Title: Uplifting AdS/CFT to Cosmology

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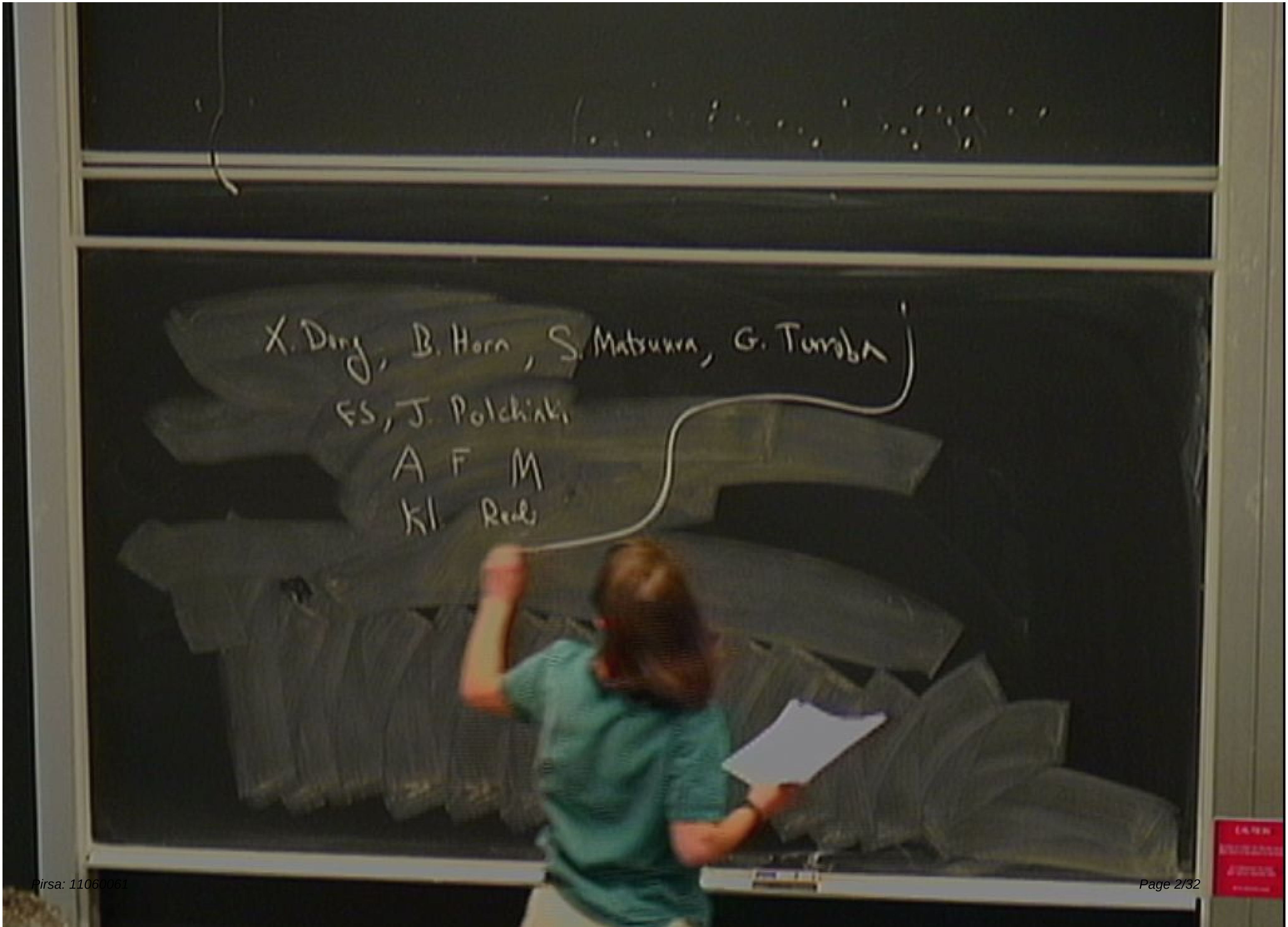
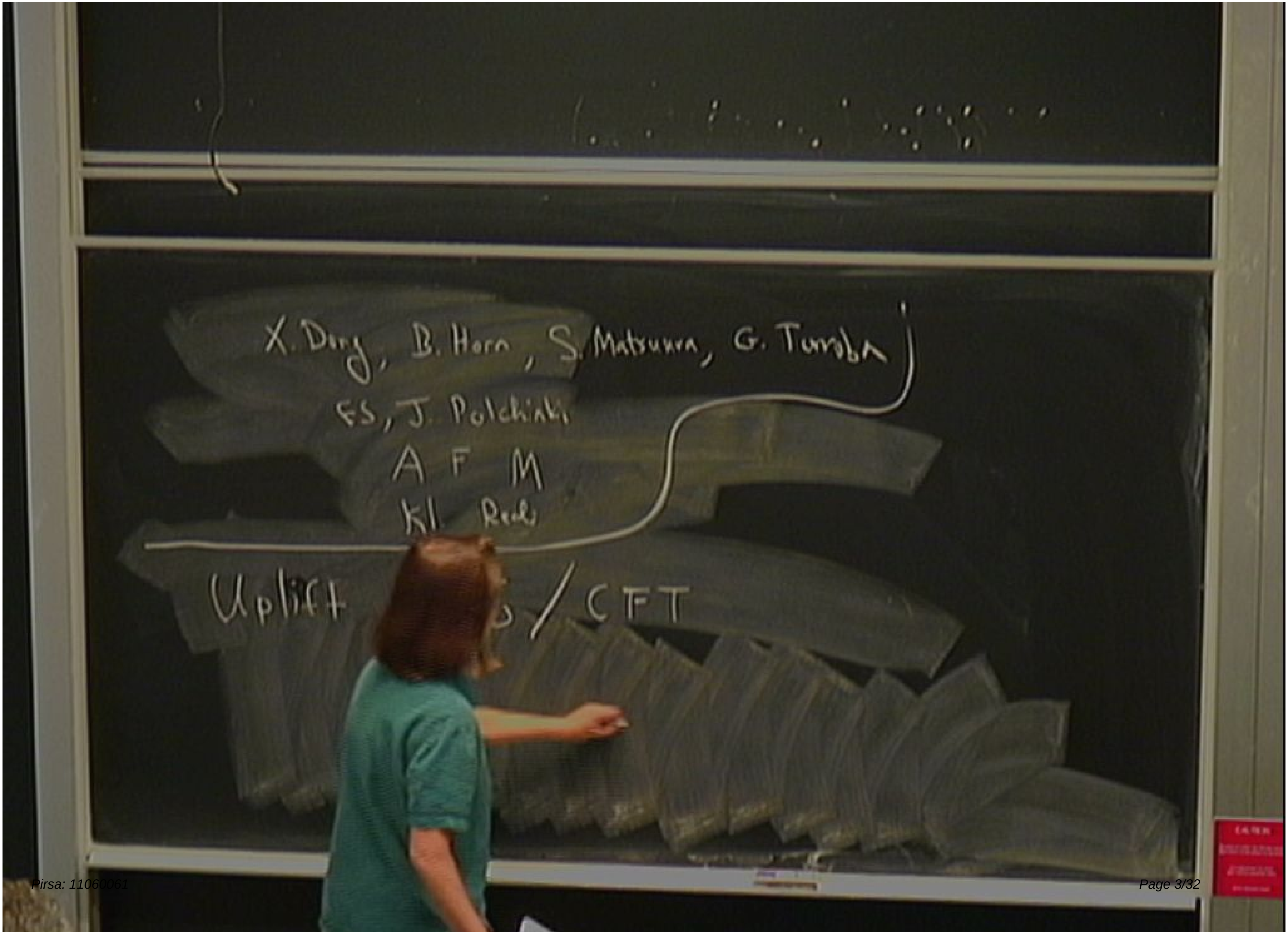
Abstract: Starting from AdS/CFT, one can introduce ingredients which produce cosmological solutions, including metastable de Sitter and its decay to FRW. In the de Sitter case, this produces a compact brane construction which mirrors the dS/dS correspondence realizing de Sitter as a pair of warped throats coupled to gravity. In the FRW case, I will present simple solutions sourced by magnetic flavor branes and explore their holographic description. The basic strategy is to exhibit a time-dependent warped metric on the solution and test the interpretation of the resulting region of gravitational redshift as a low energy effective field theory (EFT) by analyzing particle dynamics and correlation functions. At finite times, the EFT has a finite cutoff since system has a propagating lower dimensional graviton and a finite covariant entropy bound, but the graviton decouples at late times as the Planck mass goes off to infinity along with the entropy. This is work in collaboration with X. Dong, B. Horn, S. Matsuura, and G. Torroba. Along the way I will make some comments on the role of microscopic (UV complete) physics in cosmological holography and mention several different approaches to deriving landscape duals.


X. Dong, B. Horn, S. Matsuura, G. Torroba
ES, J. Polchinski
A F M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Uplift
/CFT

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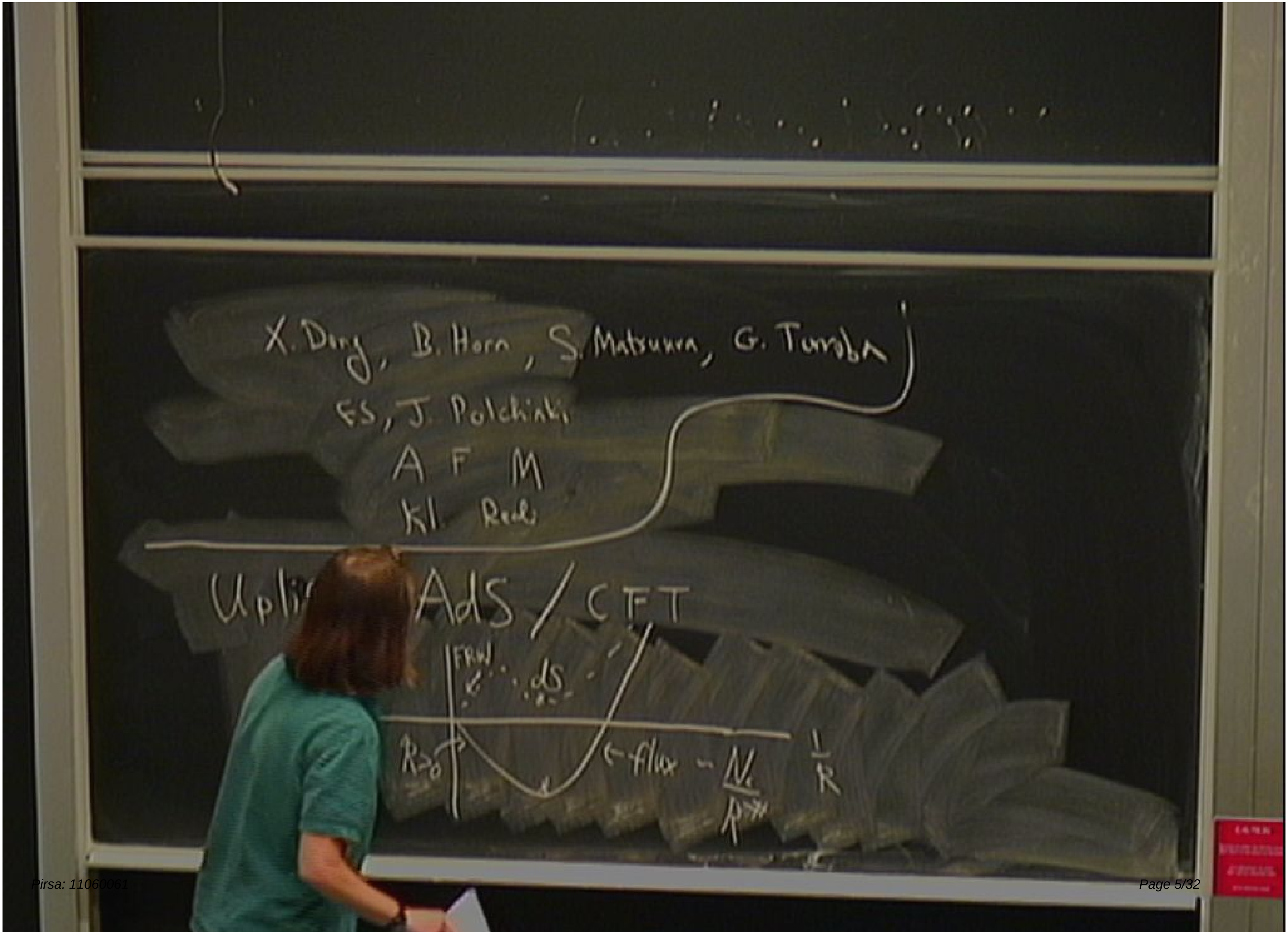
A F M

Kl Rudi

Uplift AdS / CFT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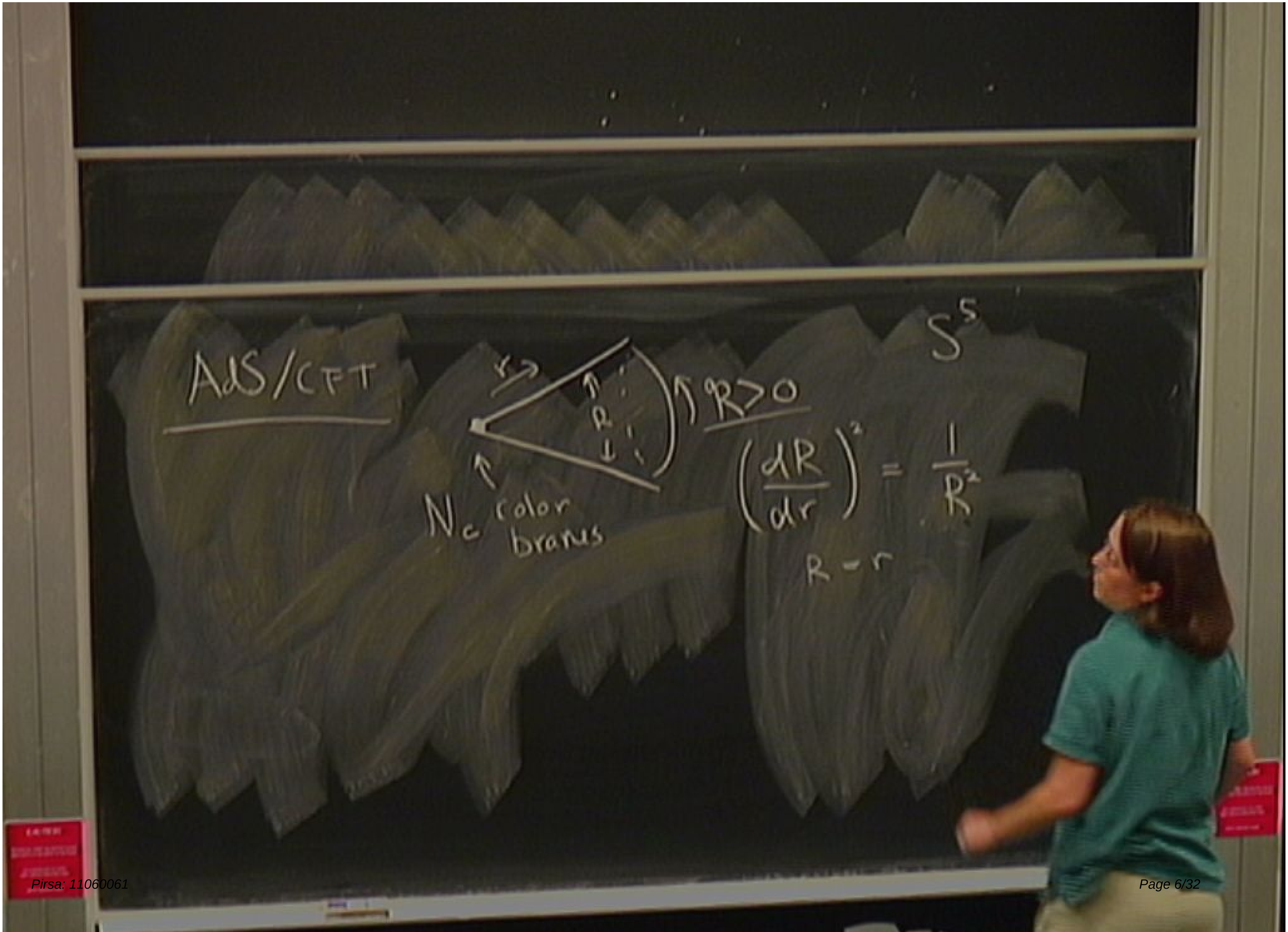
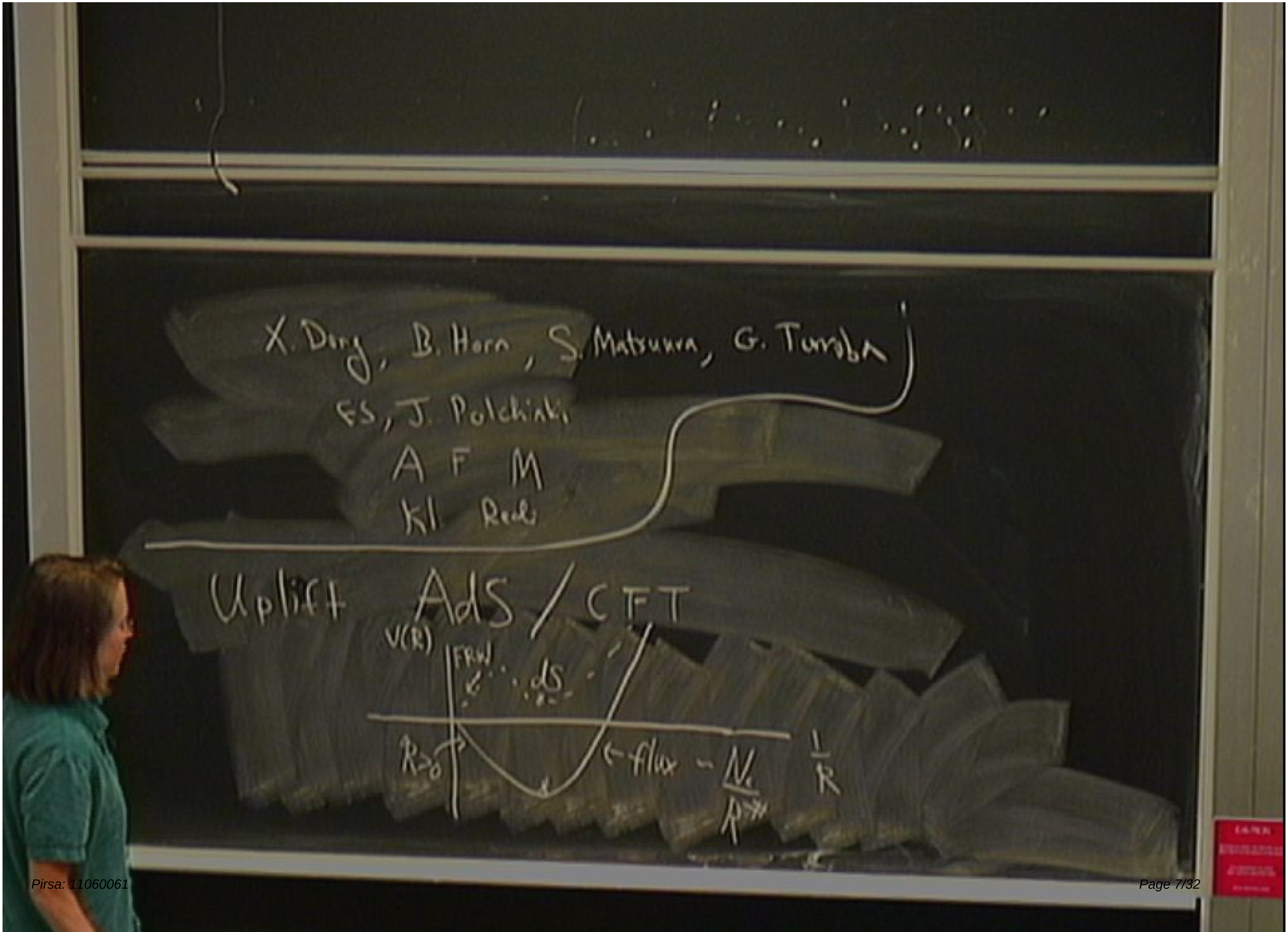
AdS / CFT
FRW
dS
flux
1/R



AdS/CFT
r
R
R>0
N_c color branes
S^5
(dR/dr)^2 = 1/R^2
R = r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A F M
Uplift AdS / CFT
V(R)
FRW
dS
← flux ~ N
R
1
R

AdS/CFT

brane construction

N_c color branes

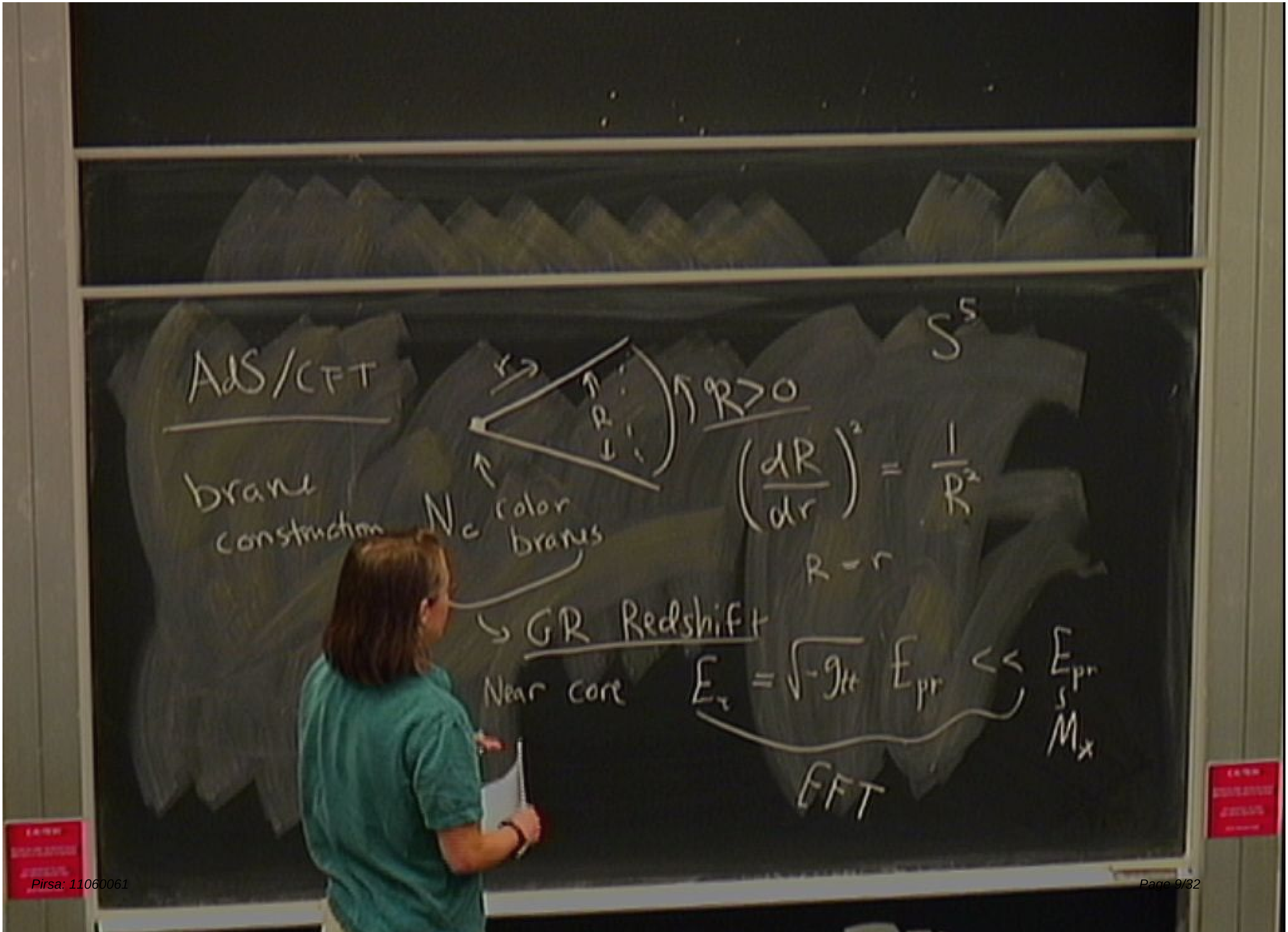
$R > 0$

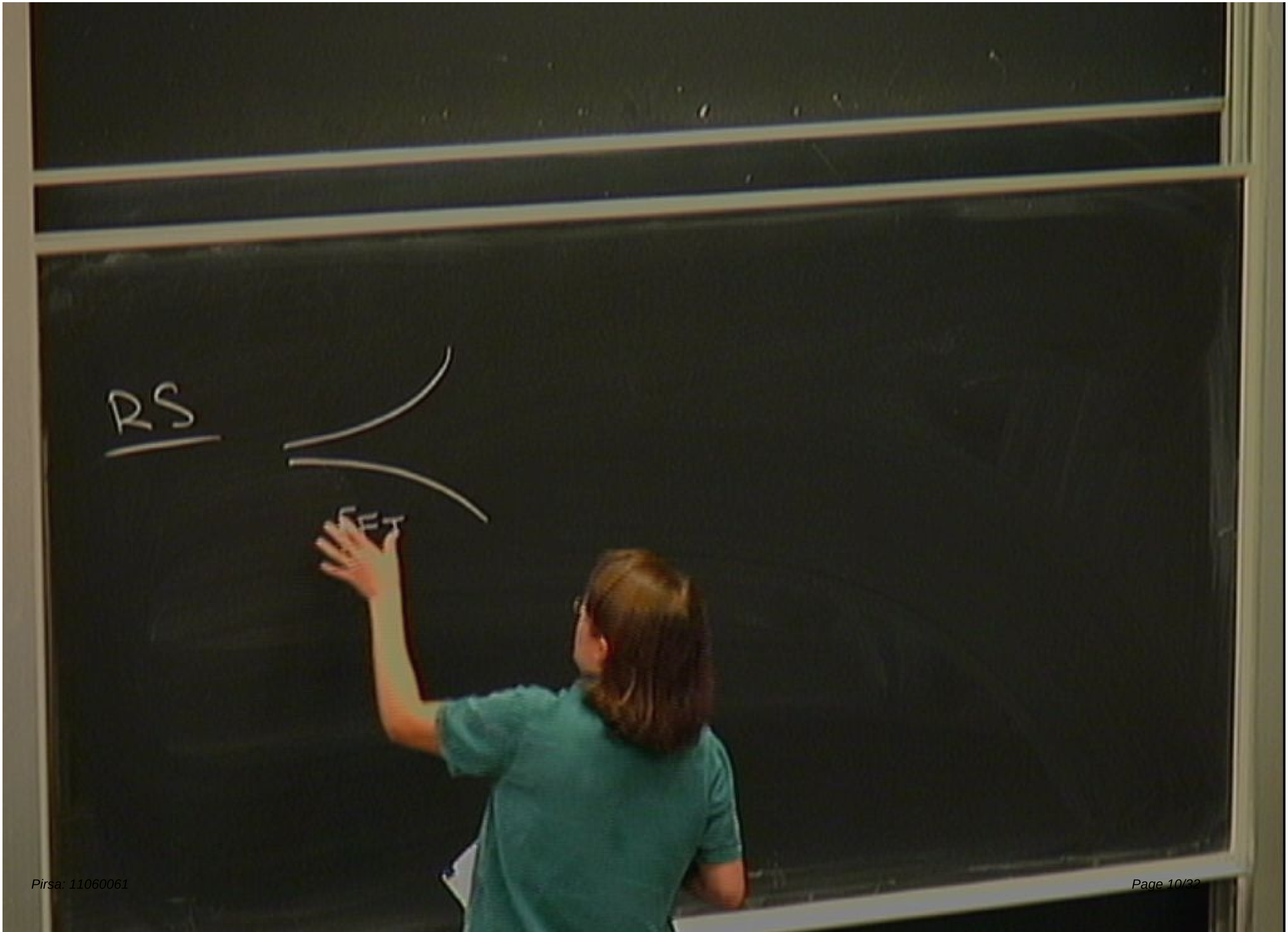
S^5

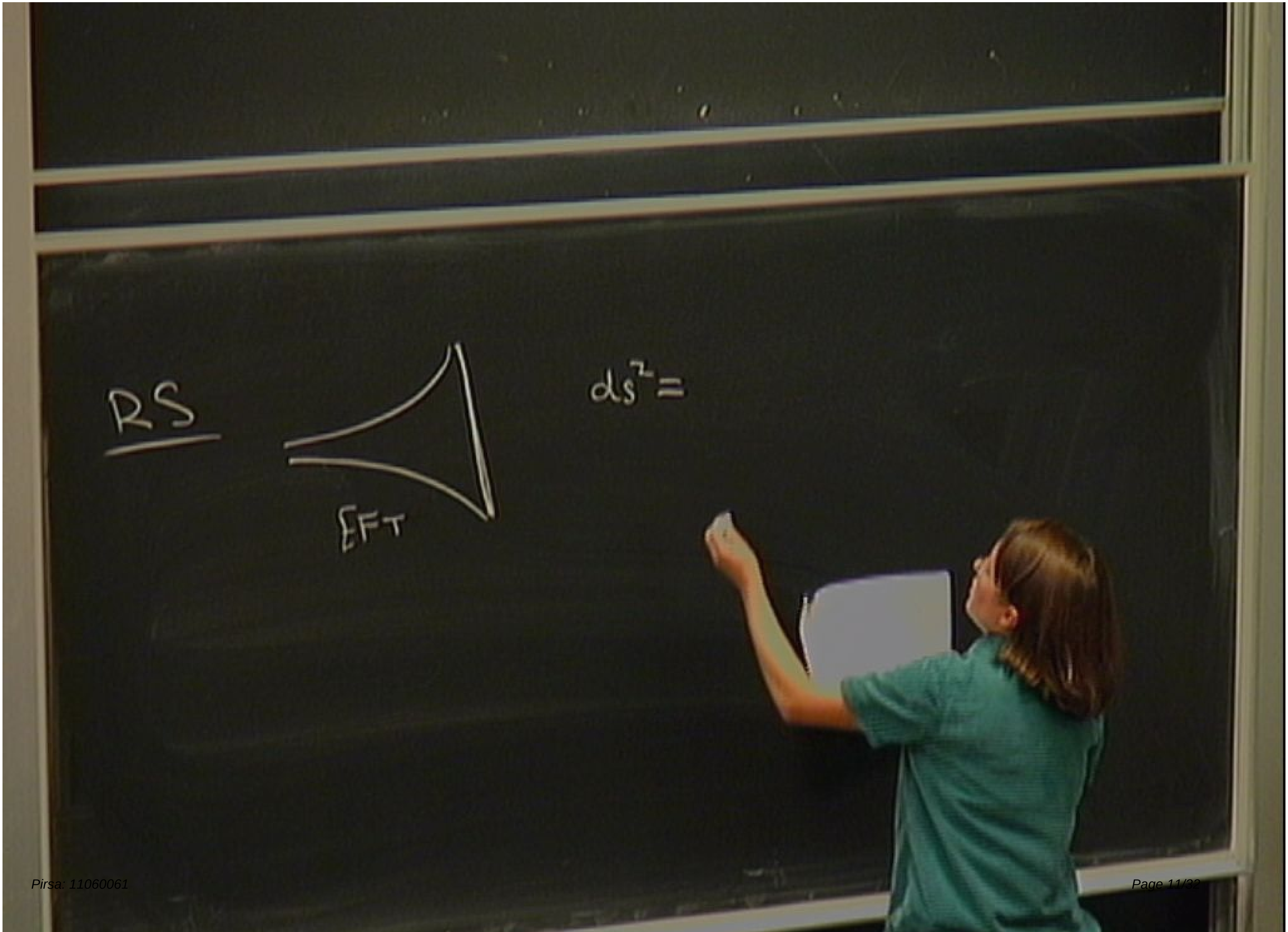
$$\left(\frac{dR}{dr}\right)^2 = \frac{1}{R^2}$$

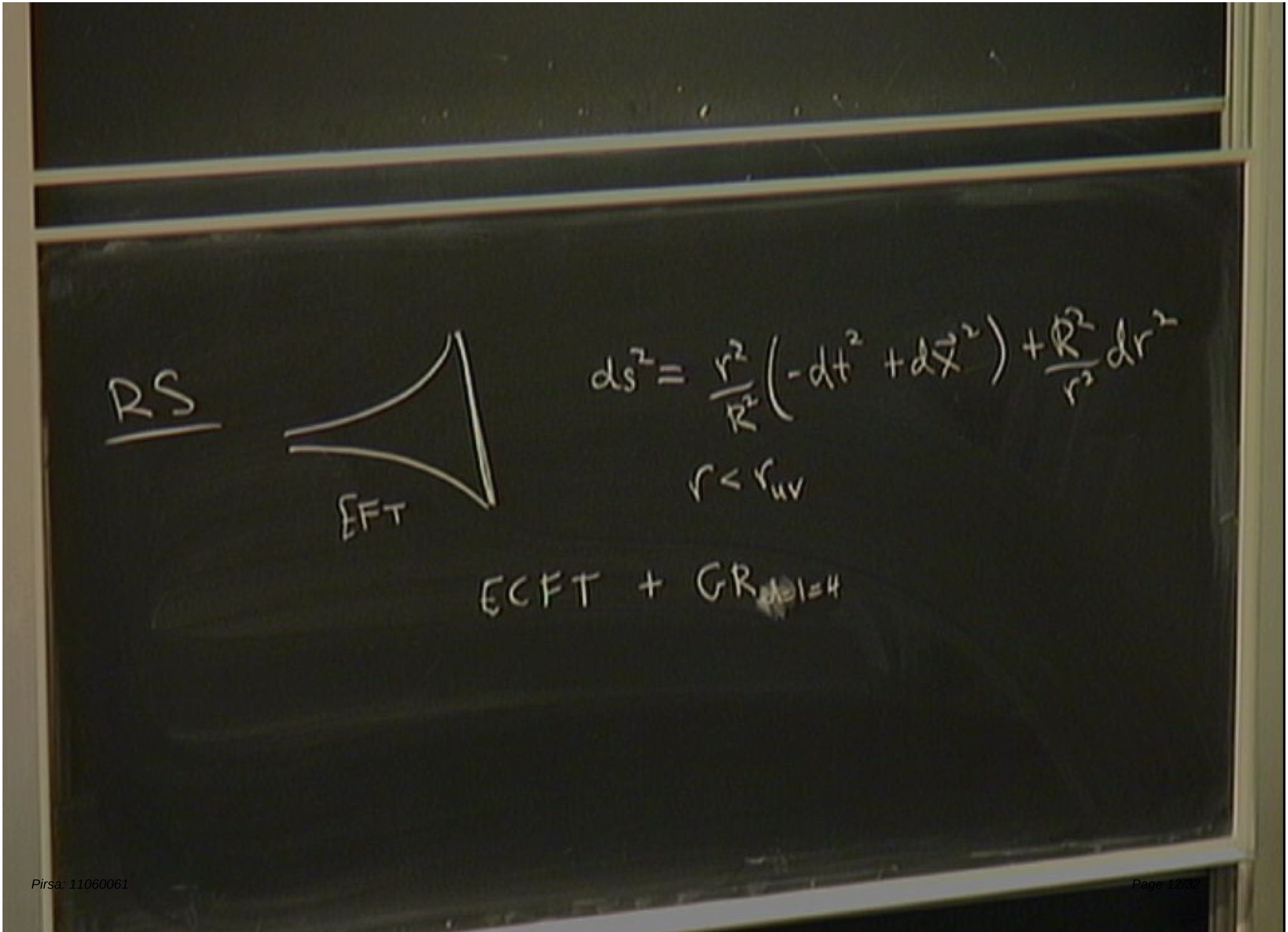
$R \sim r$

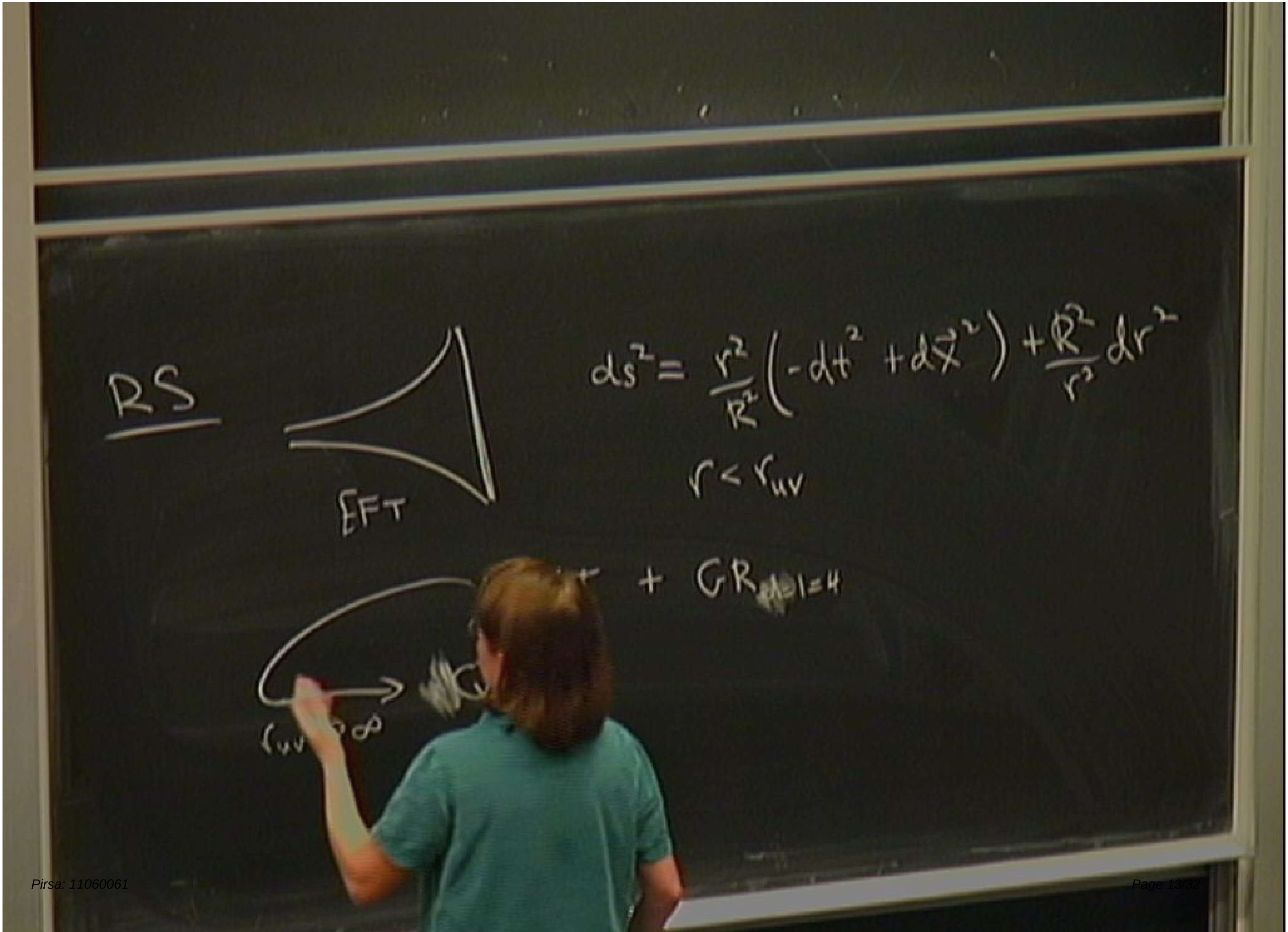
GR Redshift


AdS/CFT
brane construction
N_c color branes
r
R
R>0
S^5
(dR/dr)^2 = 1/R^2
R = r
GR Redshift
Near core
E_* = √(-g_tt) E_pr << E_pr
M_*
EFT

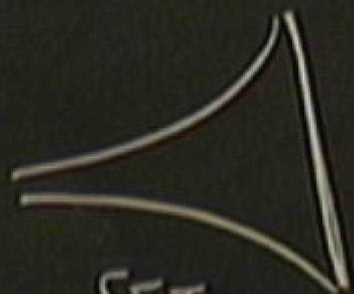

RS
EFT


RS
EFT
ds² =


RS
EFT
$ds^2 = \frac{r^2}{R^2}(-dt^2 + d\vec{x}^2) + \frac{R^2}{r^2} dr^2$
$r < r_{UV}$
ECFT + GR


RS
EFT
ds² = r²/R² (-dt² + dx⃗²) + R²/r² dr²
r < r_uv
+ GR
r_uv → ∞

RS



EFT

$$ds^2 = \frac{r^2}{R^2}\left(-dt^2 + d\vec{x}^2\right) + \frac{R^2}{r^2}dr^2$$

H. Verlinde

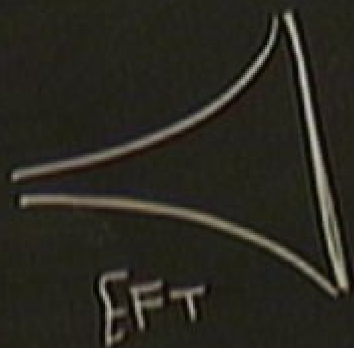
GKP

$r < r_{uv}$

$\mathrm{ECFT} + \mathrm{GR}_{d-1=4}$

$\xrightarrow{r_{uv} \to \infty}$ QFT

RS

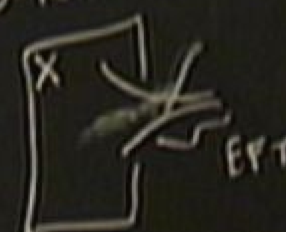


$$ds^2 = \frac{r^2}{R^2}\left(-dt^2 + d\vec{x}^2\right) + \frac{R^2}{r^2}dr^2$$

H. Verlinde

$r < r_{UV}$

GKP



ECFT + $GR_{d+1=4}$

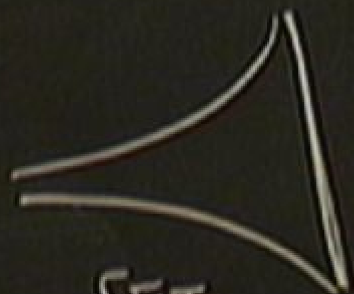
$\frac{R^4}{\alpha'^2}$

QFT

$r_{UV} \to \infty$

$$\frac{1}{G_{N,d+1}} = M_p^2 = \left(\frac{r_{UV}}{R^2}\right)^2 \cdot N^2 = \Lambda_c^2 \cdot N_{d.o.f.}$$

RS



EFT

$$ds^2 = \frac{r^2}{R^2}\left(-dt^2 + d\vec{x}^2\right) + \frac{R^2}{r^2}dr^2$$

H. Verlinde

GKP

X

EFT

$r < r_{UV}$

ECFT + $GR_{d=4}$

QFT

$\frac{R^4}{g^{\dots}}$

$r_{UV} \to \infty$

$$\frac{1}{G_{N,d=4}} = M_p^2 = \left(\frac{r_{UV}}{R^2}\right)^2 \cdot N^2 = \Lambda_c^2 \cdot N_{d.o.f.}$$

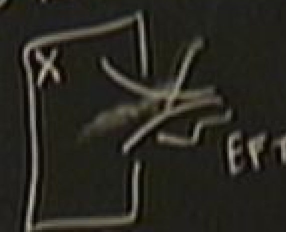
+ Vol(X)

RS

$$ds^2 = \frac{r^2}{R^2}\left(-dt^2 + d\vec{x}^2\right) + \frac{R^2}{r^2}dr^2$$

H. Verlinde

GKP



$r < r_{UV}$

$\underline{ECFT} + GR_{d+1=4}$

$\frac{R^4}{g^4}$

QFT

$r_{UV} \to \infty$

$$\frac{1}{G_{N,d+1}} = M_p^2 = \left(\frac{r_{UV}}{R^2}\right)^2 \cdot N^2 = \Lambda_c^2 \cdot N_{d.o.f.} + \mathrm{Vol}(X)$$

AdS/CFT

brane construction

N_c color branes

$\uparrow \mathcal{R} > 0$

S^5

$$\left(\frac{dR}{dr}\right)^2 = \frac{1}{R^2}$$

macro:

$$ds^2_{dS_d} = \sin^2\frac{w}{L}\,\underbrace{ds^2_{dS_{d-1}}} + dw^2$$

AdS/CFT

brane construction

N_c color branes

$r \to$

$\uparrow R \downarrow$

$\int R > 0$

$$\left(\frac{dR}{dr}\right)^2 = \frac{1}{R^2}$$

S^5

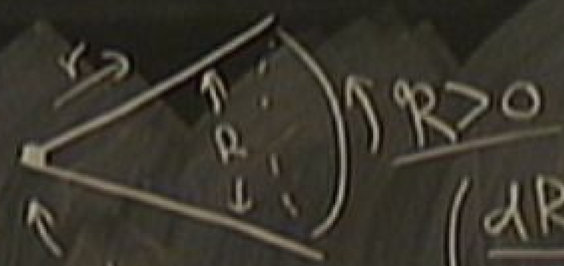
macro

$$\underbrace{ds^2_{dS_d}}\; = \underbrace{\sin^2 \frac{w}{L}}\; ds^2_{dS_{d-1}} + dw^2 = 2\text{-throat of warped comp.}$$

$\sqrt{g_{d-1}}$

AdS/CFT

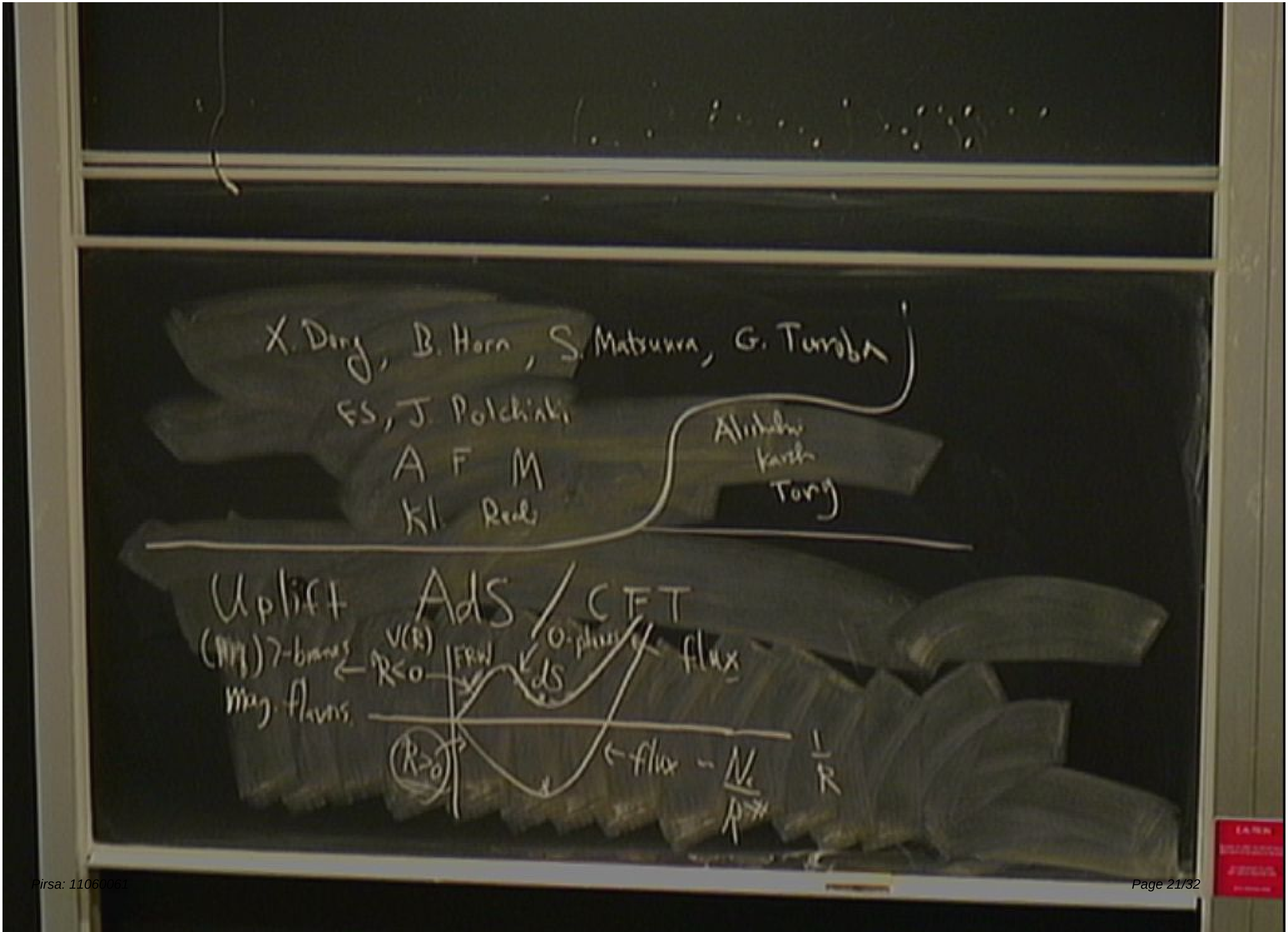
brane construction N_c color branes



S^5

$$\left(\frac{dR}{dr}\right)^2 = \frac{1}{R^2}$$

macro: $ds^2_{dS_d} = \underbrace{\sin^2 \frac{w}{L}\, ds^2_{dS_{d-1}}}_{\sqrt{g_{d-1}}} + dw^2$ = 2-throated warped comp. + GR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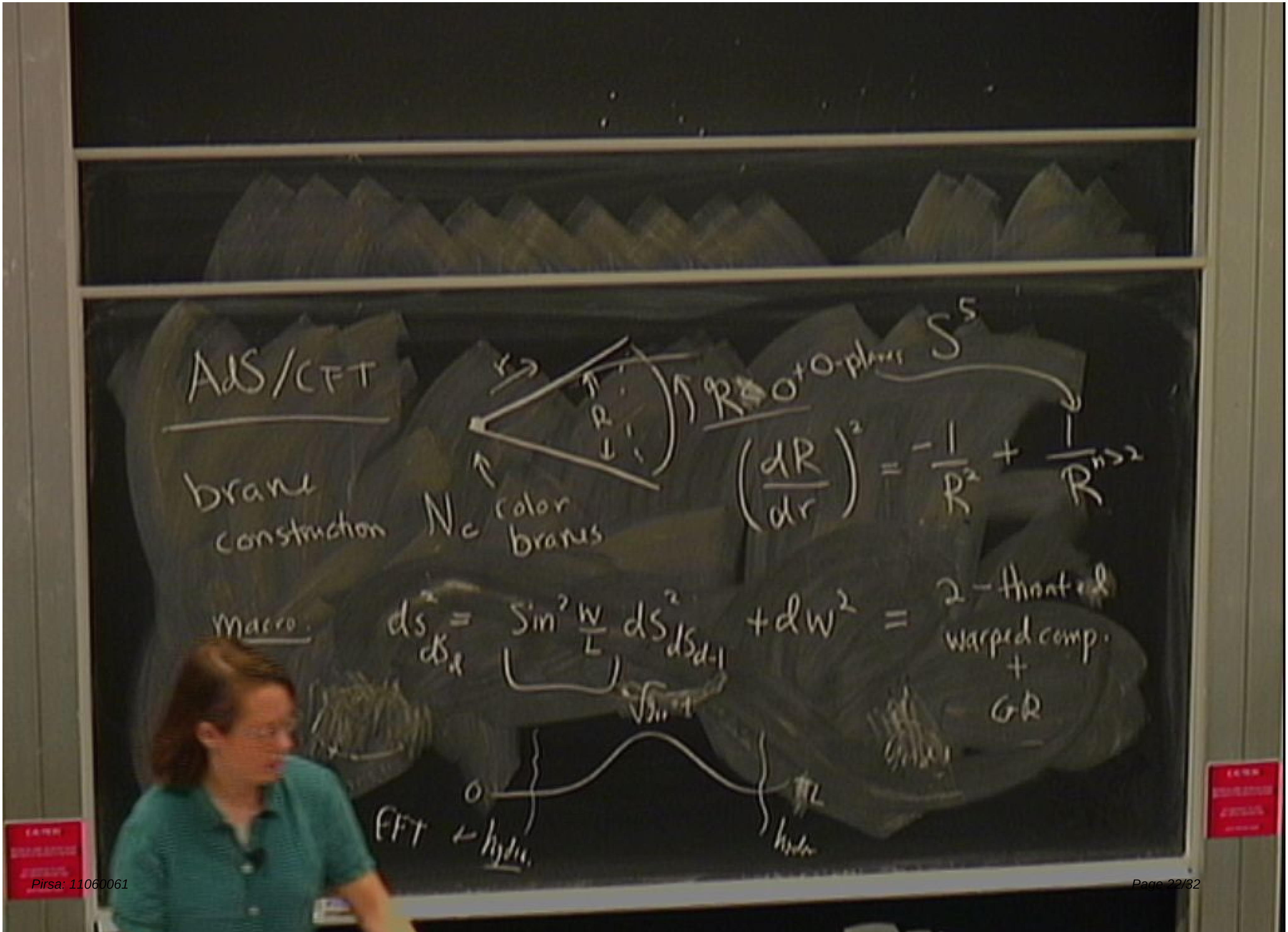
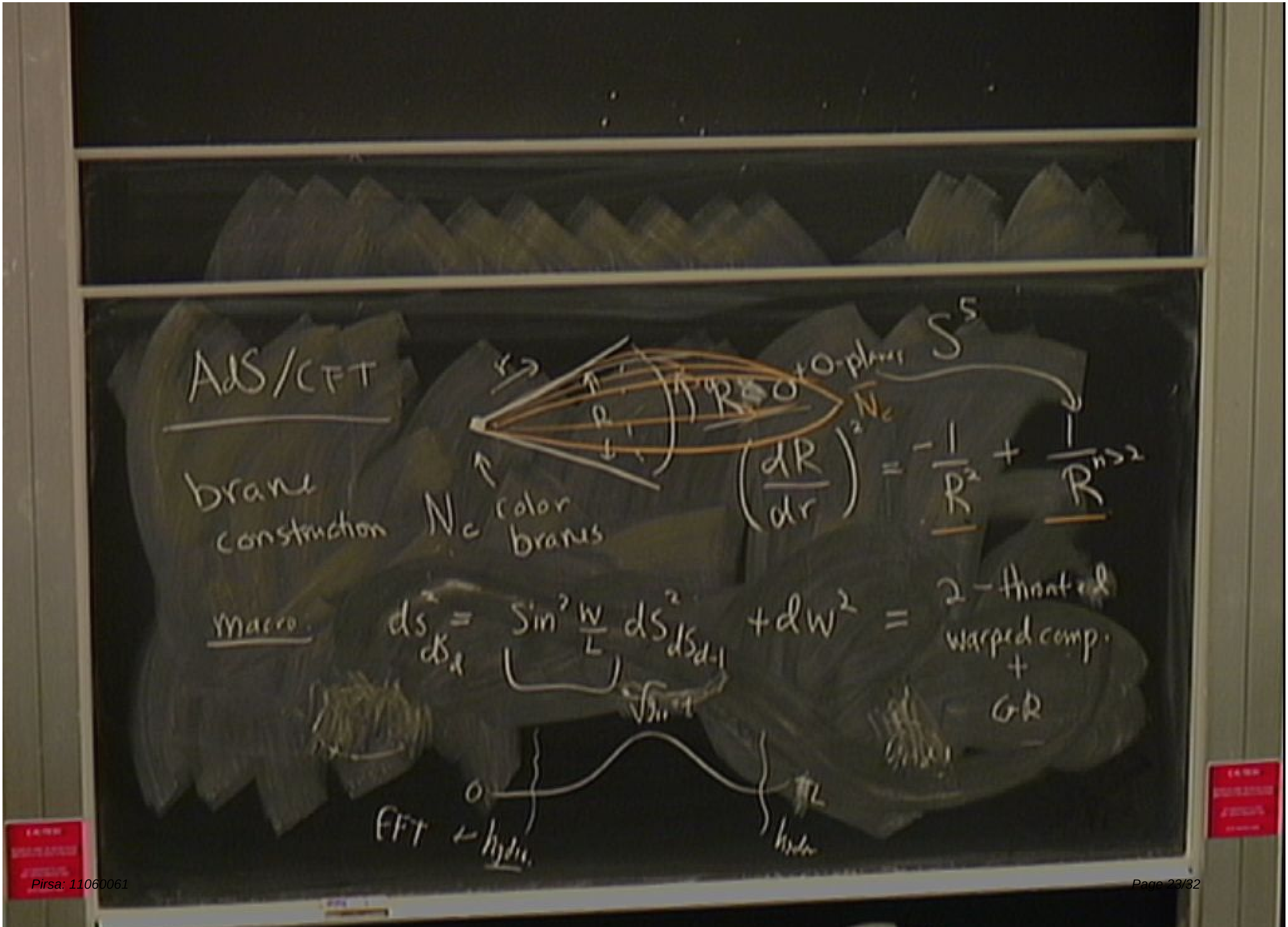
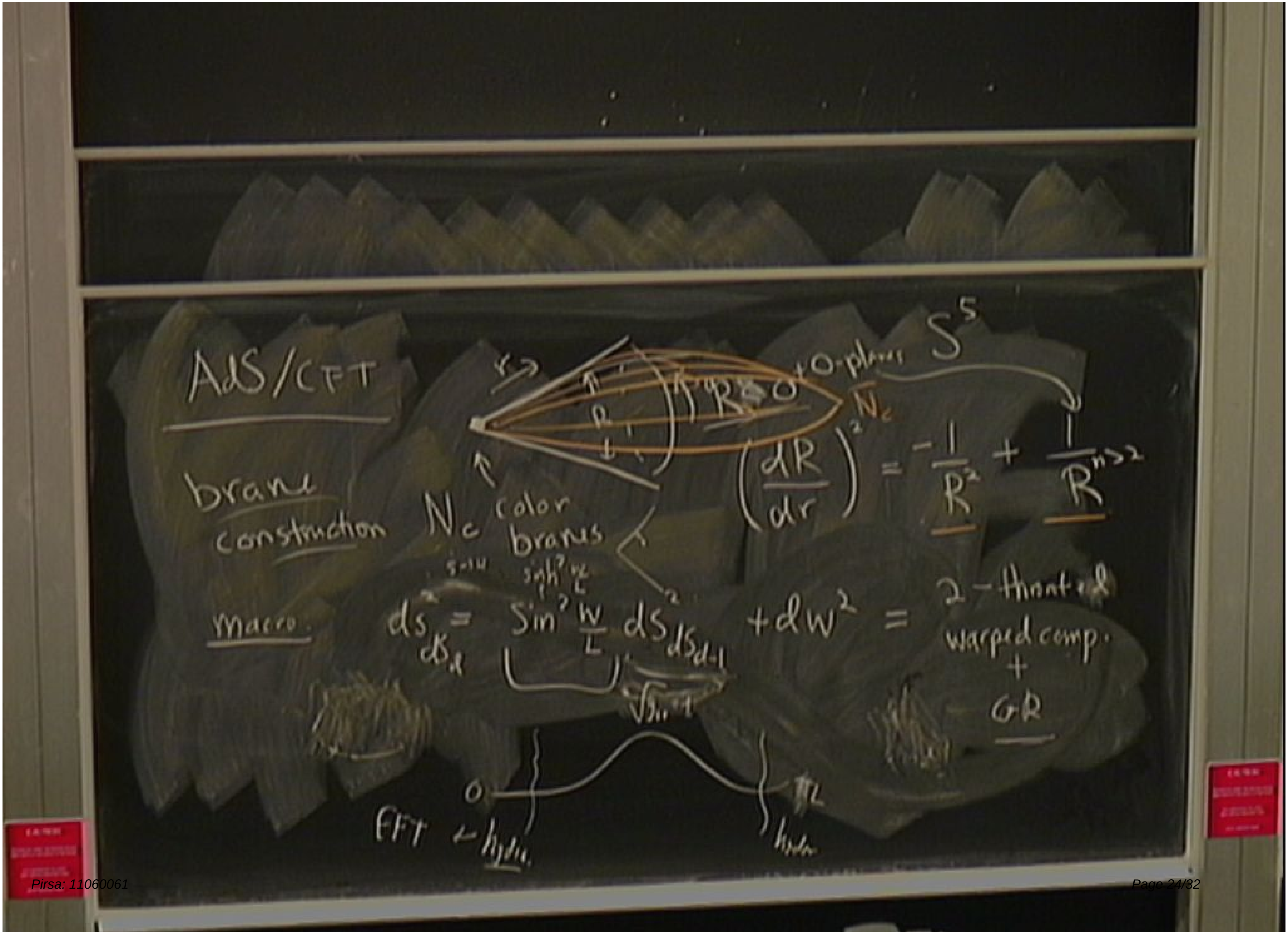
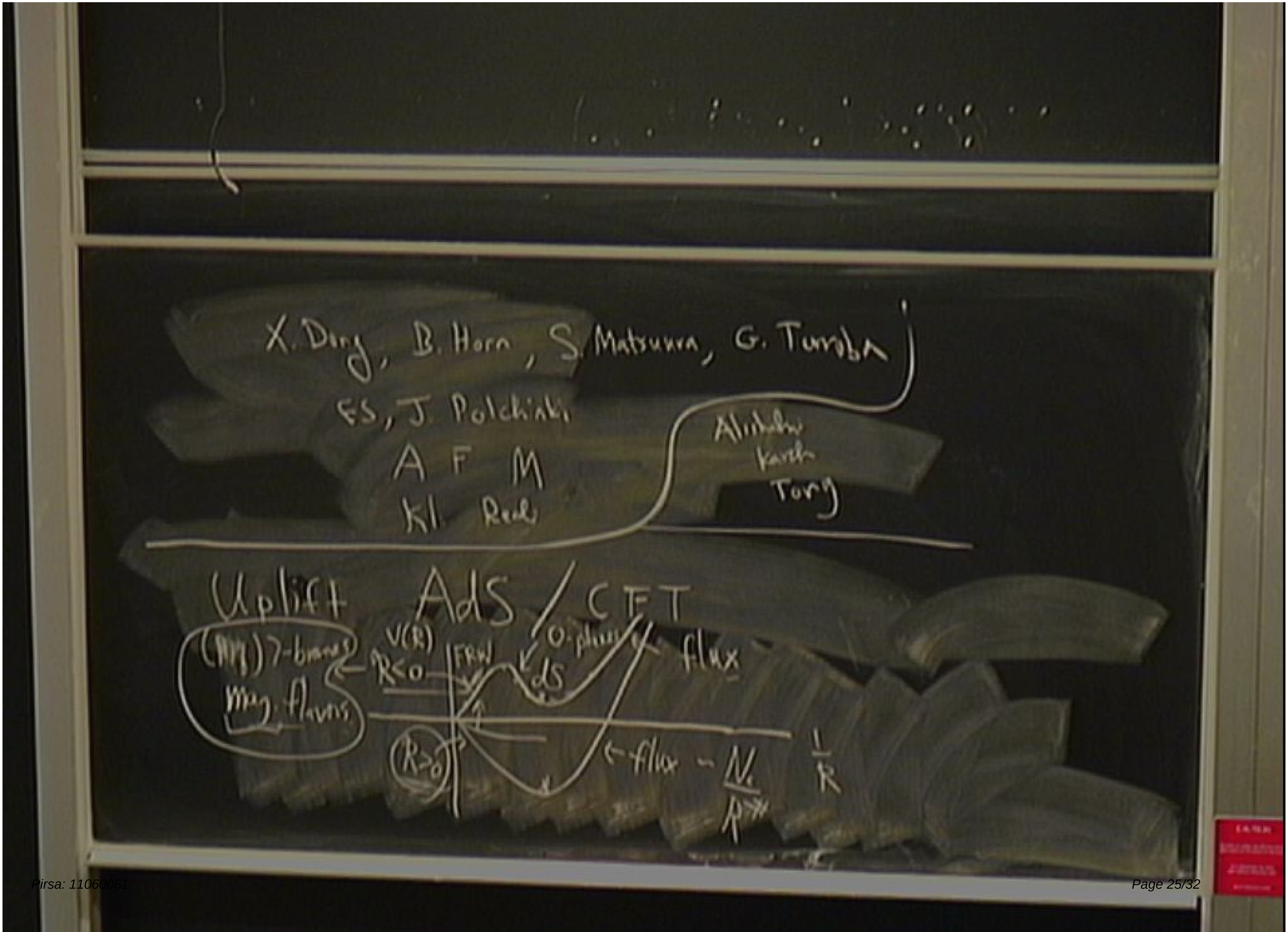
J. Polchinski
A F M
Karch
Tong
Uplift AdS / CFT
V(R)
7-branes
R<0
FRW
dS
O-planes
flux
R>0
flux
1/R


AdS/CFT
brane construction
N_c color branes
r
R
R = 0 + O-planes
S^5
(dR/dr)^2 = -1/R^2 + 1/R^{n>2}
macro.
ds^2_{dS_d} = sin^2 w/L ds^2_{dS_{d-1}} + dw^2 = 2-throated warped comp. + GR
0
πL
EFT ← hydro.
hydro


AdS/CFT
brane construction
N_c color branes
O-planes
S^5
N_c
$\left(\frac{dR}{dr}\right)^2 = -\frac{1}{R^2} + \frac{1}{R^{n>2}}$
macro
$ds^2_{dS_d} = \sin^2\frac{w}{L}\, ds^2_{dS_{d-1}} + dw^2$ = 2-throated warped comp. + GR
EFT
hydro


AdS/CFT
brane construction
N_c color branes
macro.
$\left(\frac{dR}{dr}\right)^2 = -\frac{1}{R^2} + \frac{1}{R^{n>2}}$
$ds^2_{dS_d} = \sin^2\frac{w}{L}\, ds^2_{dS_{d-1}} + dw^2$ =
2-throated warped comp.
+
GR
S^5
EFT
0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7-branes
V(R)
R<0
FRW
dS
O-planes
flux
R>0
flux
1/R

FRW?

$\exists$ Redshifted region $\to \infty$

$M_p^2 \to \infty$

$t \to \infty$

$S^1 \to S^{5,3}$

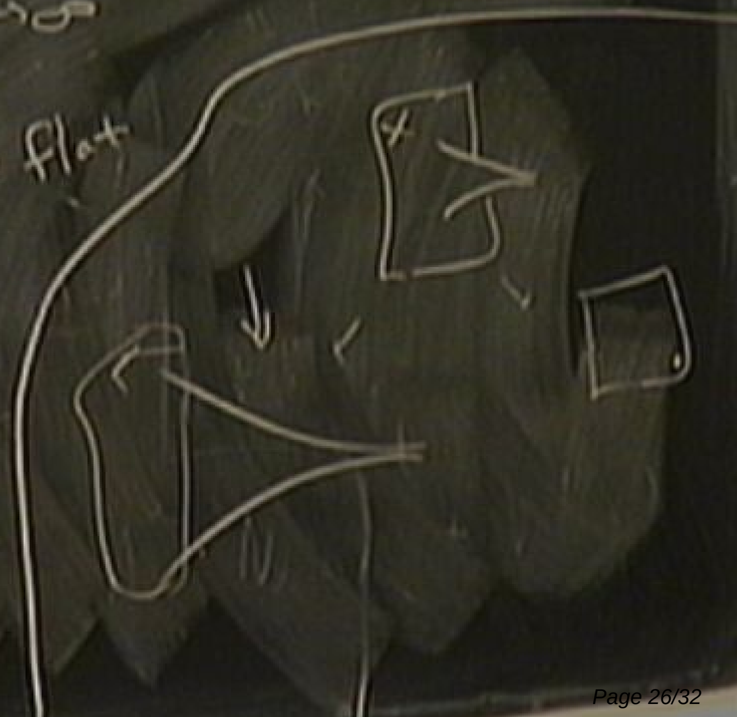
$\downarrow$

$CP^{2,1}$

36, 24 $\to$ flat

$\Delta n = n - n_{R=0}$

$\dfrac{\Delta n < 0}{AdS}$, $\Delta n = 0$, $\dfrac{\Delta n > 0}{R<0}$



Vacuum Solution

10d (str)

$$ds^2 = -dt_s^2 + \frac{t_s^2}{c^2}\left(d\mathbb{H}_{d-1}^2 + d\mathbb{H}_{d-1}^{(2)2}\right) + R_f^2\, d\varphi_f^2$$

5d

$$ds^2_{5d,E} = -dt^2 + c^2 t^2\, d\mathbb{H}_{d-1} \quad , \text{ integ}$$

Vacuum Solution

$t \to \infty$

10d (str)

$$ds^2 = -dt_s^2 + \frac{t_s^2}{c^2}\left(d\mathbb{H}_{d-1}^2 + d\mathbb{H}^{(2,2)}_{d-1}\right) + R_r^2\, d\varphi_r^2$$

5d

$$ds^2_{5d,E} = -dt^2 + c^2 t^2\, \underbrace{d\mathbb{H}_{d-1}}_{}$$

, integral space

$$c^2 = \frac{7}{3} \quad d=5$$

(cf Mink $c=1$)

Vacuum Solution

$t \to \infty$

10 d (str)

$$ds_s^2 = -dt_s^2 + \frac{t_s^2}{c^2}\left(d\mathbb{H}_{d-1}^2 + d\mathbb{H}_{d-1}^{(2,2)}\right) + R_r^2\, d\varphi_r^2$$

5d

$$ds^2_{5d,E} = -dt^2 + c^2 t^2 \left([illegible] \cosh^2 \tfrac{\chi}{\ell}\, d\mathbb{H}^2_{d-2} \right) + [illegible]$$

$c^2 = \frac{7}{3}$ $d = 5$ (cf Mink $c = 1$)

$m_{KK} \sim \frac{n_{KK}}{t}$, $m_{str} \sim \frac{1}{t^{2/3}}$, $m_{s} \sim \frac{1}{t^{2/3}}$

$$ds^2 = \frac{c^2}{\ell^{2(c-1)}} \left(r^2 - w^2\right)^{c-1} \left(dw^2 - dr^2 + \frac{r^2}{\ell^2} d\mathbb{H}_{d-2}^2 \right)$$

$$= \left(1 - \frac{w^2}{t_*^{2/c}}\right)^{c-1} \left(-dt^2 + c^2 t^2 d\mathbb{H}_{d-2}^2 \right)$$

$$+ \left(\frac{t_*}{t}\right)^{1-\frac{1}{c}} \left(1 - \frac{w^2}{t_*^{2/c}}\right)^{c-1} dw^2$$

$$E_t \sim \left(1 - \frac{w^2}{t_*^{2/c}}\right)^{\frac{c-1}{2}} E_{\text{proper}}, \quad \text{Redshift} \xrightarrow{?} \text{EFT}$$

$$ds^2 = \frac{c^2}{\ell^{2(c-1)}} \left(\eta^2 - w^2\right)^{c-1} \left(dw^2 - d\eta^2 + \frac{\eta^2}{\ell^2} d\mathbb{H}_{d-2}^2 \right)$$

$$= \left(1 - \frac{w^2}{t_h^{2/c}}\right)^{c-1} \left(-dt^2 + c^2 t^2 \, d\mathbb{H}_{d-2}^2\right)$$

$$+ \left(\frac{t_h}{T}\right)^{1-\frac{1}{c}} \left(1 - \frac{w^2}{t_h^{2/c}}\right)^{c-1} dw^2$$

$E_t \sim \left(1 - \frac{w^2}{t_h^{2/c}}\right)^{\frac{c-1}{2}} E_{proper}$, Redshift $\xrightarrow{?}$ FFT

Motion sickness | $W \sim d\eta \sim c_1 t_h^{\frac{1}{c}} \Rightarrow$ particles stay down

Vacuum Solution

$t \to \infty$ flux etc 7B

10 d (str) $ds^2 = -dt_s^2 + \frac{t_s^2}{c^2}\left(d\mathbb{H}_{d-1}^2 + d\mathbb{H}_{d-1}^{(2,2)}\right) + R_f^2\, d\varphi_f^2$

5d $ds^2_{5d,E} = -dt^2 + c^2 t^2 \left(\ldots \cosh^2 \ldots \, d\mathbb{H} \ldots \right) + \ldots$

$c^2 = \frac{7}{3} \quad d=5$ (cf Mink $c=1$)

$m_{KK} \sim \frac{n_{KK}}{t}, \quad m_{str} \sim \frac{1}{t^{1/3}}, \quad m_{15} \sim \frac{1}{t^{2/3}}$