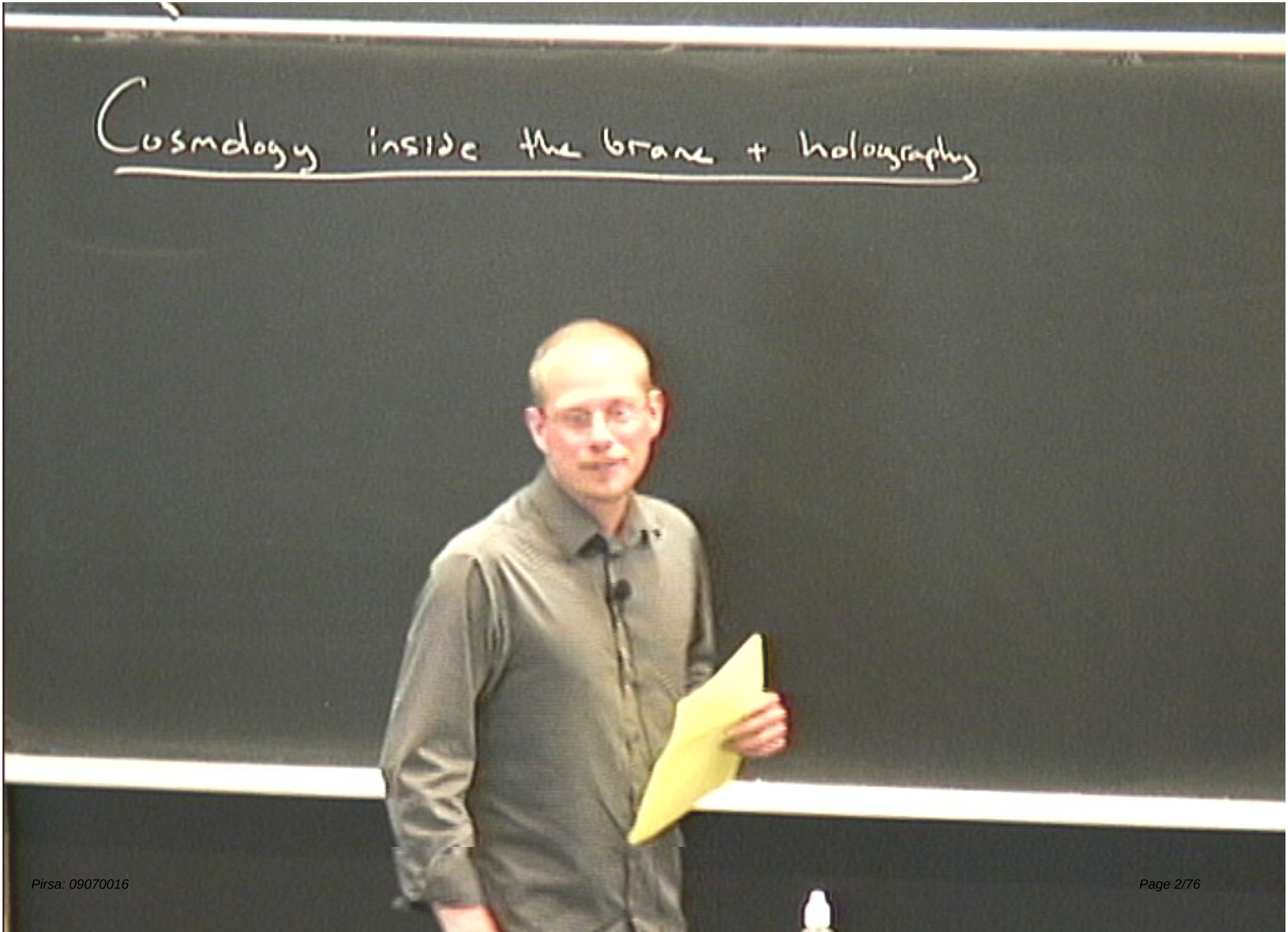
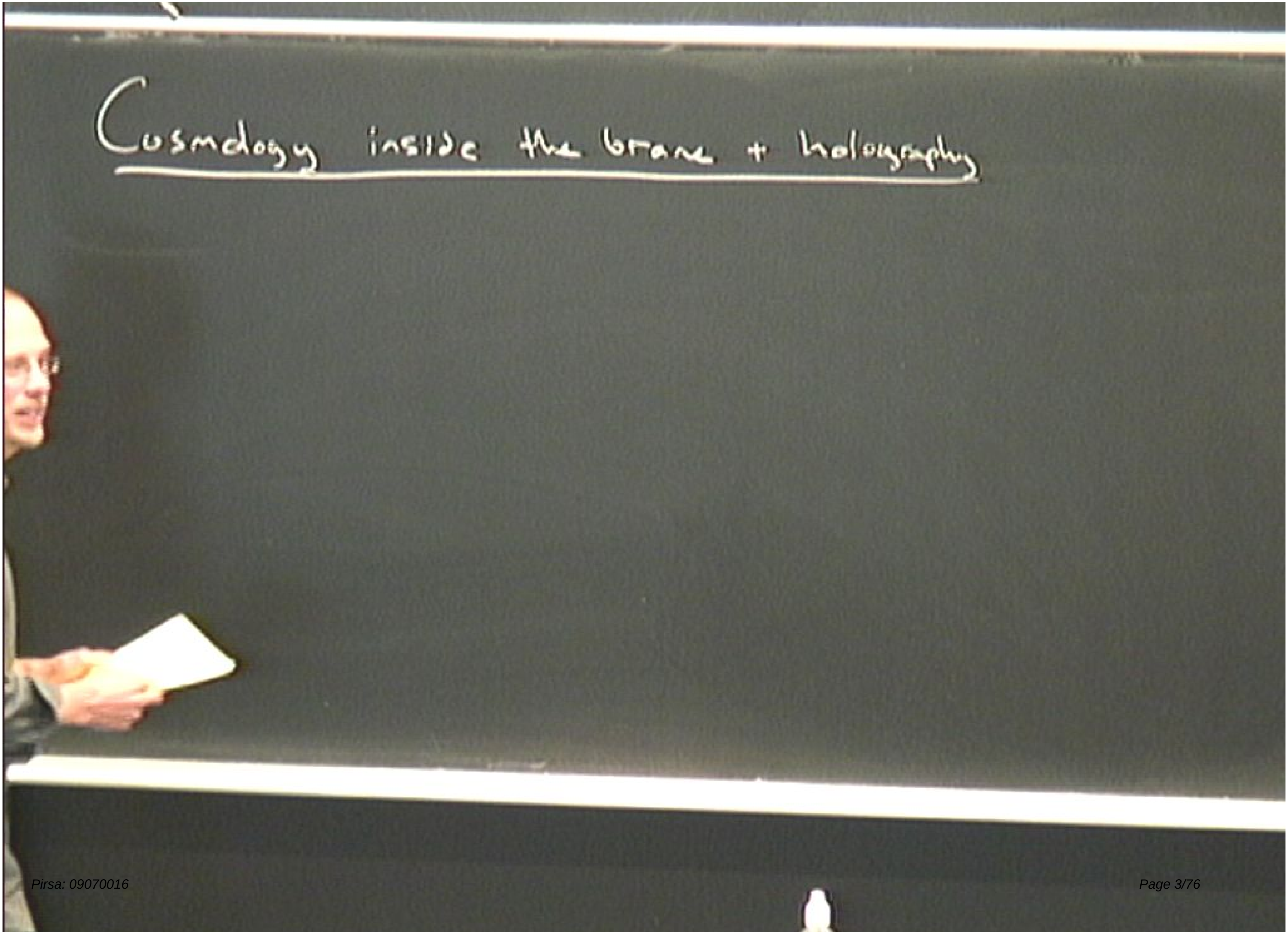
Title: Cosmology inside the brane and holography

Date: Jul 02, 2009 11:00 AM

URL: http://pirsa.org/09070016

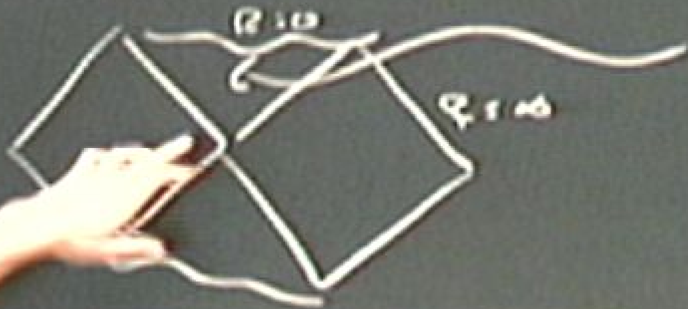
Abstract: TBA


Cosmology inside the brane + holography

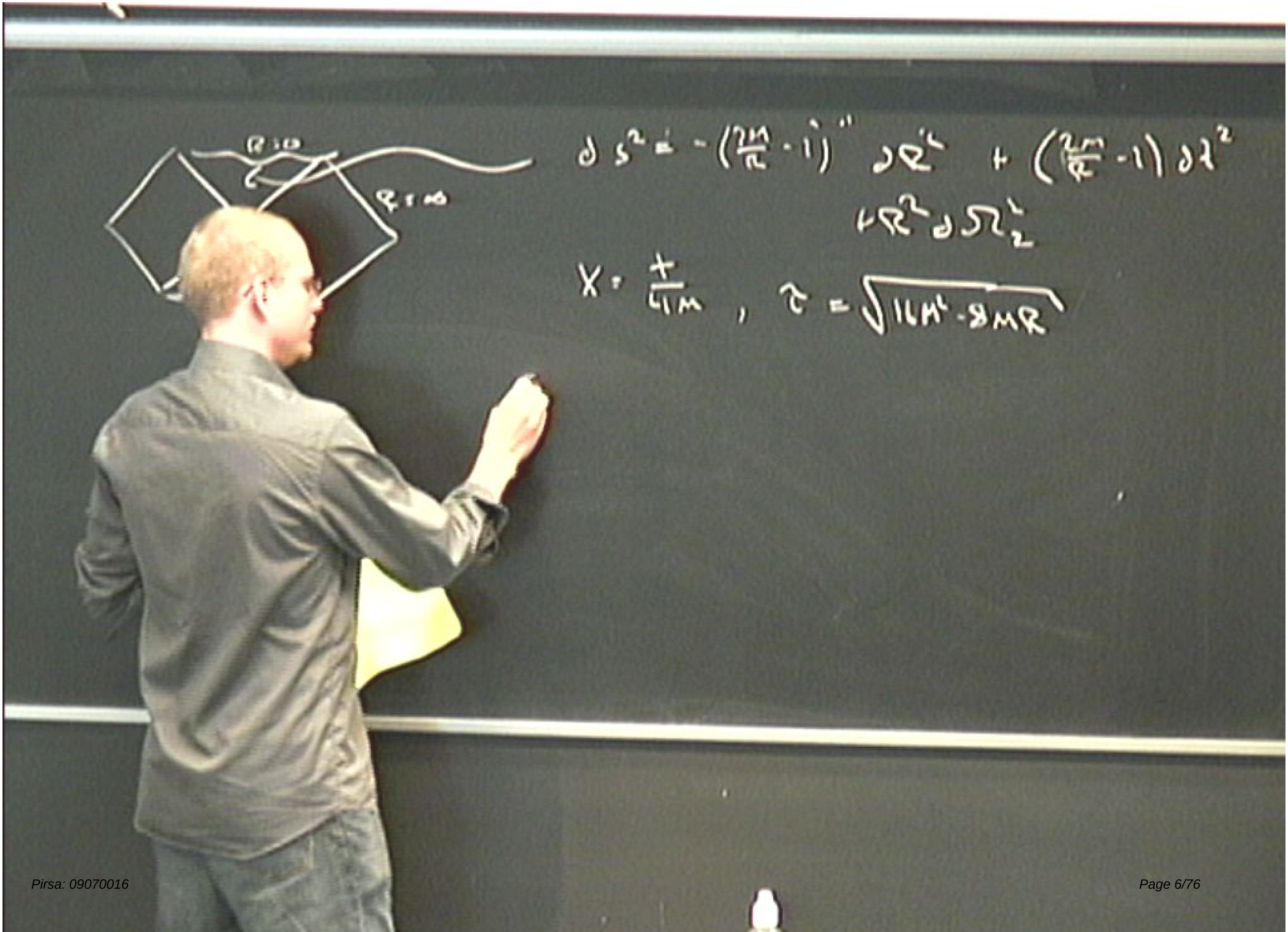

Cosmology inside the brane + holography

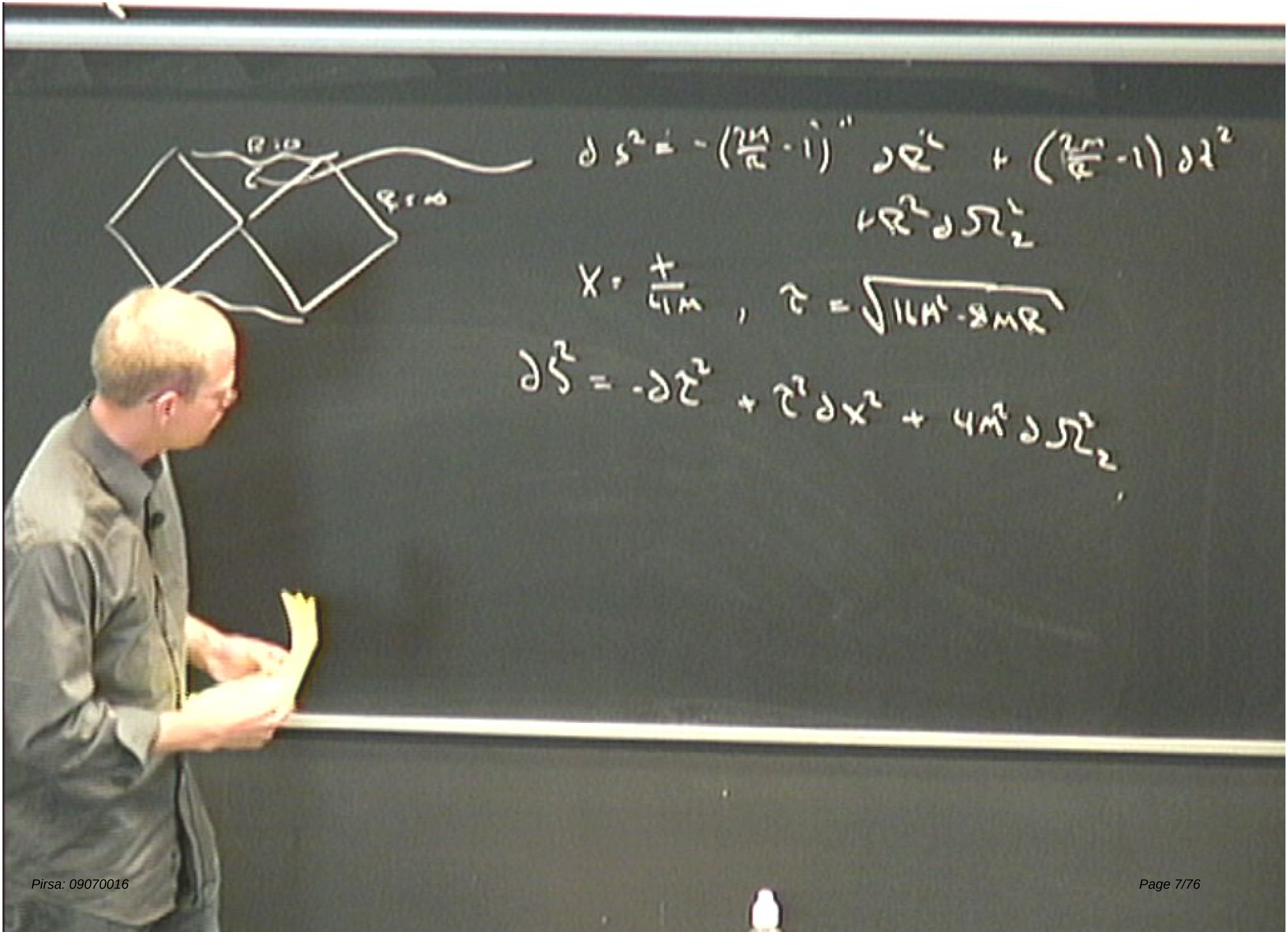
Cosmology inside the brane + holography

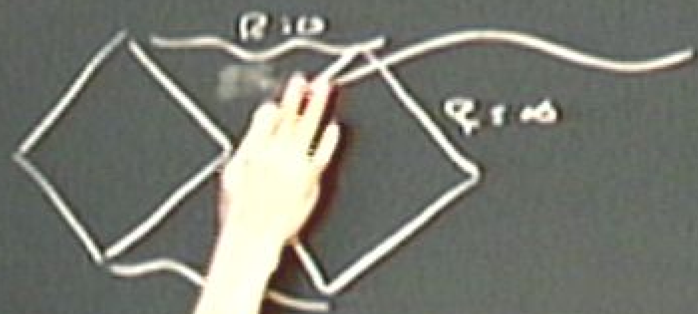
1. black holes + branes as cosmologies
2. holographic cosmology + wave f'n of the universe
3. differences between Λ and w/out Λ



$$ds^2 = -\left(\frac{2m}{R} - 1\right)^{-1} dR^2 + \left(\frac{2m}{R} - 1\right) dt^2 + R^2 \, d\Omega_2^2$$


$R=0$
$R=\infty$
$ds^2 = -\left(\frac{2m}{R}-1\right)^{-1} dR^2 + \left(\frac{2m}{R}-1\right) d\lambda^2 + R^2 d\Omega_2^2$
$X = \frac{t}{4m}\ ,\quad \tau = \sqrt{16m^2 - 8mR}$


R = 0
R = ∞
$ds^2 = -\left(\frac{2M}{R} - 1\right)^{-1} dR^2 + \left(\frac{2M}{R} - 1\right) dt^2 + R^2 d\Omega_2^2$
$X = \frac{t}{4M}, \quad \tau = \sqrt{16M^2 - 8MR}$
$ds^2 = -d\tau^2 + \tau^2 dX^2 + 4M^2 d\Omega_2^2$



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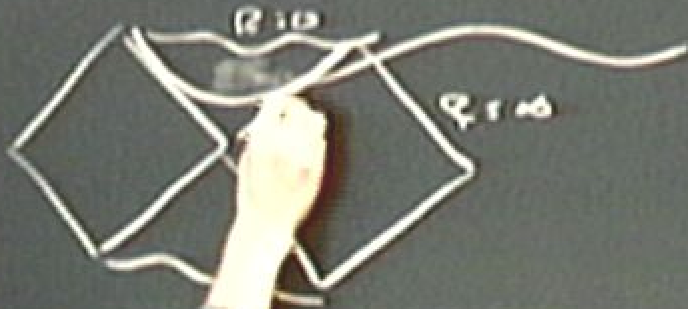
$$x = \frac{t}{4m}\,, \quad \tau = \sqrt{16m^2 - 8mR}$$

$$ds^2 = \underbrace{-d\tau^2 + \tau^2 dx^2}_{} + 4m^2\, d\Omega_2^2$$



$$ds^2 = -\left(\frac{2m}{R} - 1\right)^{-1} dR^2 + \left(\frac{2m}{R} - 1\right) dt^2 + R^2 d\Omega_2^2$$

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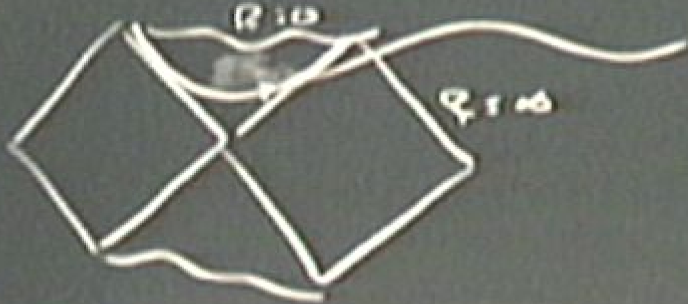

$$ds^2 = -\left(\frac{2m}{R}-1\right)^{-1} dR^2 + \left(\frac{2m}{R}-1\right) dt^2 + R^2 d\Omega_2^2$$

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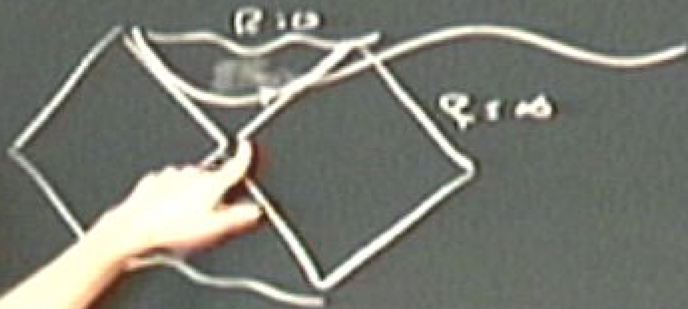
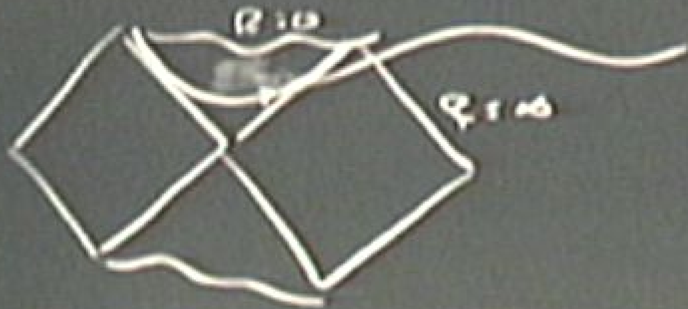


$$ds^2 = -\left(\frac{2M}{R}-1\right)^{-1} dR^2 + \left(\frac{2M}{R}-1\right) dt^2 + R^2\, d\Omega_2^2$$

$$x = \frac{t}{4M}\ , \quad \tau = \sqrt{16M^2 - 8MR}$$

$$ds^2 = \underbrace{-d\tau^2 + \tau^2 dx^2}_{\text{2d FRW}} + \underbrace{4M^2\, d\Omega_2^2}_{\text{"unperturbed } S^2\text{"}}$$



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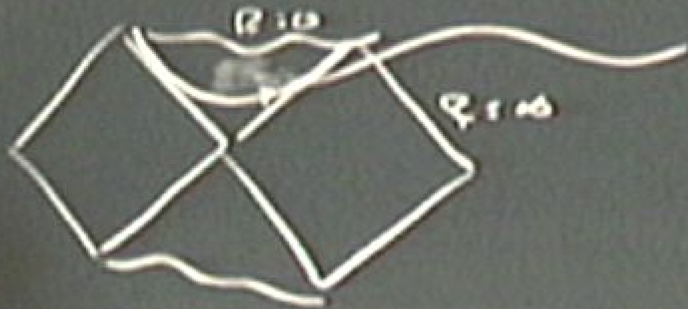

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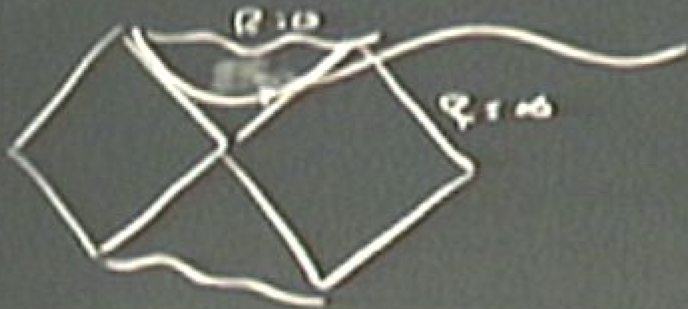
$$X = \frac{t}{4M}, \quad \tau = \sqrt{16M^2 - 8MR}$$

(near $\tau \to 0$)

$\tau \to 0$ is the big bang

$$ds^2 = \underbrace{-d\tau^2 + \tau^2 dx^2}_{\text{flat FRW}} + \underbrace{4M^2 d\Omega_2^2}_{\text{"unperturbed } S^2\text{"}}$$



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(near $\tau \to 0$)

$\tau \to 0$ is the big bang

$$ds^2 = \underbrace{-d\tau^2 + \tau^2 dx^2}_{\text{2d FRW}} + 4M^2 \underbrace{d\Omega_2^2}_{\text{"unperturbed } S^2\text{"}}$$

Move inwards from $\tau = 0$

$$ds^2 = -d\tau^2 + a(\tau)\,dx^2 + R^2(\tau)\,d\Omega_2^2$$

Move away from $\tau \approx 0$

$$ds^2 = -d\tau^2 + a(\tau)\, dx^2 + R^2(\tau)\, d\Omega_2^2$$

$$\Rightarrow R'' + \frac{R'^2}{2R} = -\frac{1}{2R} \quad ; \quad a = R'$$

Move away from $\tau \approx 0$

$$ds^2 = -d\tau^2 + a^2(\tau)\,dx^2 + R^2(\tau)\,d\Omega_2^2$$

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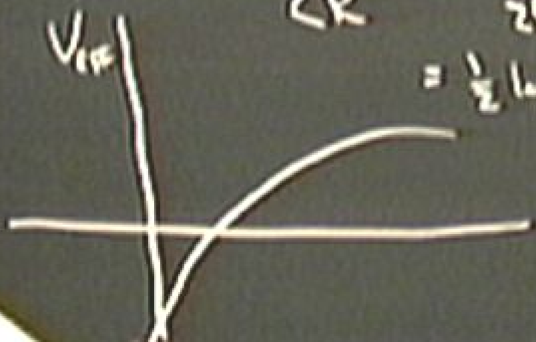
$$= \frac{1}{2}\log R$$



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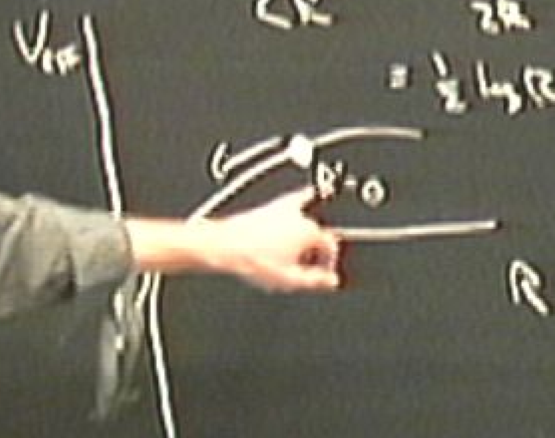

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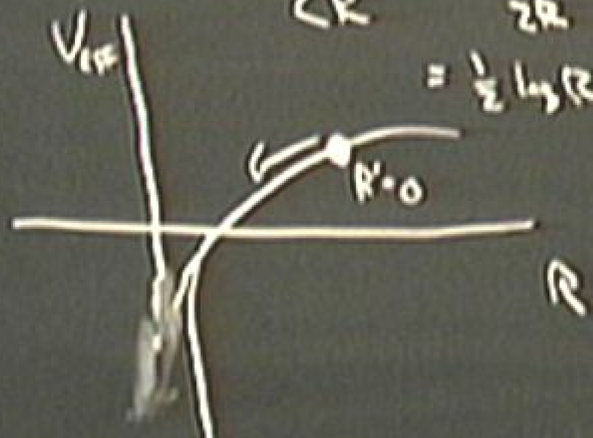

What about 4-D FRW in localized region
embedded in higher D?

What about 4-D FRW in localized region embedded in higher D?

$$S = \frac{M_{4+q}^{q+2}}{2} \int d^{4+q}x \sqrt{-g} \left\{ \tilde{R}^{(4+q)} - \frac{1}{2q!} F_q^2 - 2\Lambda \right]$$

embedded in higher D?

$$S = \frac{M_{4+q}^{q+2}}{2}\int d^{4+q}x \sqrt{-\tilde{g}}\left[\tilde{R}^{(4+q)} - \frac{1}{2q!}\tilde{F}_q^2 - 2\Lambda\right]$$

$$ds^2 = \tilde{g}^{(4)}_{\mu\nu}\, dx^\mu dx^\nu + R^2(x)\, d\Omega_q^2$$

$$= Q \sin^{q}$$

embedded in higher D?

$$S = \frac{M_{4+q}^{q+2}}{2} \int d^{4+q}x \sqrt{-\tilde{g}} \left[\tilde{R}^{(4+q)} - \frac{1}{2q!} \tilde{F}_q^2 - 2\Lambda \right]$$

$$ds^2 = \tilde{g}^{(4)}_{\mu\nu} dx^\mu dx^\nu + R^2(x)\, d\Omega_q^2$$

$$F_q = Q \sin^{q-1}\theta_1 \cdots \sin\theta_{q-1}\, d\theta_1 \wedge \cdots d\theta_q$$

What about 4-D FRW in localized region embedded in higher D?

$$S = \frac{M_{4+q}^{q+2}}{2}\int d^{4+q}x\sqrt{-g}\left[\tilde{R}^{(4+q)} - \frac{1}{2q!}F_q^2 - 2\Lambda\right]$$

$$ds^2 = g_{\mu\nu}^{(4)}\, dx^\mu dx^\nu + R^2(x)\, d\Omega_q^2$$

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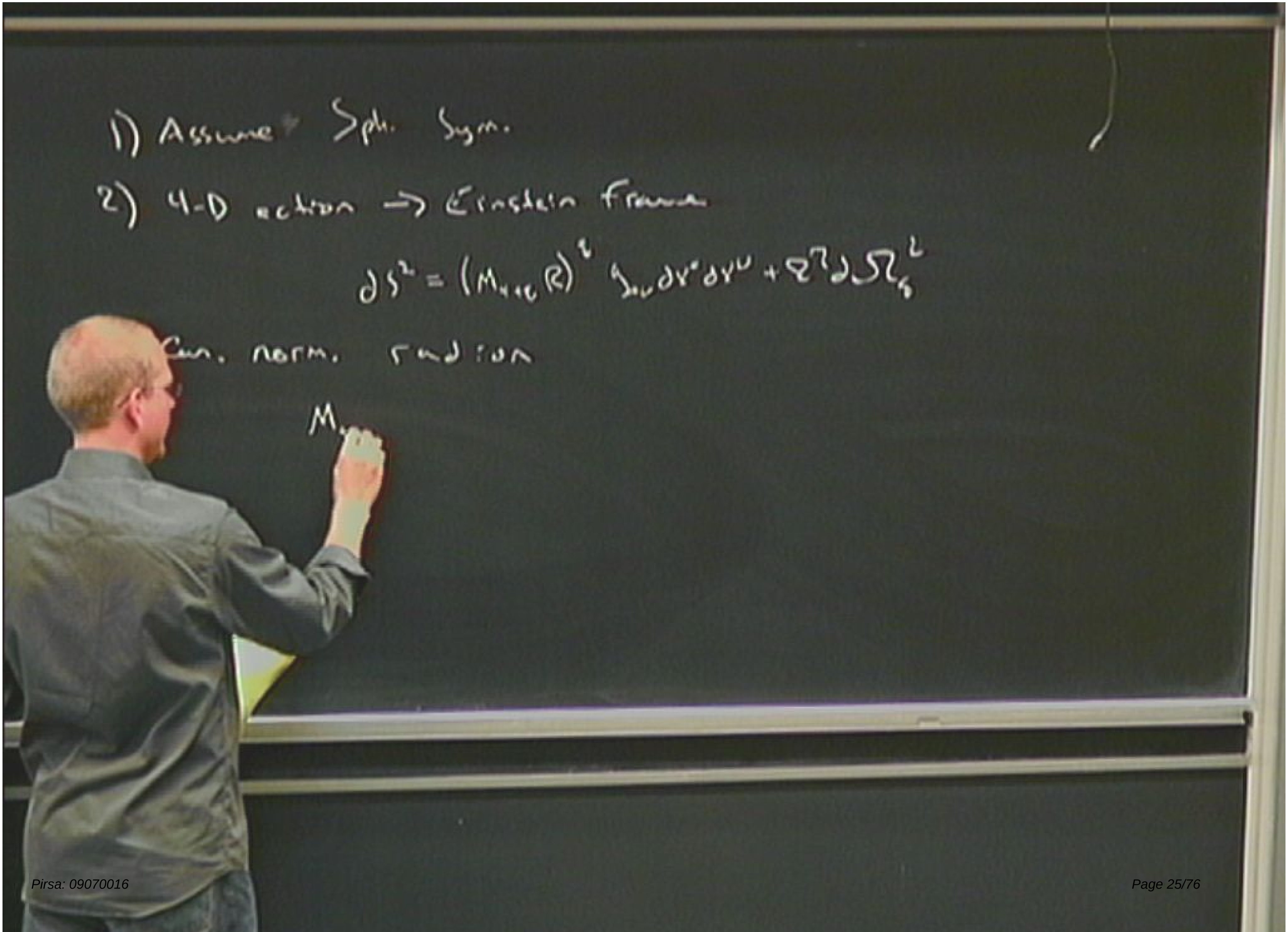
1) Assume Sph. Sym.
2) 4-D action → Einstein frame
$ds^2 = (M_{4+d} R)^d g_{\mu\nu} dx^\mu dx^\nu + R^2 d\Omega_d^2$
Can. norm. radion
M

1) Assume Sph. Sym.

2) 4-D action → Einstein frame

$$ds^2 = (M_{4+n} R)^n g_{\mu\nu} dx^\mu dx^\nu + R^2 d\Omega_n^2$$

3) Can. norm. radion

$$M_{4+n} R = \exp\left(\sqrt{\frac{2}{n(2+n)}}\frac{\phi}{M_4}\right)$$

1) Assume Sph. Sym.

2) 4-D action → Einstein frame

$$ds^2 = (M_{4+n} R)^{2} g_{\mu\nu} dx^\mu dx^\nu + R^2 d\Omega_n^2$$

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1) Assume Sph. Sym.

2) 4-D action $\rightarrow$ Einstein frame

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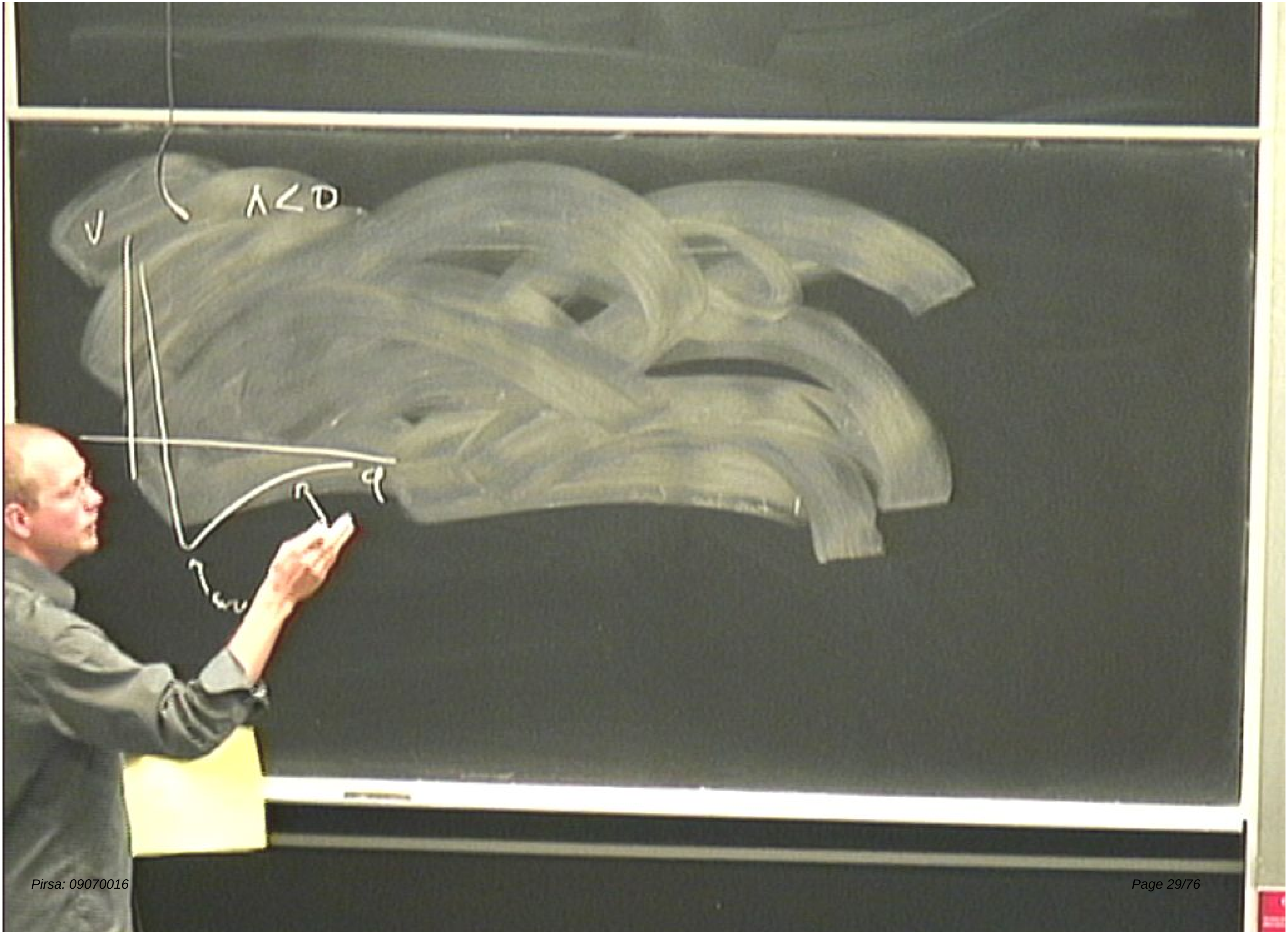
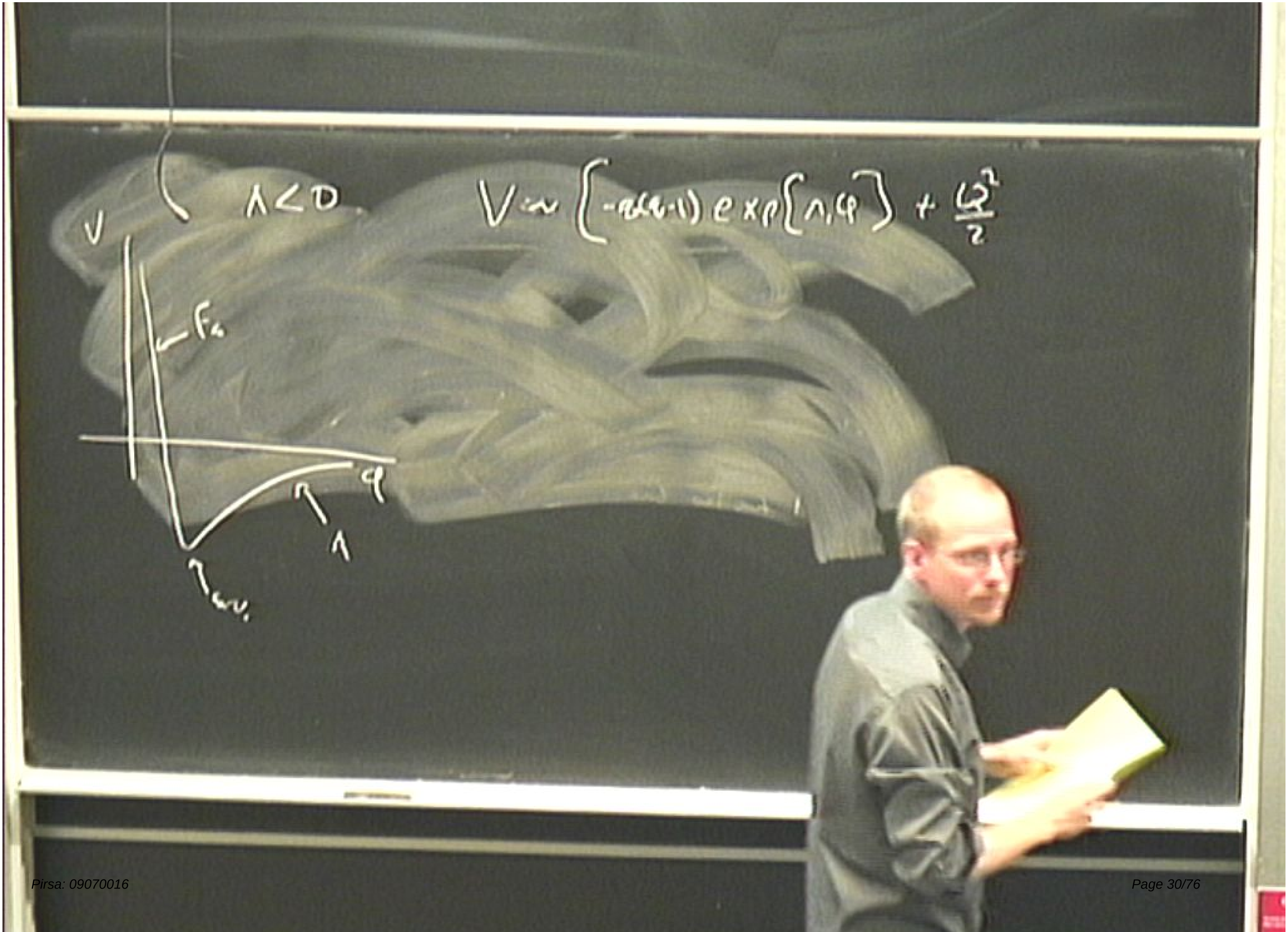
3) Can. norm. radion

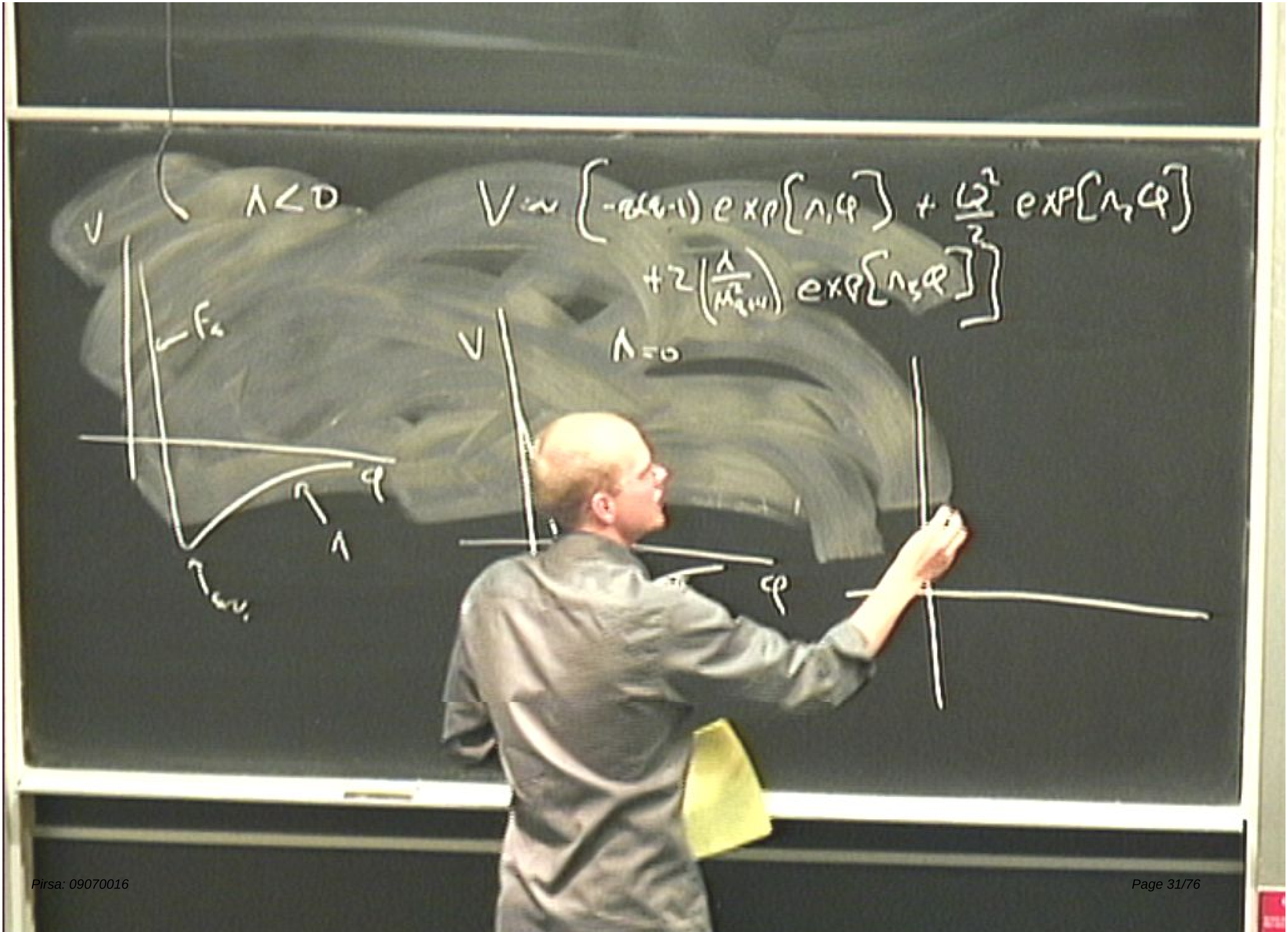
$$M_{4+n} R = \exp\left[\sqrt{\frac{2}{n(2+n)}} \frac{\varphi}{M_4}\right]$$

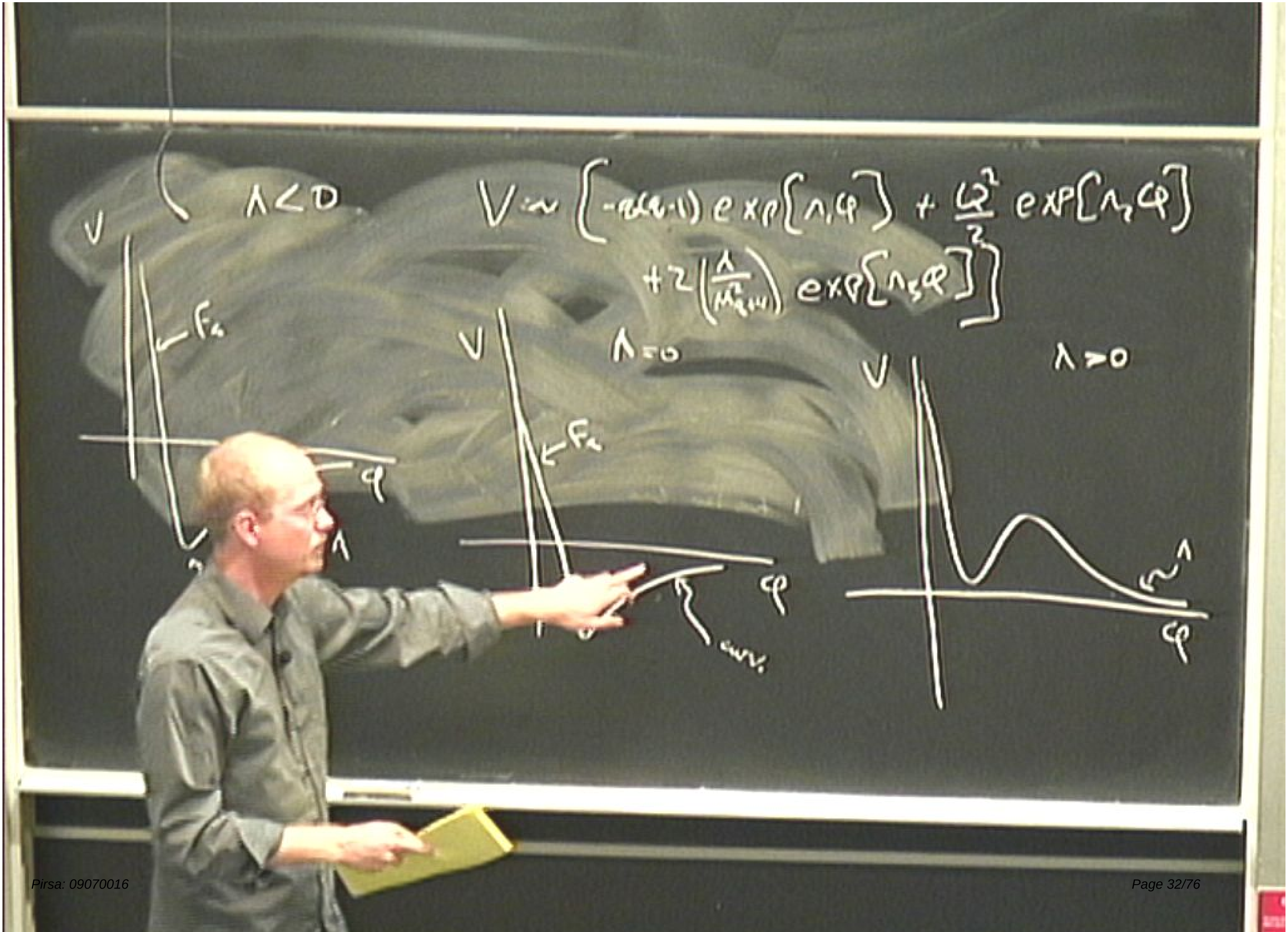
4)

$$S = \int d^4x \sqrt{-g}\left[\frac{M_4^2}{2} R^{(4)} - \frac{1}{2}(\nabla\varphi)^2 - V(\varphi)\right]$$


V
Λ<D
q


Λ<0
V
φ
Λ

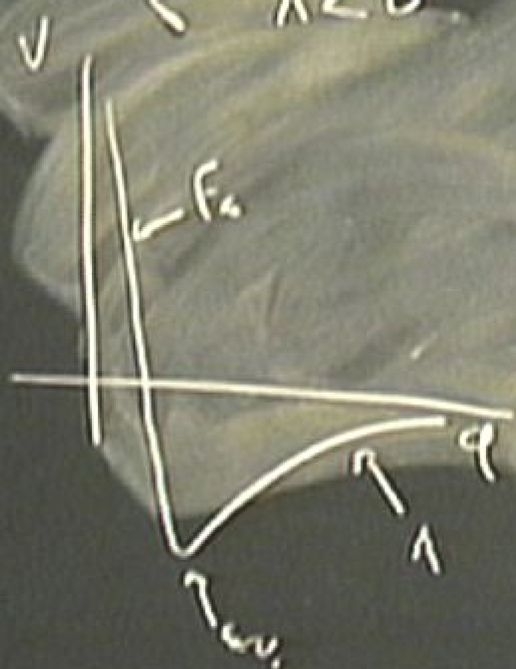

Λ<0
V
φ
Λ=0
V
φ



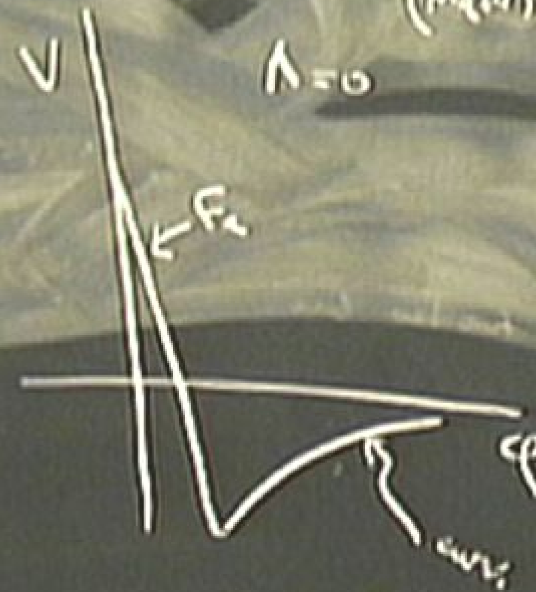
Λ < 0
Λ = 0
Λ > 0
V
φ

$\Lambda < 0$

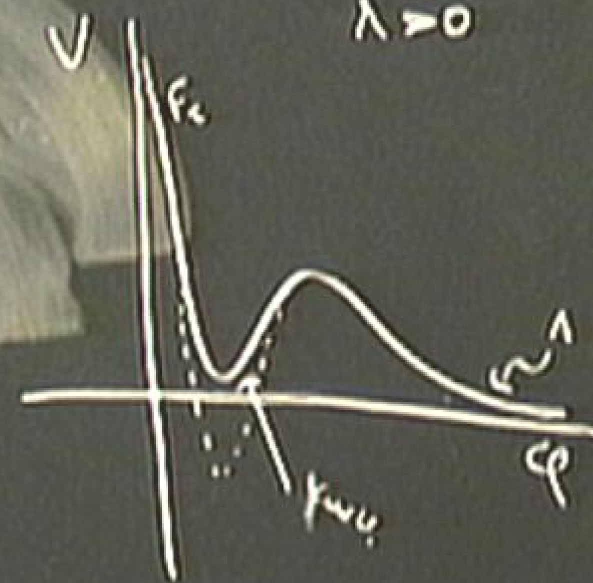
$$V \sim \left\{ -q(q-1)\, \exp[\lambda_1 \varphi] + \frac{Q^2}{2} \exp[\lambda_2 \varphi] + 2\left(\frac{\Lambda}{M_{q+1}^2}\right) \exp[\lambda_3 \varphi] \right\}$$



$\Lambda = 0$

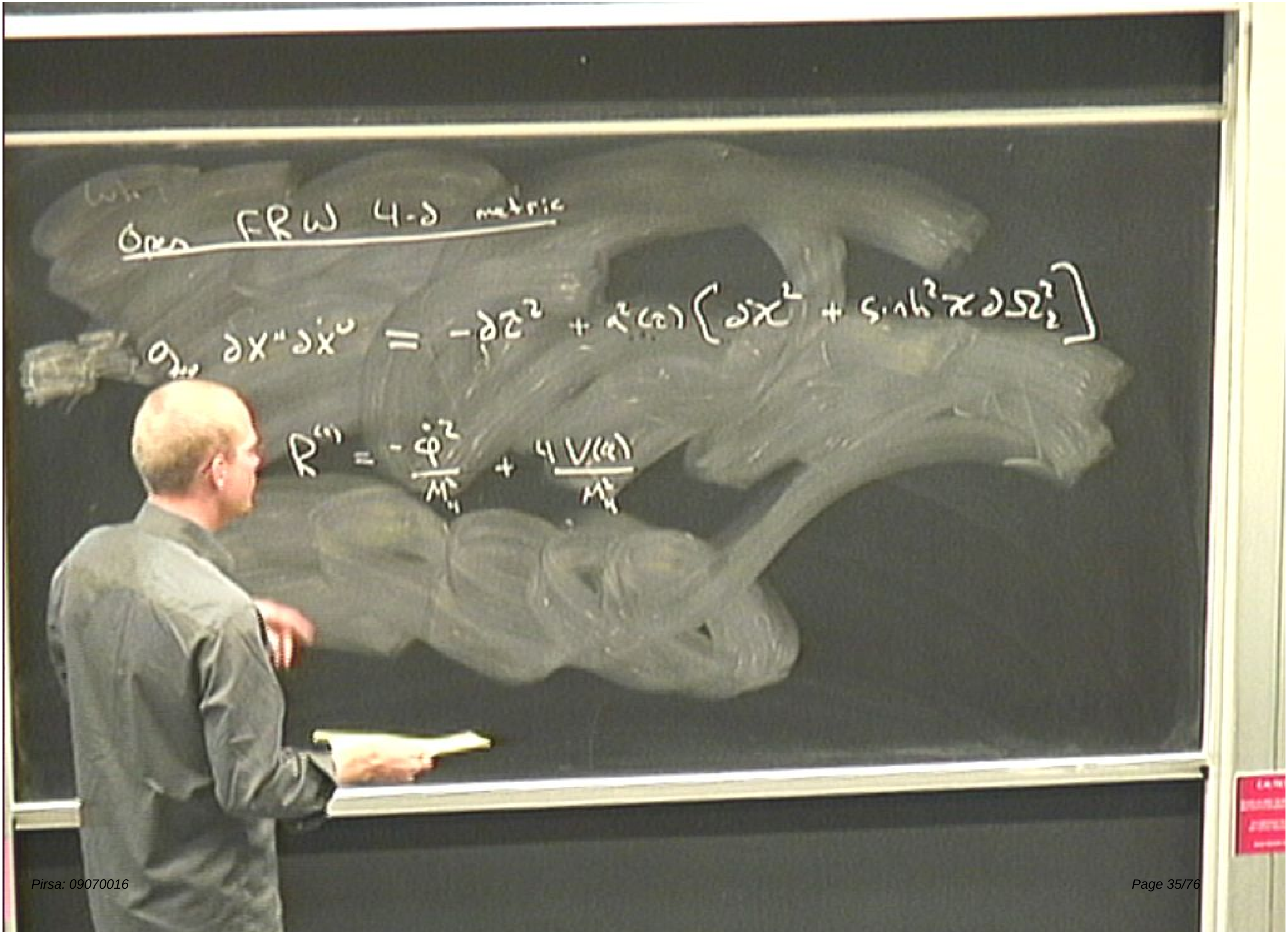


$\Lambda > 0$



Open FRW 4-d metric

$$g_{\mu\nu}\, dx^\mu dx^\nu = -d\tau^2 + a^2(\tau)\left[d\chi^2 + \sinh^2\chi\, d\Omega_2^2\right]$$


Open FRW 4-d metric
$g_{\mu\nu}\, dx^\mu dx^\nu = -d\tau^2 + a^2(\tau)\left[d\chi^2 + \sinh^2\chi\, d\Omega_2^2\right]$
$R^{(4)} = -\frac{\dot\varphi^2}{M_4^2} + \frac{4V(\varphi)}{M_4^2}$

Open FRW 4-d metric

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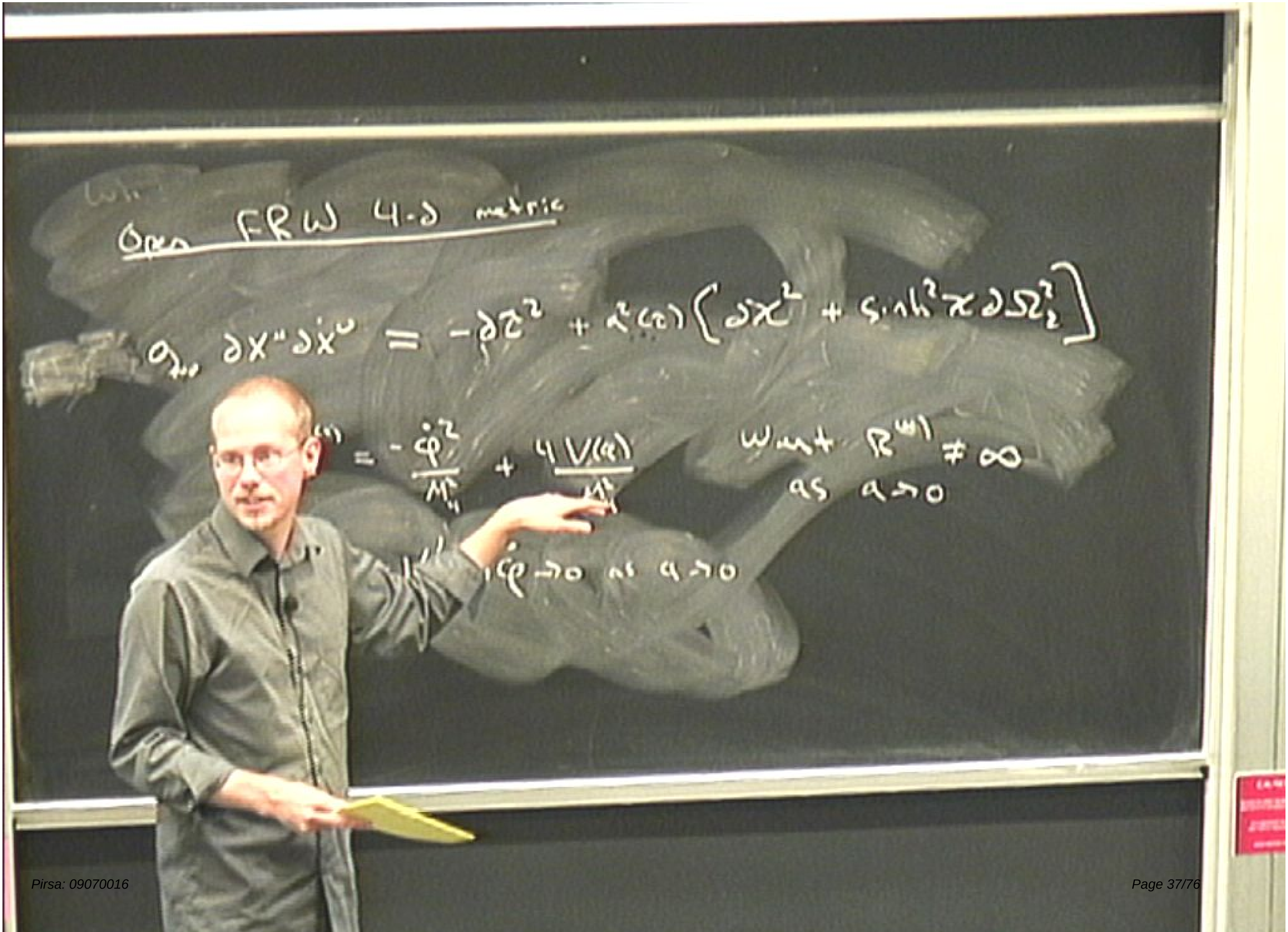
want $R^{(4)} \neq \infty$ as $a \to 0$


Open FRW 4-d metric
$g_{\mu\nu}\, dx^\mu dx^\nu = -d\tau^2 + a^2(\tau)\left(d\chi^2 + \sinh^2\chi\, d\Omega_2^2\right)$
$= -\frac{\dot\varphi^2}{M_4^2} + \frac{4V(\varphi)}{M_4^2}$
want $R^{(4)} \neq \infty$ as $a \to 0$
$\dot\varphi \to 0$ as $a \to 0$

Open FRW 4-d metric

$$g_{\mu\nu}\, dx^\mu dx^\nu = -d\tau^2 + a^2(\tau)\left[d\chi^2 + \sinh^2\chi\, d\Omega_2^2\right]$$

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want $R^{(4)} \neq \infty$ as $a \to 0$

$$\ddot\varphi + 3\frac{\dot a}{a}\dot\varphi = -V' \Rightarrow \dot\varphi \to 0 \text{ as } a \to 0$$

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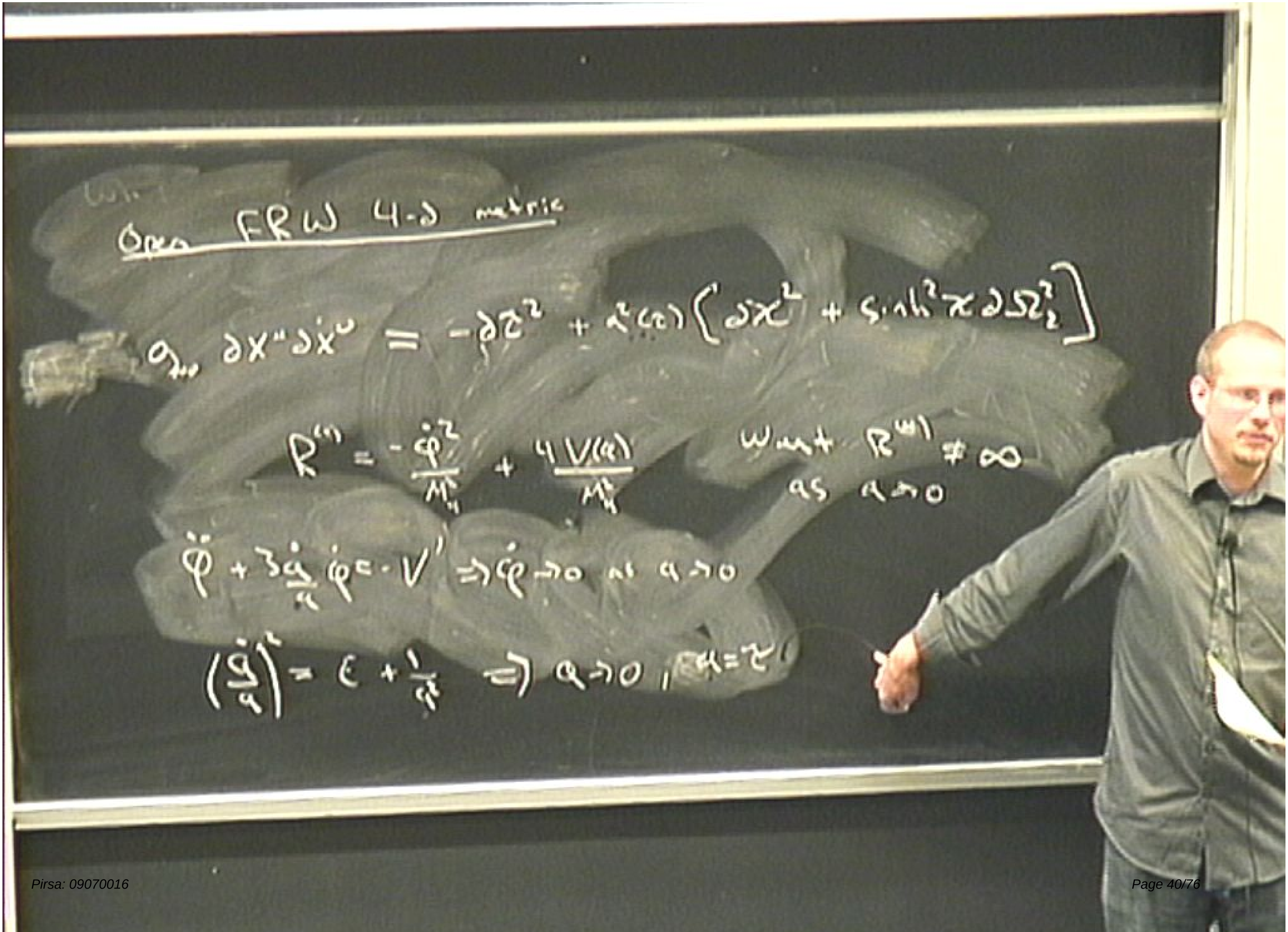
$$\left(\frac{\dot a}{a}\right)^2 = \epsilon + \frac{1}{a^2} \Rightarrow a \to 0,\ a = \tau$$


Open FRW 4-d metric
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$R^{(4)} = -\frac{\dot\varphi^2}{M_4^2} + \frac{4V(\varphi)}{M_4^2}$
want $R^{(4)} \neq \infty$
as $a \to 0$
$\ddot\varphi + 3\frac{\dot a}{a}\dot\varphi = -V' \Rightarrow \dot\varphi \to 0$ as $a \to 0$
$\left(\frac{\dot a}{a}\right)^2 = \epsilon + \frac{1}{a^2} \Rightarrow a \to 0,\ a = \tau$

Open FRW 4-d metric

$$g_{\mu\nu}\, dx^\mu dx^\nu = -d\tau^2 + a^2(\tau)\left[d\chi^2 + \sinh^2\chi\, d\Omega_2^2\right]$$

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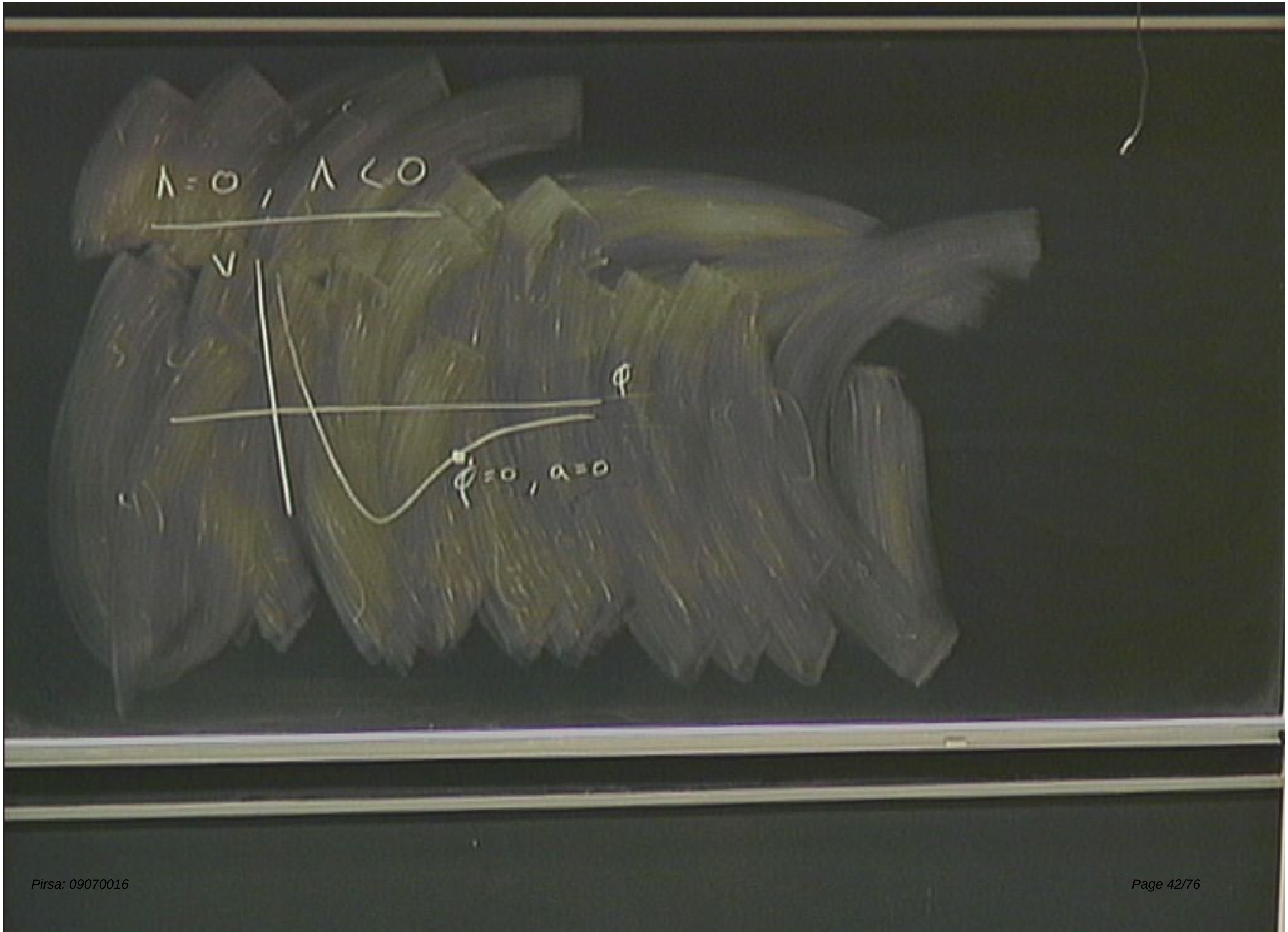
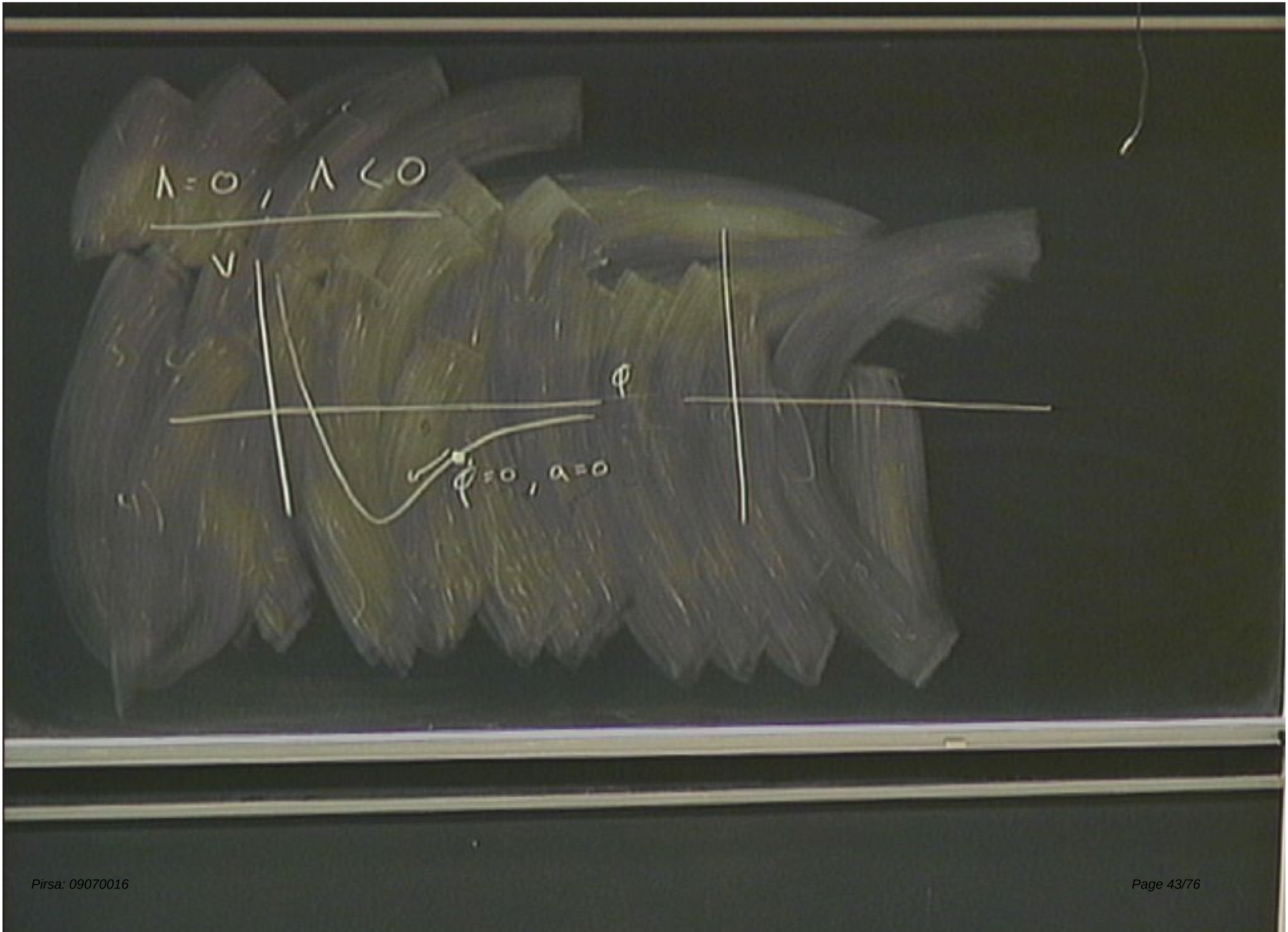
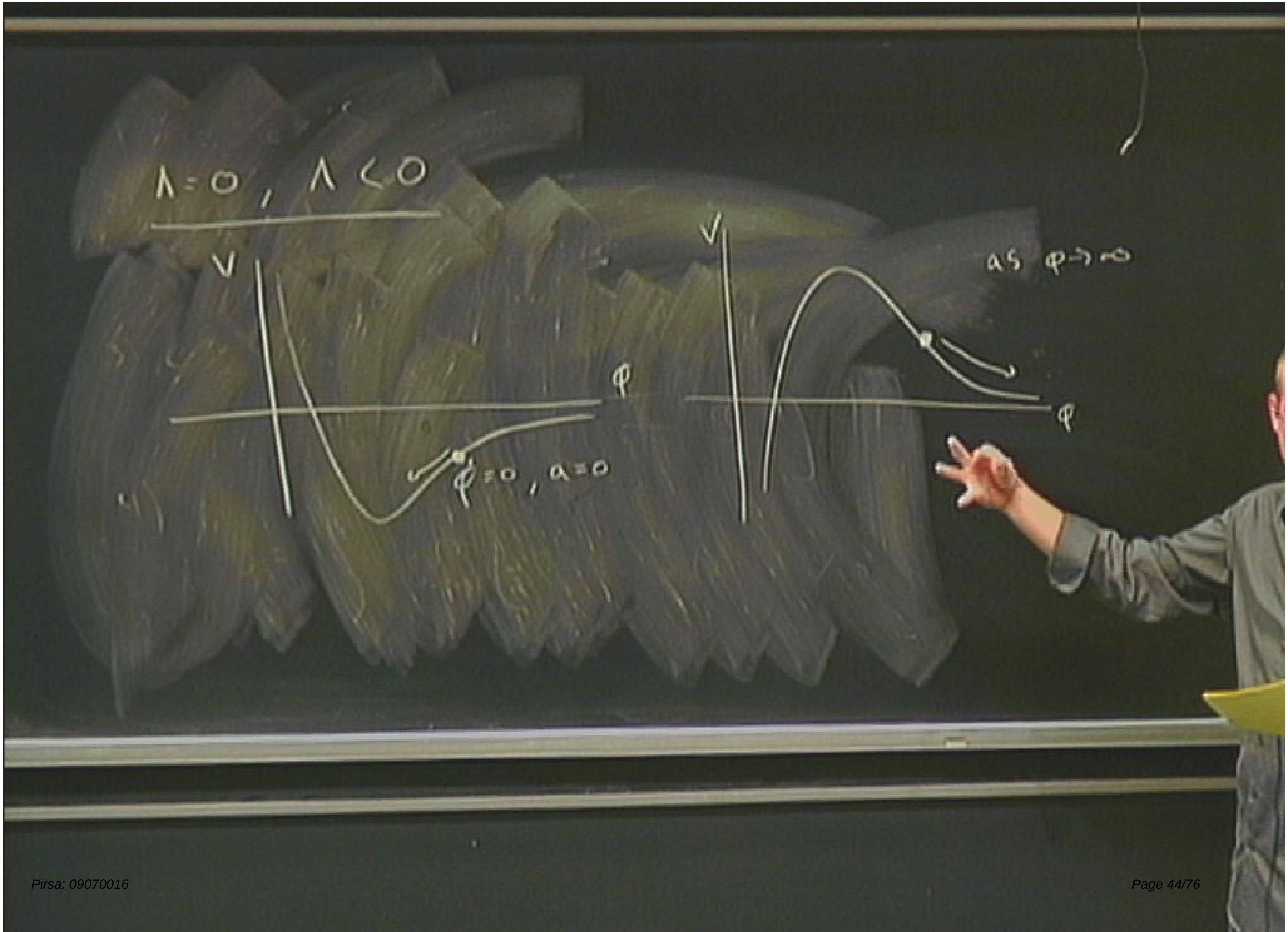
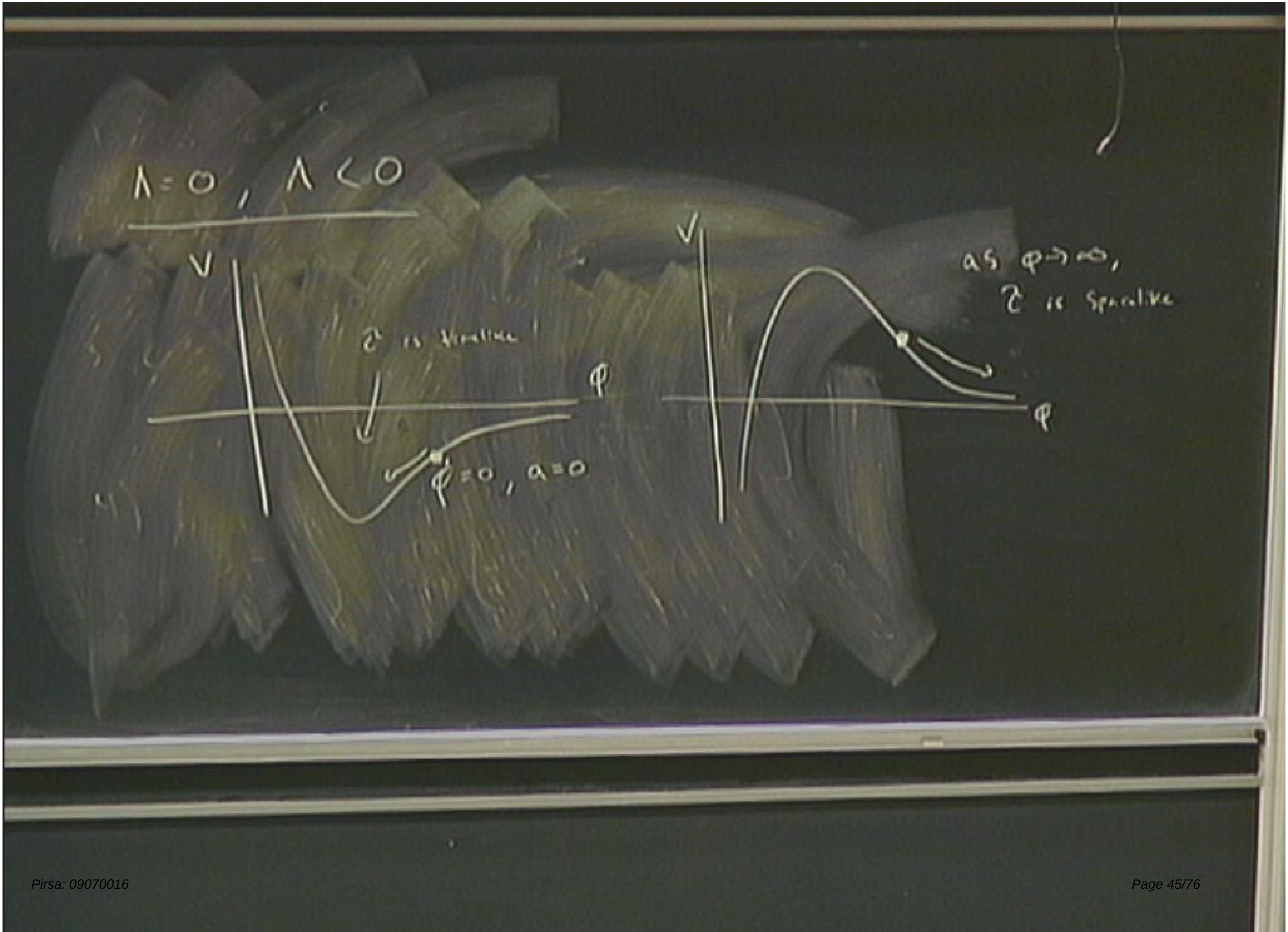
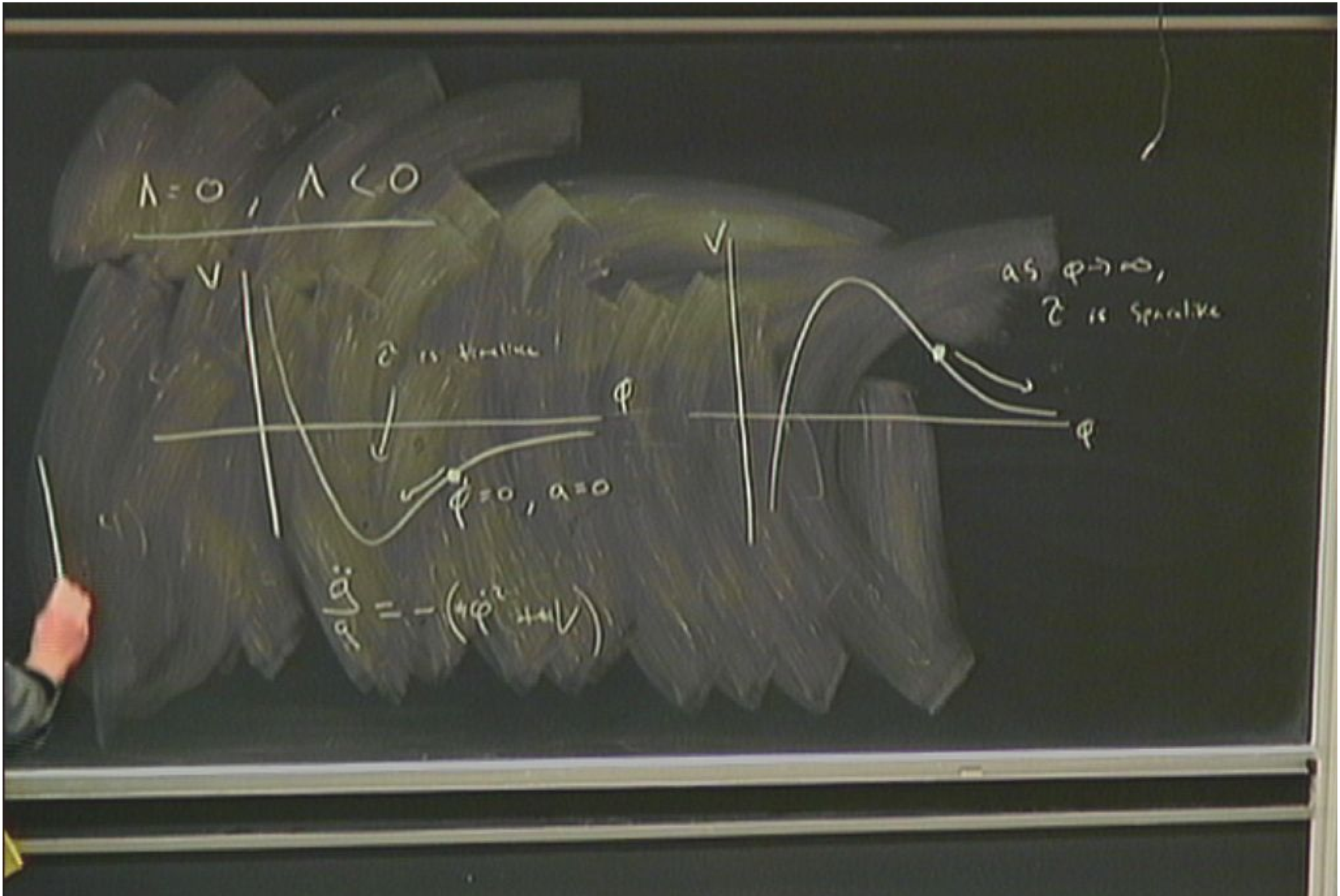

Λ=0, Λ<0
V
φ
φ̇=0, a=0


Λ=0, Λ<0
V
φ
φ=0, a=0



Λ=0 , Λ<0
V
φ
φ=0 , a=0
V
as φ→∞
φ


Λ=0 , Λ<0
V
τ is timelike
φ
φ̇=0 , a=0
V
as φ→∞,
τ is spacelike
φ


Λ=0 , Λ<0
V
τ is timelike
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φ̇=0 , a=0
V
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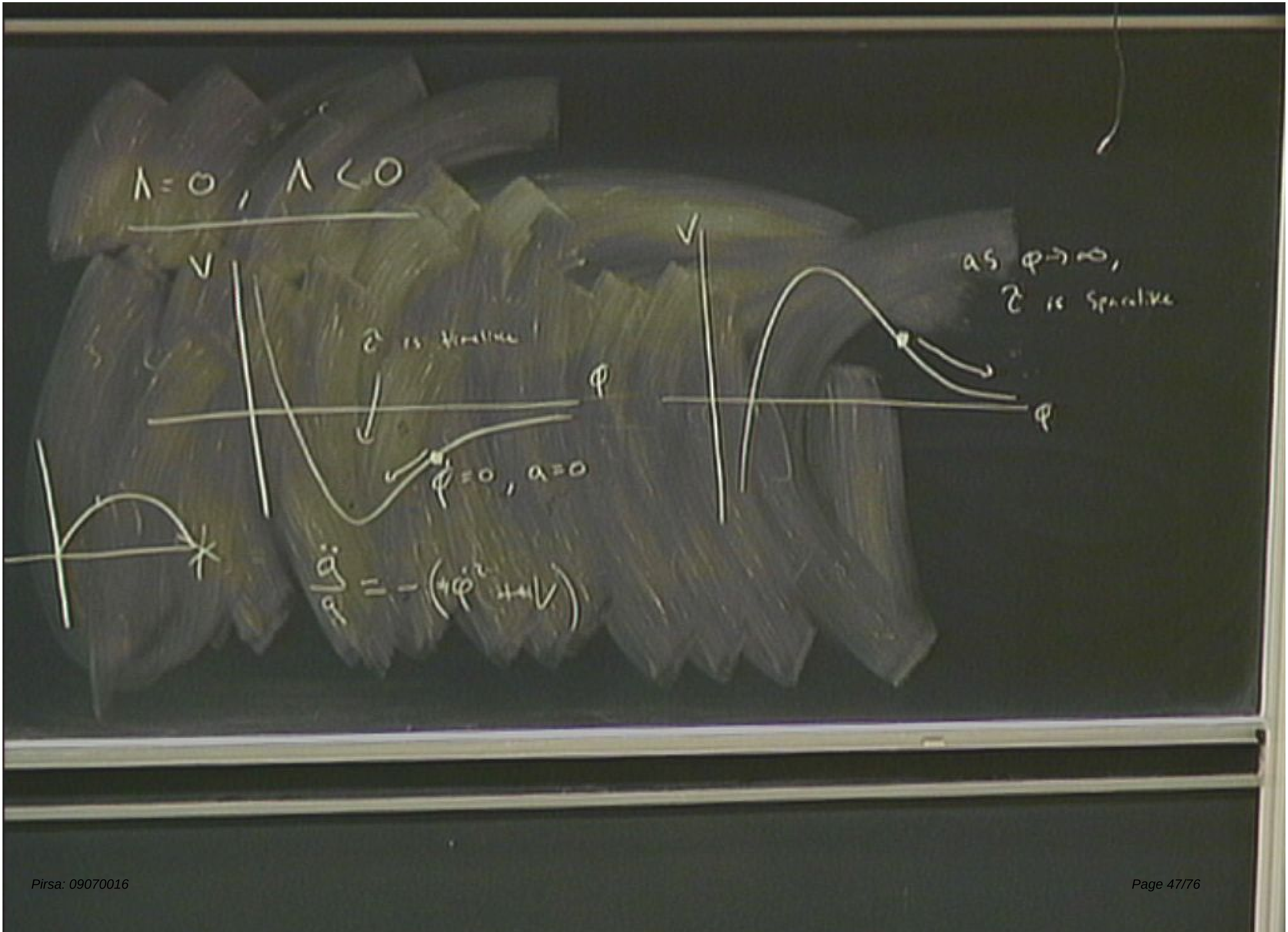
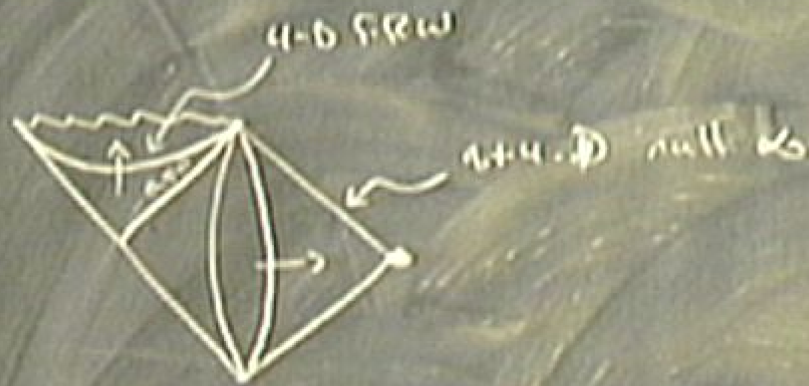
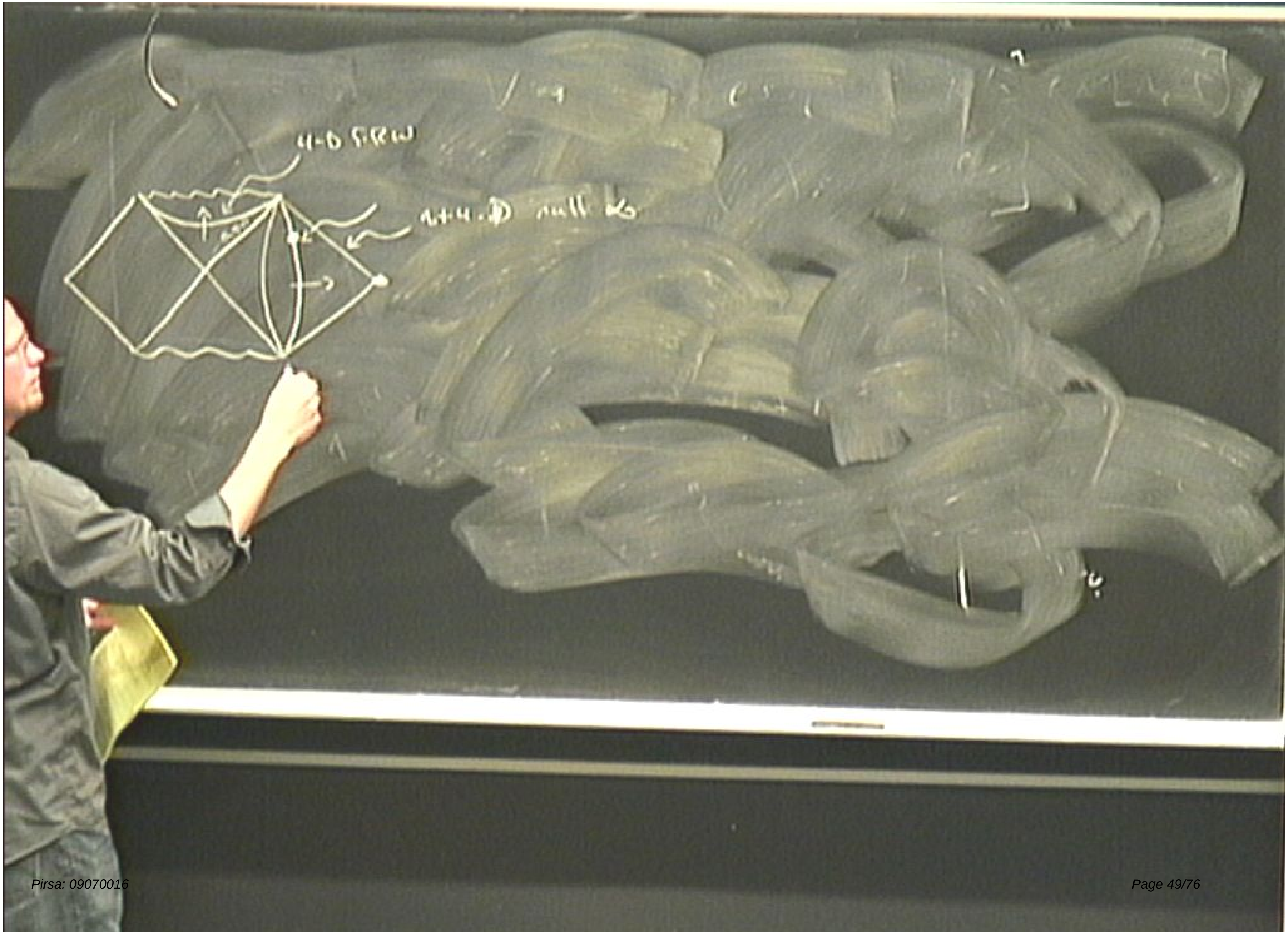
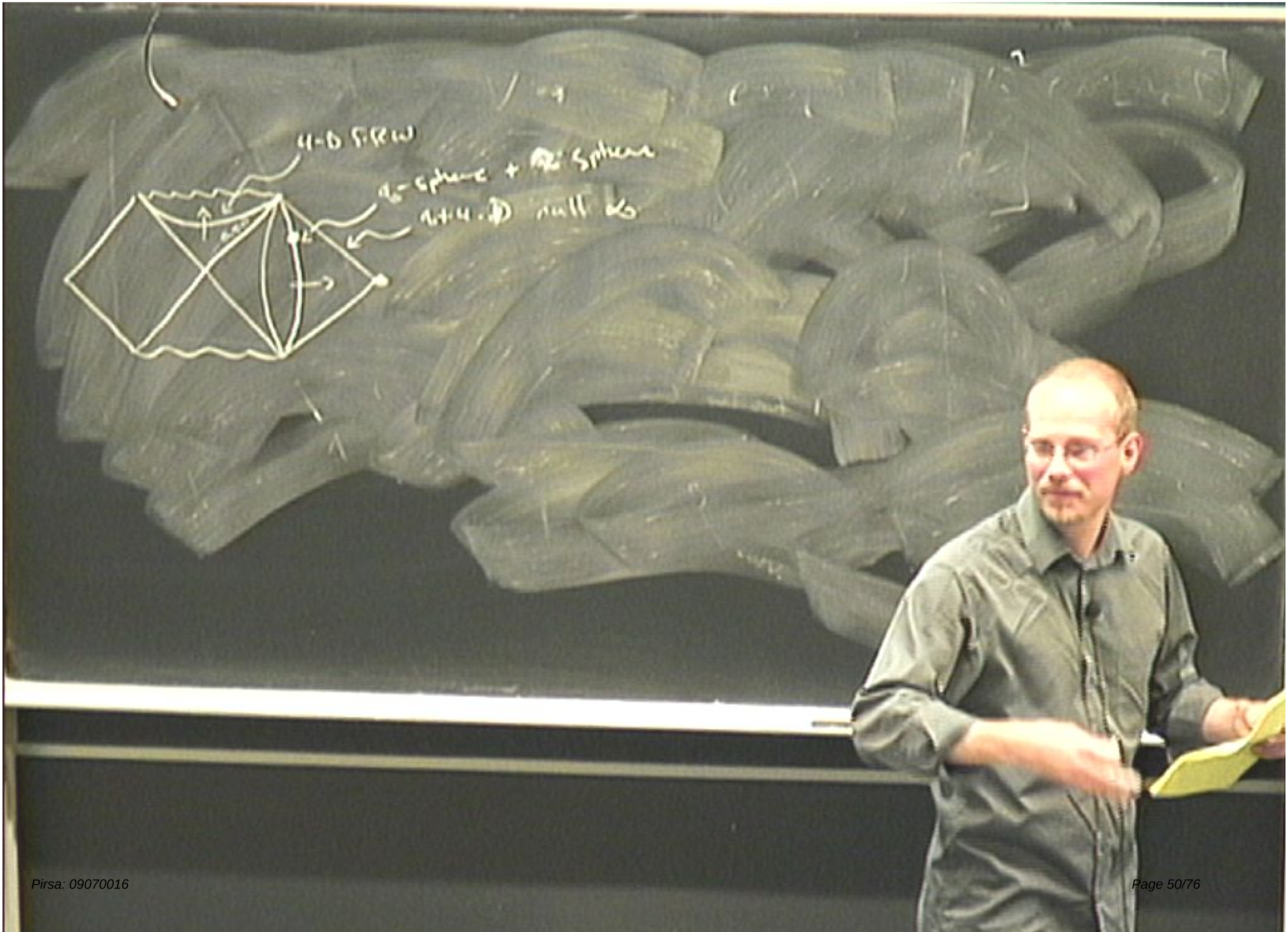
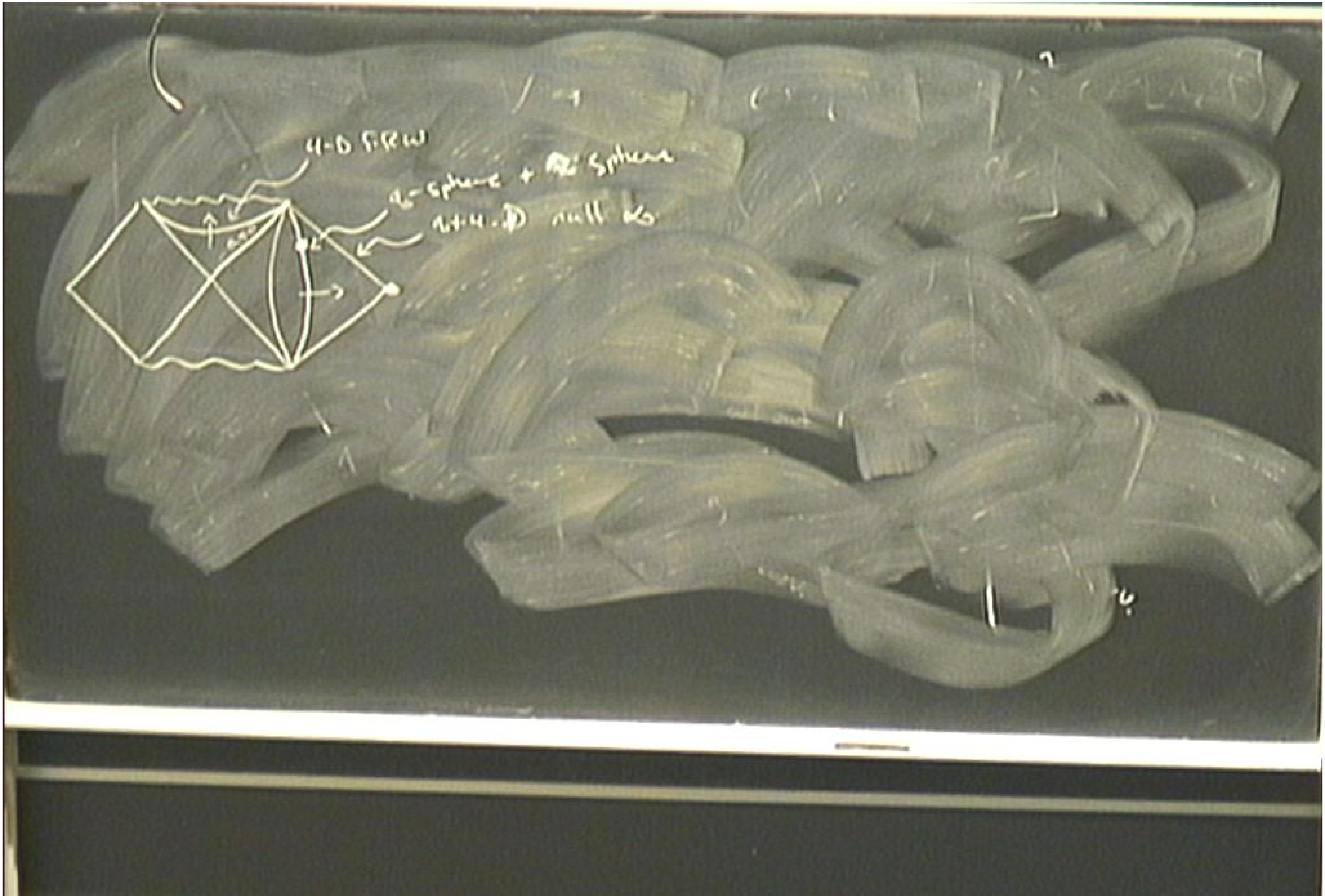

Λ=0 , Λ<0
V
φ
τ is timelike
φ̇=0 , a=0
V
as φ→∞,
τ is spacelike
φ


4-D FRW
1+4-D null


4-D FRW


4-D FRW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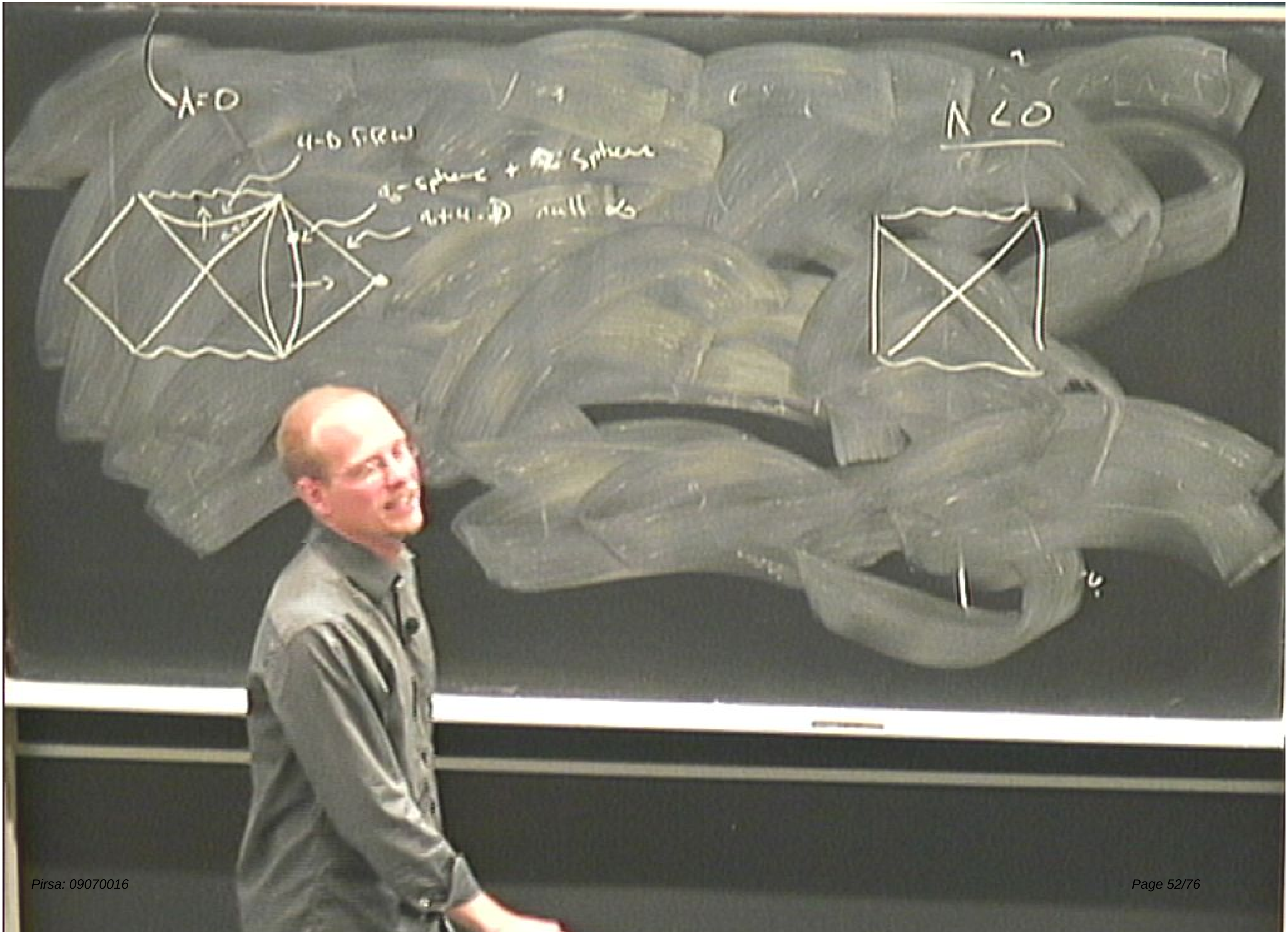
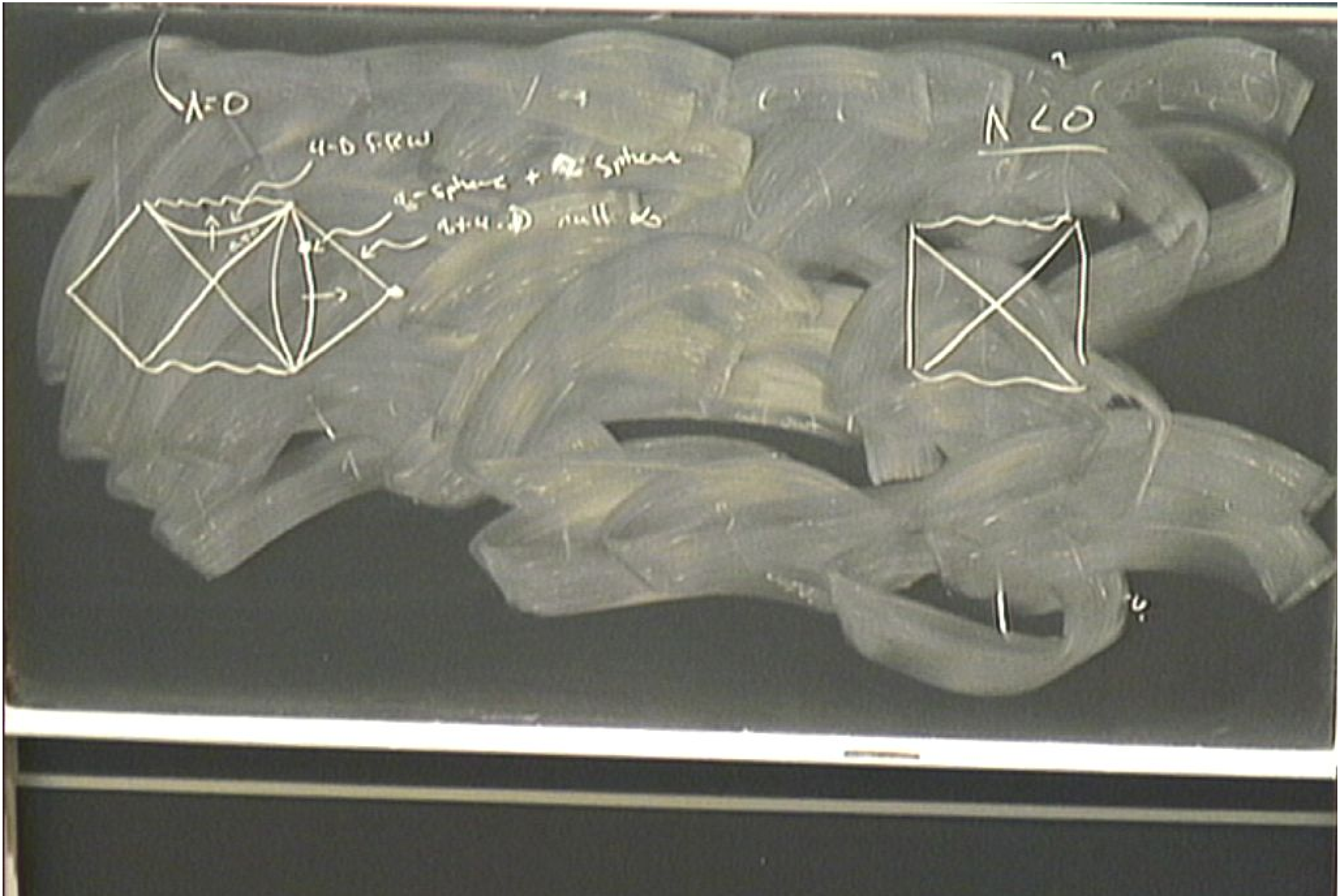
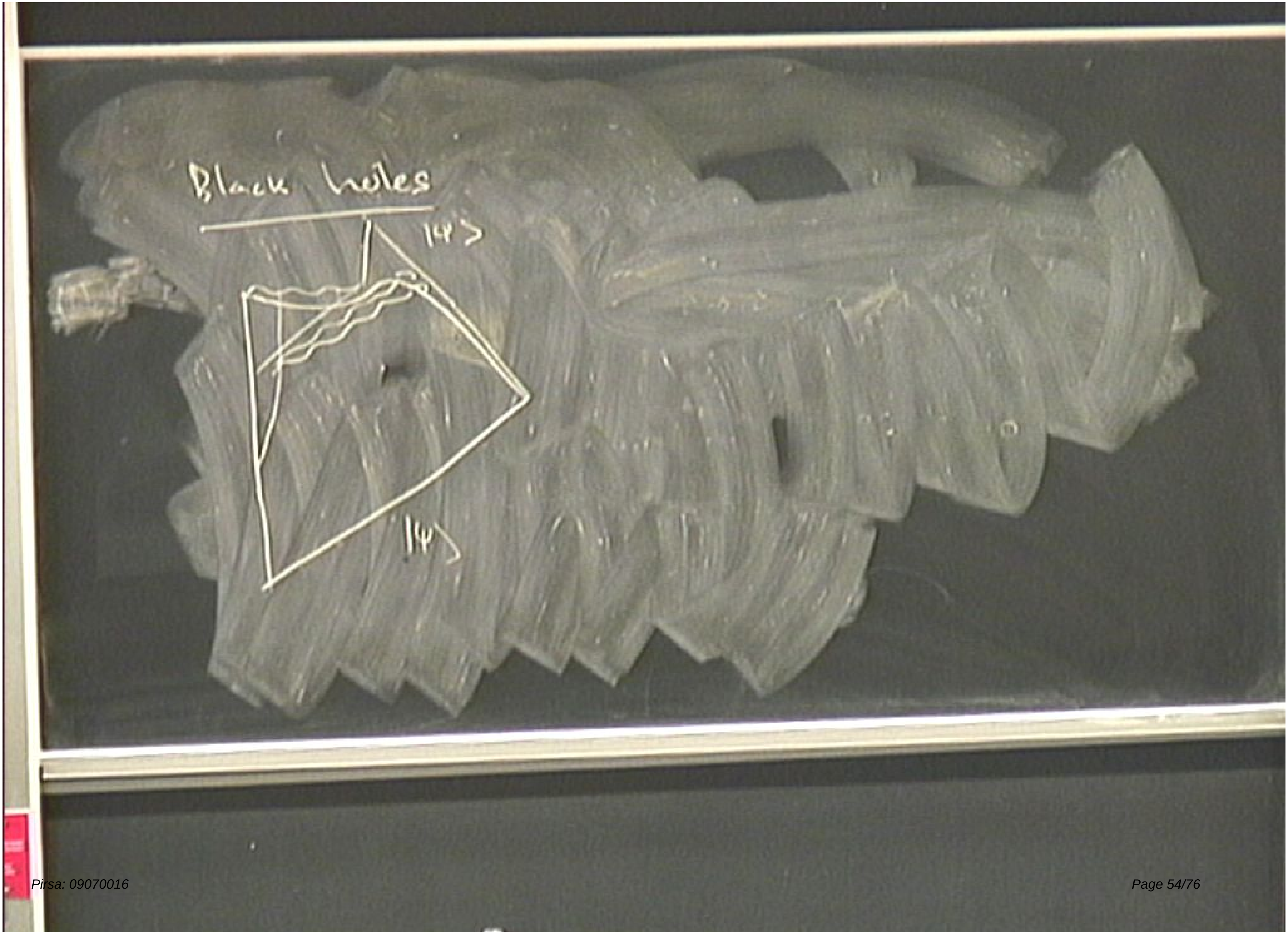
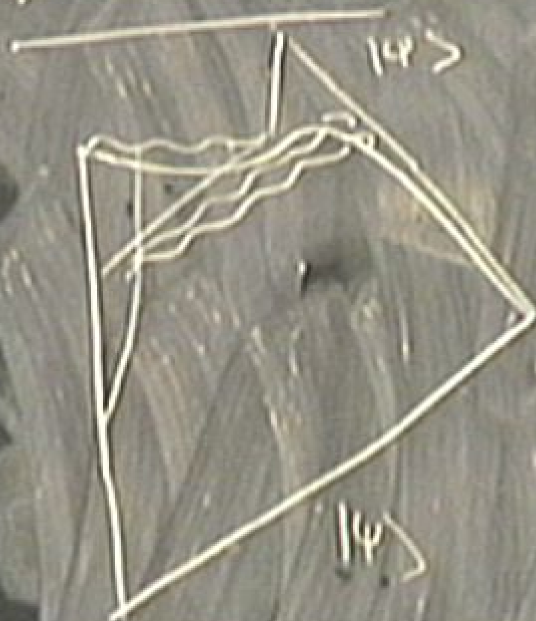
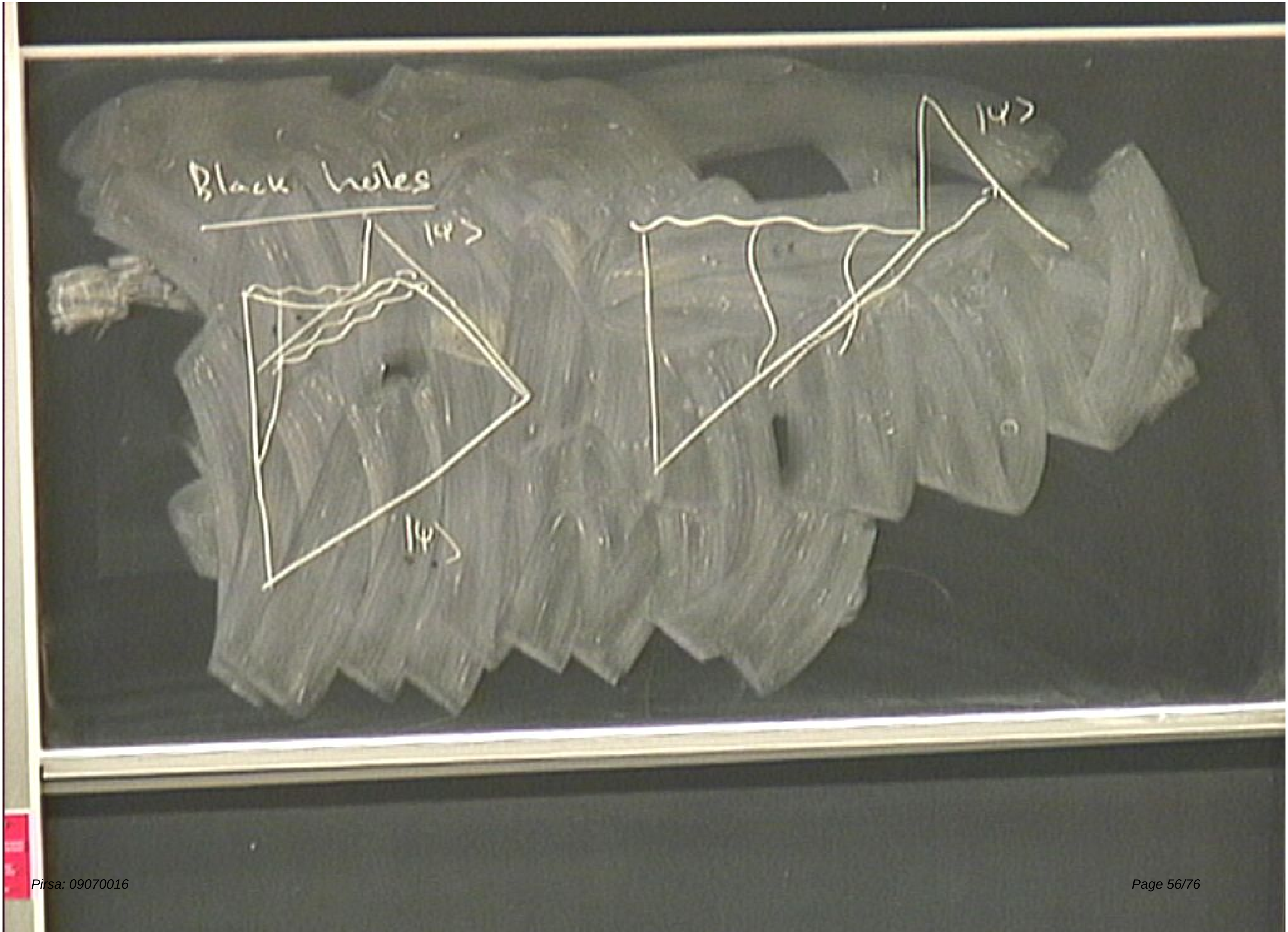

Λ=0
Λ<0

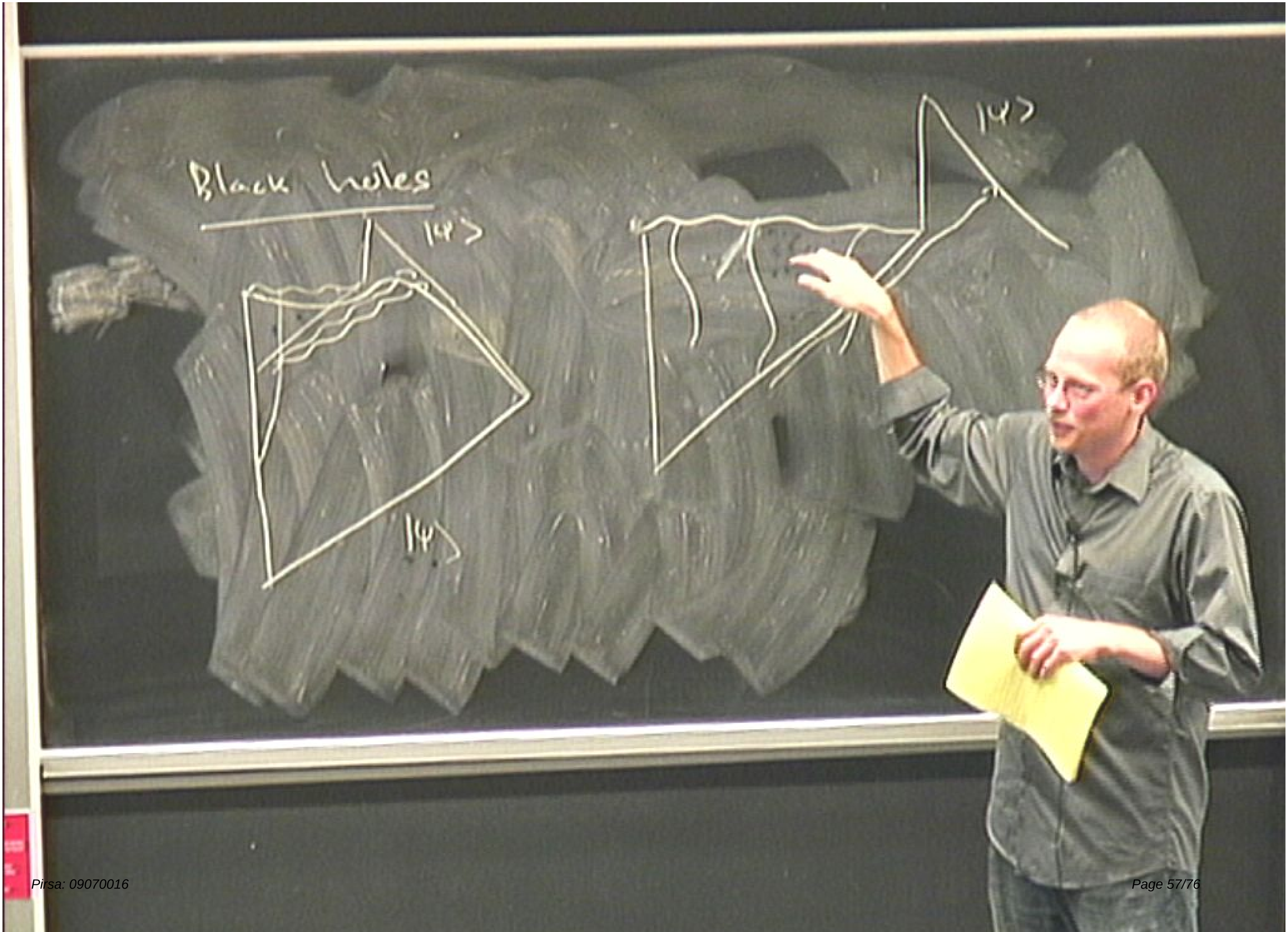

Λ=0
4-D S-FRW
Λ<0

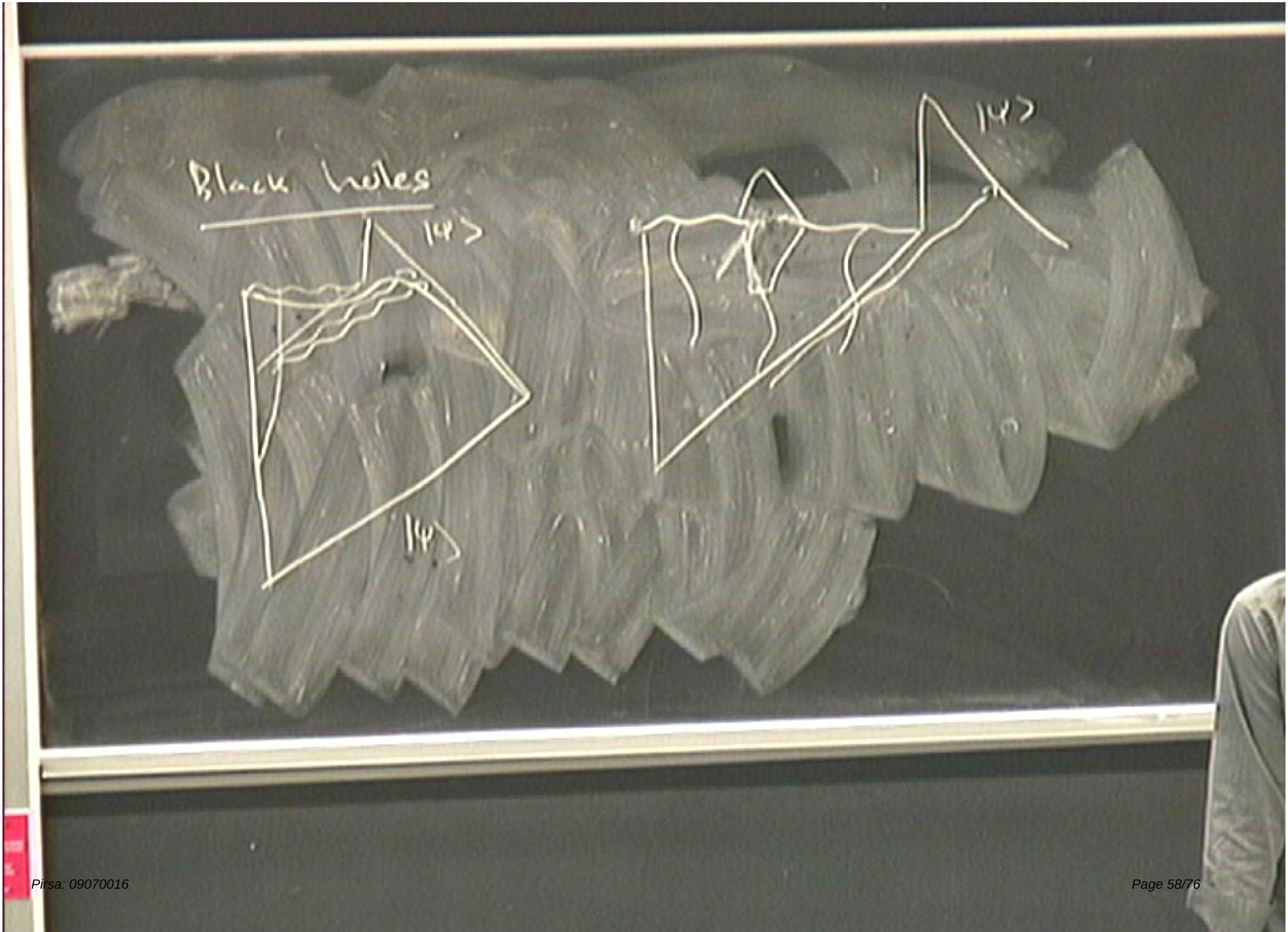

Black holes
$|\psi\rangle$
$|\psi\rangle$

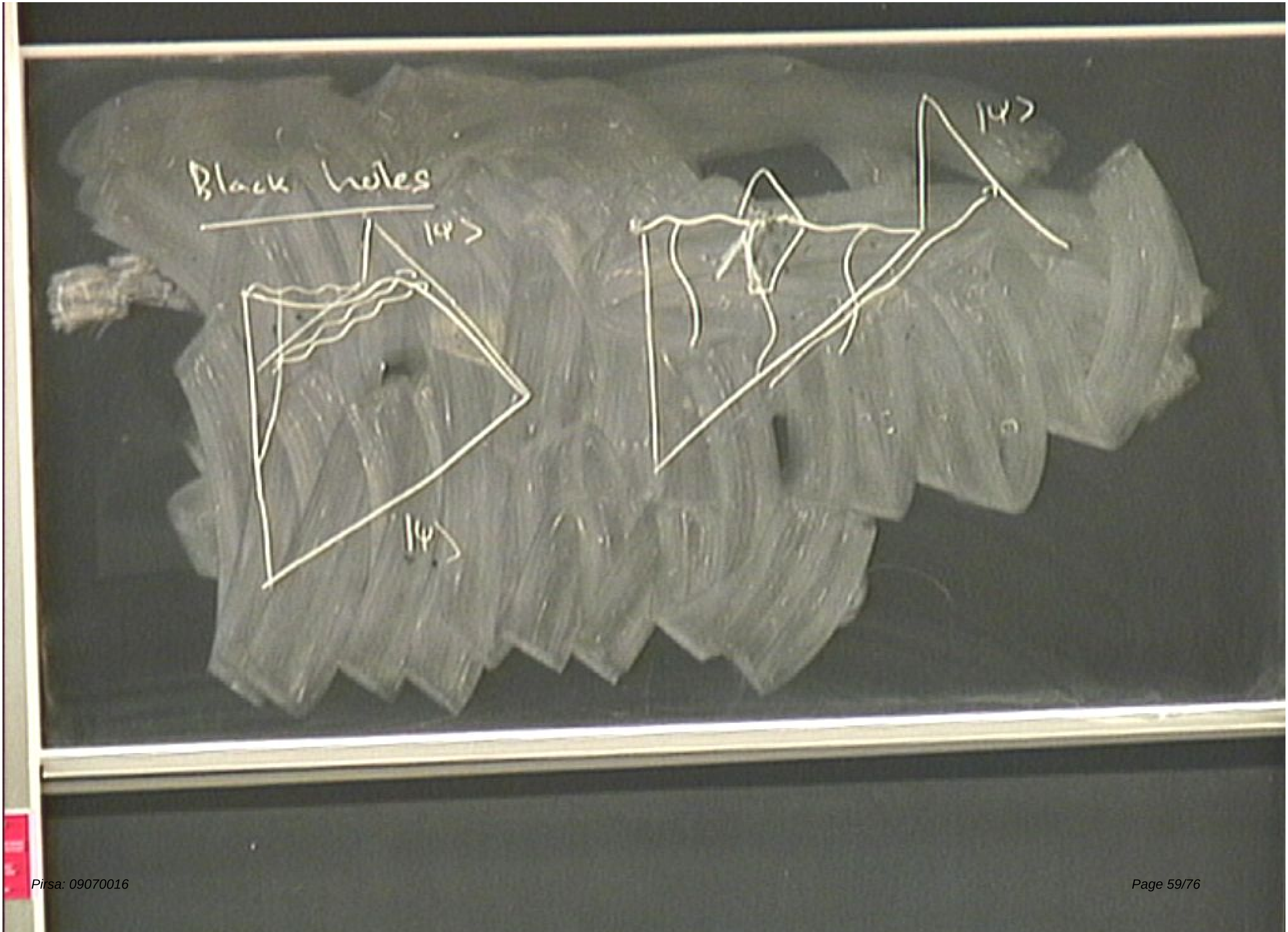
Black holes

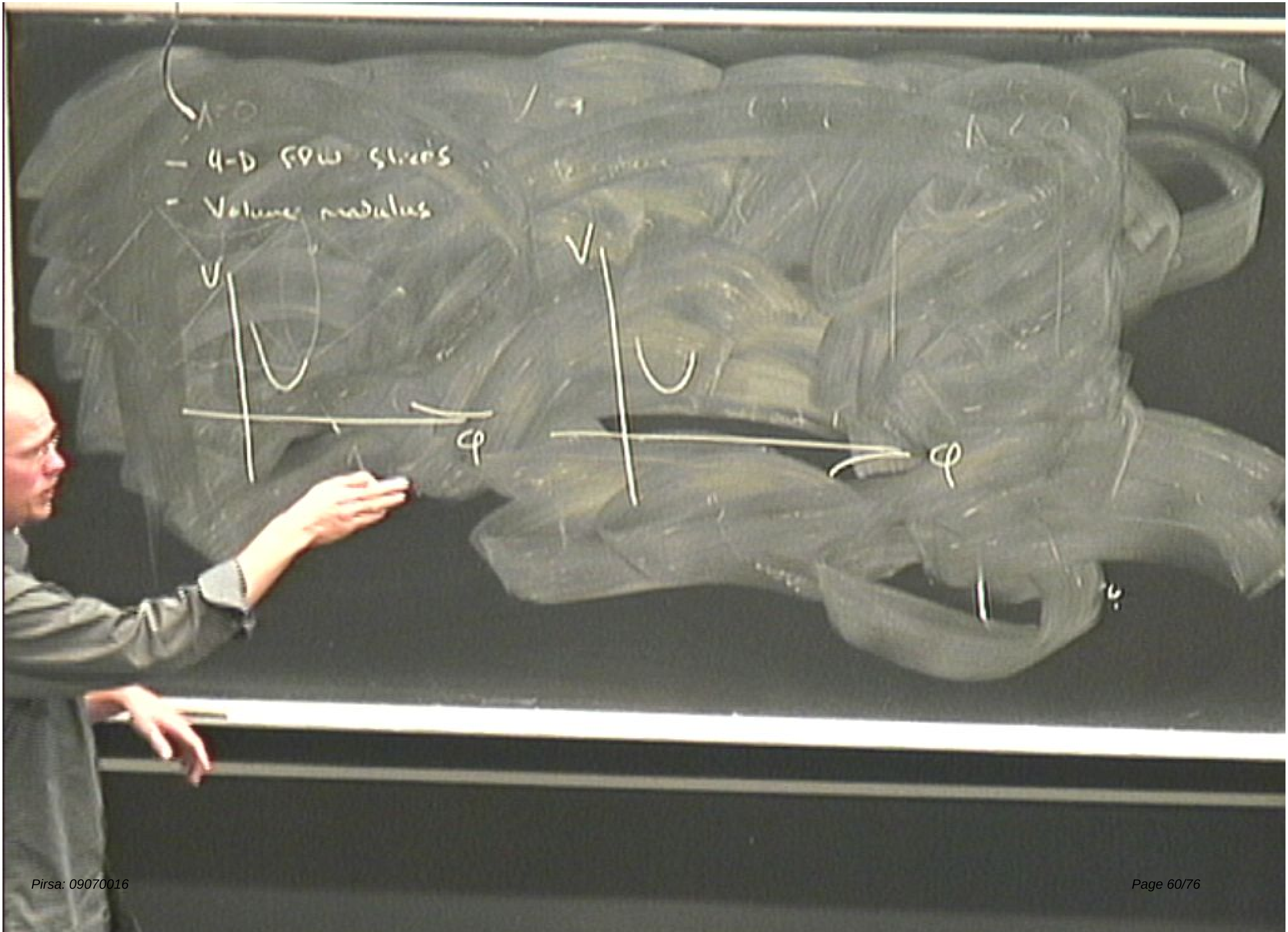


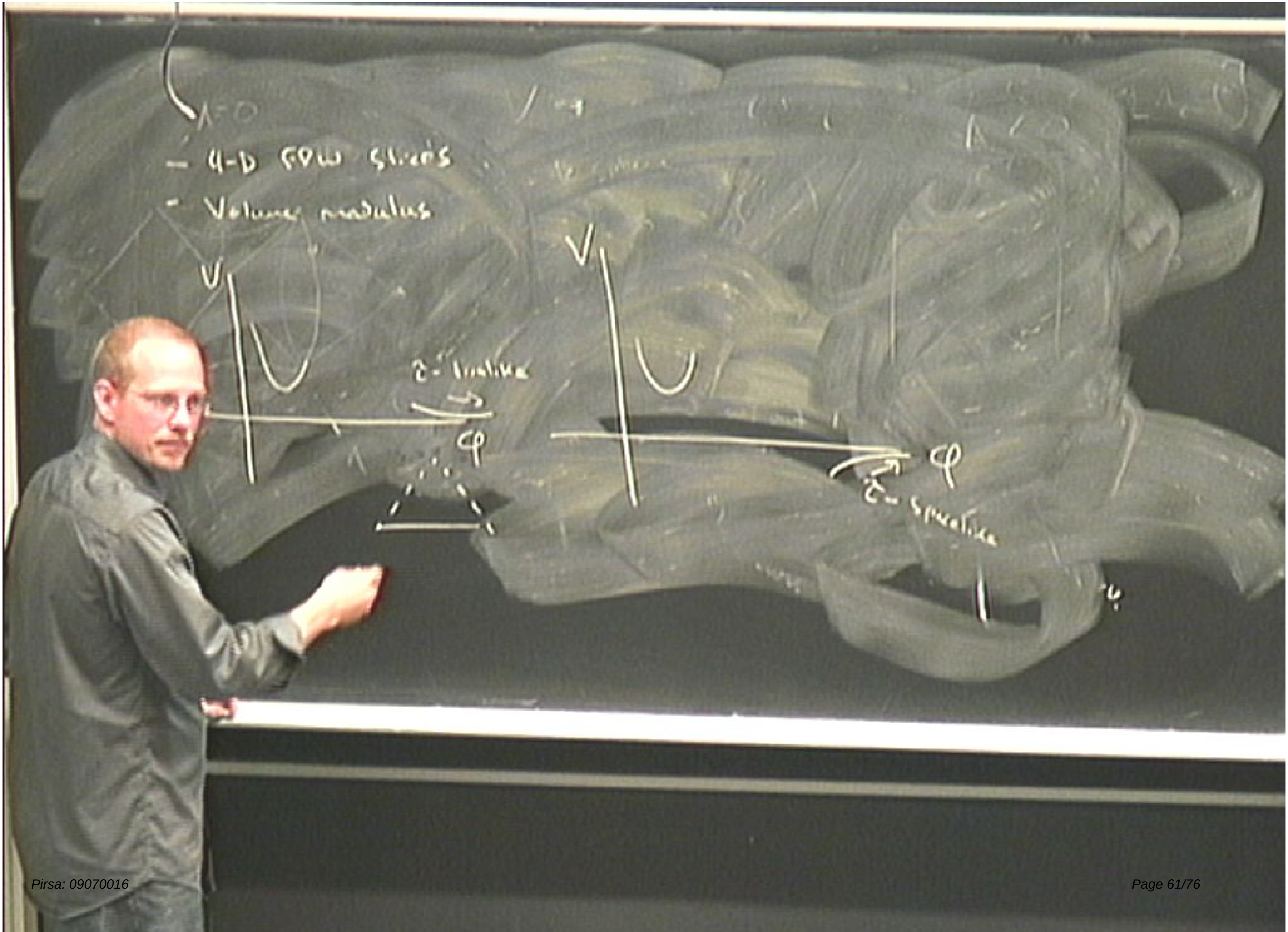

Black holes
|ψ⟩
|ψ⟩
|ψ⟩


Black holes
|ψ⟩
|ψ⟩
|ψ⟩

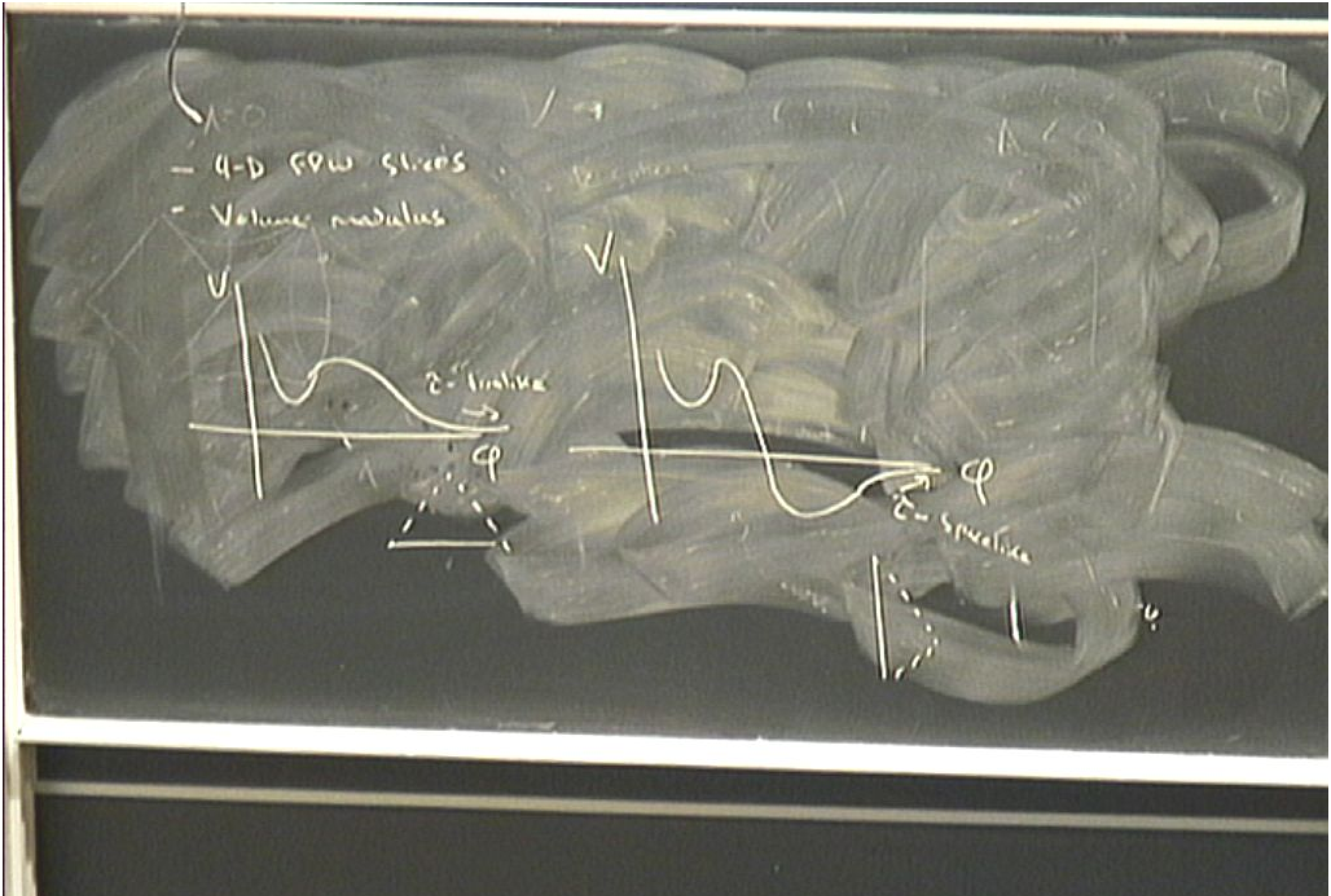

Black holes
|ψ⟩
|ψ⟩
|ψ⟩

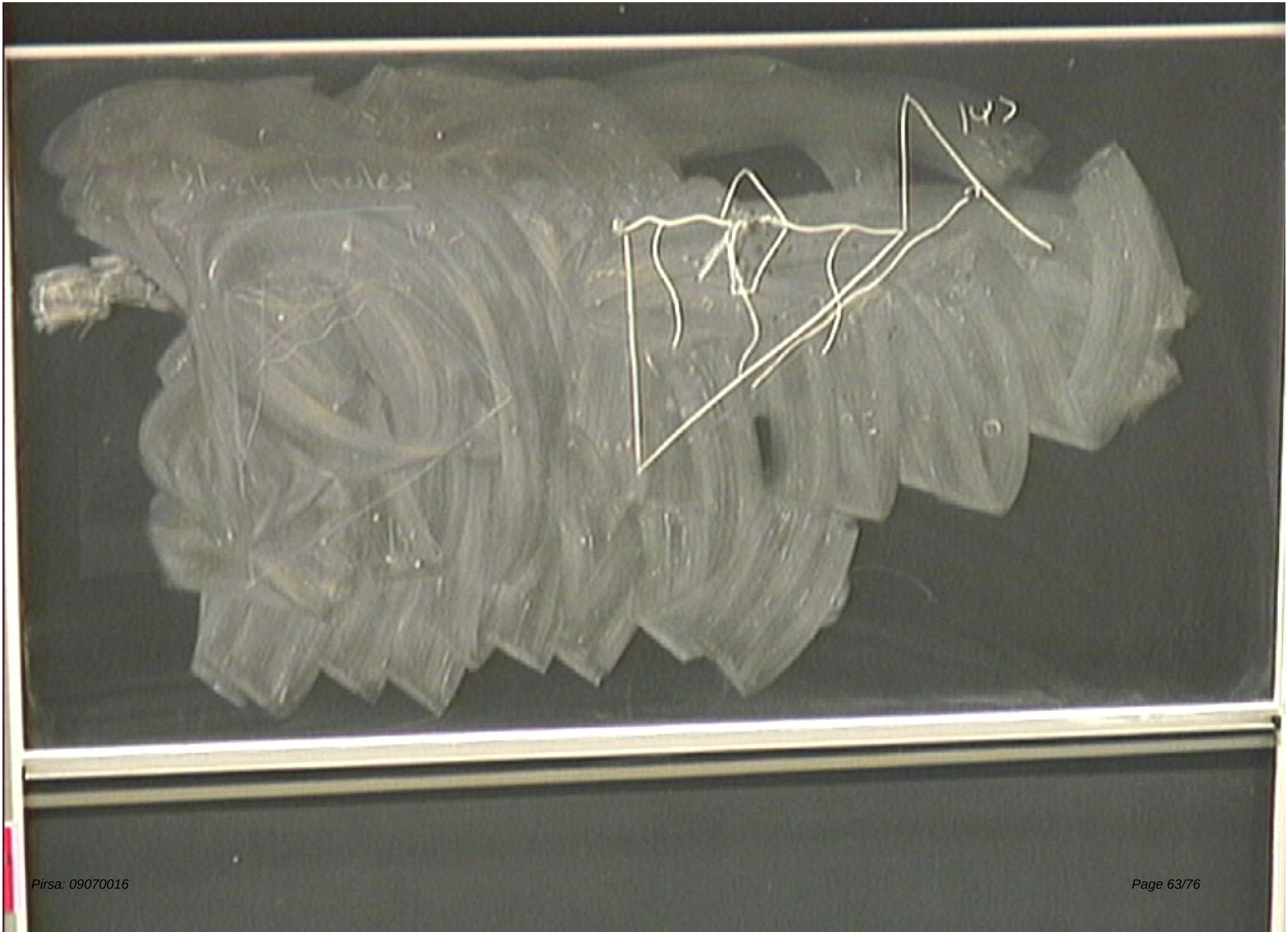

Black holes
|ψ⟩
|ψ⟩
|ψ⟩

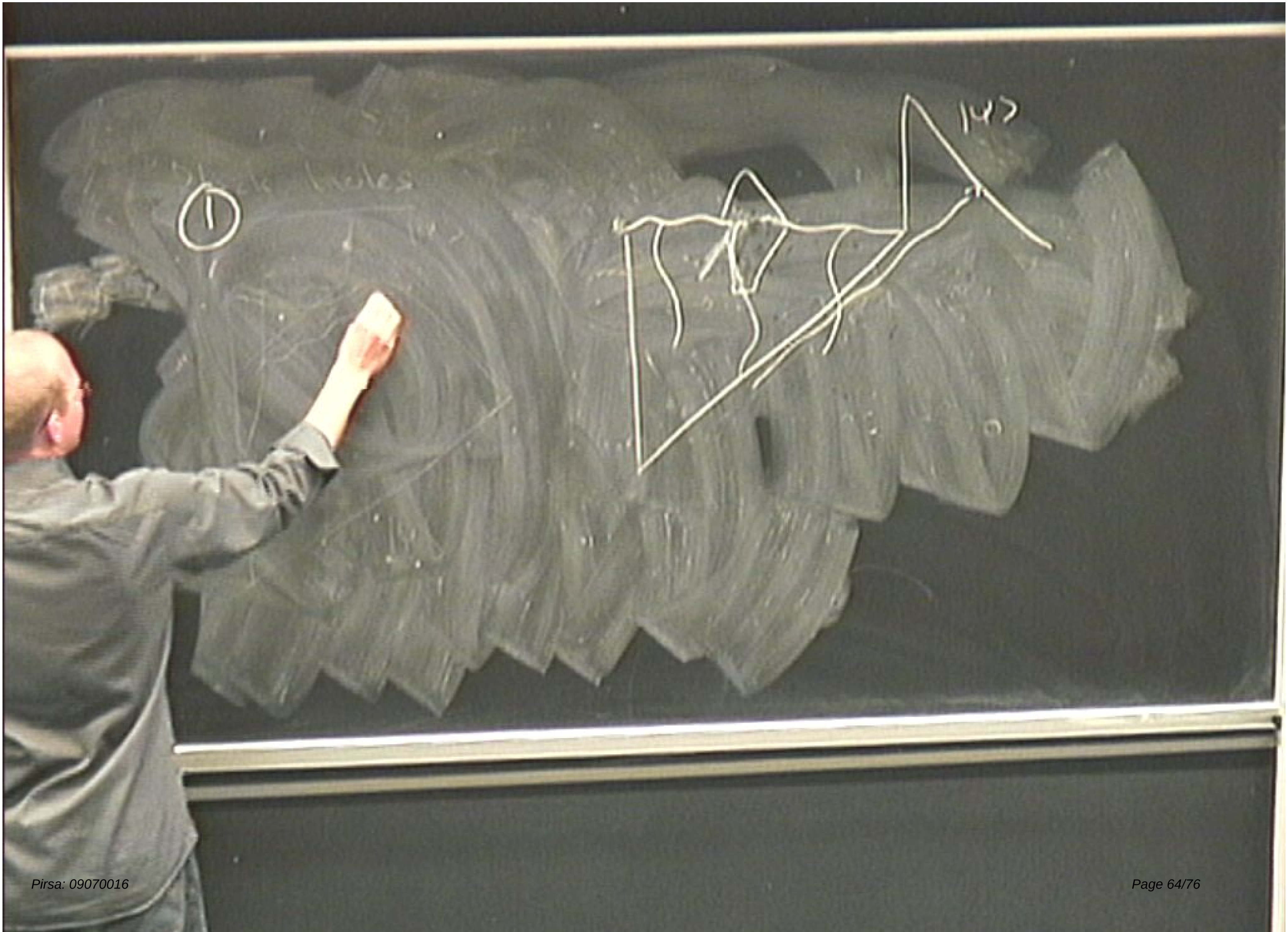

- Volume modulus
V
φ
V
φ



- Volume modulus
τ - timelike
τ - spacelike


- 4-D FRW slices
- Volume modulus
V
τ - timelike
φ
V
φ
τ - spacelike

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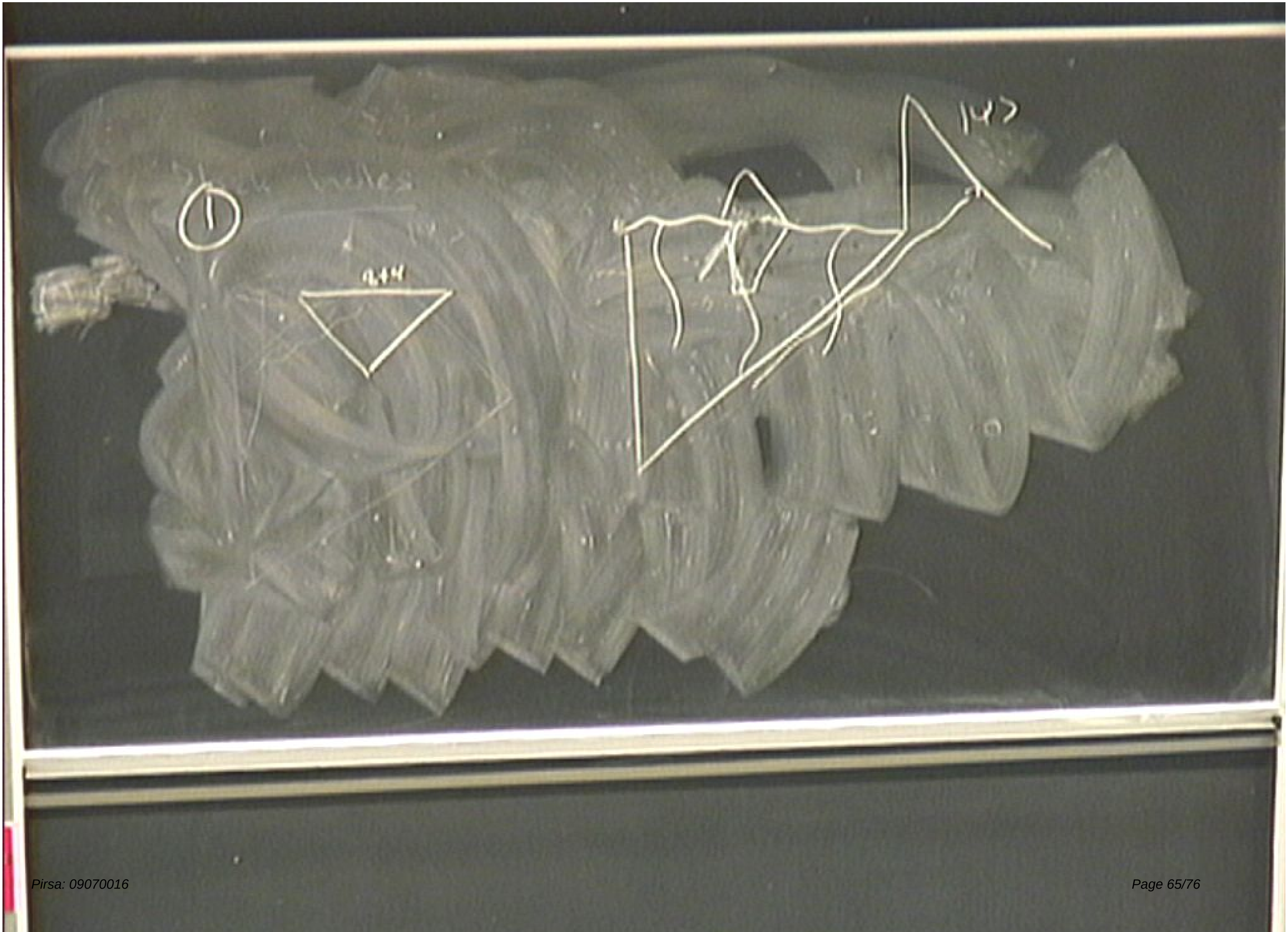
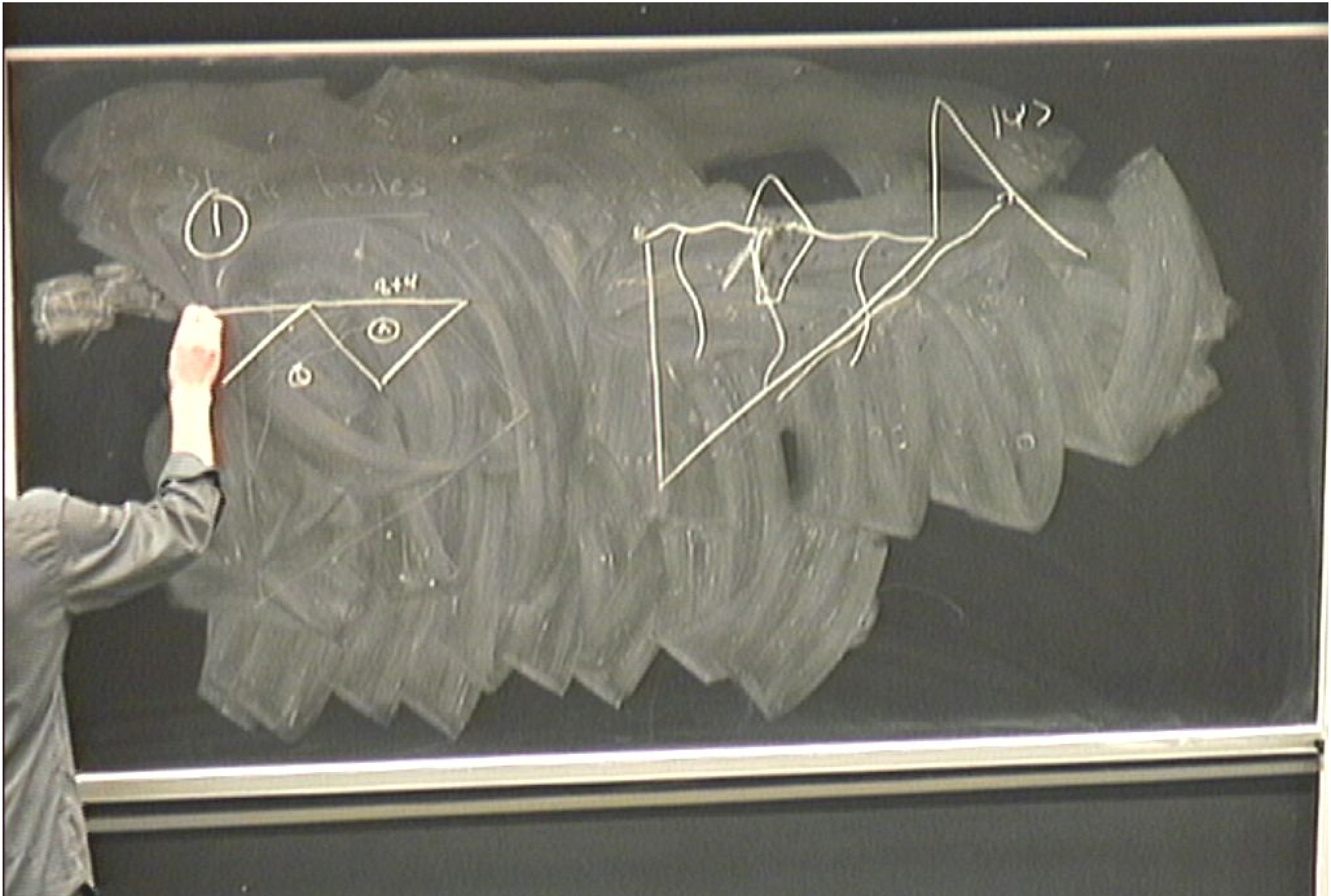
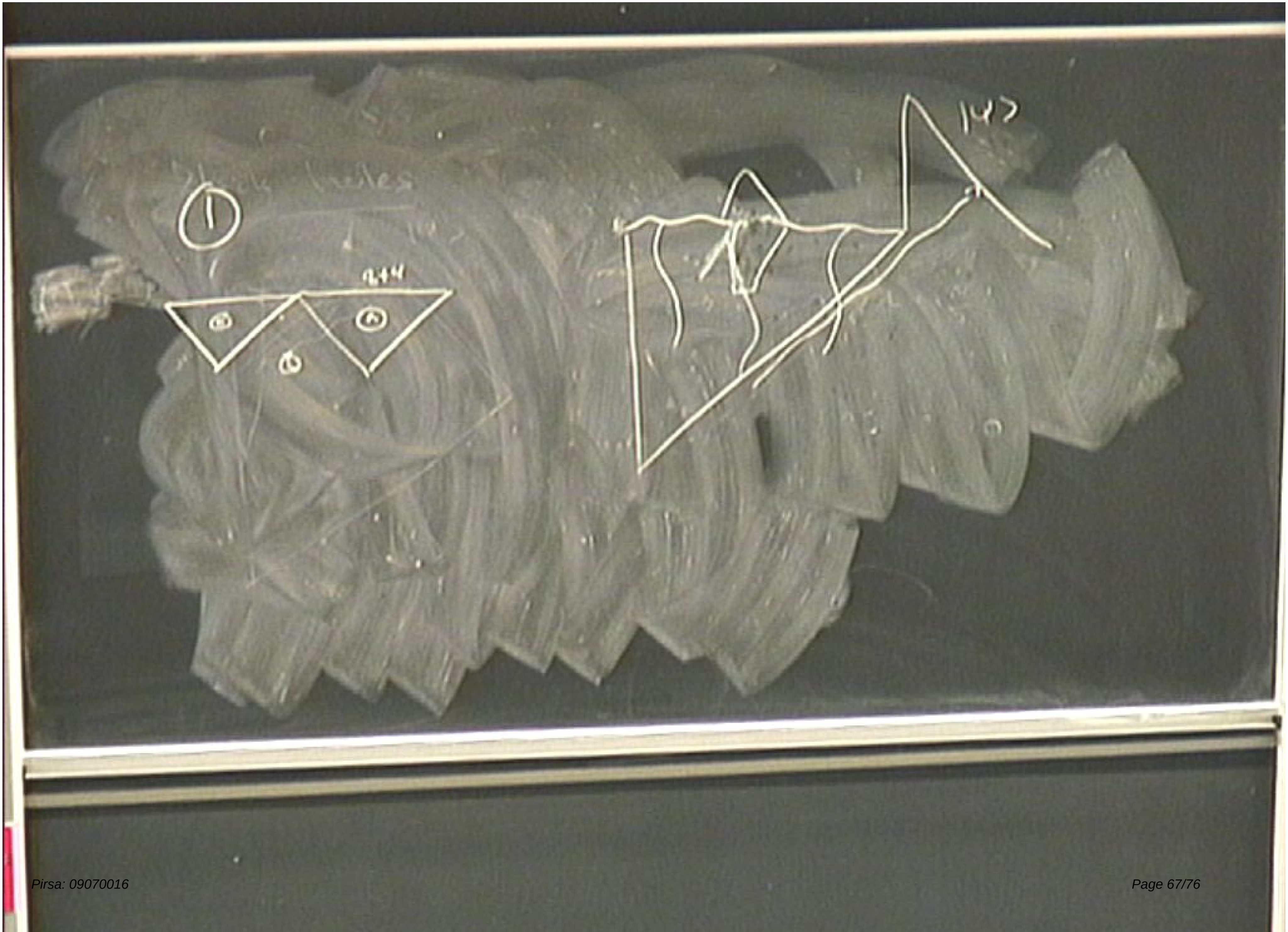
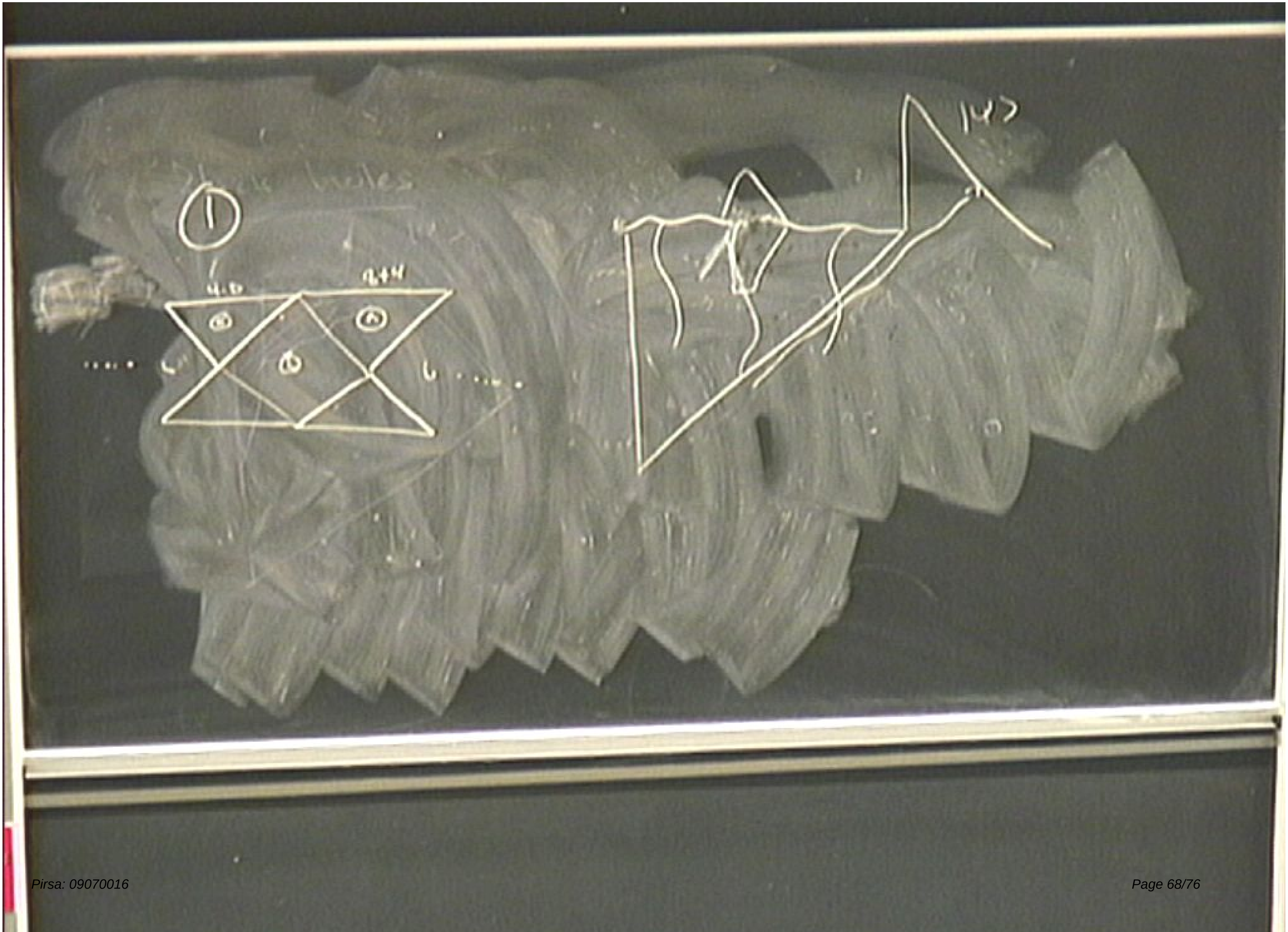


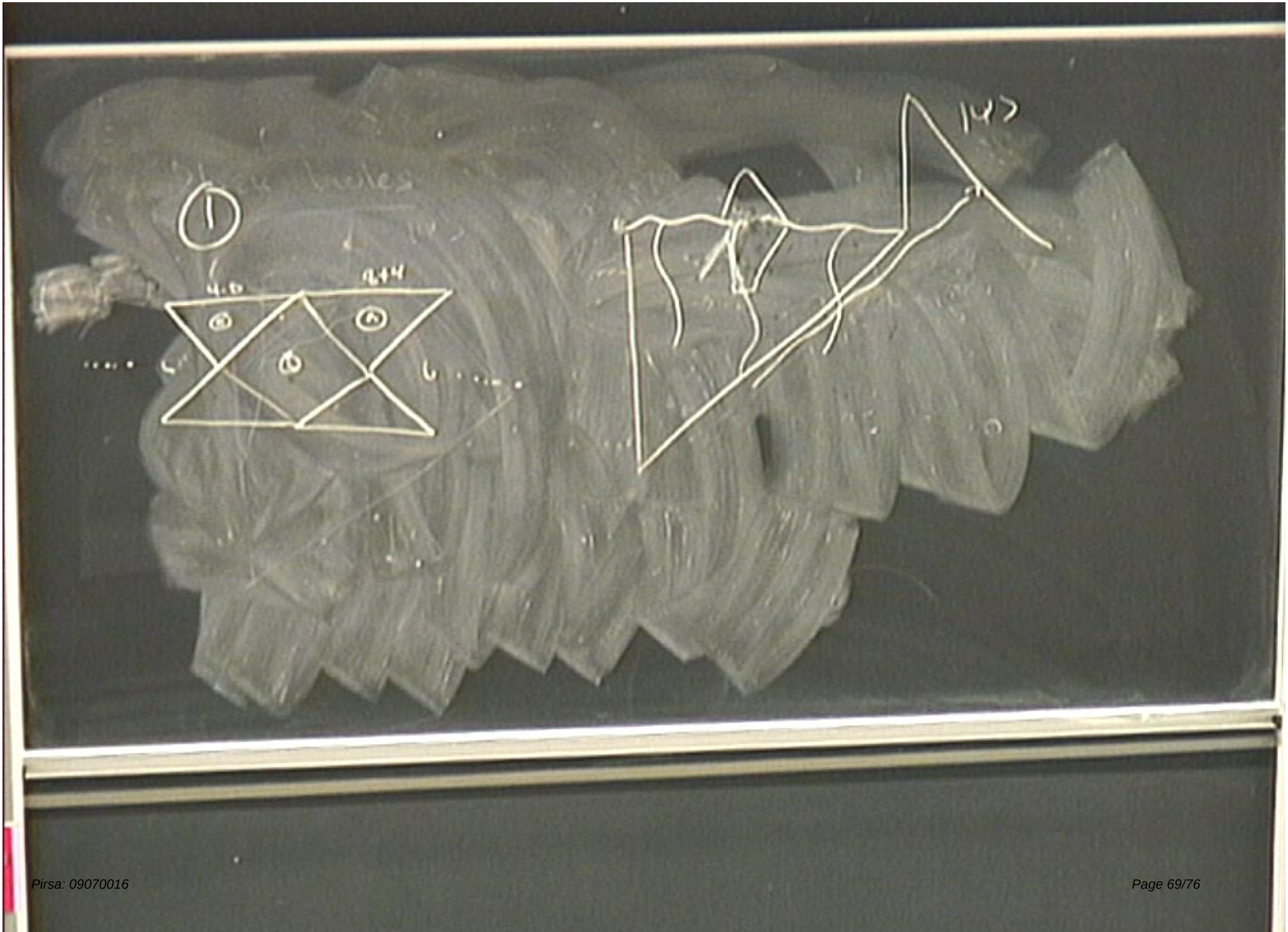
1
144
147

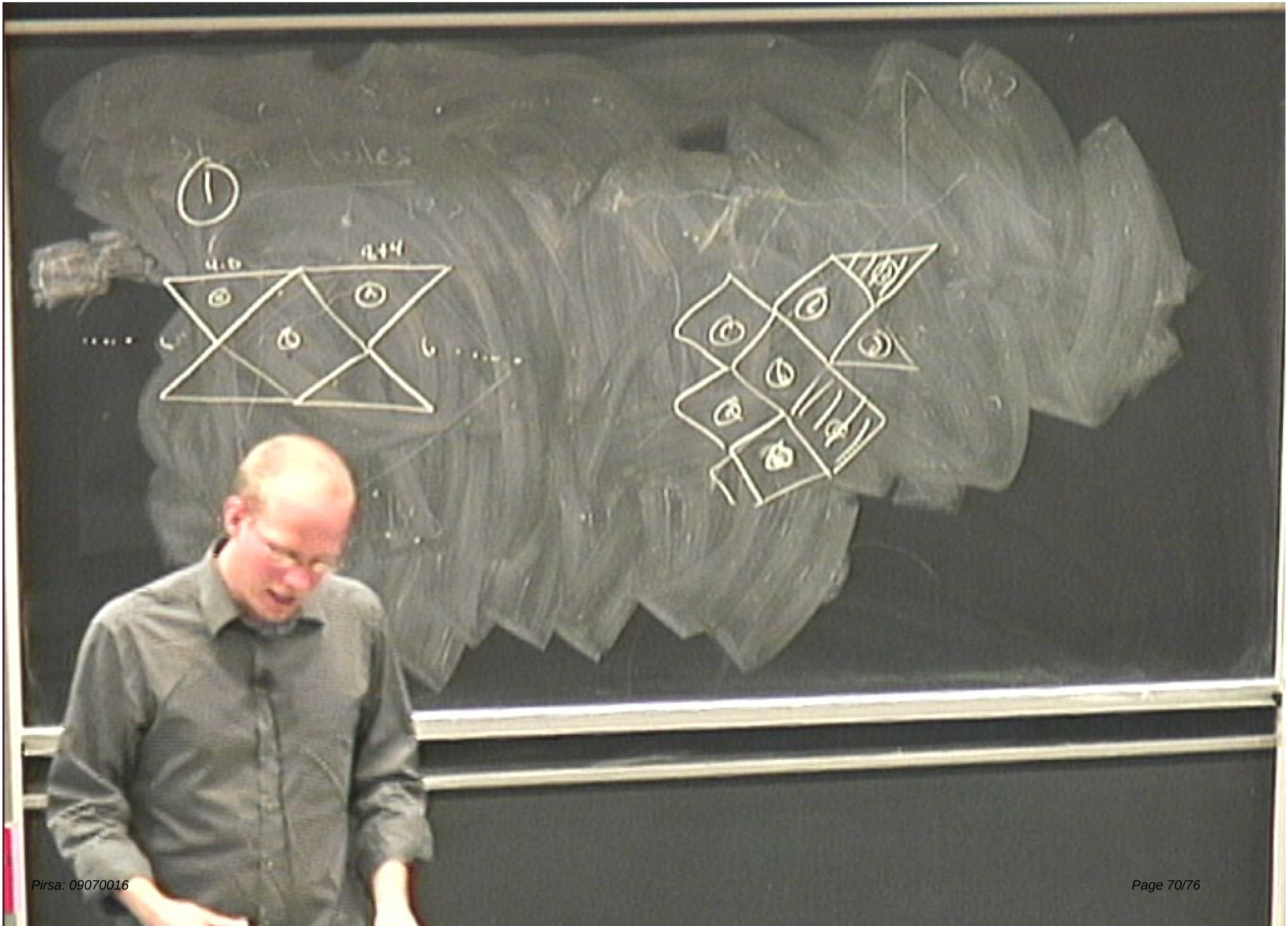


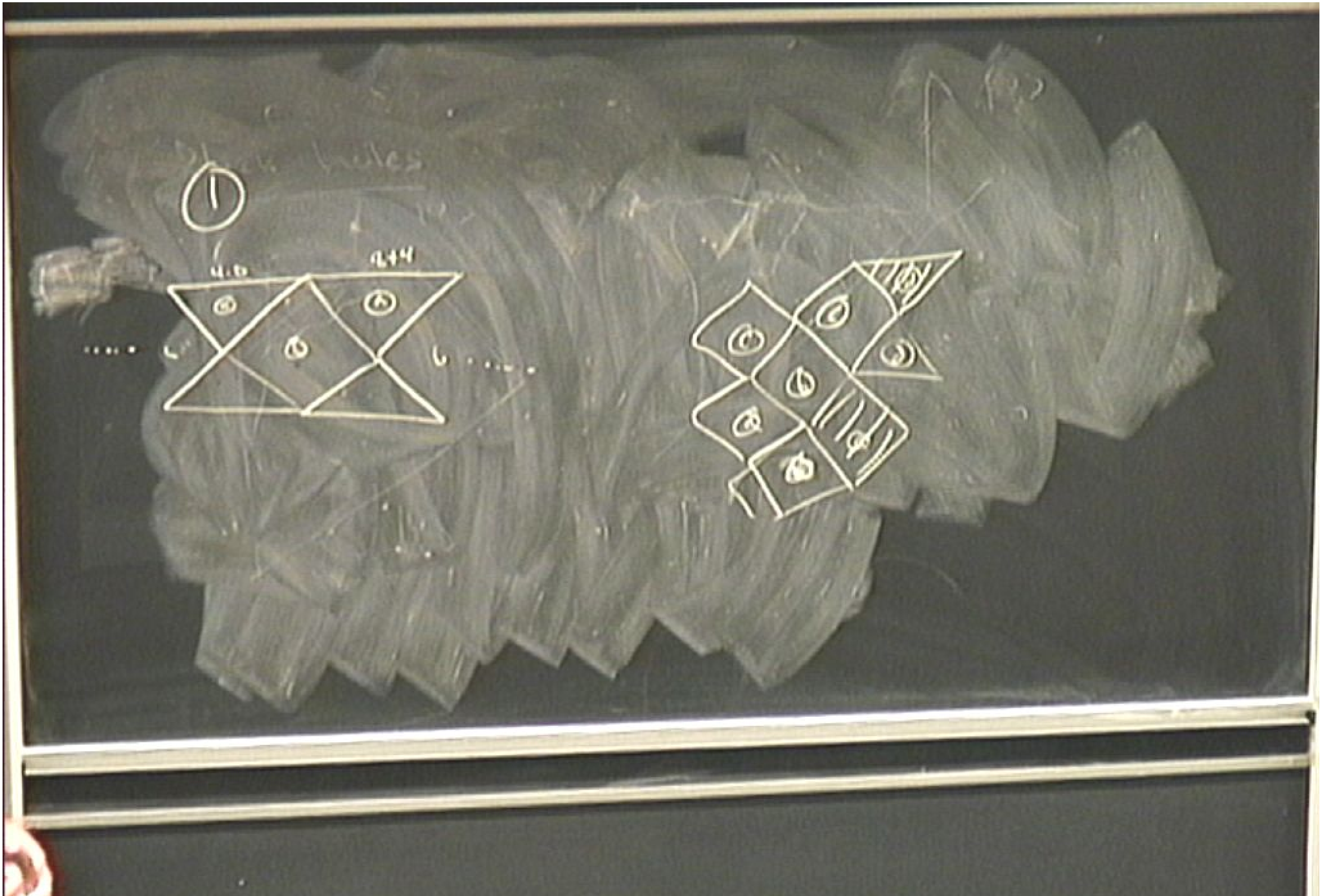


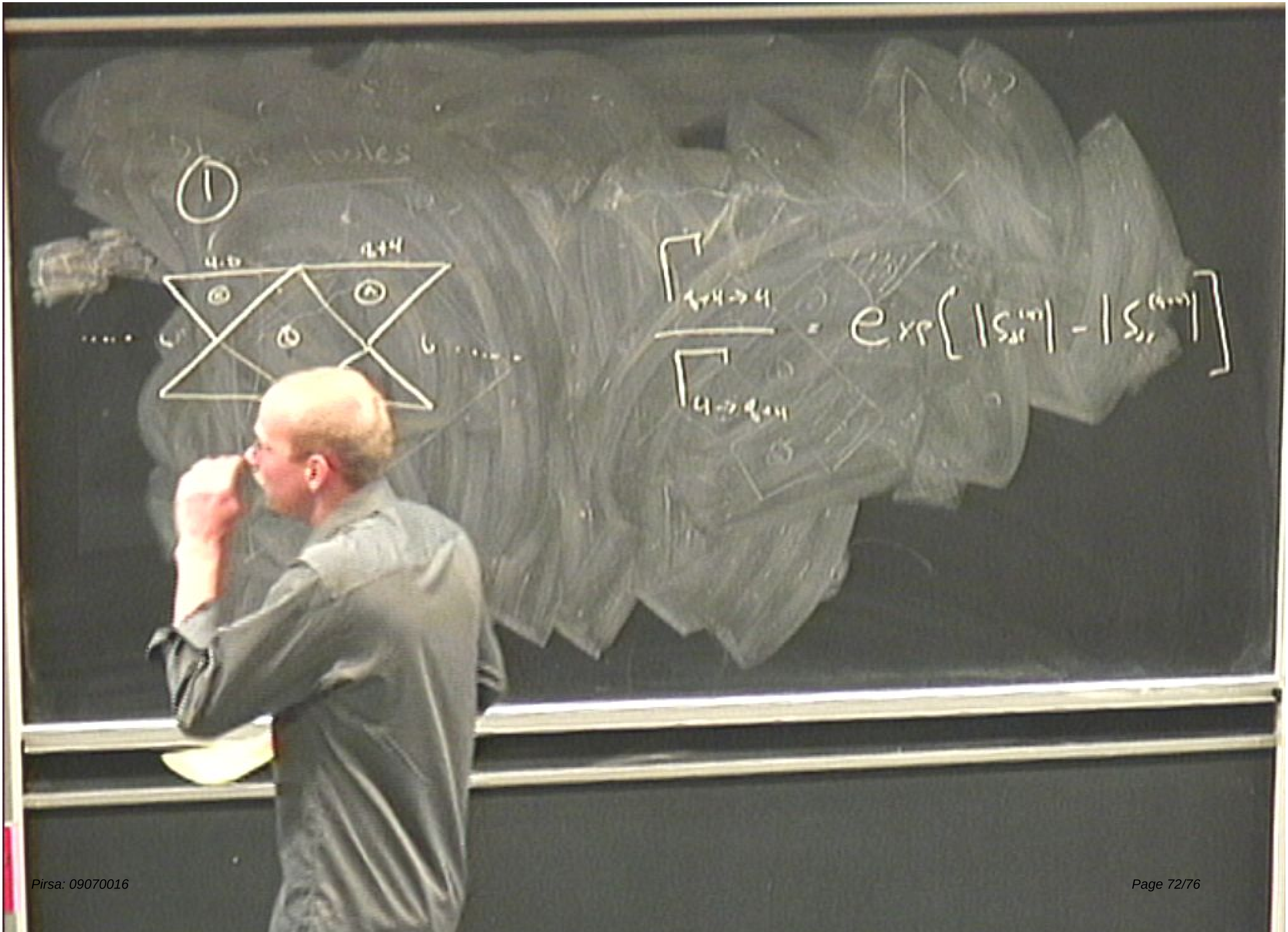
244
147

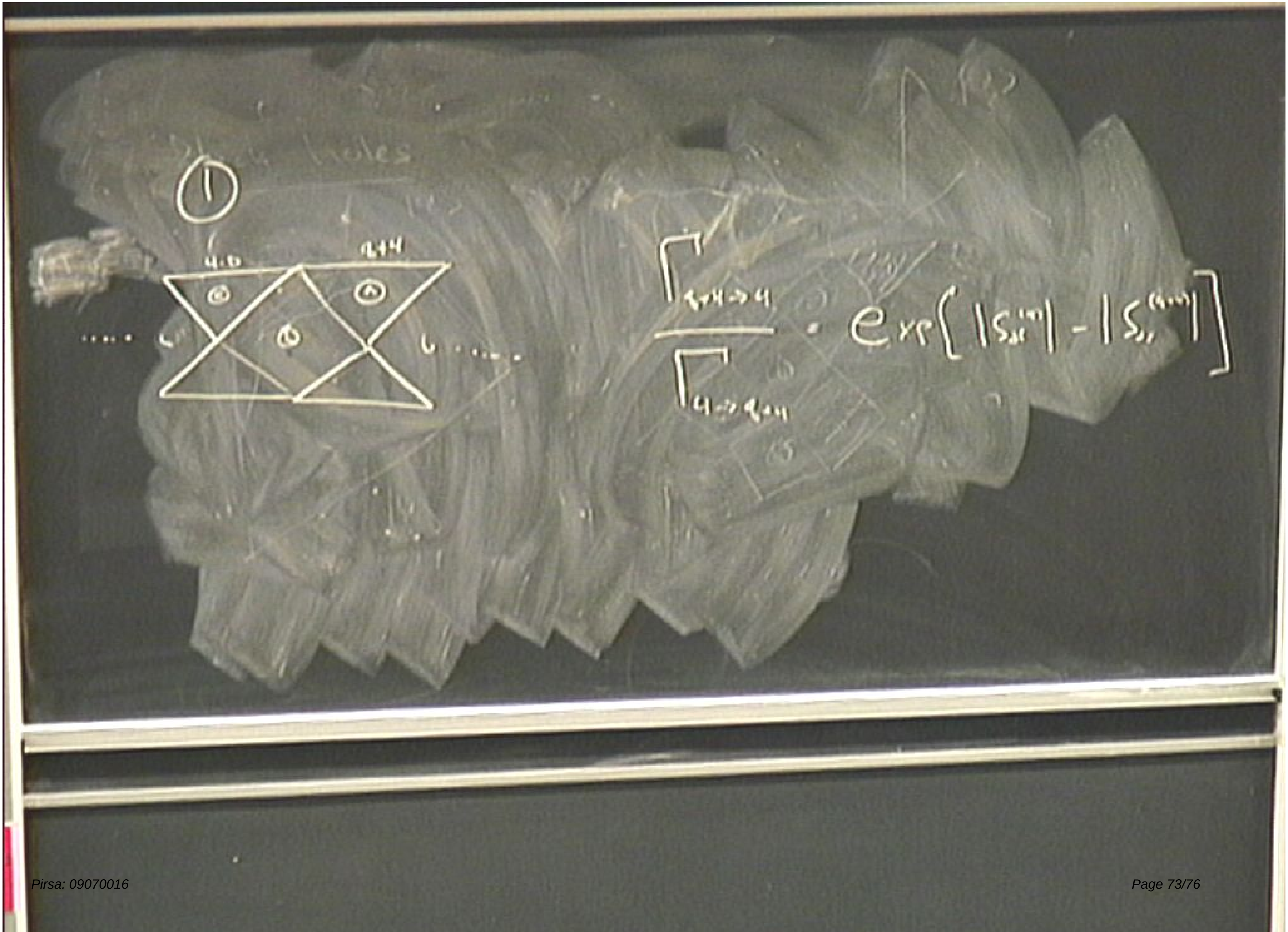


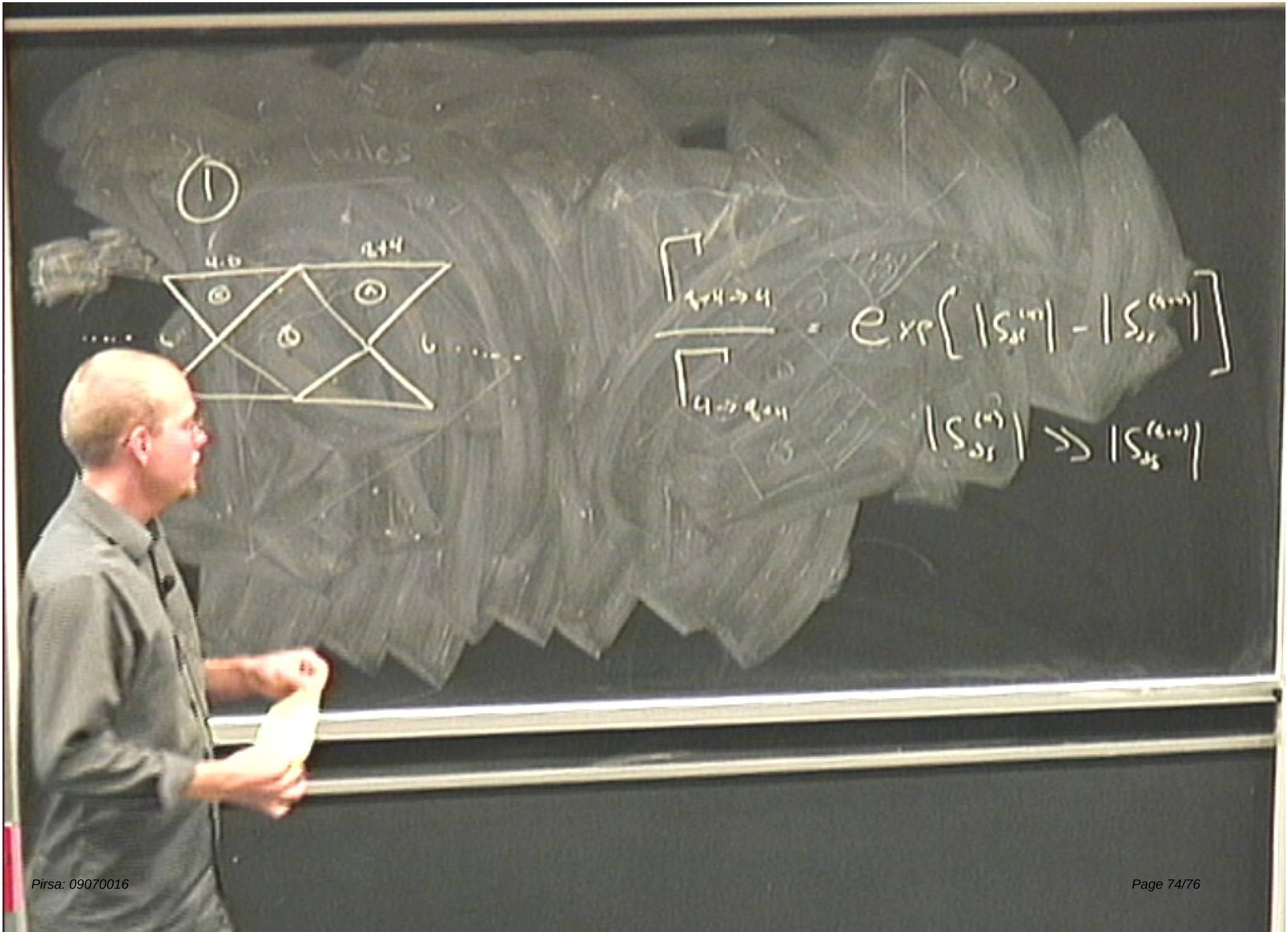


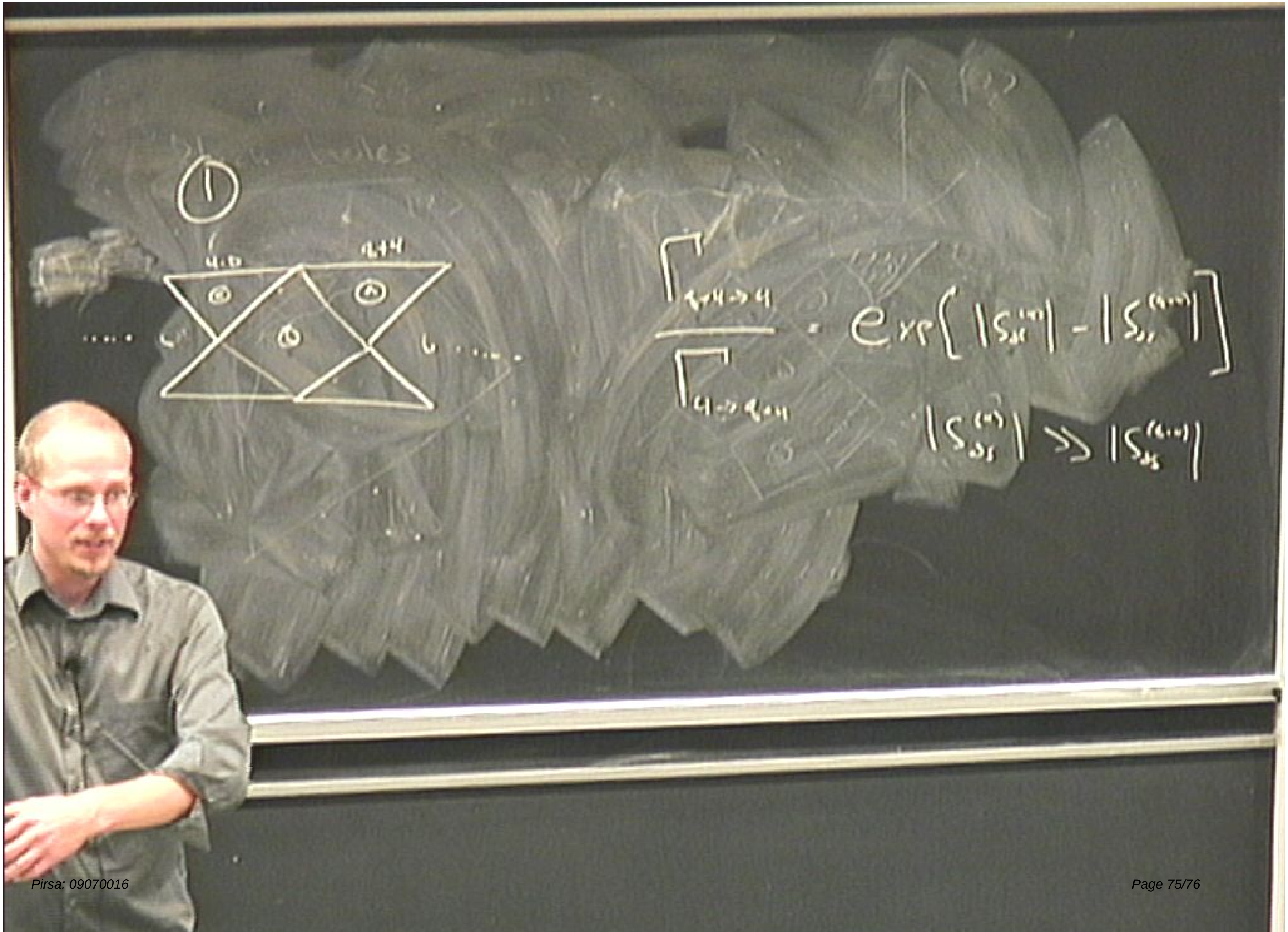


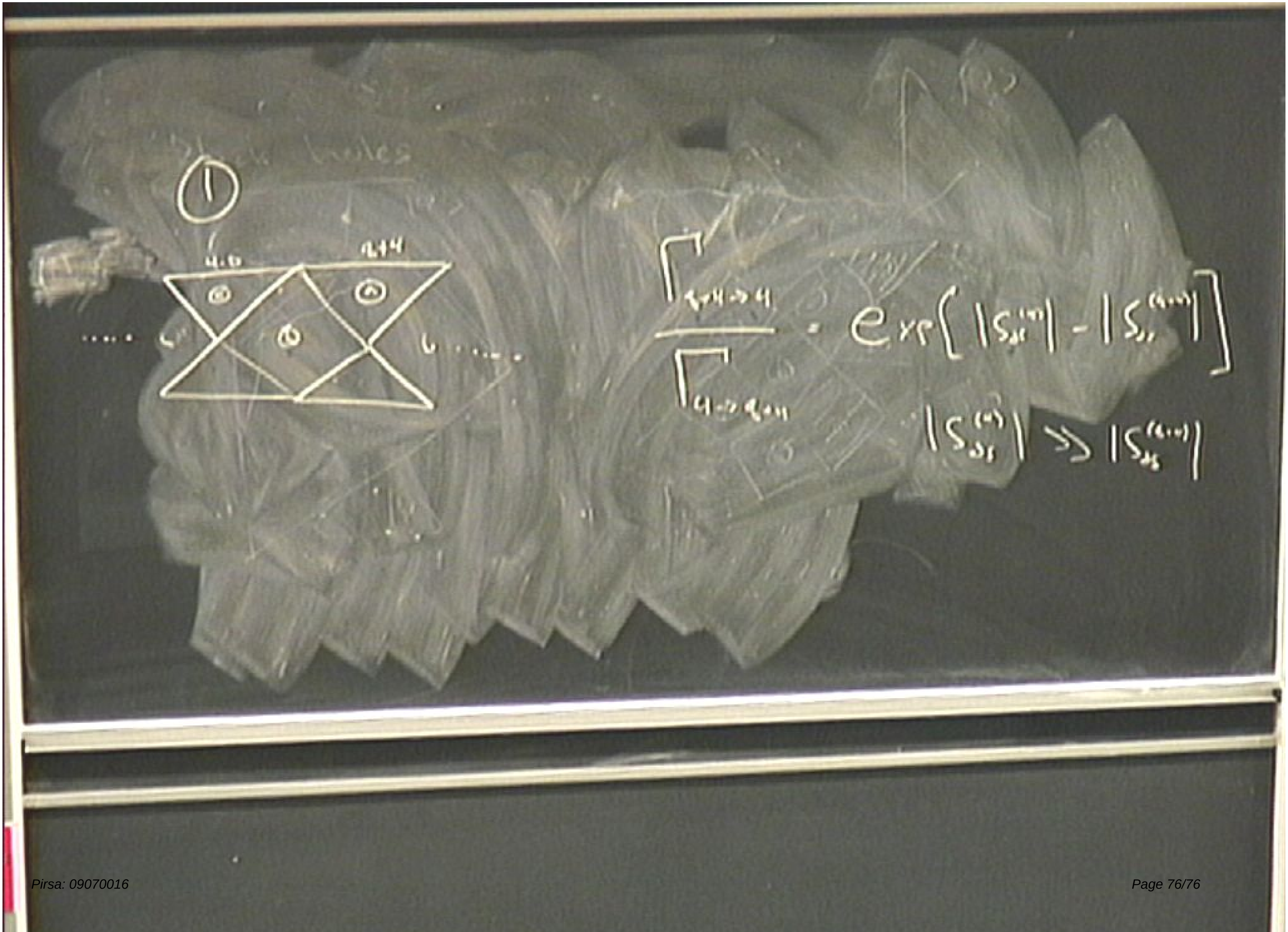







1
q+1
$\frac{\Gamma_{q+1\to q}}{\Gamma_{q\to q+1}} = \exp\left[\,|S_{d}^{(q)}| - |S_{d}^{(q+1)}|\,\right]$
$|S_{ds}^{(q)}| \gg |S_{ds}^{(q+1)}|$


q
q+4
exp



$\frac{\Gamma_{q+1 \to q}}{\Gamma_{q \to q+1}} = \exp\left[|S_{dS}^{(q)}| - |S_{dS}^{(q+1)}| \right]$
$|S_{dS}^{(q)}| \gg |S_{dS}^{(q+1)}|$