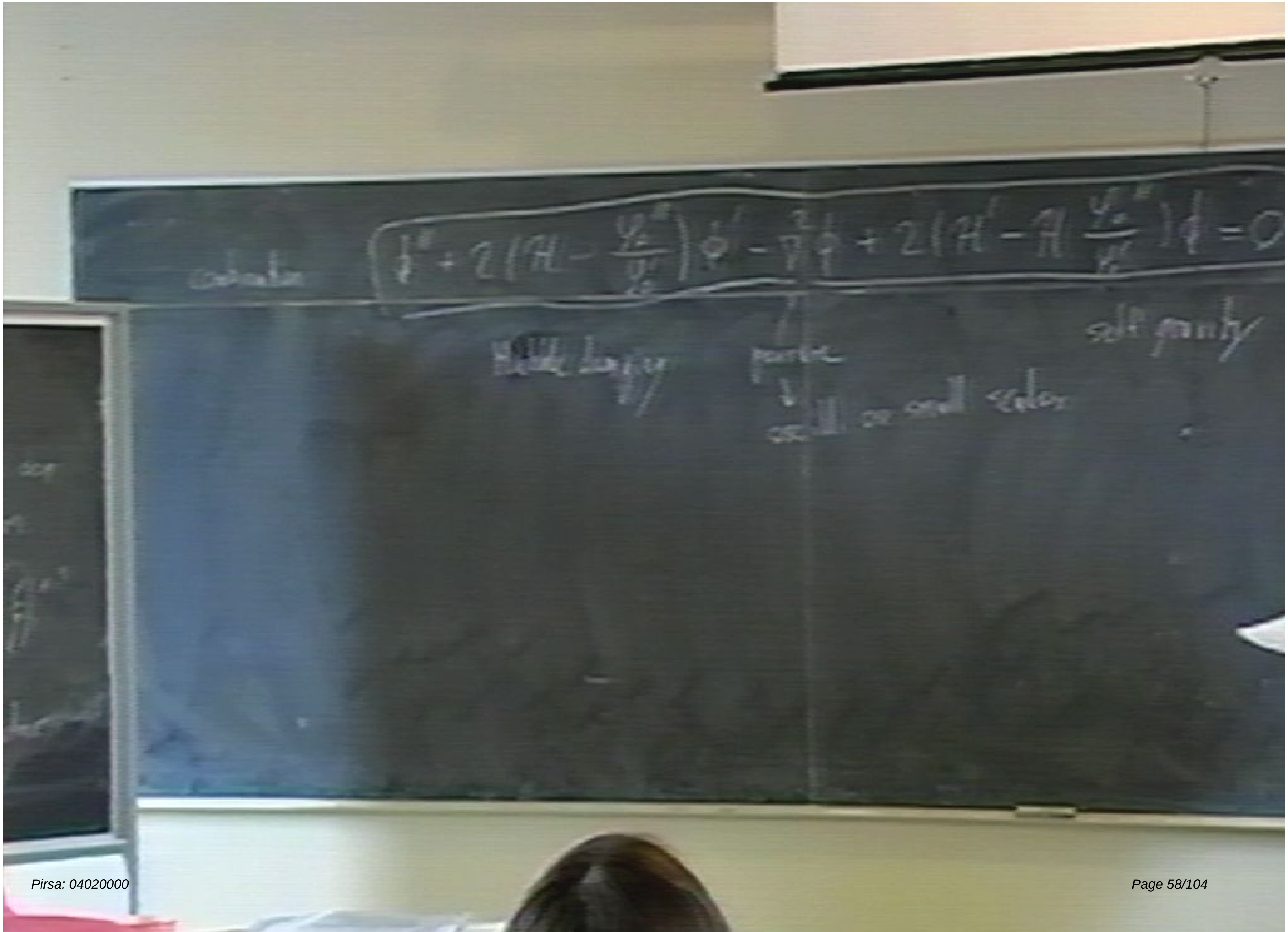
no anisotropic stress




coupled


$\phi'' + 2\left(\mathcal{H} - \frac{\psi_0''}{\psi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\psi_0''}{\psi_0'}\right)\phi = 0$


$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0$
pressure
oscill. on small scales
self gravity
$\ddot{\delta\rho} \sim G\,\delta\rho$


Hubble damping
oscill. on small scales
self gravity

combination

$$\boxed{\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\,\frac{\varphi_0''}{\varphi_0'} \right.}$$

Hubble damping

positive

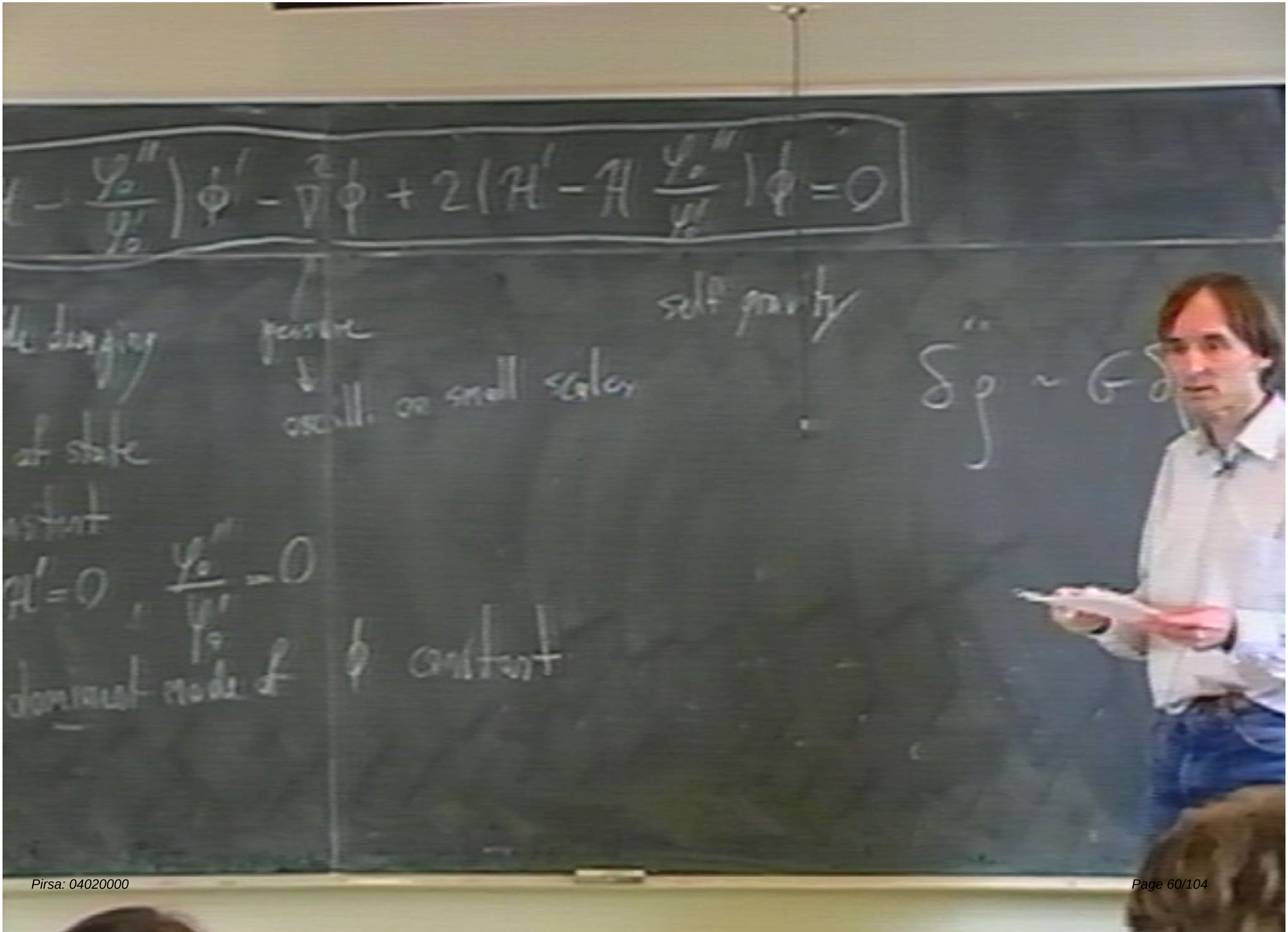
$\Downarrow$

oscill. or small scalar

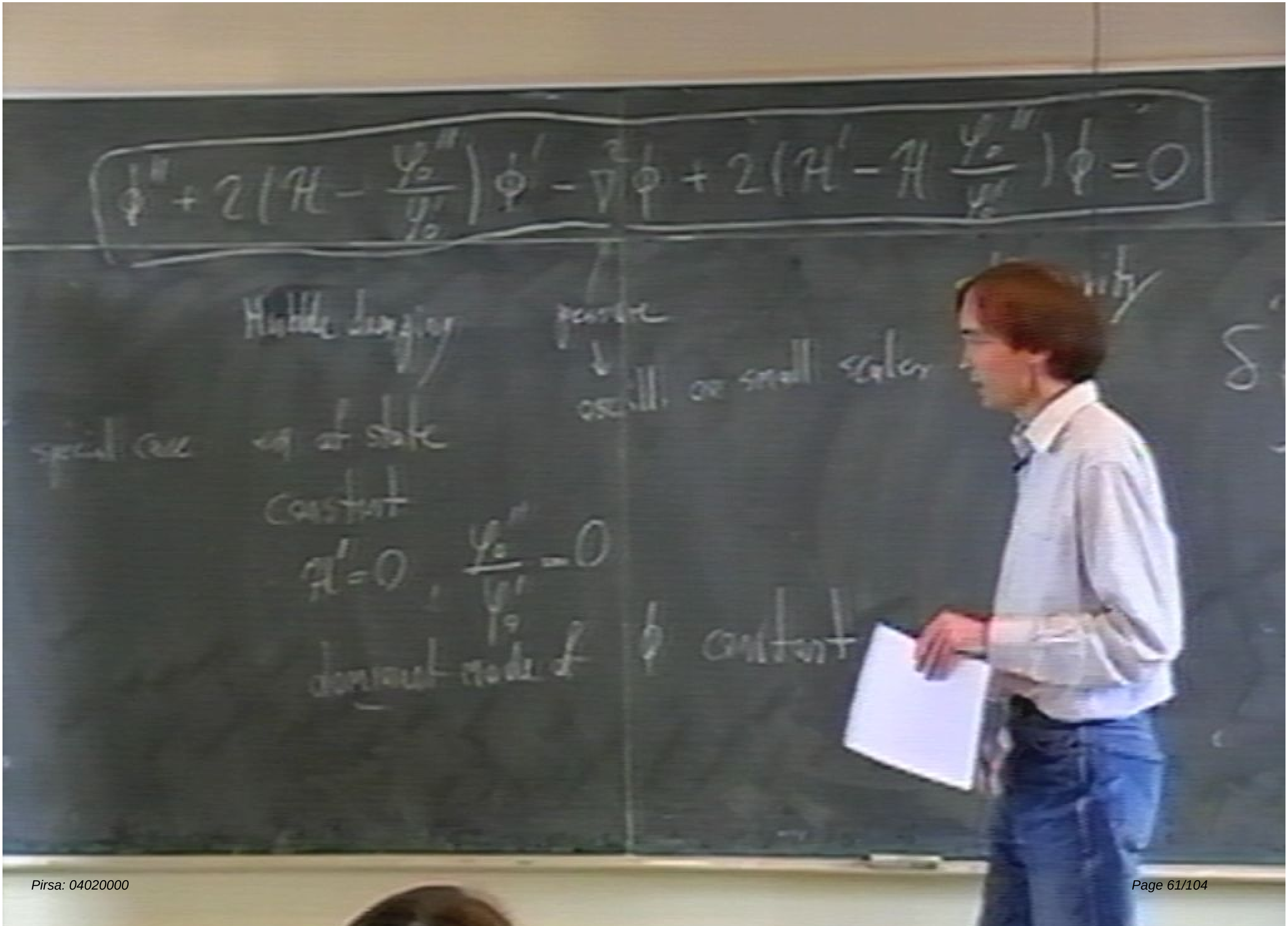
sol

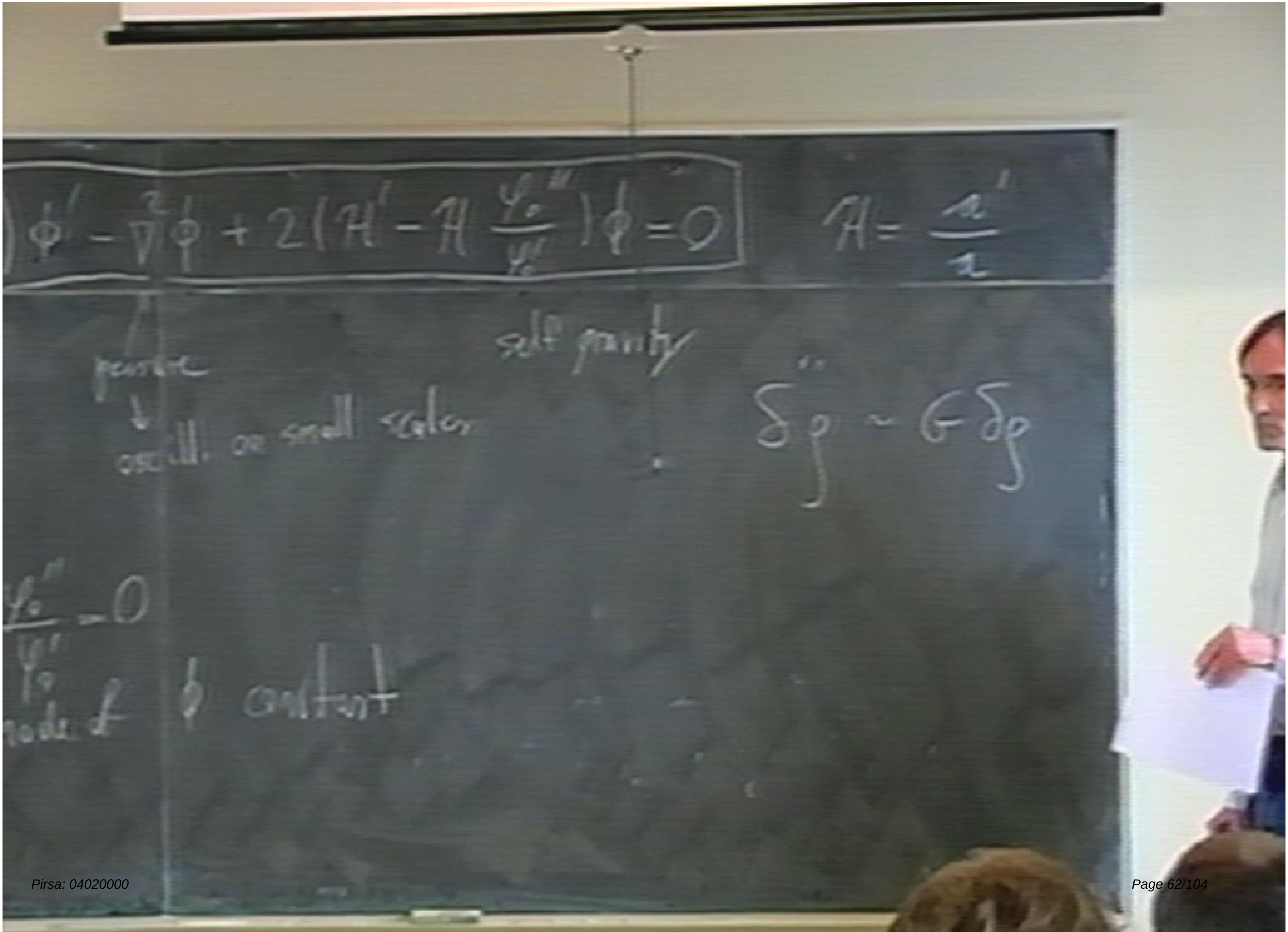
special case eq. of state constant

$$\mathcal{H}' = 0 \,, \quad \frac{\varphi_0''}{\varphi_0'} = 0$$



self parity
positive
oscill. or small scalar
of state
constant
$\mathcal{H}'=0$
dominant mode of
ϕ constant


$\phi'' + 2\left(\mathcal{H} - \frac{\psi_0''}{\psi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\psi_0''}{\psi_0'}\right)\phi = 0$
Hubble damping
positive
oscill. on small scales
special case eq of state
constant
$\mathcal{H}' = 0 , \frac{\psi_0''}{\psi_0'} = 0$
dominant mode of ϕ constant


$\phi'' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
positive
oscill. or small scalar
$\ddot{\delta\rho} \sim G\,\delta\rho$
$\frac{\varphi_0''}{\varphi_0'} = 0$
mode of
ϕ constant

$$\boxed{\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0}$$

$\mathcal{H} =$

Hubble damping

pressure

$\downarrow$

oscill. on small scales

self gravity

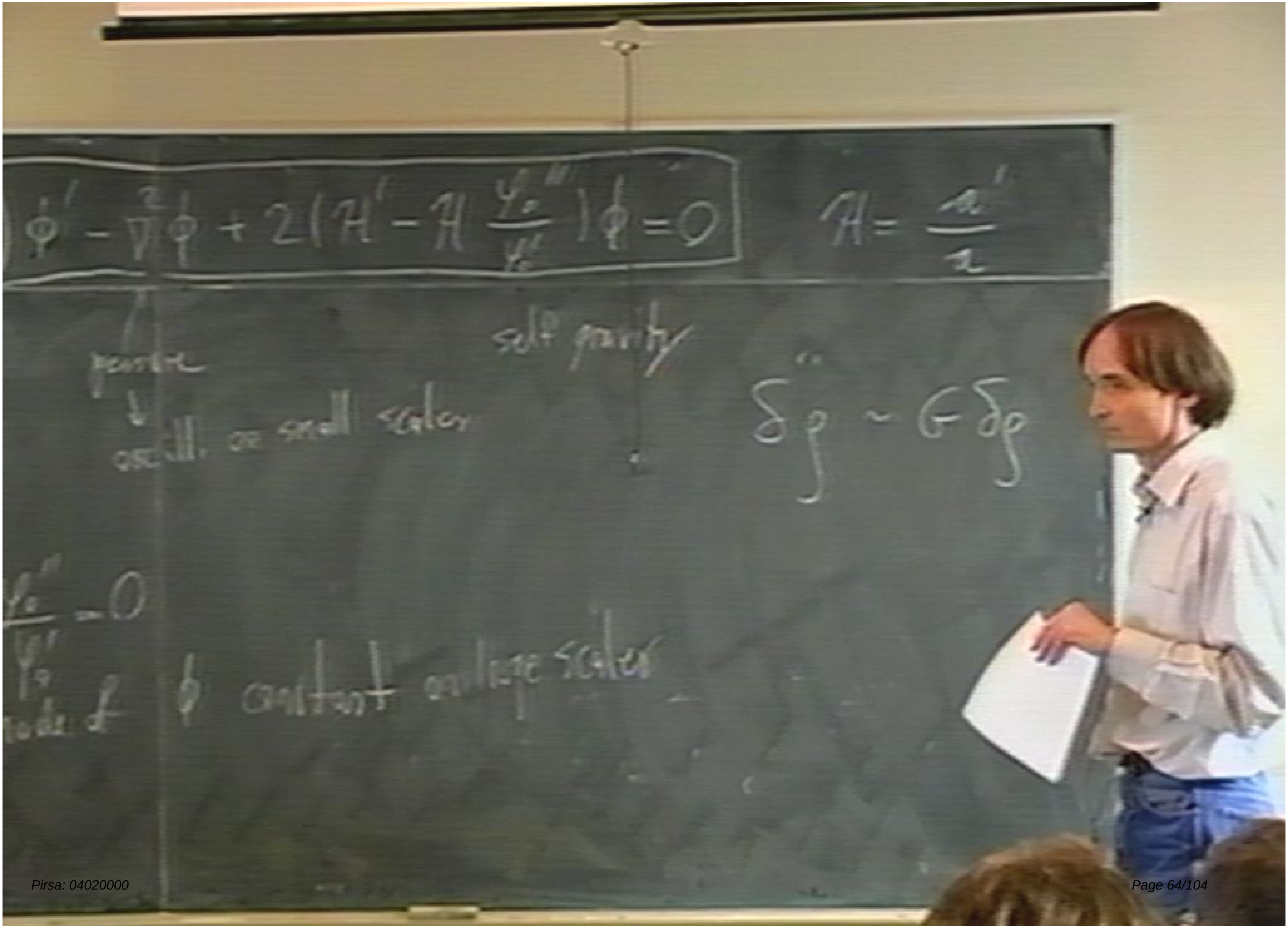
$\delta\ddot{\rho} \sim$

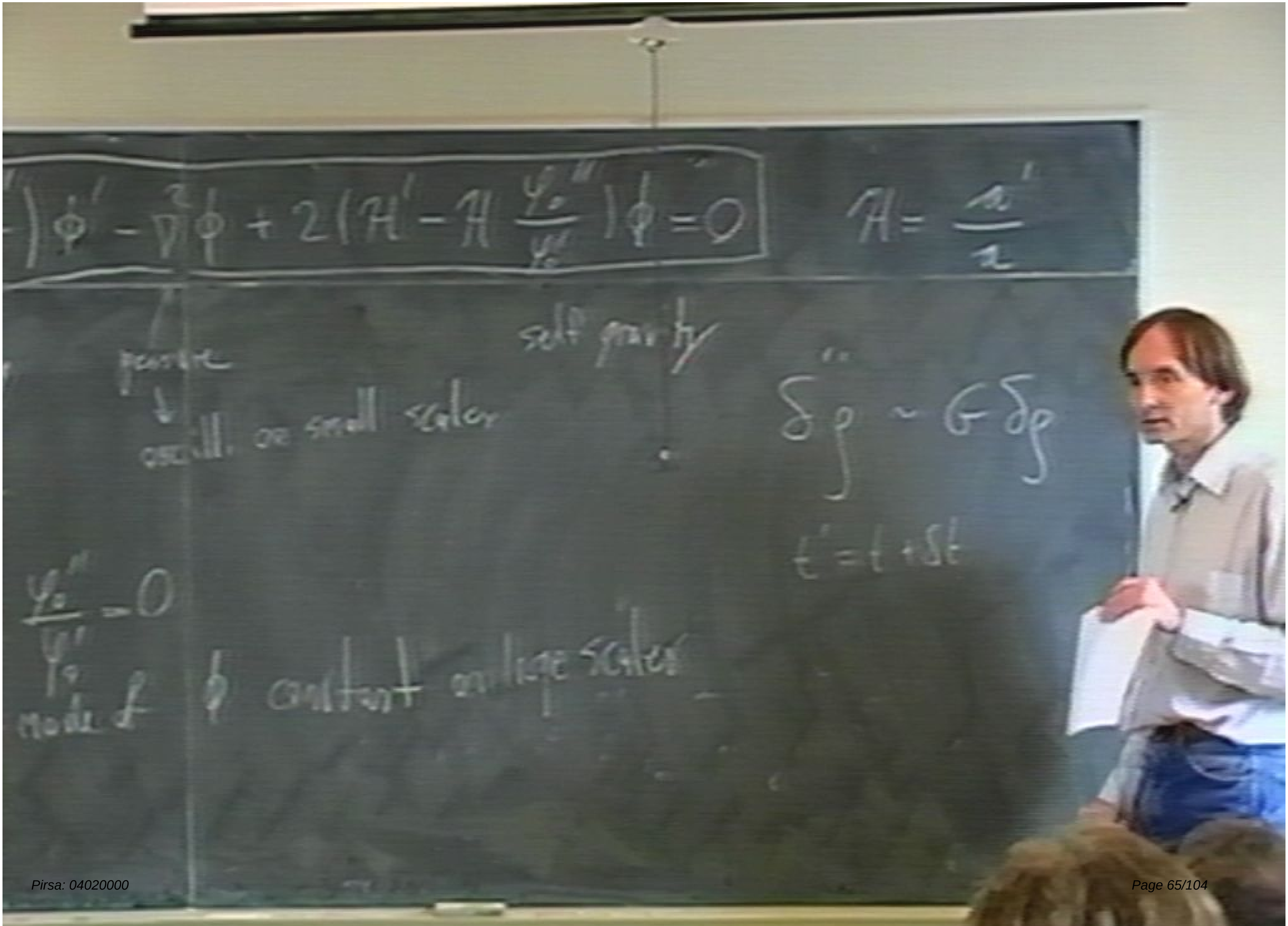
case eq. of state

constant

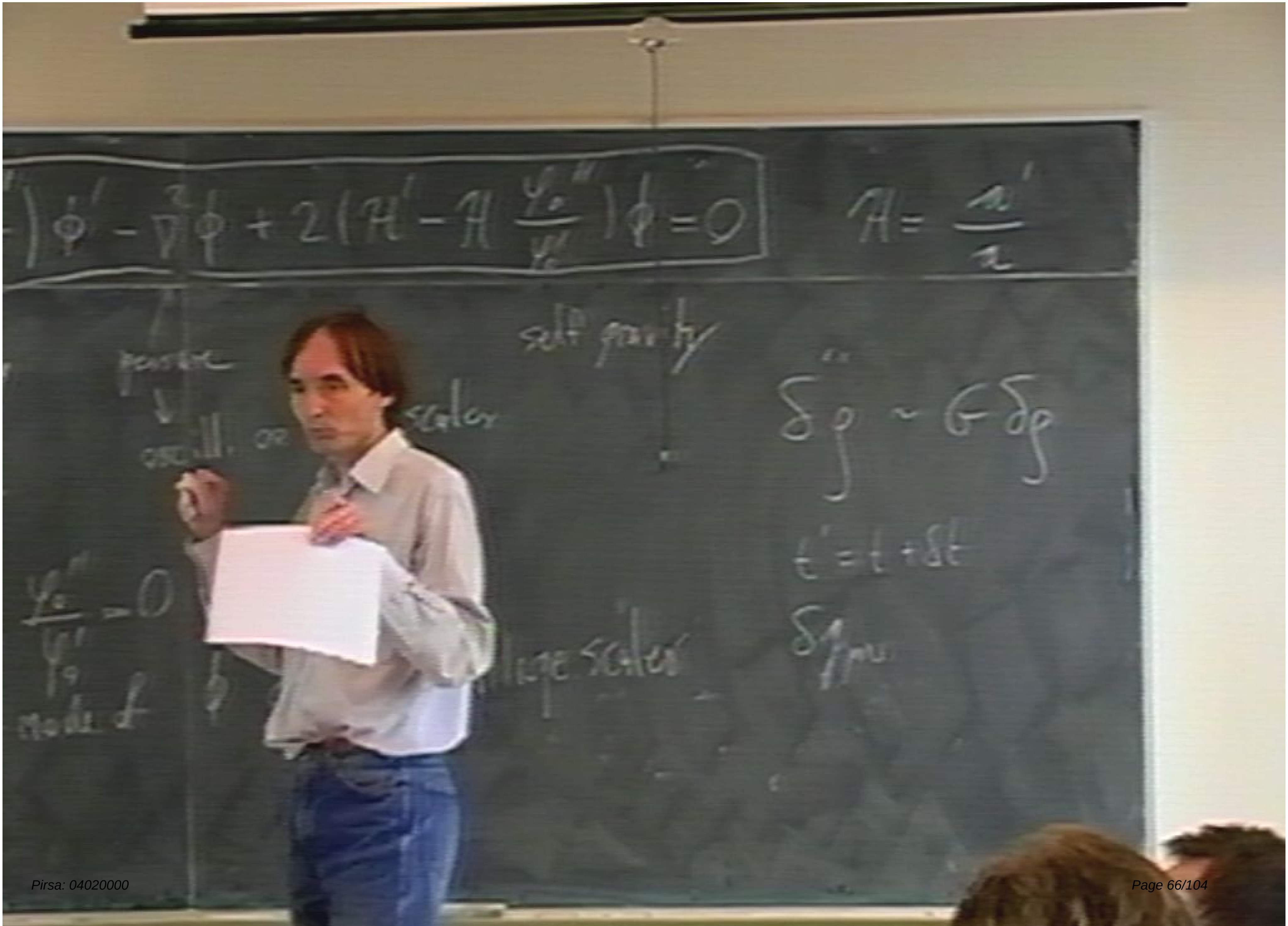
$\mathcal{H}' = 0 \; , \; \frac{\varphi_0''}{\varphi_0'} = 0$

dominant mode of ϕ constant on large scales


self parity
positive
oscill. or small scalar
constant collapse scalar
mode of



$\mathcal{H} = \frac{a'}{a}$
self gravity
positive
oscill. or small scalar
$t' = t + \delta t$
mode of


self gravity
t' = t + δt

$$\boxed{\ldots)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0} \qquad \mathcal{H} = \frac{a'}{a}$$

self gravity

positive

oscill. on small scales

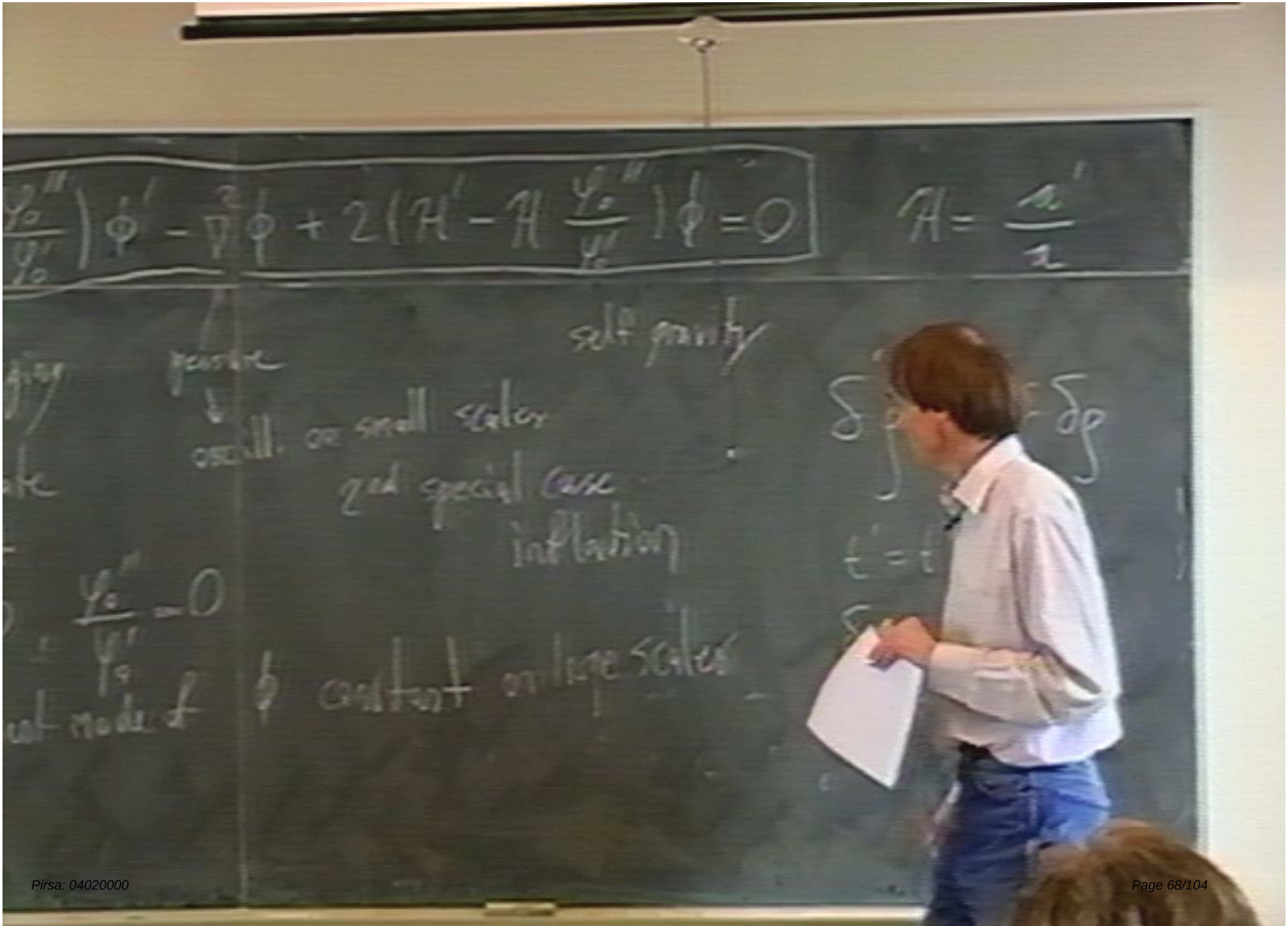
$$\ddot{\delta\rho} \sim G\,\delta\rho$$

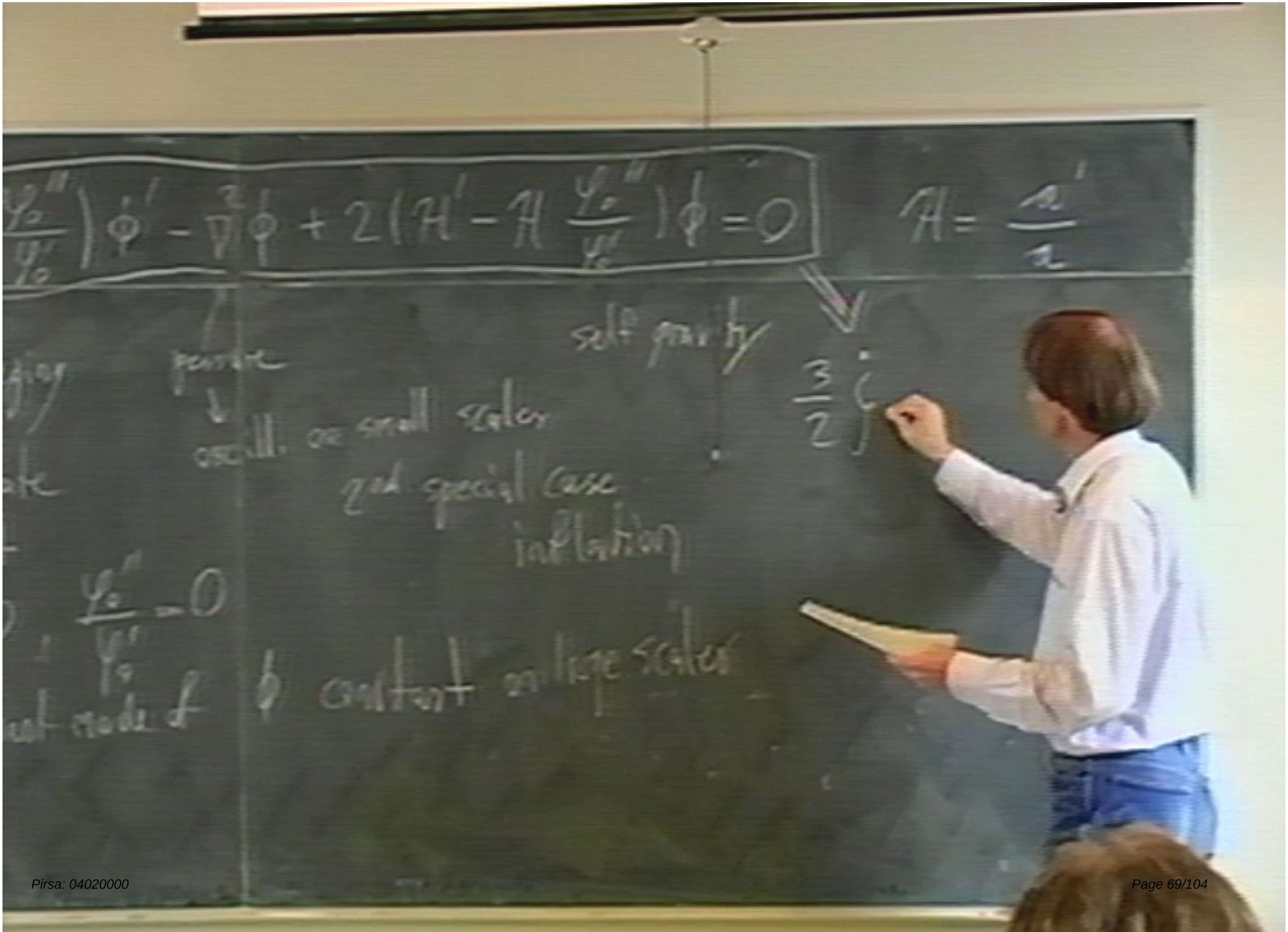
$$t' = t + \delta t$$

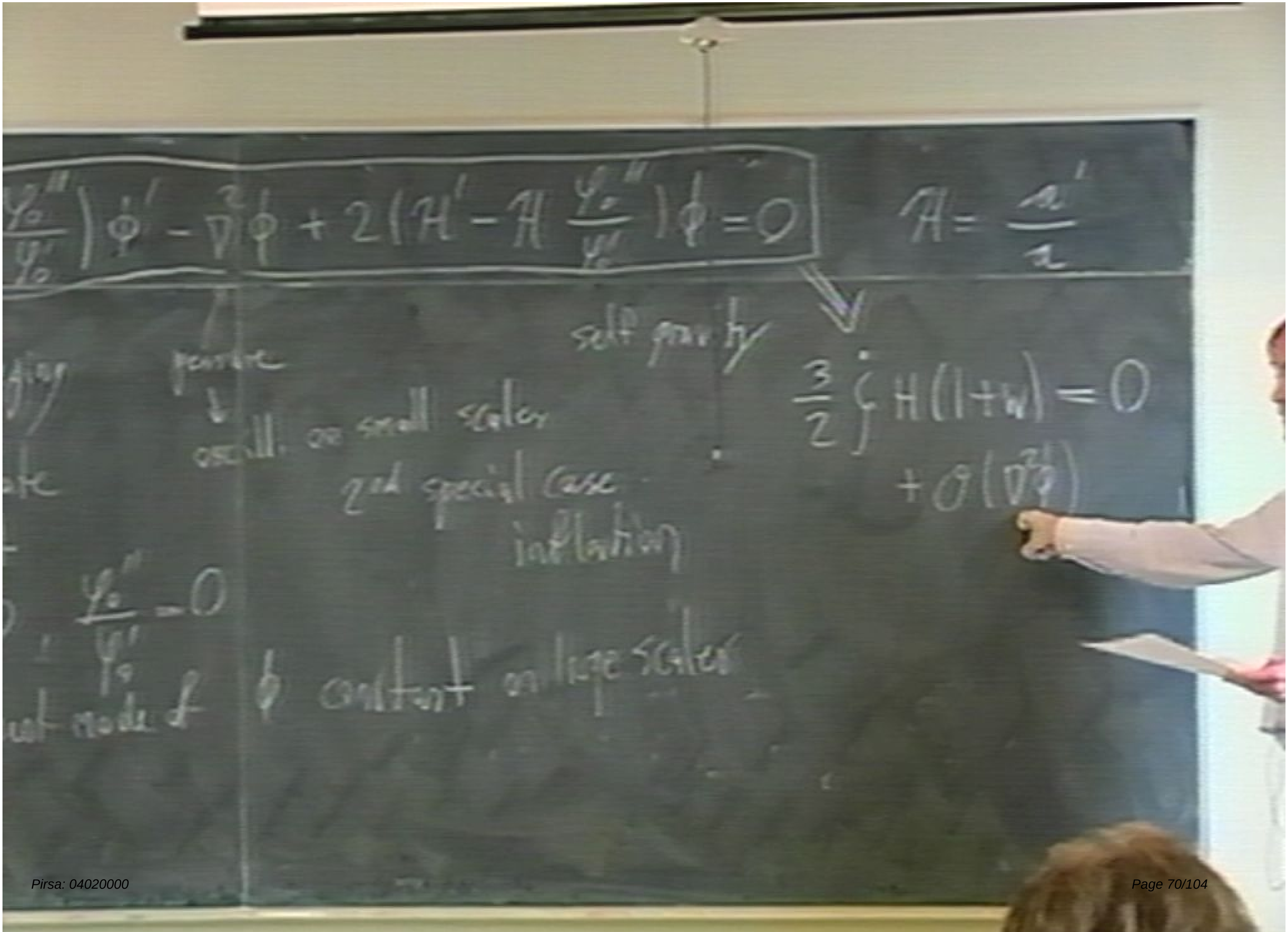
$$\frac{\varphi_0''}{\varphi_0'} = 0$$

$\delta g_{\mu\nu}$

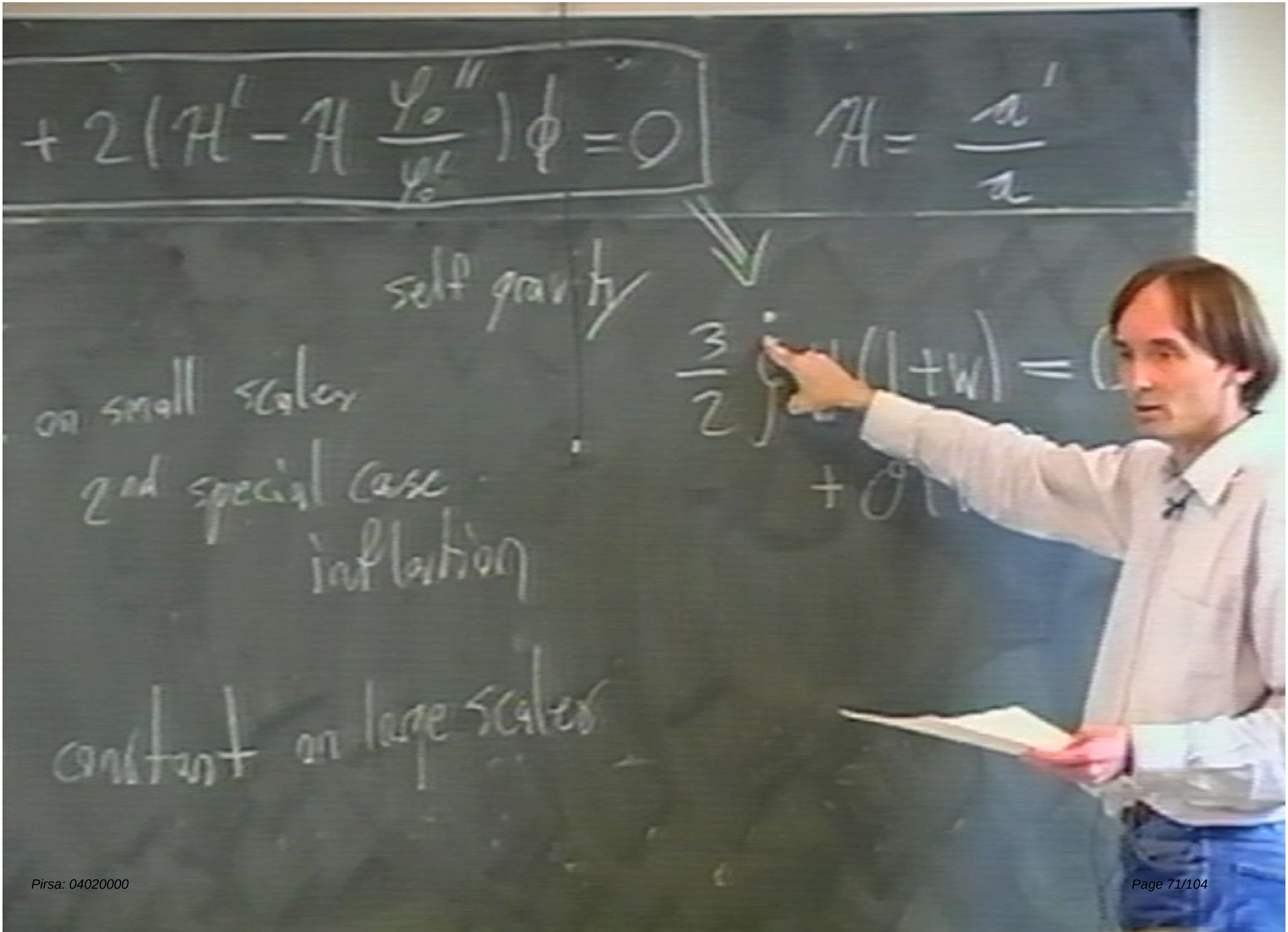
ϕ constant on large scales


self gravity
oscill. on small scales
2nd special case
inflation
constant on large scales


self gravity
2nd special case
inflation



$\left(\ldots\frac{\psi_0''}{\psi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\psi_0''}{\psi_0'}\right)\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
positive
oscill. on small scales
2nd special case
inflation
$\frac{3}{2}\dot{\zeta} H(1+w) = 0$
$+ O(\nabla^2\phi)$
$\frac{\psi_0''}{\psi_0'} = 0$
ϕ constant on large scales



$+2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\Phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
on small scales
2nd special case
inflation
constant on large scales

$$\boxed{+2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0} \qquad \mathcal{H} = \frac{a'}{a}$$

self gravity

on small scales

2nd special case

inflation

$$\frac{3}{2}\dot{\zeta} H(1+w) = 0$$

$$+\mathcal{O}(\nabla^2\phi)$$

$$w = \frac{p}{\rho}$$

constant on large scales

$$\zeta =$$

$$\boxed{+2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0}$$

$$\mathcal{H} = \frac{a'}{a}$$

self gravity

on small scales

2nd special case

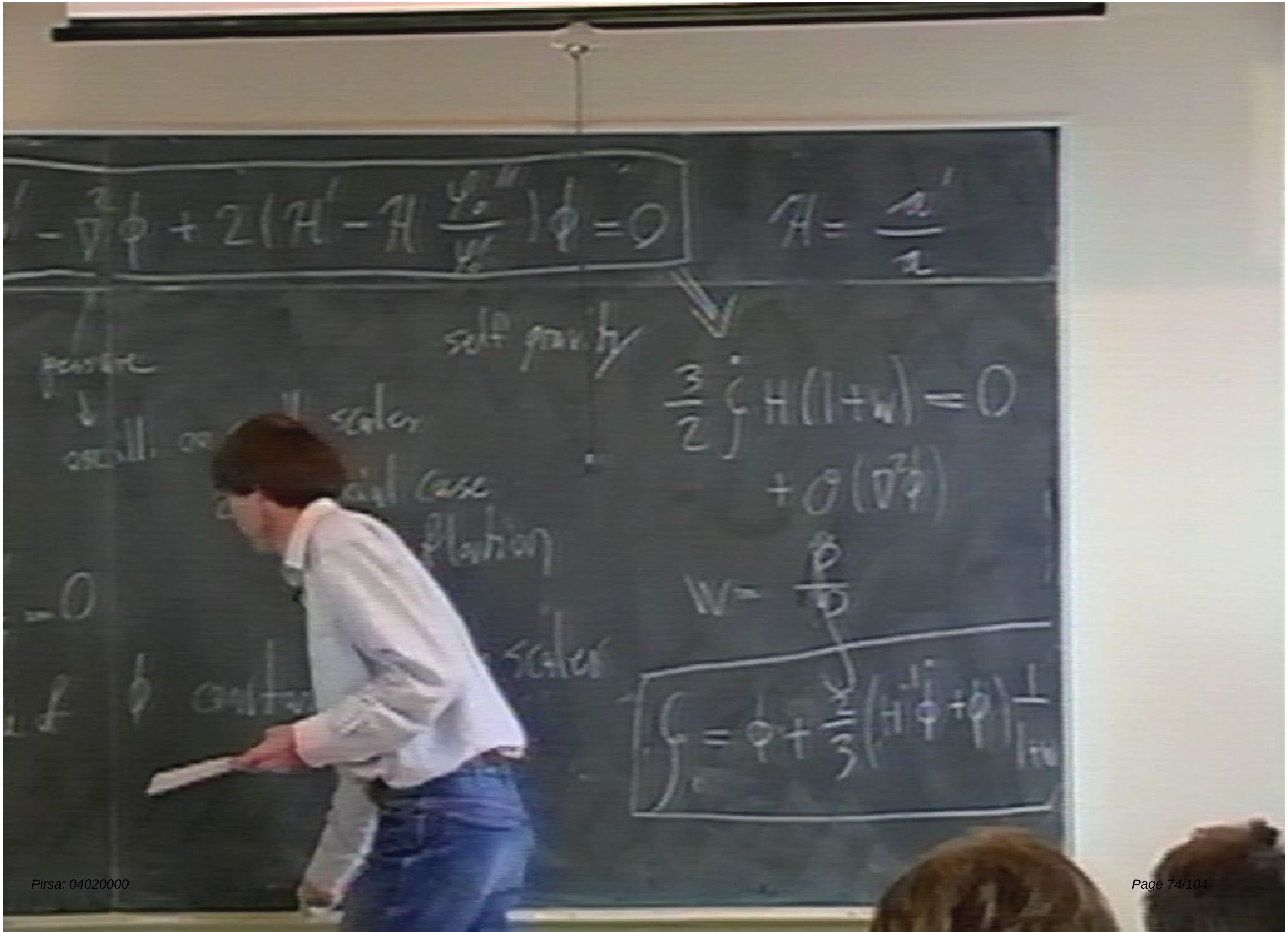
inflation

constant on large scales

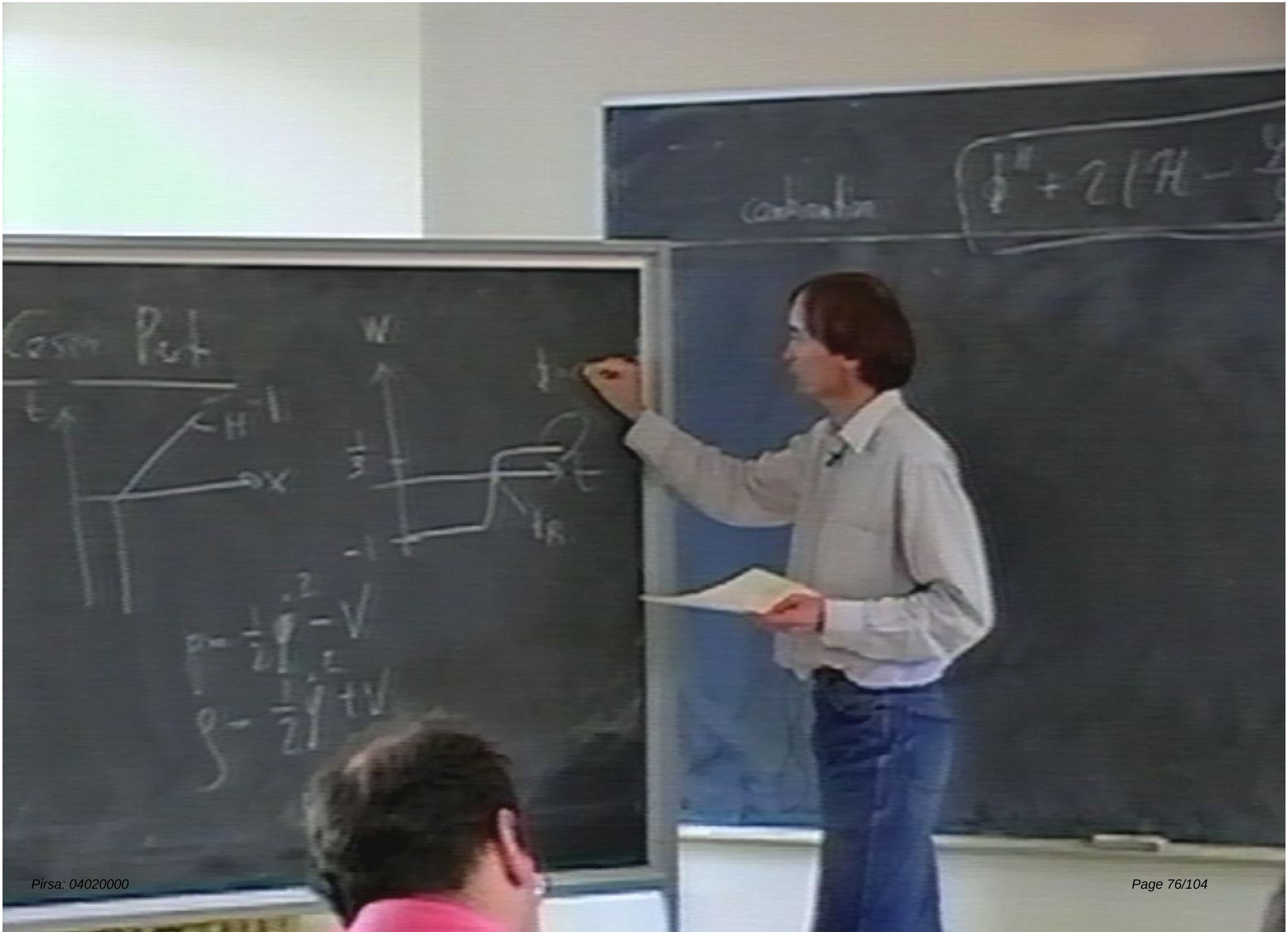
$$\frac{3}{2}\dot{\zeta} H(1+w) = 0 + \mathcal{O}(\nabla^2\phi)$$

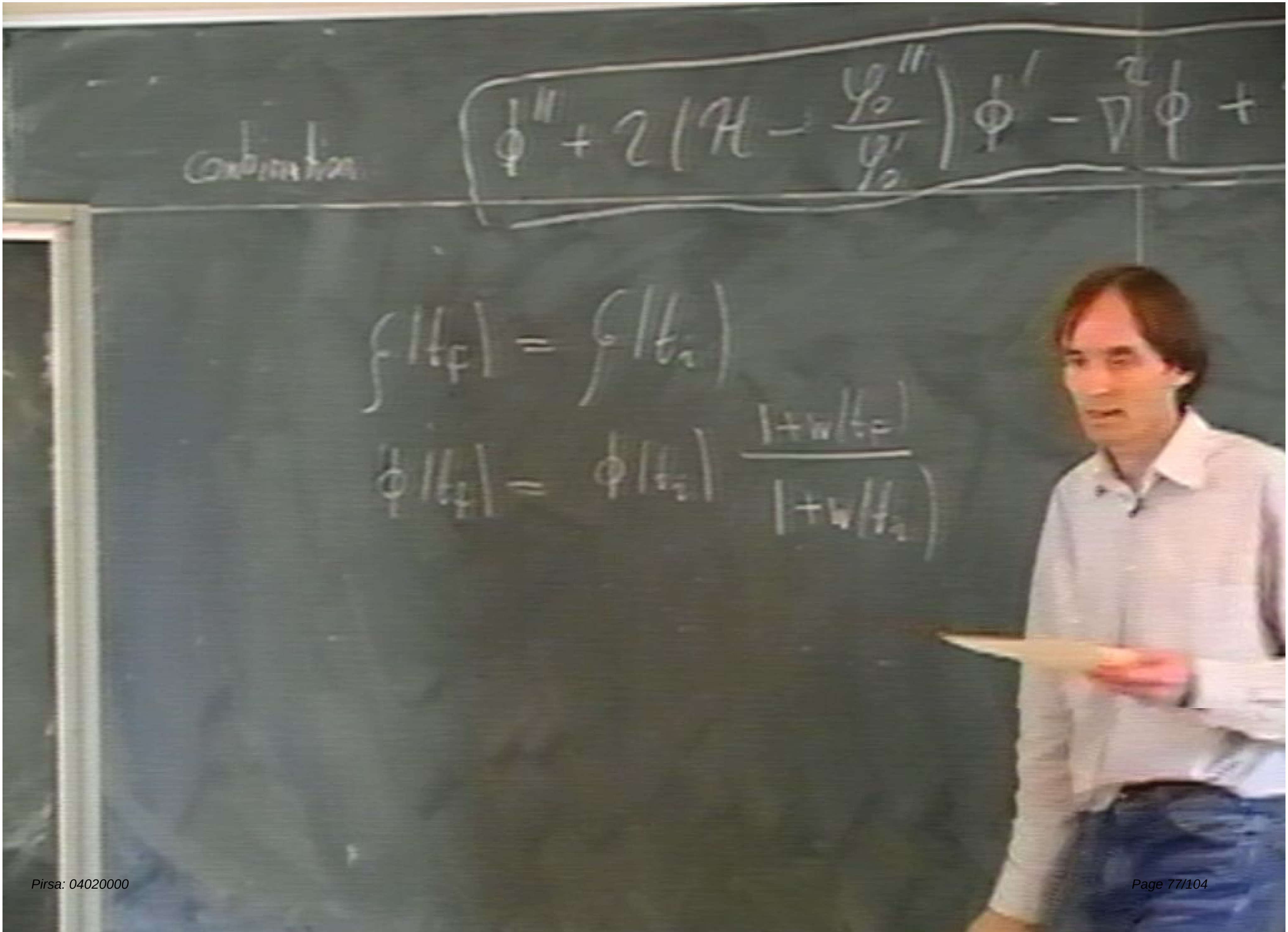
$$w = \frac{p}{\rho}$$

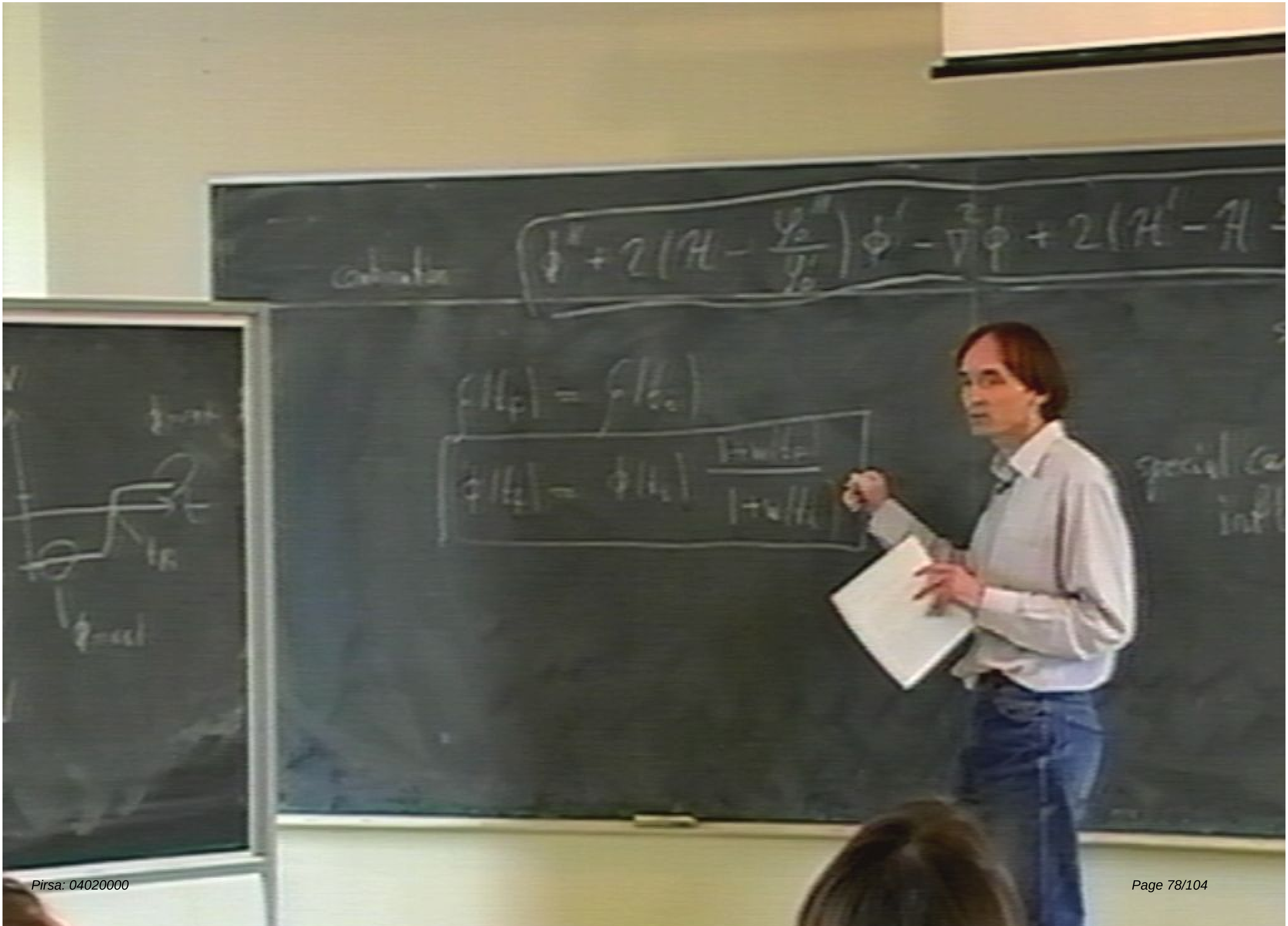
$$\zeta = \phi + \frac{2}{3}\left(H^{-1}\dot{\phi} + \phi\right)$$

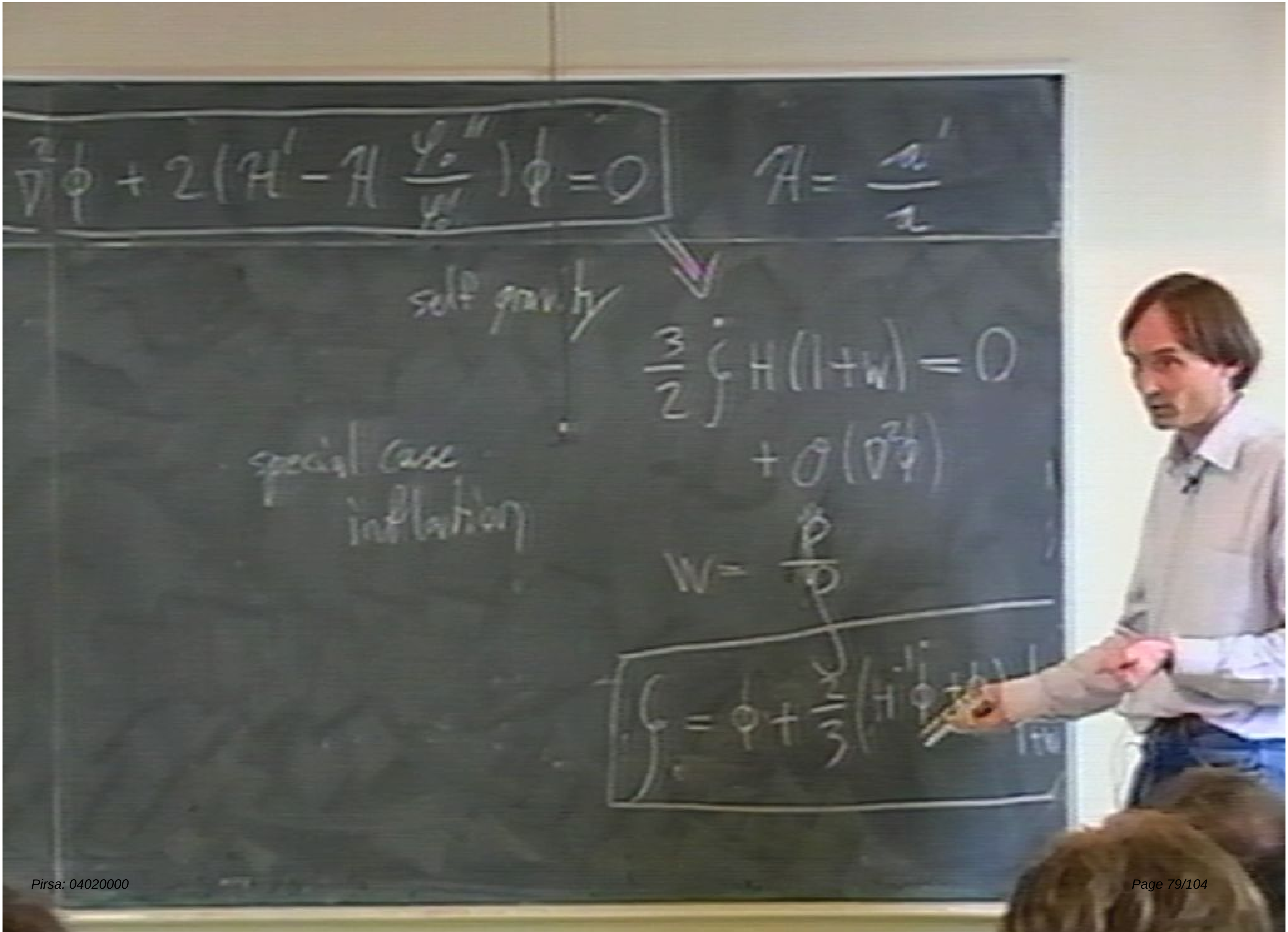

$+ 2(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'})\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
positive
scalar
case
$\frac{3}{2}\dot{\zeta} H(1+w) = 0$
$+\mathcal{O}(\nabla^2\phi)$
$w = \frac{p}{\rho}$
scalar

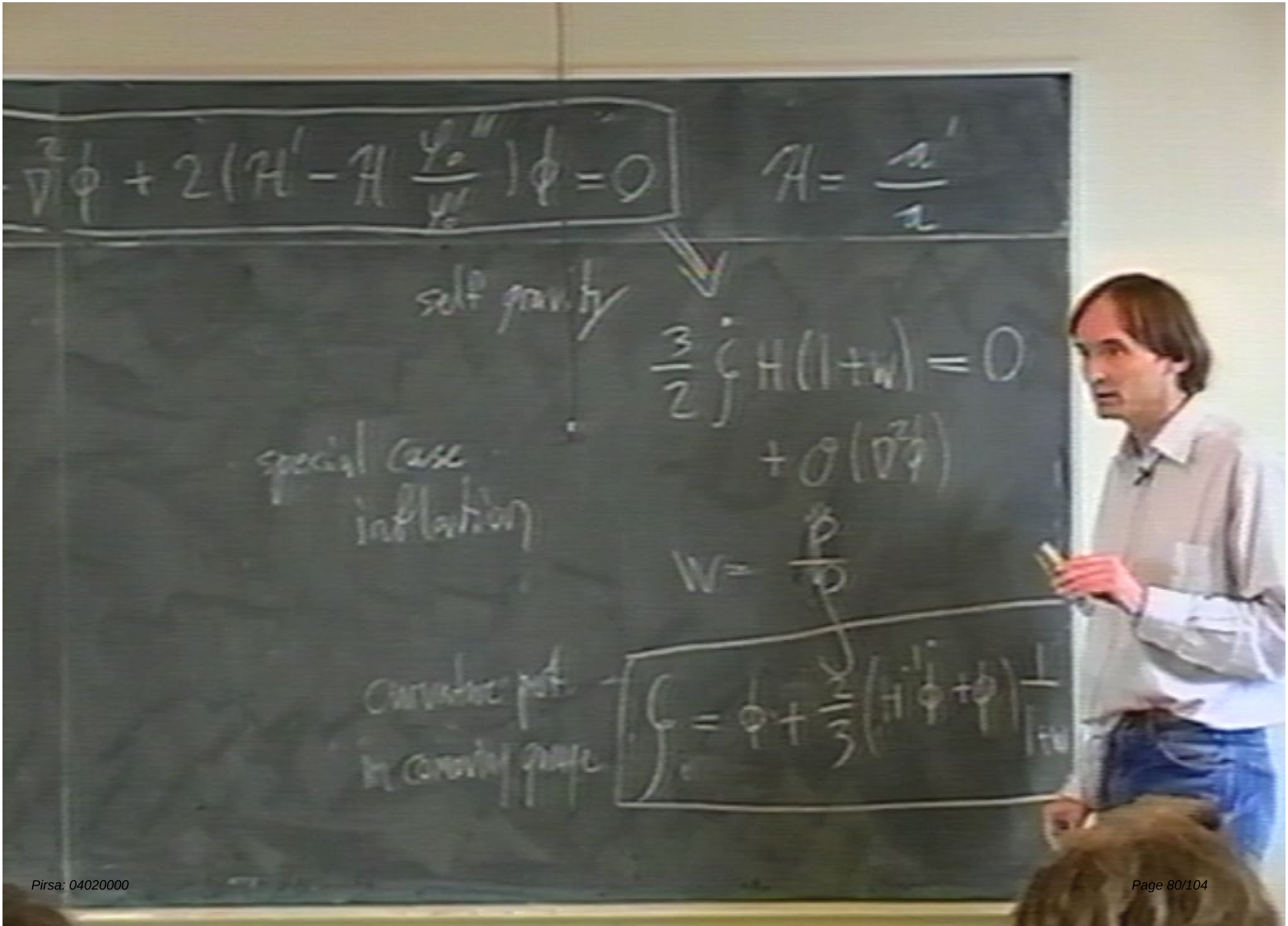

the Theory of Cosm Pert
Theory
combination

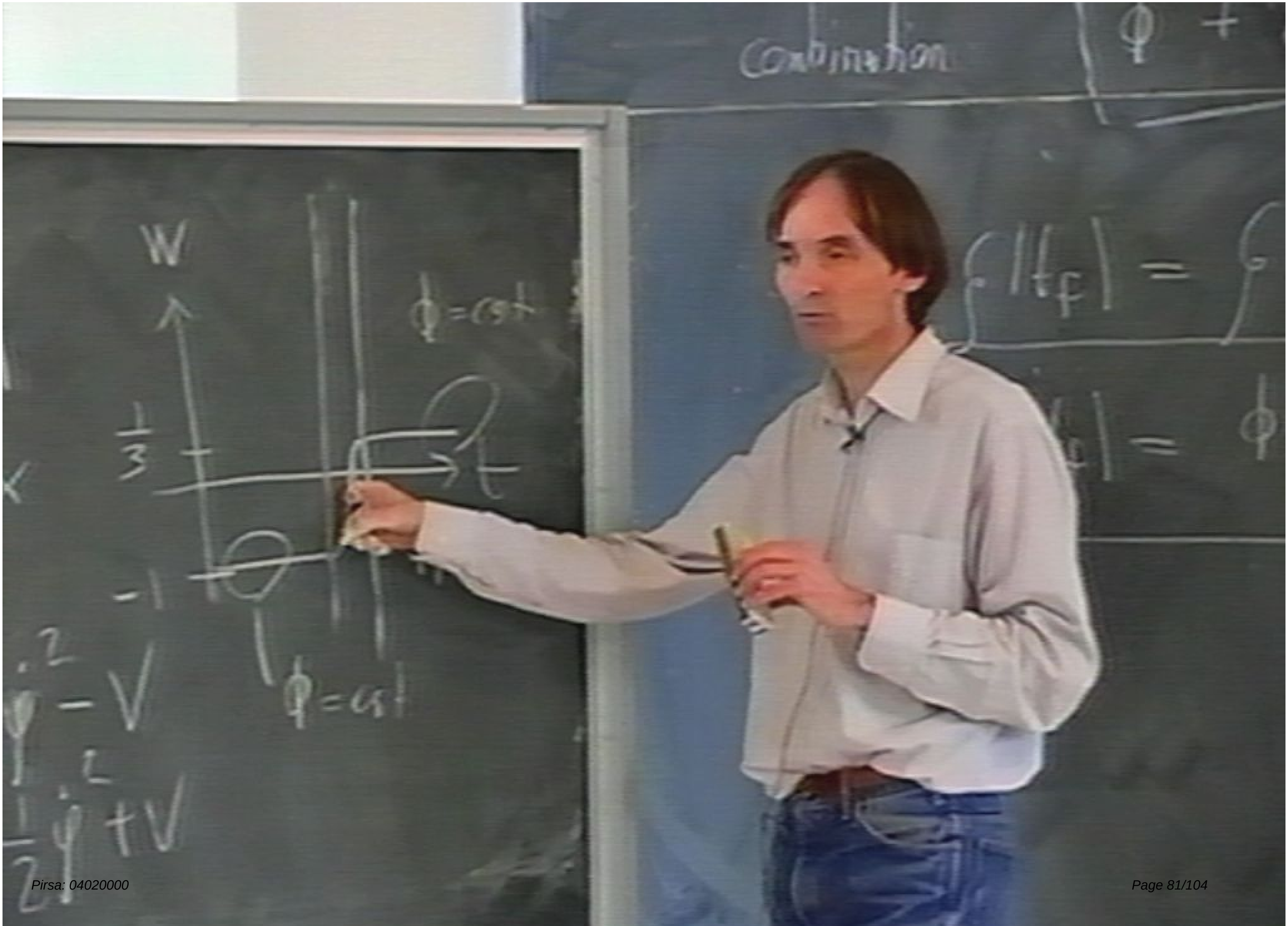

Cosm Pert
W
x
t
$\frac{1}{3}$
-1
t_R
$p = \frac{1}{2}\dot{\varphi}^2 - V$
$\rho = \frac{1}{2}\dot{\varphi}^2 + V$
combination

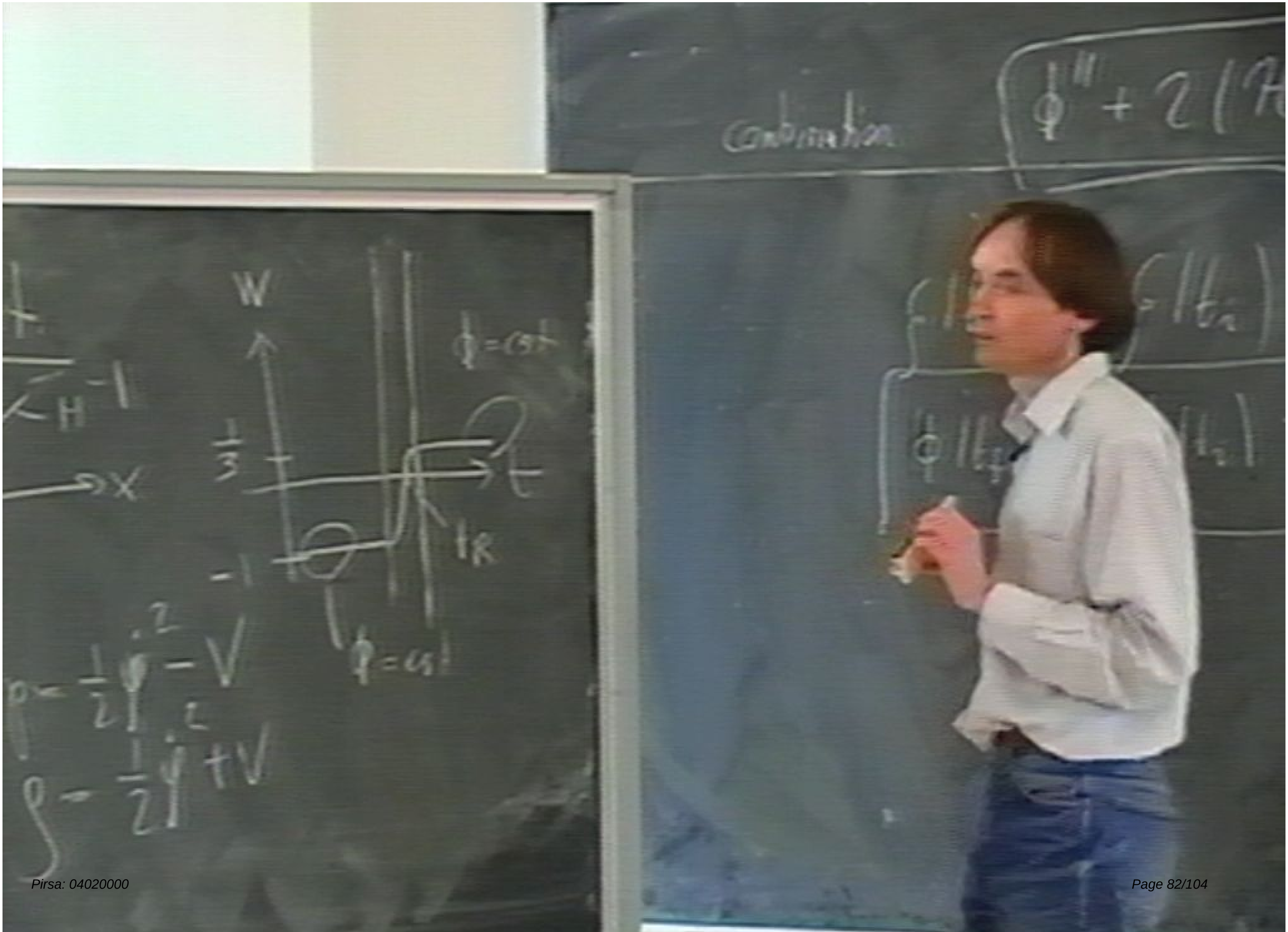

Combination
$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi +$
$\zeta(t_f) = \zeta(t_i)$
$\phi(t_f) = \phi(t_i)\,\frac{1+w(t_f)}{1+w(t_i)}$

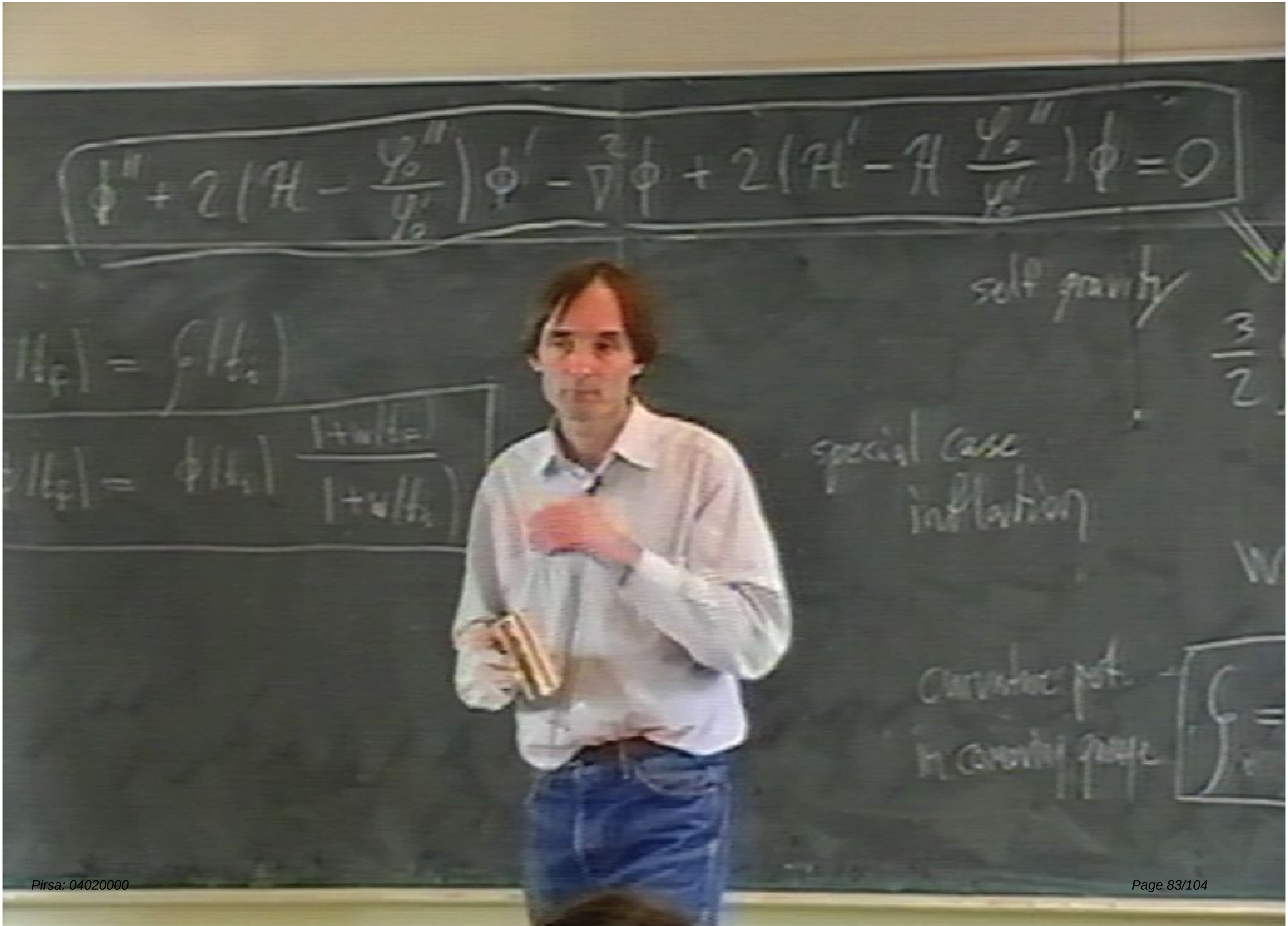


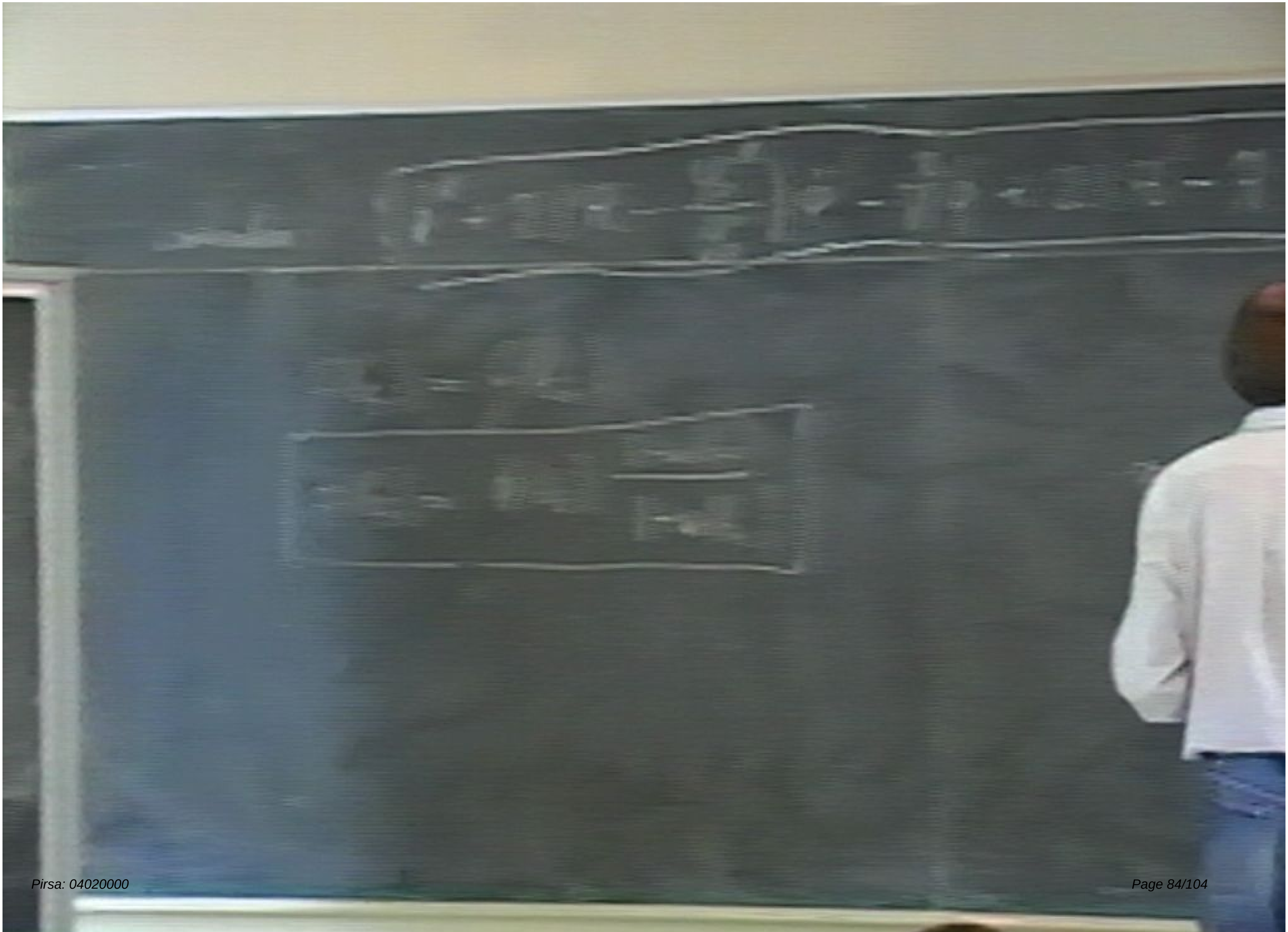

$\nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
special case
inflation
$\frac{3}{2}\dot{\zeta} H(1+w) = 0$
$+ O(\nabla^2\phi)$
$w = \frac{\dot{p}}{\dot{\rho}}$
$\zeta = \phi + \frac{2}{3}(H^{-1}\dot{\phi}$

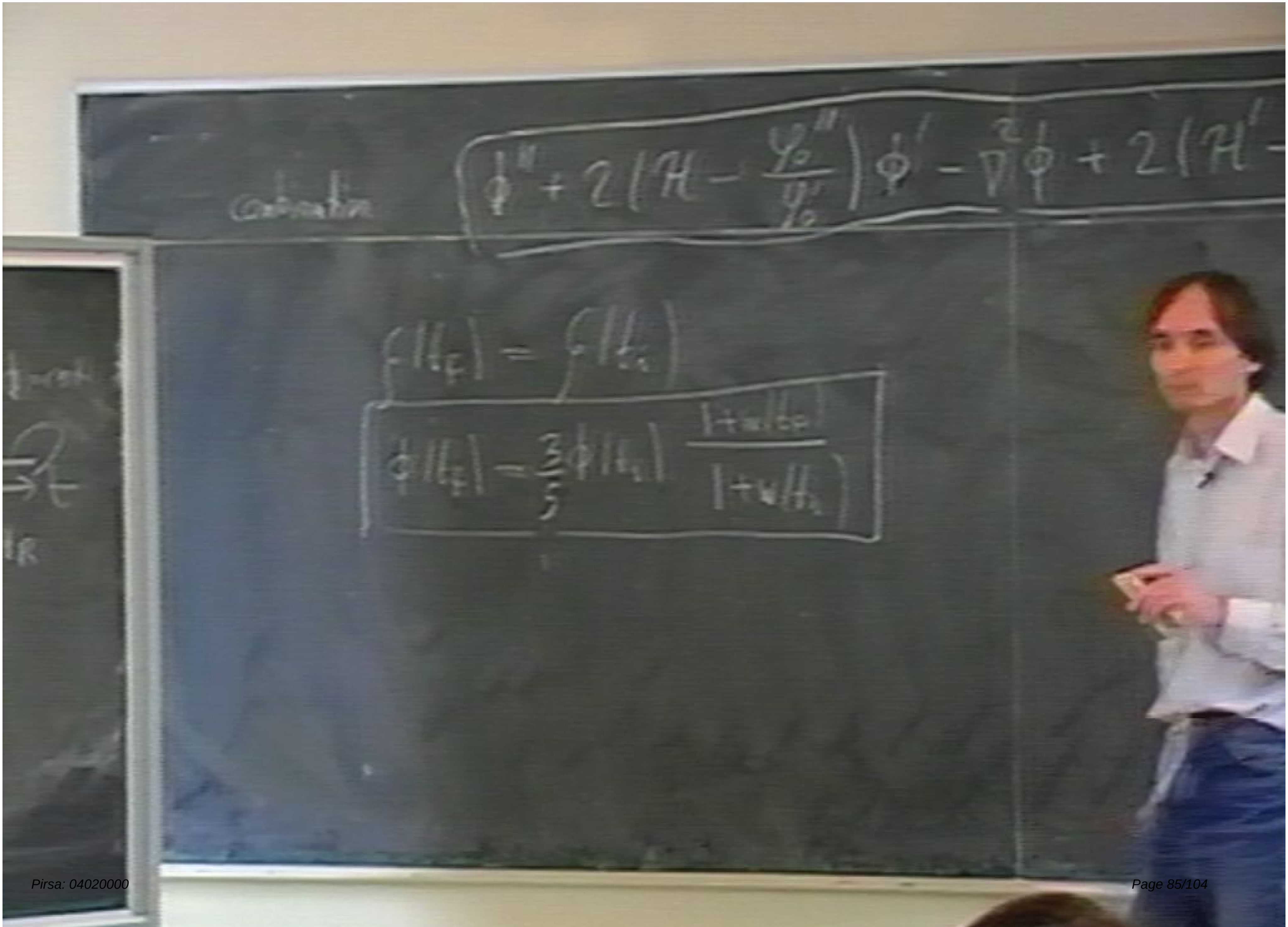

$\nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
self gravity
$\frac{3}{2}\dot{\zeta} H(1+w) = 0$
$+ O(\nabla^2\phi)$
special case
inflation
$w = \frac{p}{\rho}$
curvature pert.
in comoving gauge
$\zeta = \phi + \frac{2}{3}\left(H^{-1}\dot{\phi} + \phi\right)\frac{1}{1+w}$


Combination
W
φ=cst
1/3
-1
t
φ=cst


combination
W
x
t
t_R
φ = cst
φ = cst


$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0$
self gravity
special case
inflation
curvature pert.
in comoving gauge




Combination
$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2(\mathcal{H}' -$
$f(t_F) = f(t_i)$
$\phi(t_F) = \frac{3}{5}\phi(t_i)\,\frac{1+w(t_F)}{1+w(t_i)}$

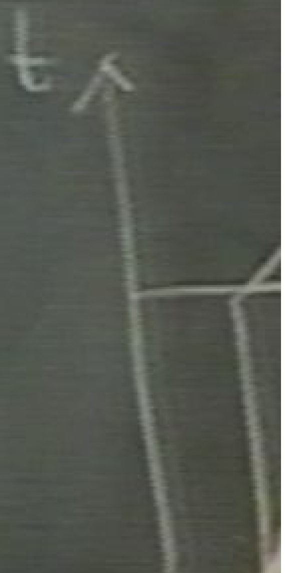
Relativistic Theory of Cosm

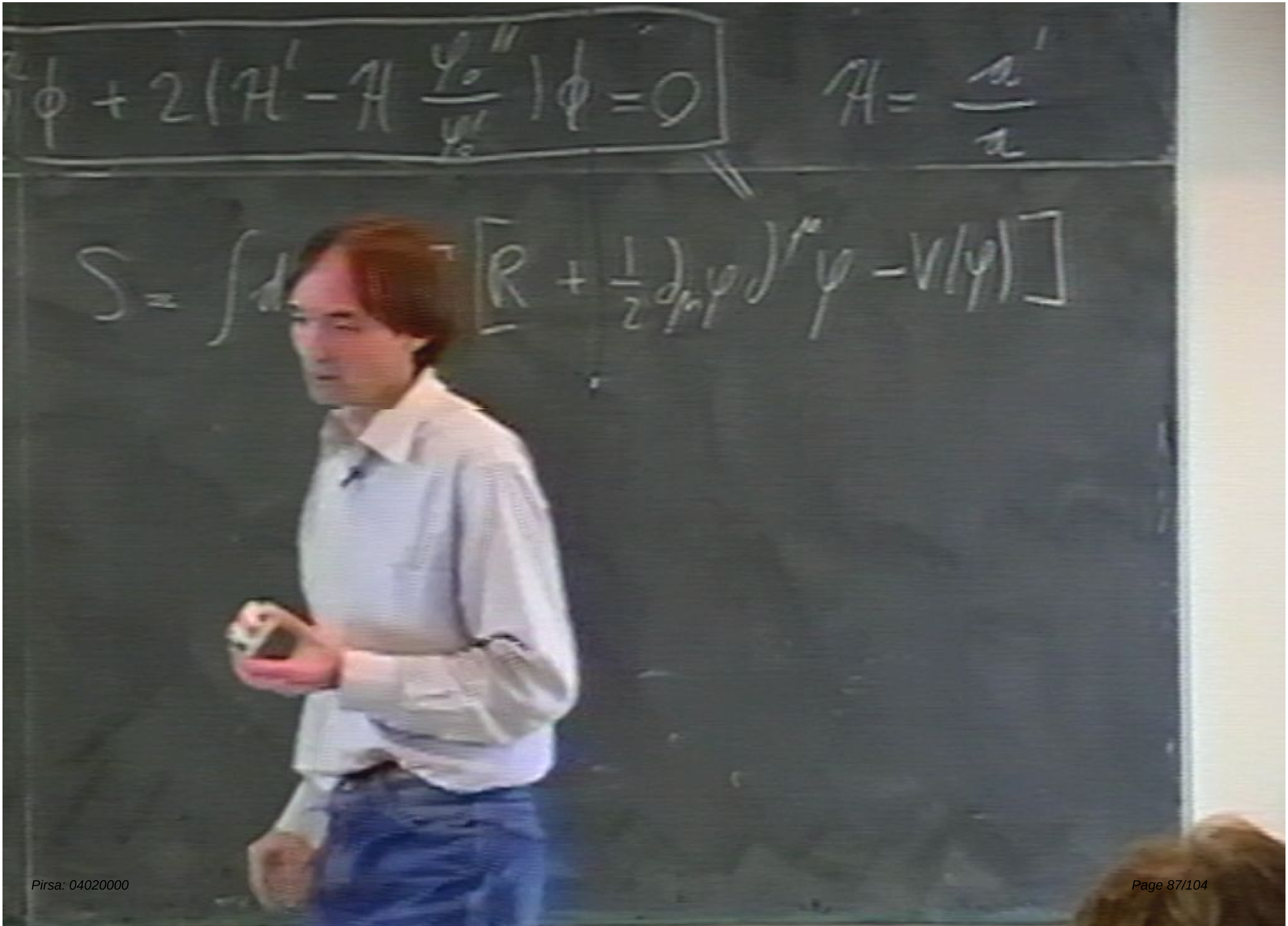
Classification

Gauge Transformations

Equations

Quantum Theory

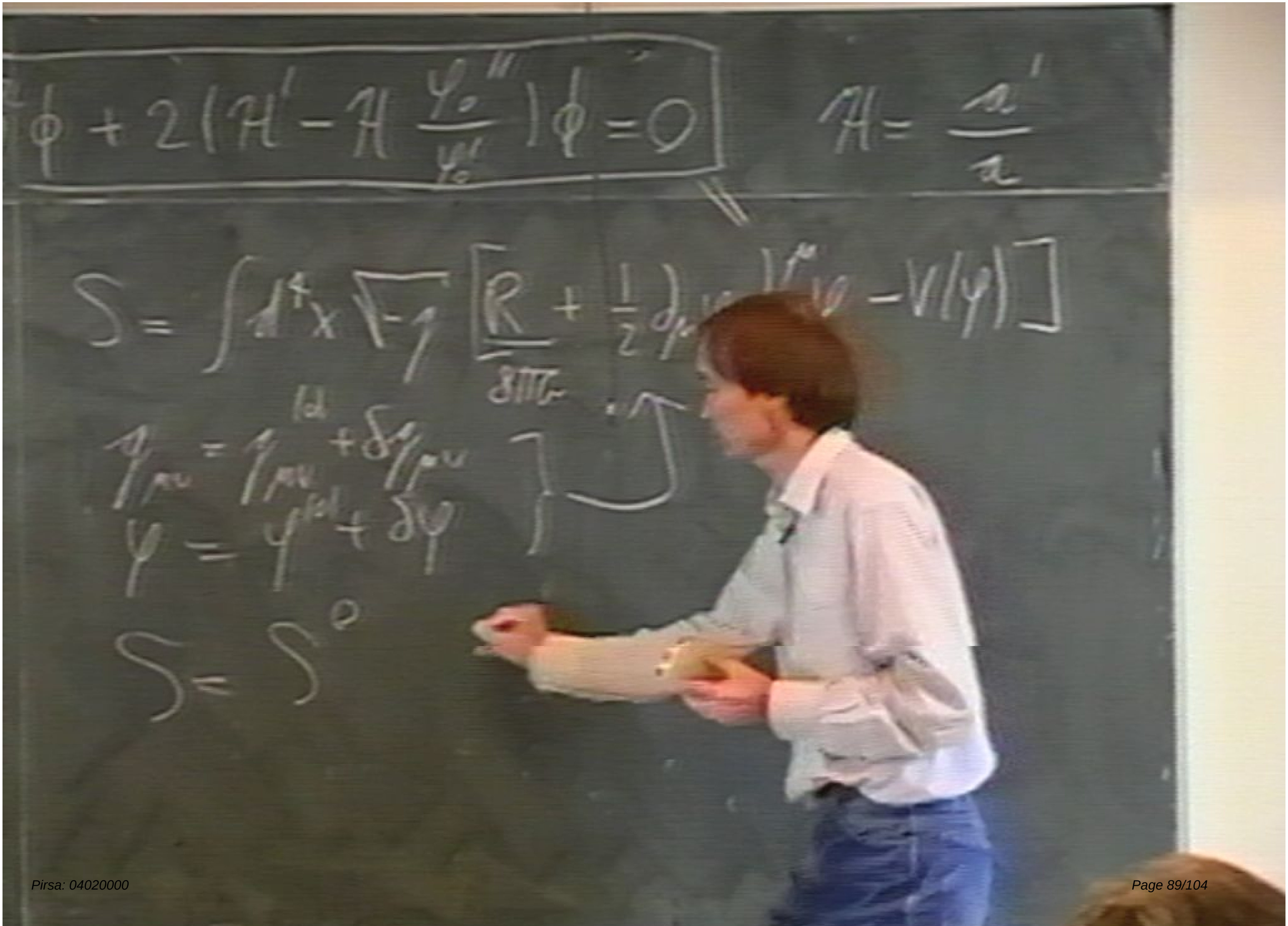




$\phi + 2(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'})\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
$S = \int d$
$[R + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)]$

$$\boxed{\ldots\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0} \qquad \mathcal{H} = \frac{a'}{a}$$

$$S = \int d^4x \sqrt{-g}\left[R + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)\right]$$



$\phi + 2(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'})\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
$S = \int d^4x \sqrt{-g}\left[\frac{R}{8\pi G} + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)\right]$
$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$
$\varphi = \varphi^{(0)} + \delta\varphi$
$S = S^0$

$$\boxed{\phi + 2\left(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'}\right)\phi = 0} \qquad \mathcal{H} = \frac{a'}{a}$$

$$S = \int d^4x \sqrt{-g}\left[\frac{R}{8\pi G} + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)\right]$$

$$\left.\begin{aligned} g_{\mu\nu} &= g_{\mu\nu}^{(0)} + \delta g_{\mu\nu} \\ \varphi &= \varphi^{(0)} + \delta\varphi \end{aligned}\right\}$$

$$S = S^{0} + S^{(2)}$$

$$\sqrt{-g}\left[\frac{R}{8\pi G} + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)\right]$$

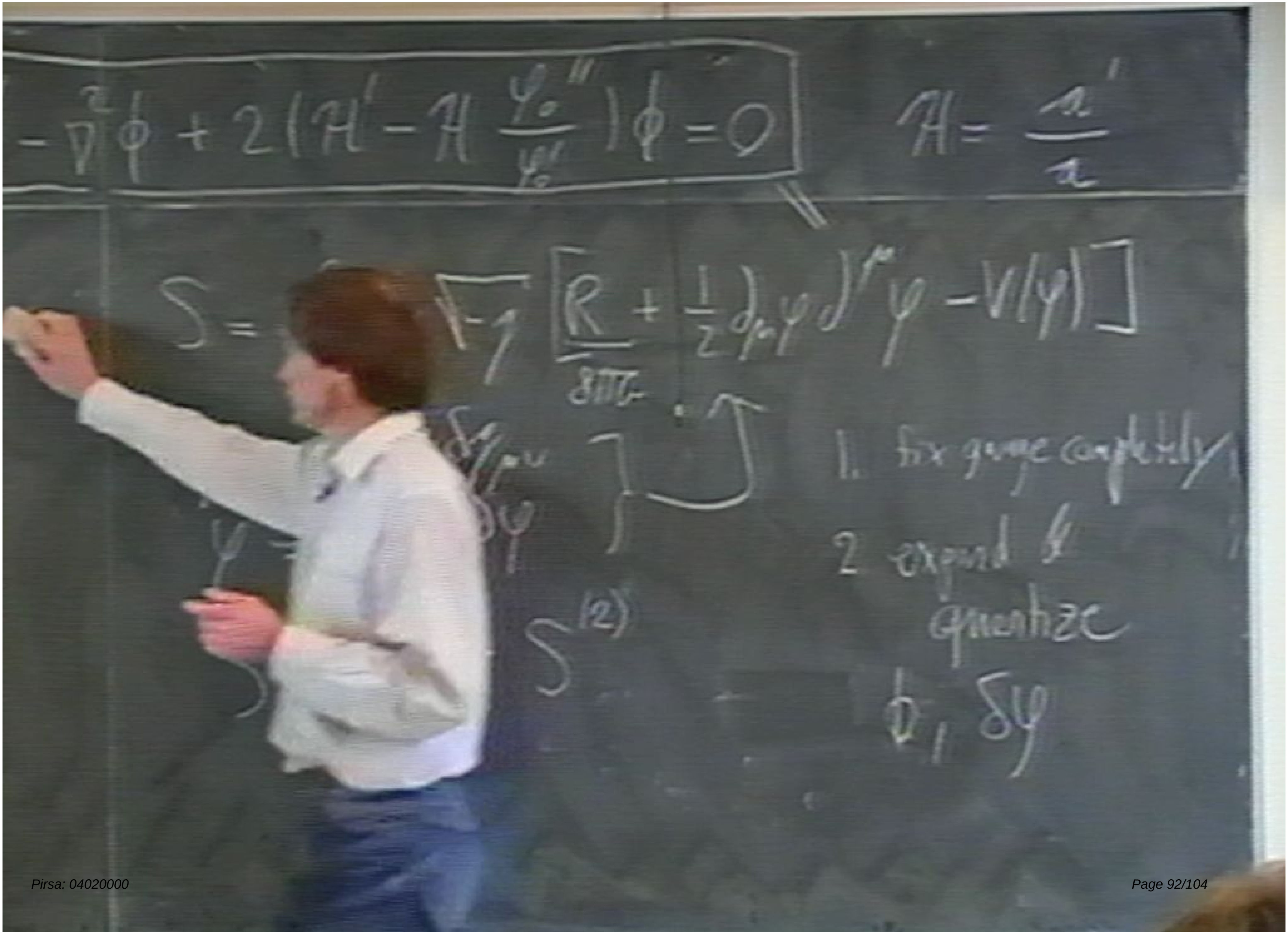
$$\delta g_{\mu\nu}$$

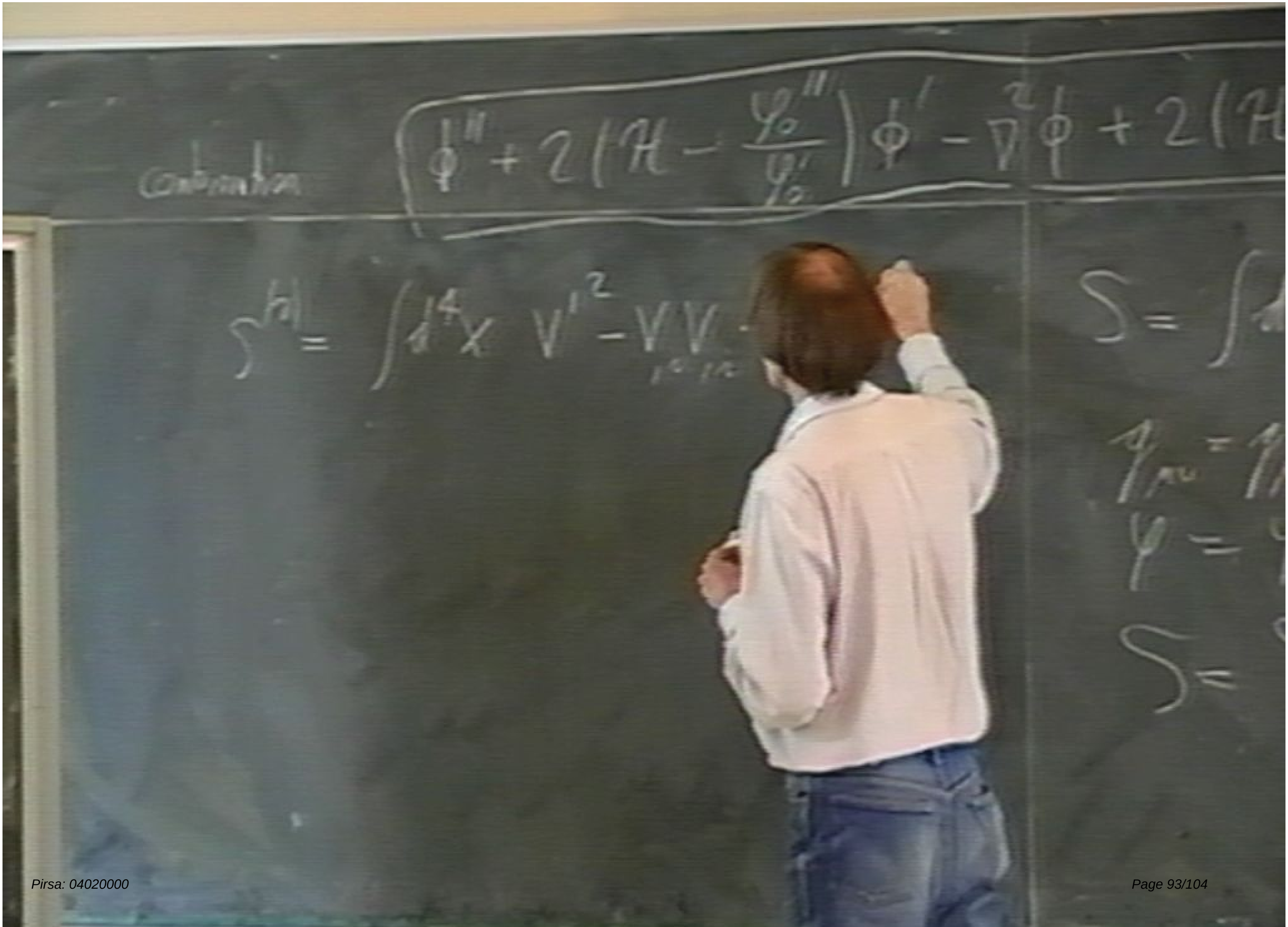
$$\delta\varphi$$

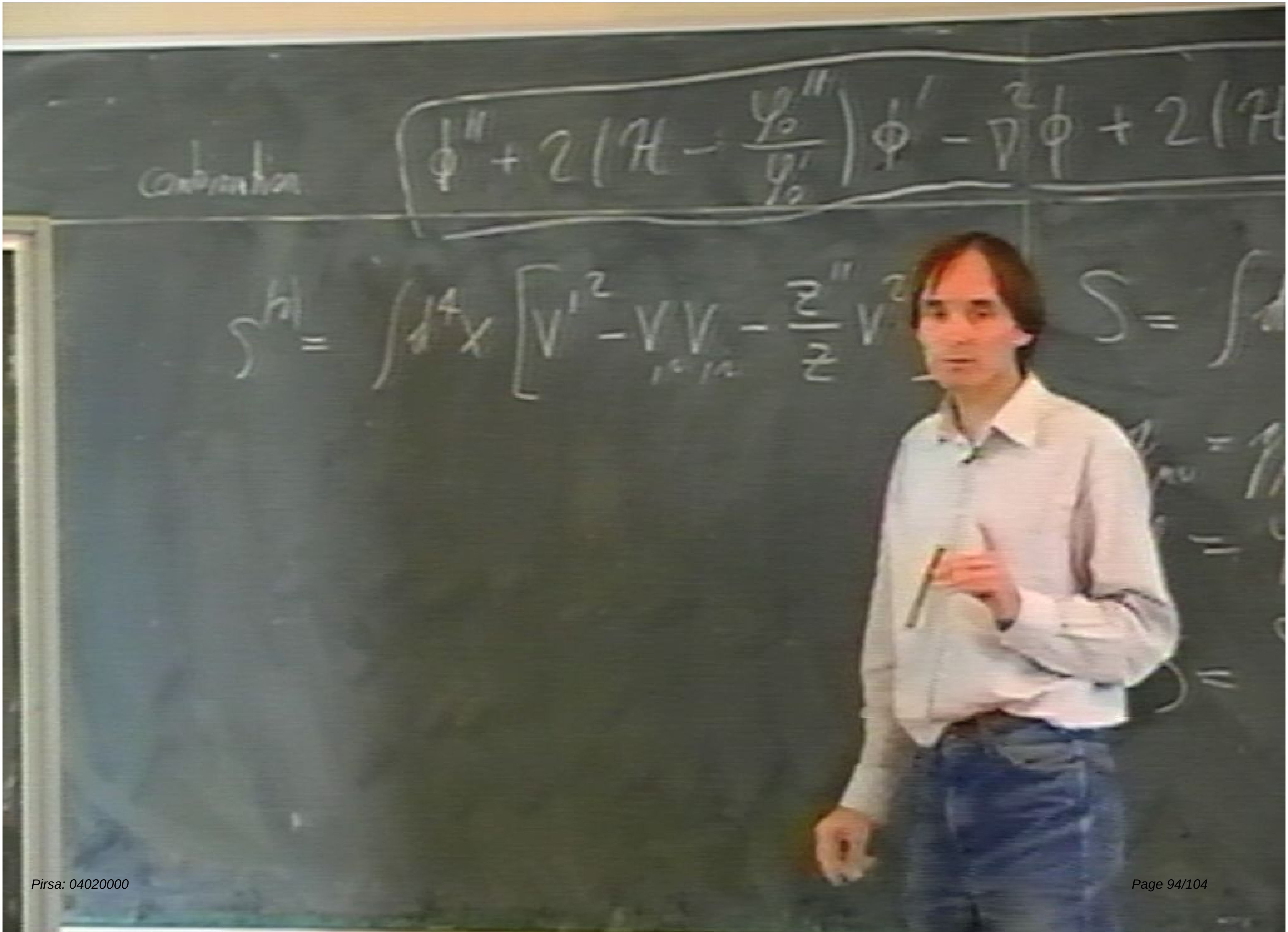
$$+\,S^{(2)}$$

1. fix gauge completely

2 expand & quantize


$-\nabla^2\phi + 2(\mathcal{H}' - \mathcal{H}\frac{\varphi_0''}{\varphi_0'})\phi = 0$
$\mathcal{H} = \frac{a'}{a}$
$S = \int \sqrt{-g}\,[\frac{R}{8\pi G} + \frac{1}{2}\partial_\mu\varphi\,\partial^\mu\varphi - V(\varphi)]$
$\delta g_{\mu\nu}$
$\delta\varphi$
1. fix gauge completely
2. expand &
quantize
$\phi,\ \delta\varphi$
$S^{(2)}$


combination
$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2(\mathcal{H}$
$S^{H} = \int d^4x \; v'^2 - V_{,i} V_{,i}$
$S = \int$
$g_{\mu\nu} =$
$\varphi =$
$S =$


combination

continuation

$$\boxed{\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2(\mathcal{H}}$$

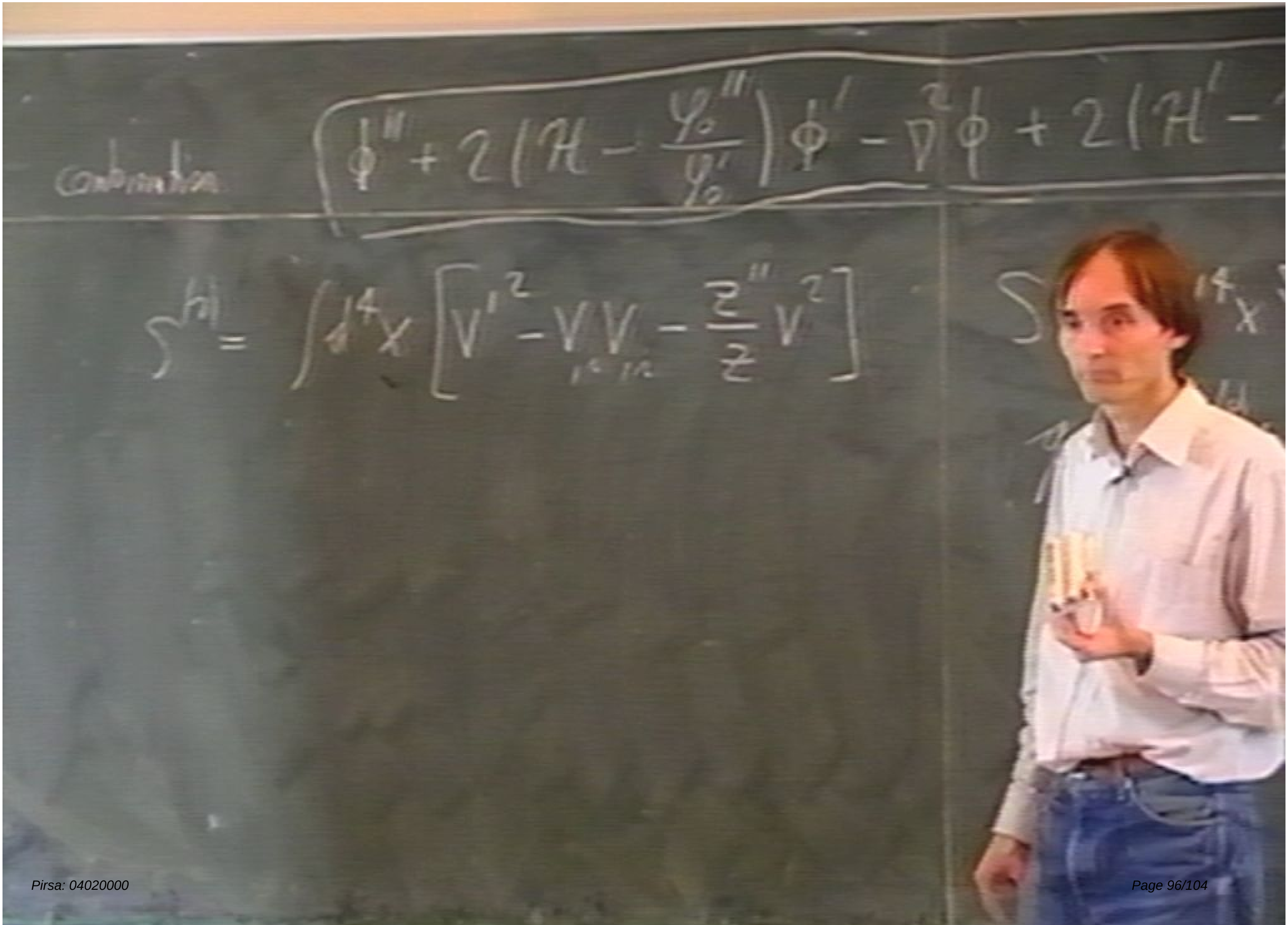
$$S^{(2)} = \int d^4x \left[v'^2 - v_{,i} v_{,i} - \frac{z''}{z} v^2 \right]$$

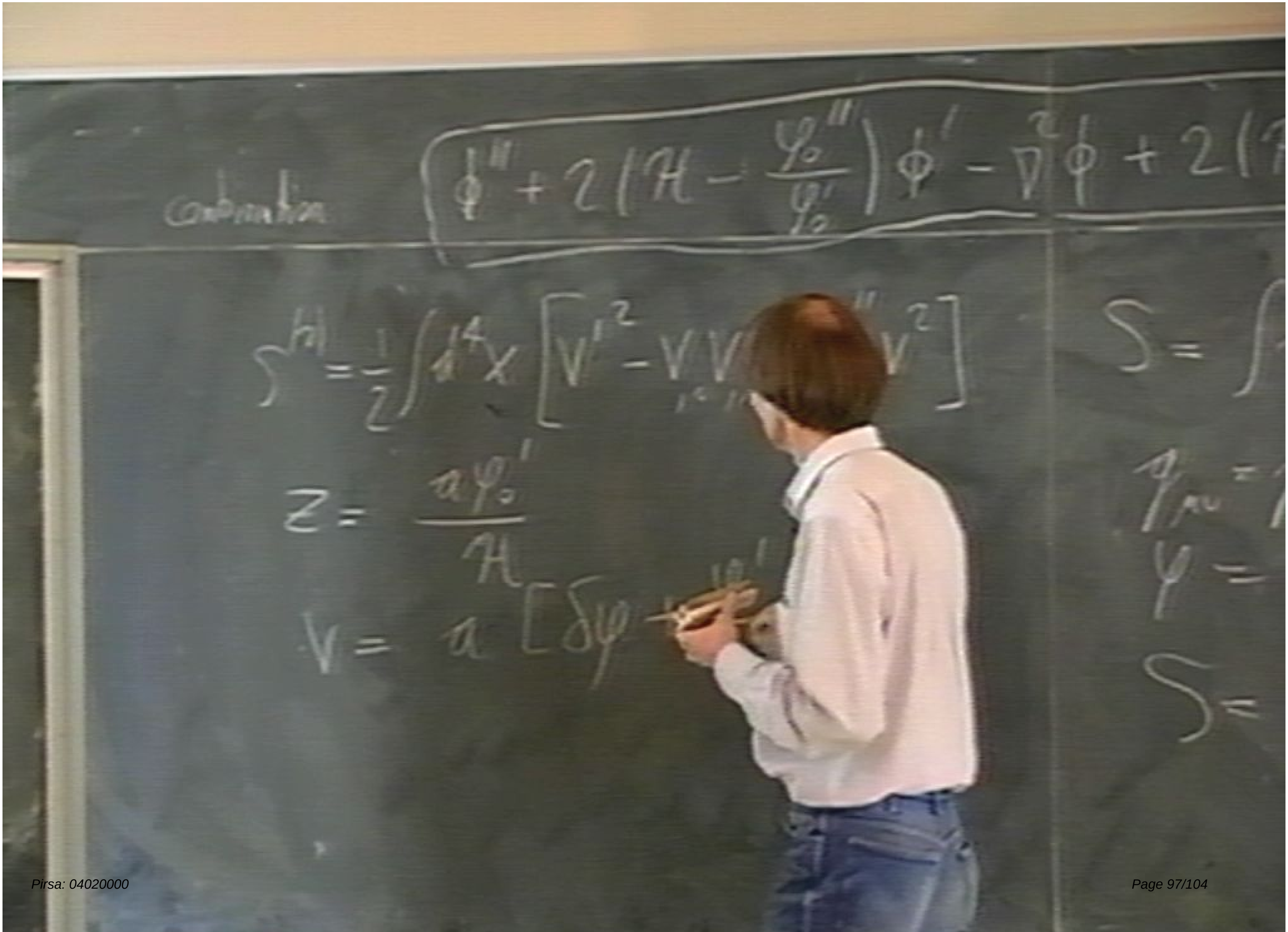
$$S = \int$$

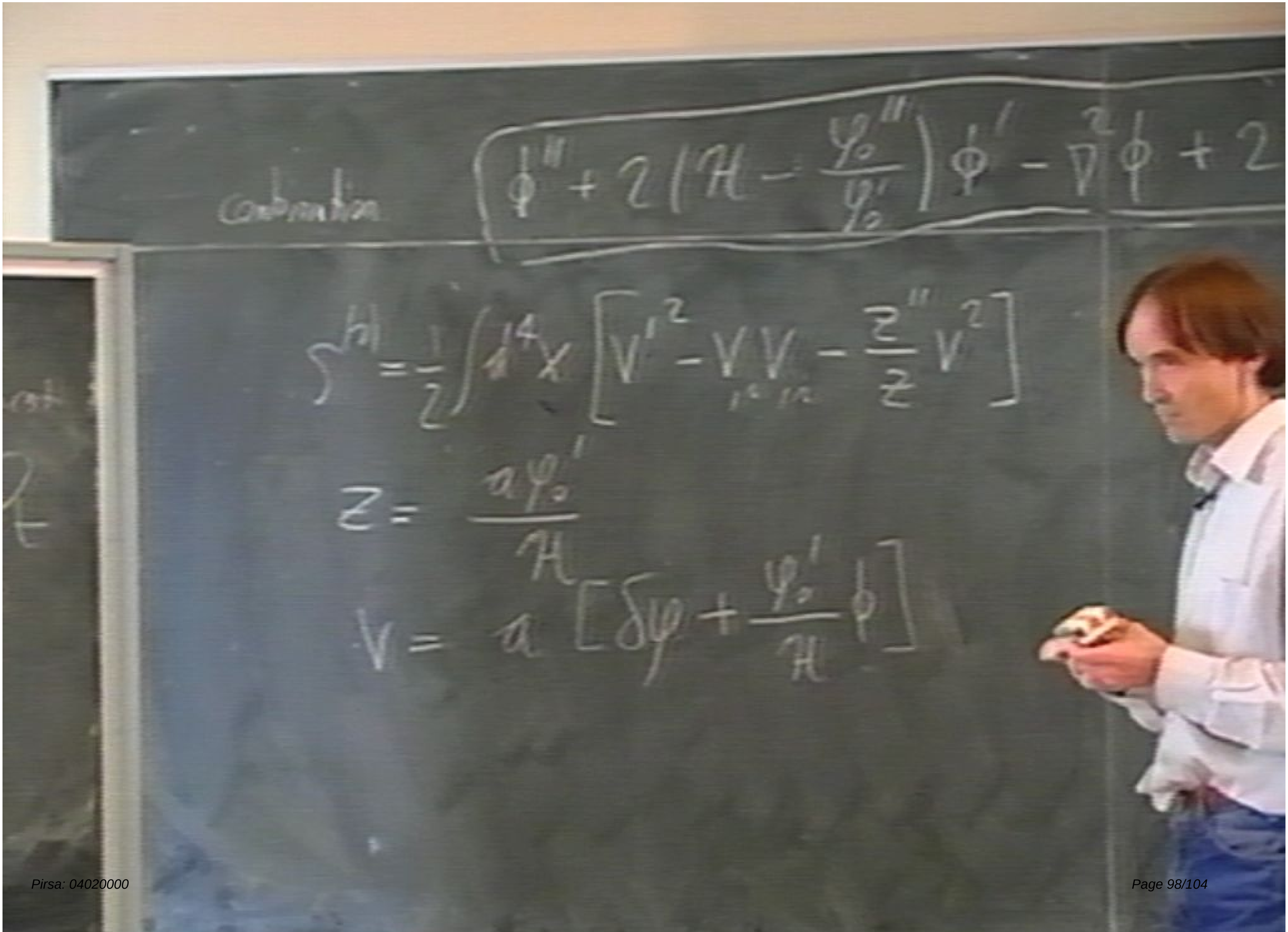
$$g_{\mu\nu} = g$$

$$\varphi =$$

$$S =$$


combination
$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2(\mathcal{H}' -$
$S^{H} = \int d^4x \left[v'^2 - v_{,i}v_{,i} - \frac{z''}{z}v^2\right]$


combination
$\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2($
$S = \frac{1}{2}\int d^4x \left[v'^2 - v_{,i}v_{,i} \quad v^2\right]$
$z = \frac{a\varphi_0'}{\mathcal{H}}$
$v = a\left[\delta\varphi\right.$
$S =$
$\varphi =$
$S =$


combination
$\phi''' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2$
$S^{H} = -\frac{1}{2}\int d^4x \left[v'^2 - v_{,i}v_{,i} - \frac{z''}{z}v^2 \right]$
$z = \frac{a\varphi_0'}{\mathcal{H}}$
$v = a\left[\delta\varphi + \frac{\varphi_0'}{\mathcal{H}}\phi\right]$

combination $\boxed{\phi'' + 2\left(\mathcal{H} - \frac{\varphi_0''}{\varphi_0'}\right)\phi' - \nabla^2\phi + 2}$

$$S^{(2)} = \frac{1}{2}\int d^4x \left[v'^2 - v_{,i}v_{,i} - \frac{z''}{z}v^2\right]$$

$$z = \frac{a\varphi_0'}{\mathcal{H}}$$

$$v = a\left[\delta\varphi + \frac{\varphi_0'}{\mathcal{H}}\phi\right]$$

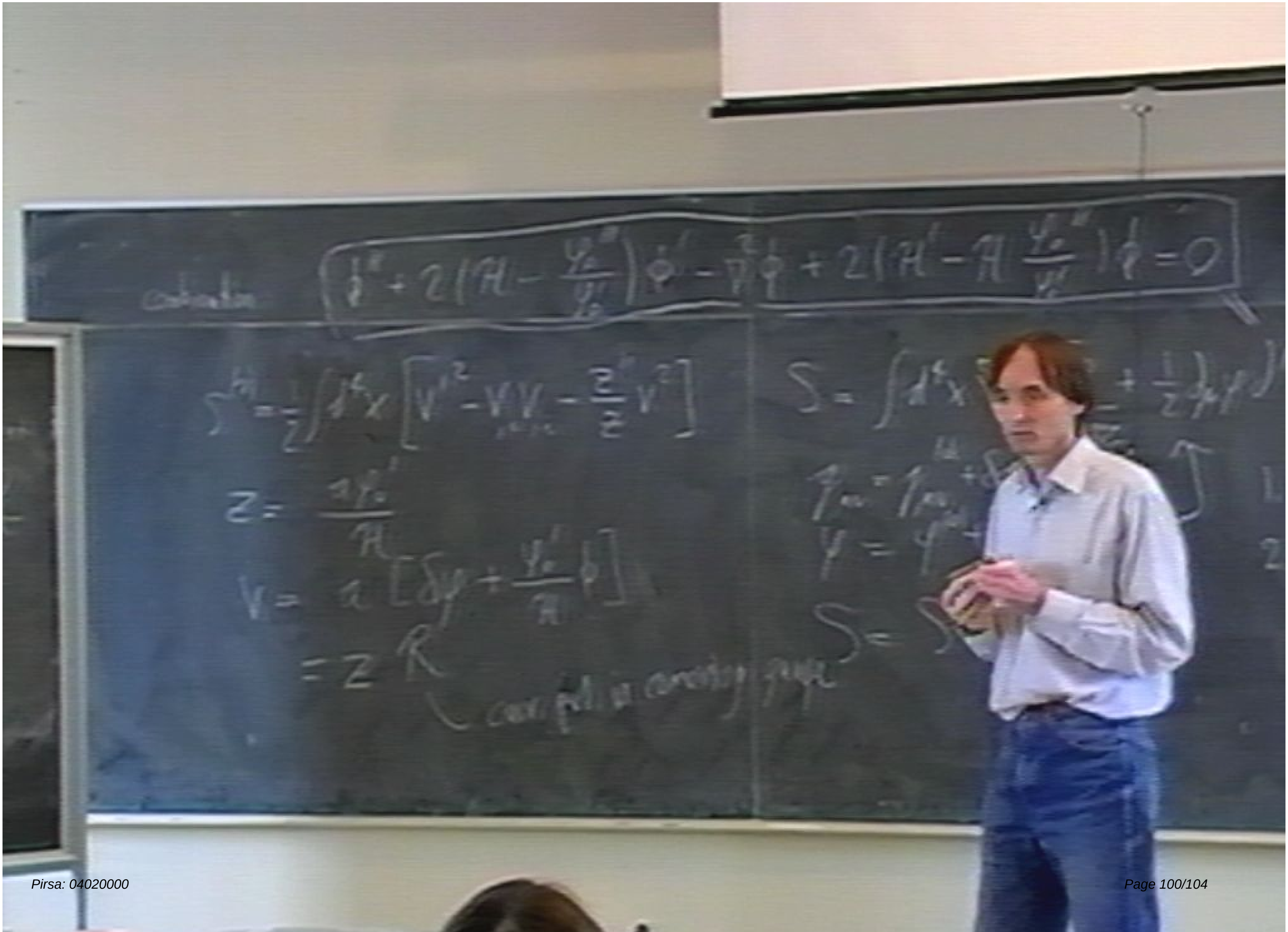
$$= z\,\mathcal{R}$$

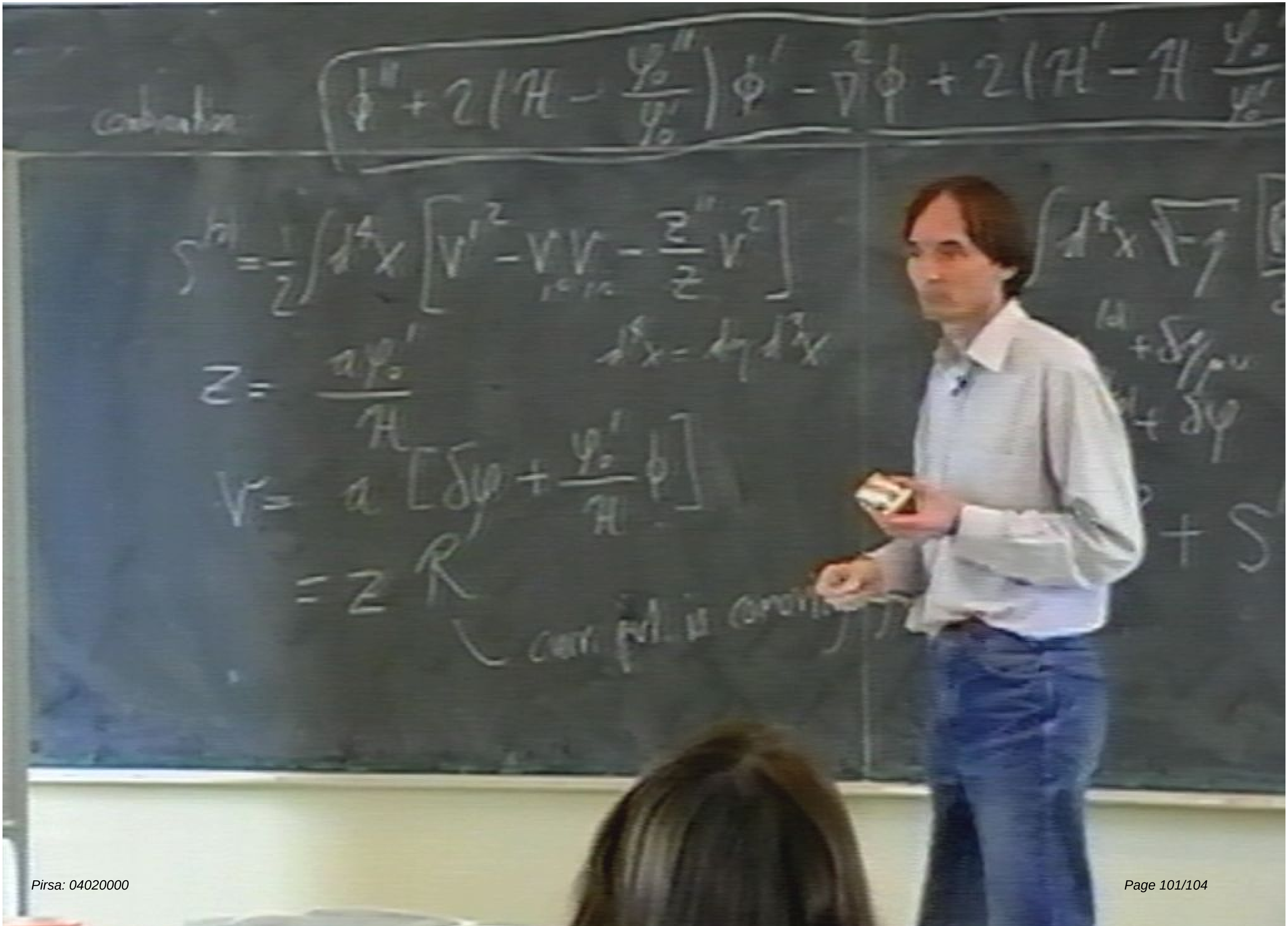
curv. pert. in comoving

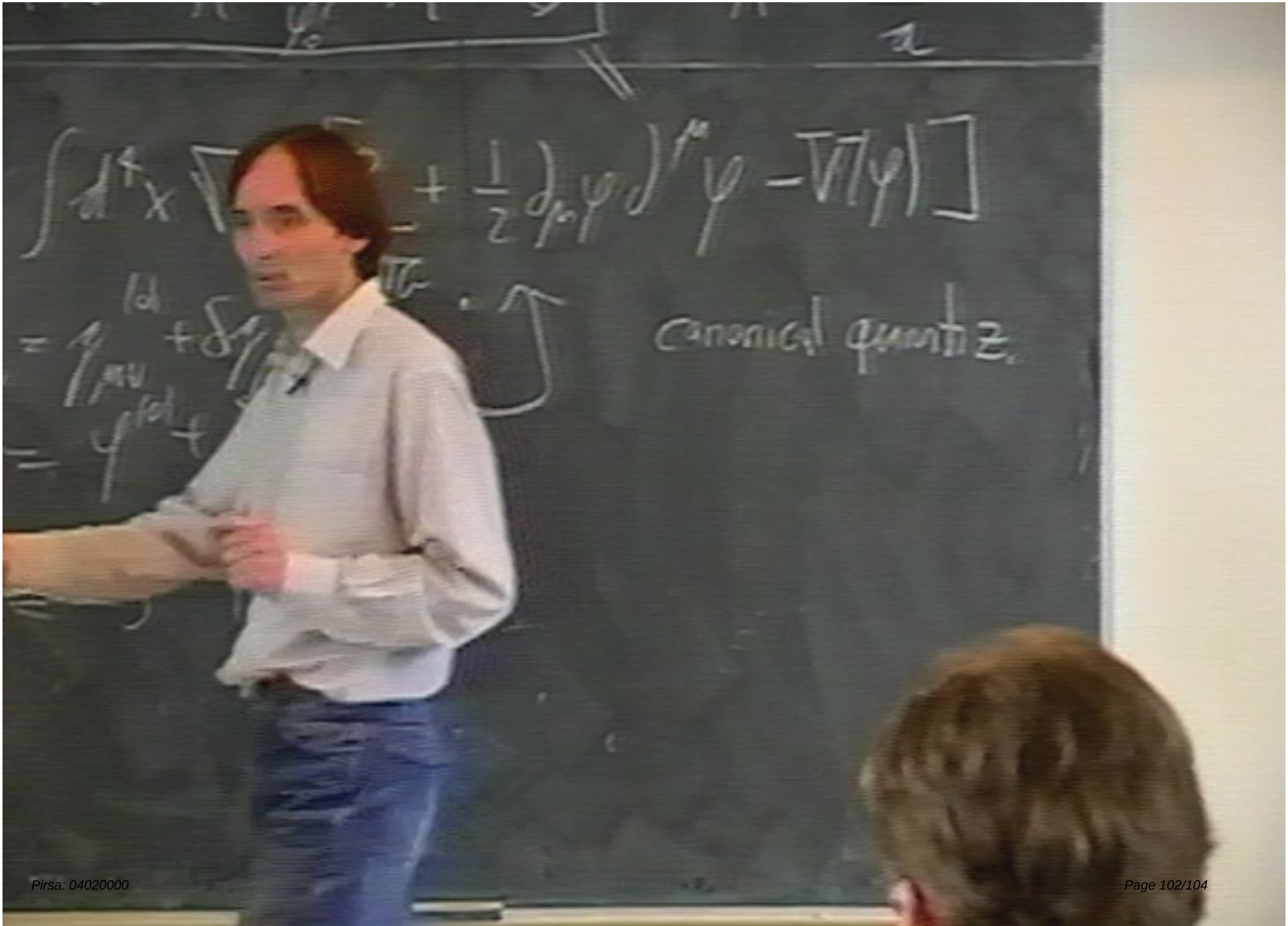
$S =$

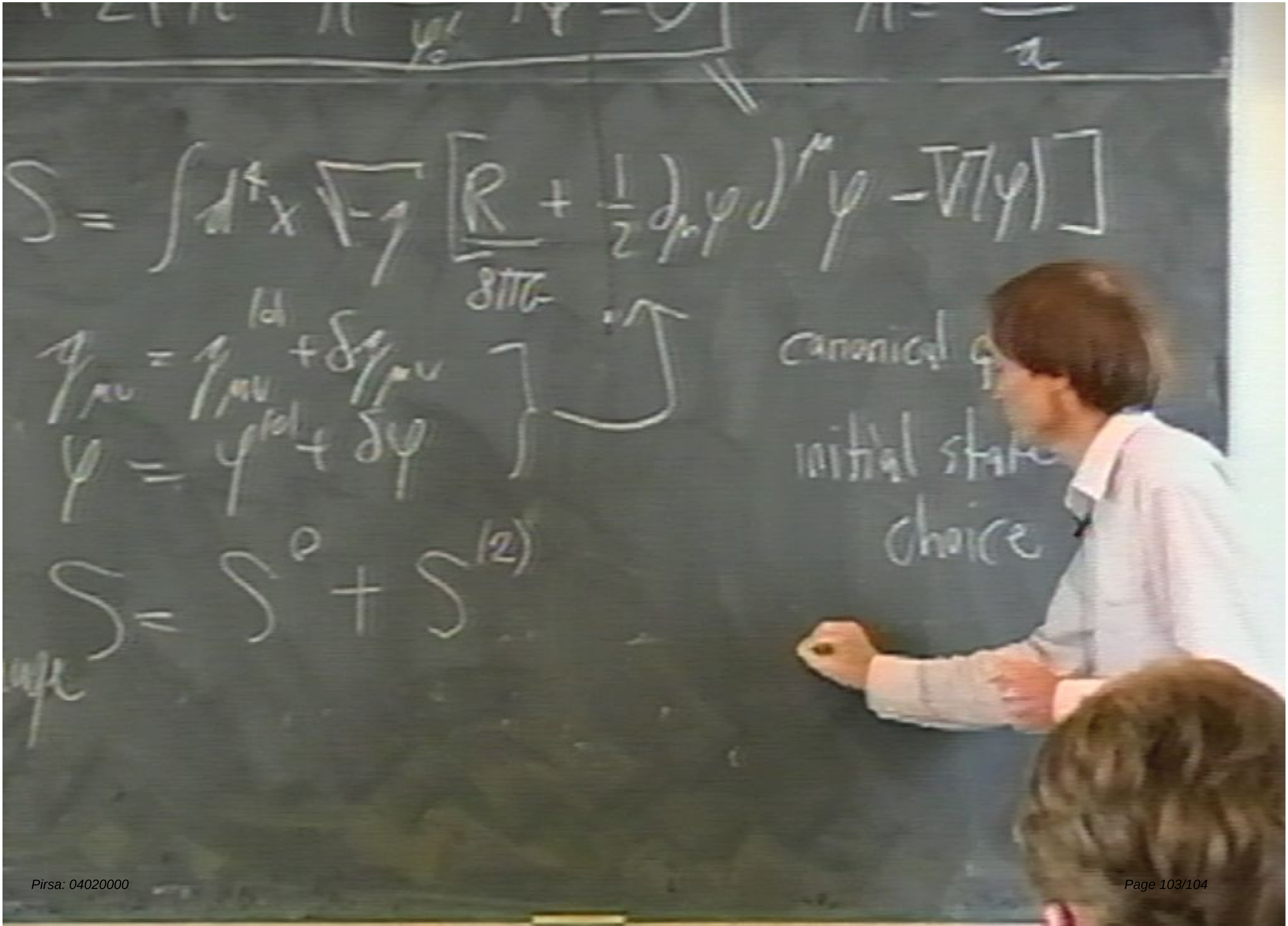
$\varphi =$

$S =$




combination
Z = aφ0'/H
v = a [δφ + φ0'/H ϕ]
= Z R
d⁴x = dη d³x


canonical quantiz.


$S = \int d^4x \sqrt{-g} \left[\frac{R}{8\pi G} + \frac{1}{2} \partial_\mu \varphi \partial^\mu \varphi - V(\varphi) \right]$
$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$
$\varphi = \varphi^{(0)} + \delta\varphi$
$S = S^{0} + S^{(2)}$
canonical
initial state
choice

$$S = \int d^4x \sqrt{-g}\left[\frac{R}{8\pi G} + \frac{1}{2}\partial_\mu \varphi \partial^\mu \varphi - V(\varphi)\right]$$

$$g_{\mu\nu} = g^{(0)}_{\mu\nu} + \delta g_{\mu\nu}$$

$$\varphi = \varphi^{(0)} + \delta\varphi$$

$$S = S^{0} + S^{(2)}$$

canonical quantiz.

initial state choice

at t_1 vacuum