Title: A Tomimatsu-Sato/CFT Correspondence

Date: Nov 16, 2010 11:00 AM

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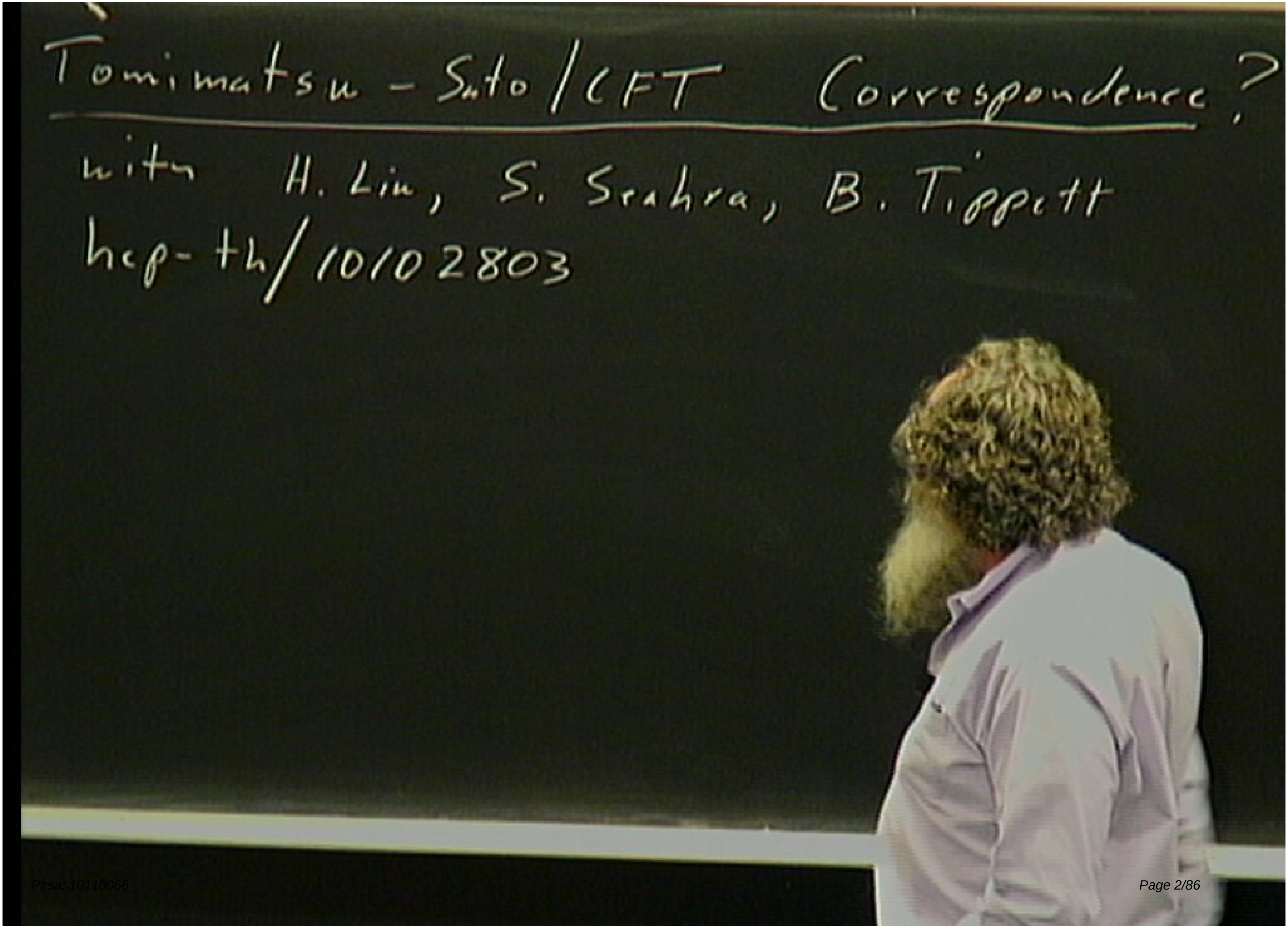
Abstract: We analyze the delta = 2 Tomimatsu-Sato spacetime in the context of the proposed Kerr/CFT correspondence. This 4-dimensional vacuum spacetime is asymptotically flat and has a well-defined ADM mass and angular momentum, but also involves several exotic features including a naked ring singularity, and two disjoint Killing horizons separated by a region with closed timelike curves and a rod-like conical singularity. We demonstrate that the near horizon geometry belongs to a general class of Ricci-flat metrics with SL(2,R) X U(1) symmetry that includes both the extremal Kerr and extremal Kerr-bolt geometries. We calculate the central charge and temperature for the CFT dual to this spacetime and confirm the Cardy formula reproduces the Bekenstein-Hawking entropy. We find that all of the basic parameters of the dual CFT are most naturally expressed in terms of charges defined intrinsically on the horizon, which are distinct from the ADM charges in this geometry.


Tomimatsu - Sato / CFT Correspondence ?
with H. Lin, S. Seahra, B. Tippett
hep-th/1010 2803

Tomimatsu - Sato / CFT Correspondence?

with H. Liu, S. Sabra, B. Tippett

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Kerr / CFT : CFT dual to physics
in Extremal Kerr

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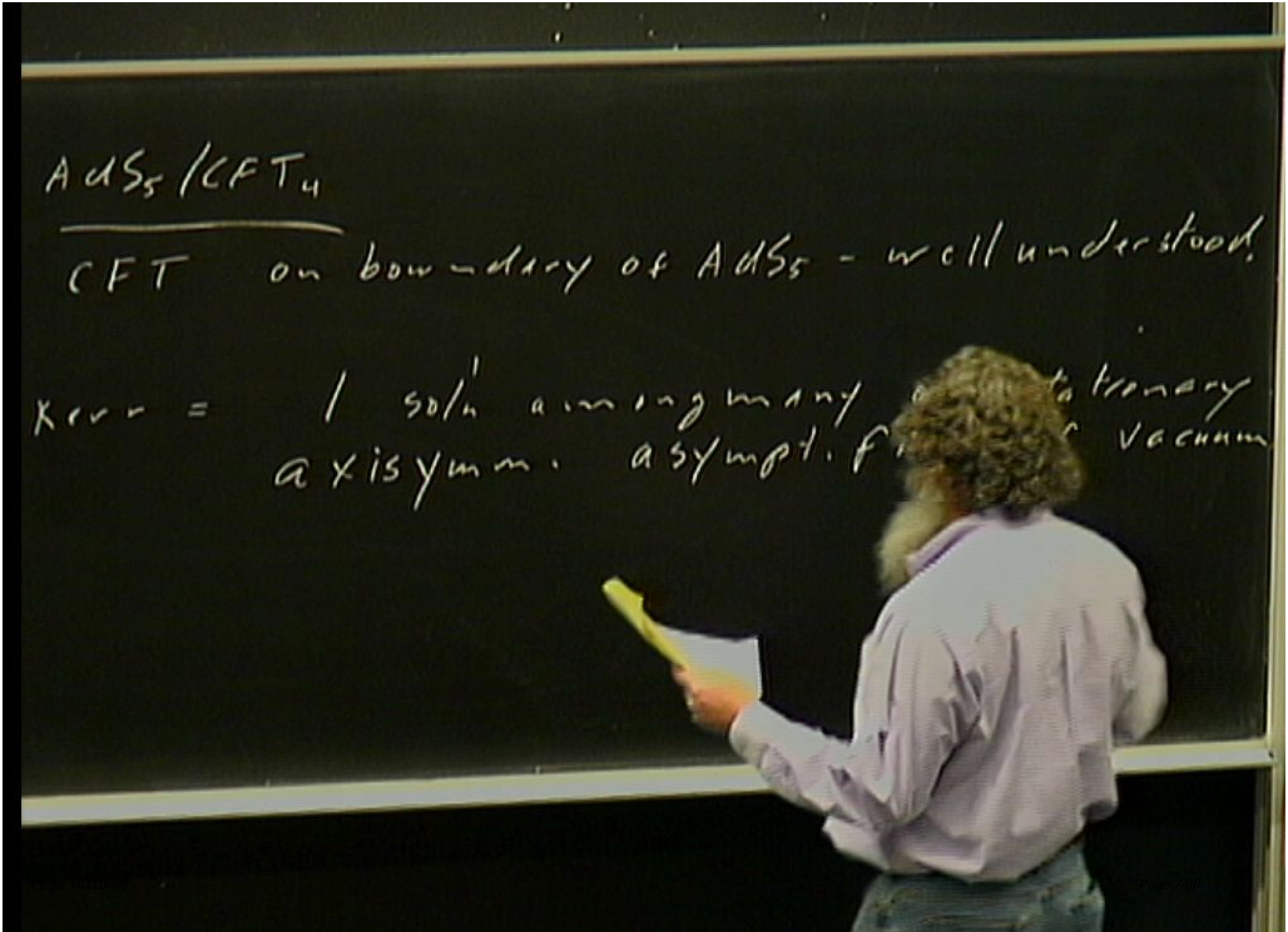
Kerr / CFT : CFT dual to physics in Extremal Kerr

CFT lives on boundary of NHEK.

AdS_5/CFT_4

CFT on boundary of AdS_5 - well understood.


AdS5/CFT4
CFT on boundary of AdS5 - well understood.
Kerr = 1 sol'n among many
axisymm. asympt.
vacuum

AdS_5/CFT_4

CFT on boundary of AdS_5 - well understood.

Kerr = 1 sol'n among many of stationary axisymm. asympt. flat of [illegible] Einstein eqns.

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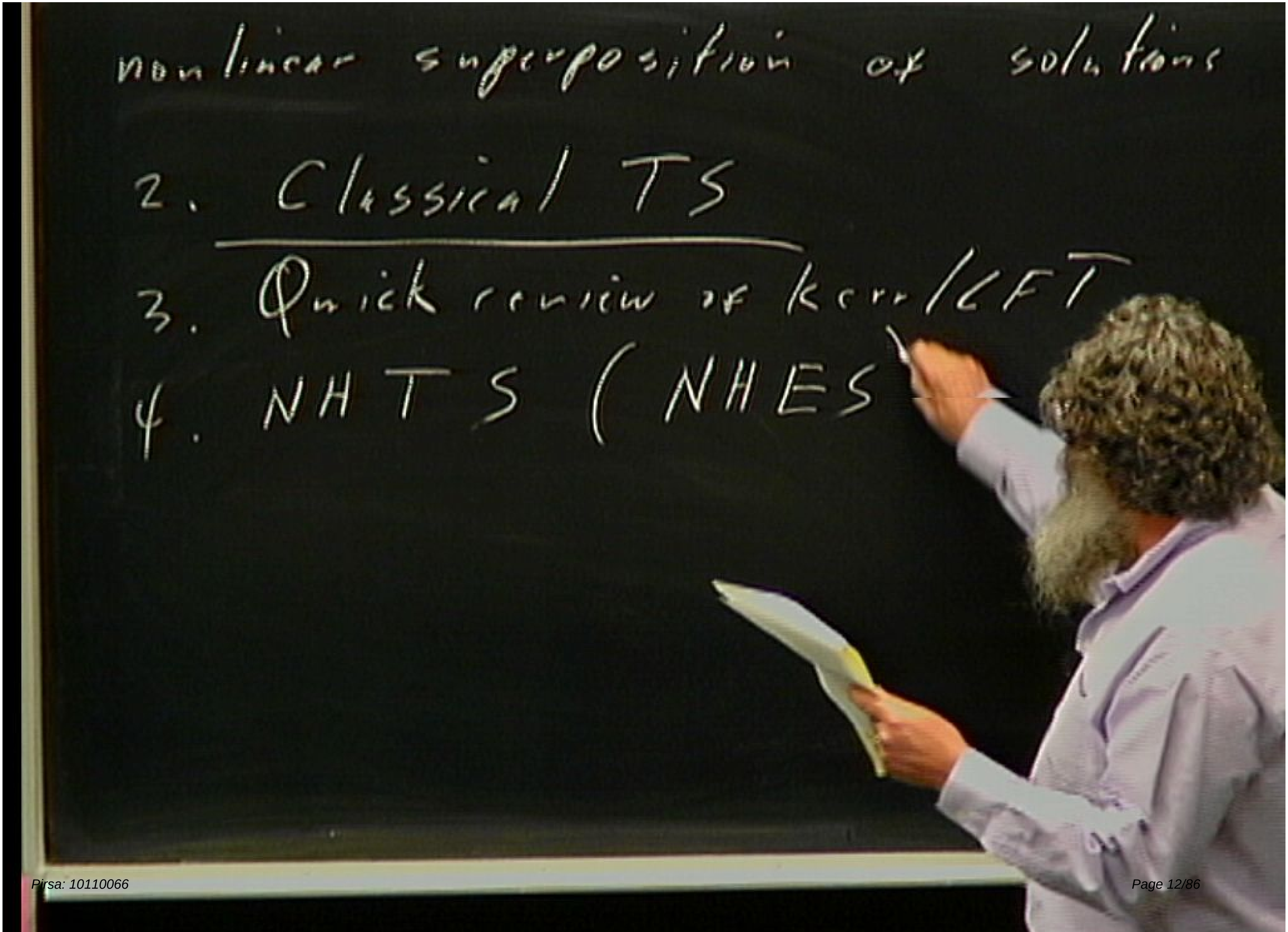
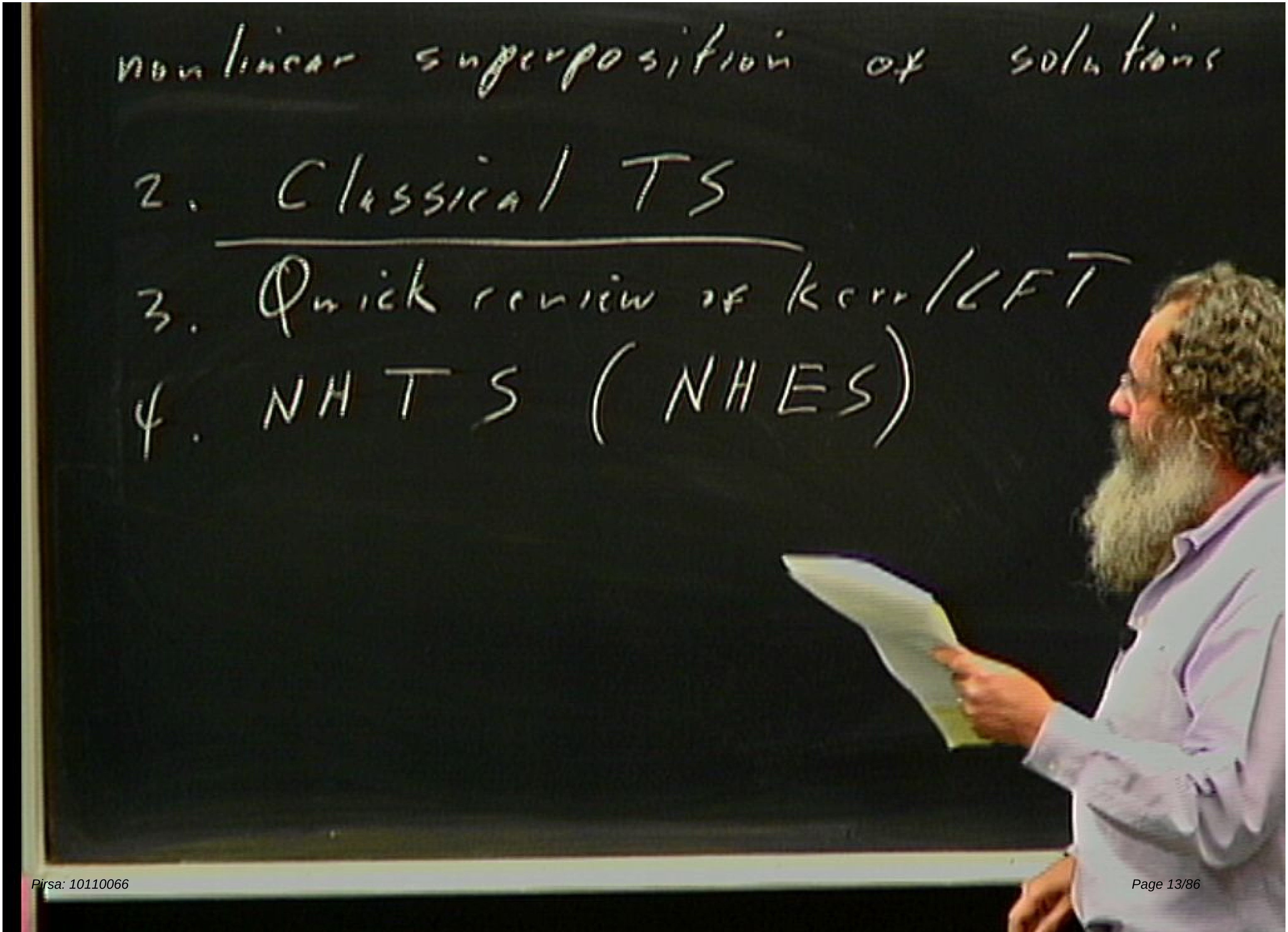
CFT on boundary of AdS_5 - well understood.

Kerr = 1 sol'n among many of Stationary axisymm. asympt. flat of vacuum Einstein eqns.

integrable

Come from Ernst eqn.


nonlinear superposition of solutions
2. Classical TS
3. Quick review of Kerr/CFT
4. NHTS (NHES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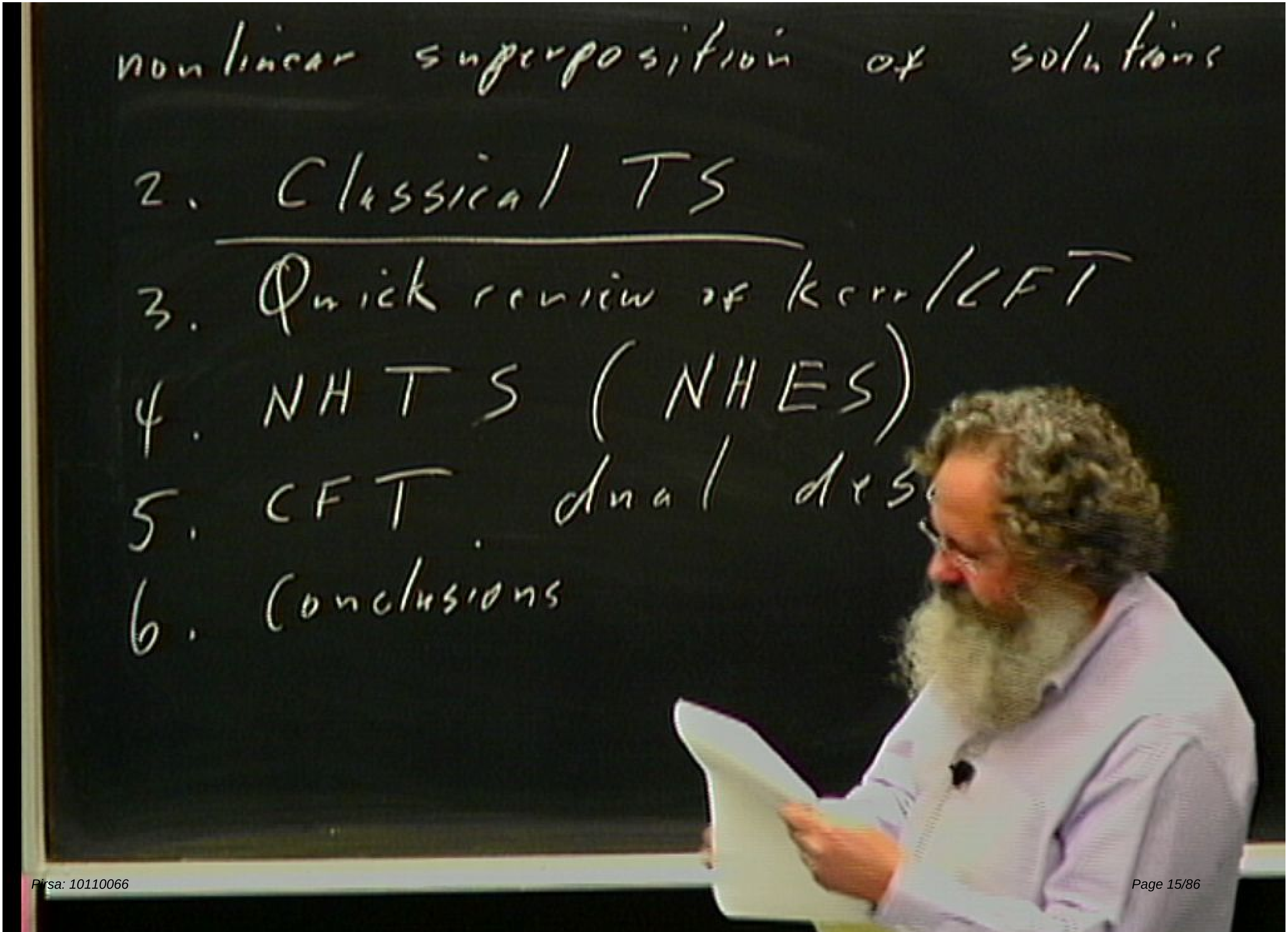
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5. CFT dual des
6. Conclusions

nonlinear superposition of solutions

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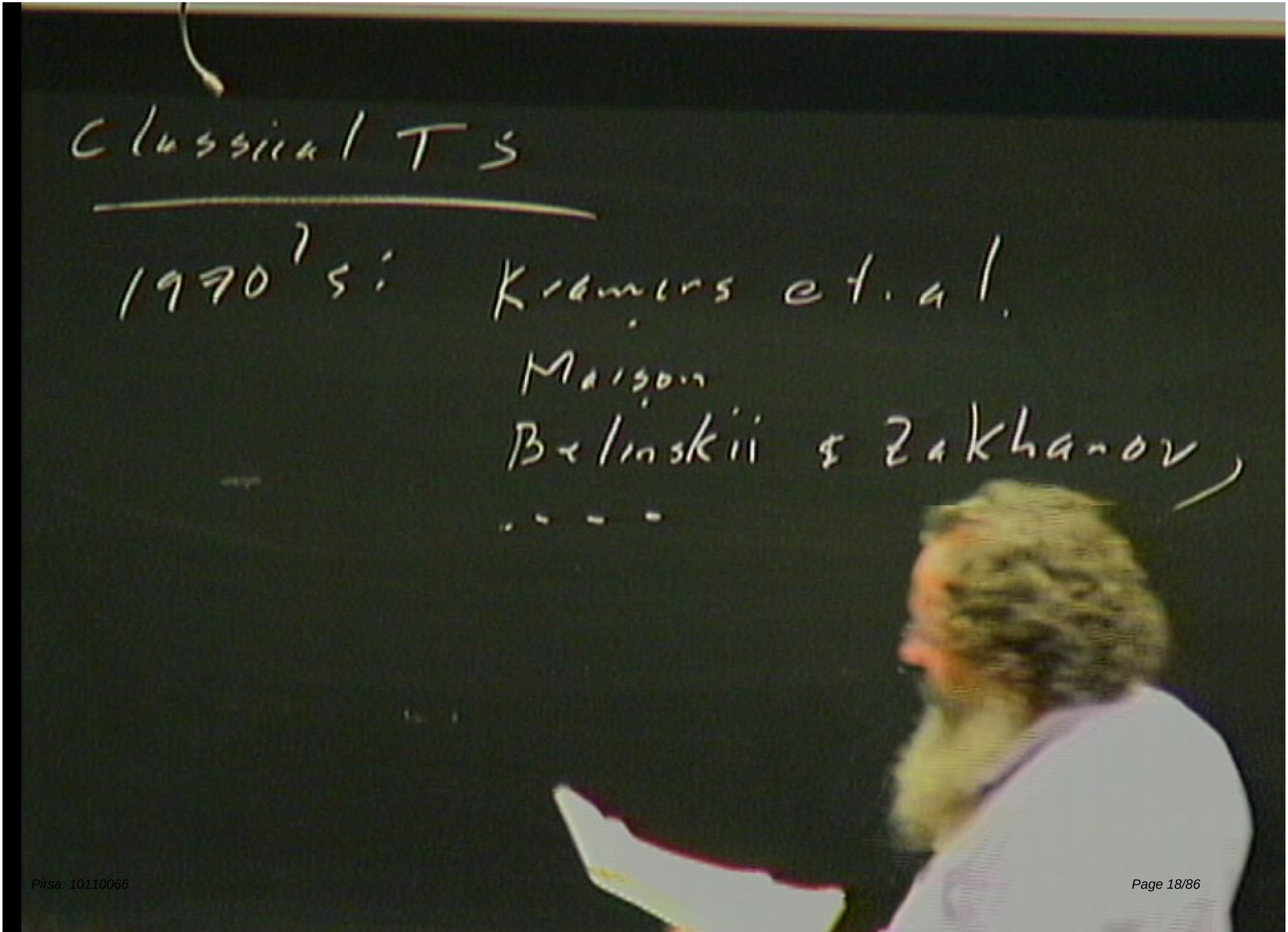
4. NHTS (NHES)

5. CFT dual description

6. Conclusions

Classical TS


Classical TS
1990's: Kramers et. al.
Maison
Belinskii & Zakharov
. . . .

Classical TS

1970's: Kramers et. al.

Maison

Belinskii & Zakharov,

. . . .

WLP metric

$$ds^2 = f^{-1}\left[e^{2k}(dt^2 + d\rho^2) + \rho^2 d\phi^2\right] + f(dt - \omega d\phi)^2$$

lussical T S

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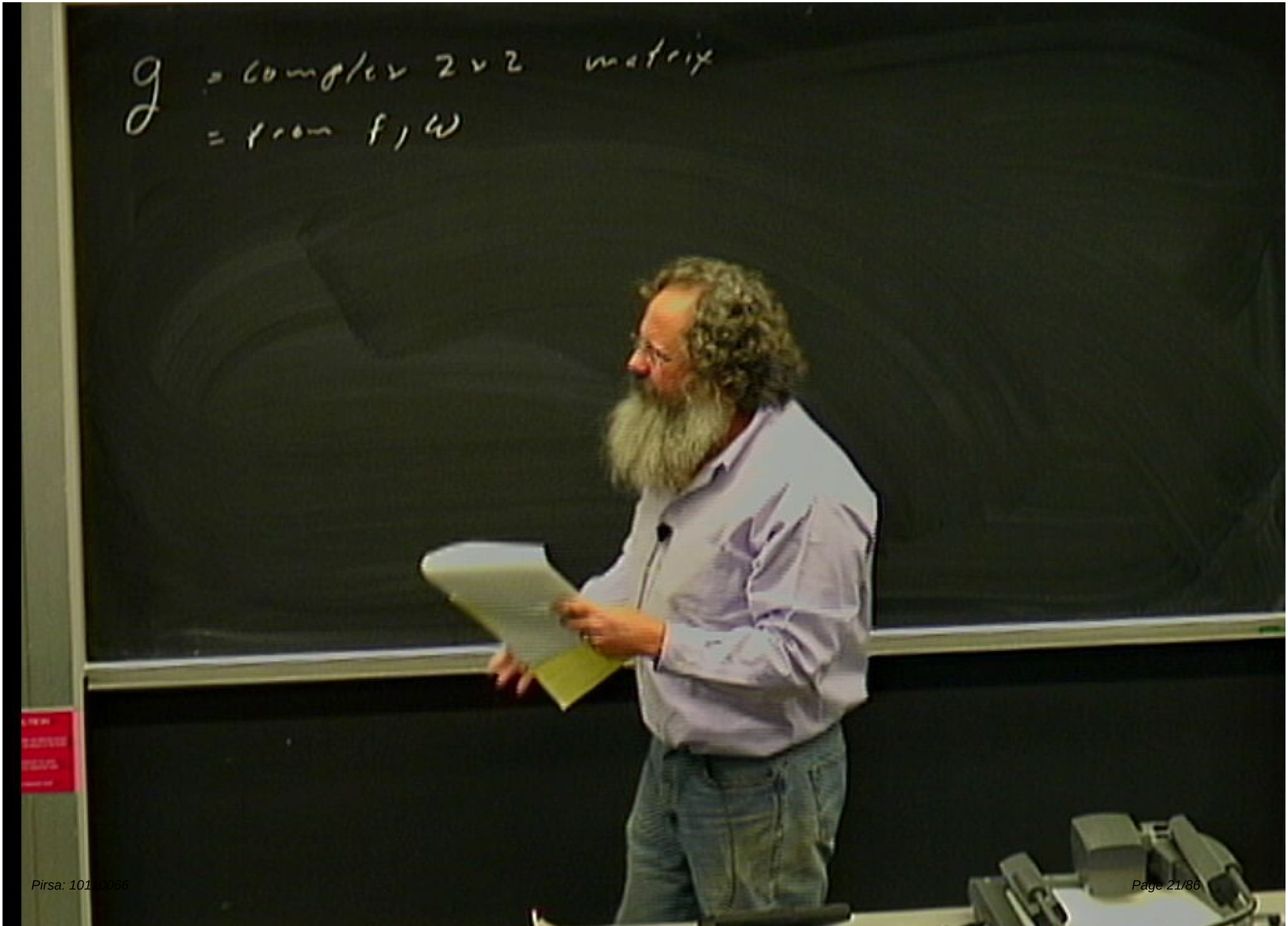
g = complex 2x2 matrix
= from f, ω

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g obeys Ernst:

$$(\rho\, g_{,\zeta}\, g^{-1})_{,\bar{\zeta}} + (\rho\, g_{,\bar{\zeta}}\, g^{-1})_{,\zeta} = 0$$

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Ernst: integrable, soliton solutions

Kerr = 1-soliton

TS = superposition of two 1-solitons

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3 real parameters: σ, p, q, $p^2+q^2=1$

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$\delta = 2$ TS

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$\delta =$ 1 soliton number

$\delta = 1$ Kerr

$\delta = 2$ TS(2)

Far field region

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Far field region

$M_{adm} = \dfrac{2\sigma}{Gp}$

$J = \dfrac{4\sigma^2 q}{Gp^2} = q\, G\, M_{adm}^2.$

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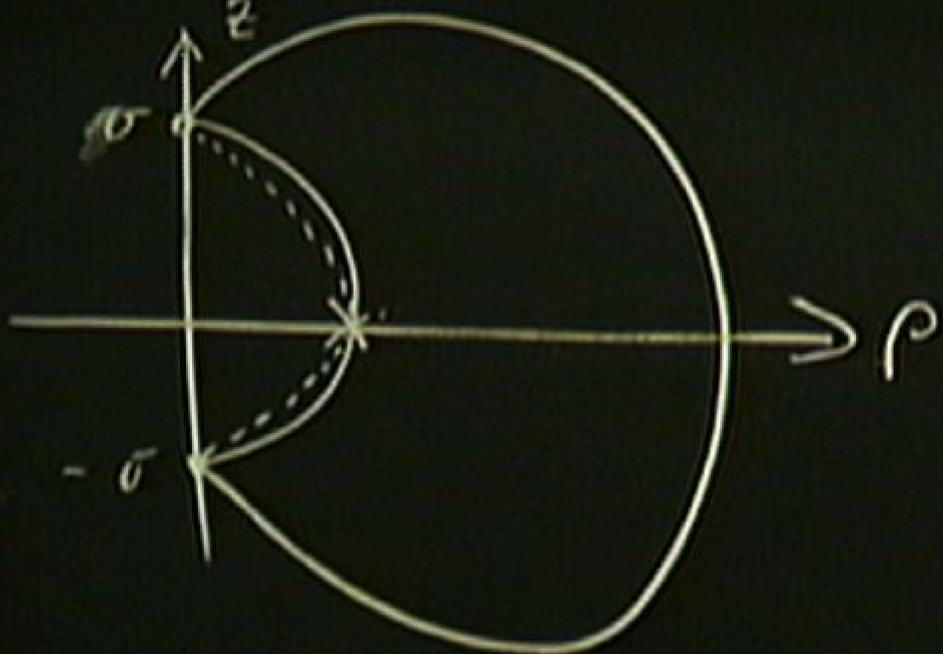
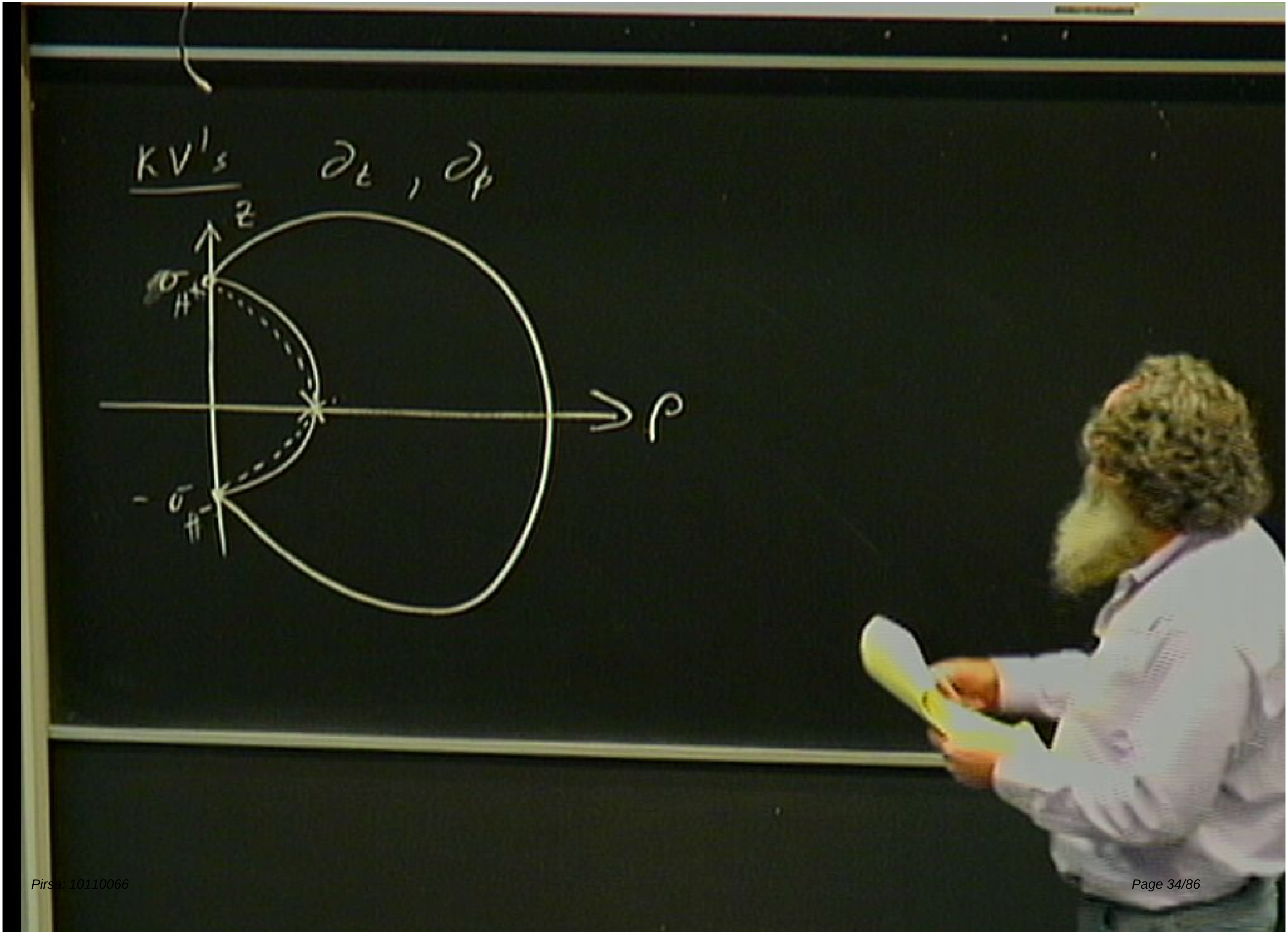
$\underline{KV's}$ ∂_t , ∂_ϕ

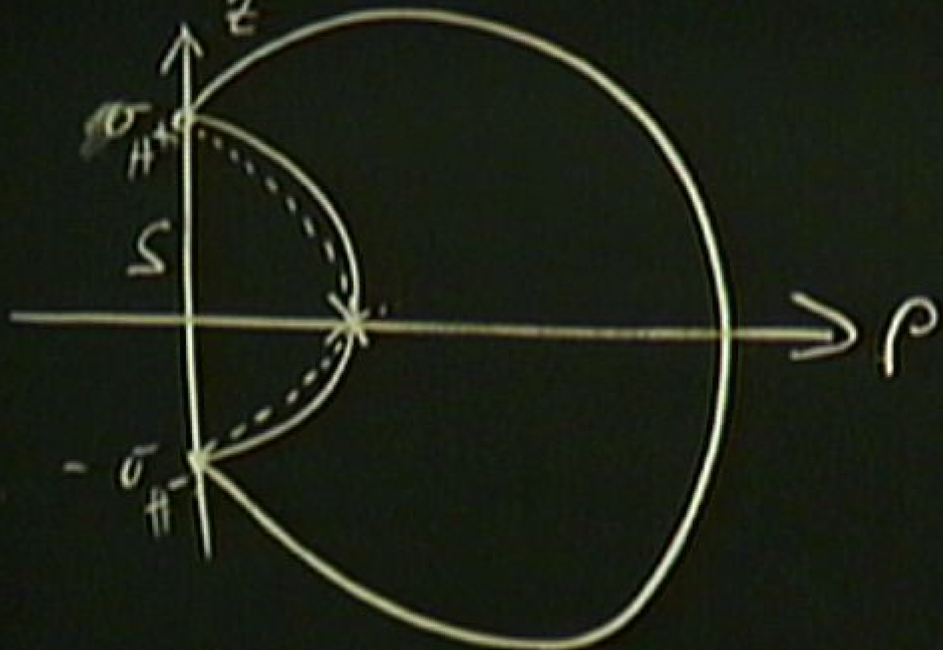



KV's
∂_t , ∂_ϕ
z
ρ
σ_{H^+}
$-\sigma_{H^-}$

KV's ∂_t, ∂_ϕ

$H^\pm$ Killing horizon

S strut



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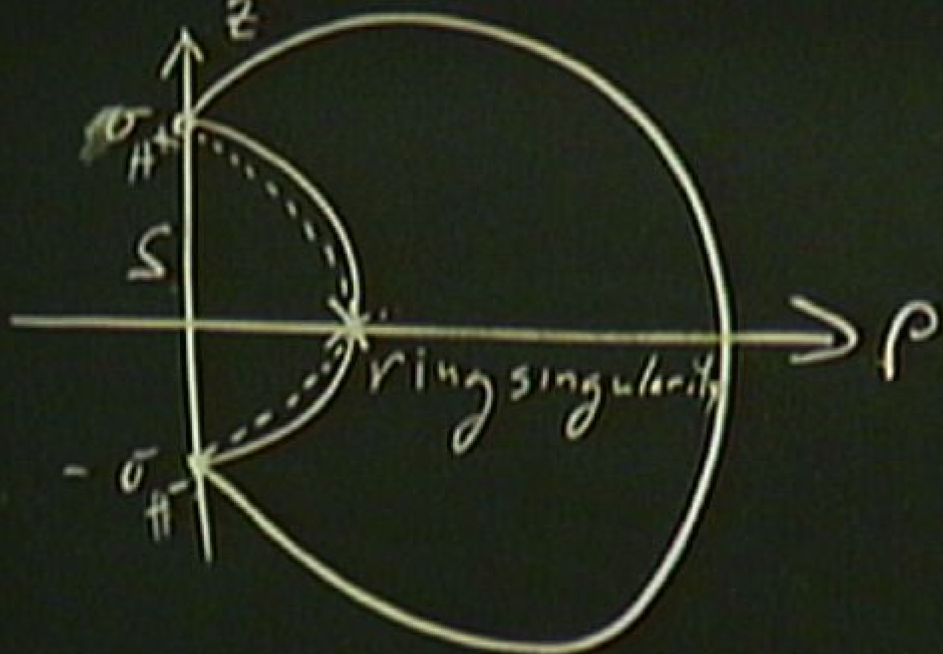

KV's ∂_t , ∂_ϕ

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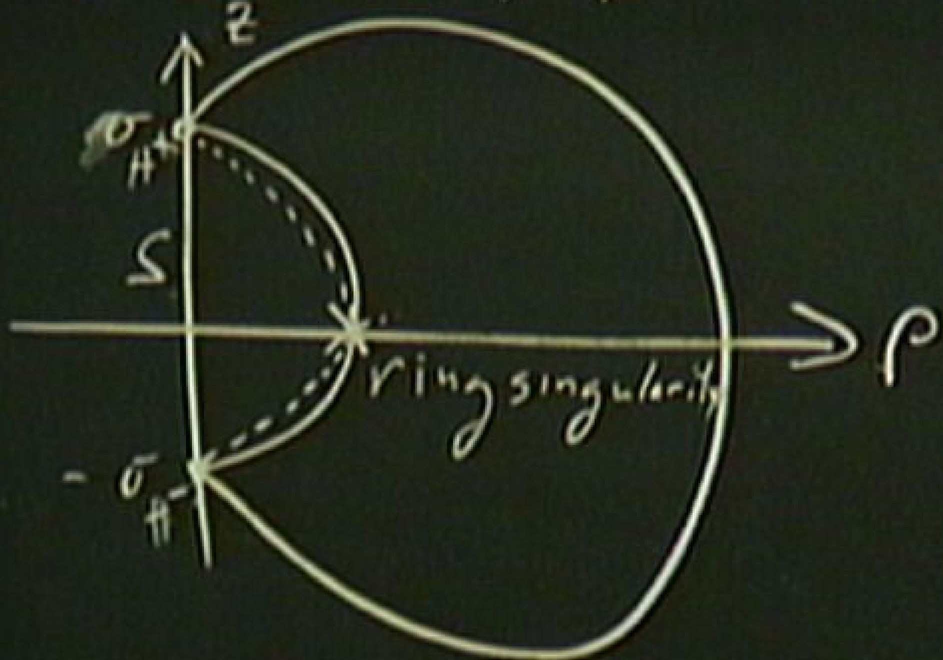
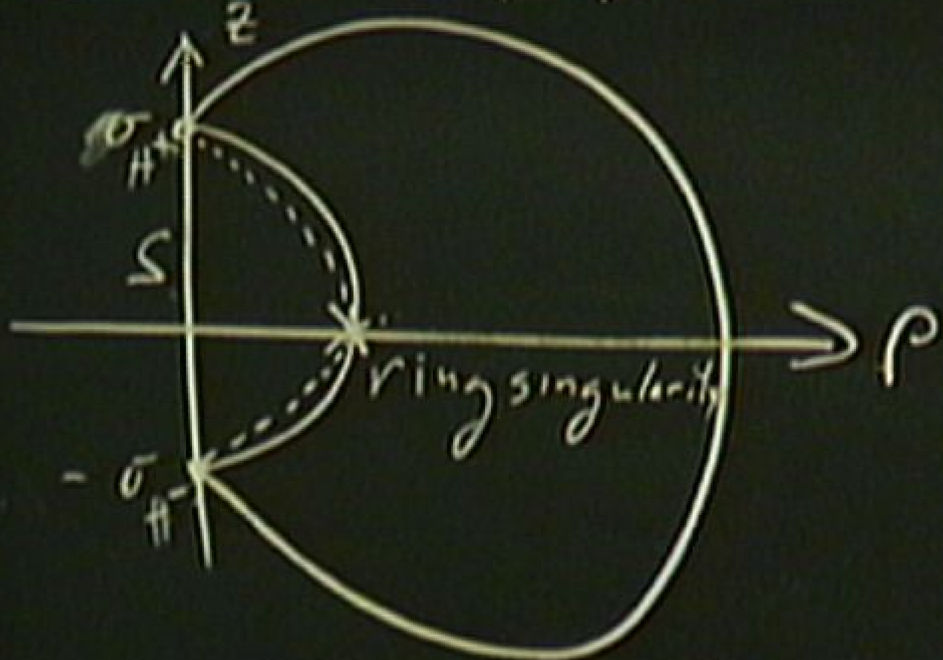
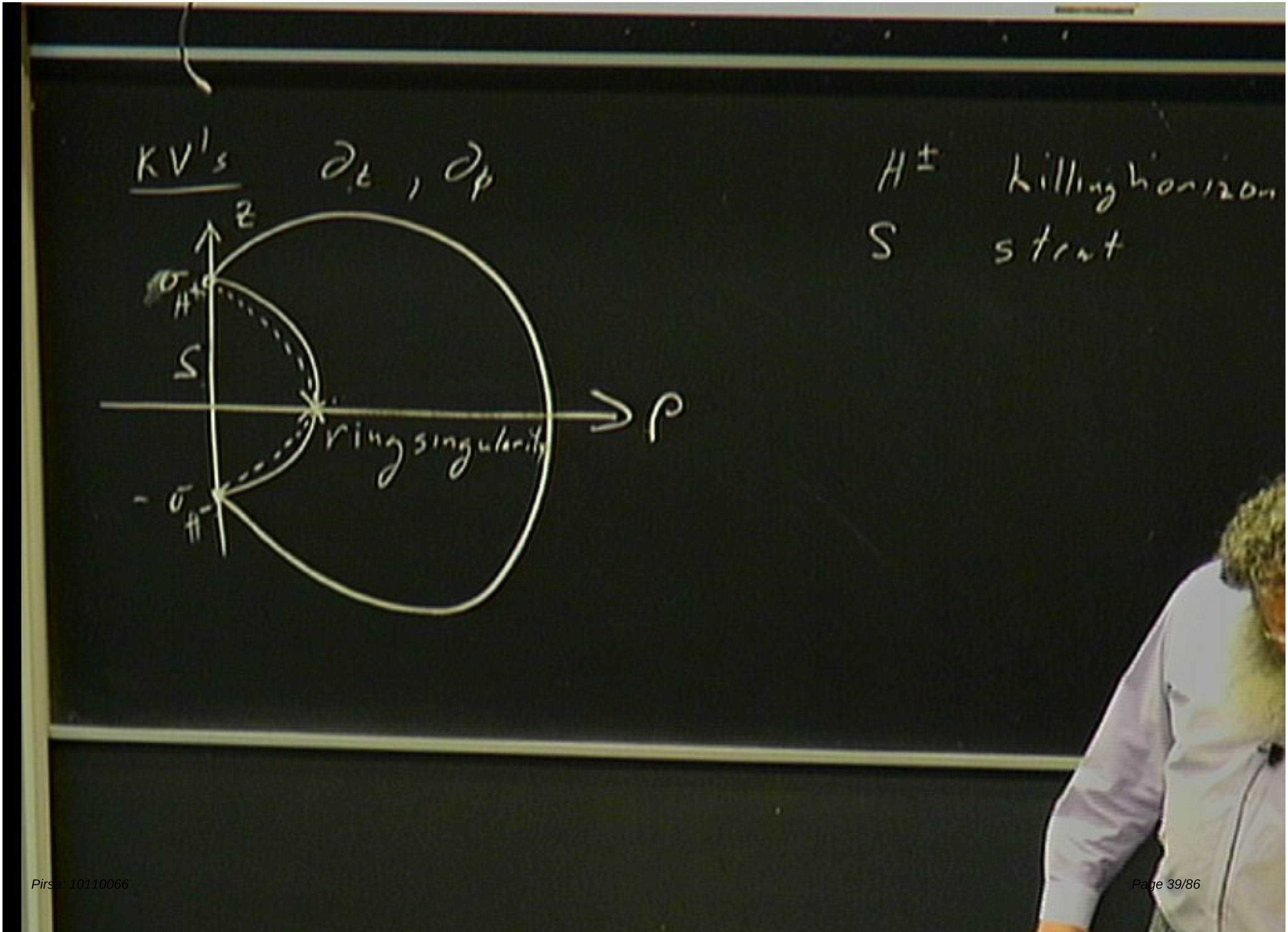


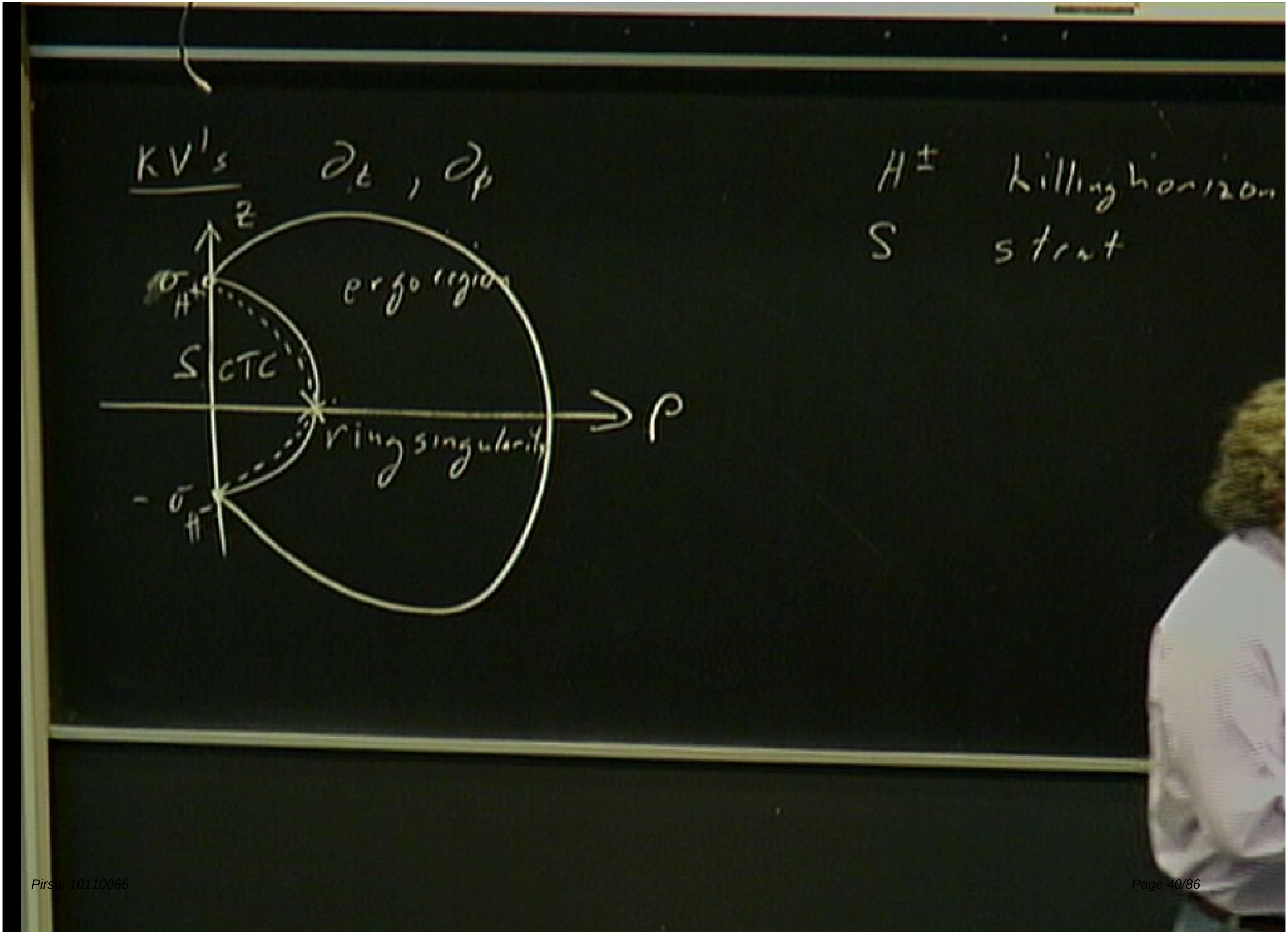
KV's $\partial_t\,,\ \partial_\phi$

$H^\pm$ killing horizon

S strut




KV's
∂_t , ∂_ϕ
$H^\pm$ Killing horizon
S strut
z
ρ
σ_{H^+}
S
ring singularity
$-\sigma_{H^-}$


KV's
∂_t , ∂_φ
H^± Killing horizon
S strut
z
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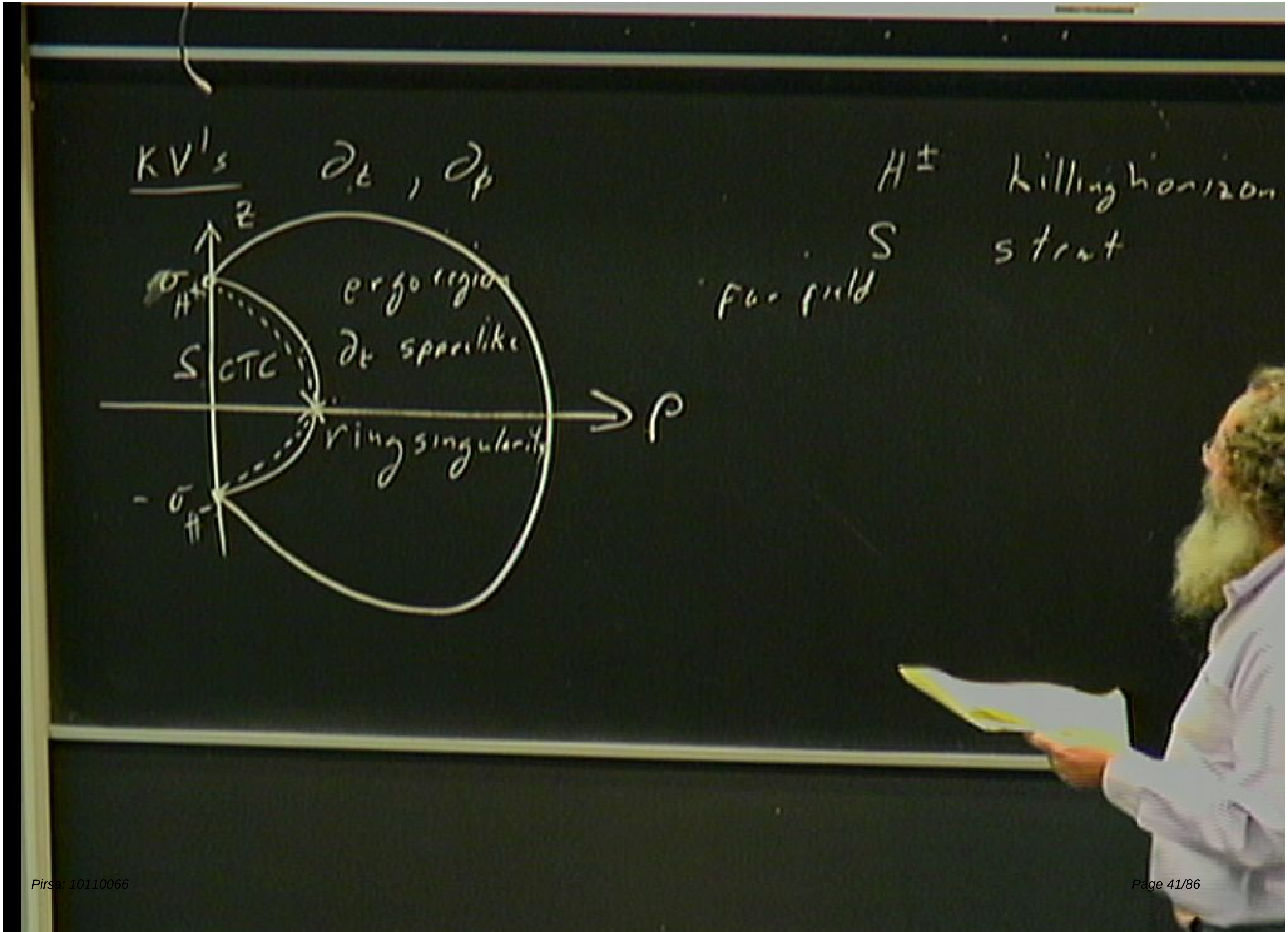
KV's ∂_t , ∂_ϕ
$H^\pm$ Killing horizon
S strut
far field
z
σ_{H^+}
ergoregion
∂_t spacelike
S
CTC
ρ
ring singularity
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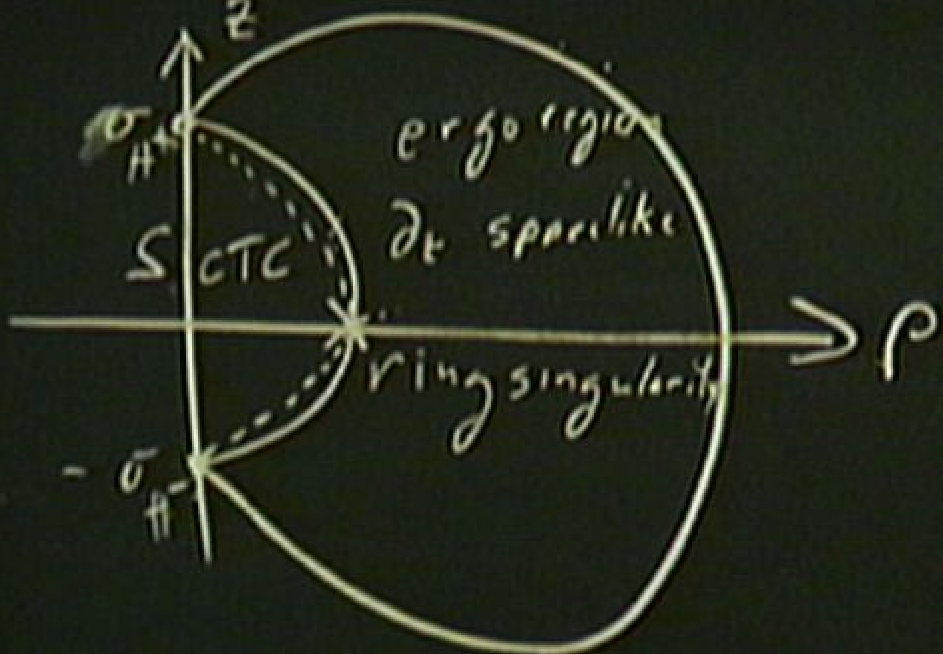
KV's ∂_t , ∂_ϕ

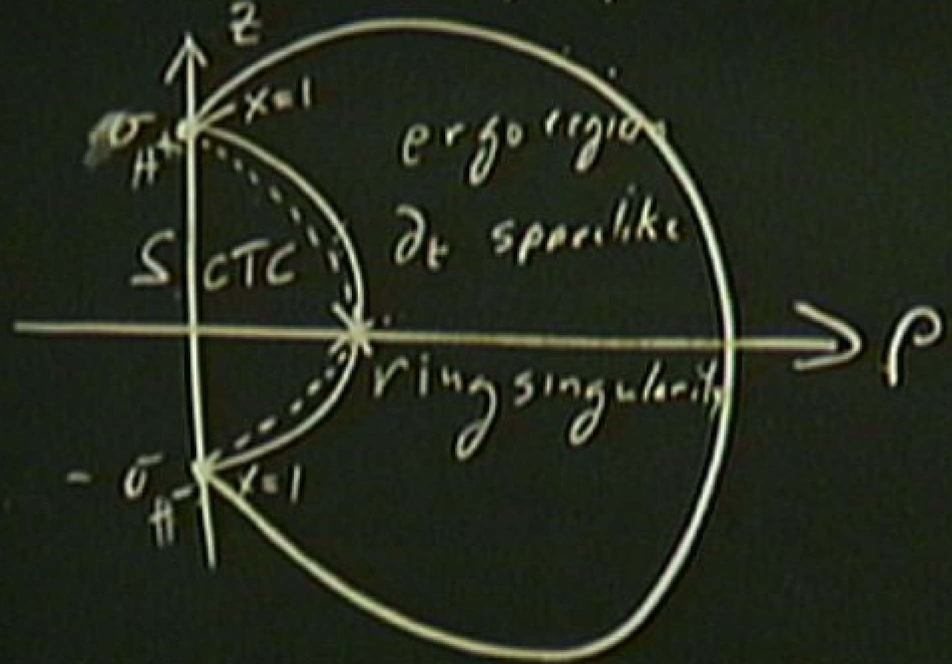
$H^\pm$ killing horizon

S strut

far field



$\underline{KV's}$ ∂_t , ∂_ϕ



$H^\pm$ Killing horizon

S strut

Far field

Compute Komar Mass/Ang.

$x, y \longleftrightarrow \rho, t$

prolate

$x = x_0 > 1$

$\partial\Sigma = \{x = x_0 > 1\}$

$M_{x_0} = M_{ADM}$. | All mass & ang. mom. contained

$J_{x_0} = J_{ADM}$. | inside $H^{\pm}$, S.

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$J_{x_0} = J_{ADM}$ | inside $H^{\pm}$, S.

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$M_S = M_{adm}$ | $J_S = \left(1 - \frac{\rho}{2}\right) J_{adm}$.

$J_I = \frac{\sigma^2}{G\rho} \cdot \sqrt{\frac{1+\rho}{1-\rho}}$

$M_{X_0} = M_{ADM}$

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All mass & ang. mom. contained inside $H^{\pm}$, S.

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Kerr characterized by M & J

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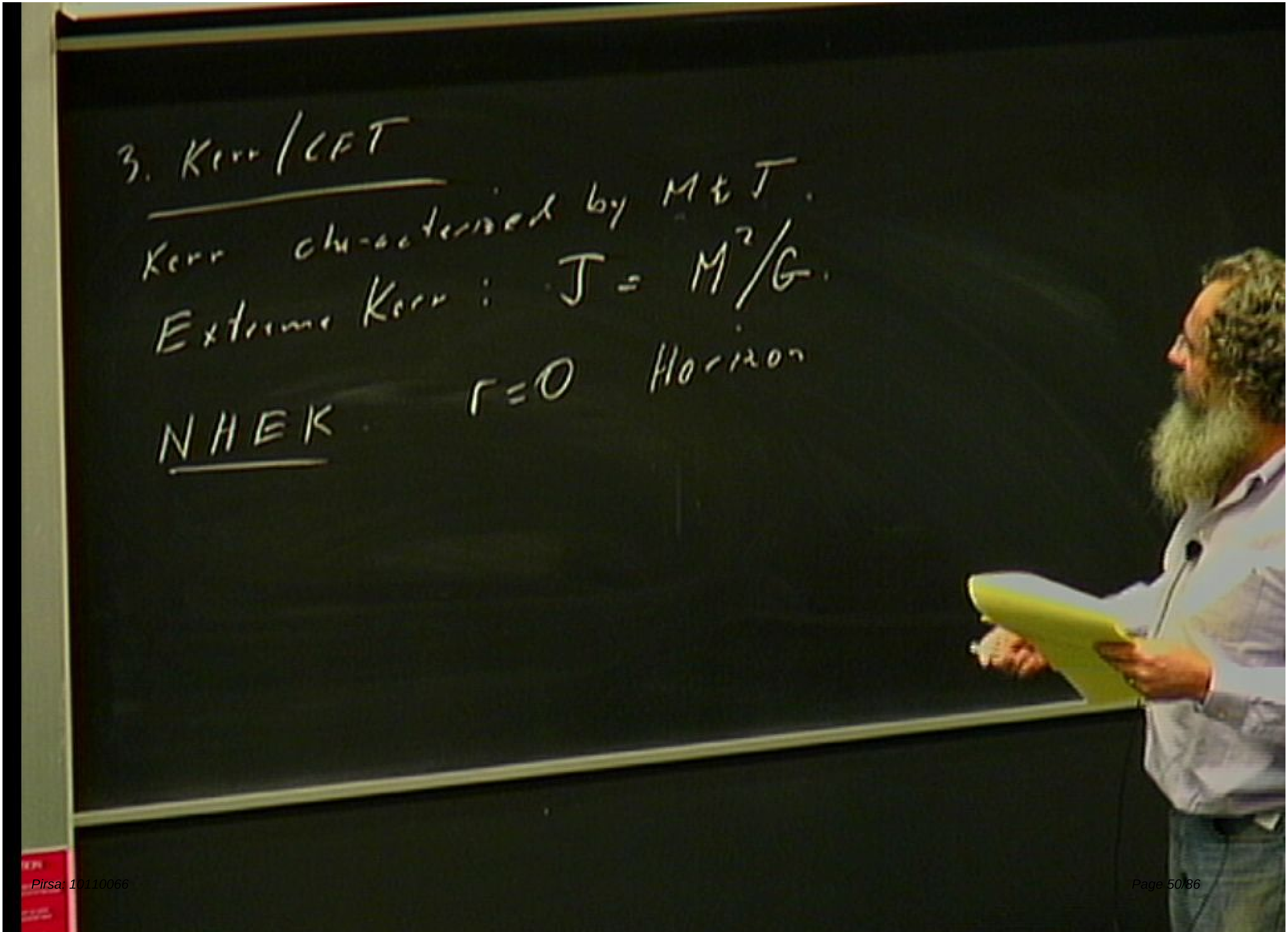
Extreme Kerr : $J = M^2/G$.

NHEK.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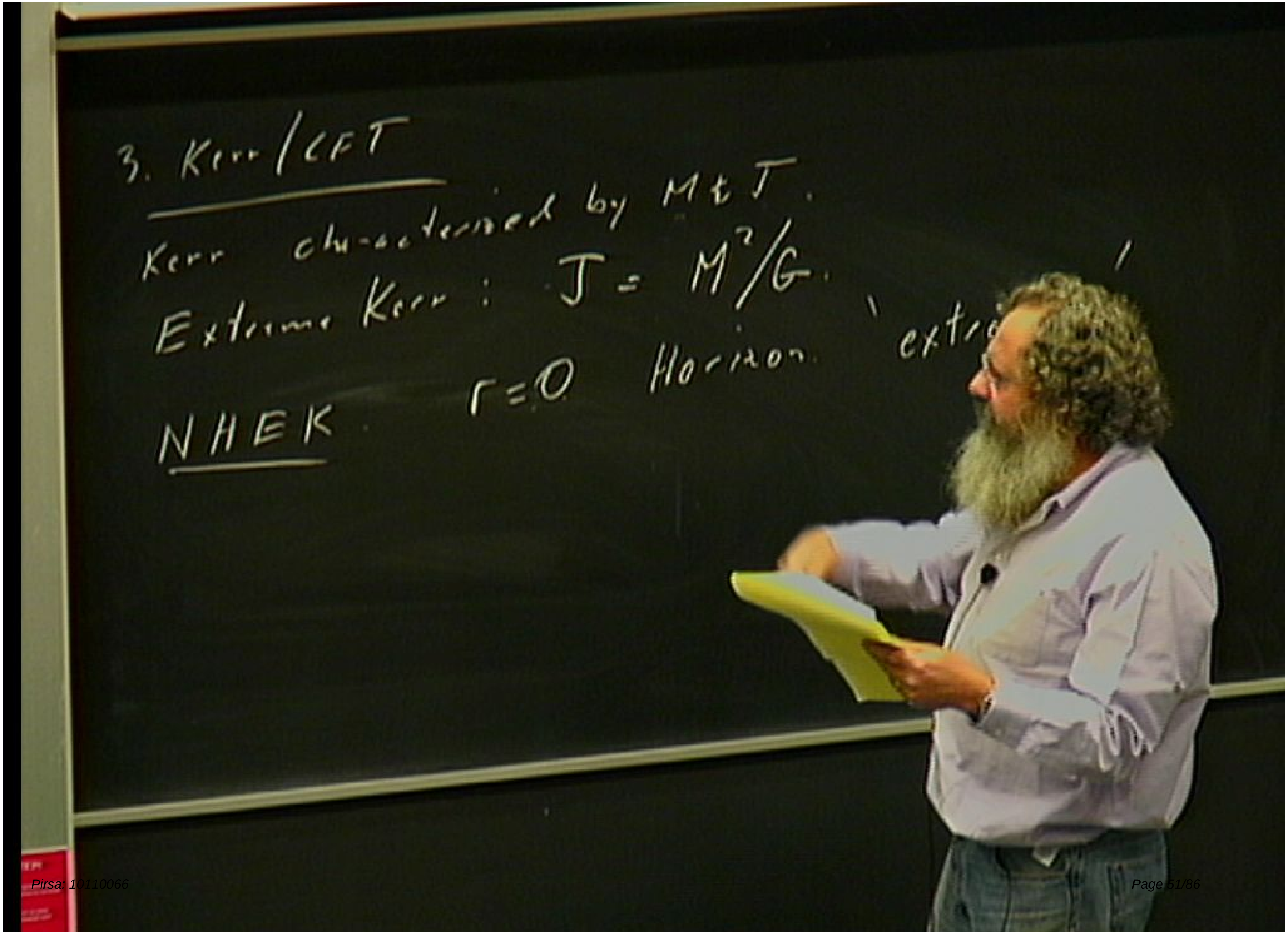
Kerr characterised by M & J.
Extreme Kerr: J = M²/G.
r=0 Horizon
NHEK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Extreme Kerr: J = M²/G.
r=0 Horizon
NHEK

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Kerr characterised by M & J.

Extreme Kerr : $J = M^2/G$. 'extremal'

$r=0$ Horizon

NHEK

$$ds^2 = \left(\frac{1+\cos^2\theta}{2}\right)\left[-\frac{r^2}{r_0^2}dt^2 + \frac{r_0^2}{r^2}dr^2 + r_0^2 d\theta^2\right] + \frac{2r_0\sin^2\theta}{(1+\cos^2\theta)}\left[d\phi + \frac{r}{r_0}dt\right]^2$$

Symm. group is $(SL(2,\mathbb{R}) \times U(1))$

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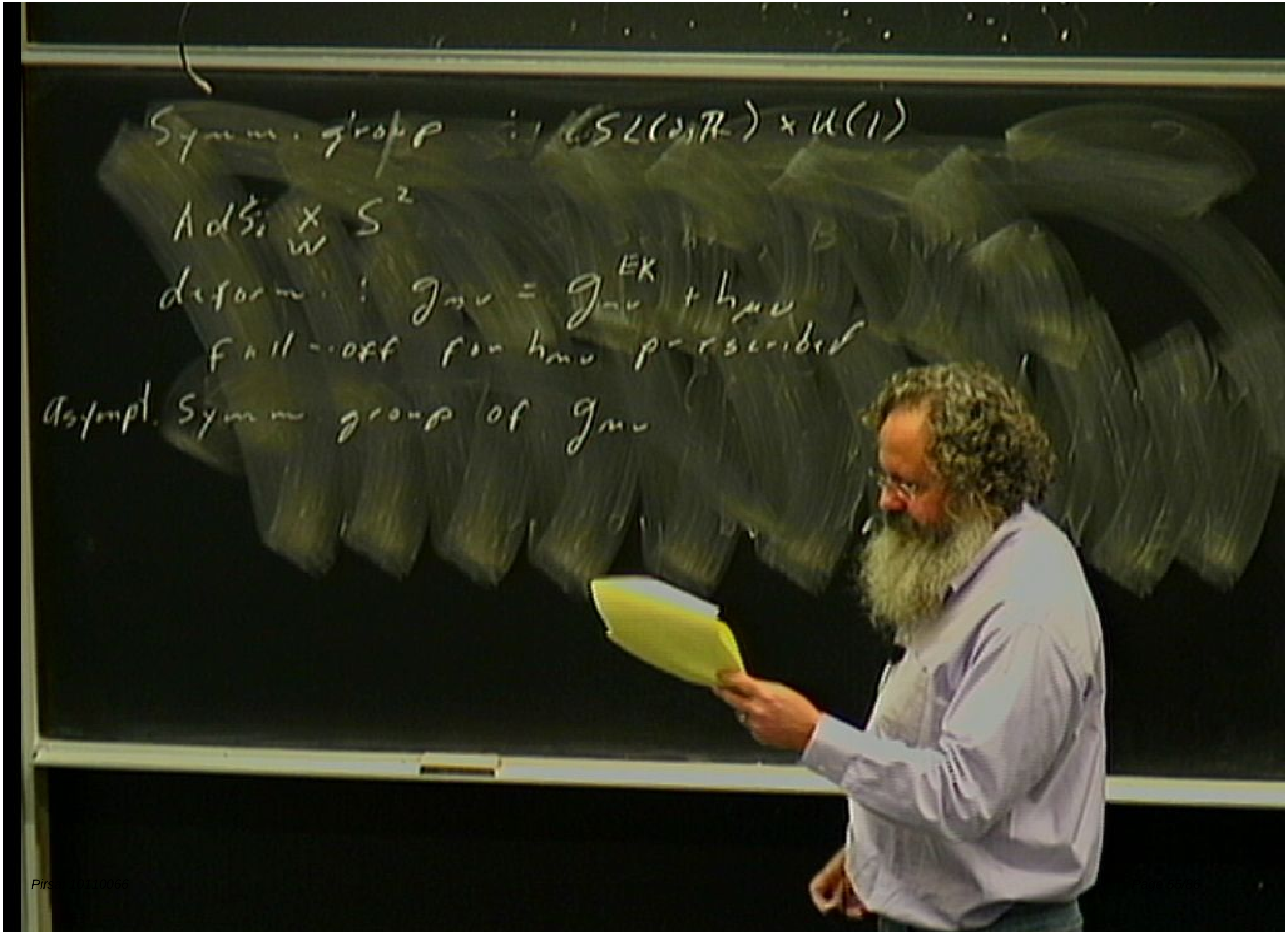
$AdS_2 \times_w S^2$

deform: $g_{\mu\nu} = g^{EK}_{\mu\nu} + h_{\mu\nu}$


Symm. group is (SL(2,R) × U(1))
$AdS_2 \times_w S^2$
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fall-off for $h_{\mu\nu}$ prescribed
asympt. symm group of $g_{\mu\nu}$

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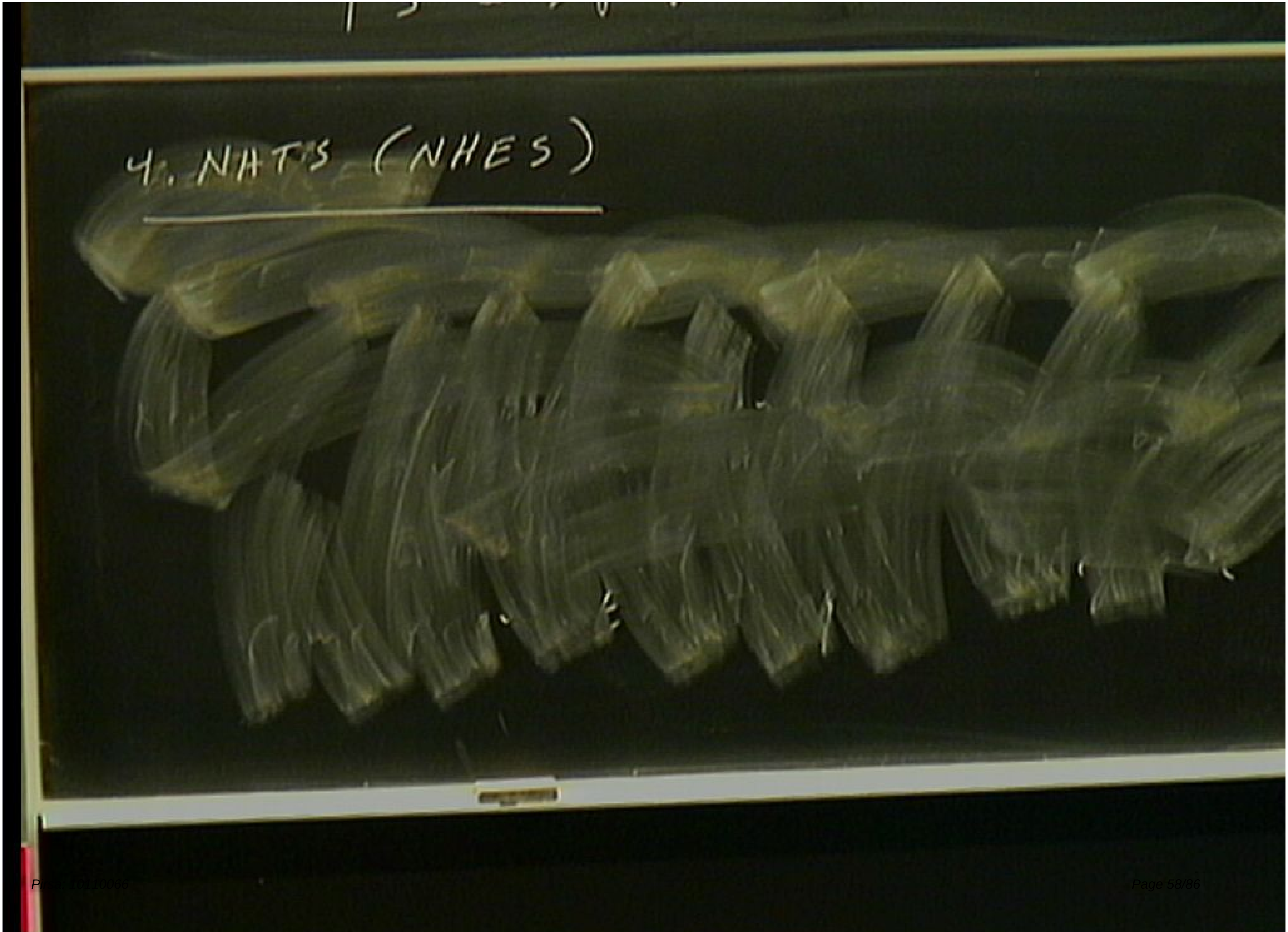
central charge

$C_R = 0$, $C_L = \frac{12 J}{\hbar}$

CFT in asympt. region of NHEK.


4. NATS (NHES)

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'bipolar coords' $(\bar{r}, \bar{\theta}) \longleftrightarrow (x, y)$ prolate

$$x^2 = \frac{\sigma}{\sigma - \sqrt{2}\,\bar{r}\cos^2\theta/2}, \quad y^2 = \frac{\sigma - \sqrt{2}\,\bar{r}}{\sigma - \sqrt{2}\,\bar{r}\cos^2\theta/2}$$

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Expand around $\bar{r} = 0$

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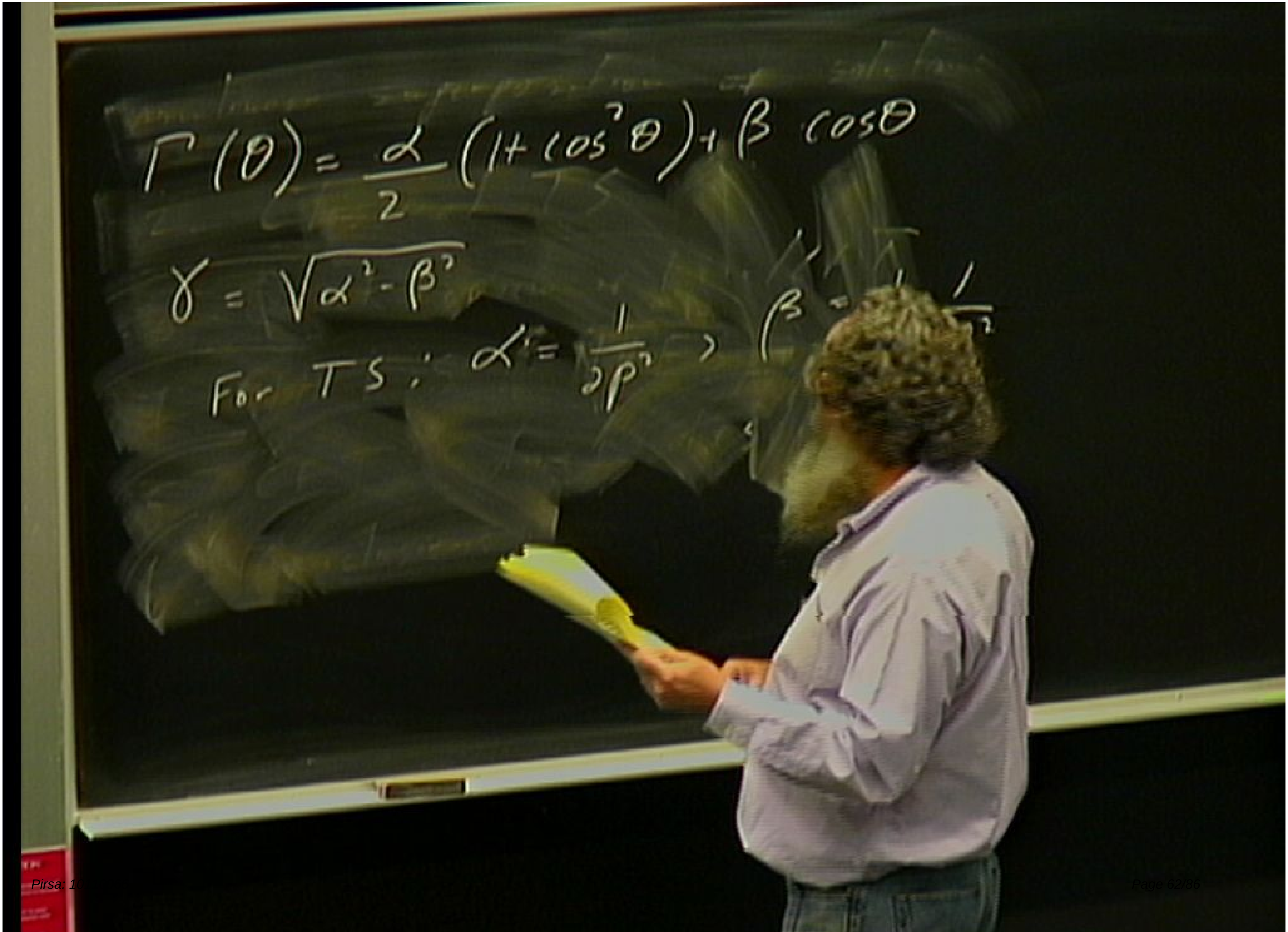
Expand around $\bar r = 0$ | $H^\pm$

$$ds^2 = \Gamma(\theta)\left[-\frac{\bar r^2}{r_0} dt^2 + \frac{r_0^2}{\bar r^2} d\bar r^2 + r_0^2 d\theta^2\right] + \frac{\sin^2\theta}{\Gamma(\theta)}\left(\frac{\gamma \bar r}{r_0} d\bar t - r_0 d\phi\right)^2$$


$\Gamma(\theta) = \frac{\alpha}{2}(1+\cos^2\theta) + \beta\cos\theta$
$\gamma = \sqrt{\alpha^2 - \beta^2}$
For TS: $\alpha = \frac{1}{2\rho^2}$

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$$r_0^2 = \sqrt{\frac{2\sigma}{\rho}\sqrt{\rho+1}} = \sqrt{2\gamma J_\Delta}$$

J_Δ = ang. mom on horizon

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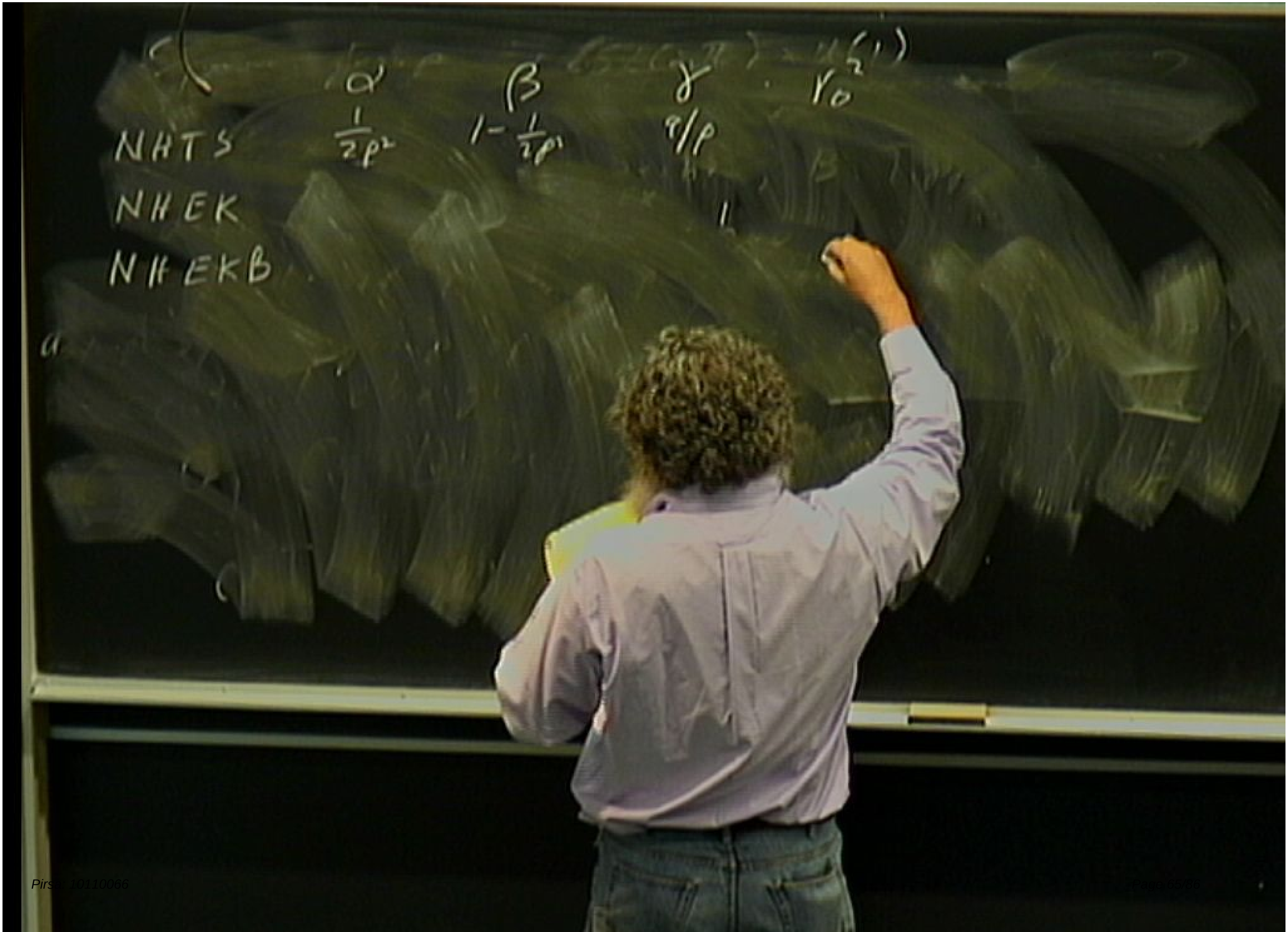
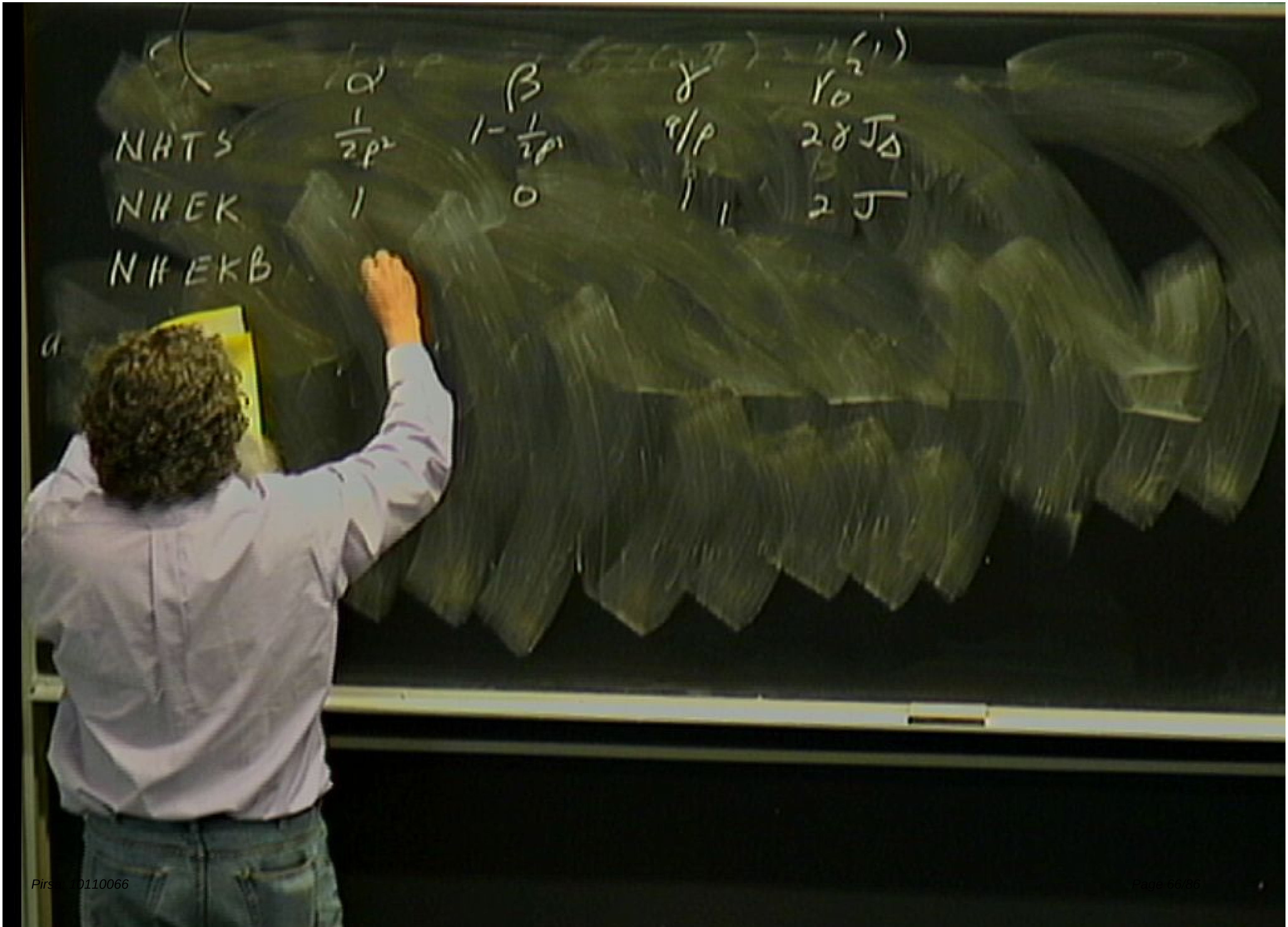
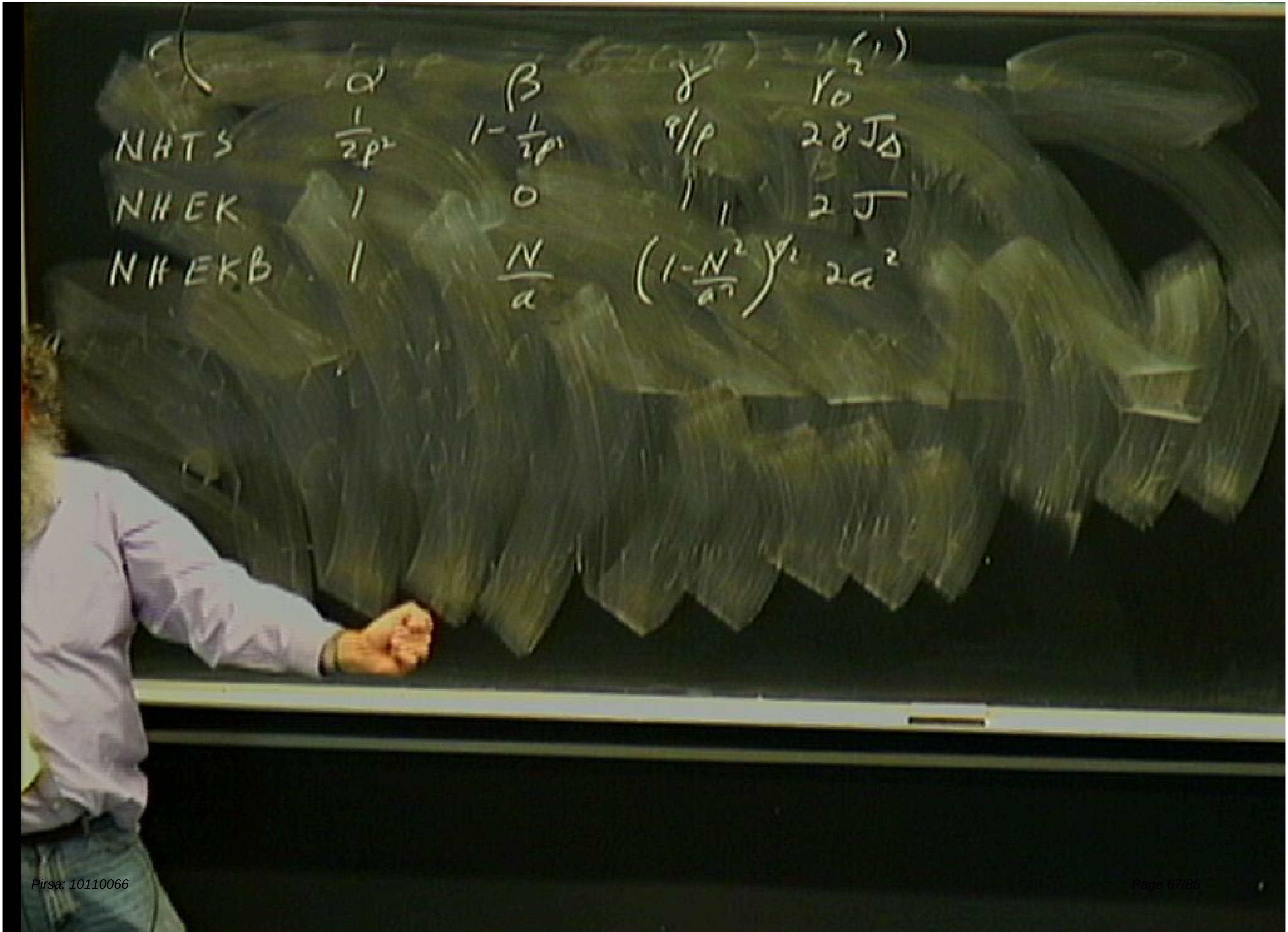
horizon

conical deficit $= 2\pi\left[1 + (\alpha \pm \beta)\right]$


α β γ r_0^2
NHTS 1/2ρ² 1 − 1/2ρ² q/ρ
NHEK
NHEKB


α β γ r0
NHTS 1/2ρ² 1 − 1/2ρ² q/ρ 2γJΔ
NHEK 1 0 1 2J
NHEKB



	α	β	γ	r_0^2
NHTS	$\frac{1}{2\rho^2}$	$1-\frac{1}{2\rho^2}$	q/ρ	$2\gamma J_\Delta$
NHEK	1	0	1	$2J$
NHEKB	1	$\frac{N}{a}$	$\left(1-\frac{N^2}{a^2}\right)^{1/2}$	$2a^2$

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NHES: $R_{\mu\nu} = 0$

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$$A_{\Delta\,(r_0,\ldots)} = 4\pi\left[G^2 M^2 + \sqrt{G^4 M^4 - G^2 J^2}\right] = \frac{1}{2} A^{Kerr}$$

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NHES	α	β	γ	r_0^2
NHTS	$\frac{1}{2p^2}$	$1-\frac{1}{2p^2}$	q/p	$2\gamma J_\Delta$
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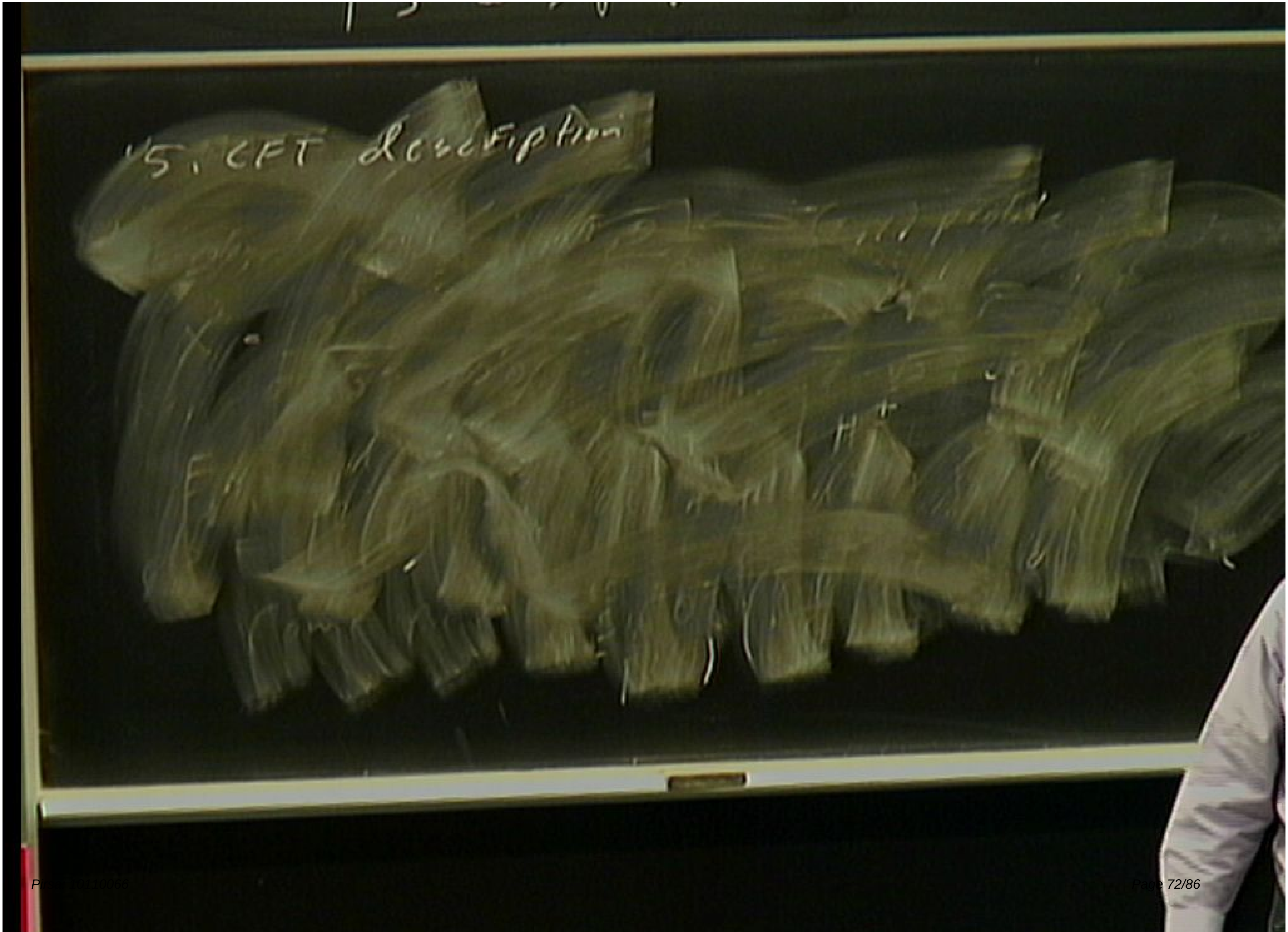
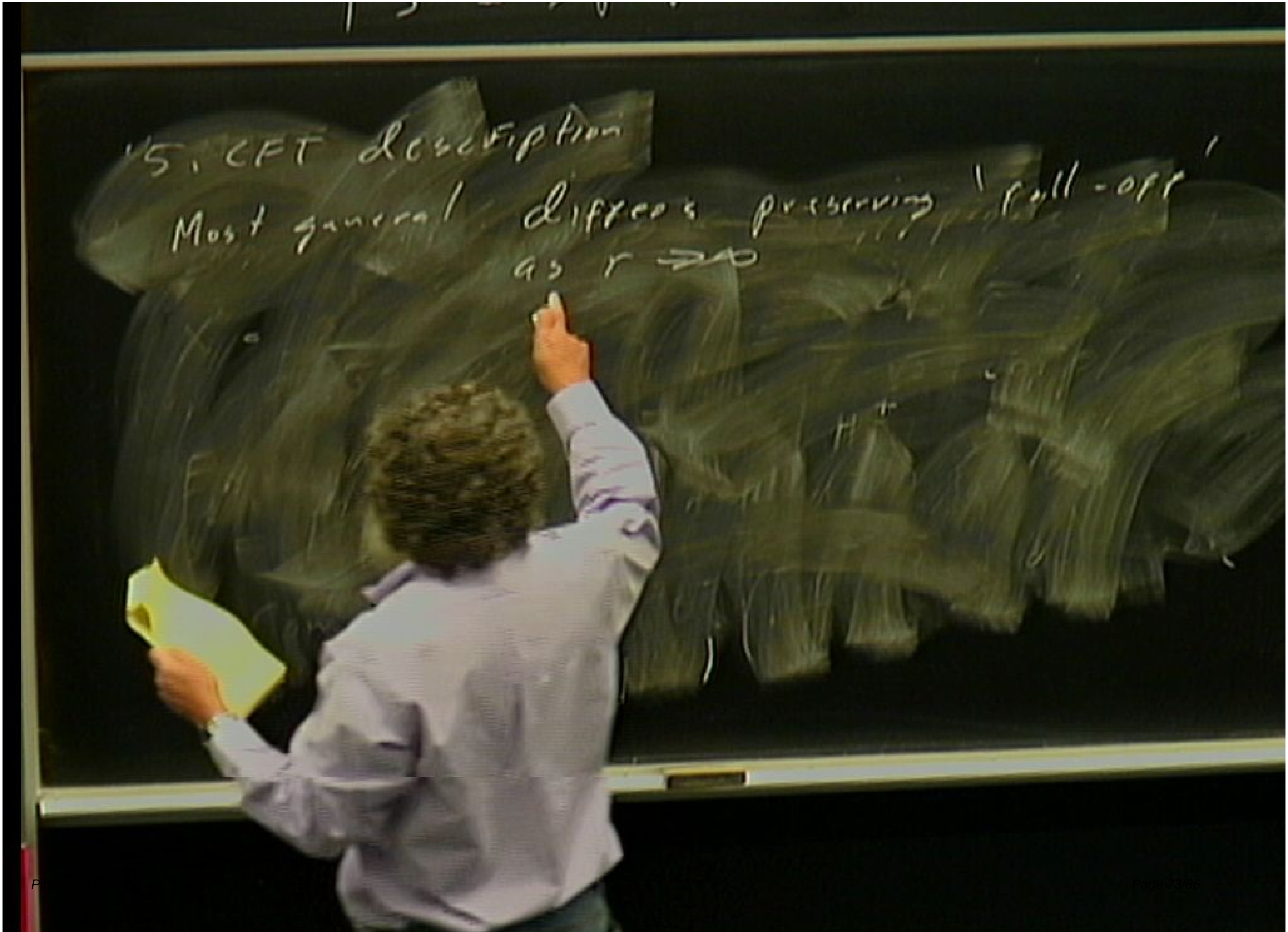
NHTS: $A_\Delta = 4\pi r_0^2$

$$A_{\Delta(r_0, 1, 1)} = 4\pi \left[G^2 M^2 + \sqrt{G^4 M^4 - G^2 J^2} \right] = \frac{1}{2} A^{\mathrm{Kerr}}$$


5. CFT Description


5. CFT description
Most general diffeos preserving 'fall-off'
as r →

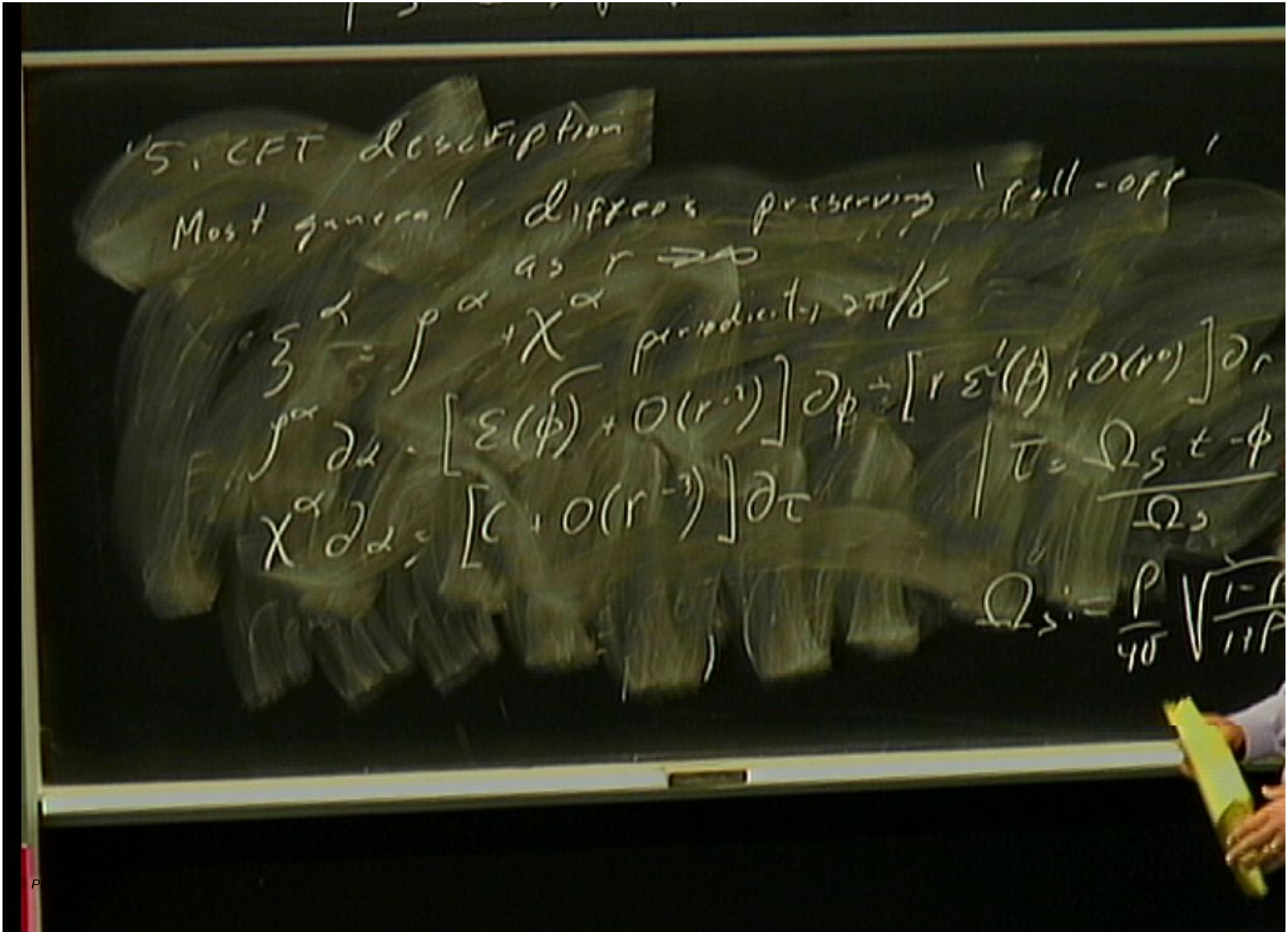
5. CFT Description

Most general diffeos preserving 'fall-off' as $r \to \infty$

$$\xi^\alpha = f^\alpha + \chi^\alpha$$

$$f^\alpha \partial_\alpha = \left[\varepsilon(\phi) + O(r^{-1})\right]\partial_\phi + \left[r\,\varepsilon'(\phi) + O(r^{0})\right]\partial_r$$

$$\chi^\alpha \partial_\alpha = \left[C + O(r^{-1})\right]\partial_\tau$$



§5. CFT description
Most general diffeos preserving 'fall-off' as $r \to \infty$
$\xi^\alpha = \rho^\alpha + \chi^\alpha$ periodicity $2\pi/\gamma$
$\rho^\alpha \partial_\alpha = [\varepsilon(\phi) + O(r^{-1})]\partial_\phi + [r\varepsilon'(\phi) + O(r^0)]\partial_r$
$\chi^\alpha \partial_\alpha = [c + O(r^{-1})]\partial_\tau$
$\tau = \frac{\Omega_s t - \phi}{\Omega_s}$
$\Omega_s = \frac{\rho}{4\pi}\sqrt{\frac{1-\ldots}{1+\ldots}}$

§5. CFT Description

Most general diffeos preserving 'fall-off' as $r \to \infty$

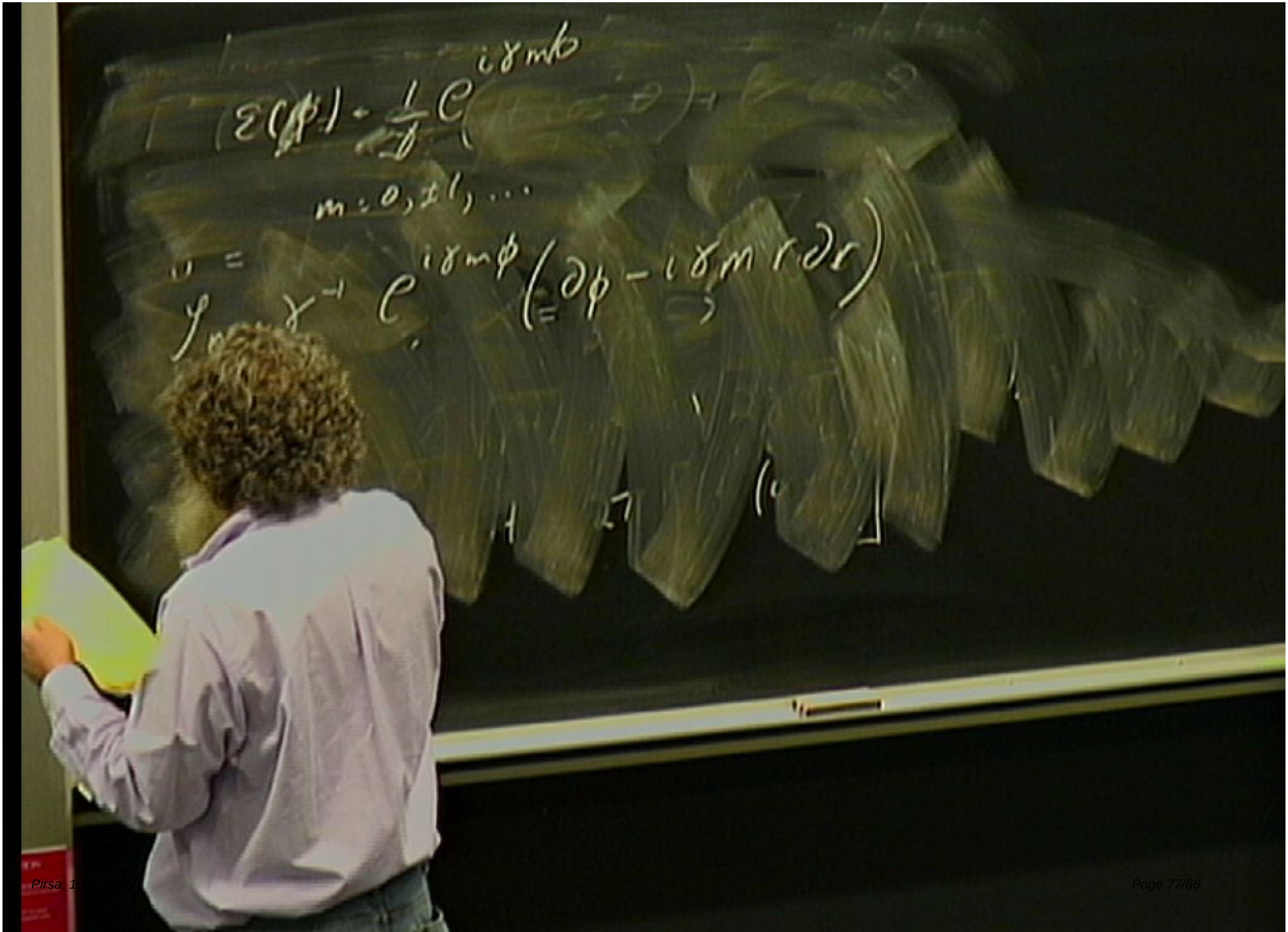
$$\xi^\alpha = \rho^\alpha + \chi^\alpha \qquad \text{periodicity } 2\pi/\gamma$$

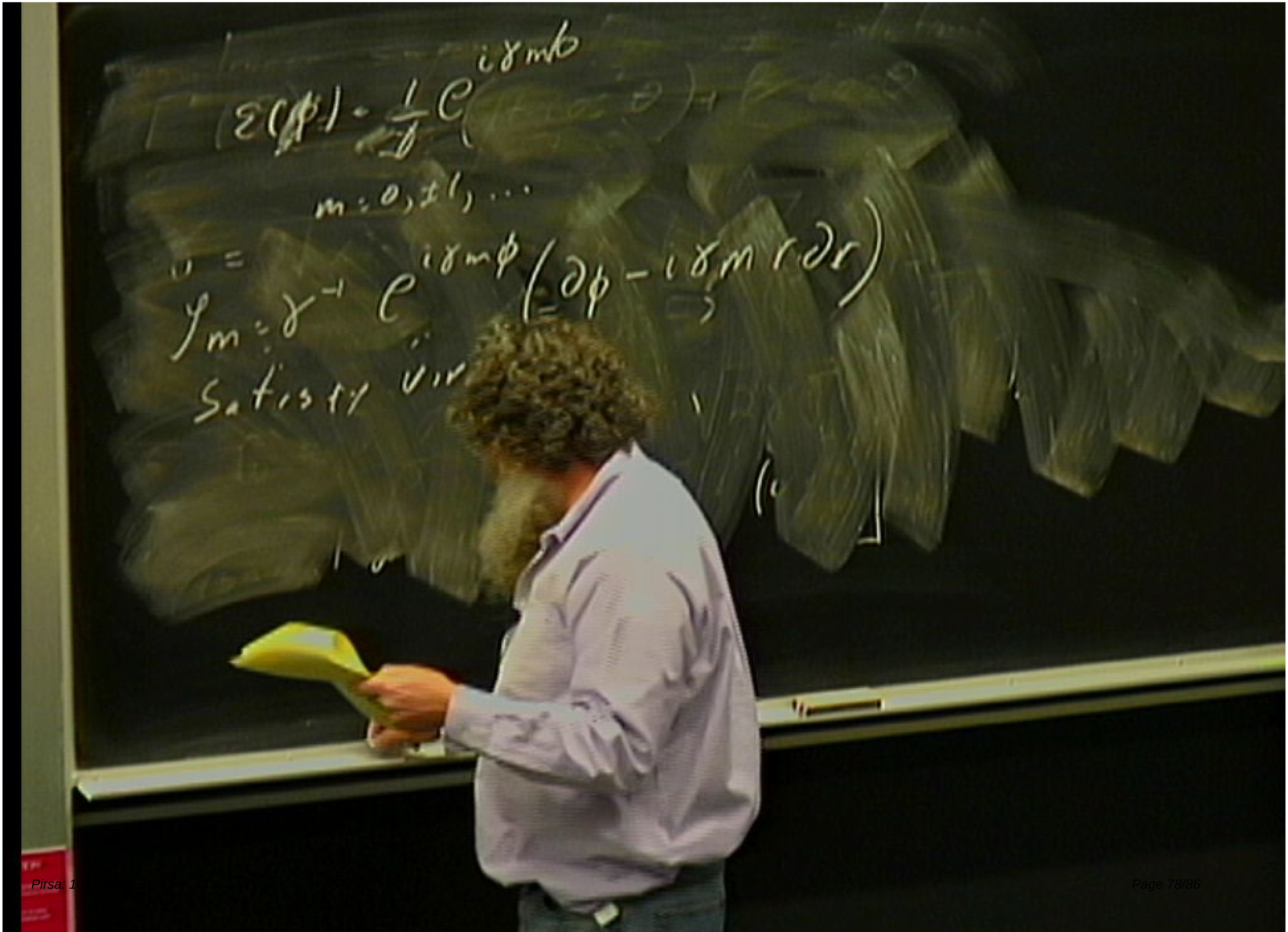
$$\rho^\alpha \partial_\alpha = [\epsilon(\phi) + O(r^{-1})]\partial_\phi - [r\epsilon'(\phi) + O(r^{0})]\partial_r$$

$$\chi^\alpha \partial_\alpha = [C + O(r^{-3})]\partial_\tau$$

$$\tau = \frac{\Omega_s t - \phi}{\Omega_s}$$

$$\Omega_s = \frac{\rho}{4\pi}\sqrt{\frac{1-\ldots}{1+\ldots}}$$


$m = 0, \pm 1, \ldots$
$e^{i\gamma m\phi}(\partial\phi - i\gamma m\, r\, \partial r)$

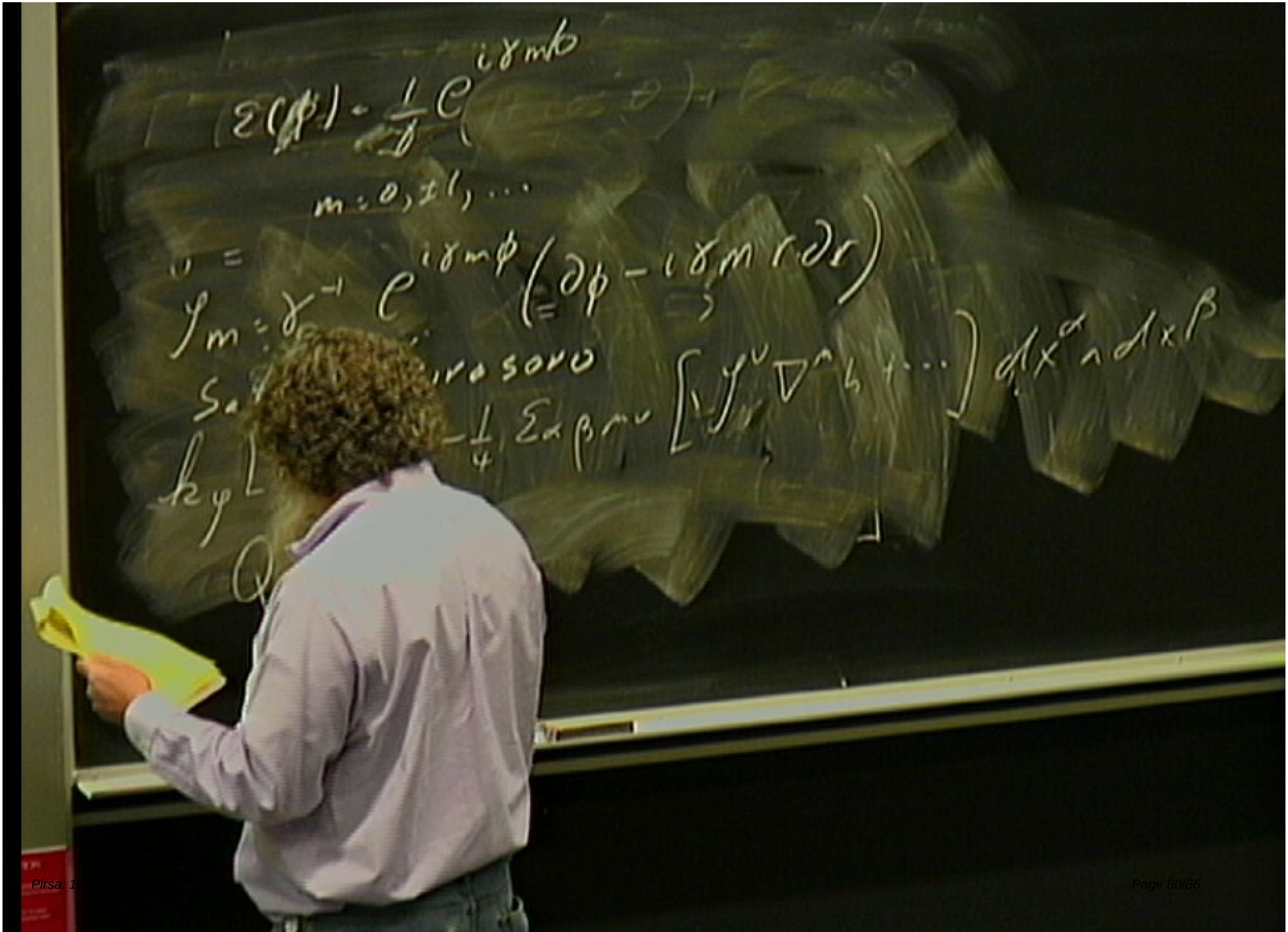

m = 0, ±1, ...
Satisfy

$\mathcal{E}(\phi) = \frac{1}{\gamma} e^{i\gamma m\phi}$

$m = 0, \pm 1, \ldots$

$\ell_m = \gamma^{-1} e^{i\gamma m\phi}\left(\partial_\phi - i\gamma m r \partial_r\right)$

Satisfy Virasoro


m = 0, ±1, ...
irasoro

$$\Sigma(\phi) = \frac{1}{\gamma} e^{i\gamma m \phi}$$

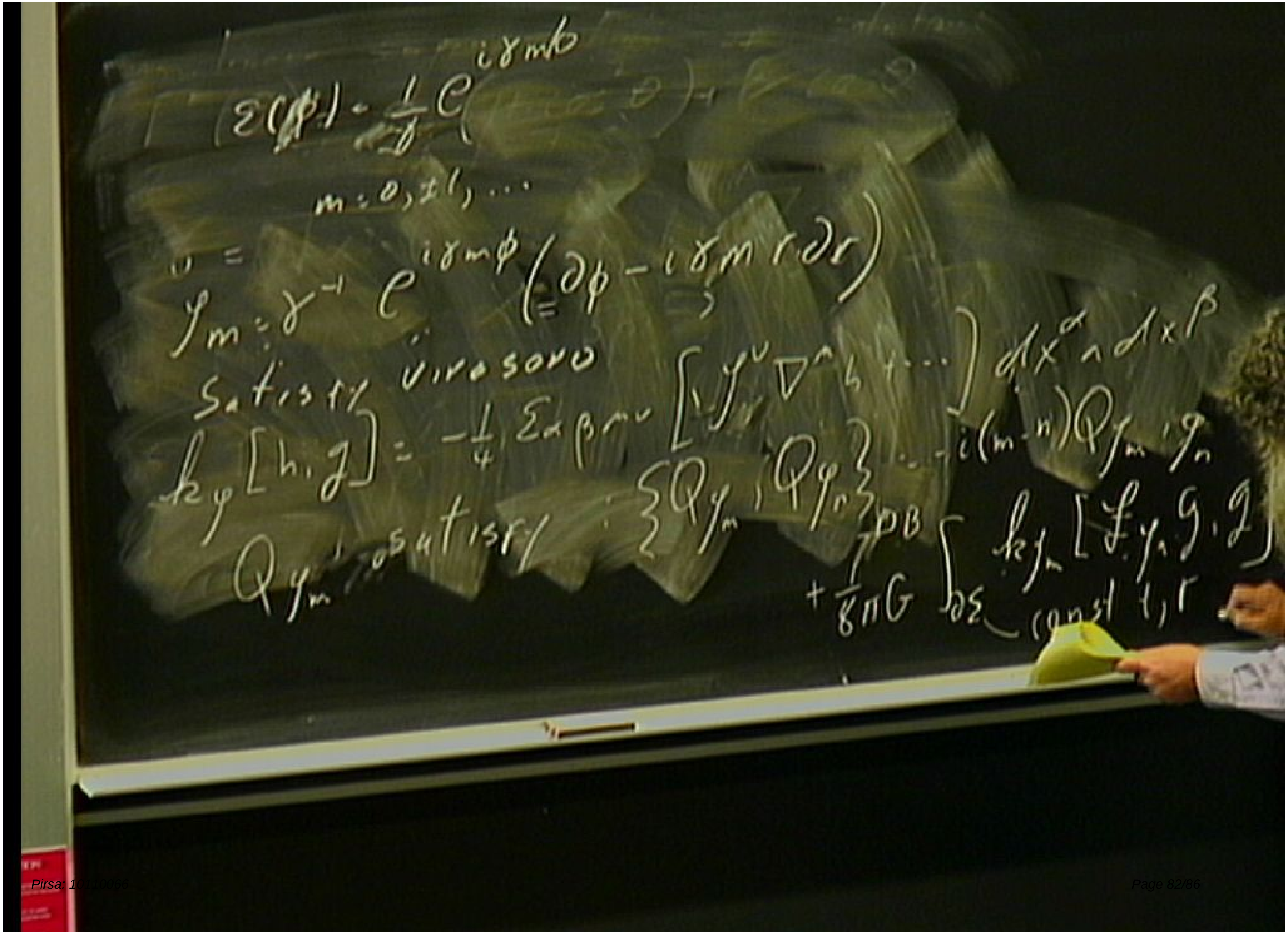
$m = 0, \pm 1, \dots$

$$\xi_m = \gamma^{-1} e^{i\gamma m \phi}\left(\partial_\phi - i\gamma m\, r\, \partial_r\right)$$

Satisfy virasoro

$$k_\xi[h, g] = -\frac{1}{4}\,\epsilon_{\alpha\beta\mu\nu}\left[\xi^\nu \nabla^\mu h + \dots\right] dx^\alpha \wedge dx^\beta$$

Q_{ξ_m} to satisfy: $\{Q_{\xi_m}, Q_{\xi_n}\}_{PB} = -i(m-n)Q_{\xi_{m+n}} + \frac{1}{8\pi G}\int_{\partial\Sigma} k_{\xi_m}[\mathcal{L}_{\xi_n} g, g]$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satisfy Virasoro
$k_\xi[h, g] = -\frac{1}{4}\epsilon_{\alpha\beta\mu\nu}[\xi^\nu \nabla^\mu h + \ldots] dx^\alpha \wedge dx^\beta$
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const t, r

$$\Sigma(\phi) = \frac{1}{\gamma} e^{i\gamma m\phi}$$

$m = 0, \pm 1, \ldots$

$$\xi_m = \gamma^{-1} e^{i\gamma m\phi}\left(\partial_\phi - i\gamma m r \partial_r\right)$$

Satisfy Virasoro

$$k_\varphi[h, g] = -\frac{1}{4}\epsilon_{\alpha\beta\mu\nu}\left[\xi^\nu \nabla^\mu h + \ldots\right] dx^\alpha \wedge dx^\beta$$

Q_{ξ_m} satisfy $\{Q_{\xi_m}, Q_{\xi_n}\}_{PB} = -i(m-n)Q_{\xi_{m+n}}$

$$+ \frac{1}{8\pi G}\int_{\partial\Sigma} k_{\xi_m}[\mathcal{L}_{\xi_n} g, g]$$

const t, r, $r \Rightarrow$

$$\boxed{c = \frac{6\gamma r_0^2}{G} = 12\gamma^2 J_\Delta}$$

$$\Xi(\phi) = \frac{1}{\gamma} e^{i\gamma m \phi}$$

$m = 0, \pm 1, \ldots$

$$\xi_m = \gamma^{-1} e^{i\gamma m \phi}\left(\partial_\phi - i\gamma m\, r\, \partial_r\right)$$

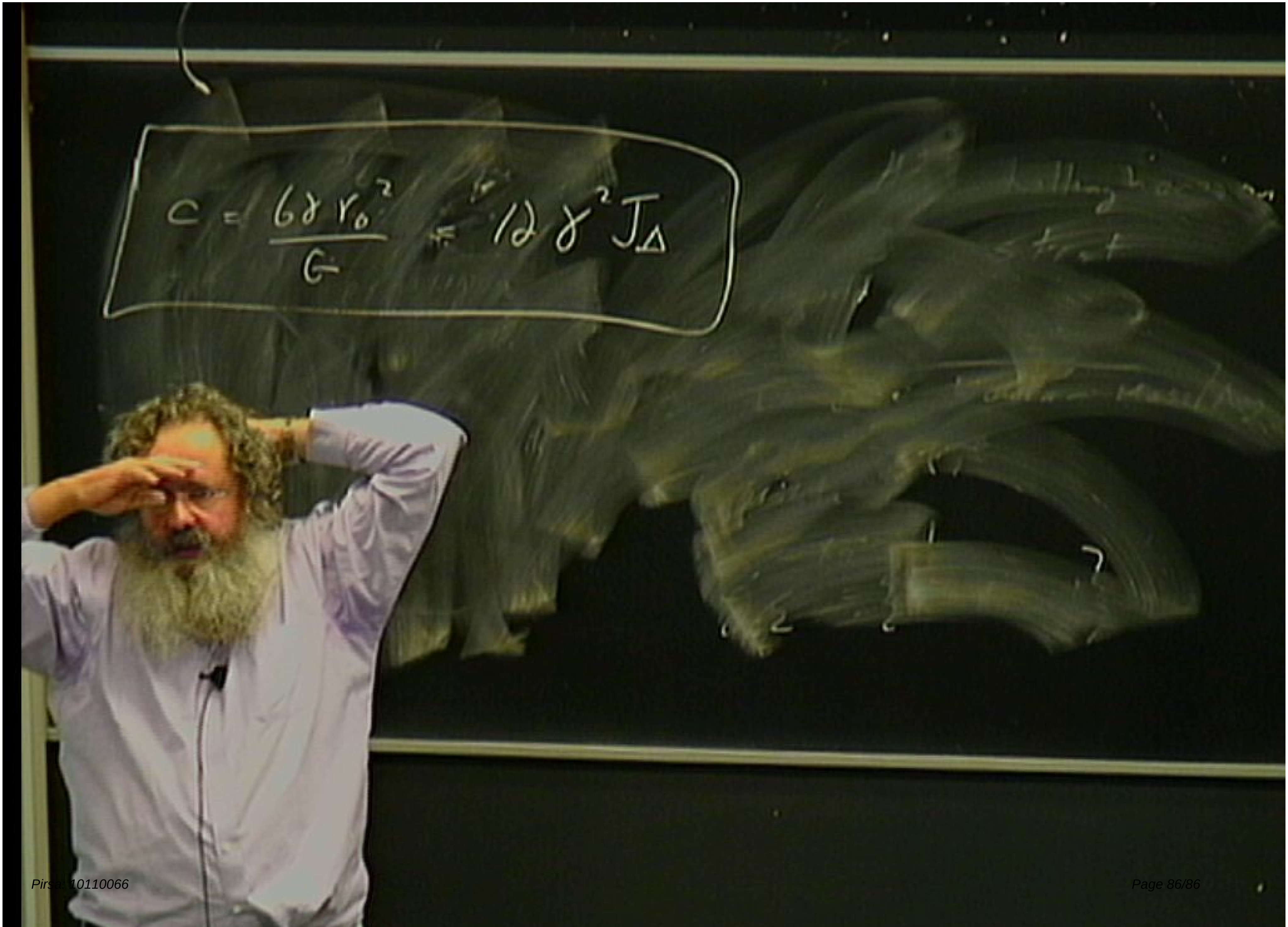
satisfy virasoro

$$k_\xi[h, g] = -\frac{1}{4}\epsilon_{\alpha\beta\mu\nu}\left[\xi^\nu \nabla^\mu h + \ldots\right] dx^\alpha \wedge dx^\beta$$

Q_{ξ_m} satisfy : $\{Q_{\xi_m}, Q_{\xi_n}\}_{PB} = -i(m-n) Q_{\xi_{m+n}}$

$$+ \frac{1}{8\pi G}\int_{\partial\Sigma} k_{\xi_m}[\mathcal{L}_{\xi_n} g, g]$$

$\partial\Sigma$ (const t, r, $r \Rightarrow$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