Title: Speical Summer Undergraduate Talk

Date: Aug 21, 2009 03:00 PM

URL: http://pirsa.org/09080031

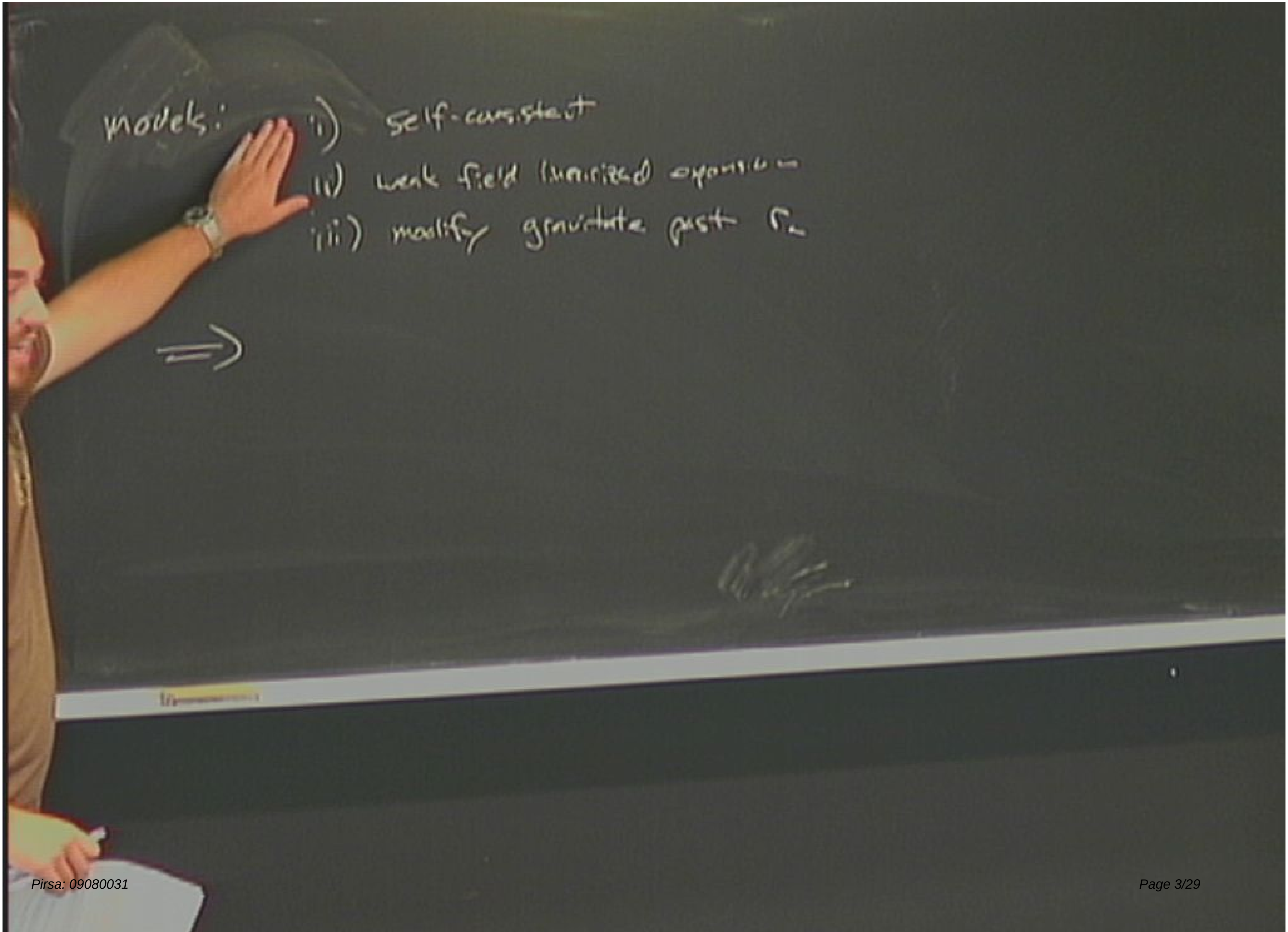
Abstract:

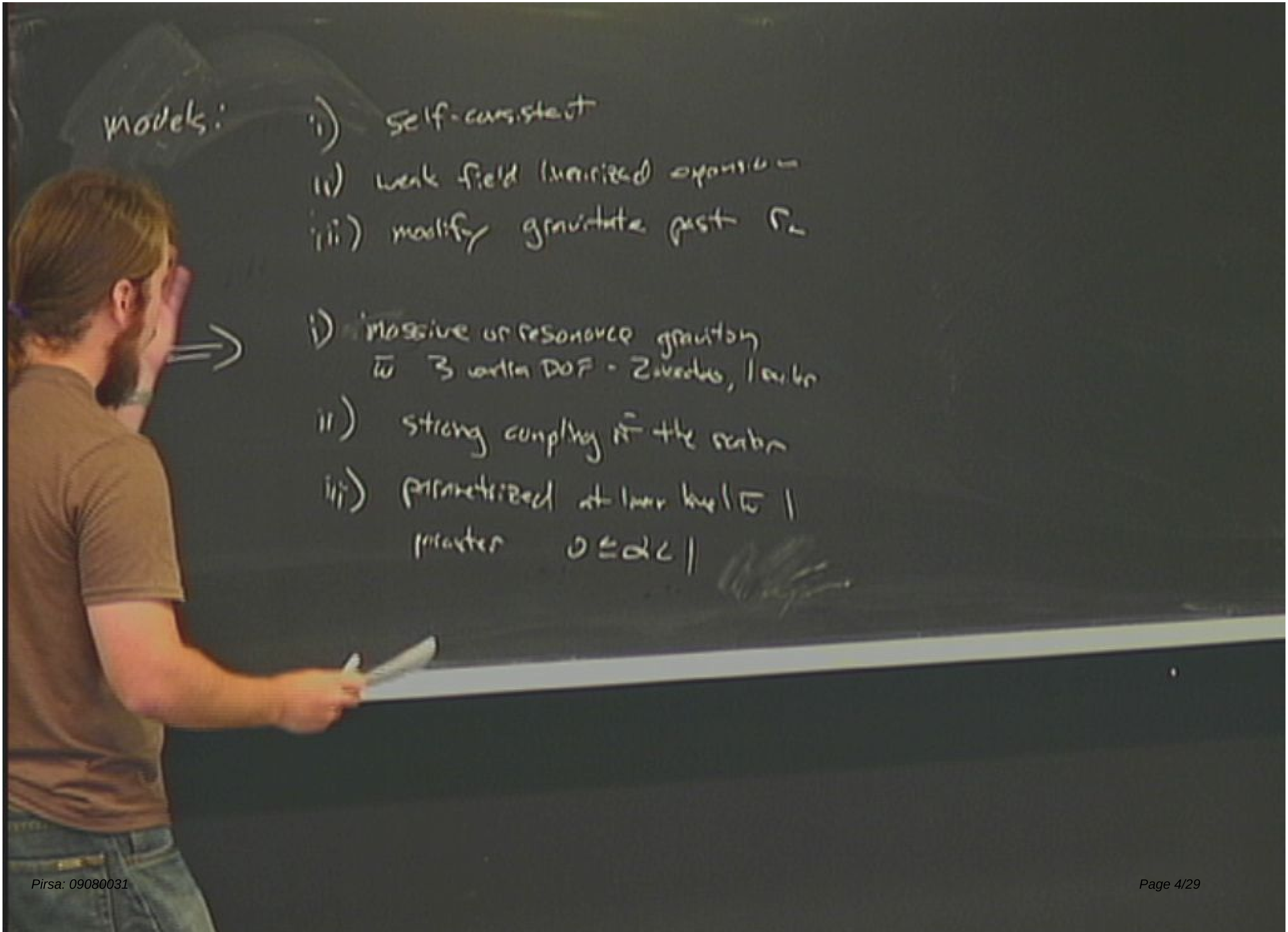
Degravitating the Vacuum

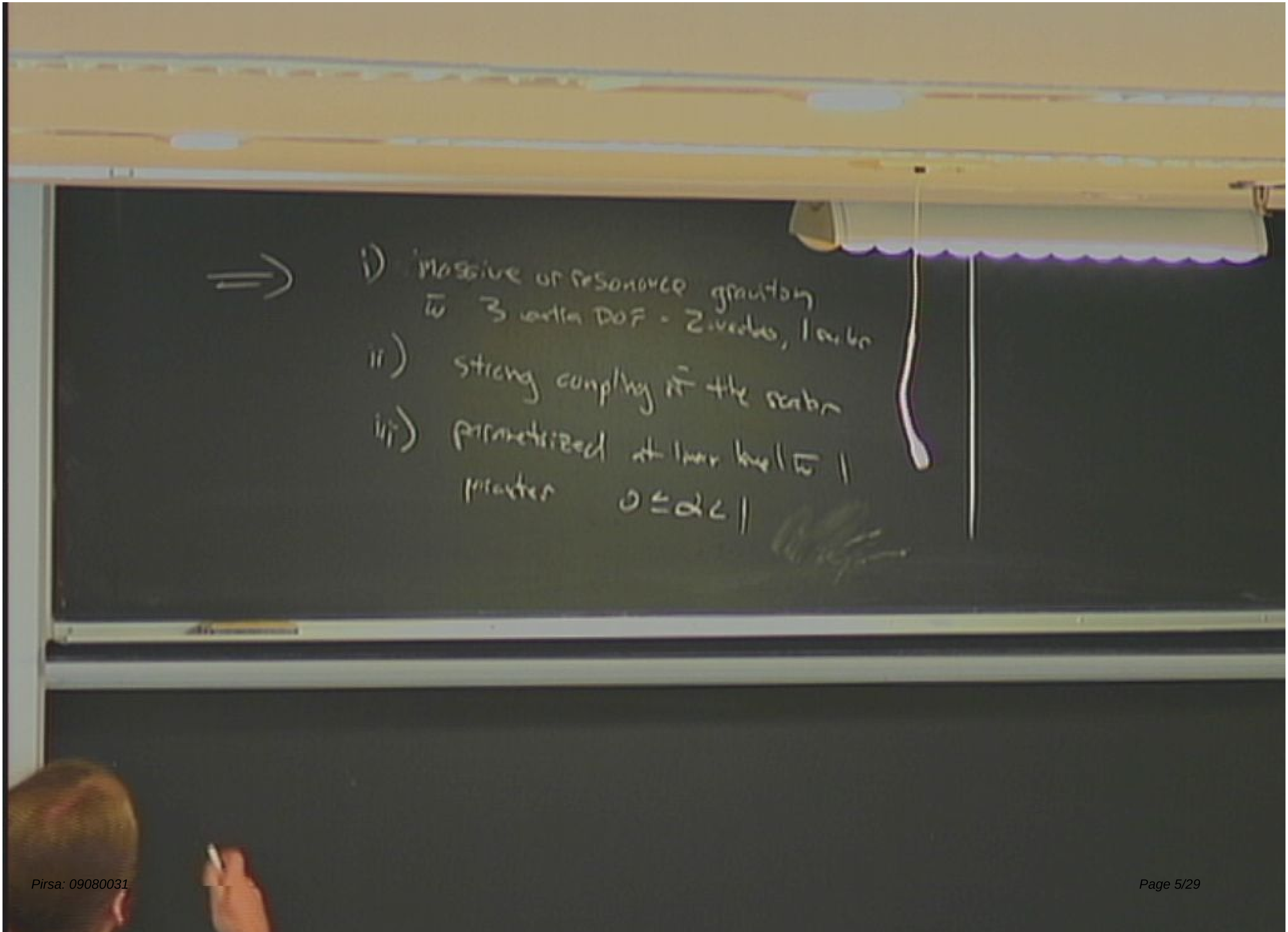
IR Modified Theories of Gravity

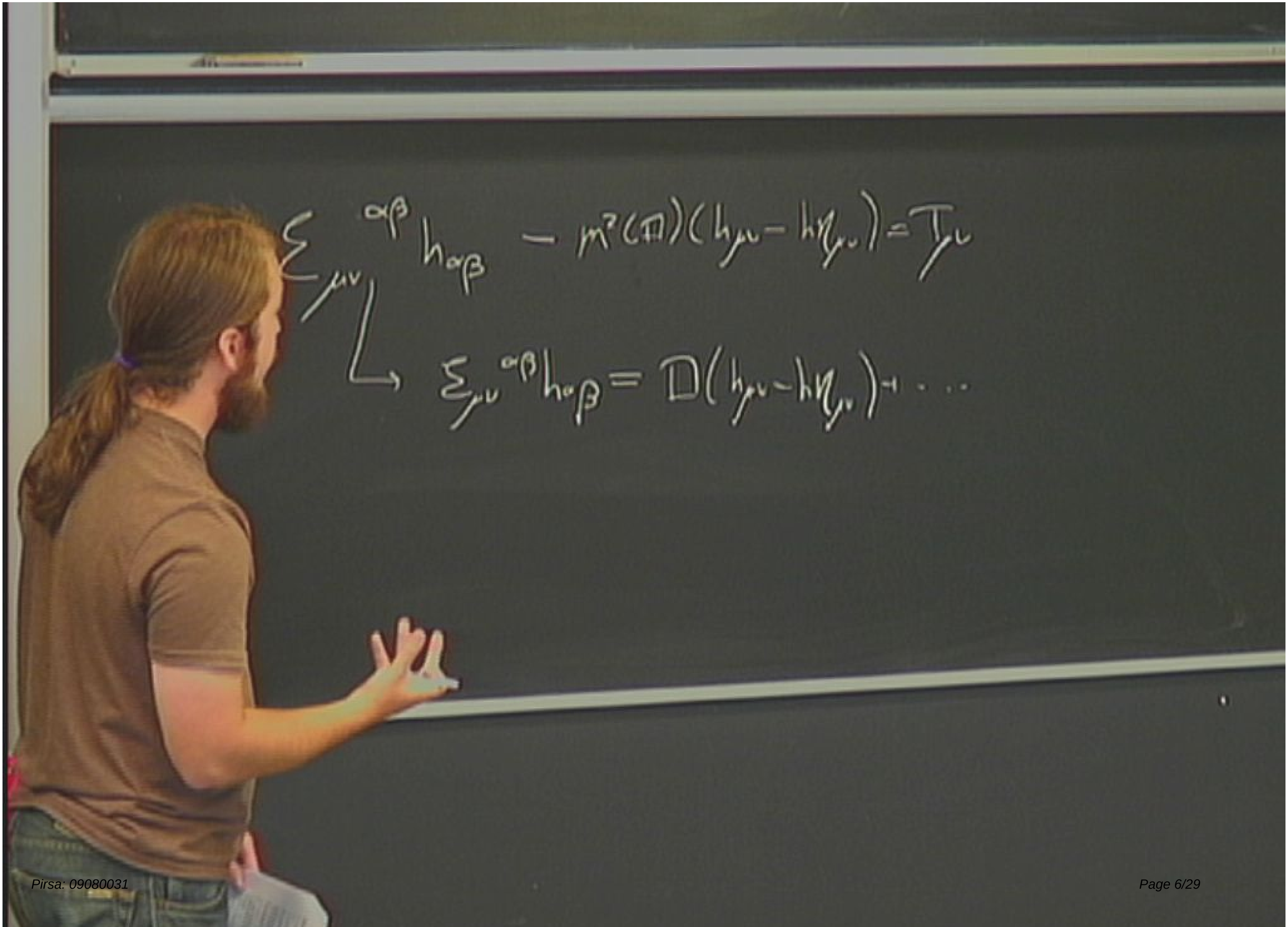
Outline:

1) intro : cosmological const. problem
2) IR modified gravity : details, strong coupling and r_*
3) extracting predictions : anomalous perihelion precession
4) outlook / conclusion : other tests, theoretical work


models: i) self-consistent
ii) weak field (linearized) expansion
iii) modify gravitate past r
⇒


models:
i) self-consistent
ii) weak field linearized expansion
iii) modify gravitation past
i) massive or resonance graviton
ii) strong coupling of the scalar
iii) parametrized at linear level
parameter 0 ≤ α < 1


$\Longrightarrow$
i) massive or resonance graviton
w/ 3 extra DOF - 2 vectors, 1 scalar
ii) strong coupling of the scalar
iii) parametrized at linear level w/ 1
parameter $0 \leq \alpha < 1$


$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$
$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \dots$

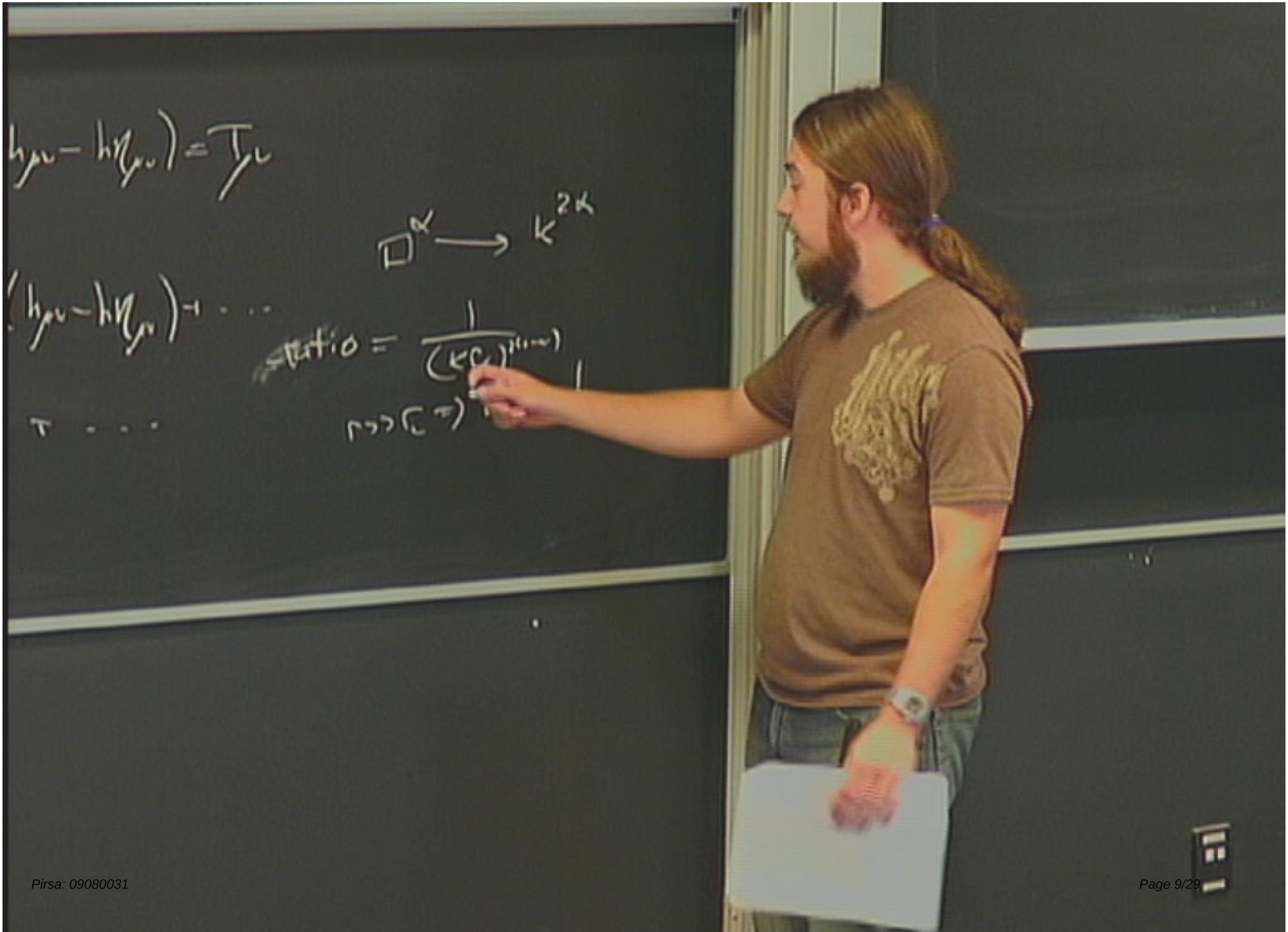
$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$$

$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \dots$$

$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$$

$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \dots$$

$$m^2(\Box) = \frac{\Box^{\alpha}}{r_c^{2(1-\alpha)}} + \dots$$


ratio =

$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$$

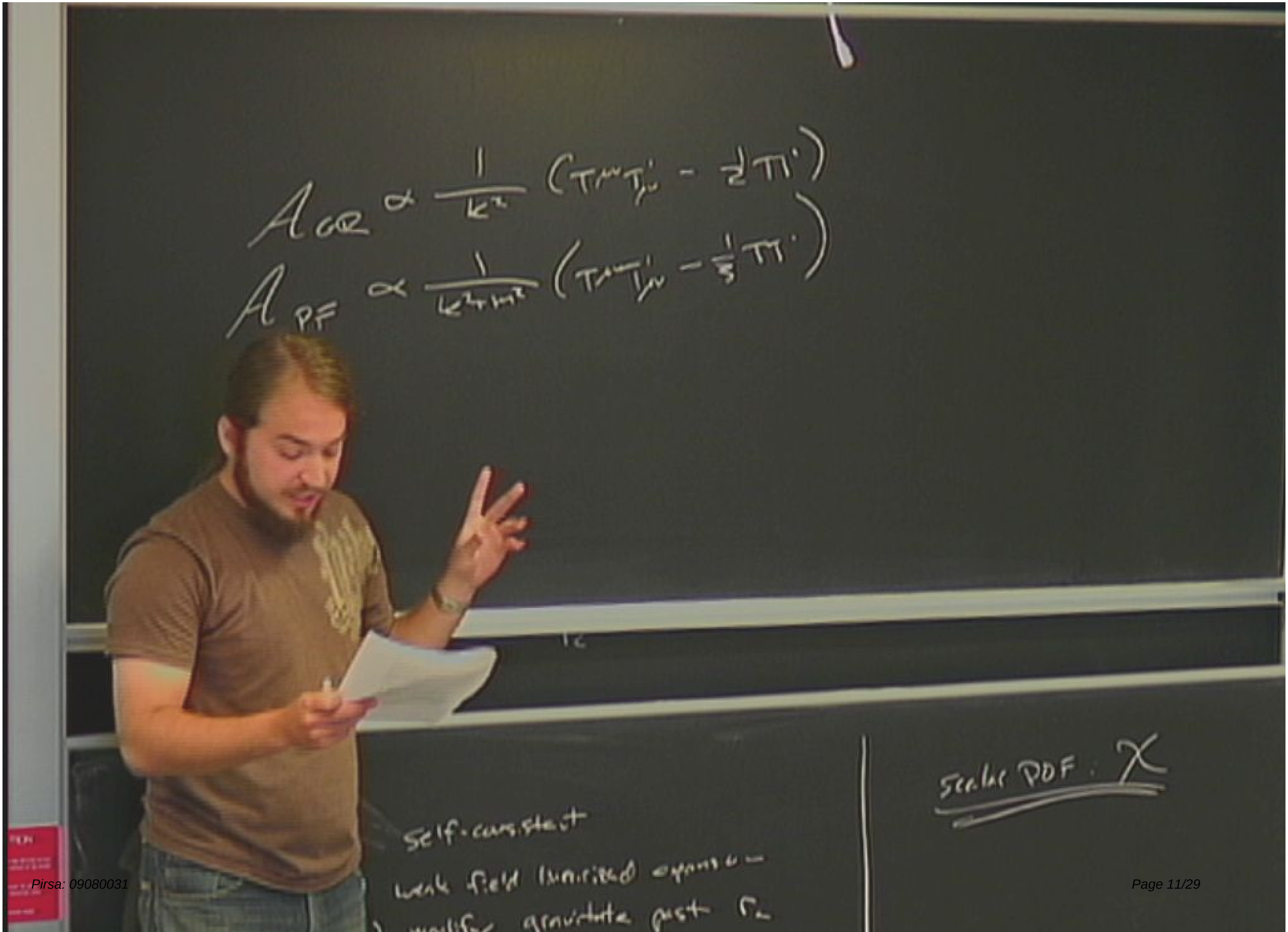
$$\hookrightarrow \mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \ldots$$

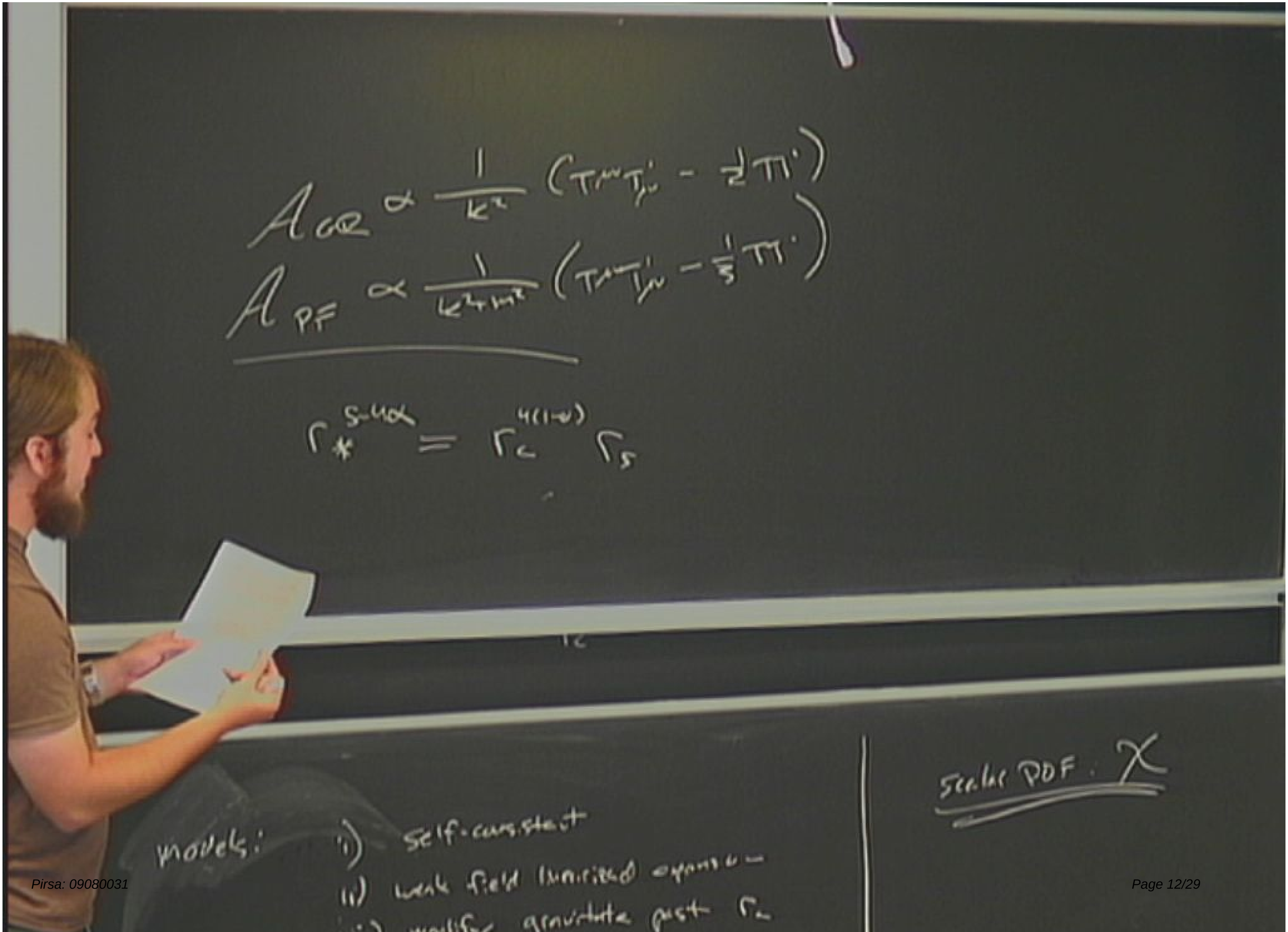
$$m^2(\Box) = \frac{\Box^\alpha}{r_c^{2(1-\alpha)}} + \ldots$$

$$\Box^\alpha \longrightarrow k^{2\alpha}$$

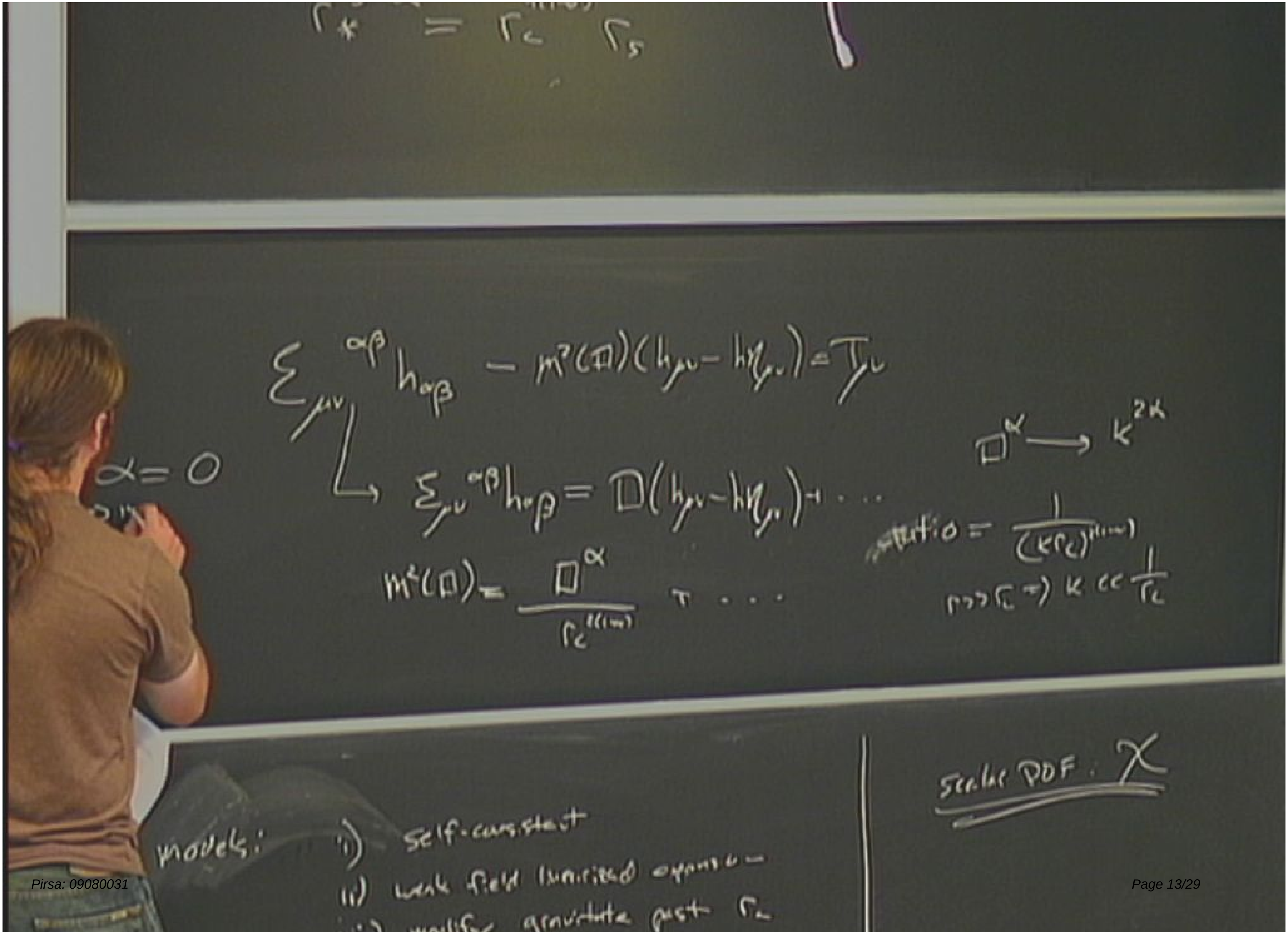
$$\text{ratio} = \frac{1}{(kr_c)^{2(1-\alpha)}}$$

$$r \gg r_c \Rightarrow k \ll \frac{1}{r_c}$$


$A_{GR} \propto \frac{1}{k^2} \left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{2}TT'\right)$
$A_{PF} \propto \frac{1}{k^2+m^2} \left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{3}TT'\right)$
Scalar PDF : χ
self-consistent
weak field linearized expansion



$A_{GR} \propto \frac{1}{k^2}\left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{2}TT'\right)$
$A_{PF} \propto \frac{1}{k^2+m^2}\left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{3}TT'\right)$
$r_*^{5-4\alpha} = r_c^{4(1-\alpha)}\, r_s$
Scalar PDF: χ
models:
i) self-consistent
ii) weak field linearized expansion


$r_* = r_c \; r_s$
$\Sigma_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$
$\alpha = 0$
$\Sigma_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \dots$
$m^2(\Box) = \frac{\Box^\alpha}{r_c^{2(1-\alpha)}} + \dots$
$\Box^\alpha \longrightarrow k^{2\alpha}$
ratio $= \frac{1}{(kr_c)^{2(1-\alpha)}}$
$r \gg r_c \Rightarrow k \ll \frac{1}{r_c}$
Scalar DOF: χ
models:
i) self-consistent
ii) weak field linearized expansion

$$r_* = r_c \quad r_s$$

$$\mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} - m^2(\Box)(h_{\mu\nu} - h\eta_{\mu\nu}) = T_{\mu\nu}$$

$$\hookrightarrow \mathcal{E}_{\mu\nu}{}^{\alpha\beta} h_{\alpha\beta} = \Box(h_{\mu\nu} - h\eta_{\mu\nu}) + \dots$$

$\alpha = 0$

$\Rightarrow$ massive gravity

$$m^2 = \frac{1}{r_c^2}$$

$$m^2(\Box) = \frac{\Box^\alpha}{r_c^{2(1-\alpha)}} + \dots$$

$$\Box^\alpha \longrightarrow k^{2\alpha}$$

$$\text{ratio} = \frac{1}{(k r_c)^{2(1-\alpha)}}$$

$r \gg r_c \Rightarrow k \ll \frac{1}{r_c}$

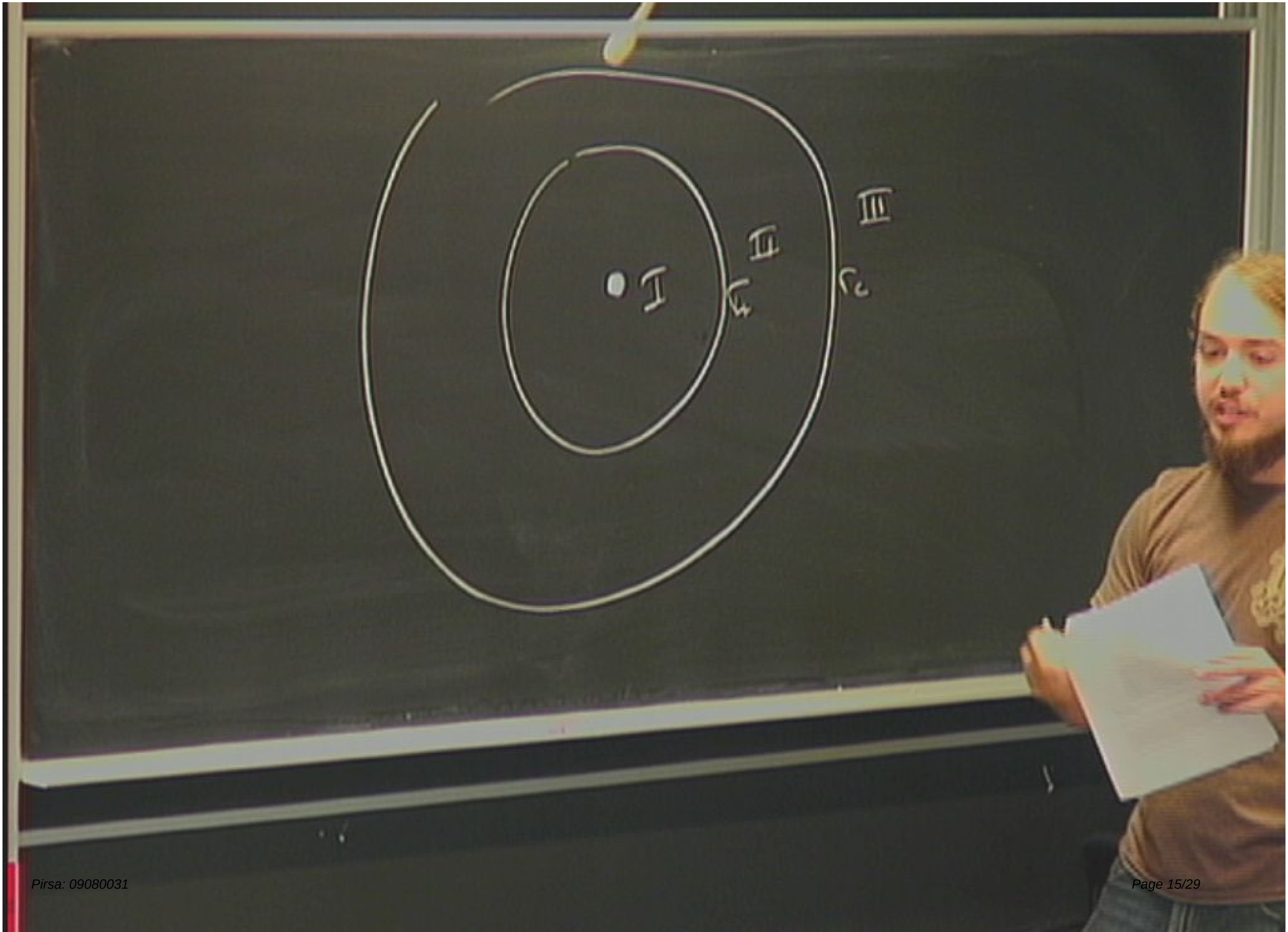
models:

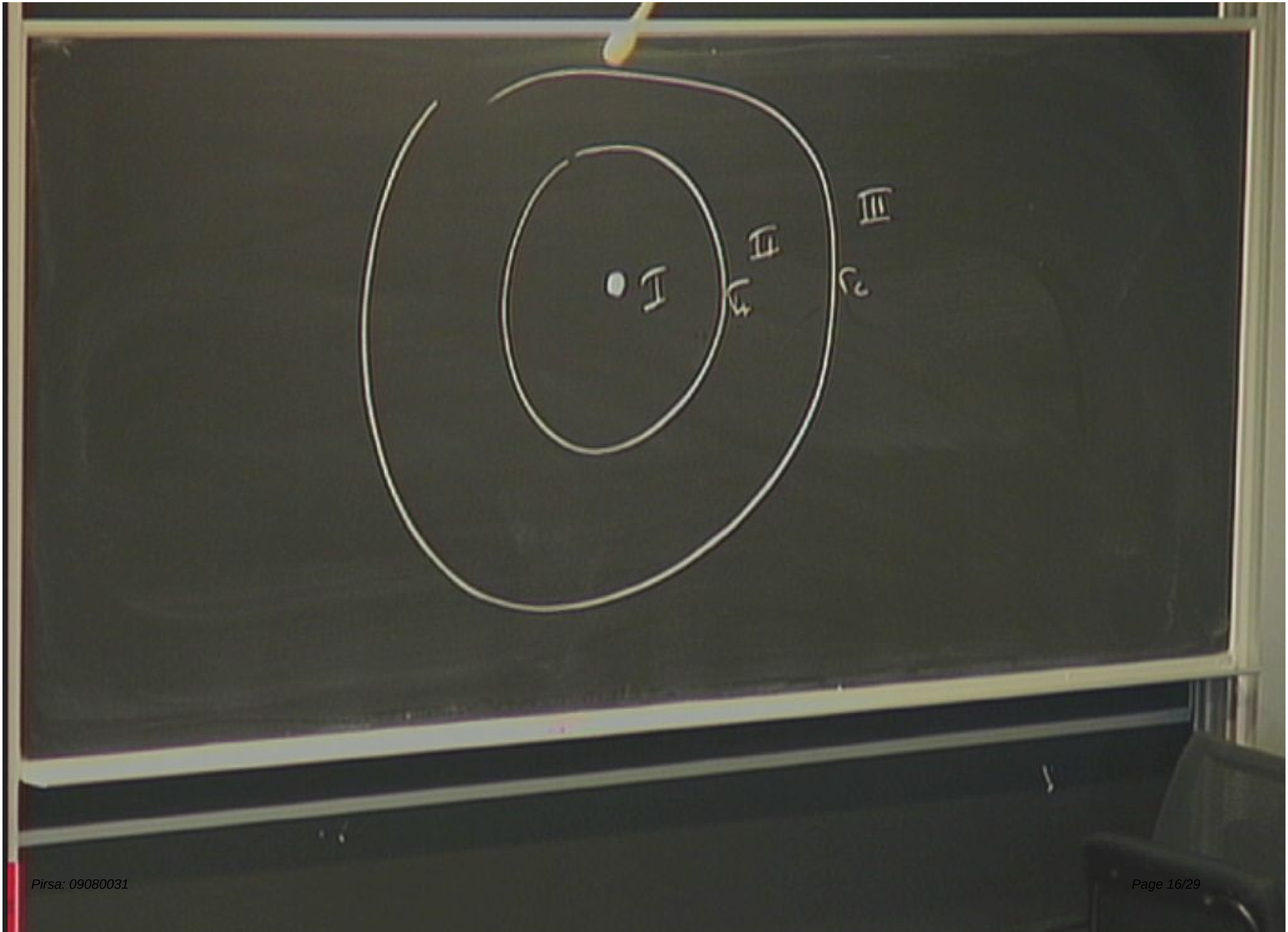
i) self-consistent

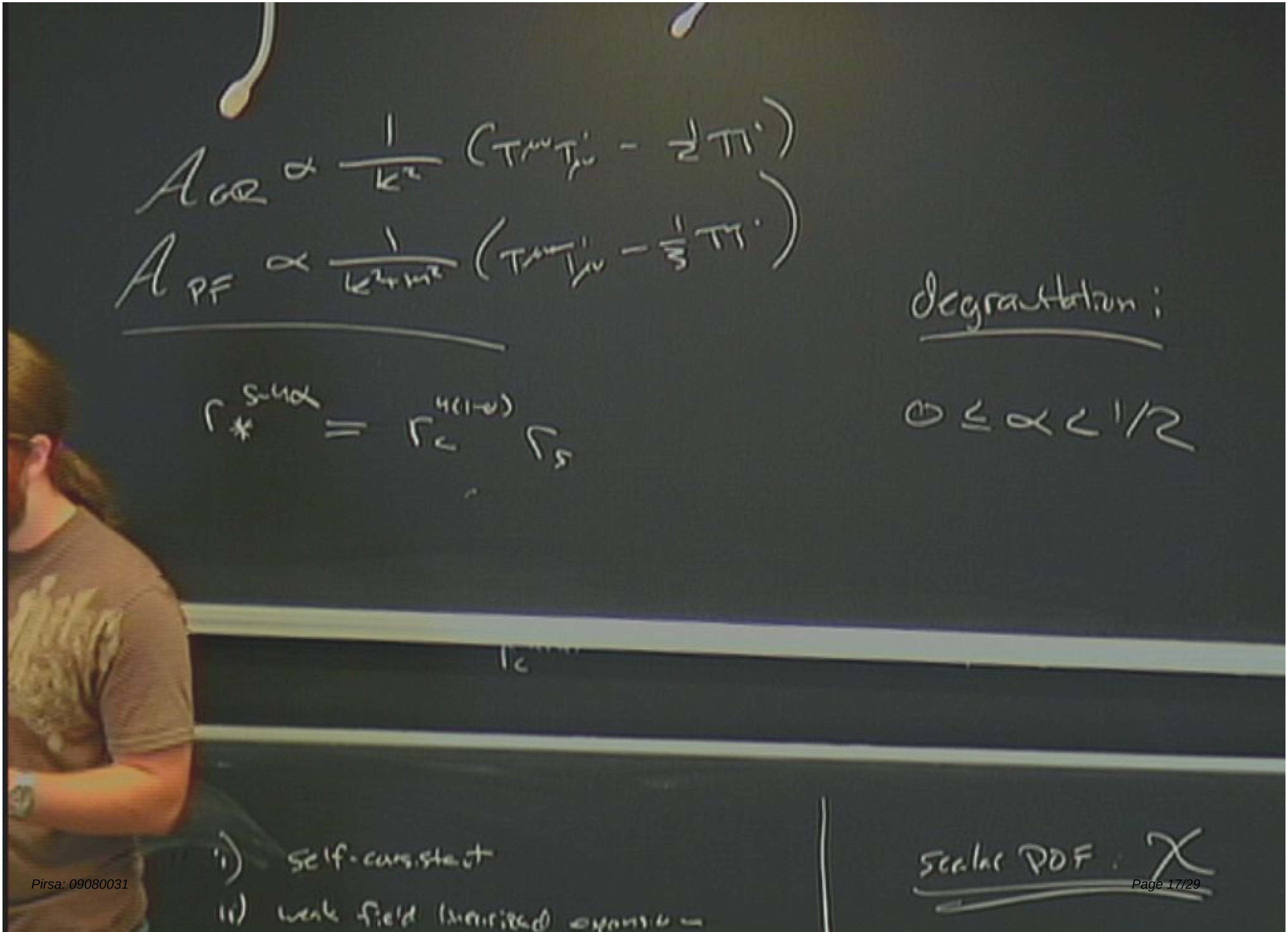
ii) weak field linearized expansion

iii) modify gravitate past r_c

Scalar PDF: χ


I
II
III


I
II
III
r_+
r_c


$A_{GR} \propto \frac{1}{k^2} \left(T^{\mu\nu} T'_{\mu\nu} - \frac{1}{2} T T' \right)$
$A_{PF} \propto \frac{1}{k^2 + m^2} \left(T^{\mu\nu} T'_{\mu\nu} - \frac{1}{3} T T' \right)$
$\Gamma_*^{5-4\alpha} = \Gamma_c^{4(1-\alpha)} \Gamma_5$
degravitation:
$0 \leq \alpha < 1/2$
i) self-consistent
ii) weak field linearized expansion
scalar PDF: χ

$$A_{GR} \propto \frac{1}{k^2}\left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{2}TT'\right)$$

$$A_{PF} \propto \frac{1}{k^2+m^2}\left(T^{\mu\nu}T'_{\mu\nu} - \frac{1}{3}TT'\right)$$

$$r_*^{\,5-4\alpha} = r_c^{\,4(1-\alpha)}\, r_s$$

degravitation:

$0 \leq \alpha < 1/2$

r_c

models:

i) self-consistent

ii) weak field (unitized expansion

scalar PDF: X

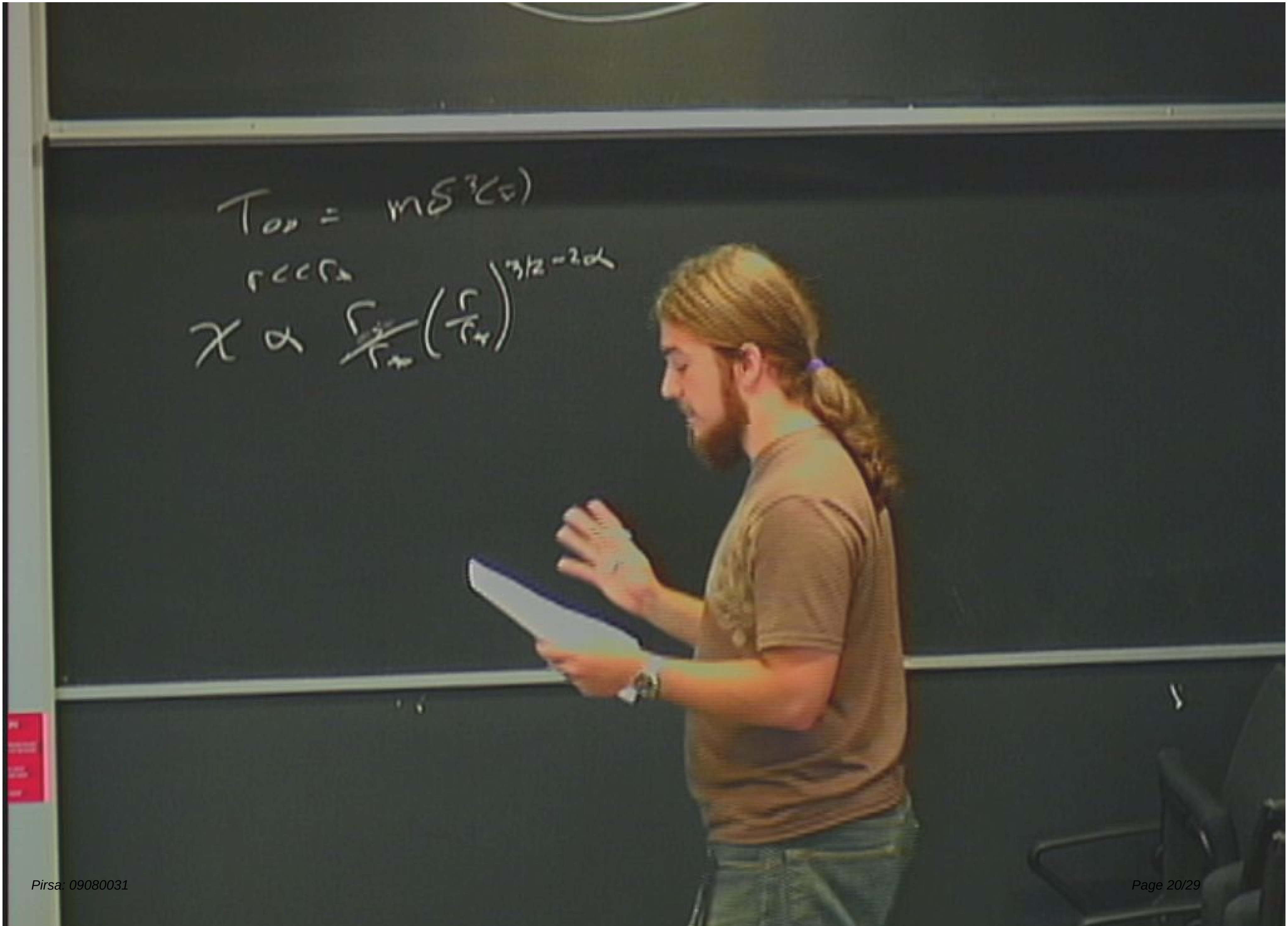
parametrized at linear level

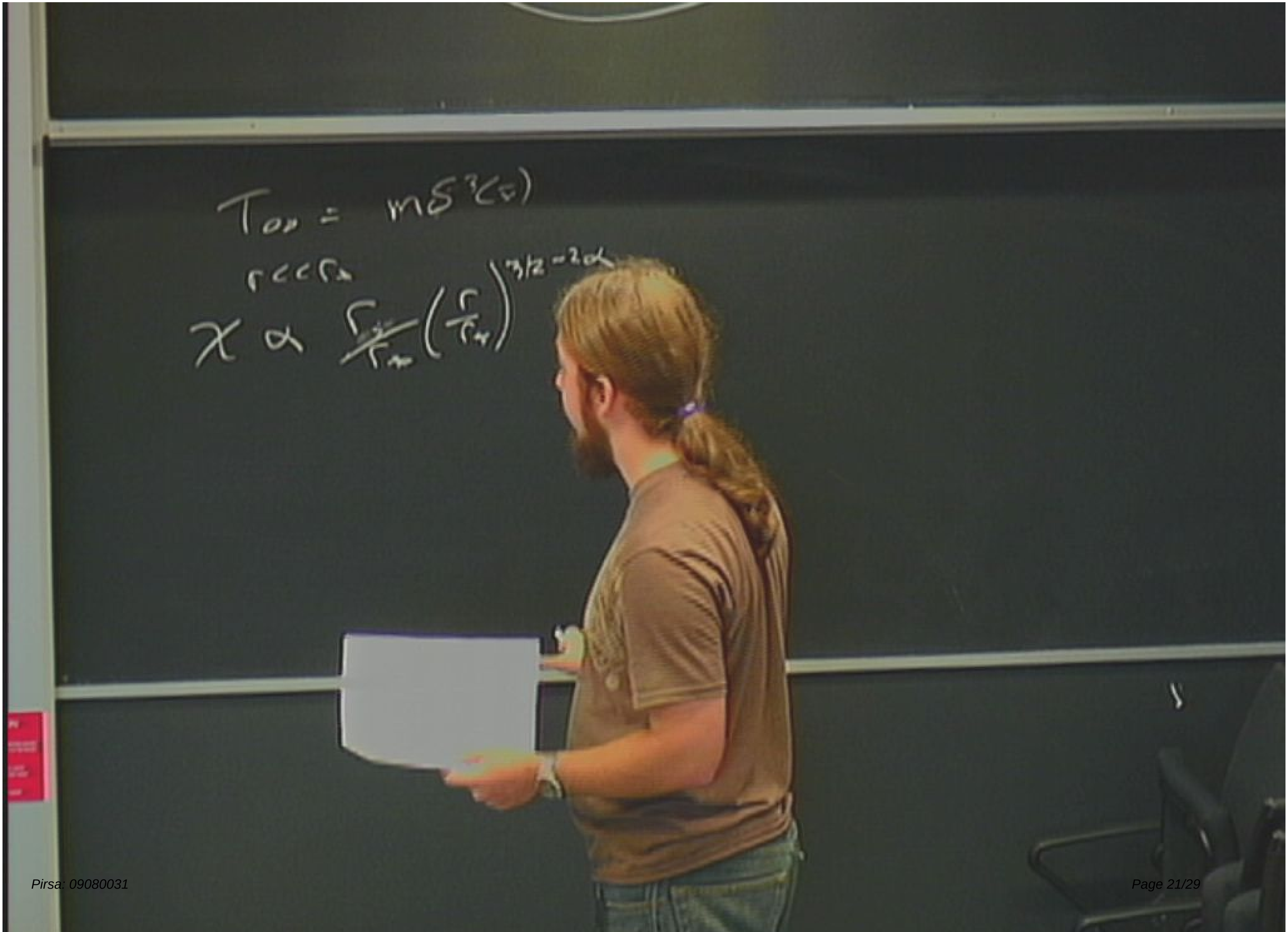
parameter $0 \le \alpha < 1$

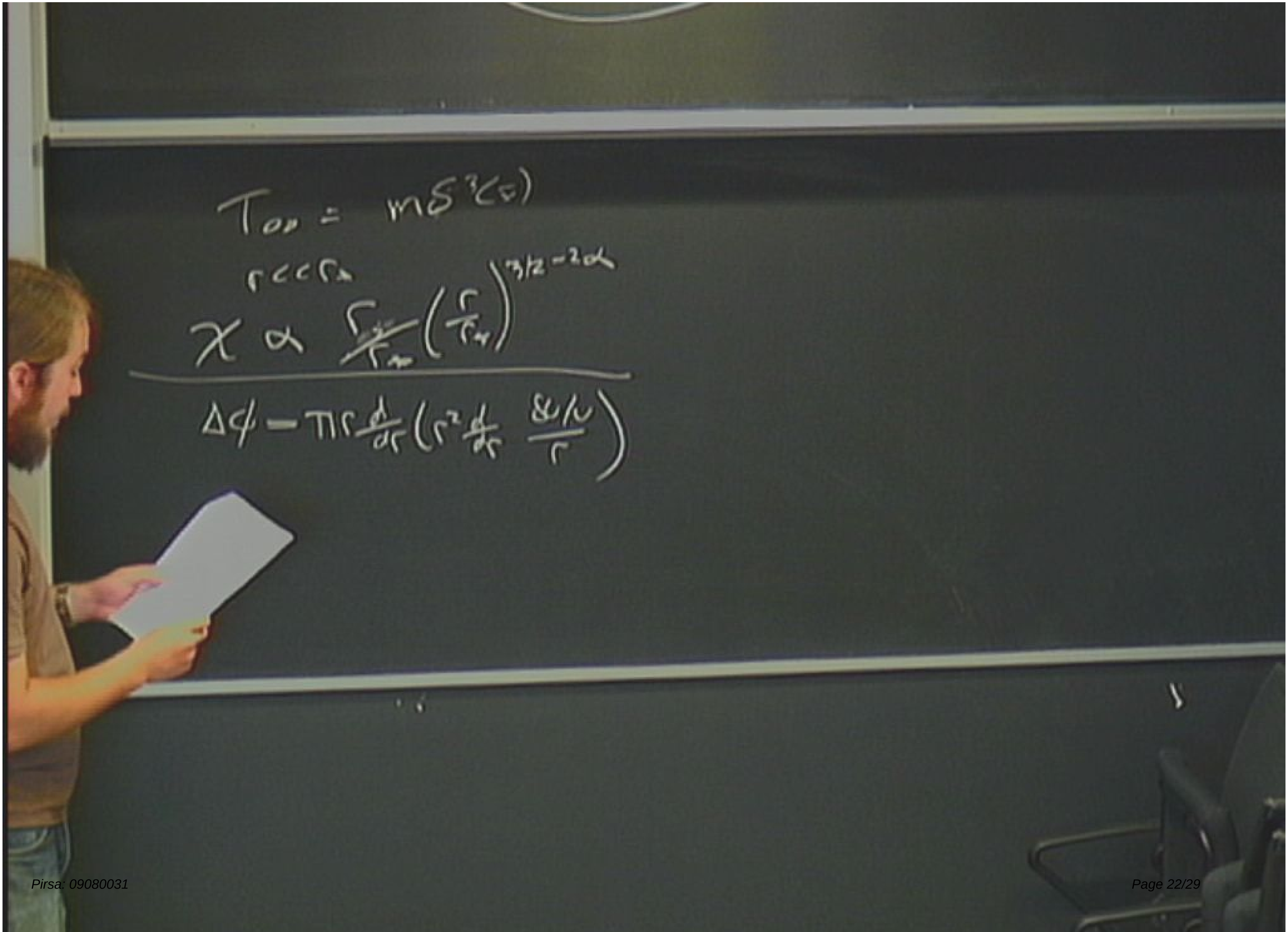
$$h_{\mu\nu} = h^{\text{Einstein}}_{\mu\nu} - \frac{1}{6}\chi\eta_{\mu\nu}$$

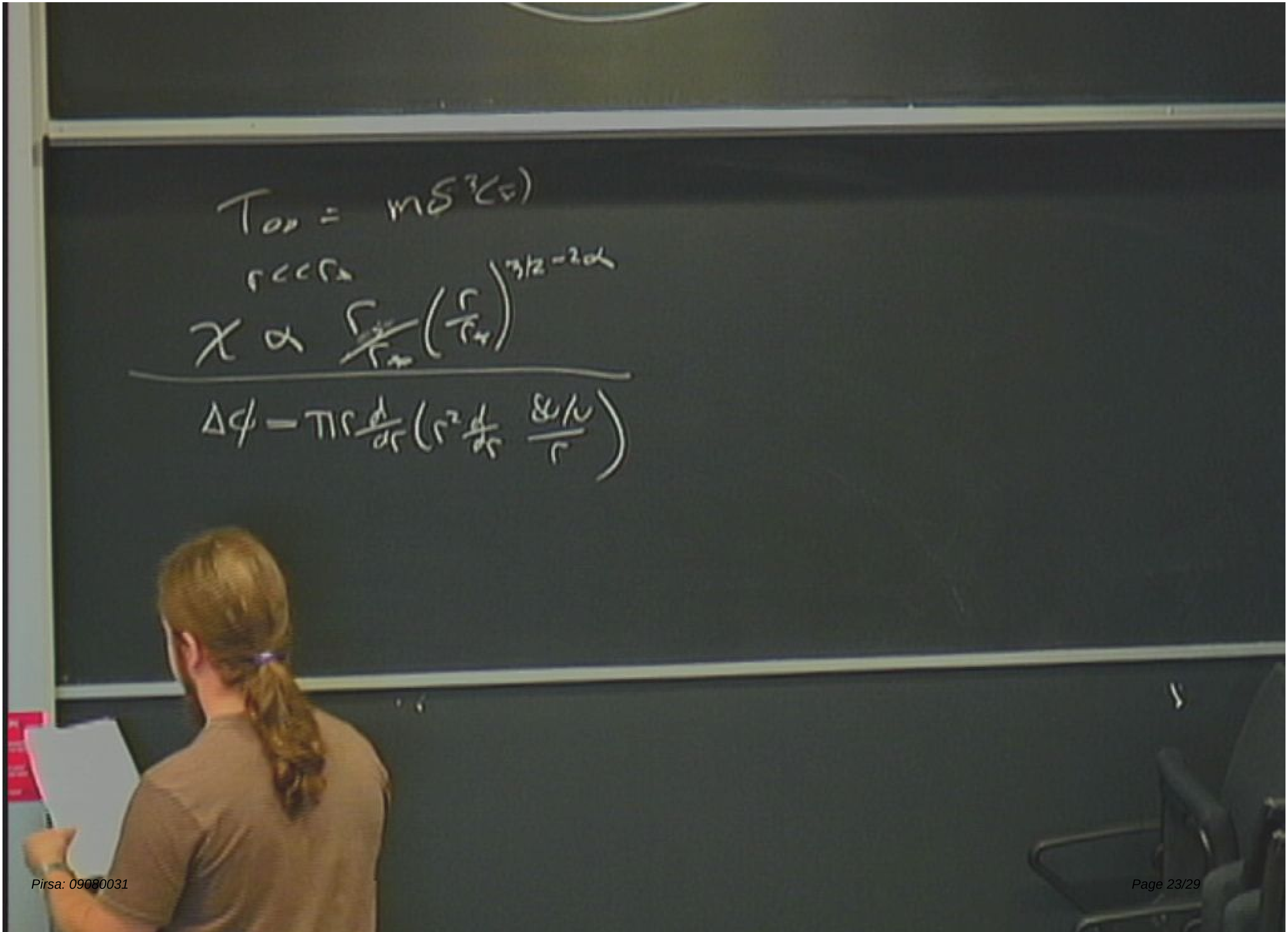
$$\left(\mathcal{E}h^{\text{Einstein}}\right)_{\mu\nu} = -\frac{T_{\mu\nu}}{M_{pl}}$$

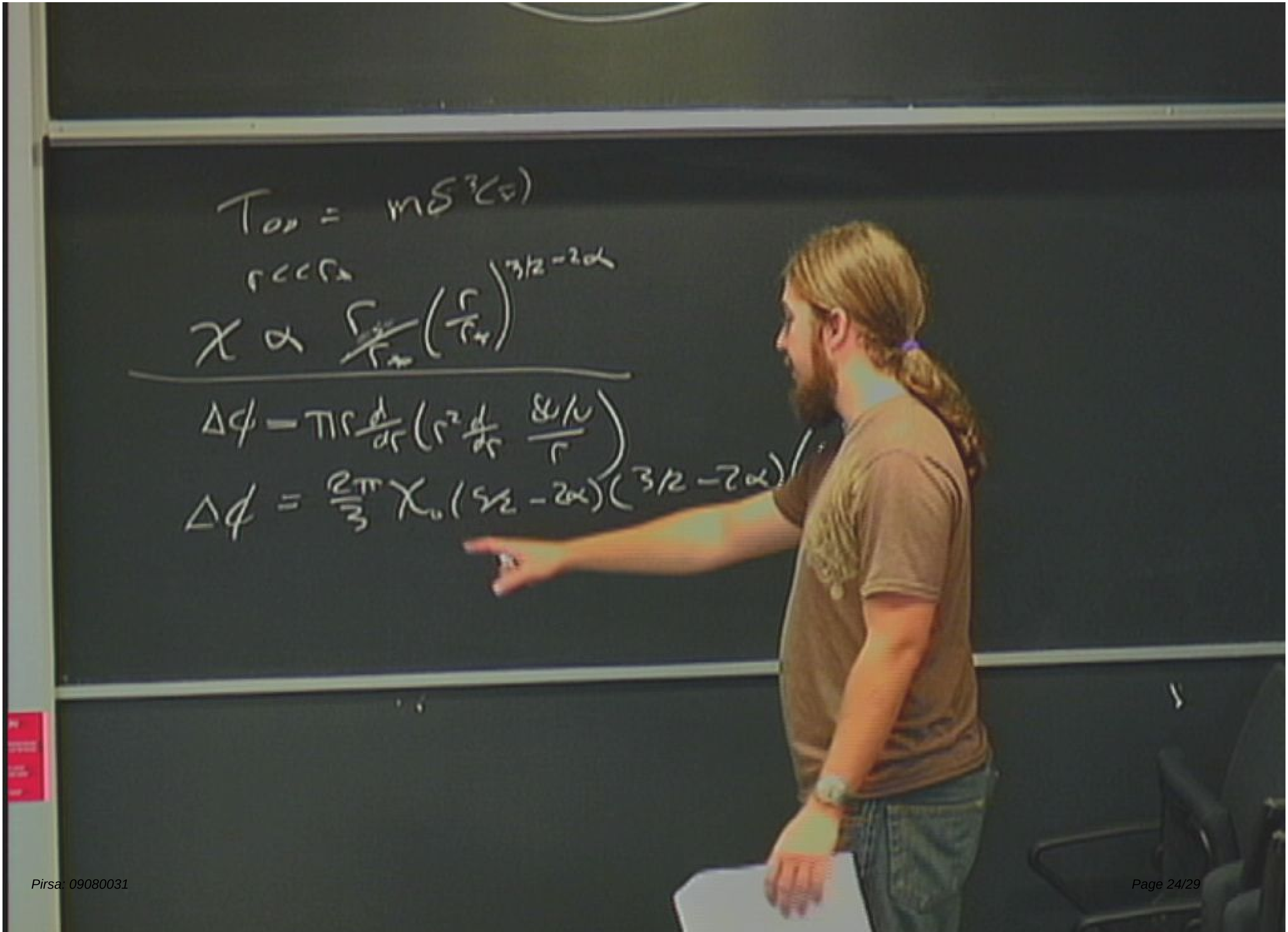
$$\Box\chi - \frac{r_c^{2(1-\alpha)}}{M_{pl}}\left[3\Box\left(\Box^{-\alpha}\chi\right)^2 - \Box\left(\frac{D_\mu D_\nu}{\Box^{\alpha}}\chi\right)^2 - 2D^\mu D^\nu\left(\frac{D_\mu D_\nu}{\Box^{\alpha}}\chi\,\Box^{-\alpha}\chi\right)\right] = -\frac{T}{M_{pl}}$$


$T_{00} = m\delta^3(r)$
$r \ll r_*$
$\chi \propto \cancel{\frac{r_*}{r_{**}}}\left(\frac{r}{r_*}\right)^{3/2-2\alpha}$


$T_{00} = m\delta^3(r)$
$r << r_s$
$\chi \propto \frac{r_{s}}{r_{s}} \left(\frac{r}{r_{s}}\right)^{3/2 - 2\alpha}$


$T_{00} = m\delta^3(r)$
$r \ll r_*$
$\chi \propto \frac{r_*}{r_{ss}} \left(\frac{r}{r_*}\right)^{3/2 - 2\alpha}$
$\Delta\phi - \pi r \frac{d}{dr}\left(r^2 \frac{d}{dr} \frac{\delta\omega/\omega}{r}\right)$


$T_{00} = m\delta^3(r)$
$r \ll r_a$
$\chi \propto \cancel{\frac{r_{a}}{r_{m}}} \left(\frac{r}{r_{a}}\right)^{3/2-2\alpha}$
$\Delta\phi = \pi r \frac{d}{dr}\left(r^2 \frac{d}{dr} \frac{\delta r}{r}\right)$


T00 = m δ³(r)
r << r*
χ ∝ r*/r (r/r*)^(3/2 − 2α)
Δφ = πr d/dr (r² d/dr δr/r)
Δφ = 2π/3 χ0 (5/2 − 2α)(3/2 − 2α)

$$T_{00} = m\delta^3(\vec{r})$$

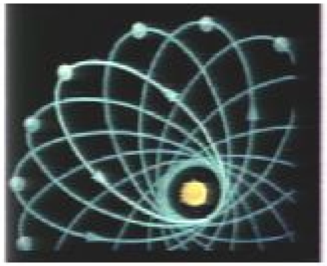
$r << r_*$

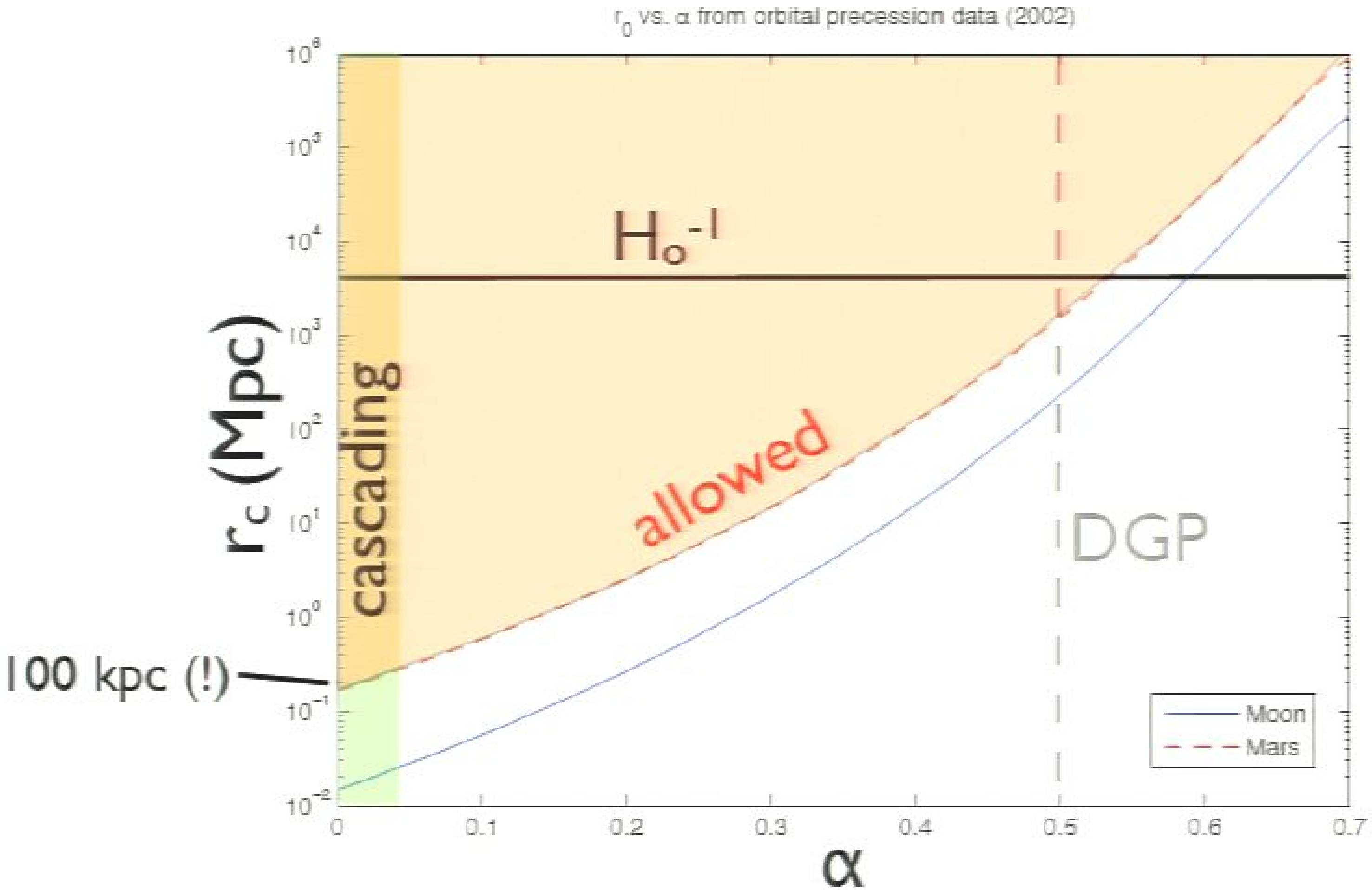
$$\chi \propto \cancel{\frac{r_*}{r_{*}}}\left(\frac{r}{r_*}\right)^{3/2-2\alpha}$$

$$\Delta\phi - \pi r \frac{d}{dr}\left(r^2 \frac{d}{dr} \frac{\delta\omega/\omega}{r}\right)$$

$$\Delta\phi = \frac{2\pi}{3}\chi_0(5/2-2\alpha)(3/2-2\alpha)\left(\frac{r}{r_*}\right)^{3/2-2\alpha}$$

Parameter limits





with A. Bognat and C. de Rham, forthcoming / cf. Afshordi et al. 2009

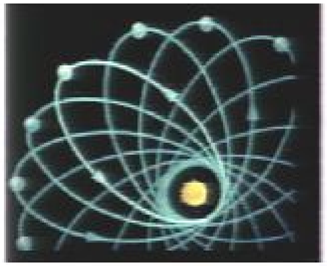
$$h_{\mu\nu} = h_{\mu\nu}^{\text{Einstein}} - \frac{1}{6}\chi\eta_{\mu\nu}$$

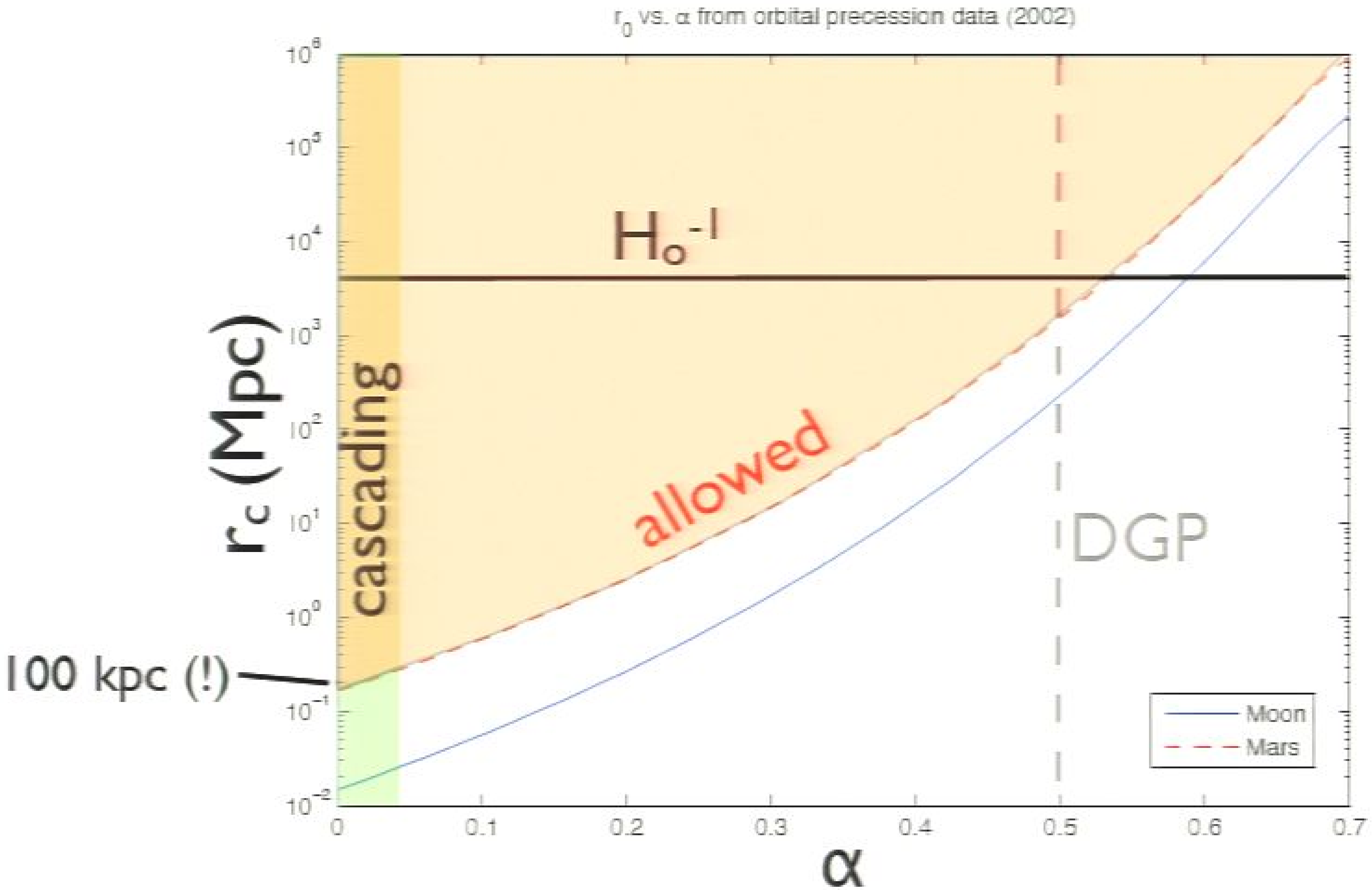
$$\Gamma_*^{5-4\,\text{dim}} = \Gamma_c^{4(1-\text{loop})}\,\Gamma_5$$

$$\left(\mathcal{E}h^{\text{Einstein}}\right)_{\mu\nu} = -\frac{T_{\mu\nu}}{m_{pl}}$$

$$\Box\chi - \frac{\Gamma_c^{4(1-\text{loop})}}{m_{pl}}\left[3\Box(\Box^{-1}\chi)^2 - \Box\left(\frac{\nabla_\mu\nabla_\nu}{\Box}\chi\right) - 2\Box^{-1}\nabla\left(\frac{\nabla_\mu\nabla_\nu}{\Box}\chi\,\Box^{-1}\chi\right)\right] = -\frac{T}{m_{pl}}$$

Parameter limits





with A. Bognat and C. de Rham, forthcoming / cf. Afshordi et al, 2009

$$h_{\mu\nu} = h_{\mu\nu}^{\text{Einstein}} - \frac{1}{6}\chi\eta_{\mu\nu} \qquad \Gamma_*^{5-4m} = \Gamma_c^{4(1-m)}\,\Gamma_5$$

$$\left(\mathcal{E}h^{\text{Einstein}}\right)_{\mu\nu} = -\frac{T_{\mu\nu}}{M_{pl}}$$

$$\Box\chi - \frac{\Gamma_c^{4(1-m)}}{M_{pl}}\left[3\Box\left(\Box^{1-m}\chi\right)^2 - \Box\left(\frac{\nabla_\mu\nabla_\nu}{\Box^m}\chi\right)^2 - 2\Box^{1-m}\nabla\left(\frac{\nabla_\mu\nabla_\nu}{\Box^m}\chi\,\Box^{1-m}\chi\right)\right] = -\frac{T}{M_{pl}}$$

Γ_c