Title: An Effective Field Theory Dual of FRW Spacetime

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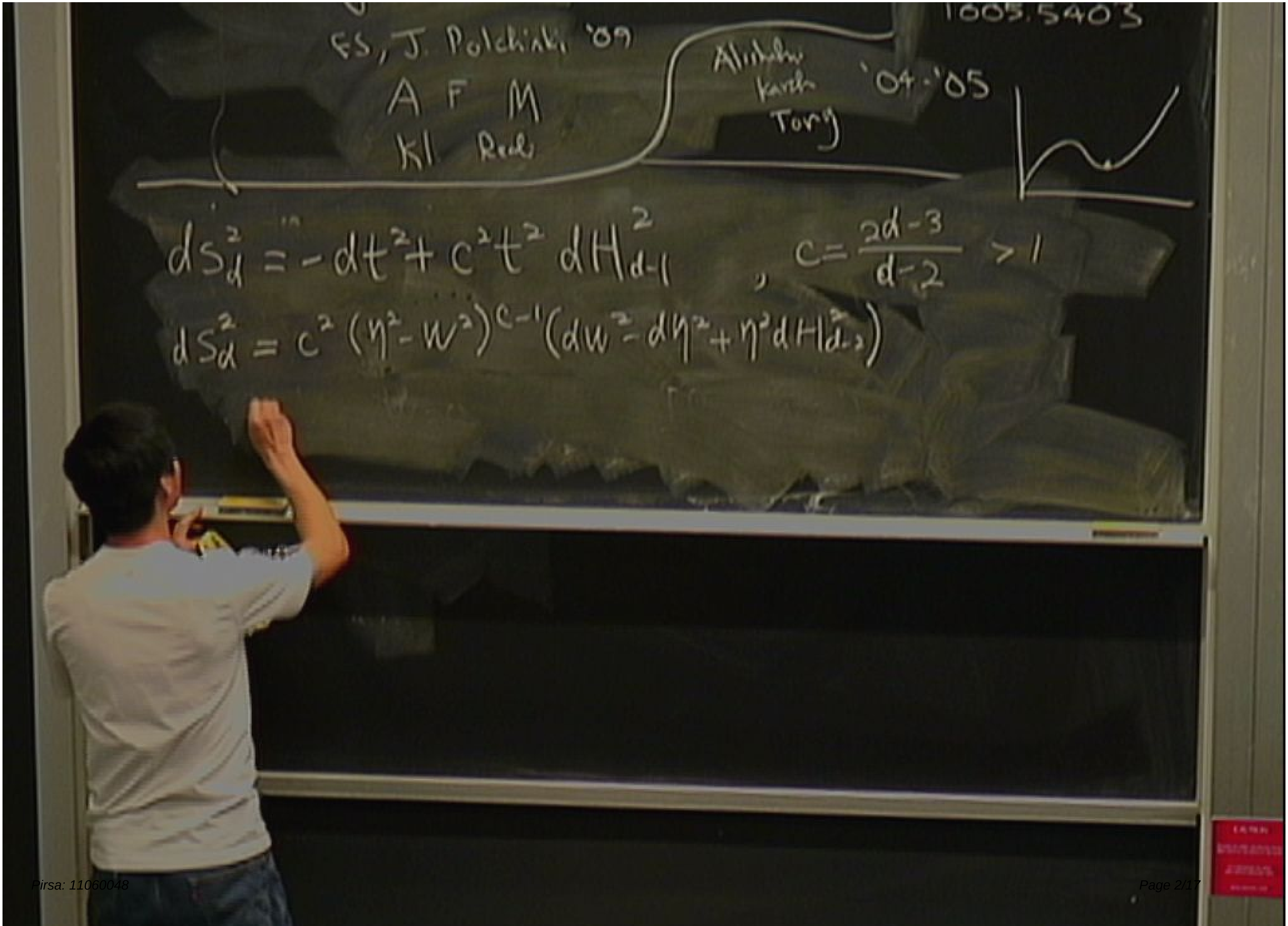
Abstract: We investigate a simple FRW spacetime realized by a brane construction. This also comes from a Coleman-de Luccia decay from a metastable de Sitter. We motivate a dual description in terms of a low energy effective field theory (EFT) on FRW in one lower dimensions. This EFT is coupled to gravity with a time-dependent Planck mass that grows to infinity at late times. We investigate the entropy bound, correlation functions, and various particle/brane probes as first steps to understand the degrees of freedom building up the EFT. This is work in collaboration with B. Horn, S. Matsuura, E. Silverstein, and G. Torroba.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$ds_d^2 = -dt^2 + c^2 t^2 \, dH_{d-1}^2$, $c = \frac{2d-3}{d-2} > 1$
$ds_d^2 = c^2 (\eta^2 - w^2)^{c-1} (dw^2 - d\eta^2 + \eta^2 dH_{d-2}^2)$

$$t = (\eta^2 - w^2)^{1/2} \quad , \quad \chi = \frac{1}{2} \ln \frac{\eta + w}{\eta - w}$$

$$M_{d-1} \;,\; N_{d+f} \;,\; \Lambda_c \qquad t_{uv} = \eta^c$$

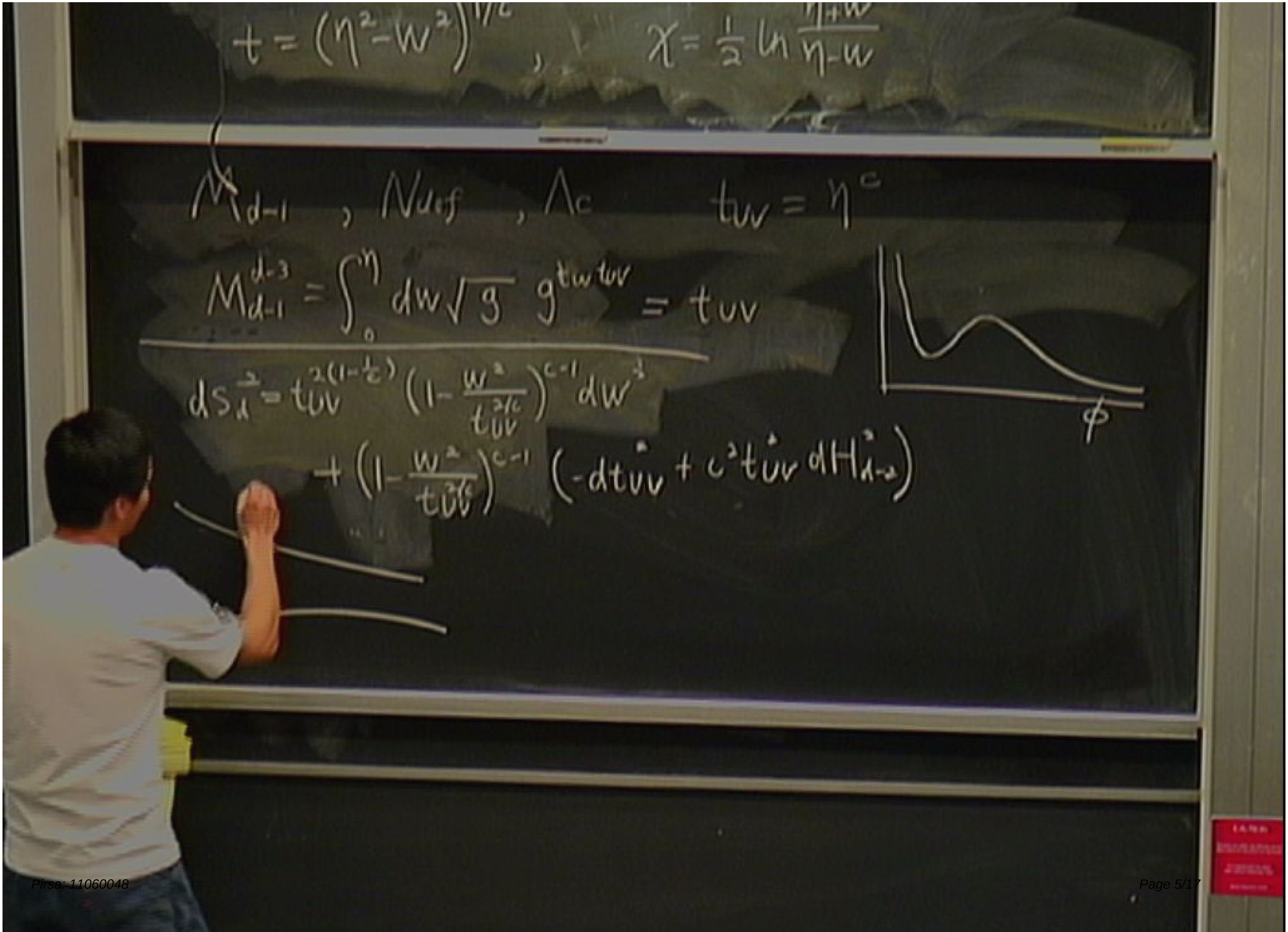
$$M_{d-1}^{d-3} = \int_0^\eta dw \sqrt{g}\; g^{t_{uv} t_{uv}} = t_{uv}$$

$$t = (\eta^2 - w^2)^{1/c}, \quad x = \frac{1}{2}\ln\frac{\eta+w}{\eta-w}$$

$$M_{d-1}, \quad N_{eff}, \quad \Lambda_c \qquad t_{UV} = \eta^c$$

$$M_{d-1}^{d-3} = \int_0^\eta dw \sqrt{g}\; g^{t_{UV} t_{UV}} = t_{UV}$$

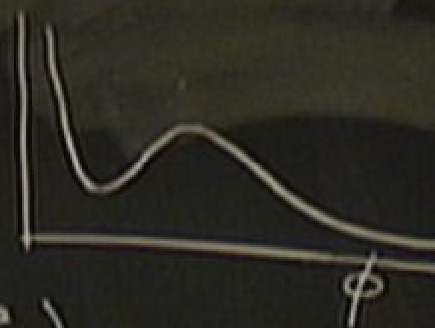
$$ds_d^2 = t_{UV}^{2(1-\frac{1}{c})}\left(1-\frac{w^2}{t_{UV}^{2/c}}\right)^{c-1} dw^2 + \left(1-\frac{w^2}{t_{UV}^{2/c}}\right)^{c-1}\left(-dt_{UV}^2 + c^2 t_{UV}^2\, dH_{d-2}^2\right)$$


$t = (\eta^2 - w^2)^{1/2}$, $\chi = \frac{1}{2} \ln \frac{\eta + w}{\eta - w}$
M_{d-1} , N_{uif} , Λ_c $t_{uv} = \eta^c$
$M_{d-1}^{d-3} = \int_0^\eta dw \sqrt{g}\, g^{t_{uv} t_{uv}} = t_{uv}$
$ds_d^2 = t_{uv}^{2(1-\frac{1}{c})} \left(1 - \frac{w^2}{t_{uv}^{2/c}}\right)^{c-1} dw^2$
$+ \left(1 - \frac{w^2}{t_{uv}^{2/c}}\right)^{c-1} \left(-dt_{uv}^2 + c^2 t_{uv}^2\, dH_{d-2}^2\right)$
ϕ

$$t = (\eta^2 - w^2)^{1/c}, \quad x = \frac{1}{2}\ln\frac{\eta + w}{\eta - w}$$

M_{d-1}, N_{eff}, Λ_c $\quad t_{UV} = \eta^c$

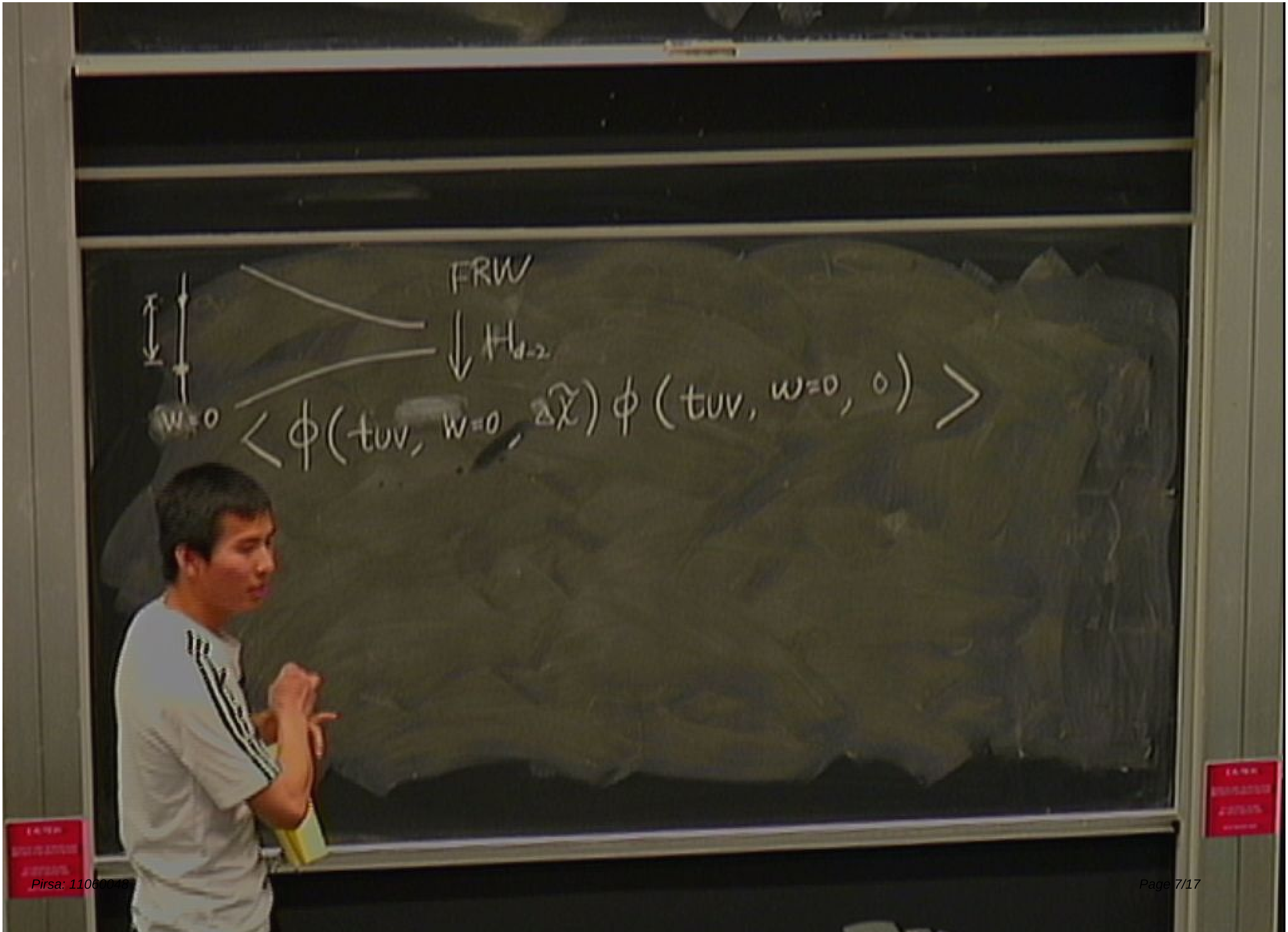
$$M_{d-1}^{d-3} = \int_0^\eta dw \sqrt{g}\, g^{t_{UV} t_{UV}} = t_{UV}$$

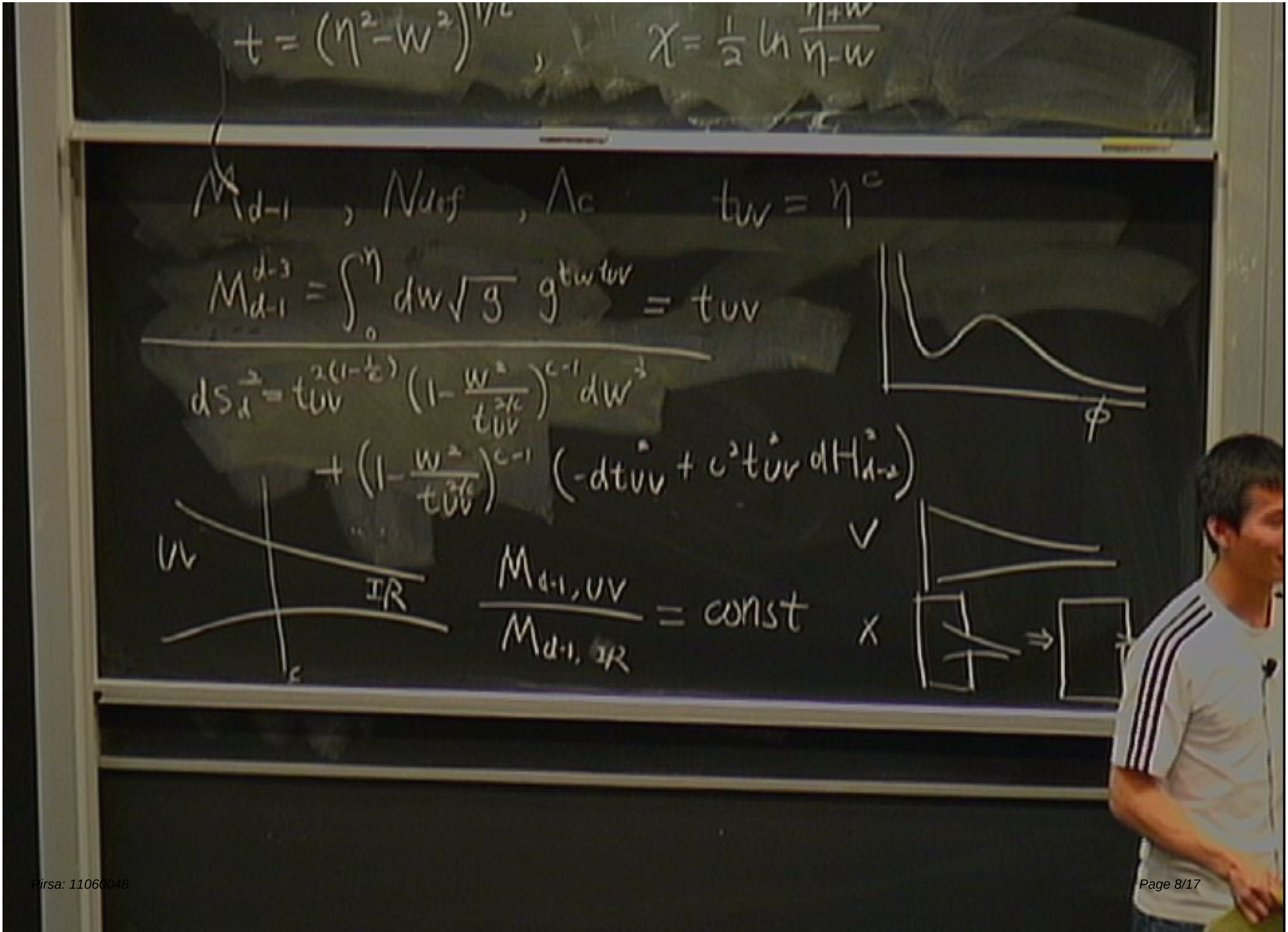


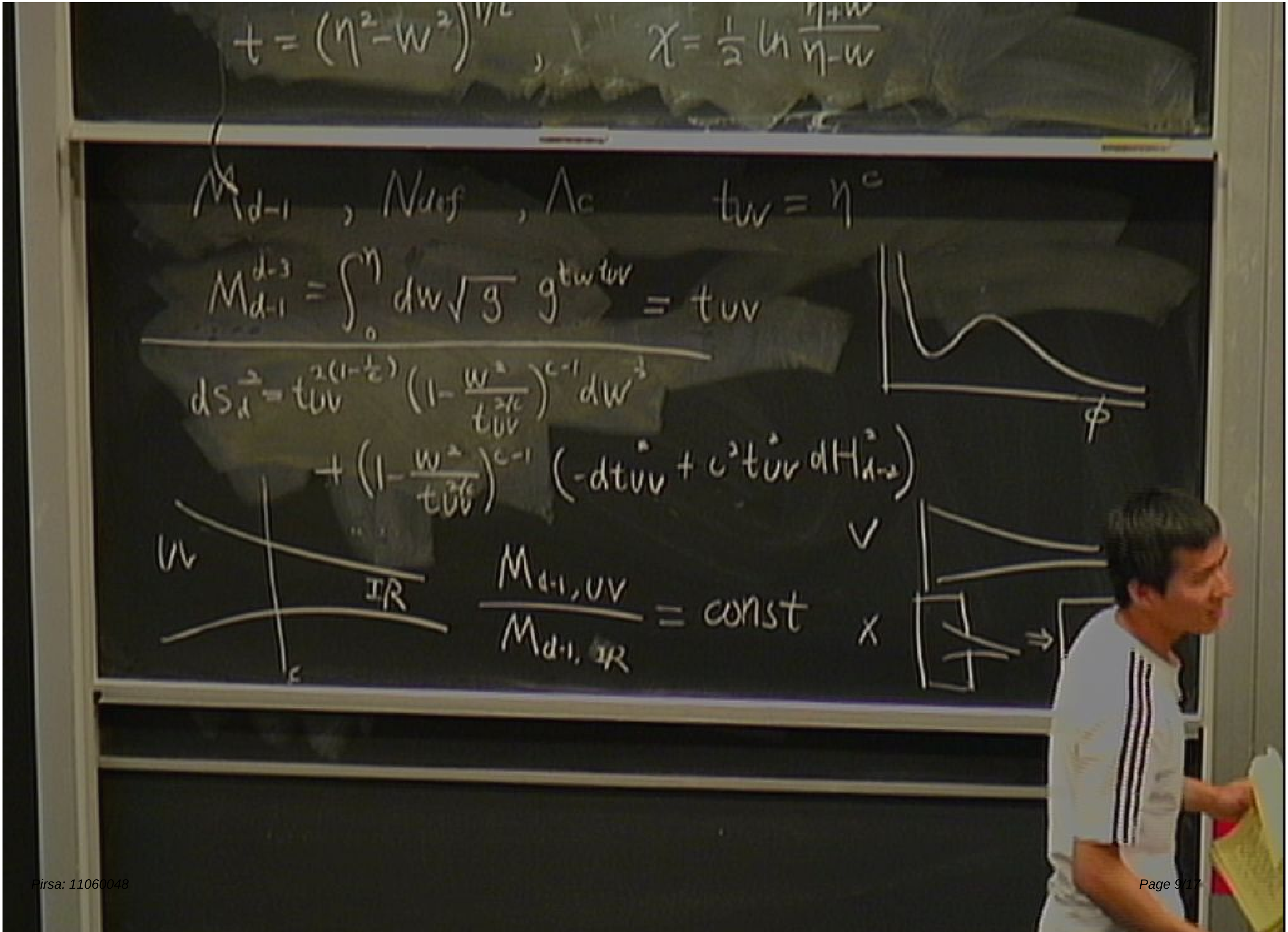
$$ds_d^2 = t_{UV}^{2(1-\frac{1}{c})}\left(1 - \frac{w^2}{t_{UV}^{2/c}}\right)^{c-1} dw^2 + \left(1 - \frac{w^2}{t_{UV}^{2/c}}\right)^{c-1}\left(-dt_{UV}^2 + c^2 t_{UV}^2\, dH_{d-2}^2\right)$$

$$\frac{M_{d-1,UV}}{M_{d-1,IR}} = \text{const}$$

x


FRW
H_{d-2}
$w=0$
$\langle \phi(t_{UV}, w=0, \Delta\tilde{\chi})\, \phi(t_{UV}, w=0, 0) \rangle$


t = (η² − w²)^{1/2} , x = ½ ln (η+w)/(η−w)
M_{d-1} , N_{eff} , Λ_c   t_{UV} = η^c
M_{d-1}^{d-3} = ∫_0^η dw √g g^{t_{UV} t_{UV}} = t_{UV}
ds_d² = t_{UV}^{2(1−1/c)} (1 − w²/t_{UV}^{2/c})^{c−1} dw²
+ (1 − w²/t_{UV}^{2/c})^{c−1} (−dt_{UV}² + c² t_{UV}² dH_{d-2}²)
φ
UV
IR
M_{d-1, UV} / M_{d-1, IR} = const
V
x


t = (η² − w²)^{1/c} , x = ½ ln (η+w)/(η−w)
M_{d−1} , N_{eff} , Λ_c   t_{uv} = η^c
M_{d−1}^{d−3} = ∫_0^η dw √g g^{tuv tuv} = t_{uv}
ds_d² = t_{uv}^{2(1−1/c)} (1 − w²/t_{uv}^{2/c})^{c−1} dw² + (1 − w²/t_{uv}^{2/c})^{c−1} (−dt_{uv}² + c² t_{uv}² dH²_{d−2})
φ
UV
IR
M_{d−1, UV} / M_{d−1, IR} = const × ⇒

$m(t)$

$$\langle \phi(t_{UV}, w=0, \Delta\tilde{x})\, \phi(t_{UV}, w=0, 0)\rangle$$

$$m_{KK} \sim \frac{n_{KK}}{t}, \quad m_{str} \sim \frac{1}{t^{4/7}}, \quad m_{77} \sim \frac{1}{t^{1/7}}$$

$$\boxed{\langle \phi_{KK}\phi_{KK}\rangle = e^{-c\, n_{KK}\Delta\tilde{x}}}$$

$$\langle \phi(t_{UV}, w=0, \Delta\tilde{x})\, \phi(t_{UV}, w=0, 0) \rangle$$

$$m_{KK} \sim \frac{n_{KK}}{t}, \quad m_{str} \sim \frac{1}{t^{4/7}}, \quad m_{77} \sim \frac{1}{t^{1/7}}$$

$$\boxed{\langle \phi_{KK} \phi_{KK} \rangle = e^{-c\, n_{KK} \Delta\tilde{x}}}$$

CFT, $\langle \phi\phi \rangle \sim \frac{1}{|\Delta x|^{\Delta}}$

$w=0 \quad \langle \phi(t_{UV}, w=0, \Delta\tilde{x})\, \phi(t_{UV}, w=0, 0) \rangle$

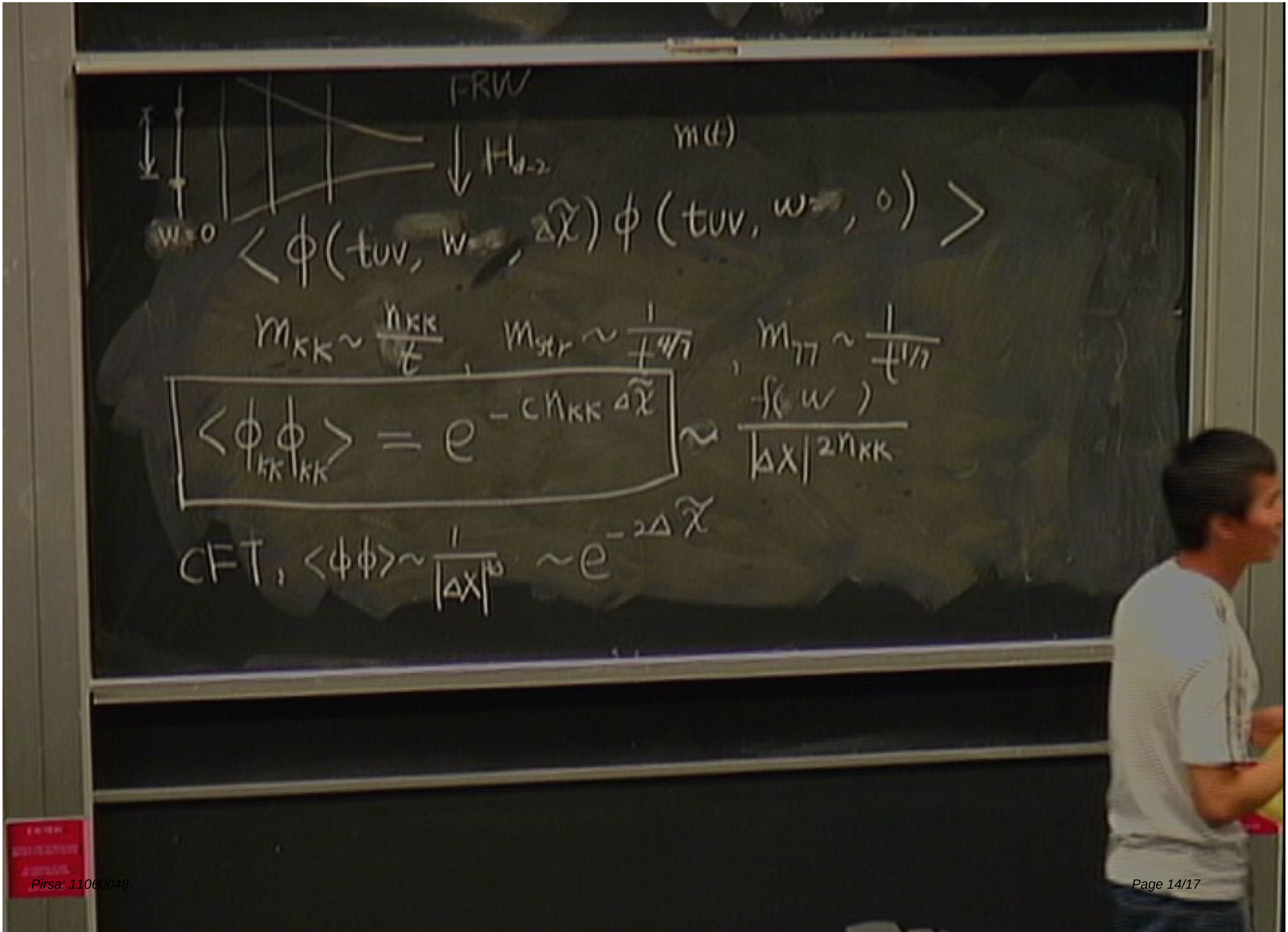
$m_{KK} \sim \frac{n_{KK}}{t}, \quad m_{str} \sim \frac{1}{t^{4/7}}, \quad m_{77} \sim \frac{1}{t^{1/7}}$

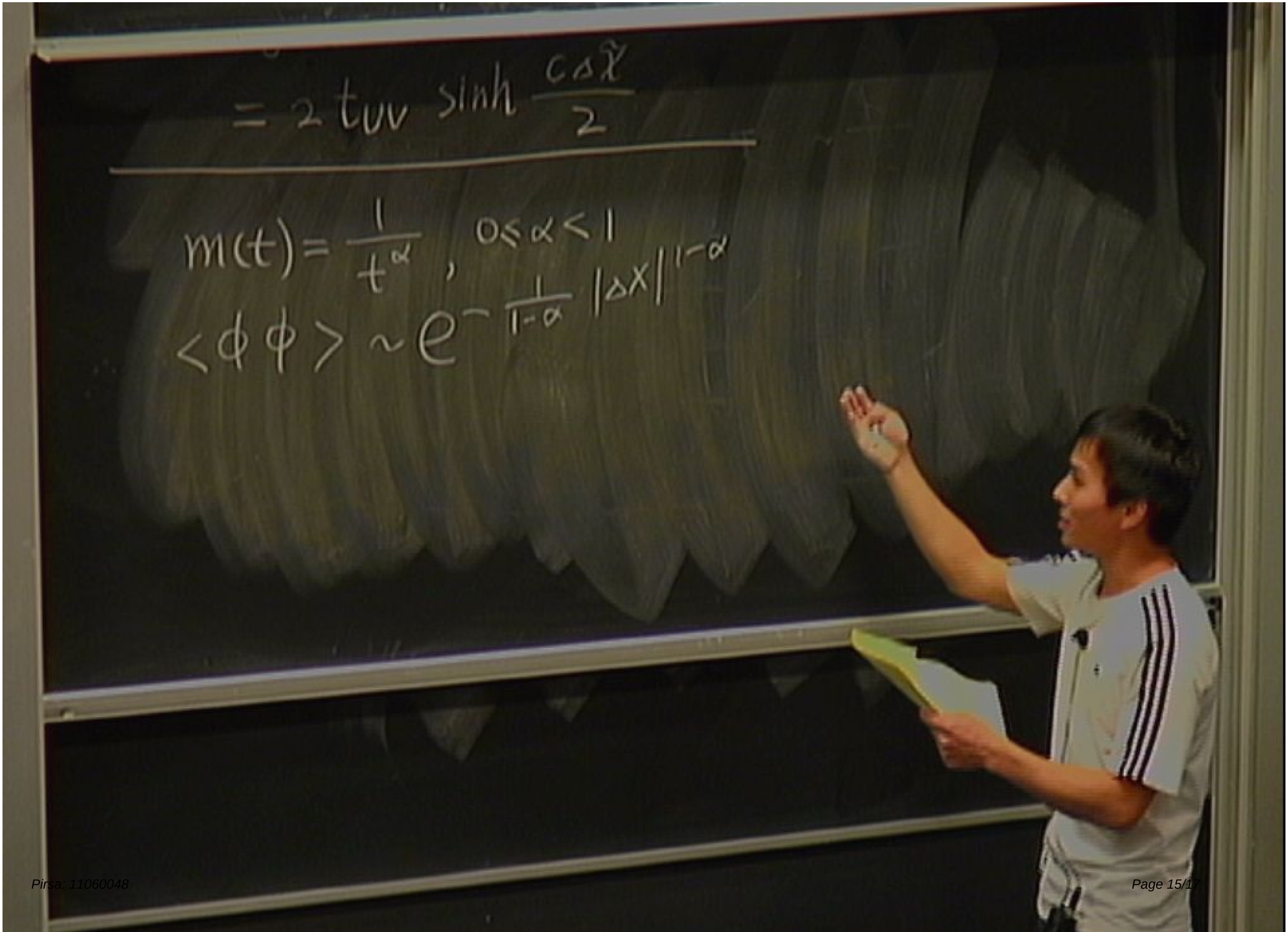
$$\boxed{\langle \phi_{KK} \phi_{KK} \rangle = e^{-c\, n_{KK} \Delta\tilde{x}}}$$

CFT, $\langle \phi\phi \rangle \sim \frac{1}{|\Delta x|^{2\Delta}} \sim e^{-2\Delta \tilde{x}}$

$$\Delta X = \text{geod dist on } dS^2_{d+1}$$

$$= 2\, t_{UV} \sinh \frac{c\,\Delta \tilde{x}}{2}$$


FRW
$m(t)$
H_{d-2}
$w=0$
$\langle \phi(t_{uv}, w, \Delta\tilde{x})\, \phi(t_{uv}, w, 0) \rangle$
$m_{KK} \sim \frac{n_{KK}}{t}$, $m_{str} \sim \frac{1}{t^{4/7}}$, $m_{11} \sim \frac{1}{t^{1/7}}$
$\boxed{\langle \phi_{KK} \phi_{KK} \rangle = e^{-c\, n_{KK} \Delta\tilde{x}}} \sim \frac{f(w)}{|\Delta x|^{2 n_{KK}}}$
CFT, $\langle \phi\phi \rangle \sim \frac{1}{|\Delta x|^{2\Delta}} \sim e^{-2\Delta \tilde{x}}$


$= 2 t_{UV} \sinh \frac{c \Delta \tilde{x}}{2}$
$m(t) = \frac{1}{t^\alpha}, \quad 0 \le \alpha < 1$
$\langle \phi \phi \rangle \sim e^{-\frac{1}{1-\alpha} |\Delta x|^{1-\alpha}}$

ΔX = geod dist on dS^2_{d+1}

$$= 2\, t_{UV} \sinh \frac{c\,\Delta\tilde{x}}{2}$$

$$m(t) = \frac{1}{t^\alpha}, \quad 0 \le \alpha < 1$$

$$\langle \phi\,\phi \rangle \sim e^{-\frac{1}{1-\alpha}|\Delta X|^{1-\alpha}}$$

$$t = (\eta^2 - w^2)^{1/c}, \quad \chi = \frac{1}{2} \ln \frac{\eta + w}{\eta - w}$$

M_{d-1}, N_{dof}, Λ_c $\quad t_{UV} = \eta^c$

RS: $M_{d-1}^{d-3} \sim N_{dof} \Lambda_c^{d-3}$

$$S \sim N_{dof} (Vol)_{QFT} \Lambda_c^{d-2}$$

known: $M_{d-1}^{d-3} \sim t_{UV}$

$$S \sim t_{UV}^{d-2}, \quad Vol_{QFT} \sim t^{d-2}$$

$$\Rightarrow N_{dof} \sim t_{UV}^{d-2}, \quad \Lambda_c \sim \frac{1}{t_{UV}}$$