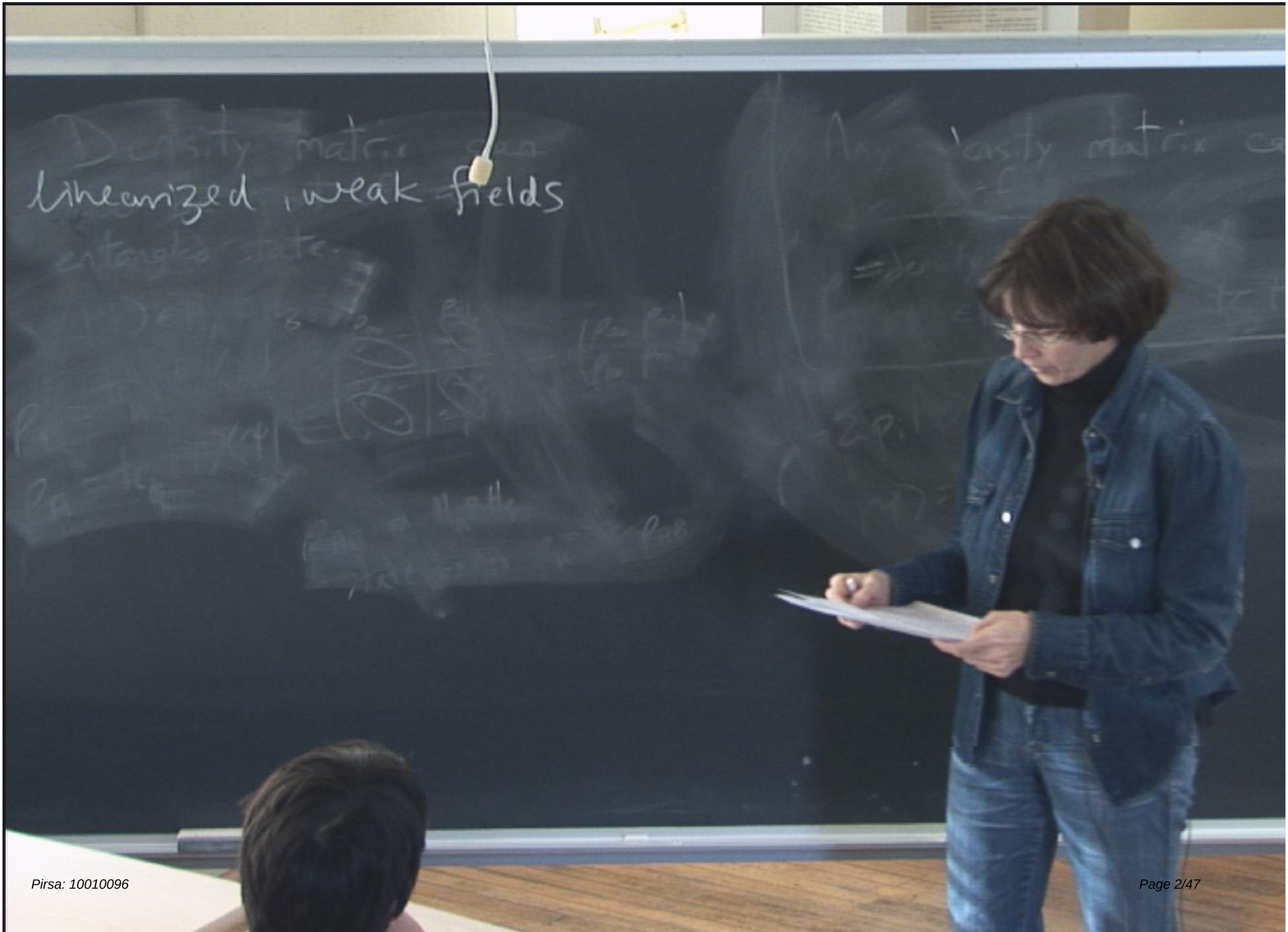
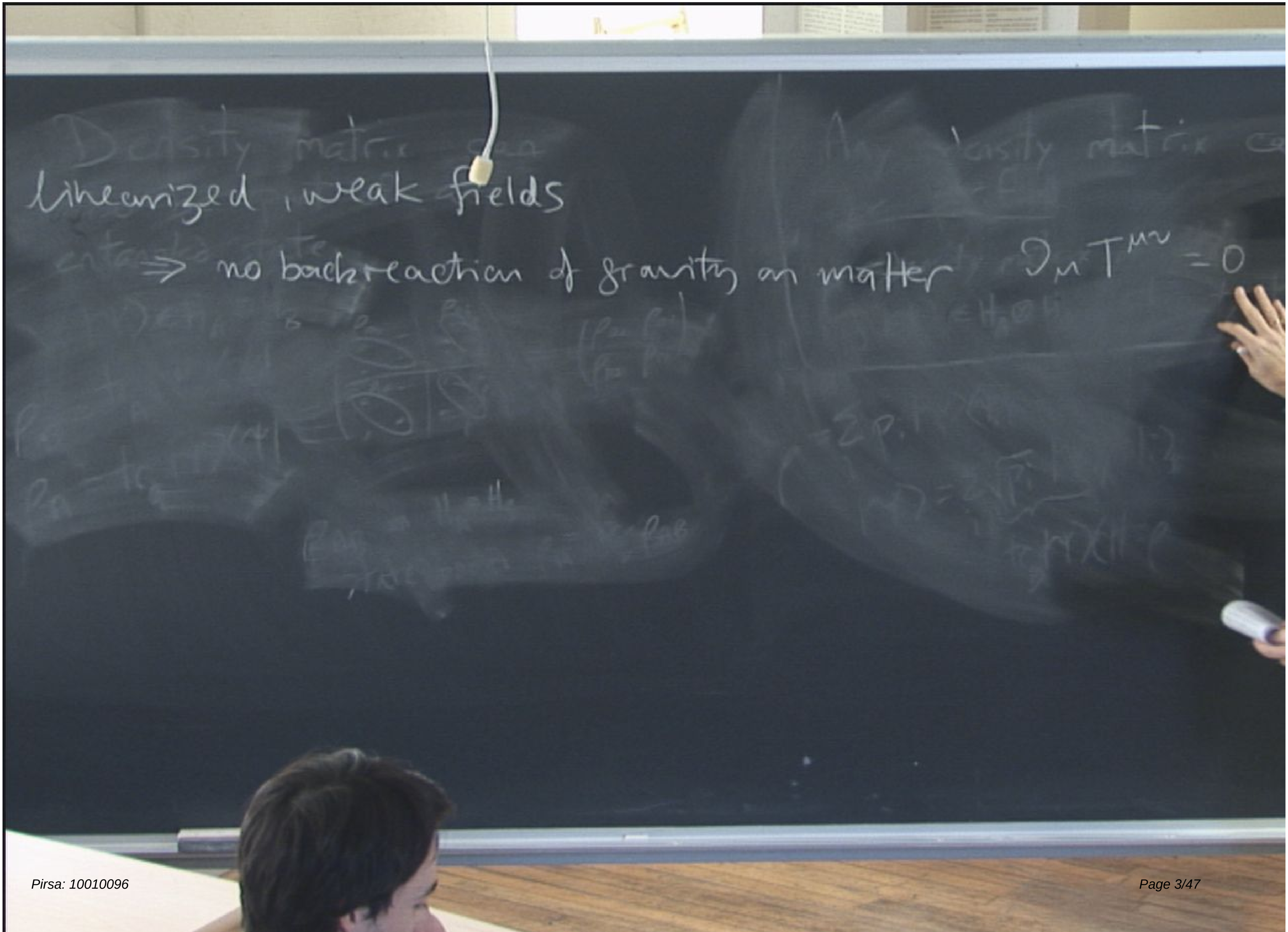
Title: Quantum Gravity - Review (PHYS 638) - Lecture 3

Date: Jan 27, 2010 10:00 AM

URL: http://pirsa.org/10010096

Abstract:


linearized, weak fields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$\Rightarrow$ no backreaction of gravity on matter $\partial_\mu T^{\mu\nu} = 0$

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self-consistent inclusion of self-interactions

$\Rightarrow$ full Einstein theory

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self-consistent inclusion of self-interactions

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(Deser, gr-qc/0411023)

$$g_{\mu\nu} = \eta_{\mu\nu} + f_{\mu\nu}$$

Under spatial rotations

$$e_y' = \cos\Theta \; e_y - \sin\Theta \; e_z$$

$$e_z' = \sin\Theta \; e_y + \cos\Theta \; e_z$$

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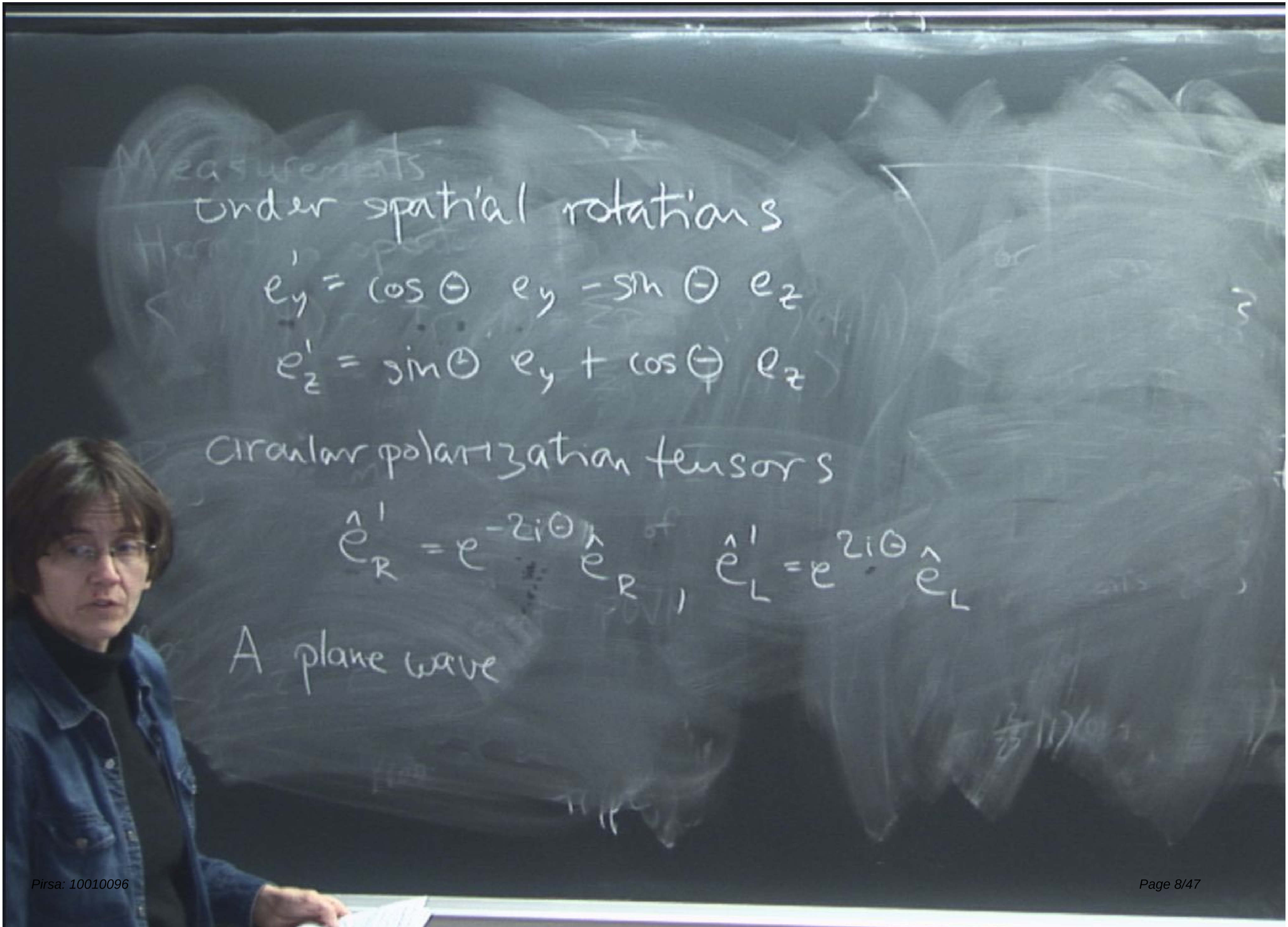
Circular polarization tensors

$$\hat{e}_R' = e^{-2i\Theta}\,\hat{e}_R \,, \quad \hat{e}_L' = e^{2i\Theta}\,\hat{e}_L$$



under spatial rotations
$e'_y = \cos\Theta \; e_y - \sin\Theta \; e_z$
$e'_z = \sin\Theta \; e_y + \cos\Theta \; e_z$
circular polarization tensors
$\hat{e}'_R = e^{-2i\Theta} \hat{e}_R \, , \quad \hat{e}'_L = e^{2i\Theta} \hat{e}_L$
A plane wave

Under spatial rotations

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Circular polarization tensors

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A plane wave φ transforming as $\varphi \mapsto e^{ih\Theta} \varphi$ under a rotation by Θ around the axis of propagation is said to have helicity h.

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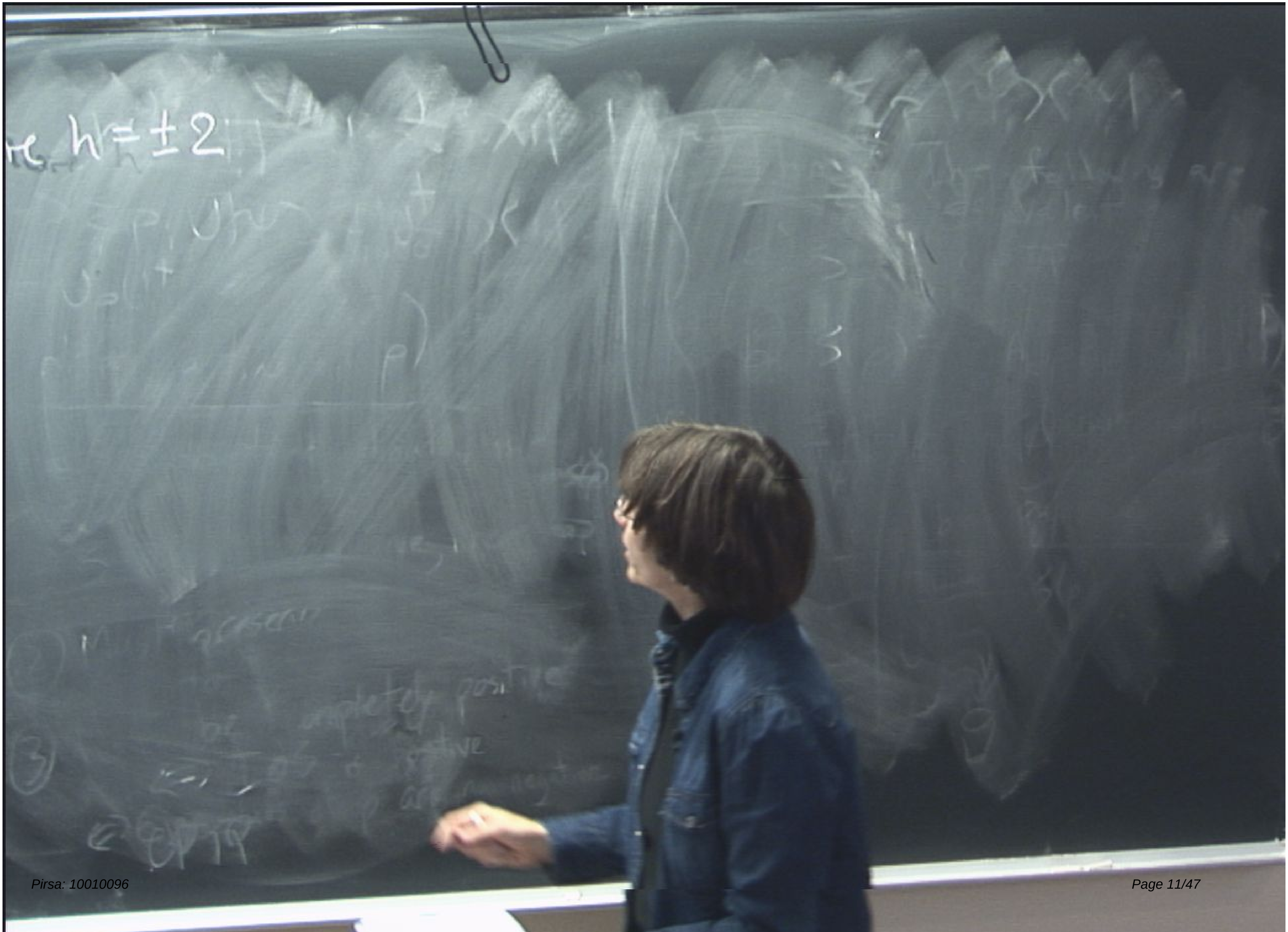
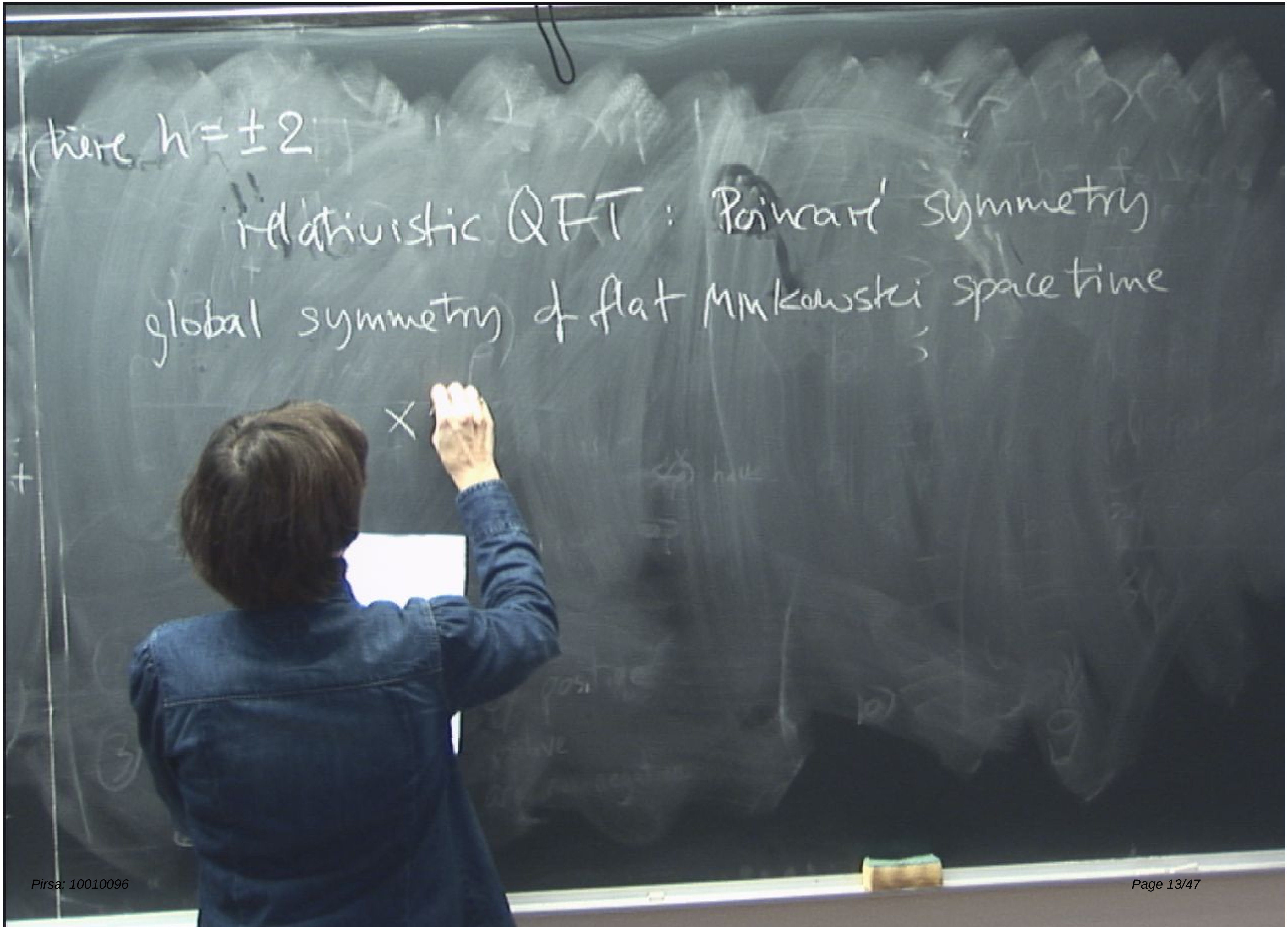

h = ±2


there $h = \pm 2$

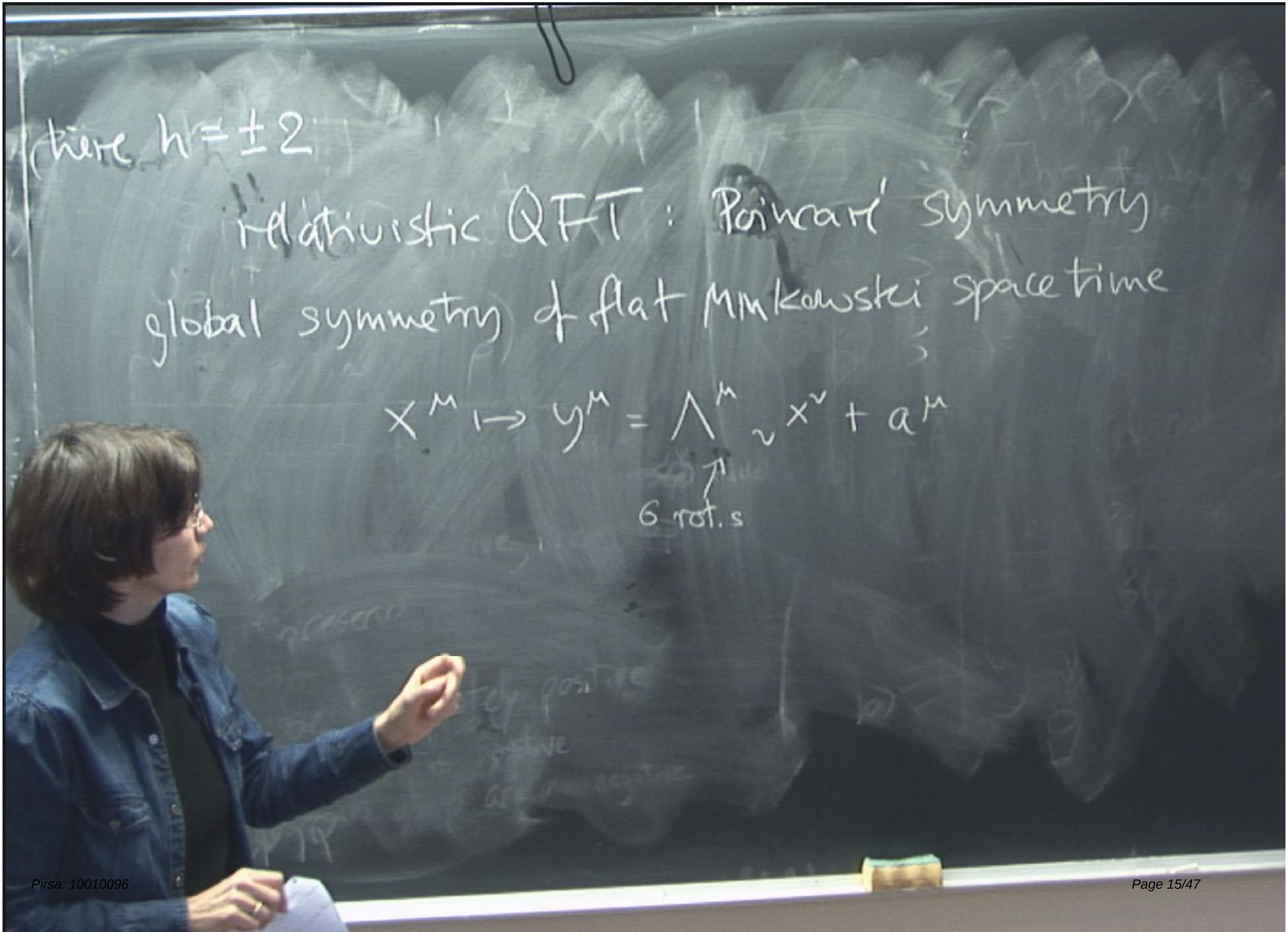

(here h = ±2
relativistic QFT : Poincaré symmetry
global symmetry of flat Minkowski spacetime
X

(here $h = \pm 2$)

relativistic QFT : Poincaré symmetry

global symmetry of flat Minkowski spacetime

$$x^\mu \mapsto y^\mu = \Lambda^\mu{}_\nu x^\nu + a^\mu$$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relativistic QFT : Poincaré symmetry
global symmetry of flat Minkowski spacetime
$x^\mu \mapsto y^\mu = \Lambda^\mu{}_\nu x^\nu + a^\mu$
6 rot.s

here $h = \pm 2$

relativistic QFT : Poincaré symmetry

global symmetry of flat Minkowski spacetime

$$x^\mu \mapsto y^\mu = \underbrace{\Lambda^\mu{}_\nu}_{\text{6 rot.s}} x^\nu + \underbrace{a^\mu}_{\text{4 transl.}}$$

here $h = \pm 2$

relativistic QFT : Poincaré symmetry

global symmetry of flat Minkowski spacetime

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4 transl.

10-dim noncompact Lie group

(here $h = \pm 2$)

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$\rightarrow$ 10-dim noncompact Lie group

unitary action on states $\psi \mapsto U(\Lambda, a)\psi$

$\rightarrow$ classify "particles" according to their transf behaviour

(here $h = \pm 2$)

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global symmetry of flat Minkowski space time

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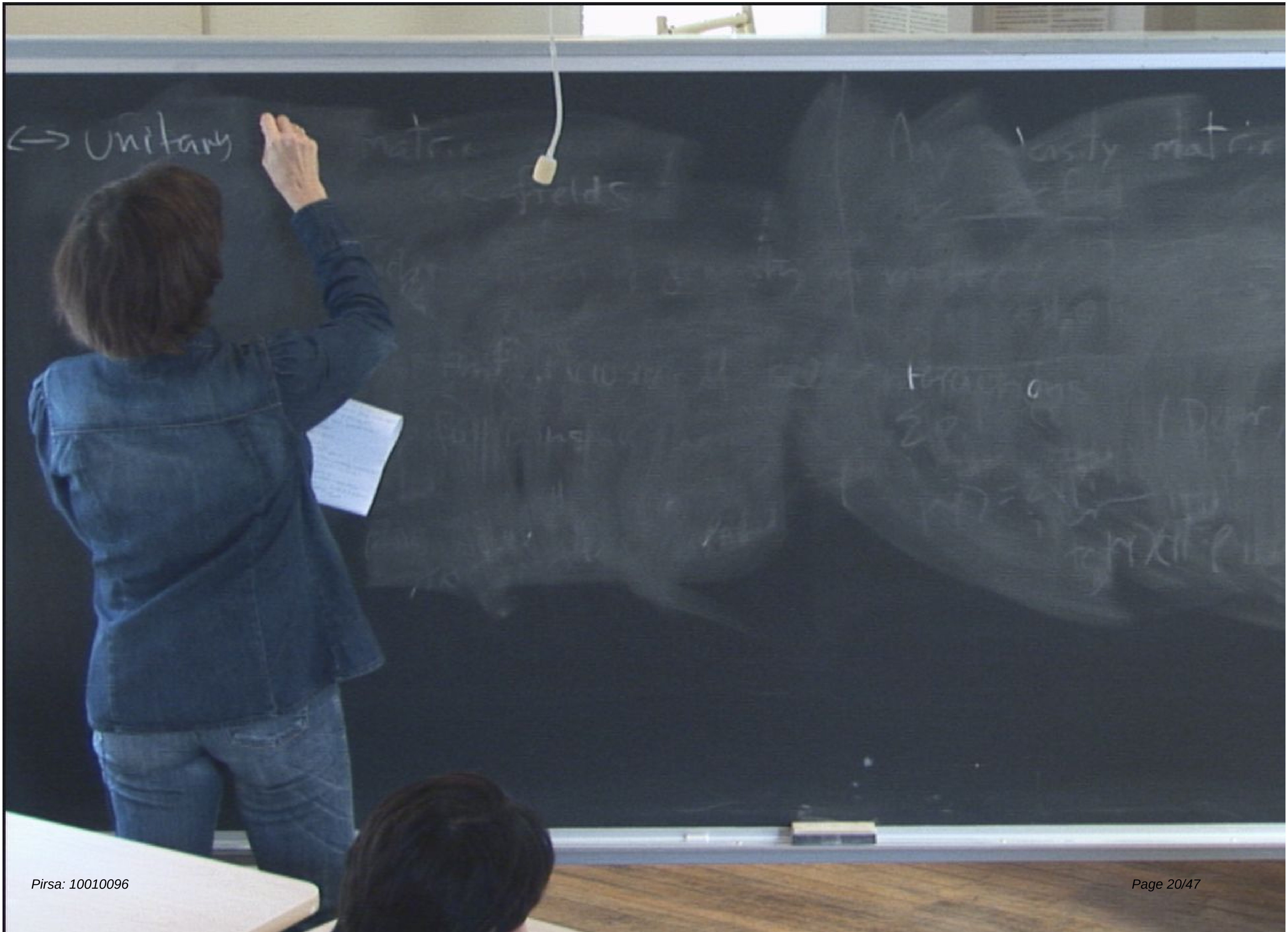
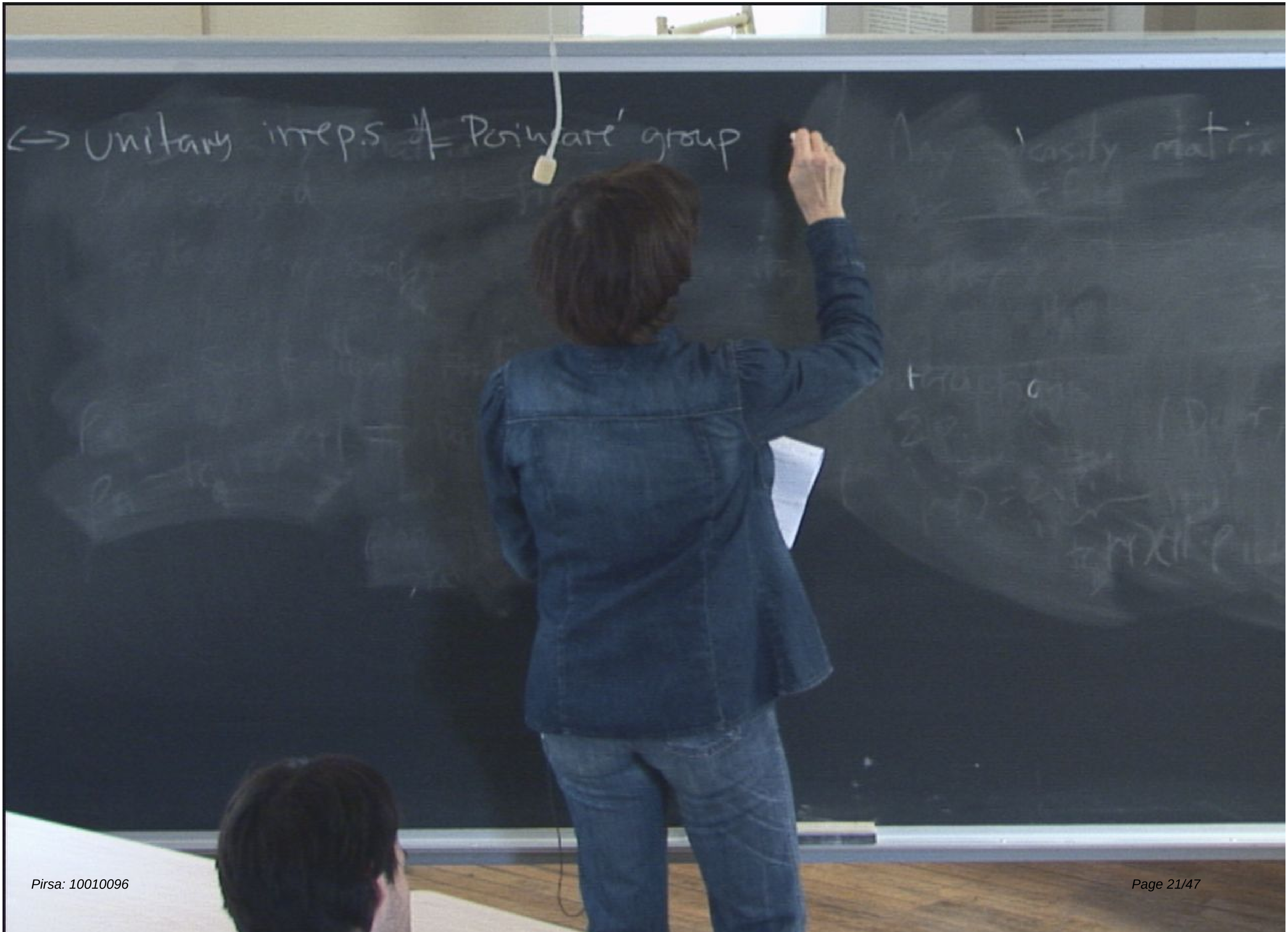
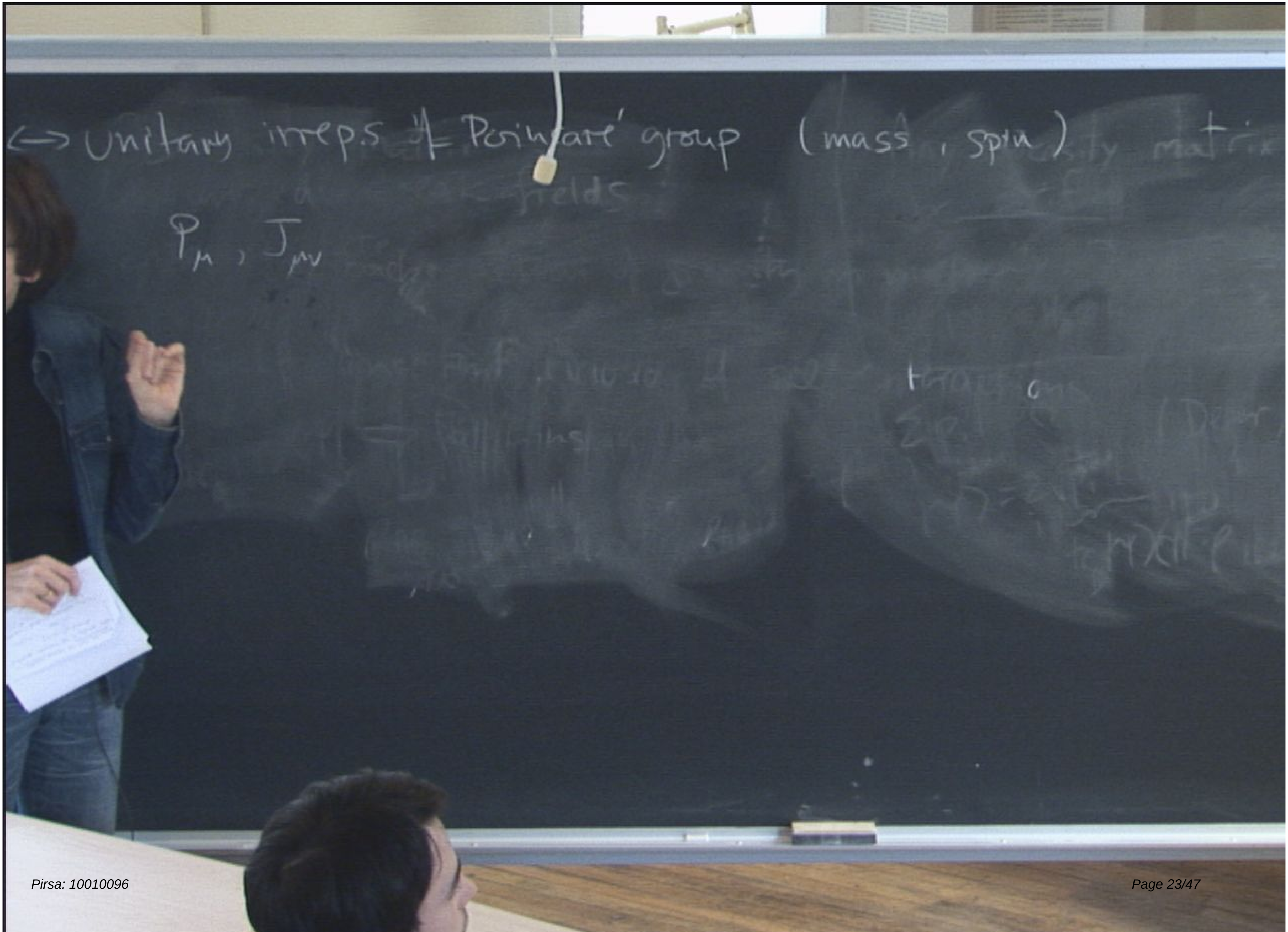
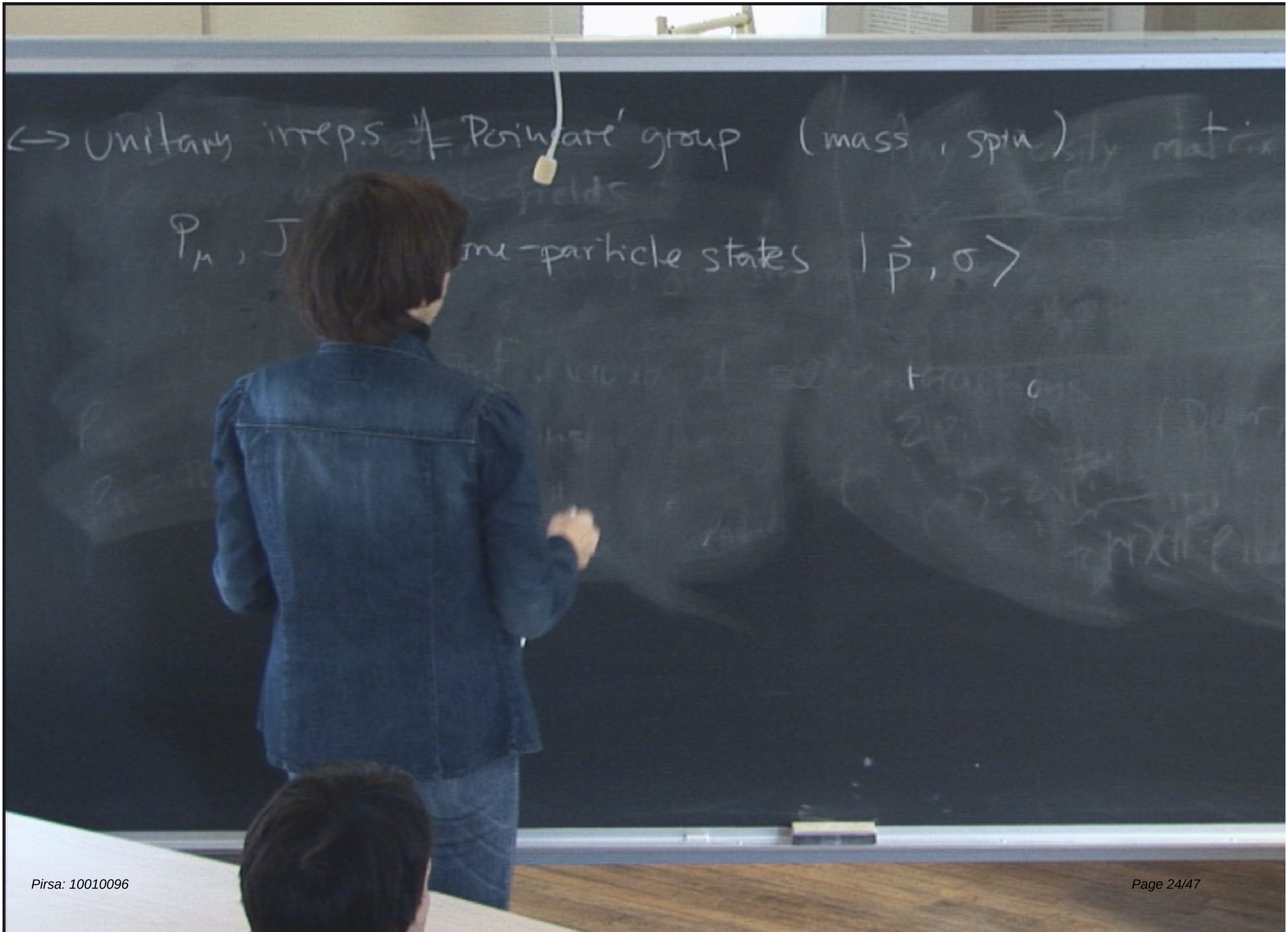
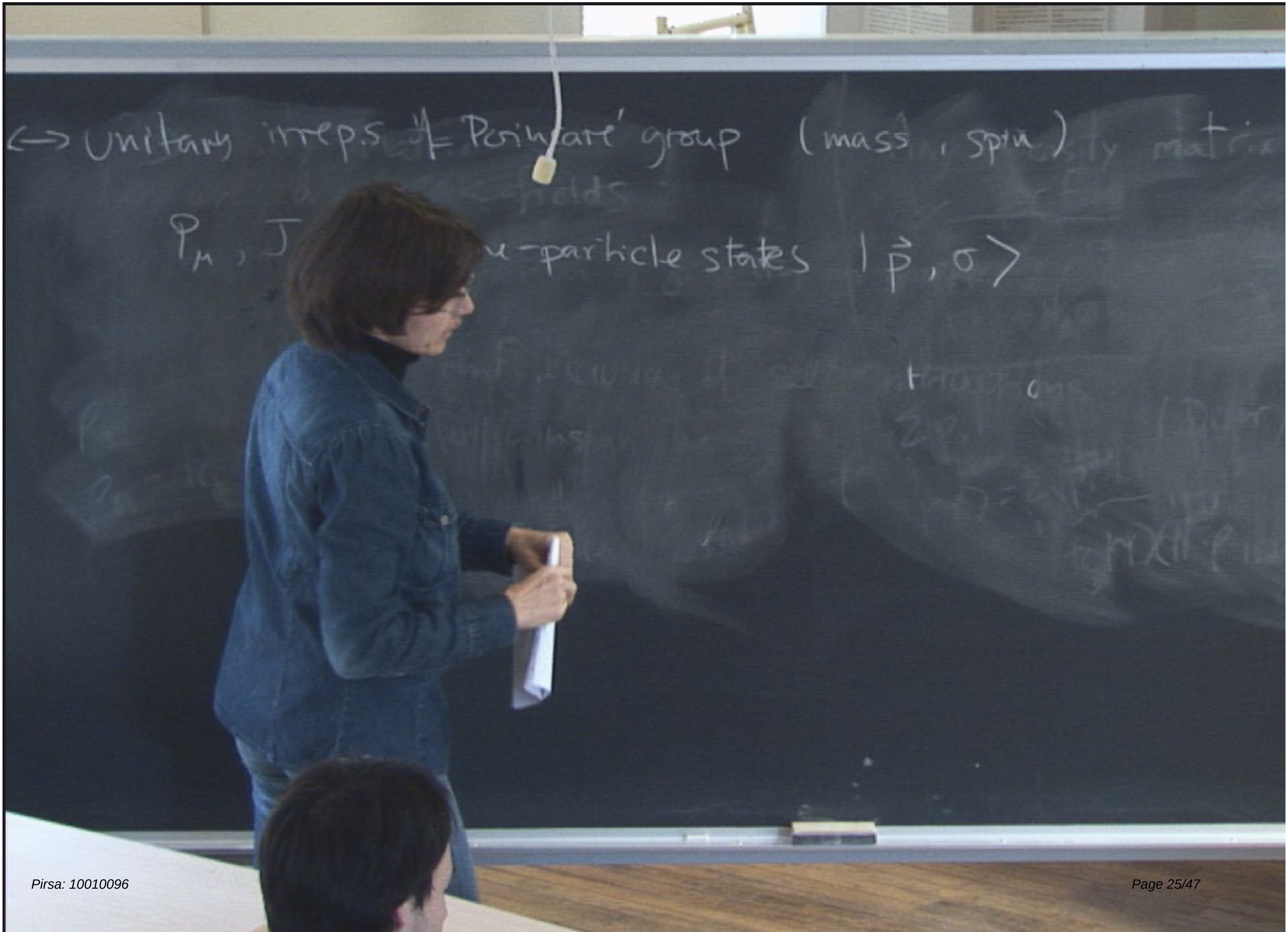

Unitary


⟷ Unitary irreps of Poincaré group

$\longleftrightarrow$ Unitary irreps. of Poincaré group (mass, spin)


↔ Unitary irrep.s of Poincaré group (mass, spin)
P_μ, $J_{\mu\nu}$


⟷ Unitary irreps of Poincaré group (mass , spin)
P_μ , J
ne-particle states $|\vec{p}, \sigma\rangle$


Unitary irrep.s of Poincaré group (mass, spin)
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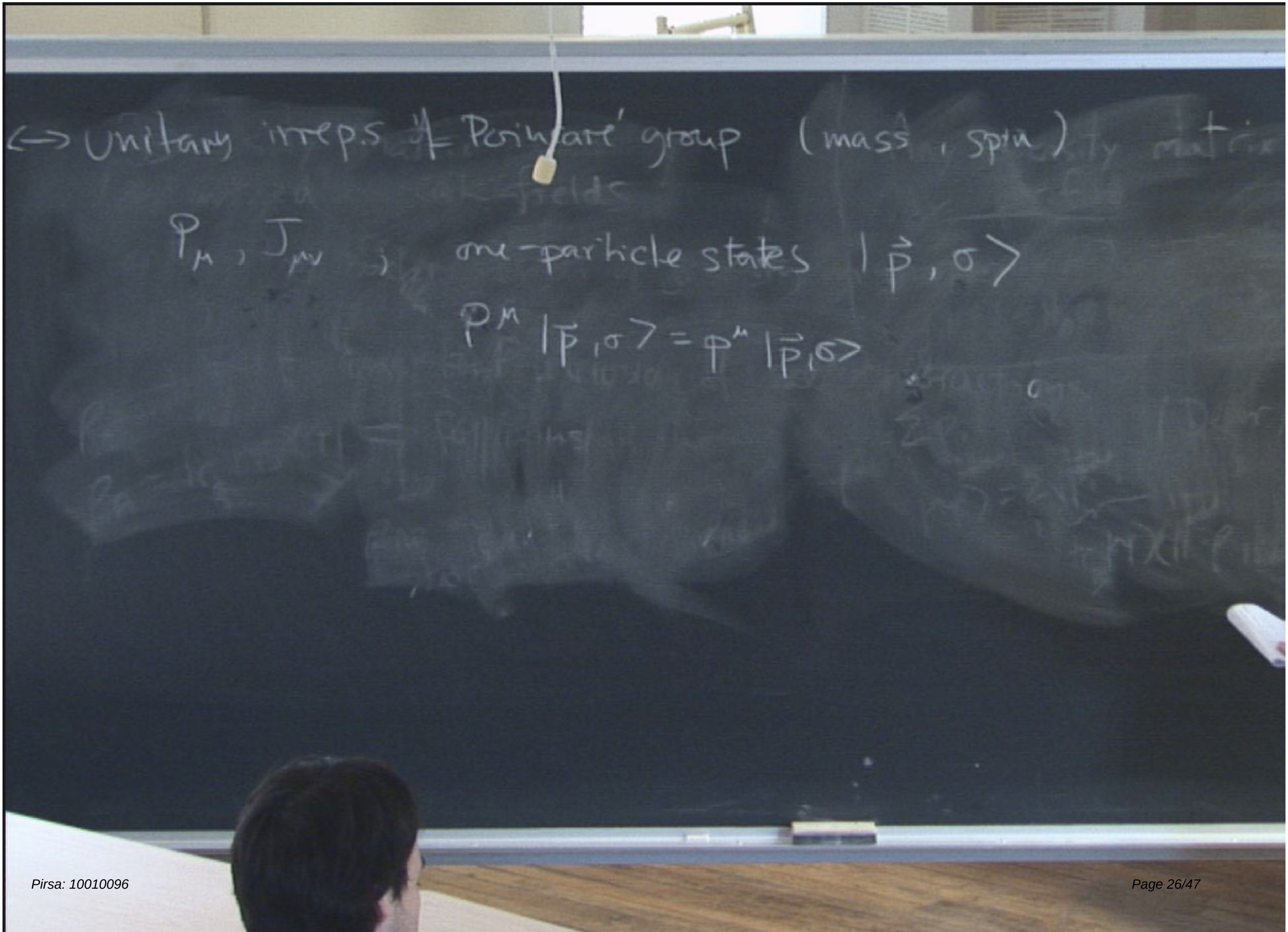
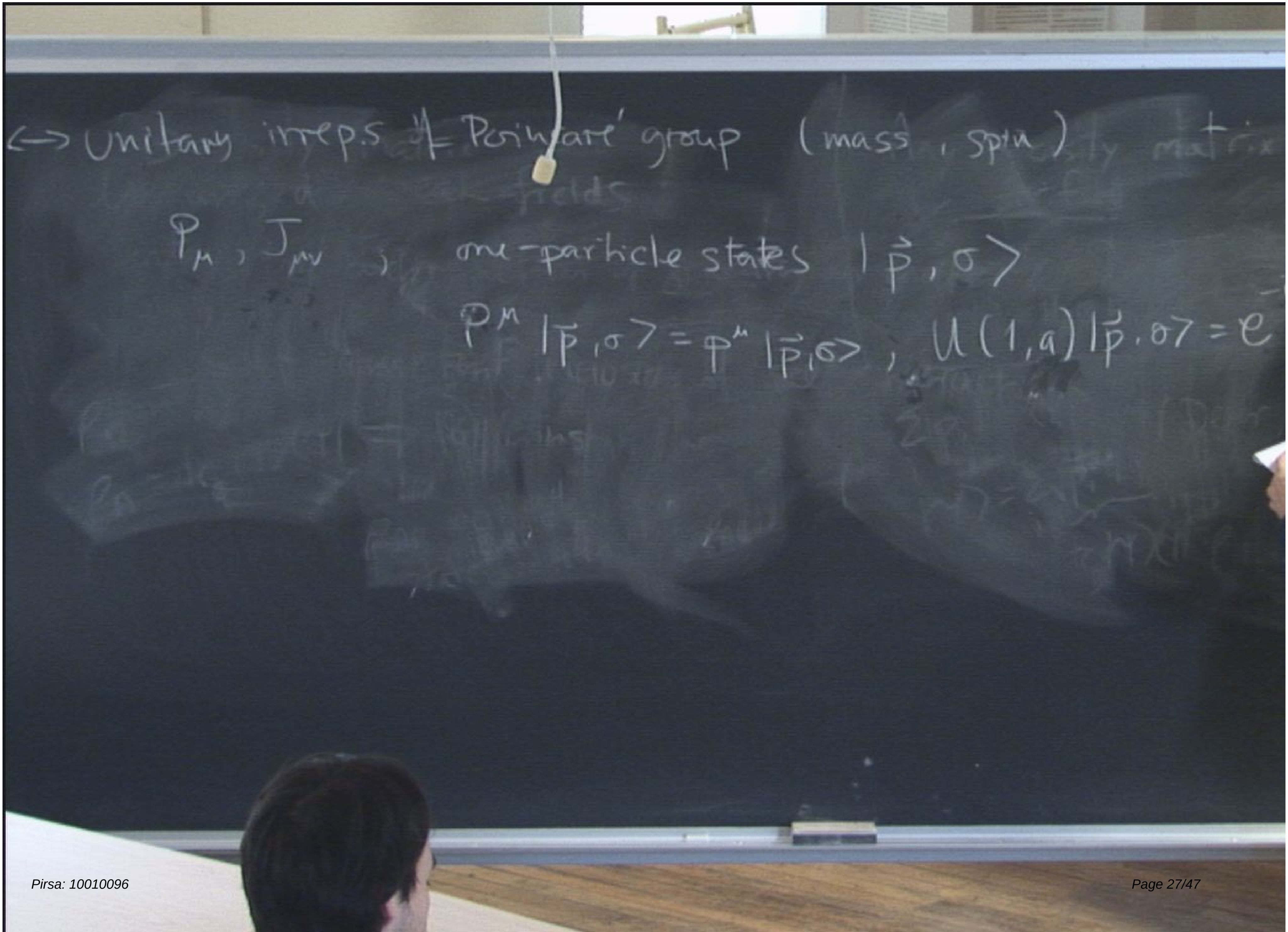
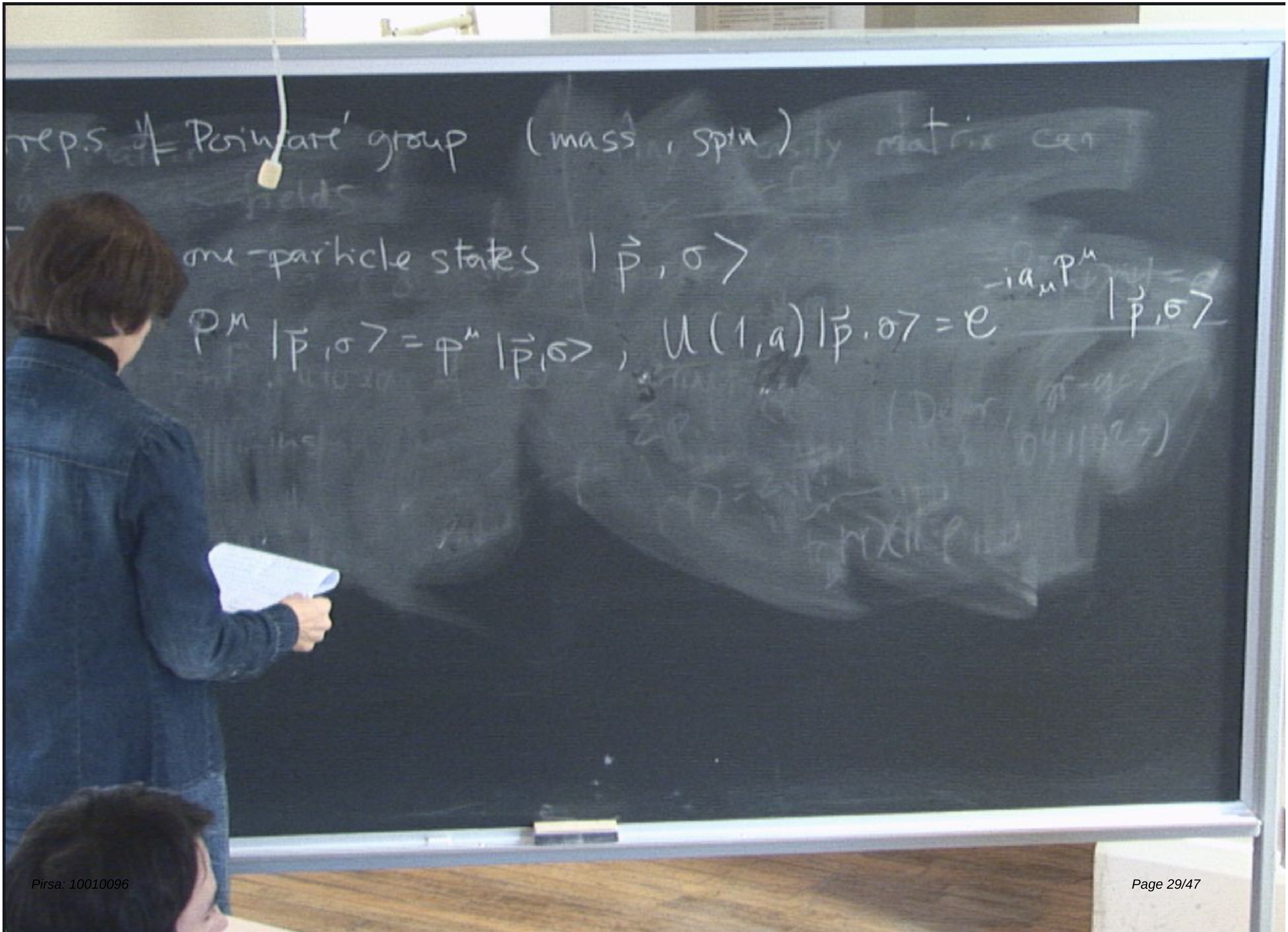

⟷ Unitary irreps. of Poincaré group (mass, spin)
P_μ, $J_{\mu\nu}$; one-particle states $|\vec{p}, \sigma\rangle$
$P^\mu |\vec{p}, \sigma\rangle = p^\mu |\vec{p}, \sigma\rangle$


⟷ Unitary irreps. of Poincaré group (mass, spin)
P_μ, $J_{\mu\nu}$; one-particle states $|\vec{p}, \sigma\rangle$
$P^\mu |\vec{p}, \sigma\rangle = p^\mu |\vec{p}, \sigma\rangle$; $U(1,a)|\vec{p}, \sigma\rangle = e$

irreps. of Poincaré group (mass, spin)

$J_{\mu\nu}$; one-particle states $|\vec{p},\sigma\rangle$

$$P^\mu|\vec{p},\sigma\rangle = p^\mu|\vec{p},\sigma\rangle \; ; \quad U(1,a)|\vec{p},\sigma\rangle = e^{-ia_\mu p^\mu}|\vec{p},\sigma\rangle$$

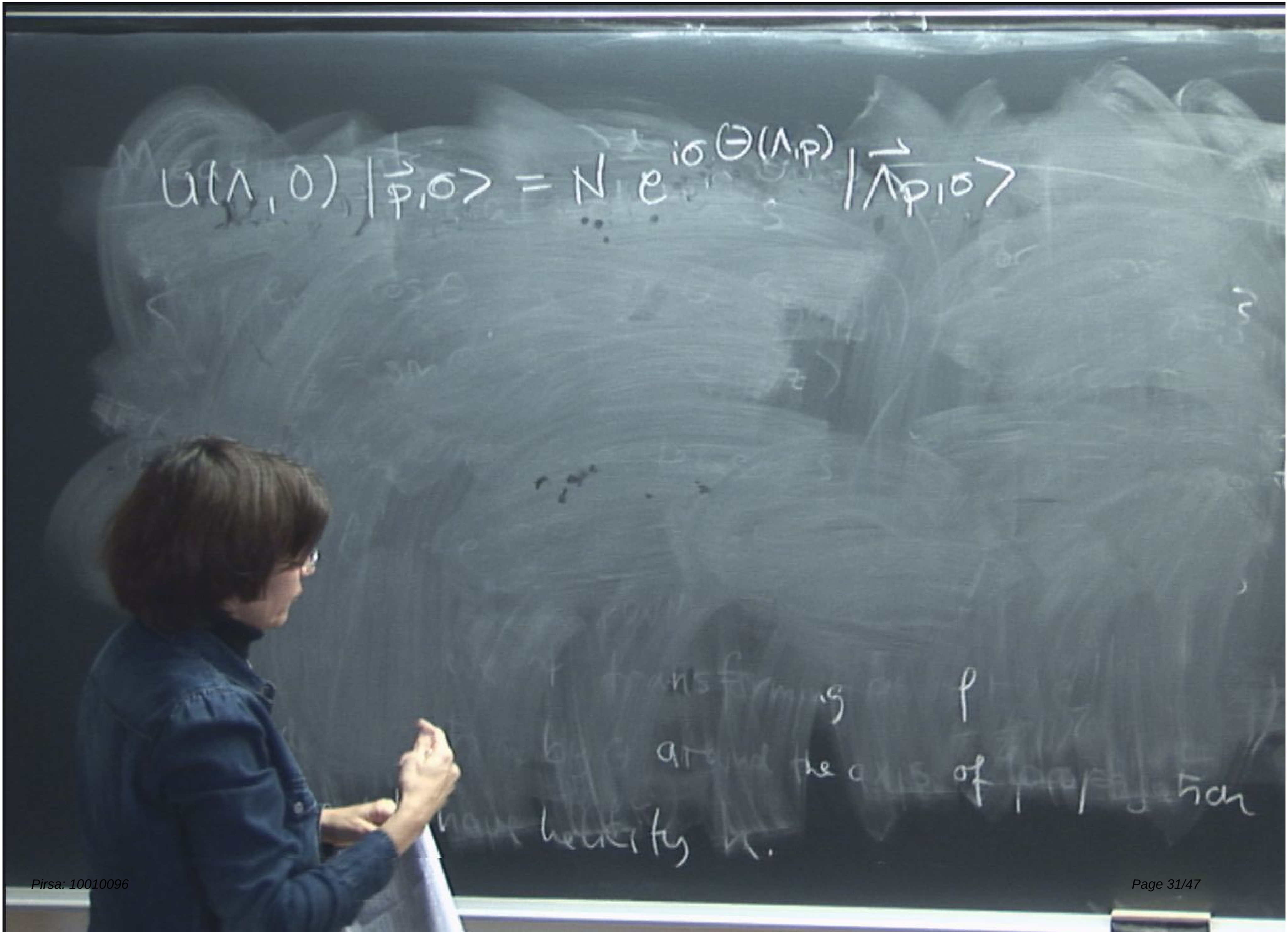

reps.s of Poincaré group (mass, spin)
one-particle states $|\vec{p},\sigma\rangle$
$P^\mu |\vec{p},\sigma\rangle = p^\mu |\vec{p},\sigma\rangle$; $U(1,a)|\vec{p},\sigma\rangle = e^{-ia_\mu p^\mu} |\vec{p},\sigma\rangle$

irreps. of Poincaré group (mass, spin)

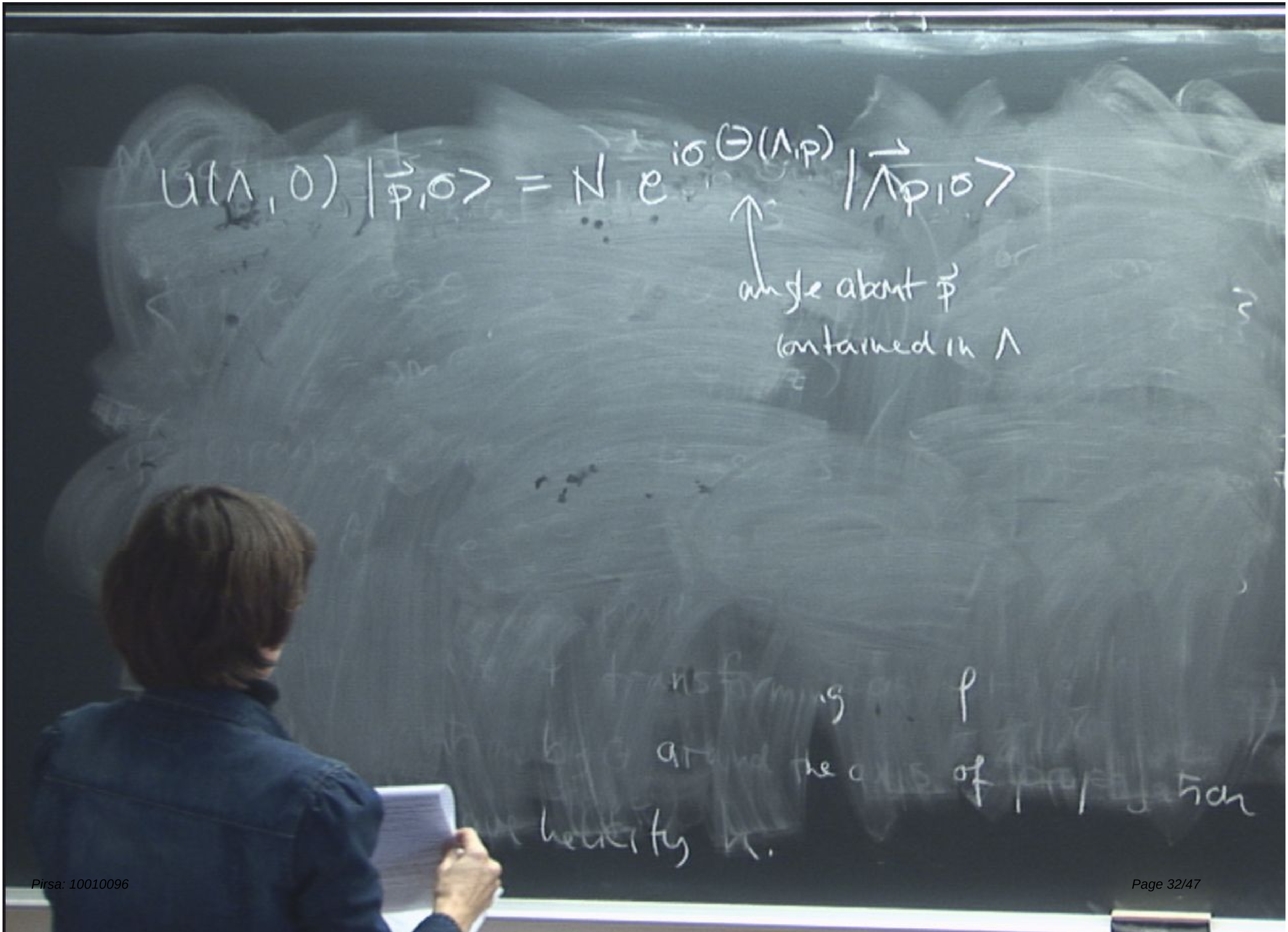
$J_{\mu\nu}$; one-particle states $|\vec{p}, \sigma\rangle$

$P^\mu |\vec{p}, \sigma\rangle = p^\mu |\vec{p}, \sigma\rangle$; $U(1,a)|\vec{p}, \sigma\rangle = e^{-ia_\mu P^\mu} |\vec{p}, \sigma\rangle$

$m^2 = 0$, $p^0 > 0$; helicity = (component of angular momentum along 3-momentum $\vec{k} = (0,0,\omega)$ $J_3 |\vec{k}, \sigma\rangle = \sigma |\vec{k}, \sigma\rangle$



$U(\Lambda, 0) |\vec{p}, \sigma\rangle = N e^{i\sigma\Theta(\Lambda,p)} |\vec{\Lambda p}, \sigma\rangle$
around the axis of propagation
have helicity h.


$U(\Lambda, 0)\,|\vec{p}, \sigma\rangle = N\, e^{i\sigma\Theta(\Lambda,p)}\,|\vec{\Lambda p}, \sigma\rangle$
angle about $\vec{p}$
contained in Λ
around the axis of propagation
helicity h.

$$U(\Lambda, 0)\,|\vec{p}, \sigma\rangle = N\, e^{i\sigma\Theta(\Lambda, p)}\,|\vec{\Lambda p}, \sigma\rangle$$

angle about $\vec{p}$
contained in Λ

$|\sigma| \sim$ "spin"

$f_{\mu\nu}$

$$U(\Lambda, 0)\,|\vec{p}, \sigma\rangle = N\, e^{i\sigma\,\Theta(\Lambda, p)}\,|\vec{\Lambda p}, \sigma\rangle$$

angle about $\vec{p}$

contained in Λ

$|\sigma| \sim$ "spin"

$$f_{\mu\nu}(x) = \int \frac{d^3K}{(2\pi)^{3/2}} \frac{1}{\sqrt{2\omega_K}} \sum_{\sigma=\pm 2} \left[d(\vec{K}, \sigma)\, a_{\mu\nu}(\vec{K}, \sigma)\, e^{ik}\right.$$

$\Theta(\Lambda, p)\ |\overrightarrow{\Lambda p}, \sigma\rangle$

angle about $\vec{p}$

contained in Λ

$$\sum_{\sigma=\pm 2} \left[\hat{d}(\vec{k},\sigma)\, a_{\mu\nu}(\vec{k},\sigma)\, e^{ik\cdot x} + \hat{d}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x} \right]$$

$\Theta(\Lambda, p) \; |\overrightarrow{\Lambda p}, \sigma\rangle$

angle about $\vec{p}$
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$$\sum_{\sigma=\pm 2} \left[\hat{d}(\vec{k},\sigma)\, a_{\mu\nu}(\vec{k},\sigma)\, e^{ik\cdot x} + \hat{d}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x} \right]$$

annihilation op.s

creation op.s

$$, 0)\, |\vec{p}, \sigma\rangle = N\, e^{i\sigma\Theta(\Lambda, p)}\, |\overrightarrow{\Lambda p}, \sigma\rangle$$

angle about $\vec{p}$ contained in Λ

$|\sigma| \sim$ "spin"

$$(x) = \int \frac{d^3k}{(2\pi)^{3/2}} \frac{1}{\sqrt{2\omega_{\vec{k}}}} \sum_{\sigma=\pm 2} \left[\hat{d}(\vec{k},\sigma)\, a_{\mu\nu}(\vec{k},\sigma)\, e^{ik\cdot x} + \hat{d}^{\dagger}(\vec{k}, \ldots \right.$$

annihilation op.s

creation

$$\left[\hat{d}(\vec{k},\sigma), \hat{d}^{\dagger}(\vec{k}',\sigma') \right] = \delta_{\sigma\sigma'}\, \delta^{(3)}(\vec{k}-\vec{k}')$$

L. Rosenfeld (1930), M. Bronstein (1936)

J. Stachel

$$)e^{ik\cdot x} + \hat{d}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x}\Big]$$

creation op.s

$-\vec{k}')$

L. Rosenfeld (1930), M. Bronstein (1936)

J. Stachel

How real are gravitons?

$$\hat{d}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x}]$$

Creation op.s

L. Rosenfeld (1930), M. Bronstein (1936)

J. Stachel

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$$\hat{a}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x}$$

creation op.s

typical gravit. wave

L. Rosenfeld (1930), M. Bronstein (1936)

J. Stachel

How real are gravitons?

$\hat{d}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x}$]

creation op.s

typical gravit. wave (1000 Hz)

L. Rosenfeld (1930), M. Bronstein (1936)

J. Stachel

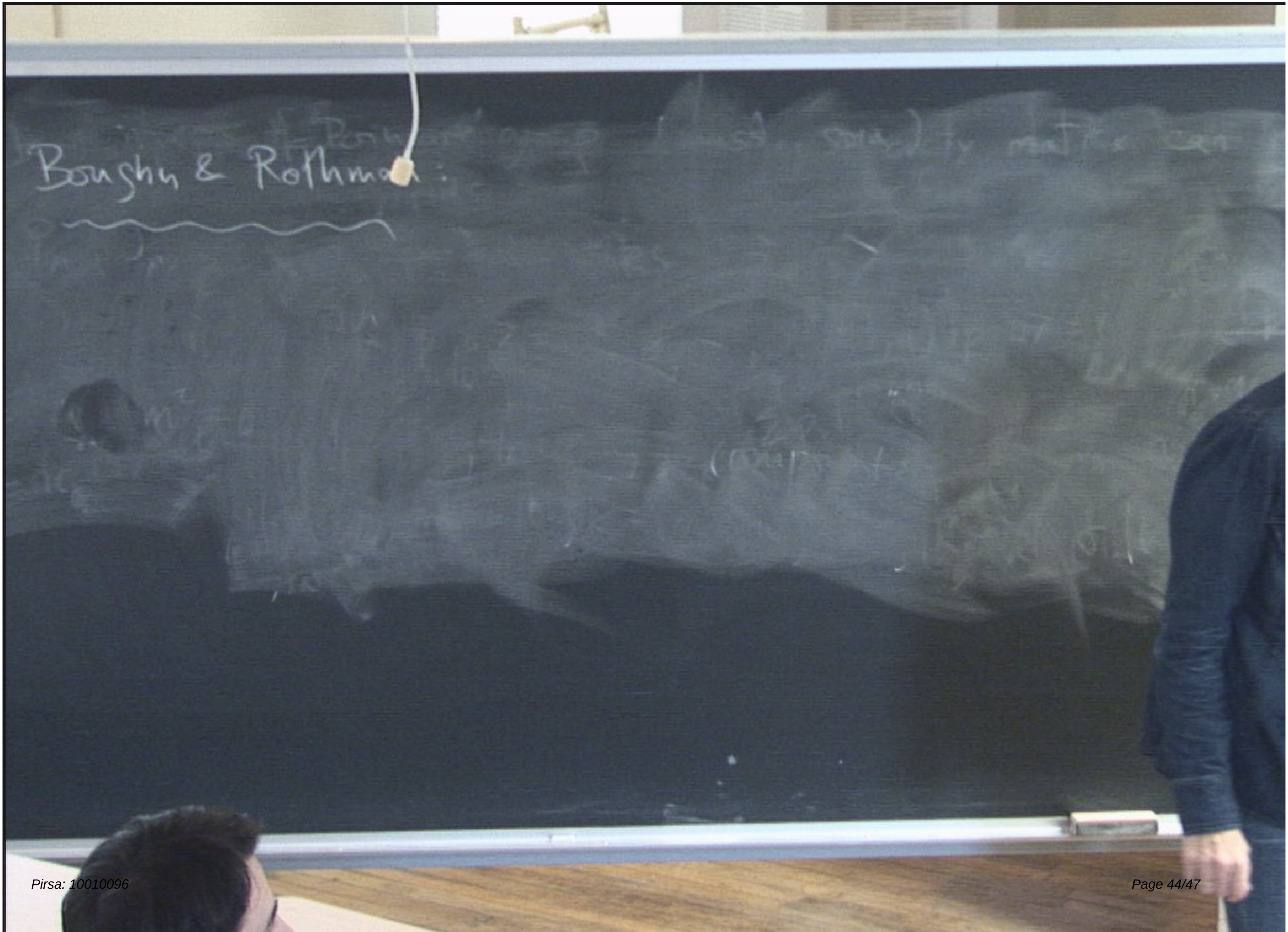
How real are gravitons?

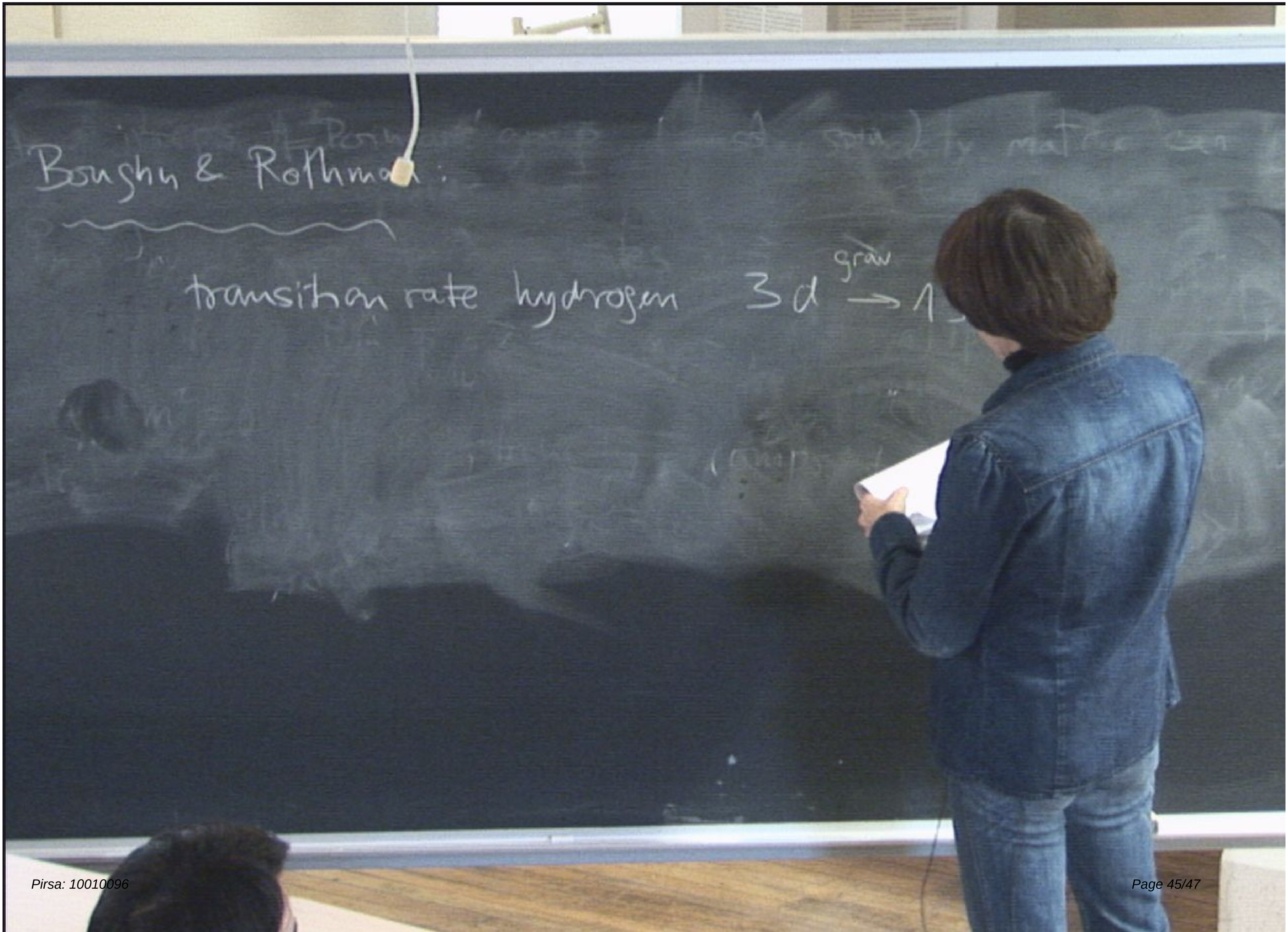
$$\hat{a}^{+}(\vec{k},\sigma)\, a^{*}_{\mu\nu}(k,\sigma)\, e^{-ik\cdot x}\Big]$$

creation op.s

typical gravit. wave (1000 Hz)

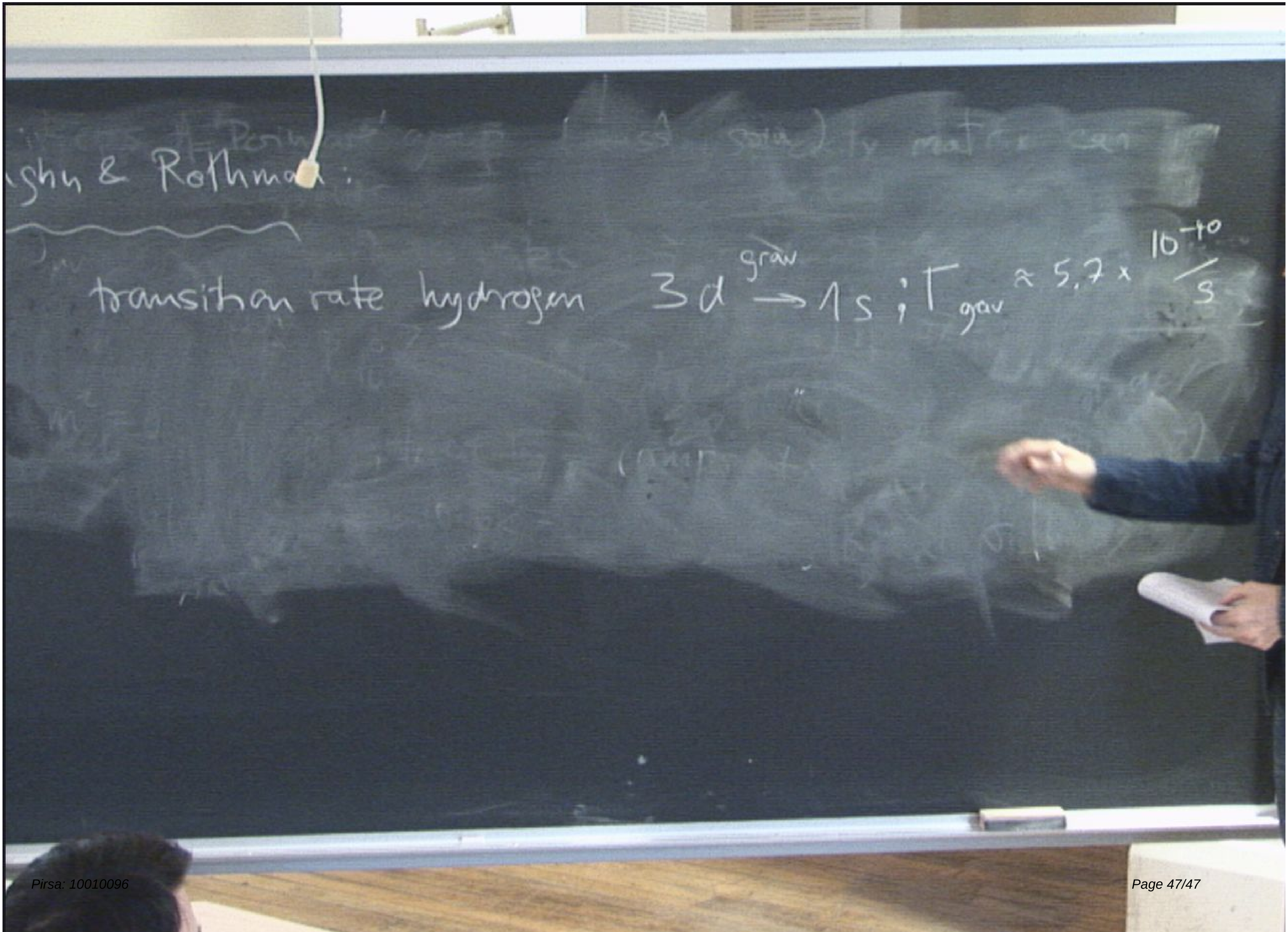
$\hookrightarrow$ graviton number density $\sim 3\times 10^{14}/\mathrm{cm}^3$


Boughn & Rothman :


Boughn & Rothman :
transition rate hydrogen 3d $\xrightarrow{grav}$ 1

Boughn & Rothman:

transition rate hydrogen $3d \xrightarrow{grav} 1s$; $\Gamma_{grav} \approx 5.7 \times 10^{-}$


ghn & Rothman :
transition rate hydrogen 3d →grav 1s ; Γgav ≈ 5,7 x 10^-40 /s