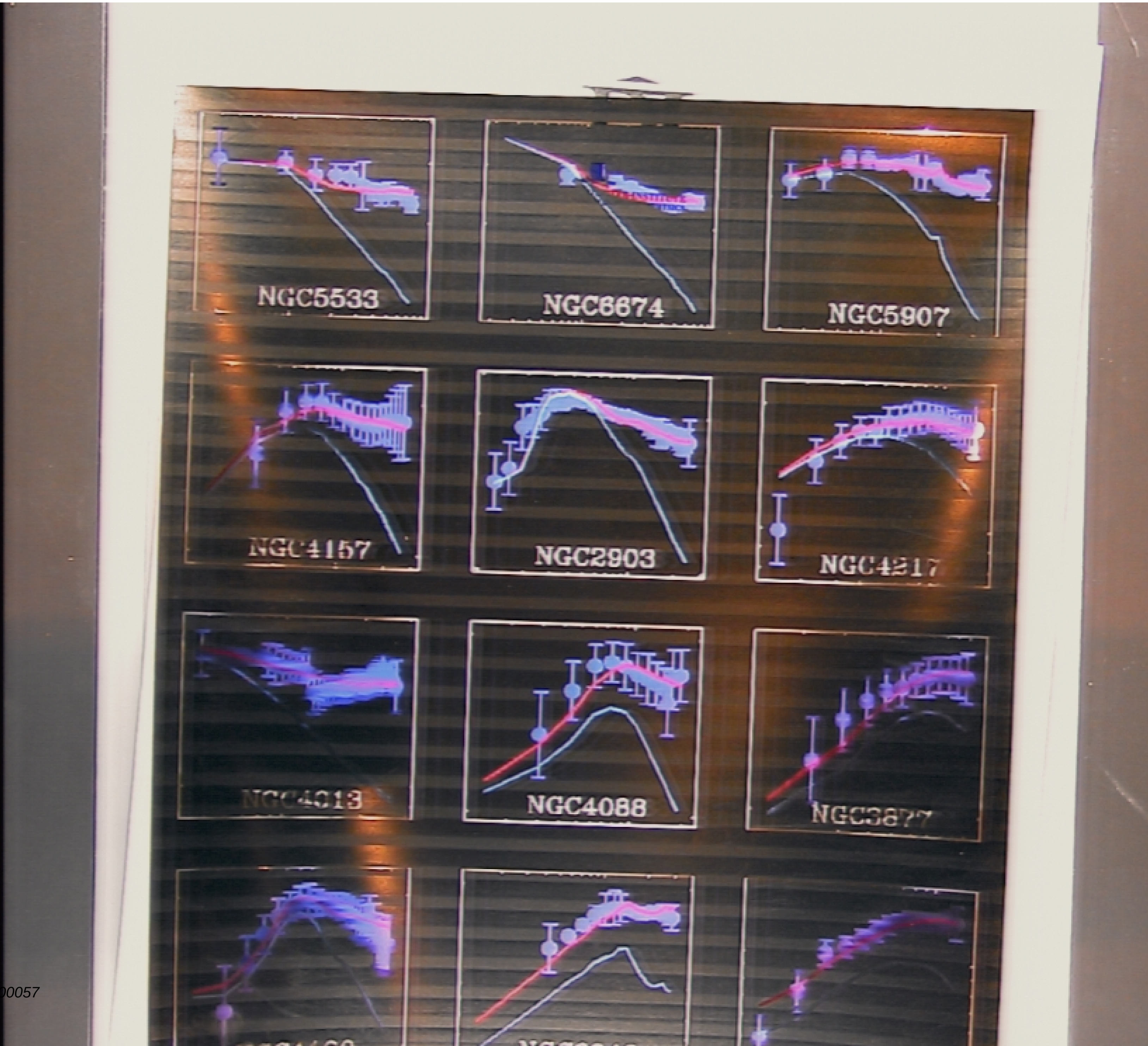
Title: Cosmology: Playground for Fundamental Physics - Panel Discussion

Date: Oct 27, 2005 03:00 AM

URL: http://pirsa.org/05100057

Abstract: Discussion Leader: C. Burgess
P. Binetruy, K. Freese, E. Linder, J. Magueijo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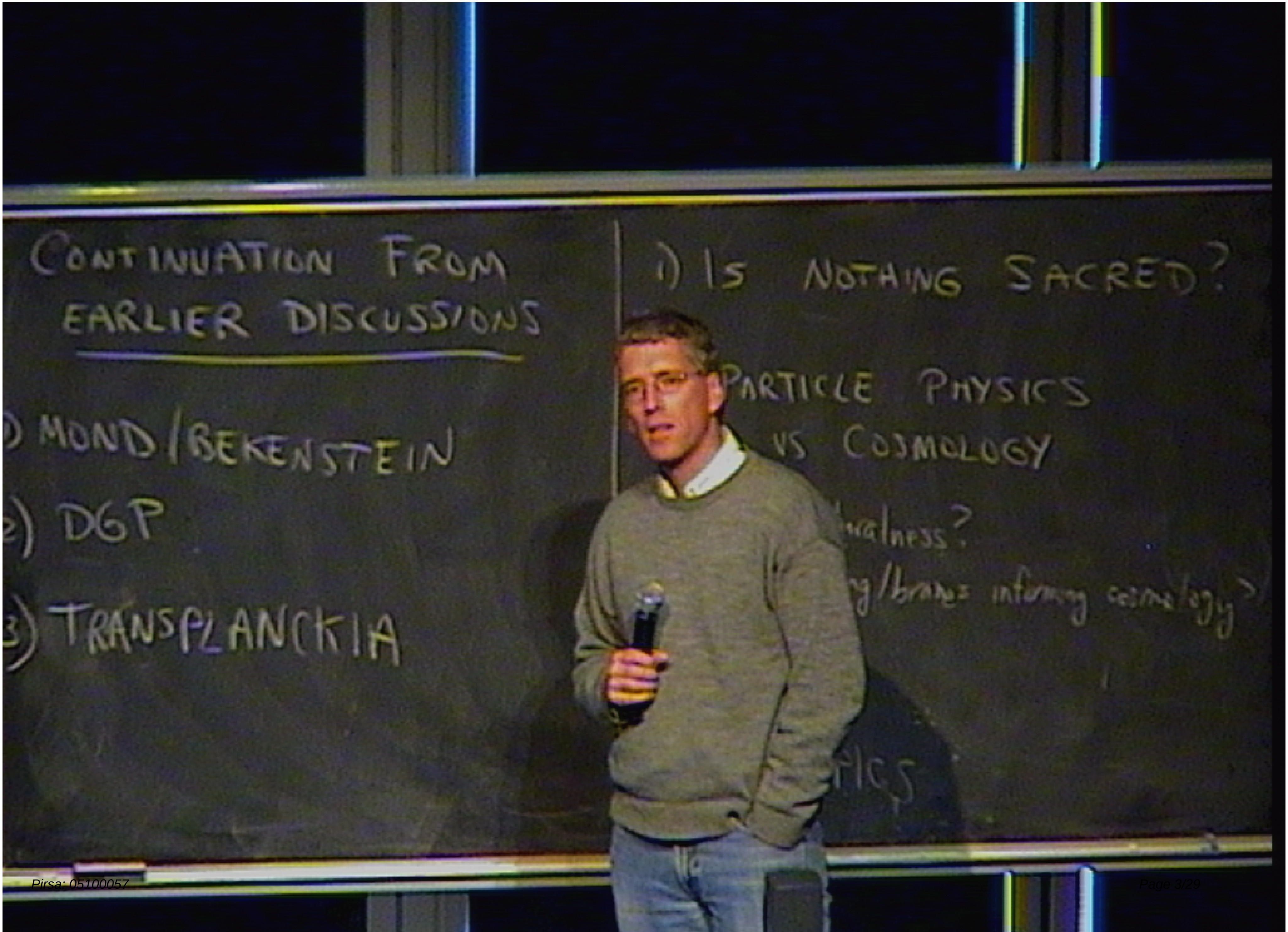
NGC4088
NGC3877


CONTINUATION FROM
EARLIER DISCUSSIONS
MOND/BEKENSTEIN
2) DGP
3) TRANSPLANCKIA
1) IS NOTHING SACRED?
PARTICLE PHYSICS
VS COSMOLOGY
branes informing cosmology?

(1) $v \to v_\infty$ $\frac{GM}{r^2} = \frac{v^2}{r}$ $v \propto \frac{1}{\sqrt{r}}$

(2) ~~Newt~~

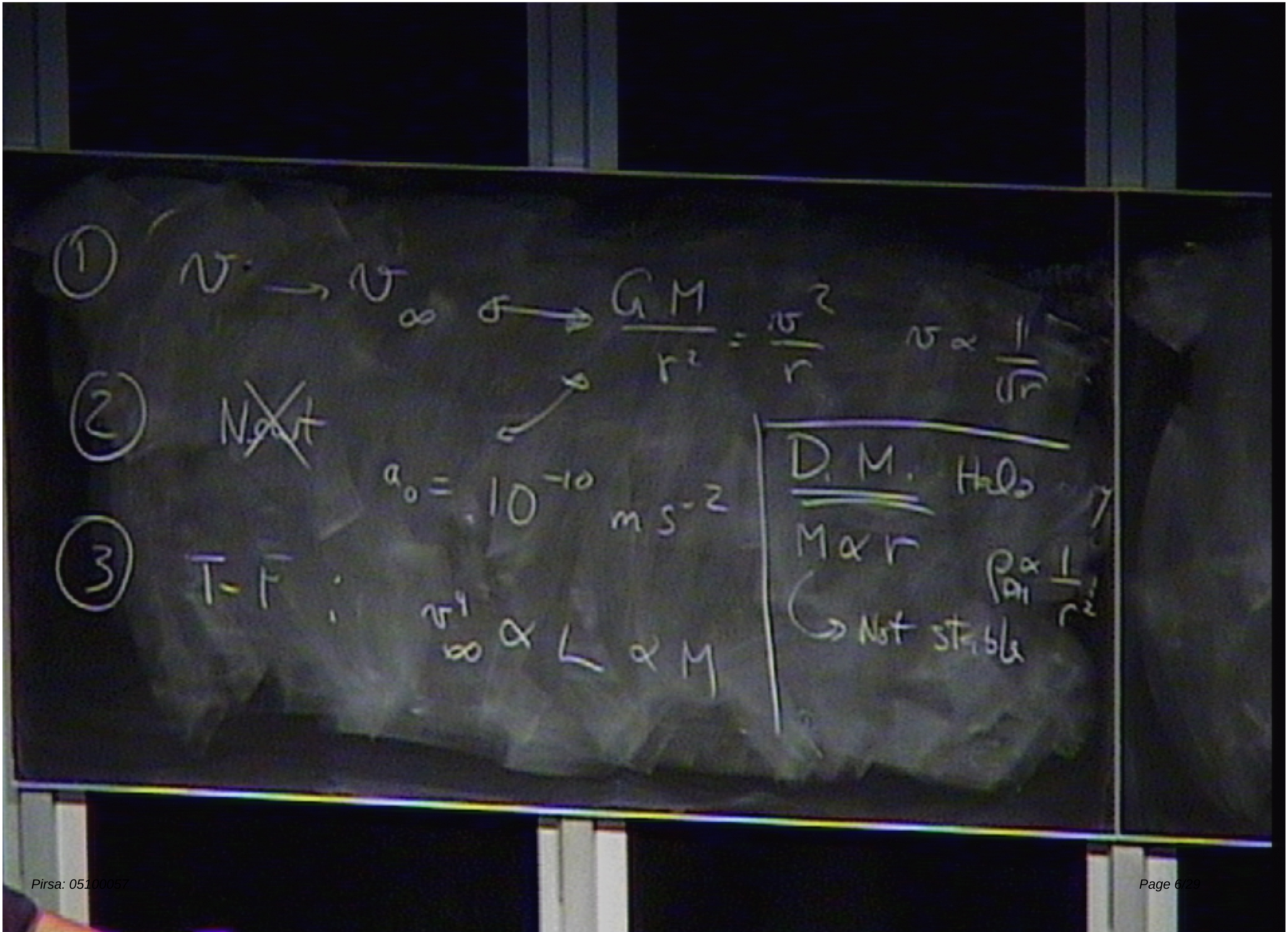
$a_0 = 10^{-10}\ m s^{-2}$

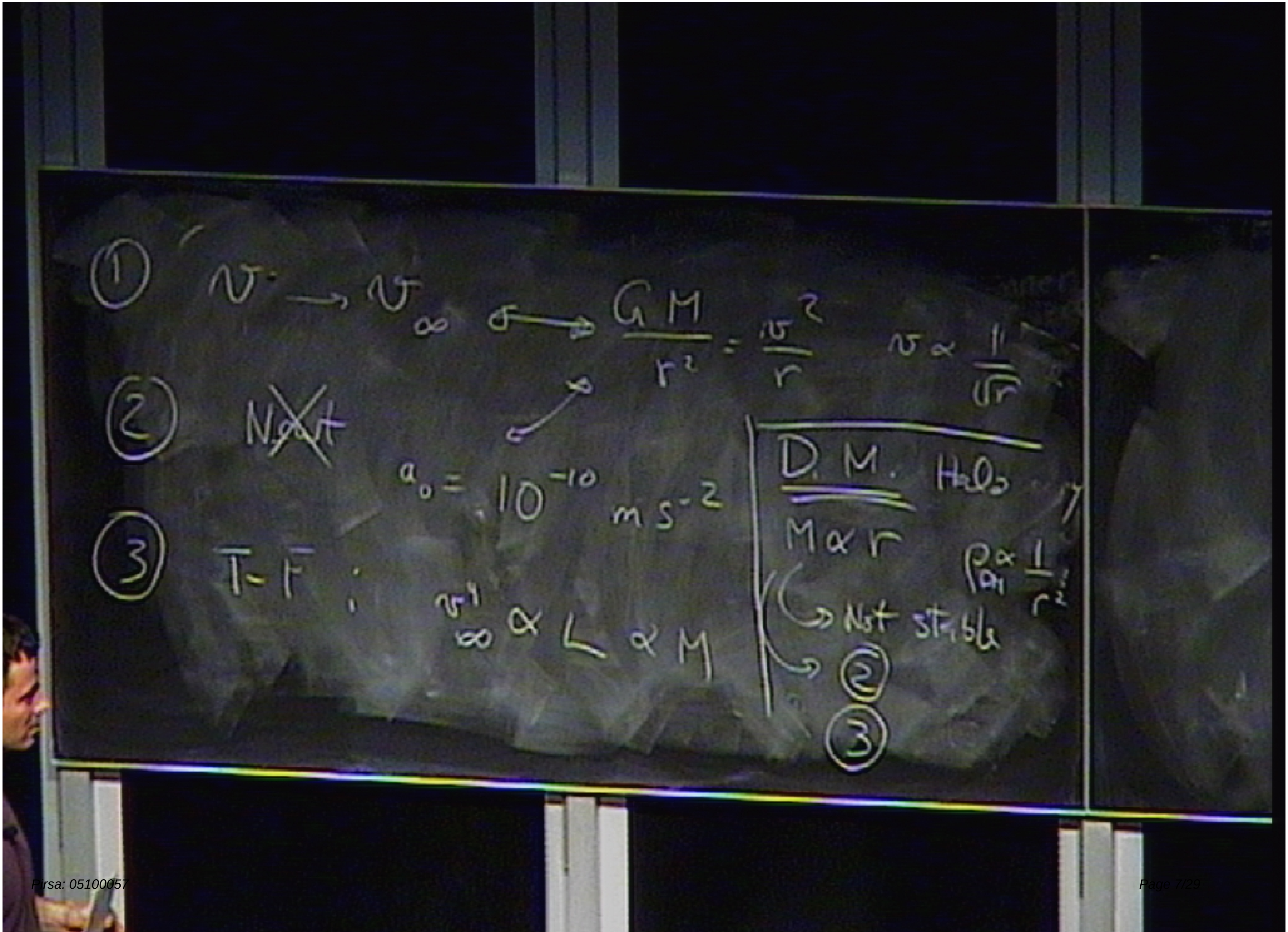
(1) $v \longrightarrow v_\infty \Longleftrightarrow \frac{GM}{r^2} = \frac{v^2}{r}$ $\quad v \propto \frac{1}{\sqrt{r}}$

(2) ~~Newt~~

$a_0 = 10^{-10}\ m\,s^{-2}$

(3) T-F : $v_\infty^4 \propto L$


1 v → v∞ ⟷ GM/r² = v²/r
v ∝ 1/√r
2 Newt
a₀ = 10⁻¹⁰ m s⁻²
3 T-F : v∞⁴ ∝ L ∝ M
D. M. Halo
M ∝ r
ρDM ∝ 1/r² !
Not stable


1
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2
Not
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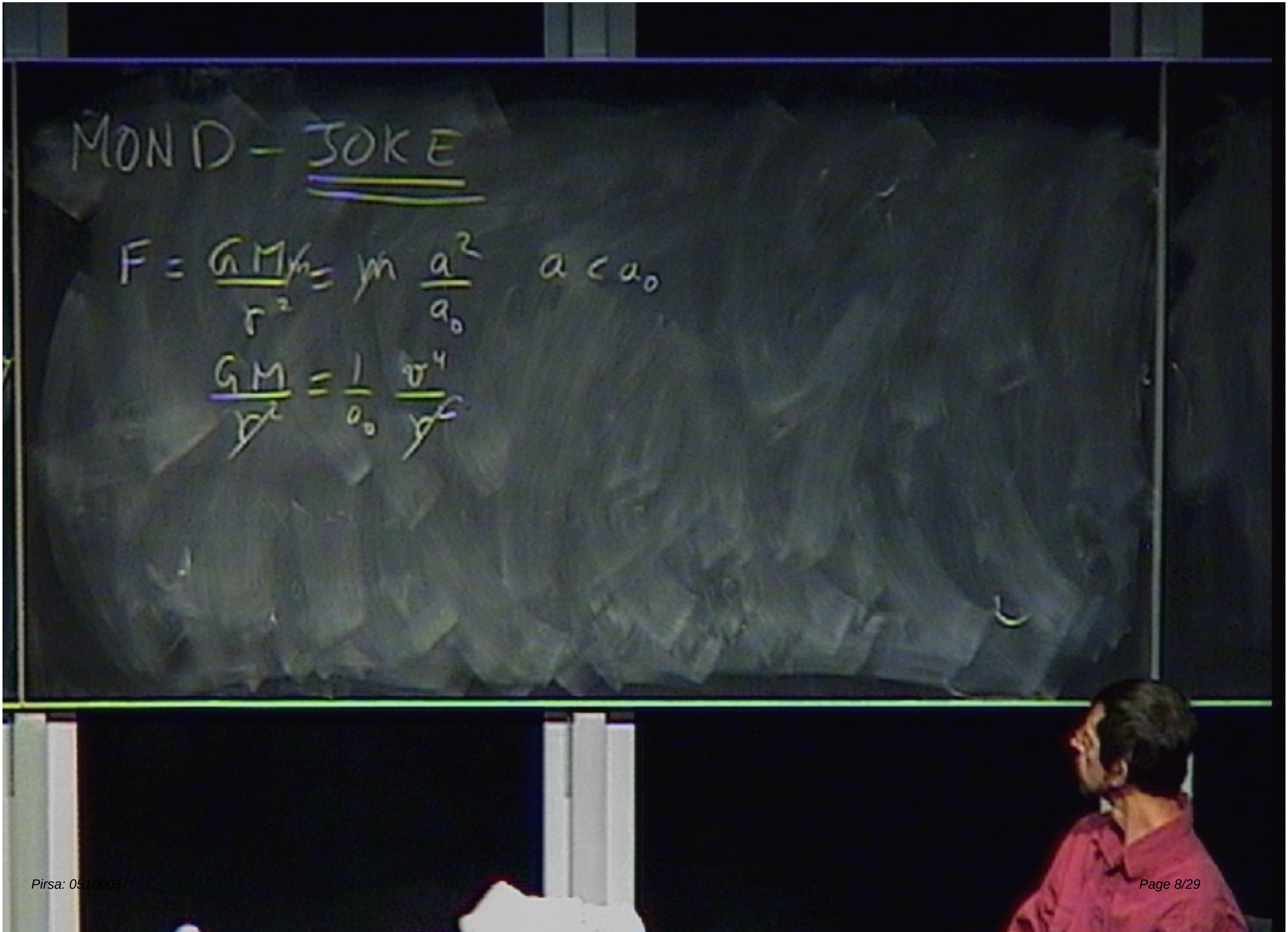
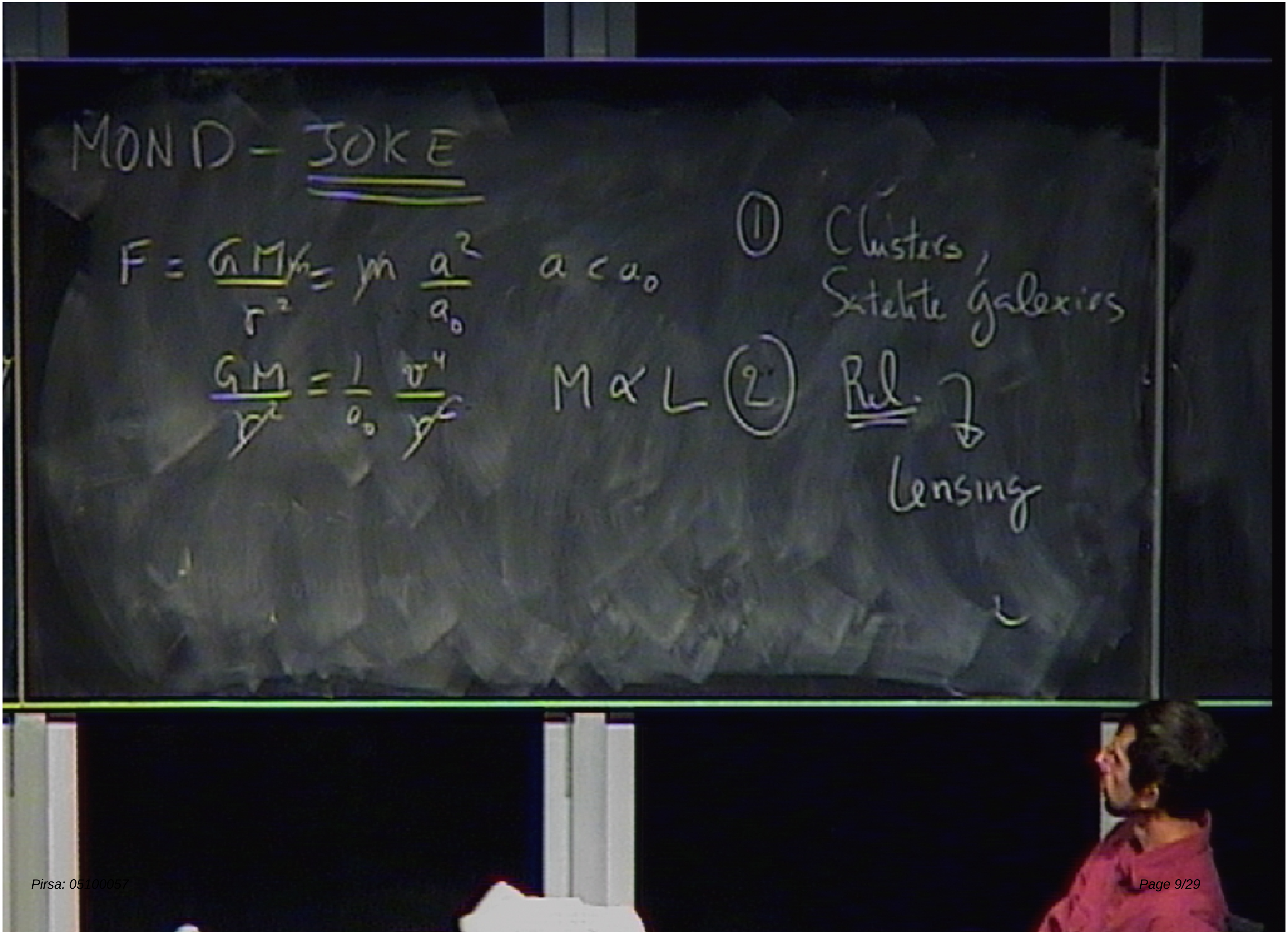
2
3


MOND - JOKE
$F = \frac{GMm}{r^2} = m\frac{a^2}{a_0}$ $a < a_0$
$\frac{GM}{r^2} = \frac{1}{a_0}\frac{v^4}{r^2}$


MOND - JOKE
$F = \frac{GMm}{r^2} = m\frac{a^2}{a_0}$
$a < a_0$
$\frac{GM}{r^2} = \frac{1}{a_0}\frac{v^4}{r^2}$
$M \propto L$
① Clusters, Satelite galexies
② Rel.
Lensing

Action for TeVeS

Metric $S_g = \frac{1}{16\pi G}\int d^4x\,\sqrt{-\tilde{g}}\,\tilde{R}$

Scalar $S_\phi = -\frac{1}{16\pi G}\int d^4x\sqrt{-\tilde{g}}\left[\mu\left(\tilde{g}^{\mu\nu} - A^\mu A^\nu\right)\tilde{\nabla}_\mu\phi\tilde{\nabla}_\nu\phi + V(\mu)\right]$

non-dynamical scalar field

"Free" function

Vector $S_A = -\frac{1}{32\pi G}\int d^4x\,\sqrt{-\tilde{g}}\,\left[\,K\,F_{\mu\nu}F^{\mu\nu} - 2\lambda(A_\mu A^\mu + 1)\right]$

Constant

$F_{\mu\nu} = \tilde{\nabla}_\mu A_\nu - \tilde{\nabla}_\nu A_\mu$

Lagrange multiplier

Matter $\delta S_m = -\frac{1}{2}\int d^4x\sqrt{-g}\,T_{\mu\nu}\,\delta g^{\mu\nu}.$

Field equations : Dynamics

metric: $$\tilde{G}_{\mu\nu} = Y_{\mu\nu} + 8\pi G S_{\mu\nu}$$

field source:
$$\begin{aligned} Y_{\mu\nu} &= \mu\left[\tilde{\nabla}_\mu\phi\tilde{\nabla}_\nu\phi - 2A^\alpha\tilde{\nabla}_\alpha\phi A_{(\mu}\tilde{\nabla}_{\nu)}\phi\right] \\ &+\frac{1}{2}\left(\mu\frac{dV}{d\mu} - V(\mu)\right)\tilde{g}_{\mu\nu} + K\left[F^\alpha{}_\mu F_{\alpha\nu} - \frac{1}{4}F_{\alpha\beta}F^{\alpha\beta}\tilde{g}_{\mu\nu}\right] - \lambda A_\mu A_\nu \end{aligned}$$

matter source: $S_{\mu\nu} = T_{\mu\nu} + 2(1 - e^{-4\phi})A^\lambda T_{\lambda(\mu}A_{\nu)}$

scalar: $$\tilde{\nabla}_\mu\left[\mu\left(\tilde{g}^{\mu\nu} - A^\mu A^\nu\right)\tilde{\nabla}_\nu\phi\right] = 8\pi G J$$

scalar source: $J = e^{-2\phi}\left[g^{\mu\nu} + 2e^{-2\phi}A^\mu A^\nu\right]T_{\mu\nu}$

vector: $$K\tilde{\nabla}_\mu F^\mu{}_\nu = -\lambda A_\nu - \mu A^\mu\tilde{\nabla}_\mu\phi\tilde{\nabla}_\nu\phi + 8\pi G j_\nu$$

vector current: $j_\mu = (1 - e^{-4\phi})A^\lambda T_{\lambda\mu}$

Bekenstein "potential"

MOND limit

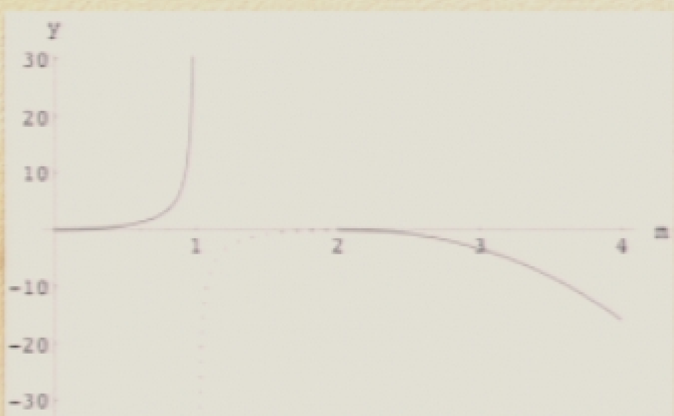
$$V' = \frac{3}{32\pi\ell^2}\frac{1}{\mu_0^2}\frac{\mu^2(\mu-2\mu_0)^2}{\mu-\mu_0}$$

Newtonian limit

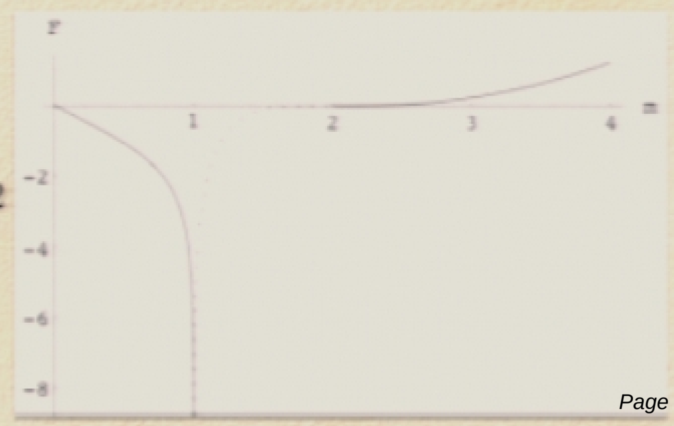
Cosmology

$$V = \frac{1}{16\pi\ell^2}\frac{3}{8\mu_0^2}\left[\mu\left(4\mu_0^3+2\mu_0^2\mu-4\mu_0\mu^2+\mu^3\right)+2\mu_0^4\ln(\mu-\mu_0)^2-4\mu_0^4\ln\mu_0\right]$$

$y = -\frac{8\pi}{\mu_0}\ell^2 V'$



$F \propto V/\mu^2$



Non-Relativistic limit

Modified Poisson equation

$$\nabla \cdot [f(|\nabla\Phi|)\nabla\Phi] = 4\pi G\rho$$

where

$$f(|\nabla\Phi|) = \frac{1}{\Xi}\frac{-1+\sqrt{1+4|\nabla\Phi|/a_0}}{1+\sqrt{1+4|\nabla\Phi|/a_0}}$$

WARNING : depend on $V(\mu)$

$$\Xi = 1 - K/2 - 2\phi_c$$

Milgrom's constant $\quad a_0 = \sqrt{\frac{3}{2\pi}}\,\frac{1}{\Xi\ell\sqrt{\mu_0}}$

cosmological value of ϕ

FLRW Universe

Matter metric $g_{\mu\nu} = a^2 \eta_{\mu\nu}$

Einstein metric $\tilde{g}_{\mu\nu} = b^2 \tilde{\eta}_{\mu\nu}$

Scale factors related by $a = b e^{-\bar{\phi}}$

Minkowski metrics related by

$$\eta_{\mu\nu} = \tilde{\eta}_{\mu\nu} - \frac{2}{a^2} \sinh(2\bar{\phi}) A_\mu A_\nu$$

FLRW equations

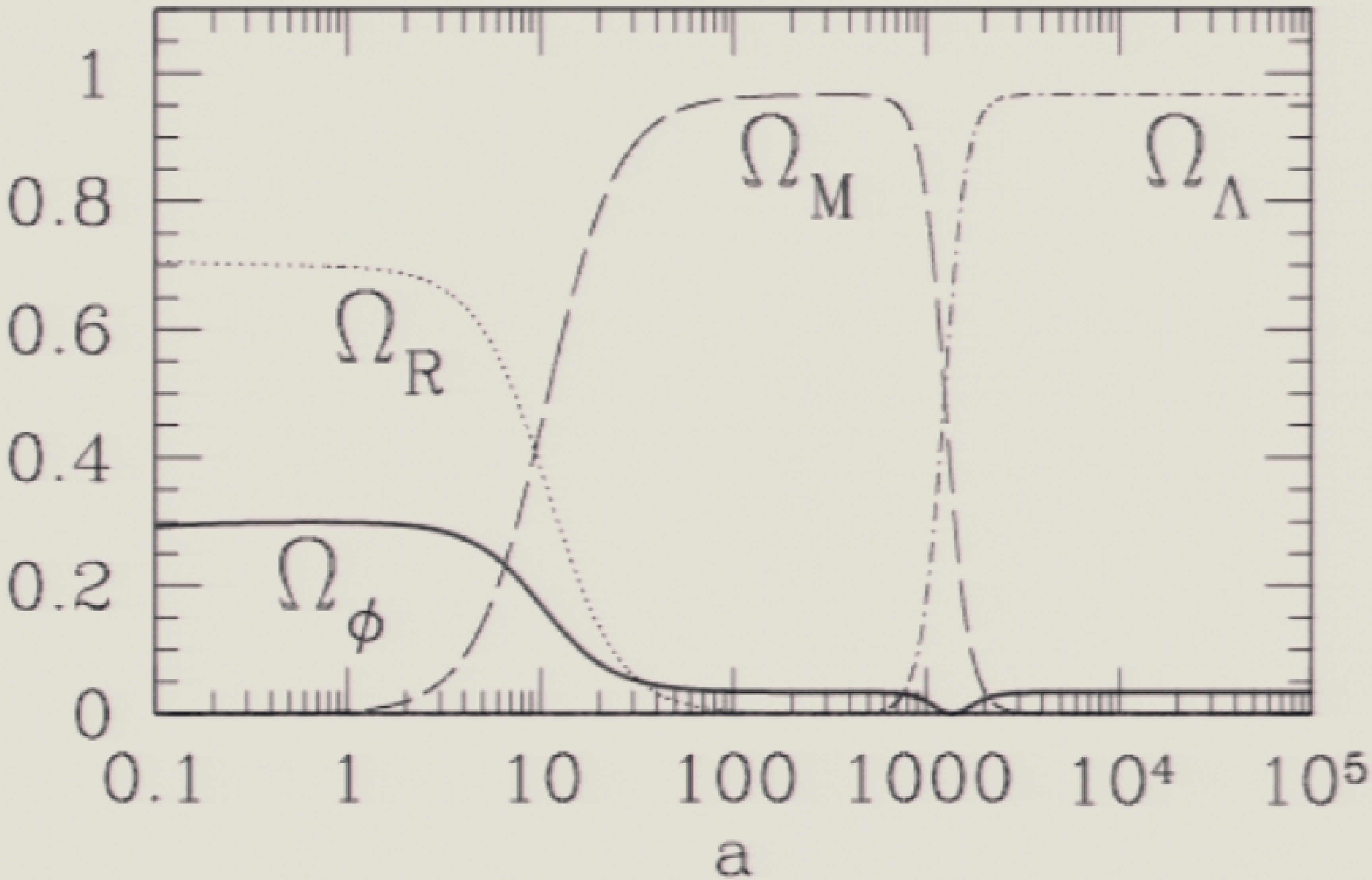
Constraint : $\dot{\bar{\phi}}^2 = \frac{1}{2} a^2 e^{-2\bar{\phi}} \frac{dV}{d\mu}$ gives $\mu = \mu(\dot{\bar{\phi}}, a, \bar{\phi})$

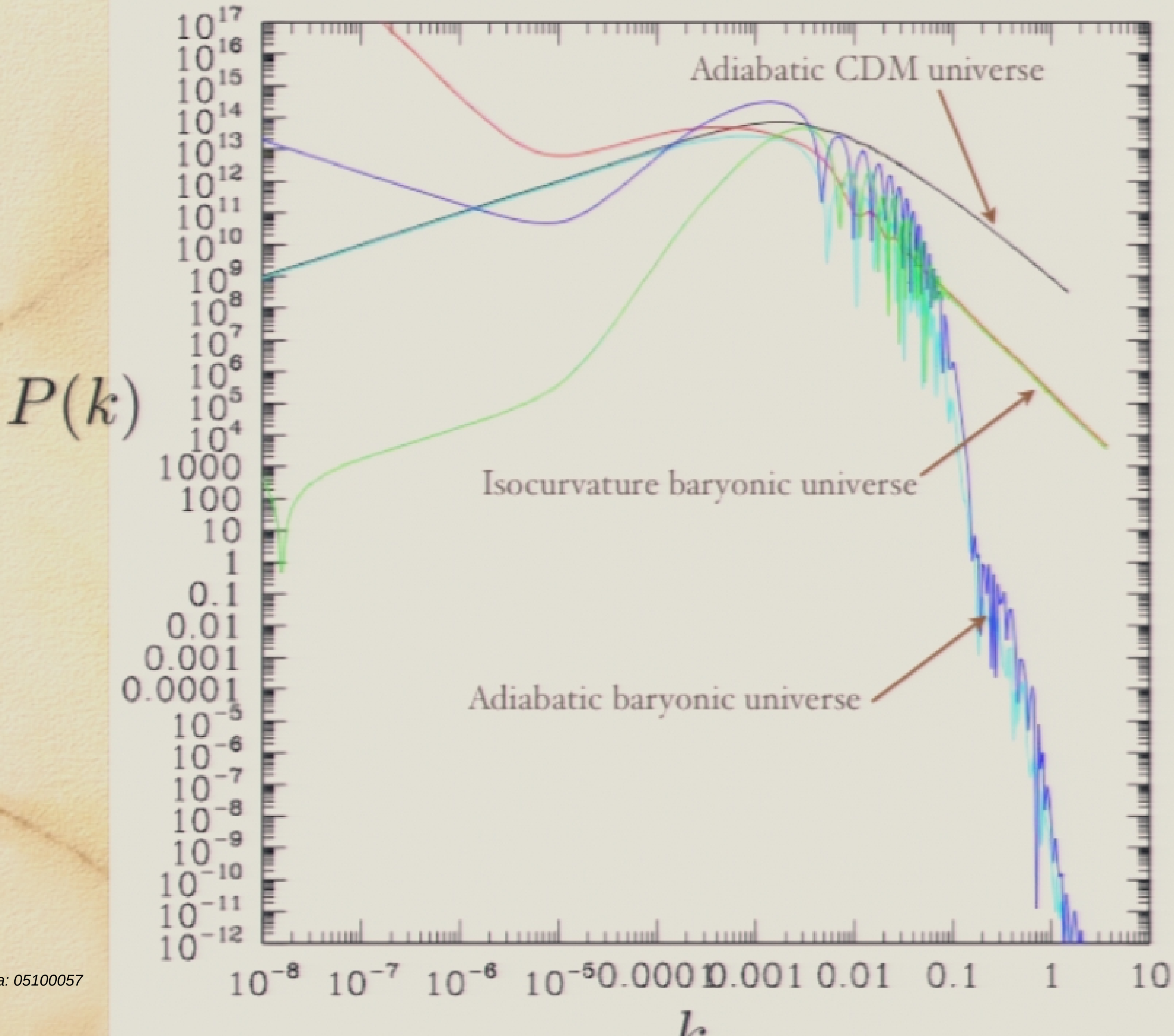
Scalar : $$\ddot{\bar{\phi}} = -a^2 e^{-2\bar{\phi}} V' - \frac{1}{U}\left[2\left(\mu - \frac{V'}{V''}\right)\frac{\dot{b}}{b}\dot{\bar{\phi}} + 4\pi G a^2 e^{-4\bar{\phi}}(\bar{\rho} + 3\bar{P})\right]$$

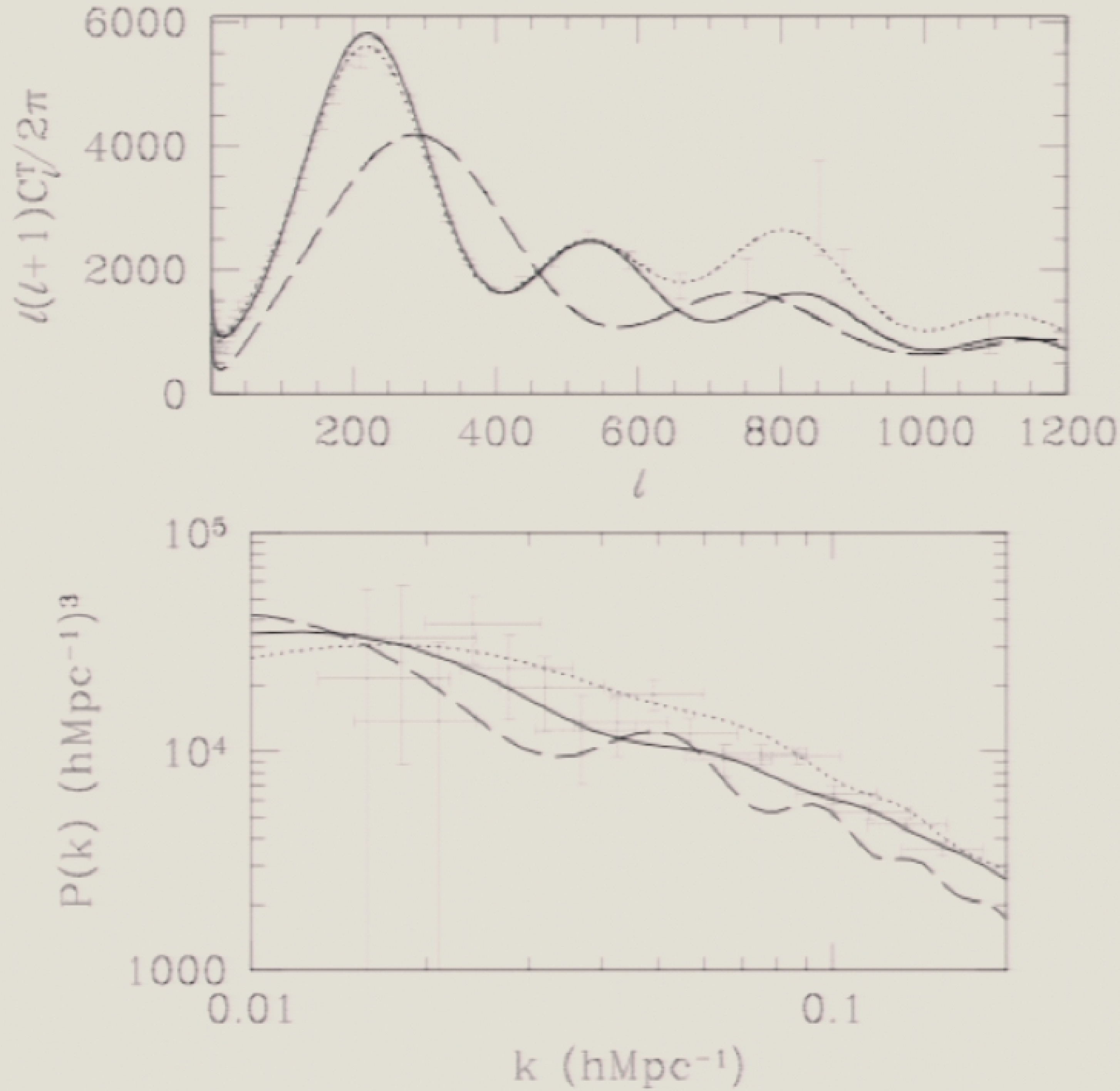
Friedman : $$3\frac{\dot{b}^2}{b^2} = a^2 \left\{\frac{1}{2} e^{-2\bar{\phi}} (\mu V' + V) + 8\pi G e^{-4\bar{\phi}} \bar{\rho}\right\}$$

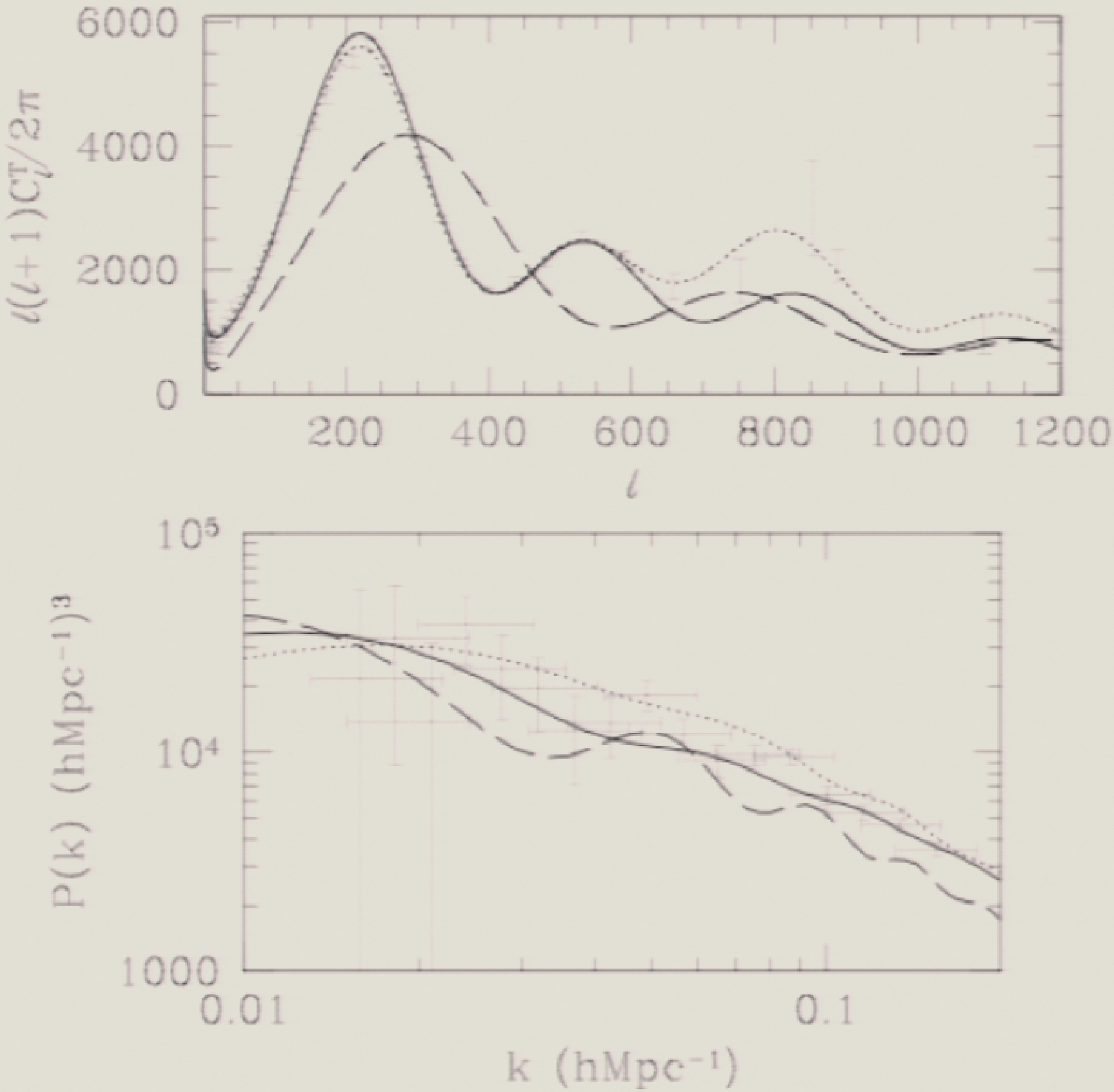
Raychandhuri : $$-2\frac{\ddot{b}}{b} + \frac{\dot{b}^2}{b^2} - 4\frac{\dot{b}}{b}\dot{\bar{\phi}} = a^2 \left[\frac{1}{2} e^{-2\bar{\phi}} (\mu V' - V) + 8\pi G e^{-4\bar{\phi}} \bar{P}\right]$$

Fluid : $$\dot{\rho} + 3\frac{\dot{a}}{a}(1+w)\rho = 0$$


1
0.8
0.6
0.4
0.2
0
0.1
1
10
100
1000
10^4
10^5
a
Ω_R
Ω_ϕ
Ω_M
Ω_Λ


Adiabatic CDM universe
Isocurvature baryonic universe
Adiabatic baryonic universe
$P(k)$
k


6000
4000
2000
0
200
400
600
800
1000
1200
$\ell(\ell+1)C_\ell^T/2\pi$
ℓ
10^5
10^4
1000
0.01
0.1
P(k) $(hMpc^{-1})^3$
k $(hMpc^{-1})$


6000
4000
2000
0
$\ell(\ell+1)C_\ell^T/2\pi$
200 400 600 800 1000 1200
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5d

$^{(4)}$

$R^{(5)}$

$$H \equiv \frac{1}{r_c}$$

5d

$^{(4)}$ $R^{(5)}$

$$H \equiv \frac{1}{r_c}$$

5d

(4) $R^{(5)}$

$$H \equiv \frac{1}{r_c}$$

$$-(\partial\phi)^2$$

$5d$

(4) $\quad R^{(5)}$

$$H = \frac{1}{r_c}$$

$$-(\partial\phi)^2$$

$$+(\partial\phi)^2$$

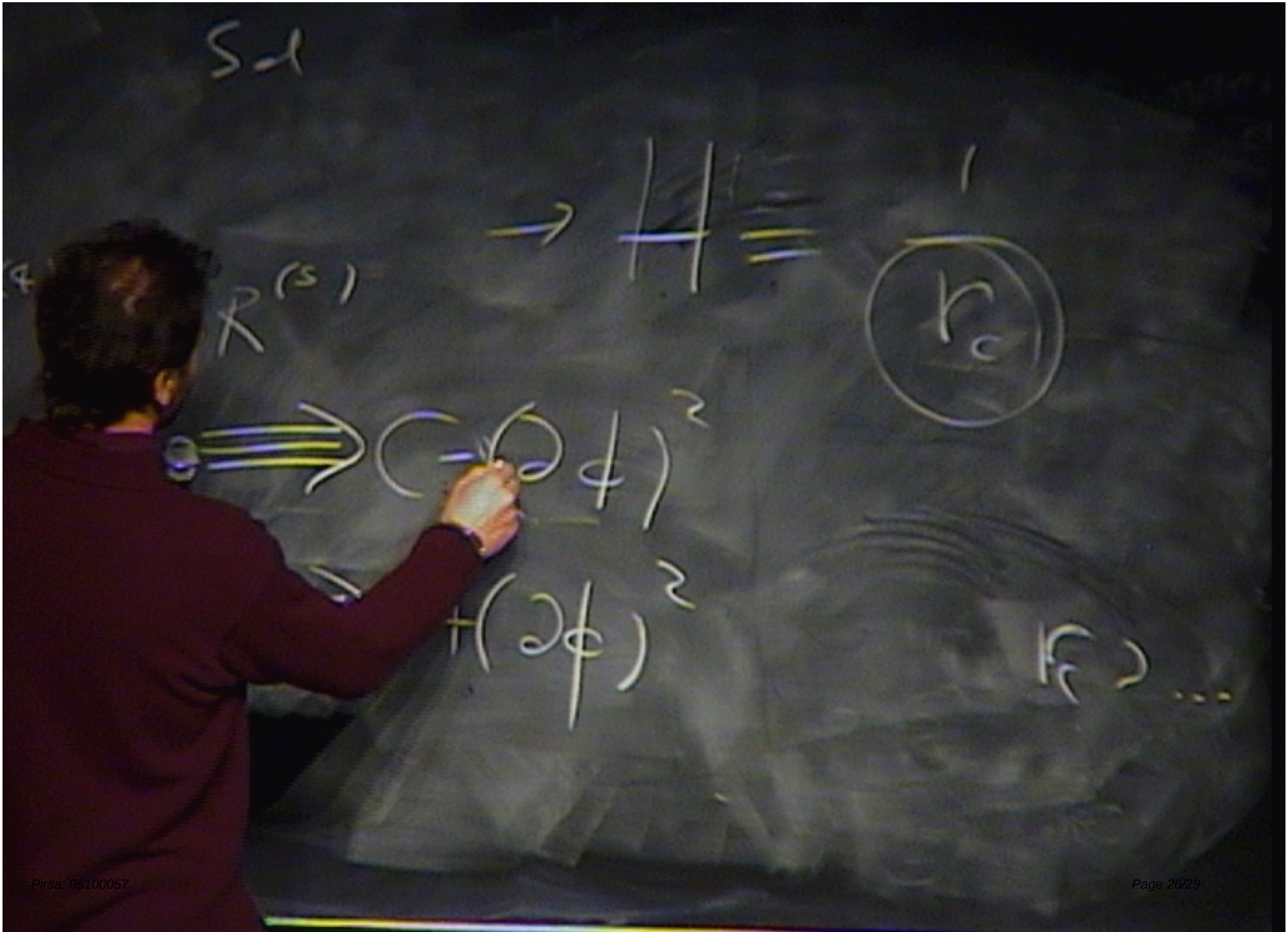
5d

(4)

$R^{(5)} \rightarrow H \equiv \frac{1}{r_c}$

$-(\partial\phi)^2$

$\longrightarrow +(\partial\phi)^2$


5d
$R^{(5)}$
$\rightarrow H = \frac{1}{r_c}$
$\Rightarrow (-(\partial\phi)^2$
$+(\partial\phi)^2$
$r_c > \ldots$

5d

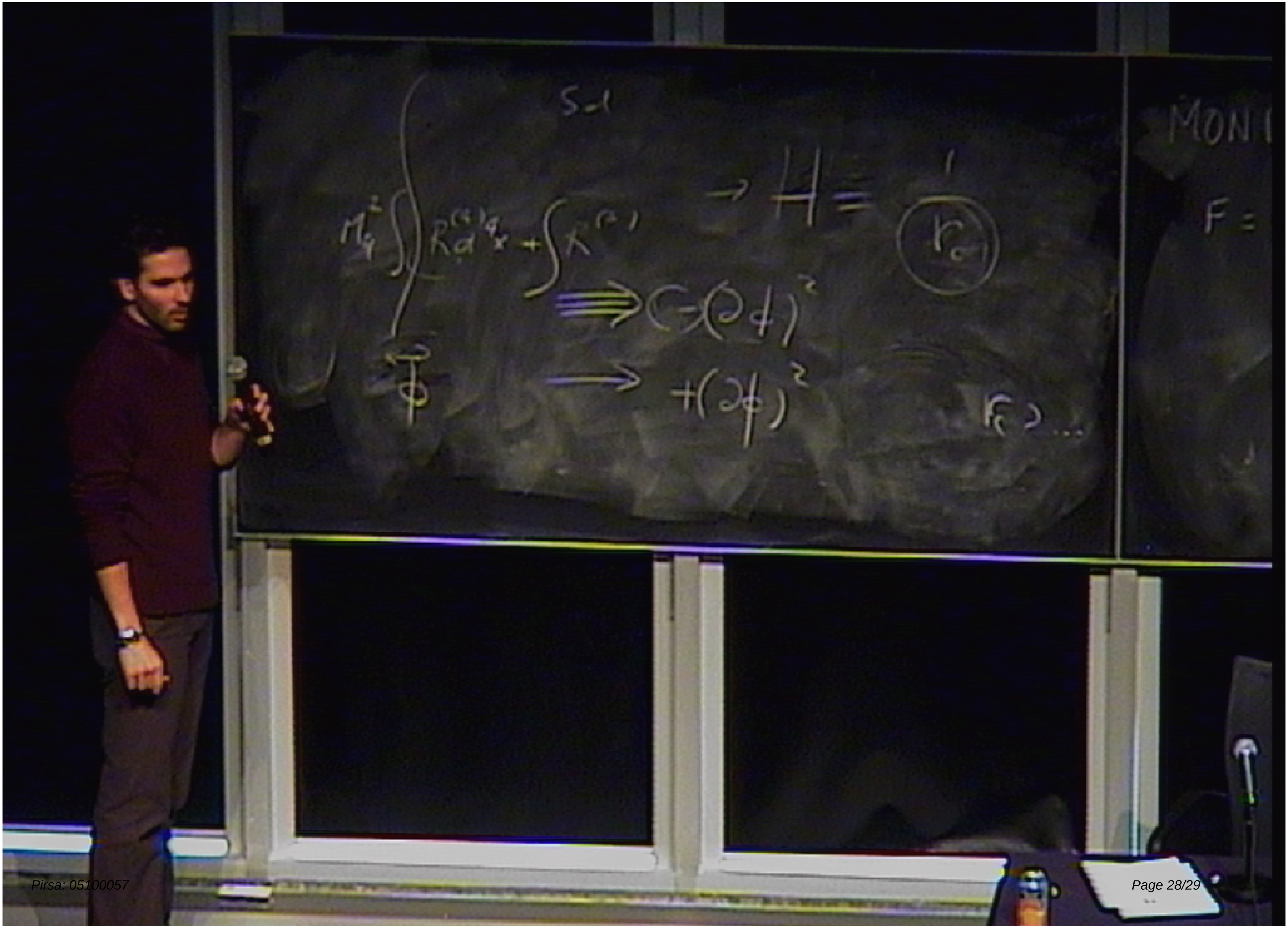
(4)

$R^{(5)} \to H \equiv \frac{1}{r_c}$

$\Longrightarrow (-)(\partial\phi)^2$

$\longrightarrow +(\partial\phi)^2$

$r_c > \dots$



5-d

$$M_4^2 \int R^{(4)} d^4x + \int R^{(5)} \longrightarrow H = \frac{1}{r_c}$$

$$\Longrightarrow (\partial\phi)^2$$

$$\phi \longrightarrow +(\partial\phi)^2$$

$M_4, M_5 \to \infty$

$\Lambda = \frac{M_4^{\#}}{M_5^{\#}}$ = fixed ...

$$(\partial\phi)^2 + \frac{1}{\Lambda^3}\Box\phi(\partial\phi)^2$$