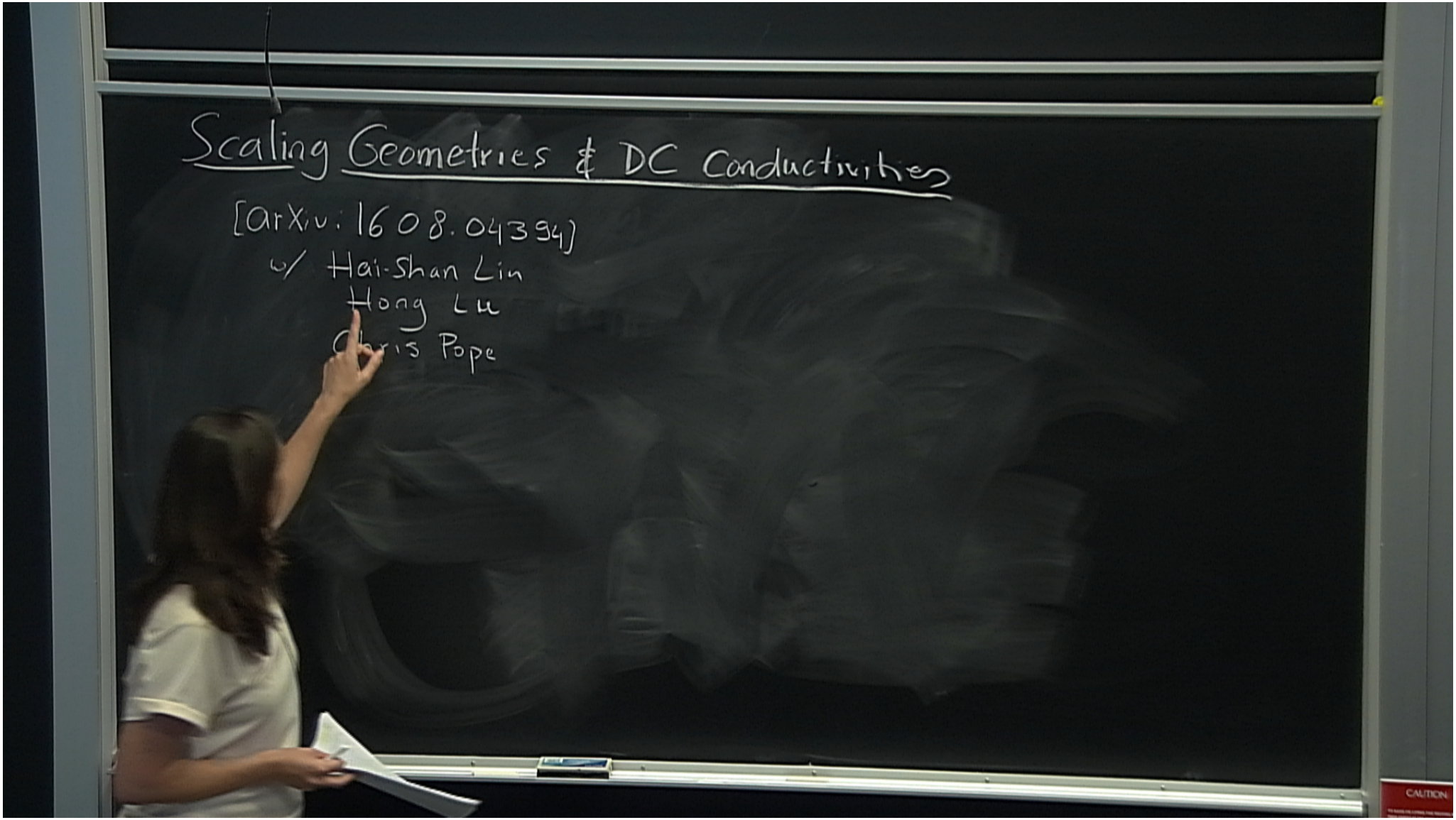
Title: Scaling geometries and DC conductivities

Date: Aug 22, 2016 04:00 PM

URL: http://pirsa.org/16080038

Abstract: Non-relativistic geometries that violate hyperscaling have been used as holographic laboratories for probing strongly coupled phases with anomalous scalings. In this talk I will discuss holographic computations of DC conductivities in gravitational systems that exhibit such scalings, and allow for momentum dissipation. I will also comment on the cases in which one obtains a linear temperature dependence for the resistivity.


Scaling Geometries & DC Conductivities
[arXiv: 1608.04394]
w/ Hai-Shan Lin
Hong Lu
Chris Pope
CAUTION

Scaling Geometries & DC Conductivities

[arXiv: 1608.04394]

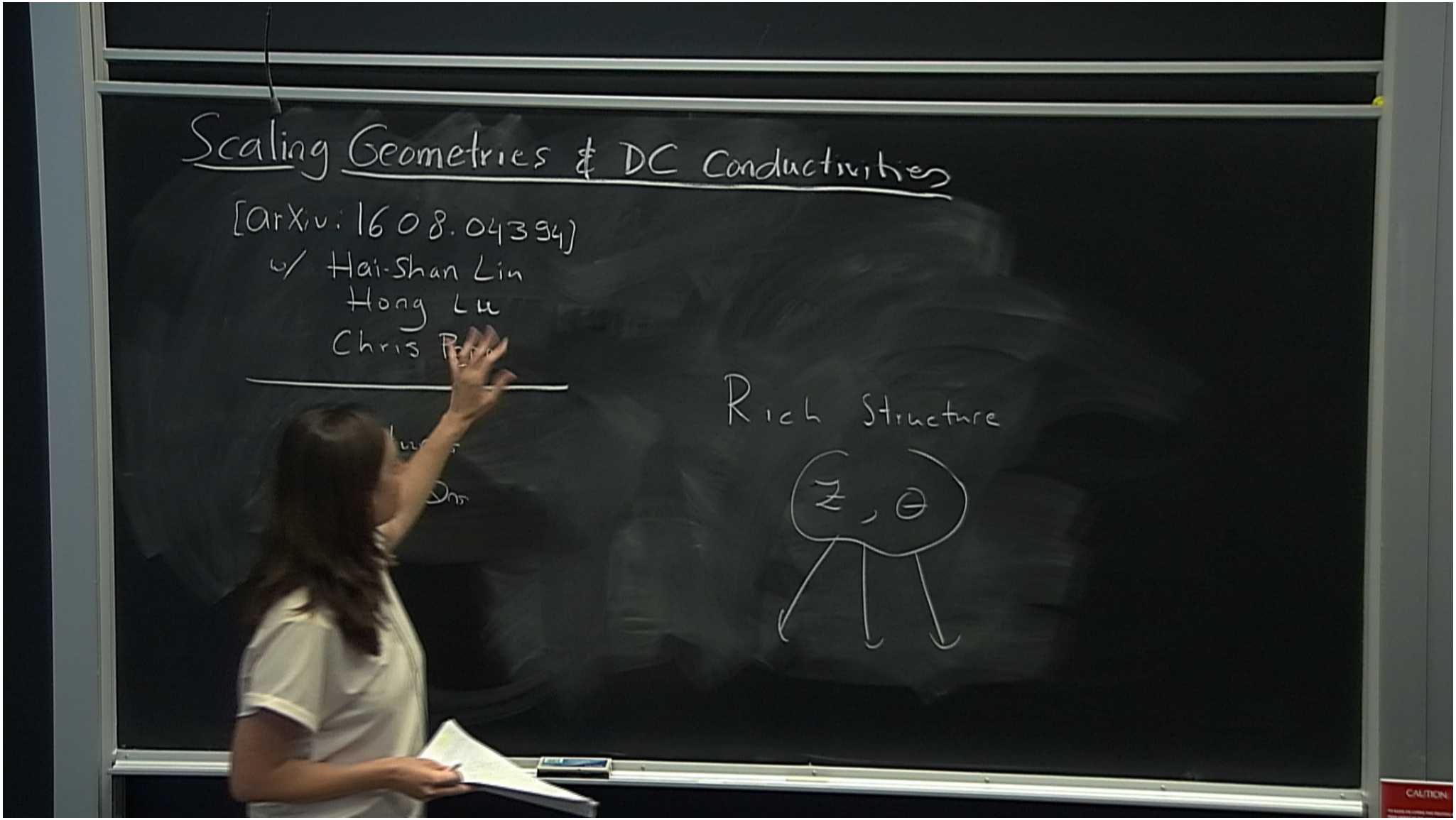
w/ Hai-Shan Lin
Hong Lu
Chris Pope

Features

Open Qns

Rich Structure

Z, Θ


Scaling Geometries & DC Conductivities
[arXiv: 1608.04394]
w/ Hai-Shan Lin
Hong Liu
Rich Structure
z, θ
CAUTION

Scaling Geometries & DC Conductivities

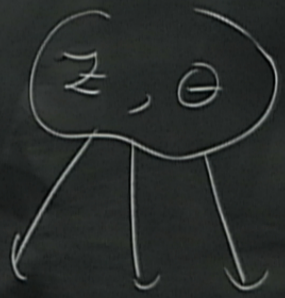
[arXiv: 1608.04394]

w/ Hai-Shan Lin
Hong Lu
Chris Pope

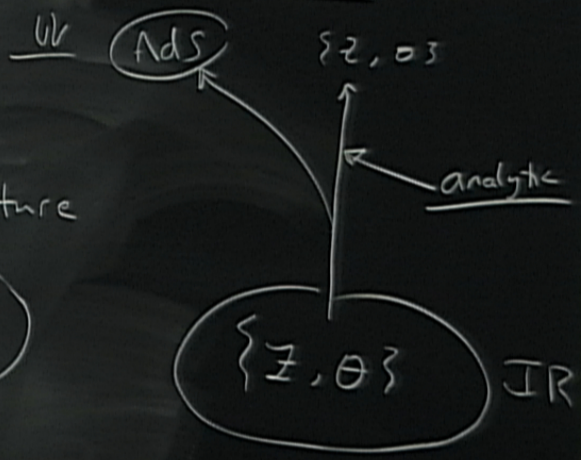
Features

Open Qns

Rich Structure



4D GR

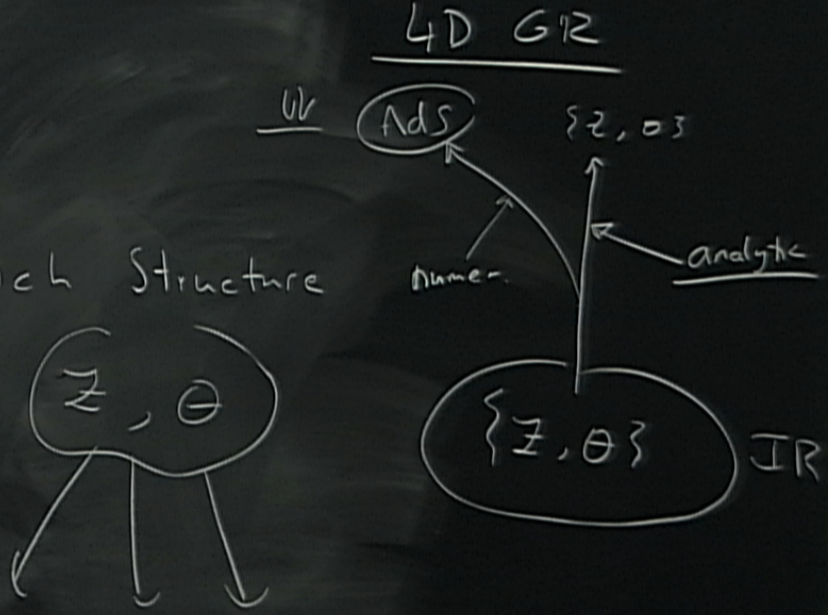


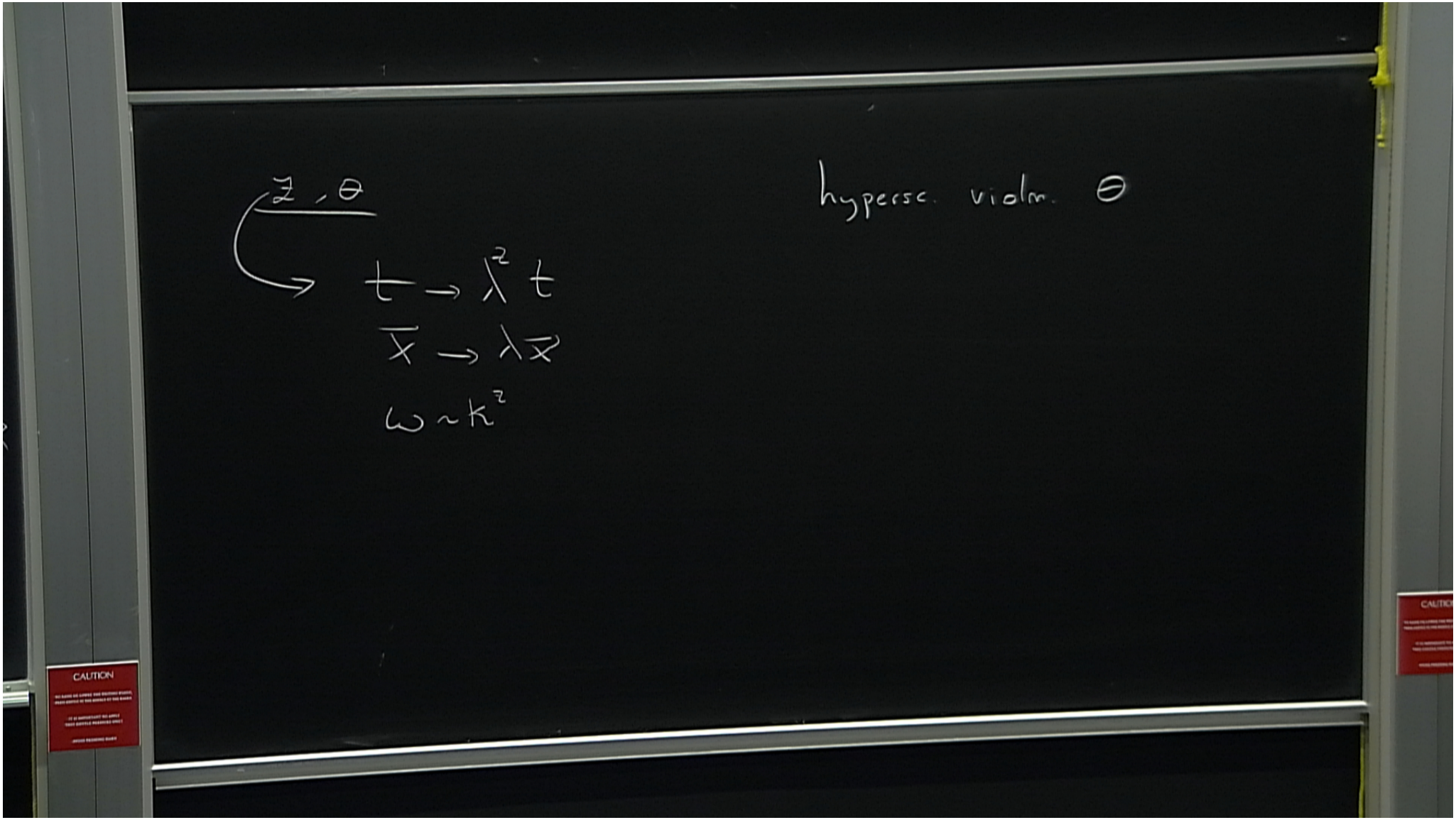
Scaling Geometries & DC Conductivities

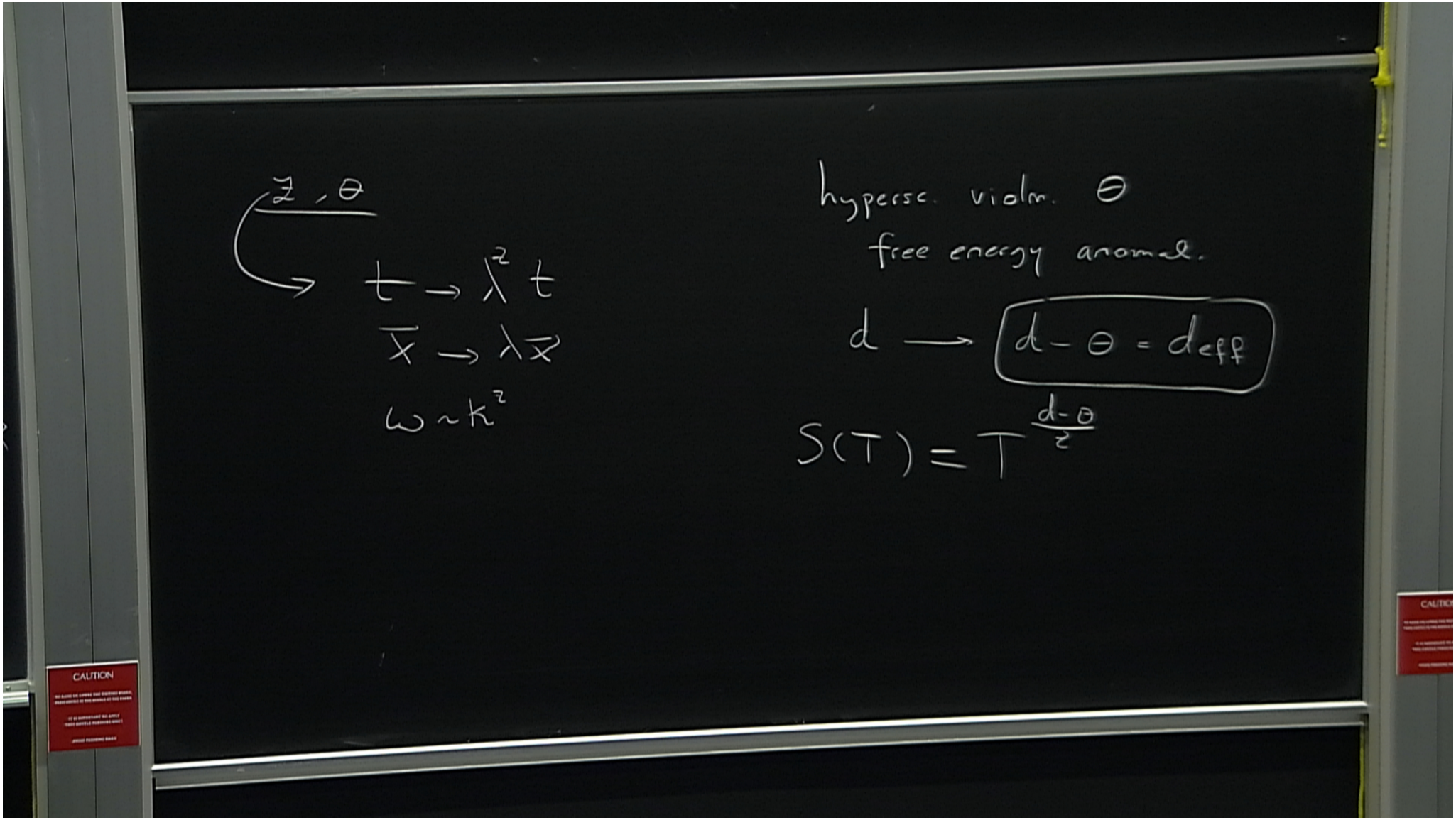
[arXiv: 1608.04394]
w/ Hai-Shan Lin
Hong Lu
Chris Pope

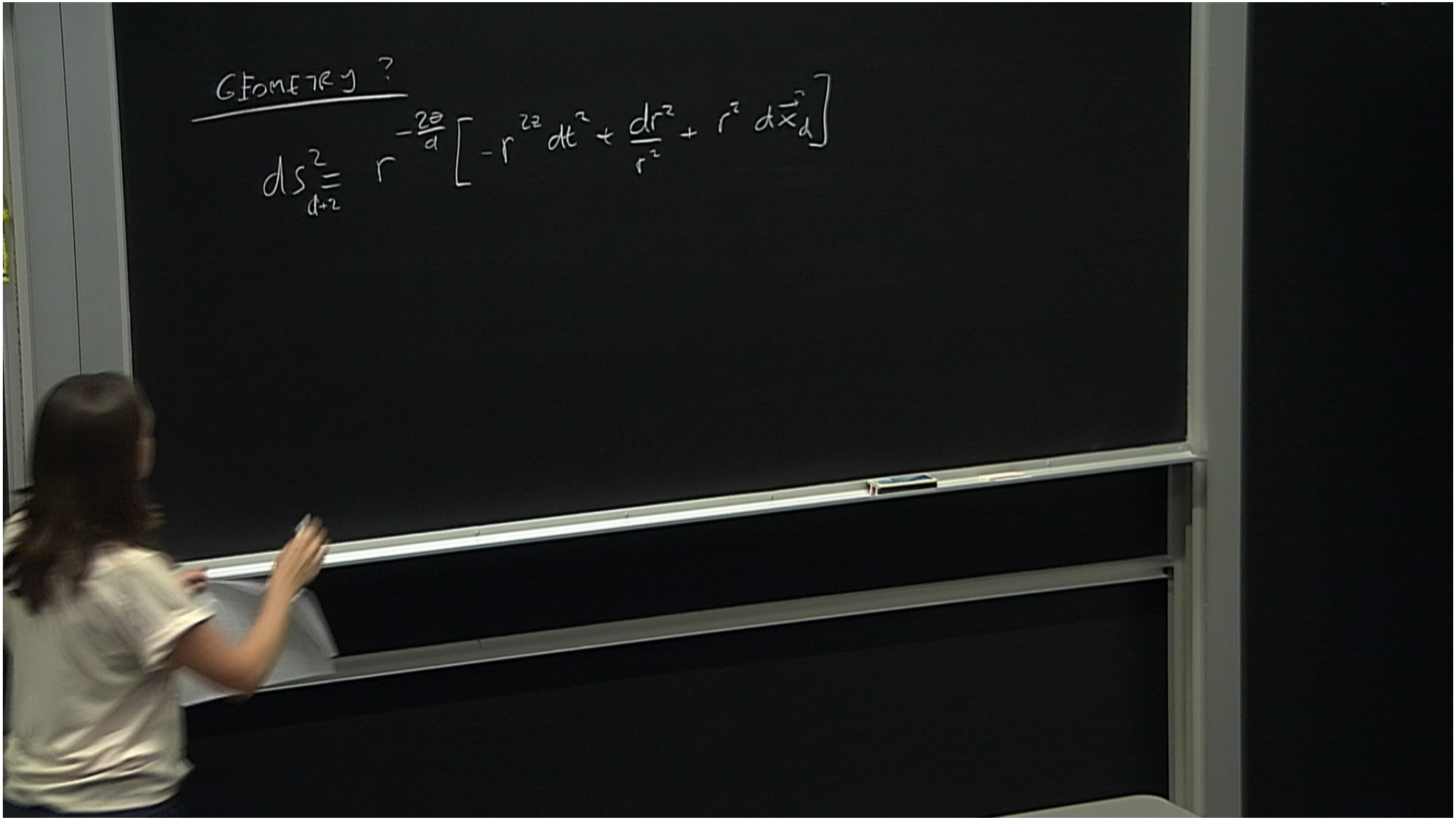
Features

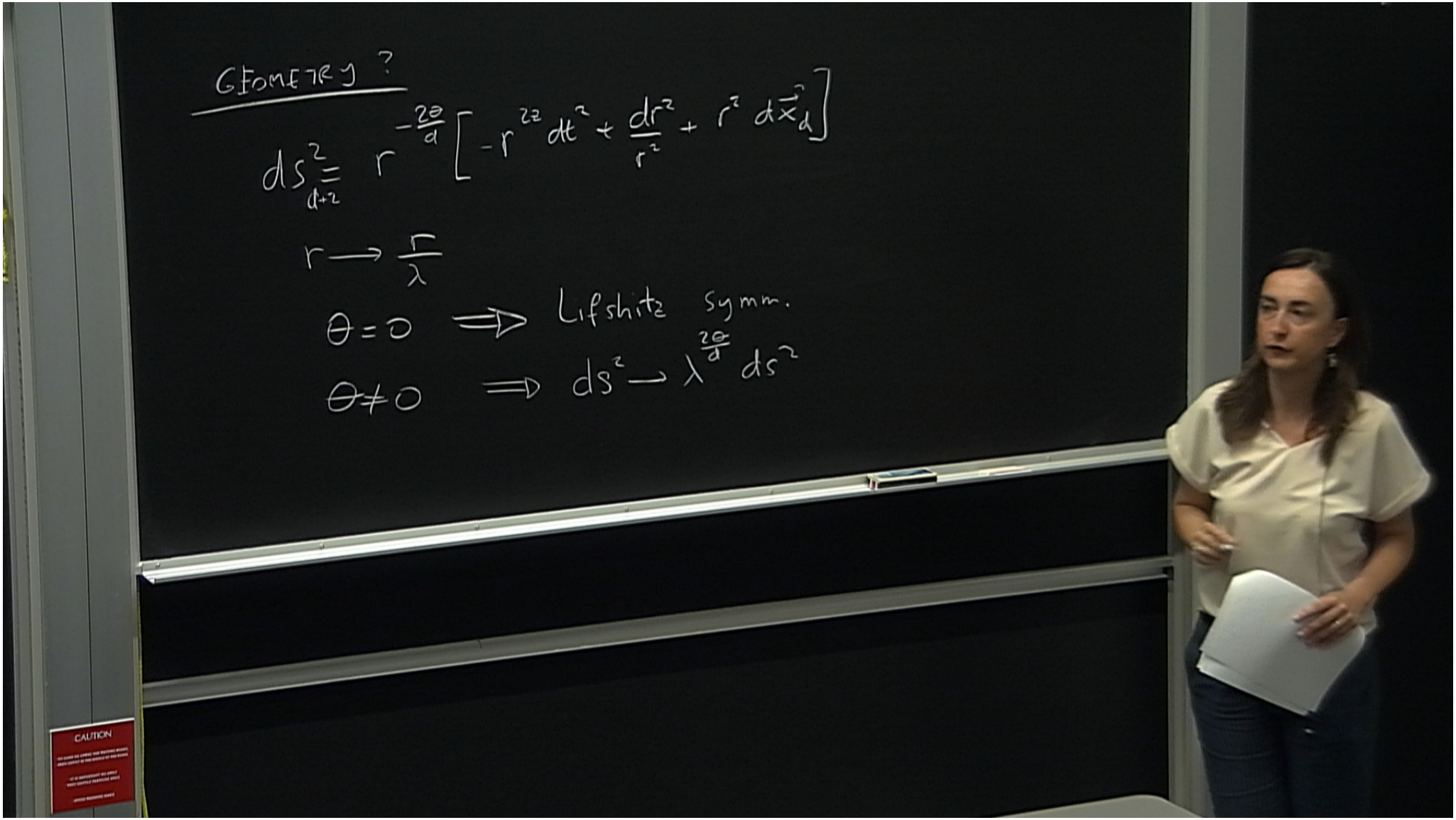
Open Qns

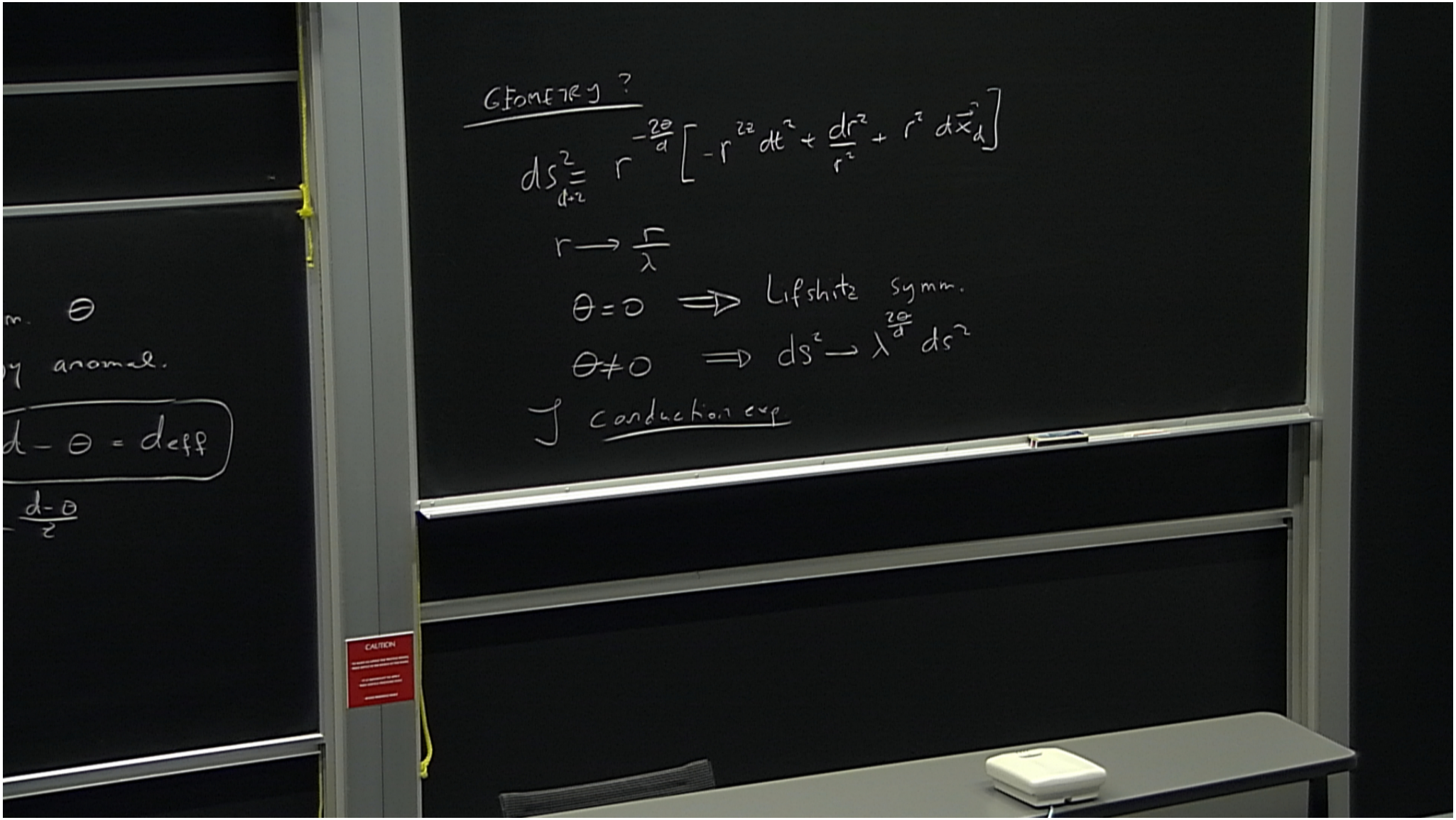


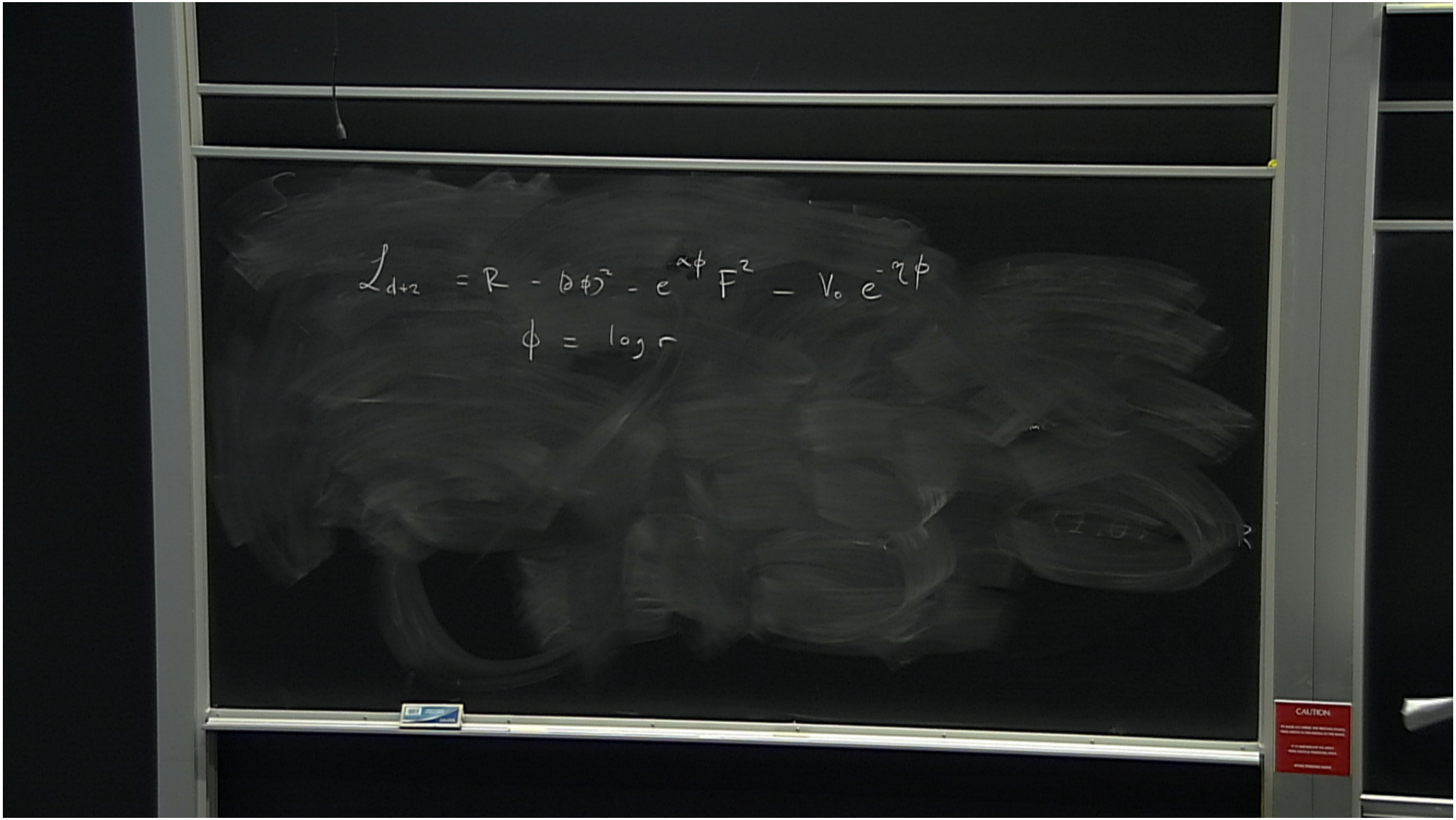

z = 0
t → λ² t
x → λ x
ω ~ k²
hypersc. violn. Θ

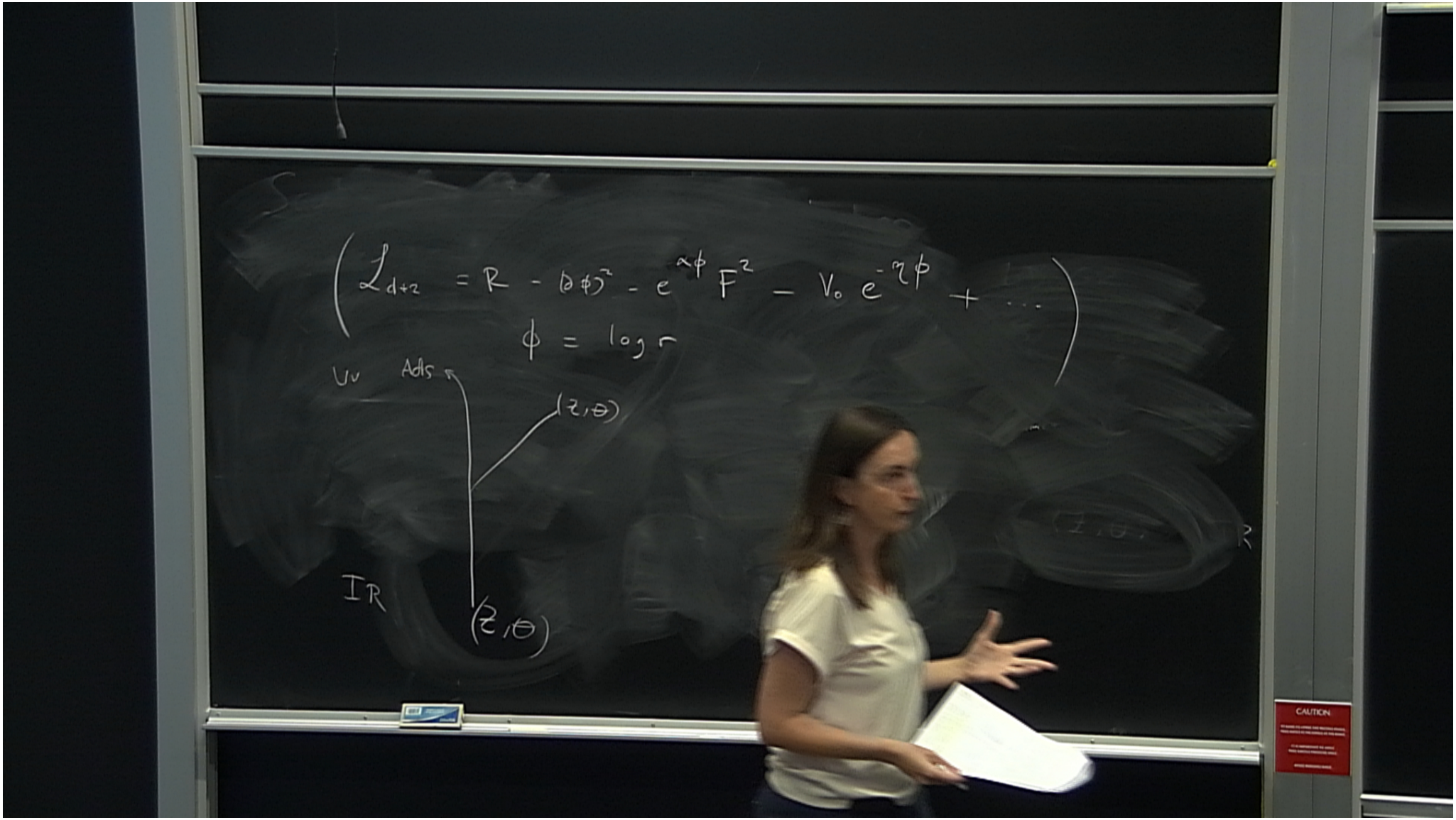

z , θ
t → λ^z t
x → λx
ω ~ k^z
hypersc. violn. θ
free energy anomal.
d → d − θ = d_eff
S(T) = T^((d−θ)/z)

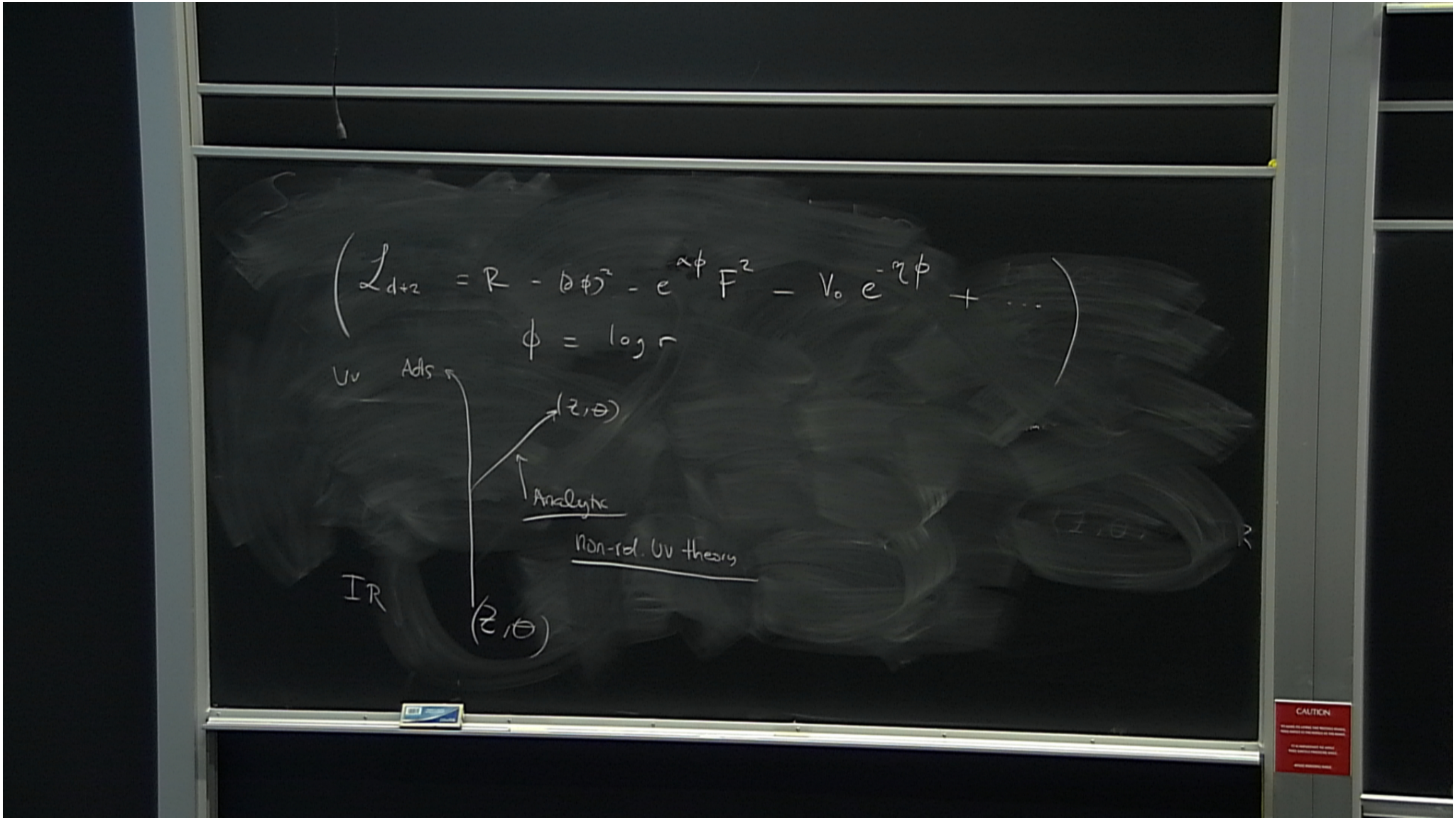

GEOMETRY ?
$ds^2_{d+2} = r^{-\frac{2\theta}{d}}\left[-r^{zz}dt^2 + \frac{dr^2}{r^2} + r^2 d\vec{x}_d^2\right]$

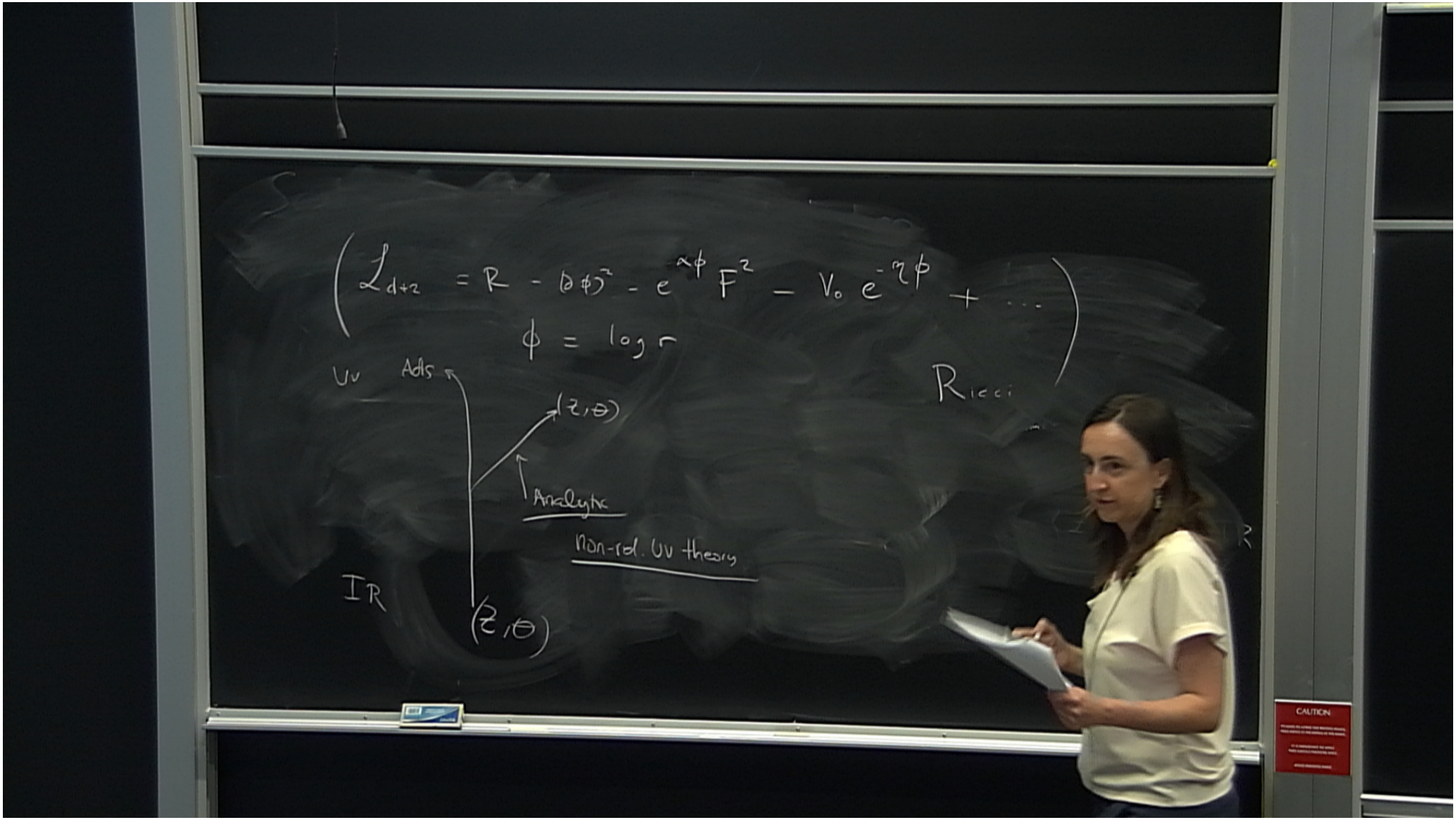

GEOMETRY ?
$ds^2_{d+2} \equiv r^{-\frac{2\theta}{d}}\left[-r^{zz}dt^2 + \frac{dr^2}{r^2} + r^2 d\vec{x}_d^2\right]$
$r \longrightarrow \frac{r}{\lambda}$
$\theta = 0 \Longrightarrow$ Lifshitz symm.
$\theta \neq 0 \Longrightarrow ds^2 \longrightarrow \lambda^{\frac{2\theta}{d}} ds^2$
CAUTION

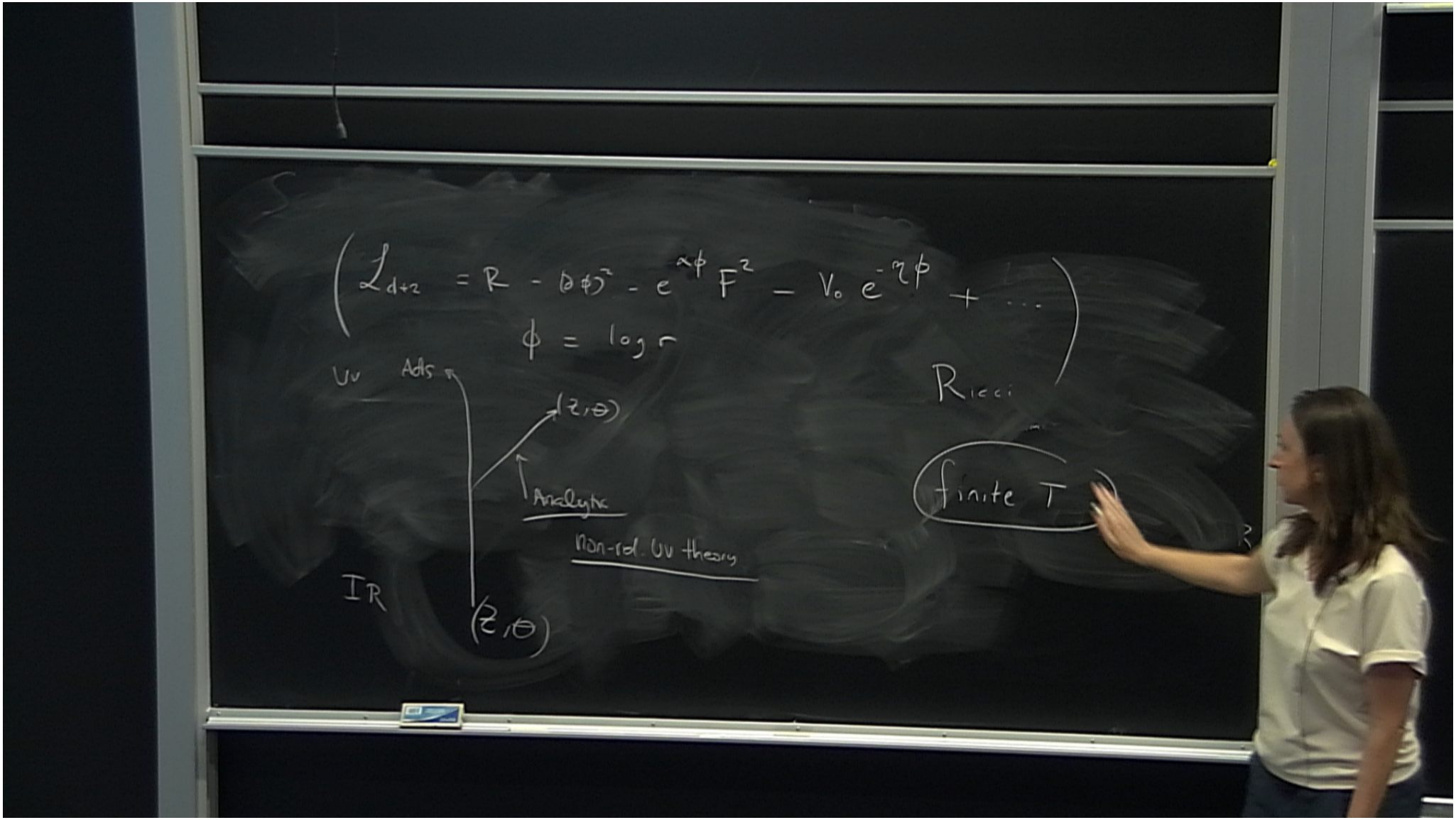

GEOMETRY ?
$ds^2_{d+2} = r^{-\frac{2\theta}{d}}\left[-r^{zz}dt^2 + \frac{dr^2}{r^2} + r^2 d\vec{x}_d^2\right]$
$r \to \frac{r}{\lambda}$
$\theta = 0 \Rightarrow$ Lifshitz symm.
$\theta \neq 0 \Rightarrow ds^2 \to \lambda^{\frac{2\theta}{d}} ds^2$
conduction exp
anomal.
$d - \theta = d_{eff}$
$\frac{d-\theta}{z}$
CAUTION

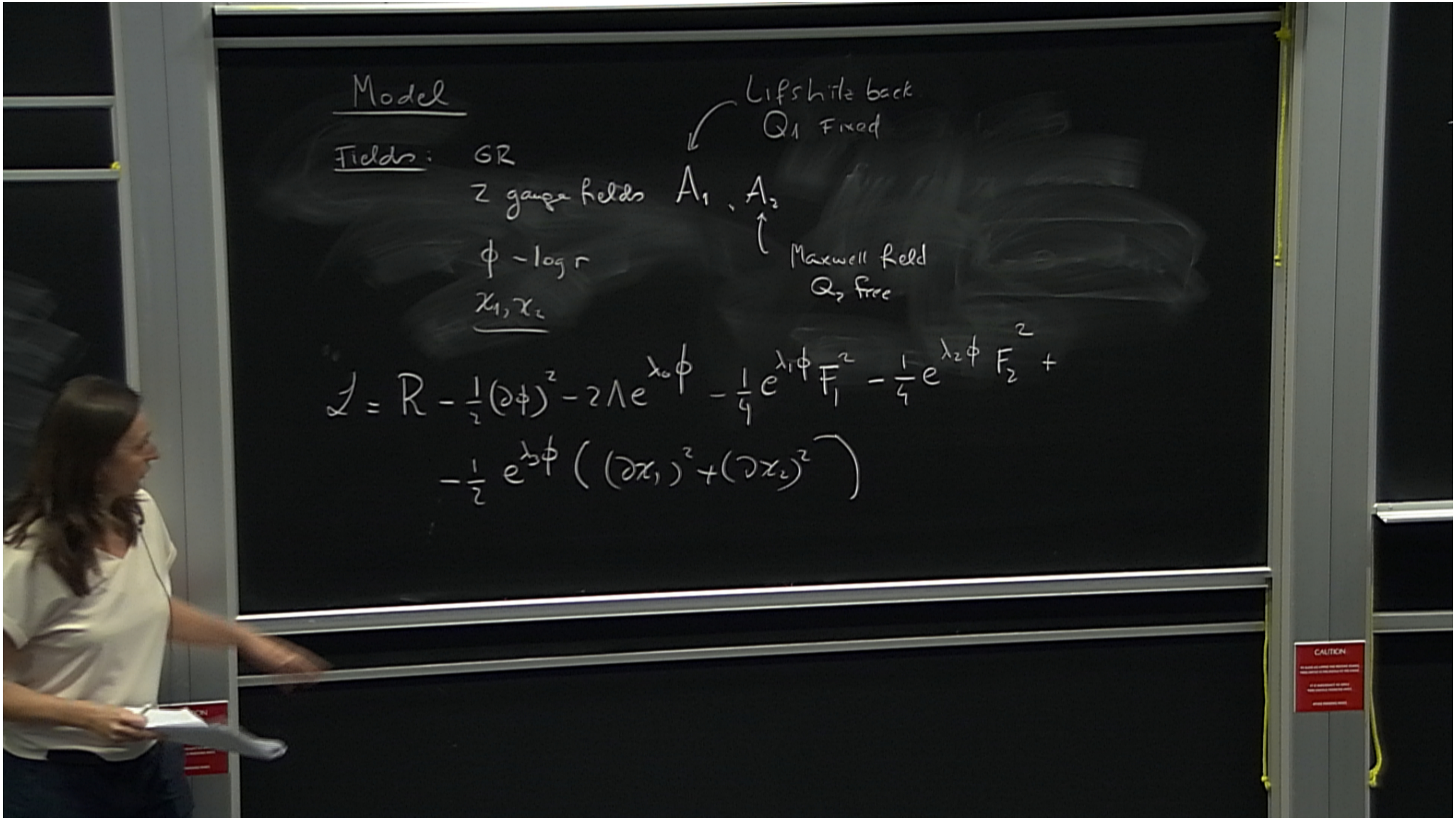

$\mathcal{L}_{d+2} = R - (\partial\phi)^2 - e^{a\phi} F^2 - V_0 e^{-2\phi}$
$\phi = \log r$
CAUTION

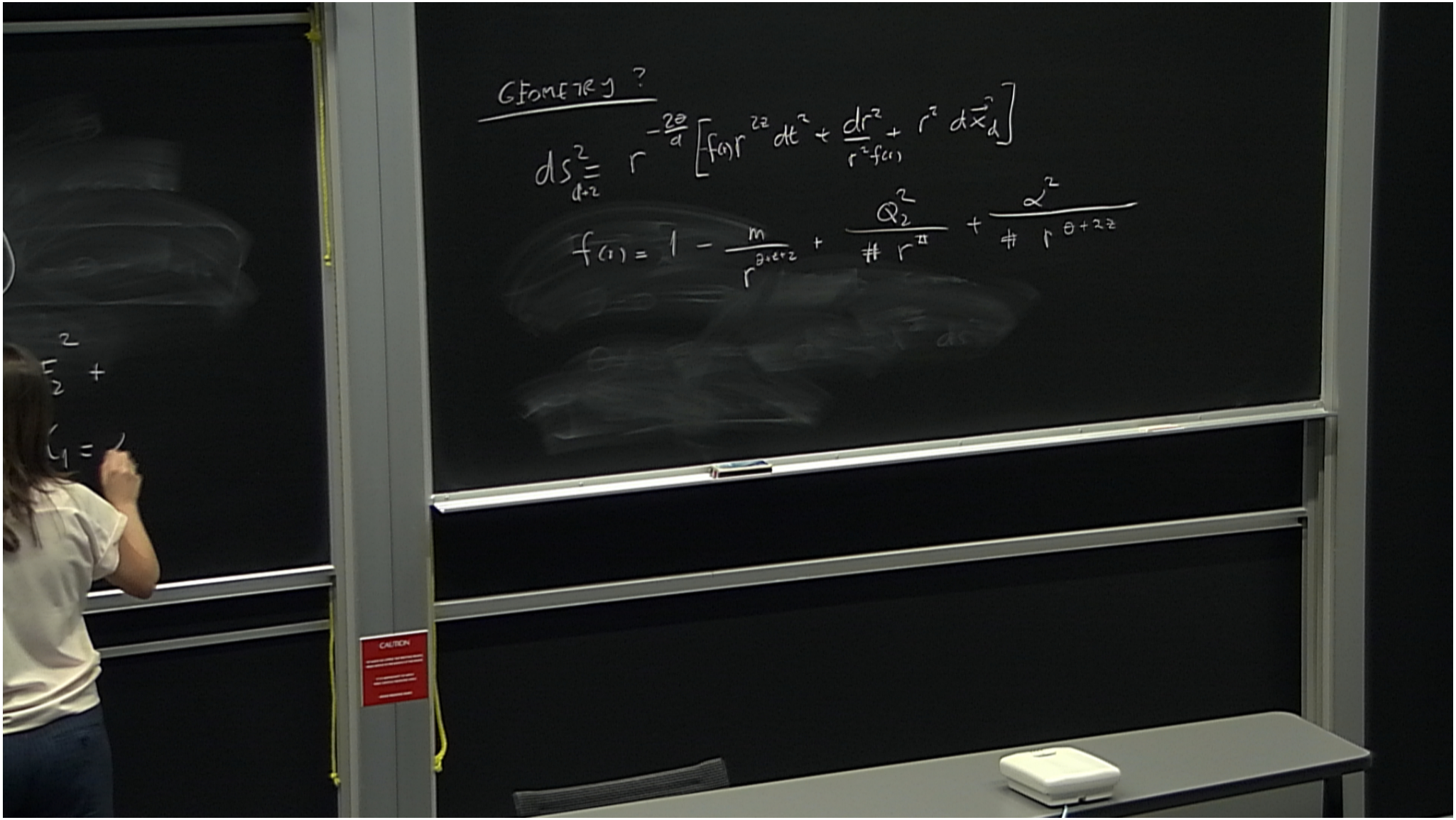

$\mathcal{L}_{d+2} = R - (\partial\phi)^2 - e^{a\phi} F^2 - V_0 e^{b\phi} + \dots$
$\phi = \log r$
UV
AdS
(z,0)
IR
(z,0)
CAUTION

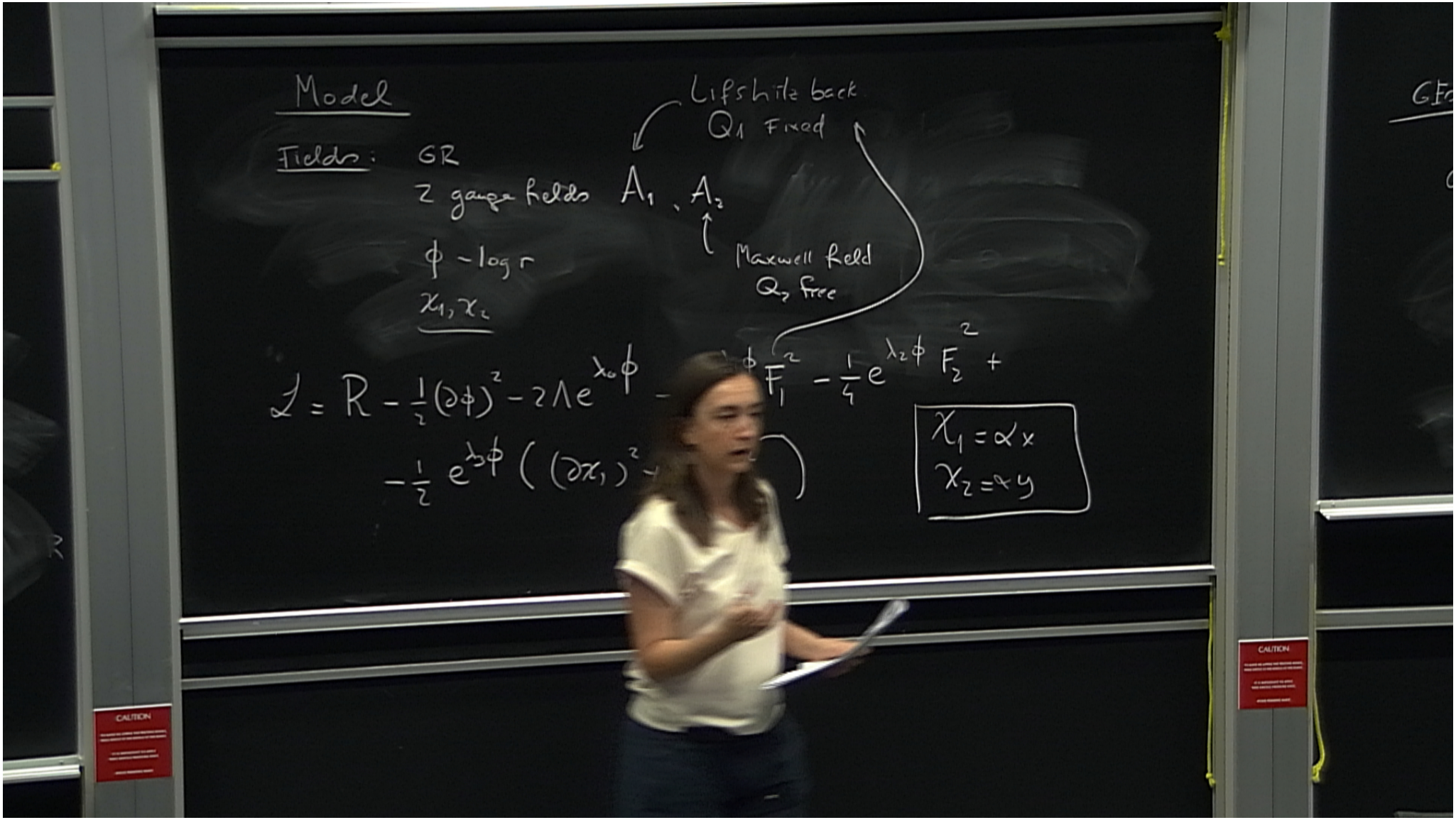

$\mathcal{L}_{d+2} = R - (\partial\phi)^2 - e^{a\phi} F^2 - V_0 e^{-b\phi} + \cdots$
$\phi = \log r$
UV
AdS
(z,0)
Analytic
non-rel. UV theory
IR
(z,0)

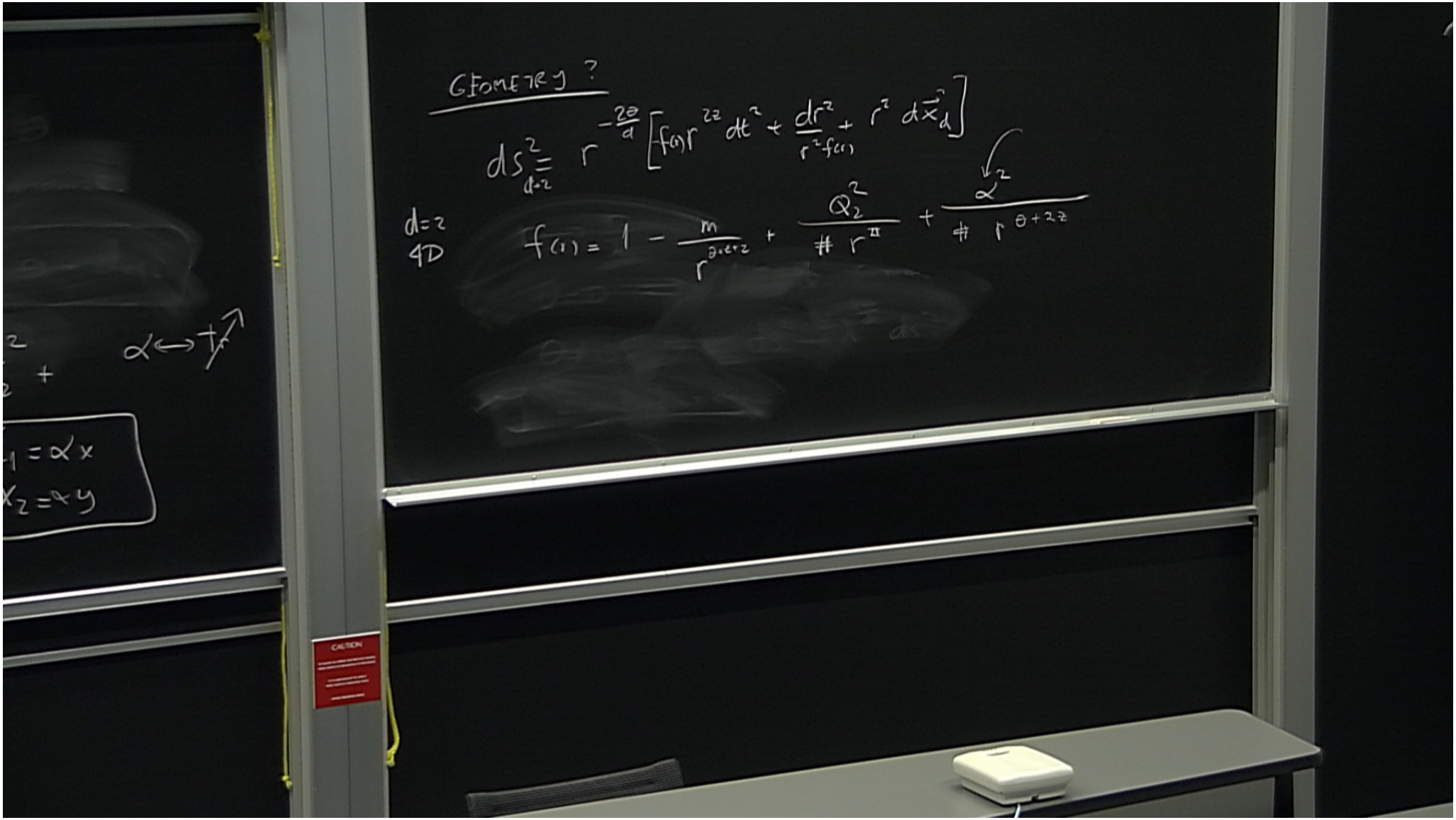

$\mathcal{L}_{d+2} = R - (\partial\phi)^2 - e^{a\phi} F^2 - V_0 e^{-\gamma\phi} + \dots$
$\phi = \log r$
UV
AdS
(z,0)
Analytic
non-rel. UV theory
IR
(z,0)
R_{ricci}
CAUTION

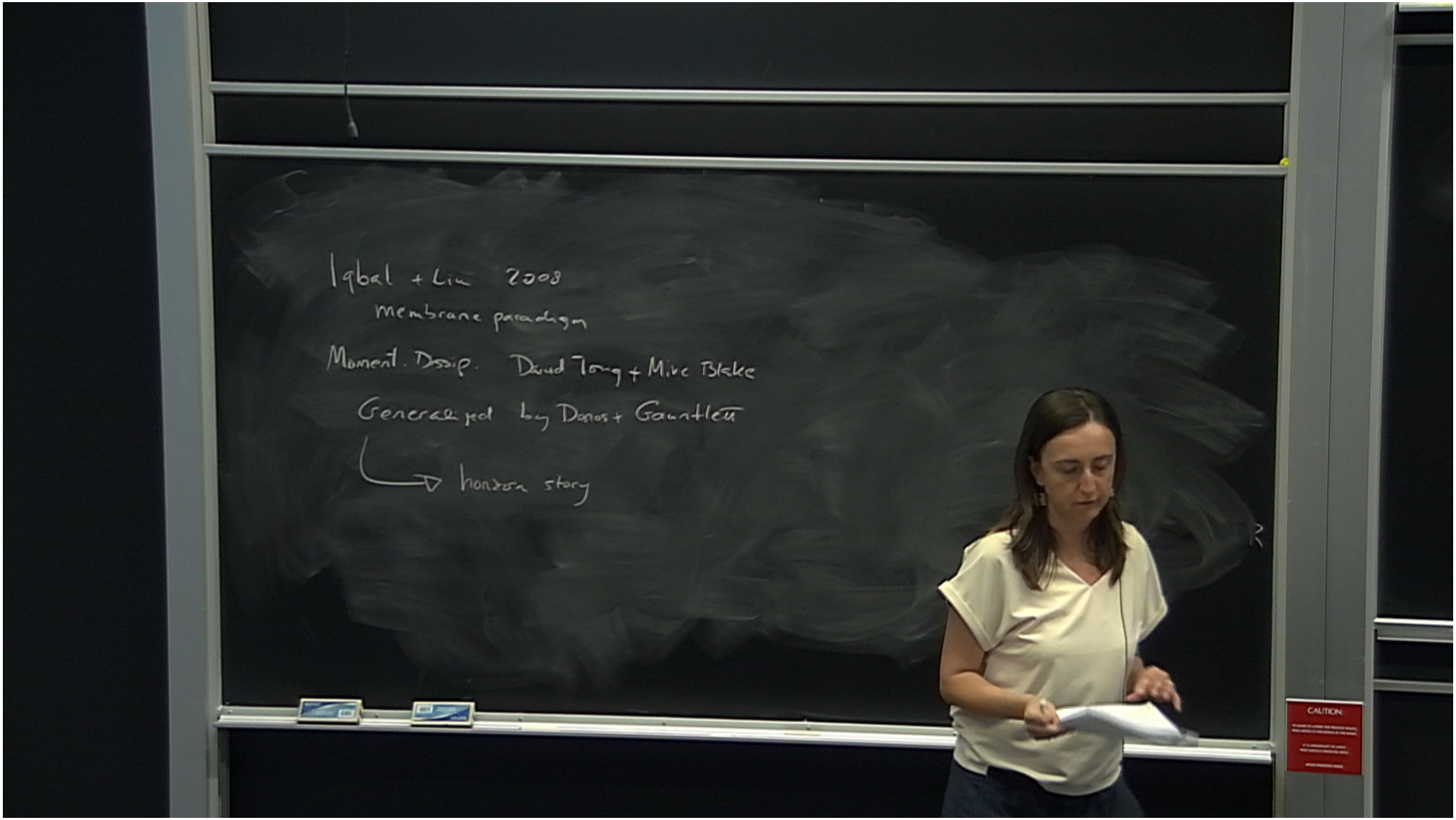

$\mathcal{L}_{d+2} = R - (\partial\phi)^2 - e^{a\phi} F^2 - V_0 e^{-b\phi} + \dots$
$\phi = \log r$
Uv
Ads
(z,0)
Analytic
non-rel. UV theory
IR
(z,0)
Ricci
finite T

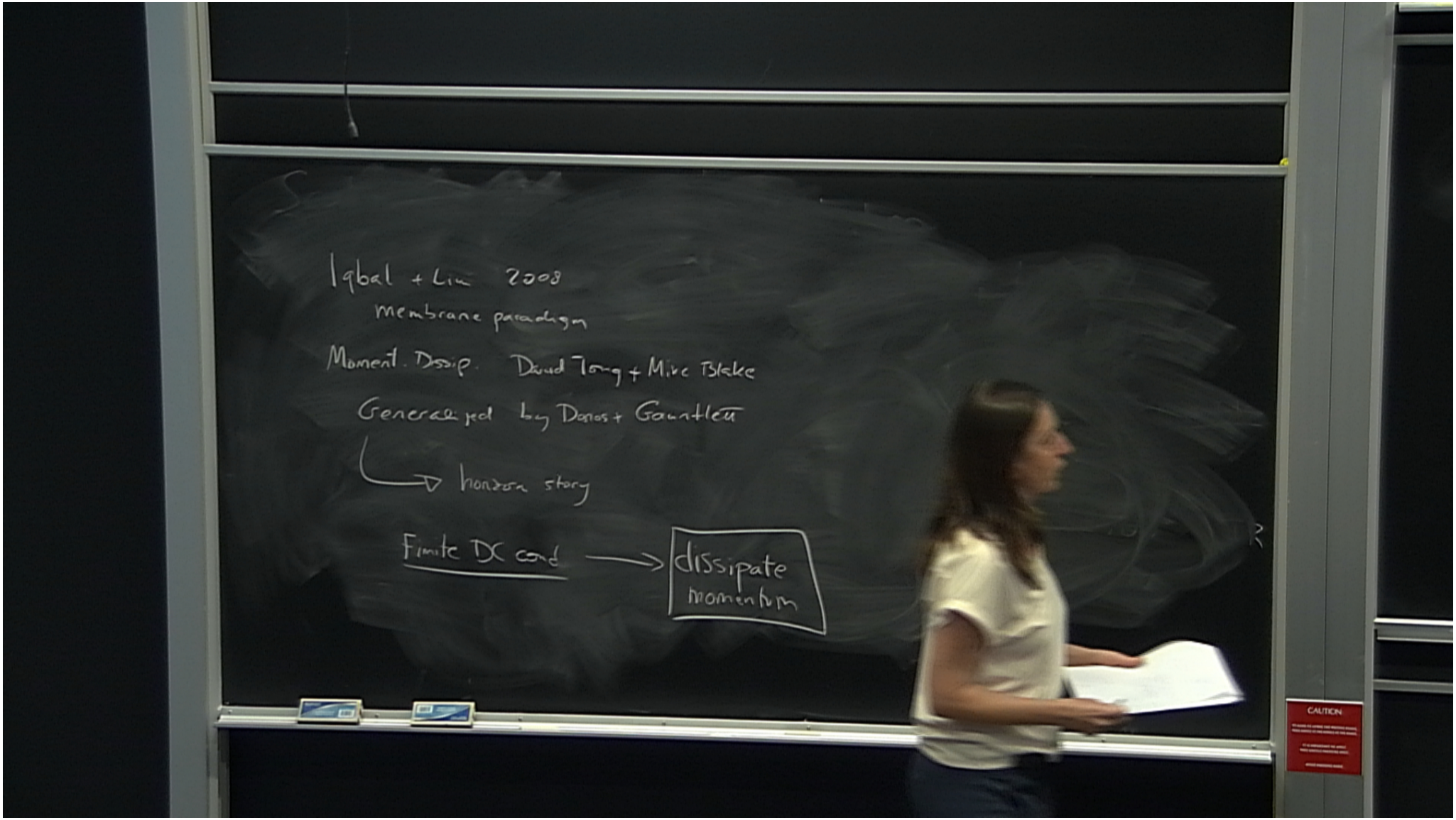

Model
Fields: GR
2 gauge fields A_1, A_2
Lifshitz back
Q_1 Fixed
Maxwell field
Q_2 free
$\phi = \log r$
χ_1, χ_2
$\mathcal{L} = R - \frac{1}{2}(\partial\phi)^2 - 2\Lambda e^{\lambda_0\phi} - \frac{1}{4}e^{\lambda_1\phi}F_1^2 - \frac{1}{4}e^{\lambda_2\phi}F_2^2 +$
$-\frac{1}{2}e^{\lambda_3\phi}\left((\partial\chi_1)^2 + (\partial\chi_2)^2\right)$

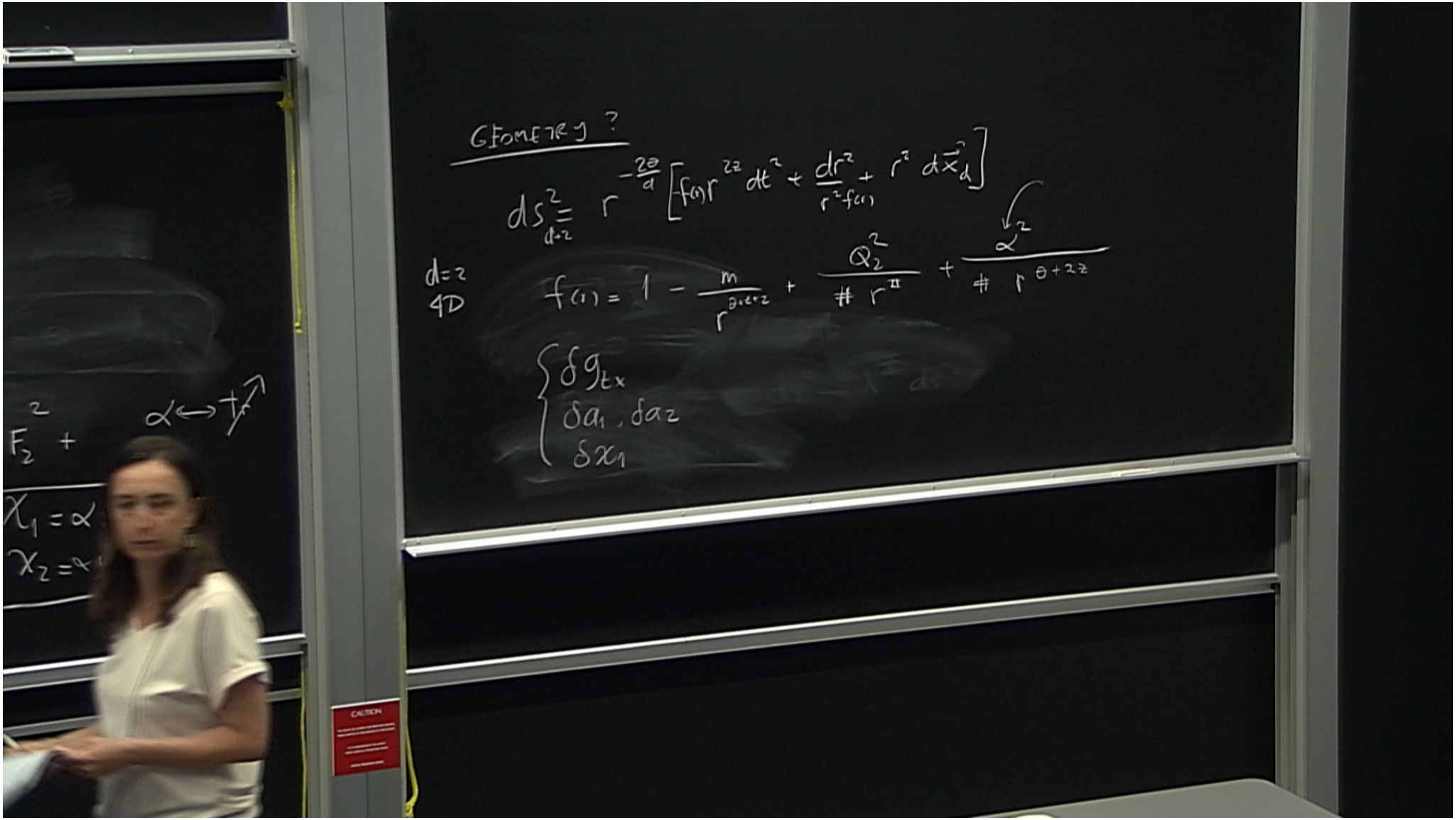

GEOMETRY ?
$ds^2_{d+2} = r^{-\frac{2\theta}{d}}\left[-f(r)r^{zz}dt^2 + \frac{dr^2}{r^2 f(r)} + r^2 d\vec{x}_d^2\right]$
$f(r) = 1 - \frac{m}{r^{\theta+z+2}} + \frac{Q_2^2}{\# r^{\Pi}} + \frac{\alpha^2}{\# r^{\theta+2z}}$
CAUTION

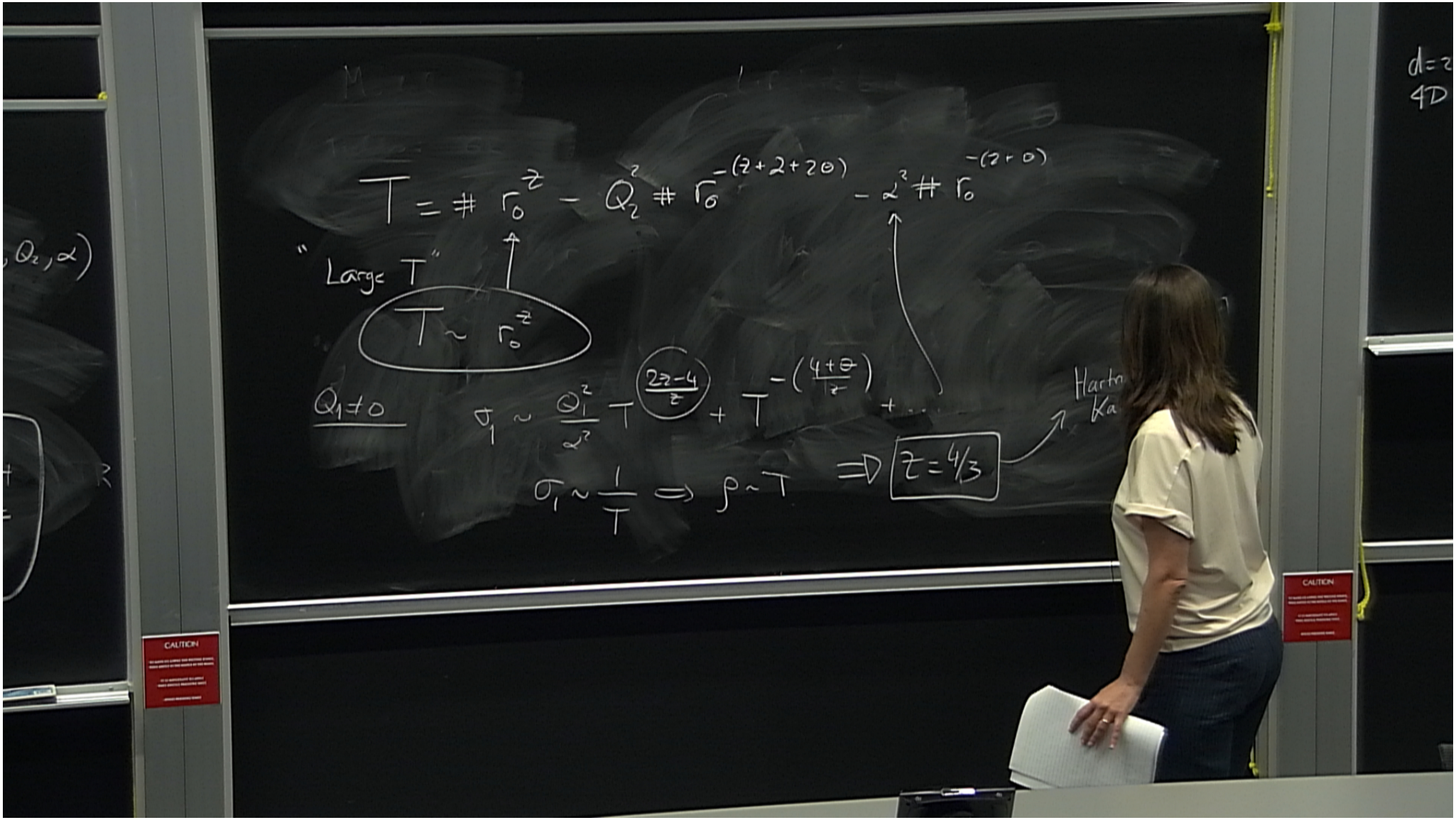

Model
Fields: GR
2 gauge fields A_1, A_2
$\phi - \log r$
x_1, x_2
Lifshitz back
Q_1 Fixed
Maxwell field
Q_2 free
$\mathcal{L} = R - \frac{1}{2}(\partial\phi)^2 - 2\Lambda e^{\lambda_0\phi} - \frac{1}{4}e^{\lambda_1\phi}F_1^2 - \frac{1}{4}e^{\lambda_2\phi}F_2^2 +$
$-\frac{1}{2}e^{\lambda_3\phi}((\partial x_1)^2$
$x_1 = \alpha x$
$x_2 = \alpha y$

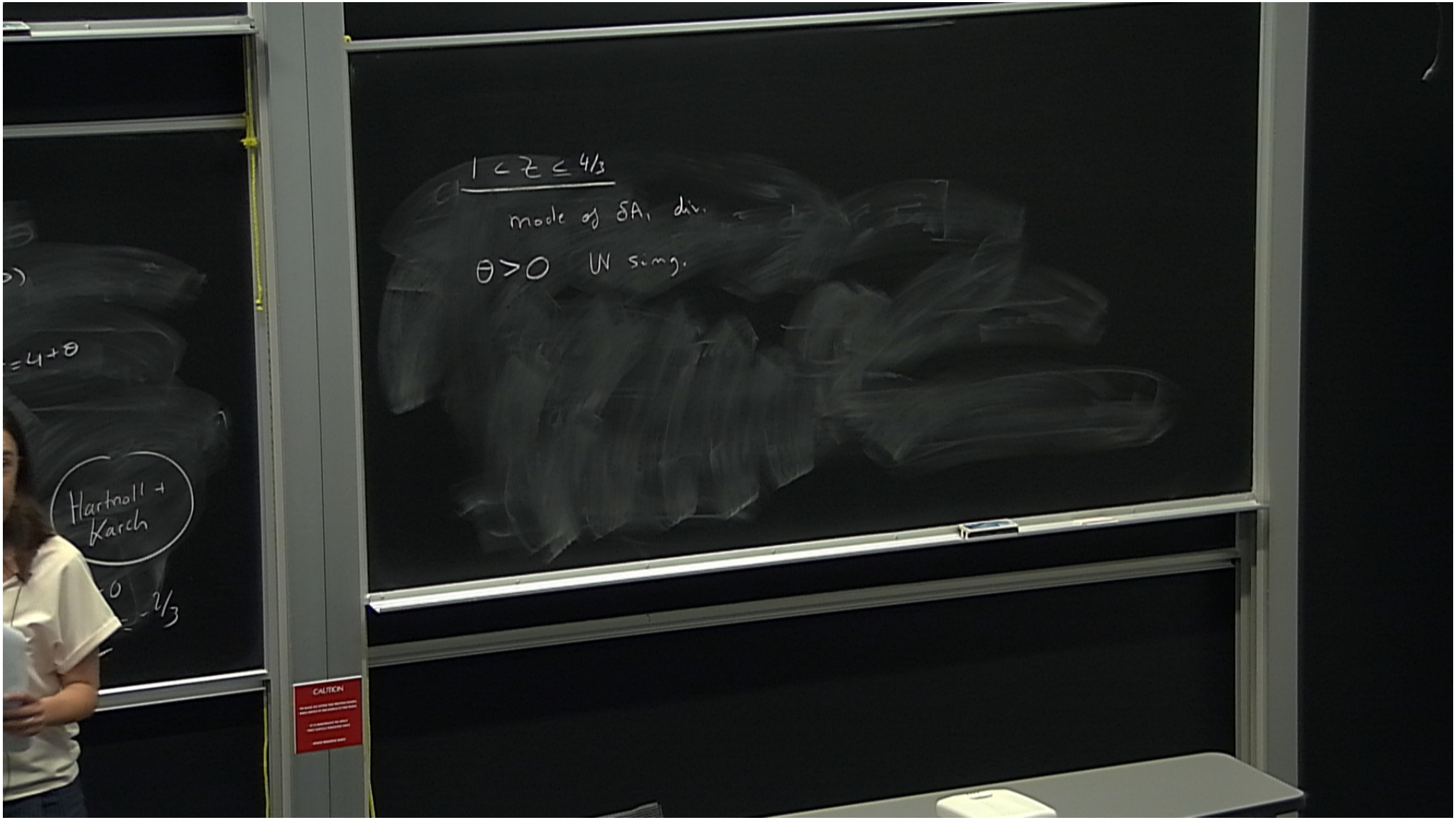

GEOMETRY ?
$ds^2_{d+2} = r^{-\frac{2\theta}{d}}\left[-f(r)r^{zz}dt^2 + \frac{dr^2}{r^2 f(r)} + r^2 d\vec{x}_d^2\right]$
d=2
4D
$f(r) = 1 - \frac{m}{r^{\theta+z+2}} + \frac{Q_2^2}{\# r^{\Pi}} + \frac{\alpha^2}{\# r^{\theta+2z}}$
$\alpha \leftrightarrow$
$= \alpha x$
$x_2 = \alpha y$
CAUTION

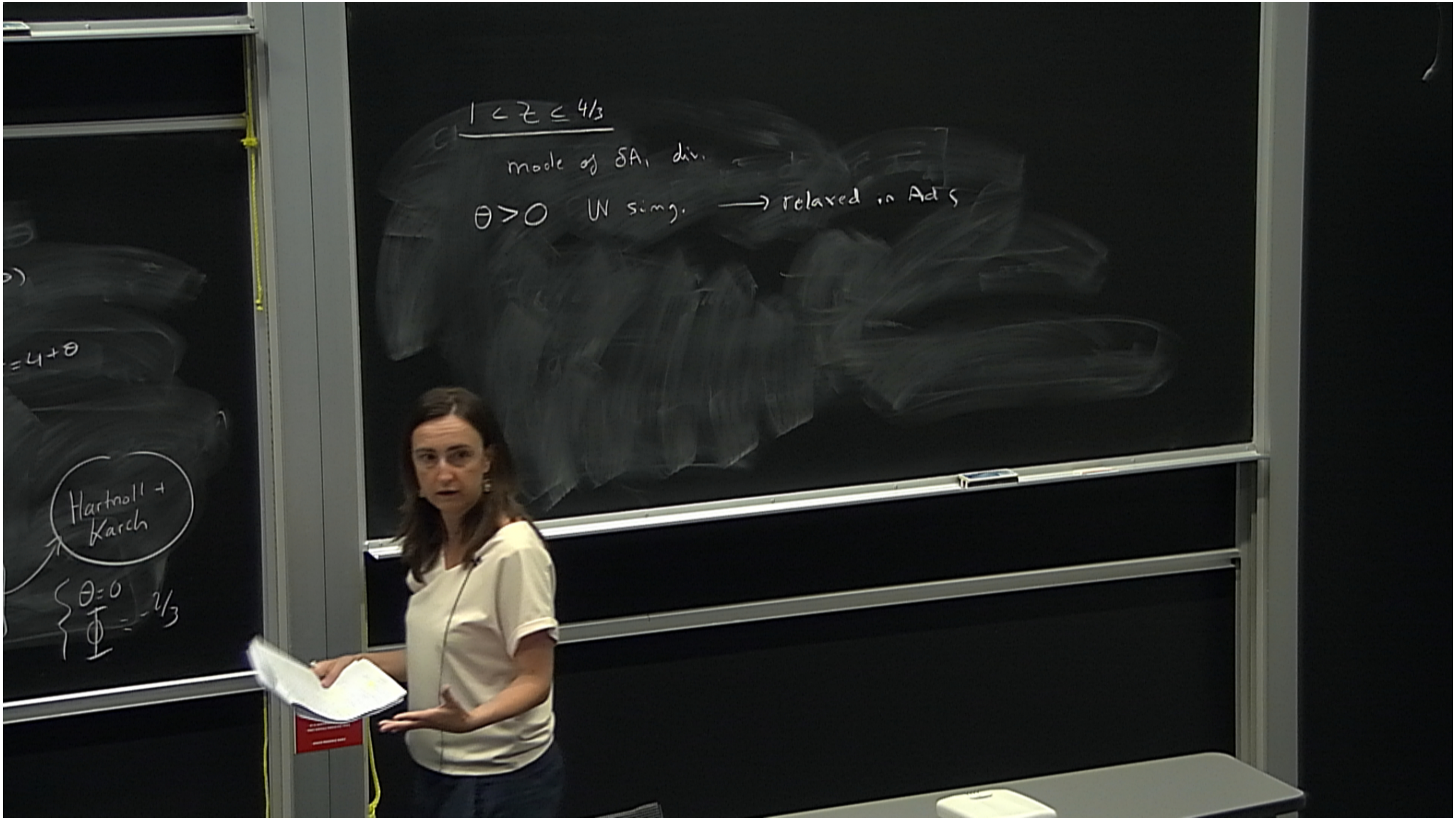

Iqbal + Liu 2008
membrane paradigm
Moment. Dissip. David Tong + Mike Blake
Generalized by Damour + Gauntlett
horizon story
CAUTION

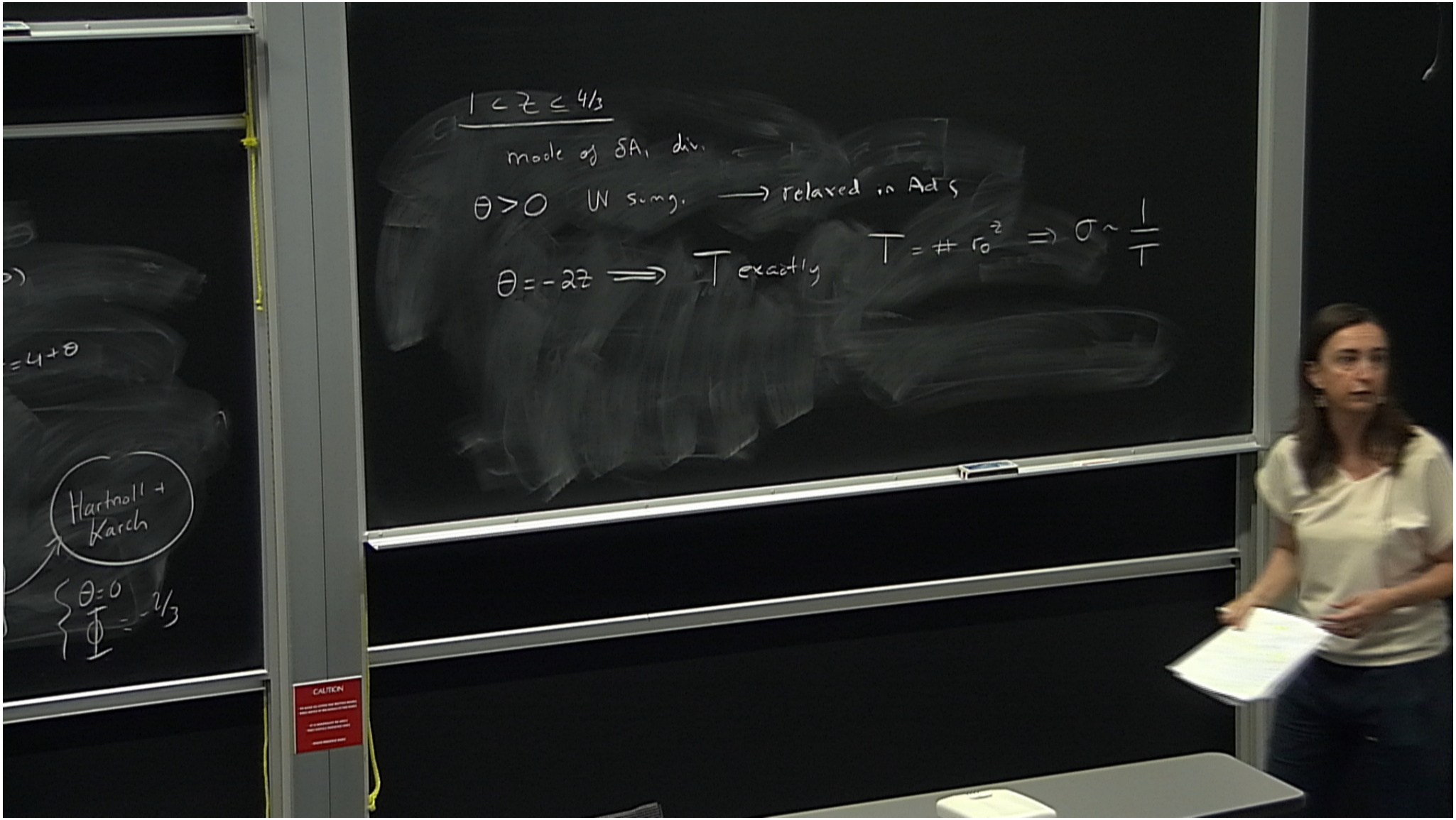

Iqbal + Liu 2008
membrane paradigm
Momentum Dissip. David Tong + Mike Blake
Generalized by Davis + Gauntlett
horizon story
Finite DC cond
dissipate momentum
CAUTION

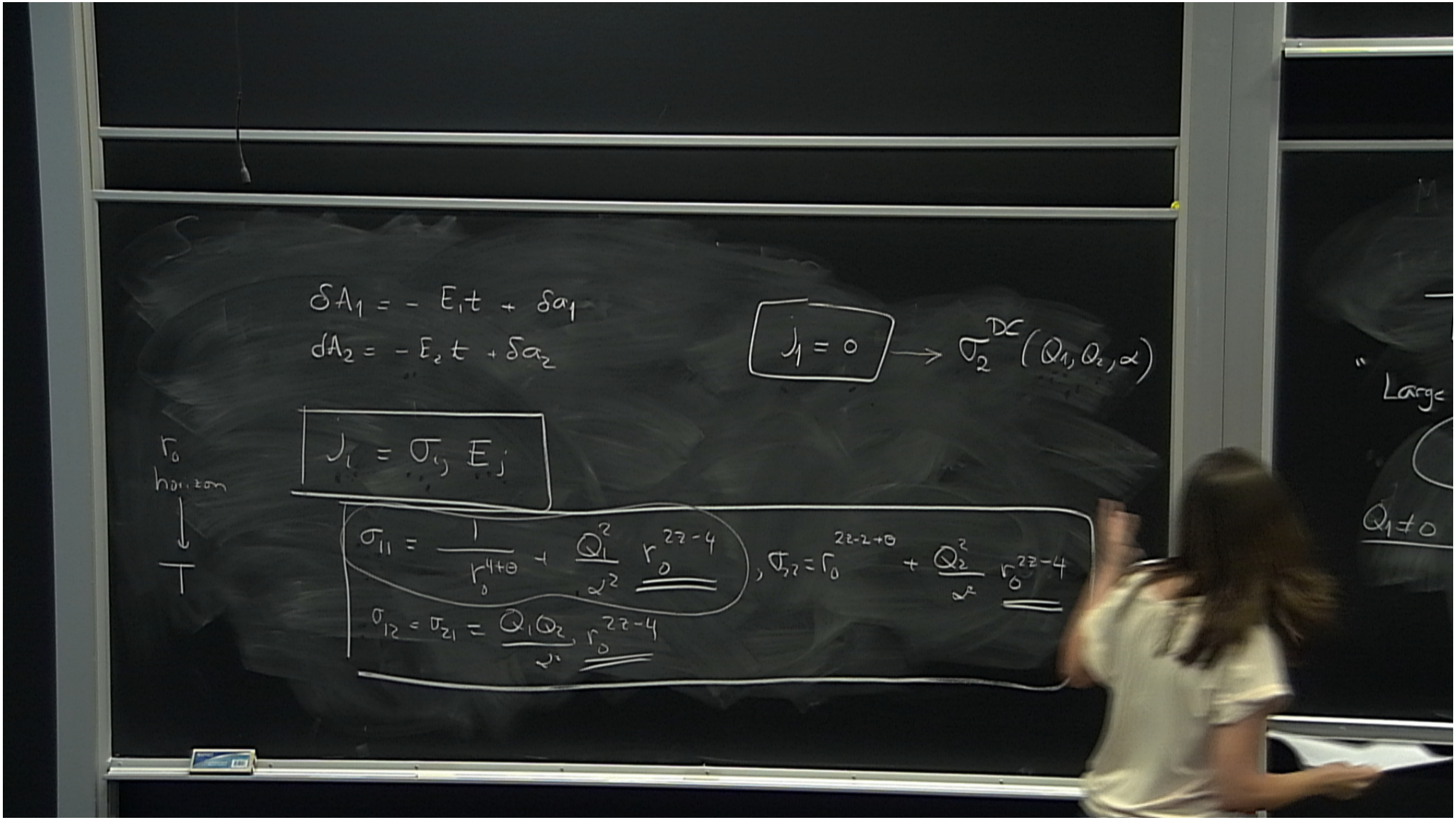

GEOMETRY ?
$ds^2_{d+2} \equiv r^{-\frac{2\theta}{d}} \left[-f(r) r^{zz} dt^2 + \frac{dr^2}{r^2 f(r)} + r^2 d\vec{x}_d^2 \right]$
d=2
4D
$f(r) = 1 - \frac{m}{r^{\theta+z+2}} + \frac{Q_2^2}{\# r^{\Pi}} + \frac{\alpha^2}{\# r^{\theta+2z}}$
$\begin{cases} \delta g_{tx} \\ \delta a_1, \delta a_2 \\ \delta x_1 \end{cases}$
$F_2^2 +$
$\alpha \leftrightarrow$
$x_1 = \alpha$
$x_2 =$
CAUTION

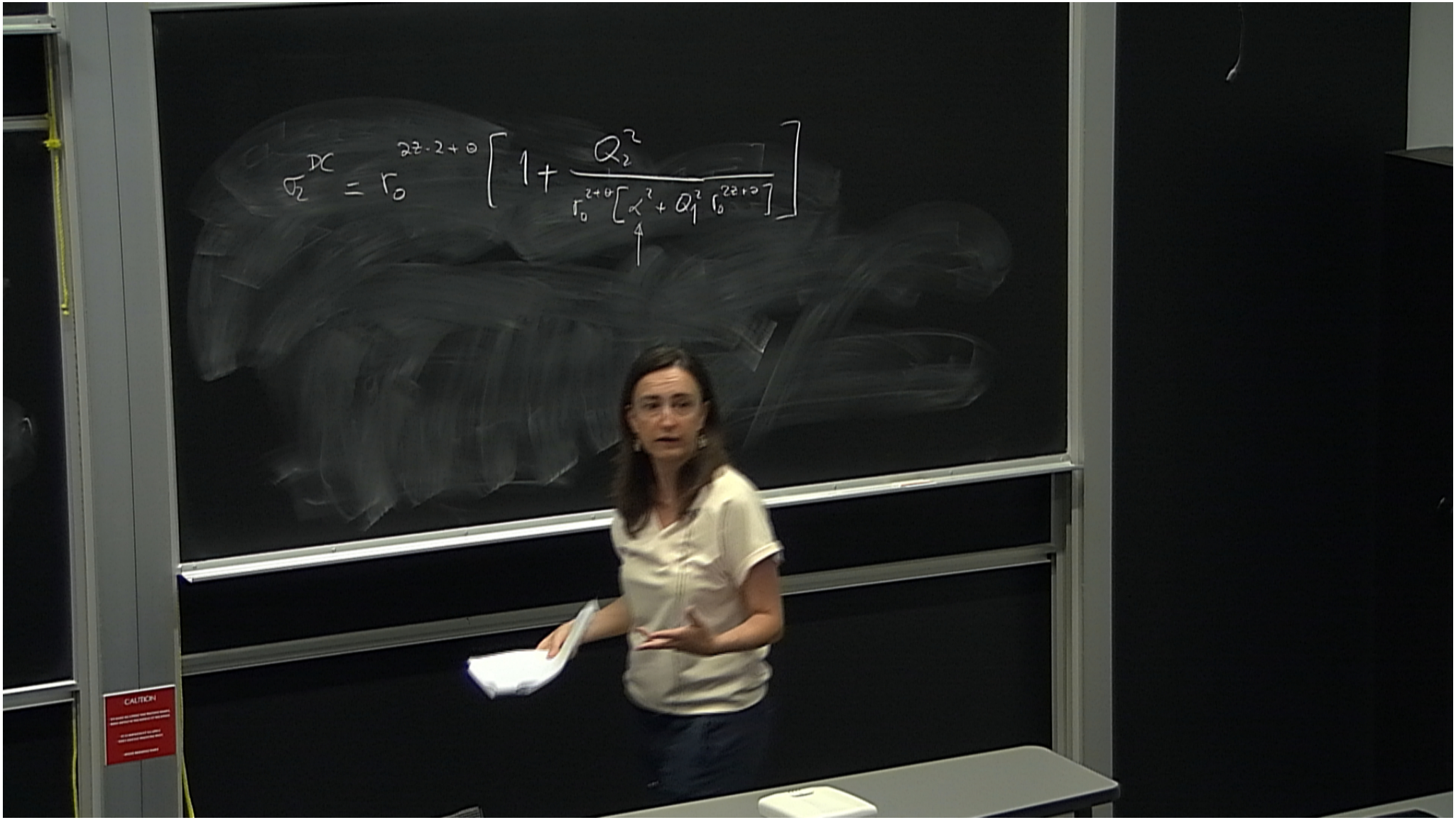

$T = \# r_0^z - Q_2^2 \# r_0^{-(z+2+2\theta)} - \alpha^2 \# r_0^{-(z+\theta)}$
"Large T"
$T \sim r_0^z$
$Q_1 \neq 0$
$\sigma_1 \sim \frac{Q_1^2}{\alpha^2} T^{\frac{2z-4}{z}} + T^{-\left(\frac{4+\theta}{z}\right)} + \dots$
$\sigma_1 \sim \frac{1}{T} \Rightarrow \rho \sim T \Rightarrow z = 4/3$
Hartn
Ka
CAUTION
CAUTION
d=2
4D

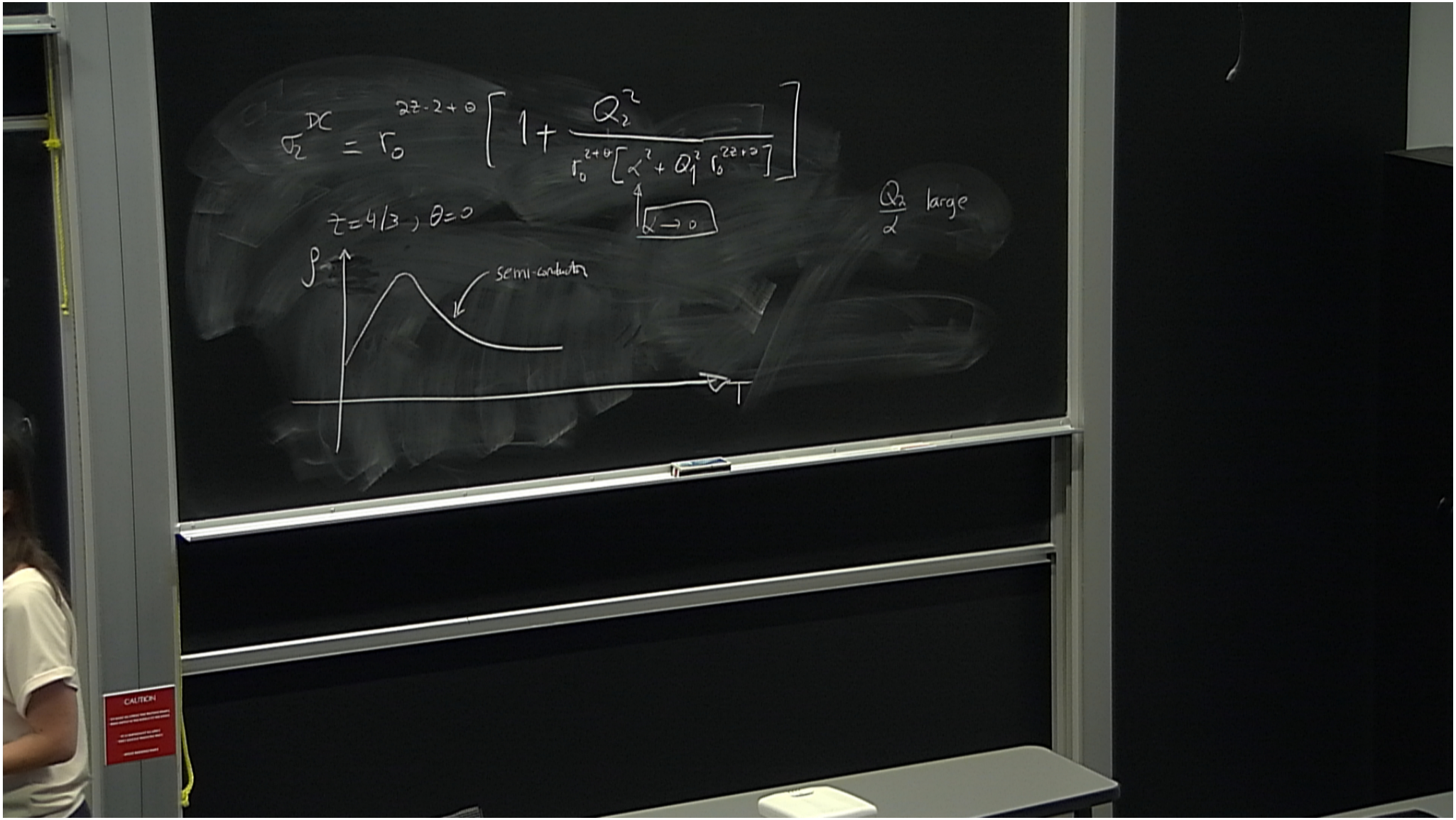

$1 < z \leq 4/3$
mode of δA_1 div.
$\theta > 0$ W sing.
$= 4 + \theta$
Hartnoll + Karch
$-2/3$
CAUTION

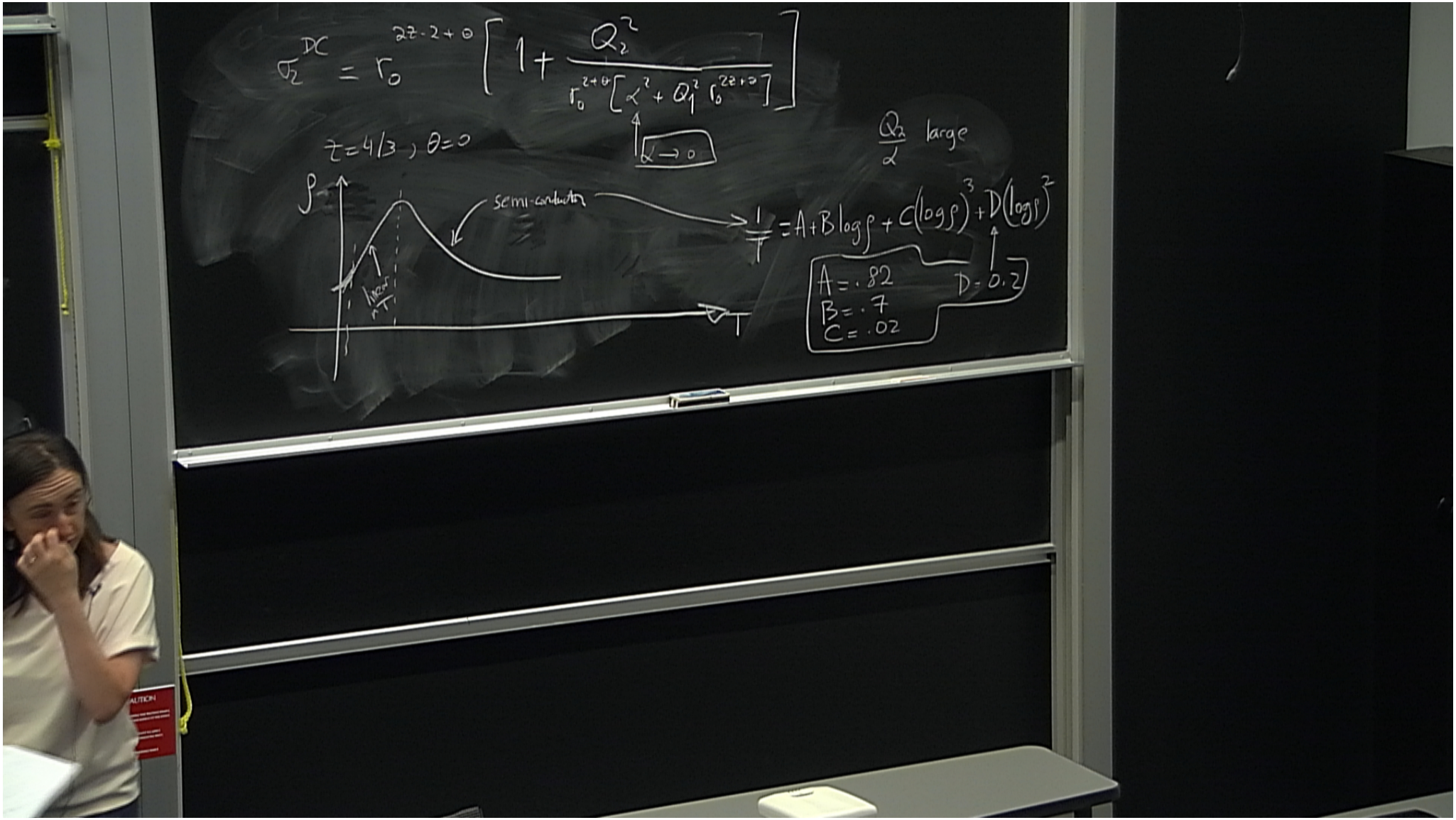

$1 < z \leq 4/3$
mode of δA_1 div.
$\theta > 0$ UV simg. $\longrightarrow$ relaxed in AdS
$= 4 + \theta$
Hartnoll + Karch
$\theta = 0$
$= -2/3$

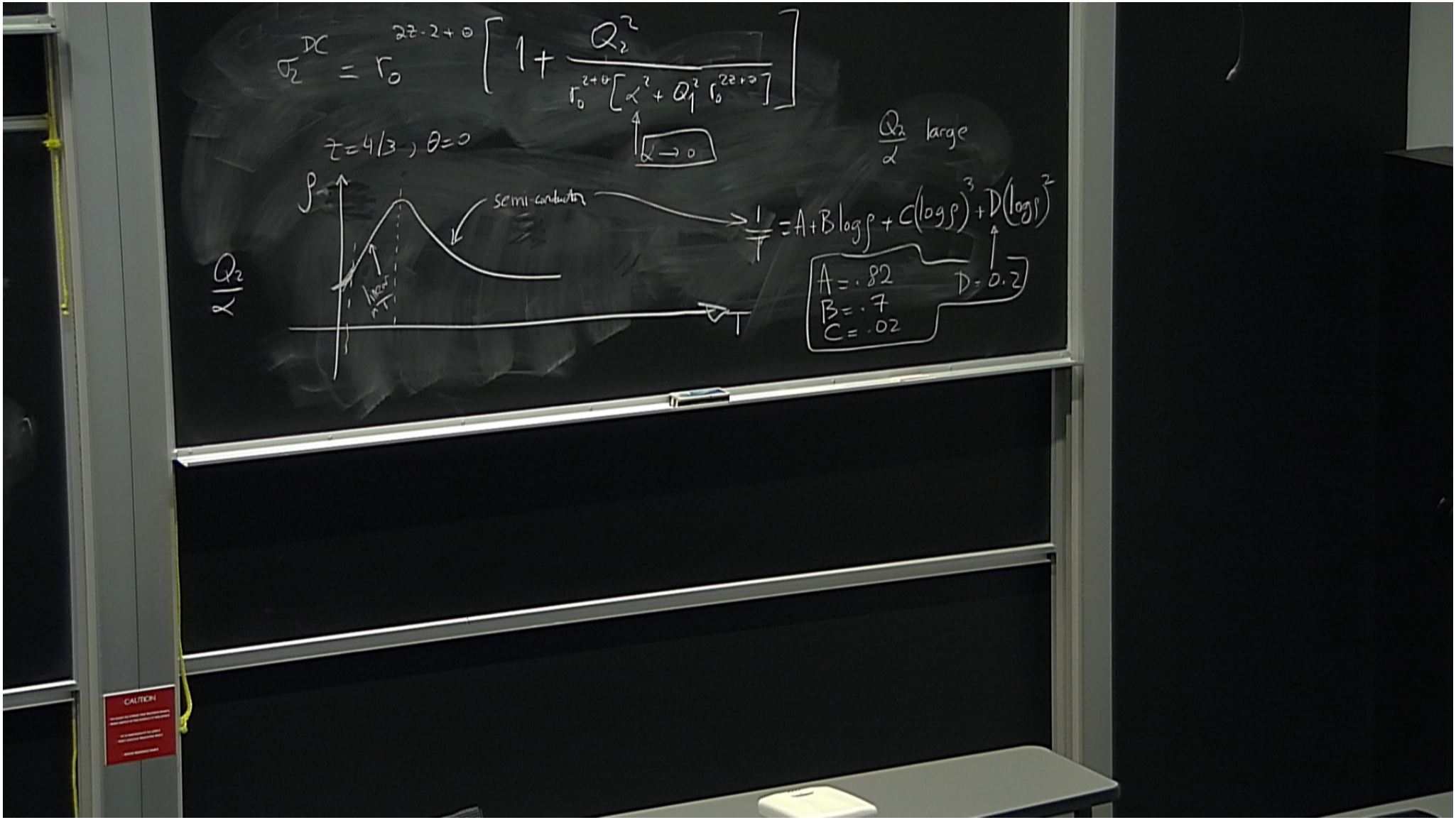

$1 < z \leq 4/3$
mode of δA_1 dis.
$\theta > 0$ UV susy. $\longrightarrow$ relaxed in AdS
$\theta = -2z \Longrightarrow$ T exactly
$T = \# r_0^z \Rightarrow \sigma \sim \frac{1}{T}$
$= 4 + \theta$
Hartnoll + Karch
$\theta = 0$
$\Phi = -2/3$
CAUTION

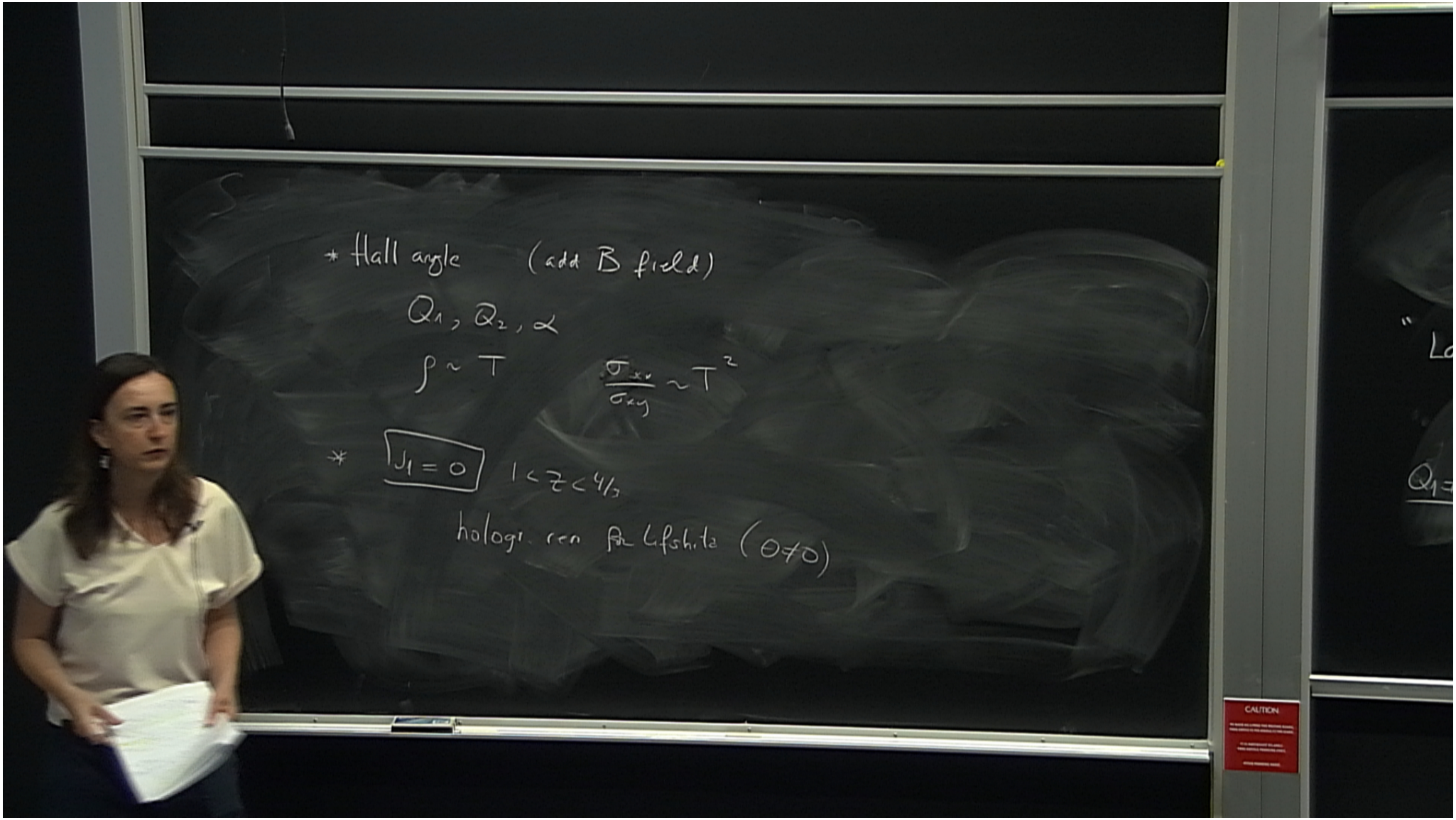

$\delta A_1 = -E_1 t + \delta a_1$
$\delta A_2 = -E_2 t + \delta a_2$
$J_1 = 0 \rightarrow \sigma_2^{DC}(Q_1, Q_2, \alpha)$
$J_i = \sigma_{ij} E_j$
r_0 horizon
$\sigma_{11} = \frac{1}{r_0^{4+\Theta}} + \frac{Q_1^2}{\alpha^2} r_0^{2z-4}$
$\sigma_{22} = r_0^{2z-2+\Theta} + \frac{Q_2^2}{\alpha^2} r_0^{2z-4}$
$\sigma_{12} = \sigma_{21} = \frac{Q_1 Q_2}{\alpha^2} r_0^{2z-4}$
"Large
$Q_1 \neq 0$

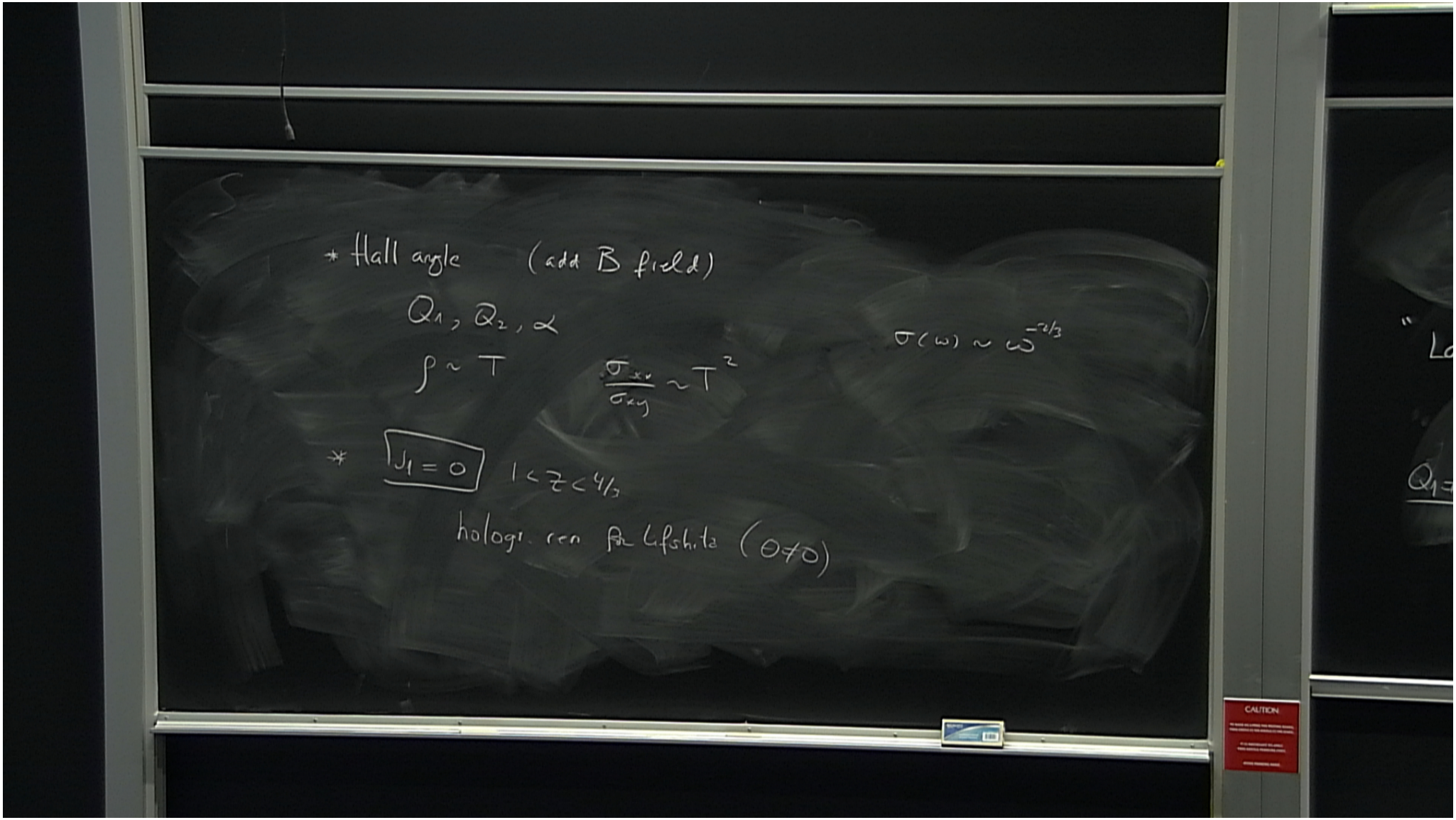

$\sigma_2^{DC} = r_0^{2z-2+\theta}\left[1+\frac{Q_2^2}{r_0^{2+\theta}\left[\alpha^2+Q_1^2 r_0^{2z+\theta}\right]}\right]$
CAUTION


$\sigma_2^{DC} = r_0^{2z-2+\theta}\left[1+\frac{Q_2^2}{r_0^{2+\theta}\left[\alpha^2+Q_1^2 r_0^{2z+\theta}\right]}\right]$
$\alpha \to 0$
$\frac{Q_2}{\alpha}$ large
$z=4/3$, $\theta=0$
ρ
semi-conductor
T


$\sigma_2^{DC} = r_0^{zz-2+\theta}\left[1+\frac{Q_2^2}{r_0^{2+\theta}\left[\alpha^2+Q_1^2 r_0^{zz+\theta}\right]}\right]$
$\alpha \to 0$
$\frac{Q_2}{\alpha}$ large
$z=4/3,\ \theta=0$
ρ
near MT
semi-conductor
T
$\frac{1}{T} = A + B\log\rho + C(\log\rho)^3 + D(\log\rho)^2$
$A = .82$
$B = .7$
$C = .02$
$D = 0.2$


$\sigma_2^{DC} = r_0^{2z-2+\theta}\left[1+\frac{Q_2^2}{r_0^{2+\theta}\left[\alpha^2+Q_1^2 r_0^{2z+2}\right]}\right]$
$\alpha \to 0$
$z=4/3,\ \theta=0$
$\frac{Q_2}{\alpha}$ large
ρ
semi-conductor
linear in T
T
$\frac{Q_2}{\alpha}$
$\frac{1}{T} = A + B\log\rho + C(\log\rho)^3 + D(\log\rho)^2$
A = .82
B = .7
C = .02
D = 0.2


* Hall angle (add B field)
Q_1, Q_2, α
$\rho \sim T$
$\frac{\sigma_{xx}}{\sigma_{xy}} \sim T^2$
* $J_1 = 0$ $1 < z < 4/3$
holog. rep. Fermi-Lifshitz ($\theta \neq 0$)
CAUTION


* Hall angle (add B field)
Q_1, Q_2, α
$\rho \sim T$
$\frac{\sigma_{xx}}{\sigma_{xy}} \sim T^2$
$\sigma(\omega) \sim \omega^{-2/3}$
* $J_1 = 0$ $1 < z < 4/3$
holog. rep. Lifshitz ($\theta \neq 0$)
CAUTION