Title: The Cyclic Model and the Cosmological Conundrums

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Abstract: Joel Erickson

THE CYCLIC MODEL AND THE COSMOLOGICAL CONUNDRUMS

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hep-th/0607164

Cosmology on the Great Lakes, 2006

OUTLINE

I. The cyclic model
II. Evolution of scales
III. The cosmological conundrums
IV. Global structure

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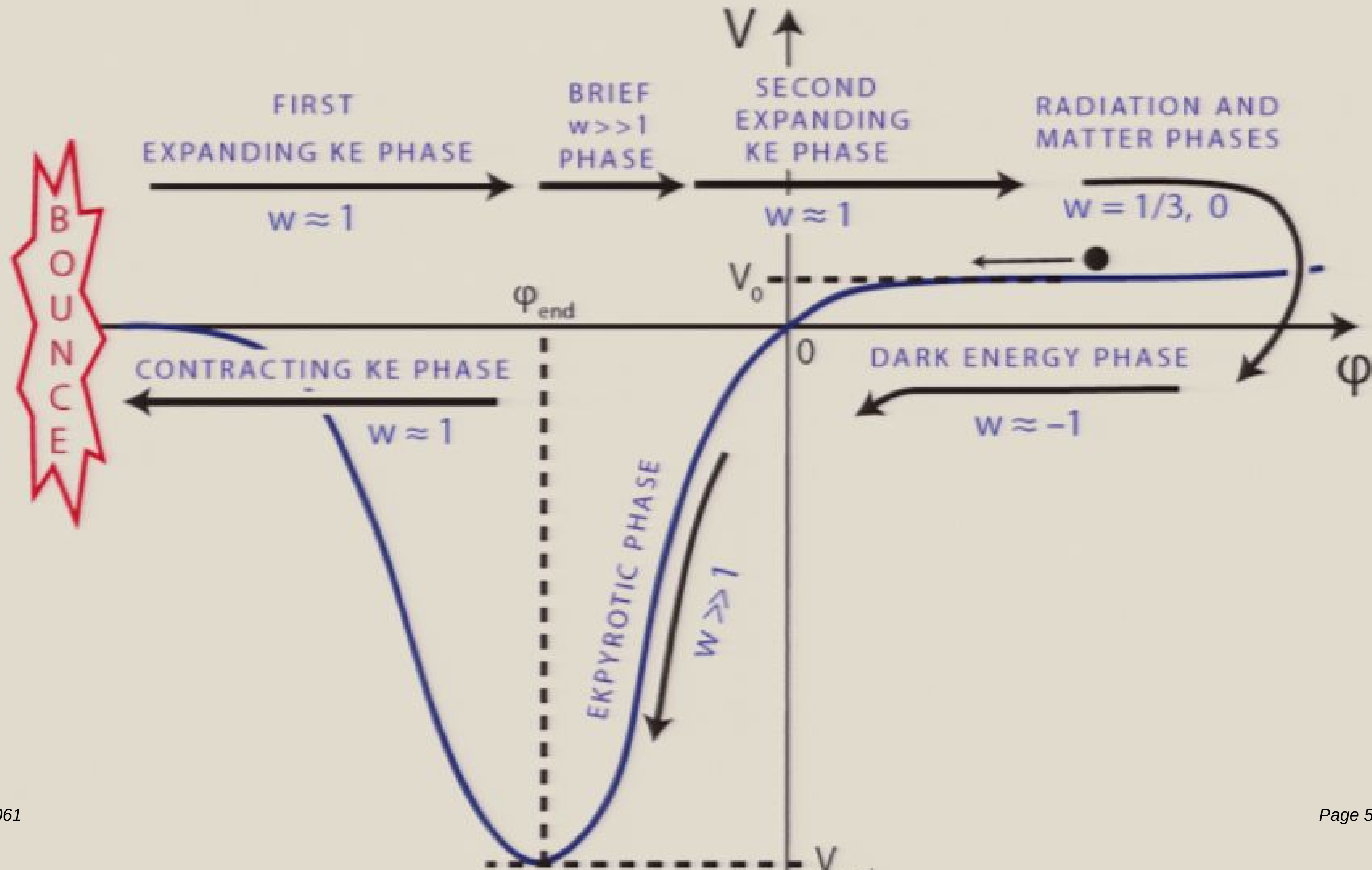
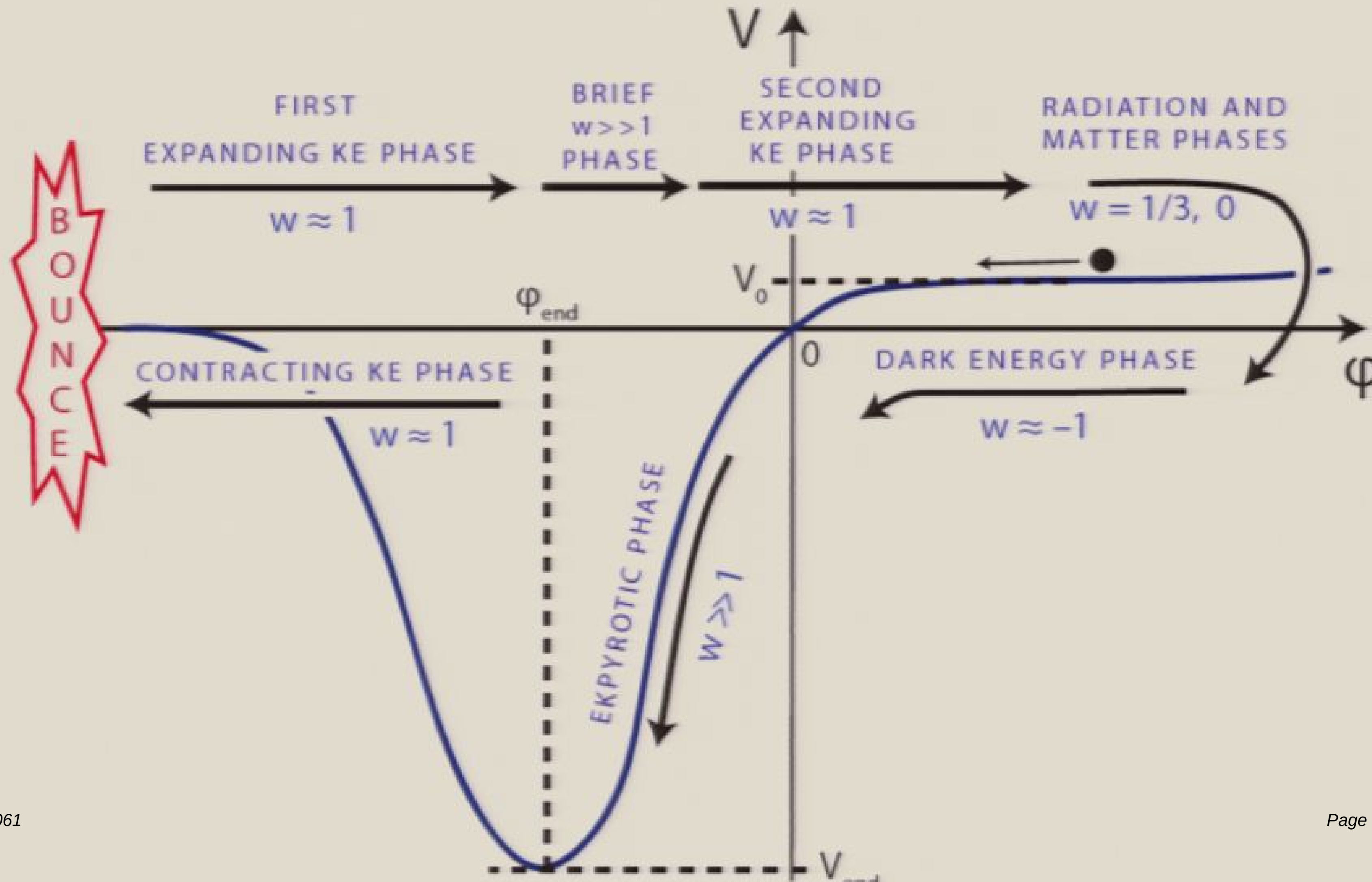
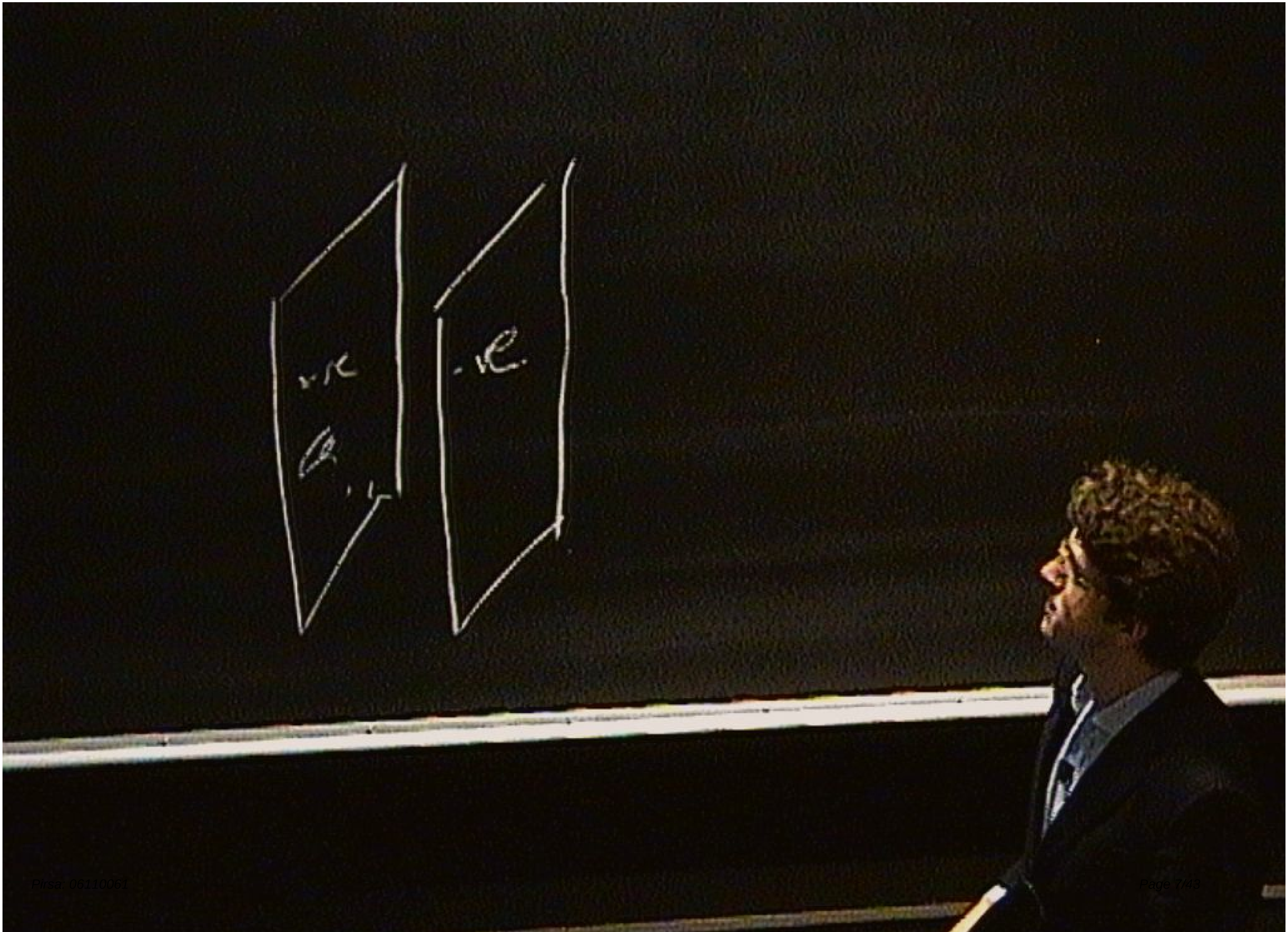
I. The cyclic model
II. Evolution of scales
III. The cosmological conundrums
IV. Global structure

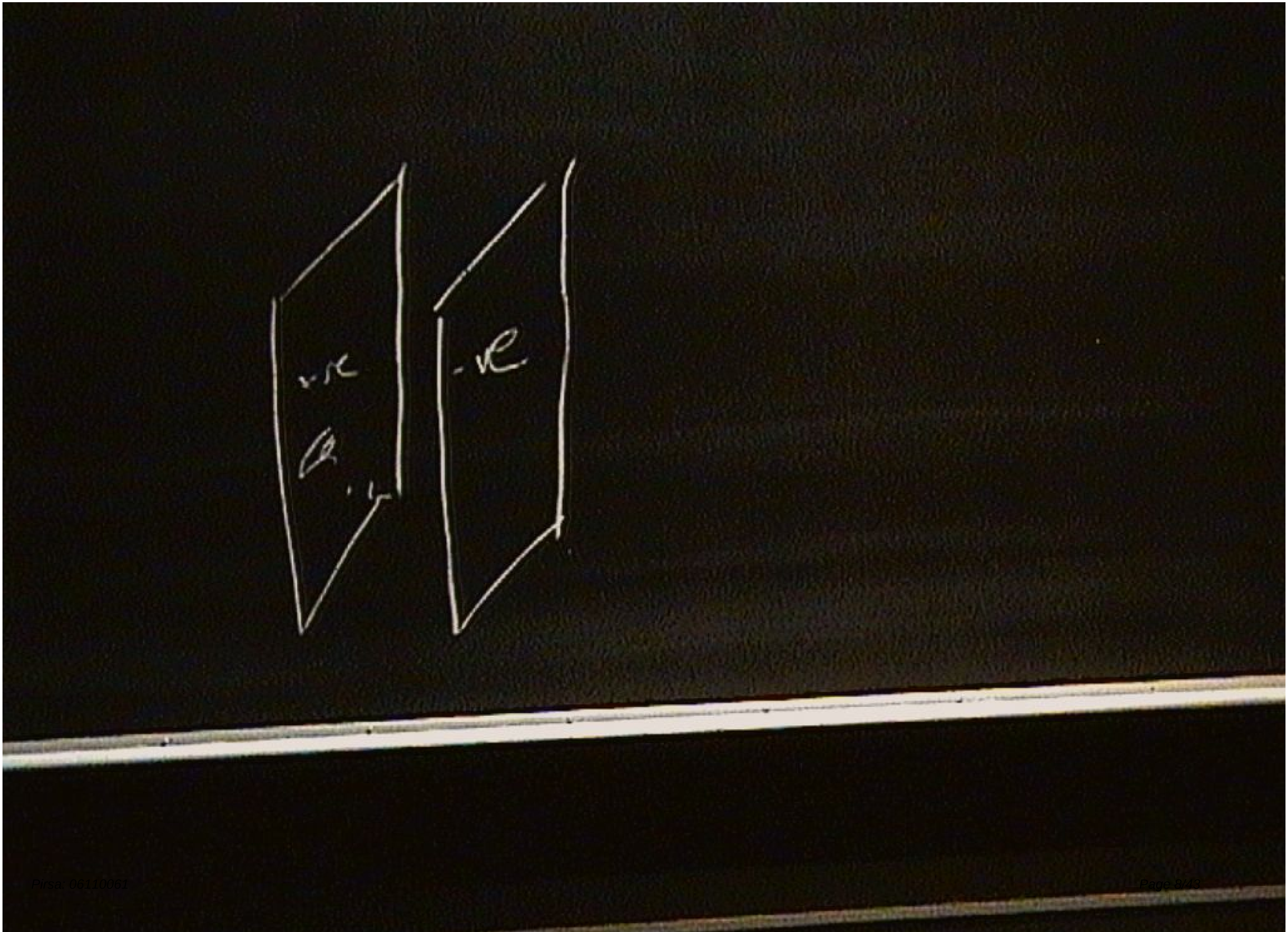
THE POTENTIAL



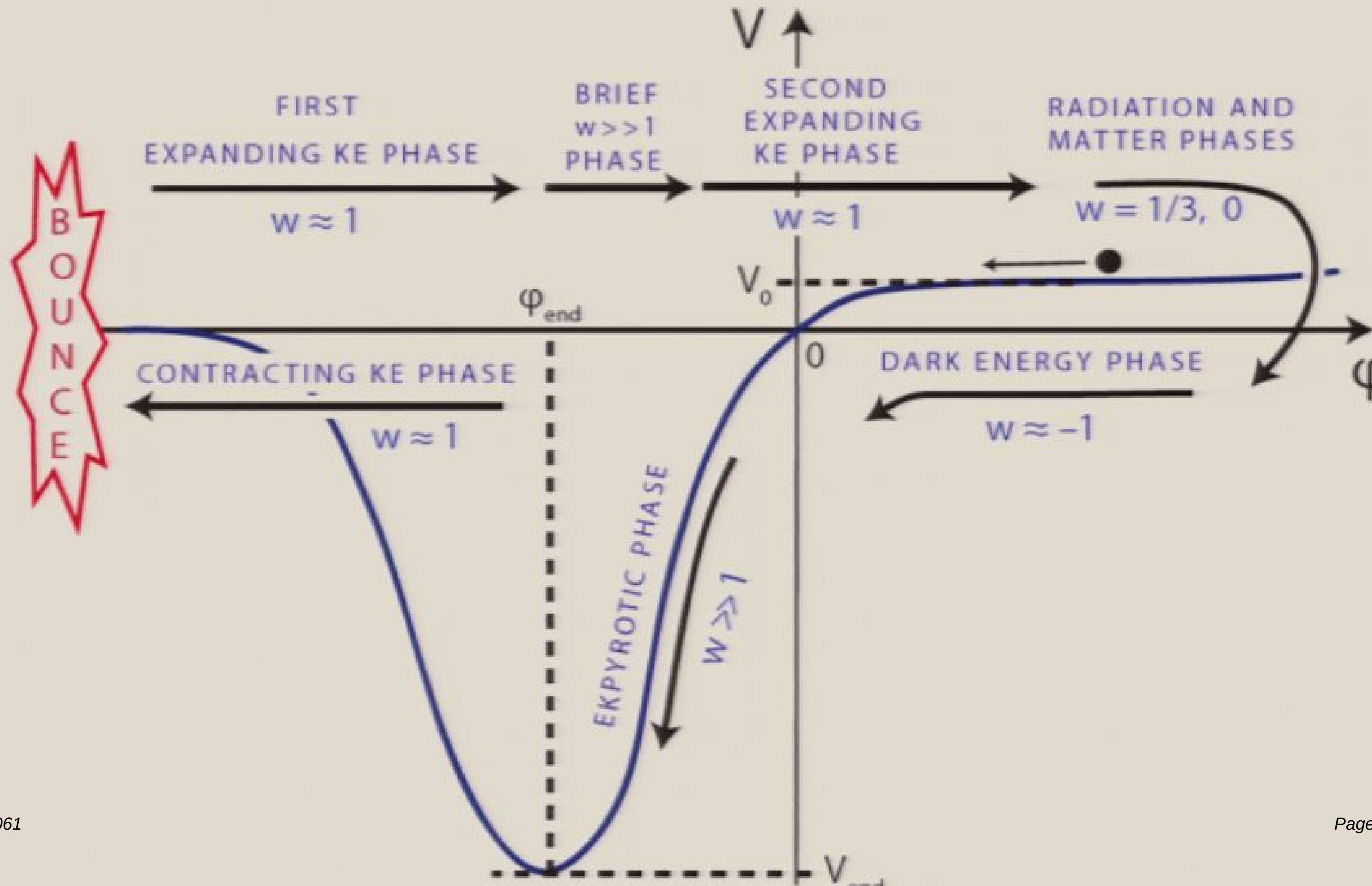
THE POTENTIAL

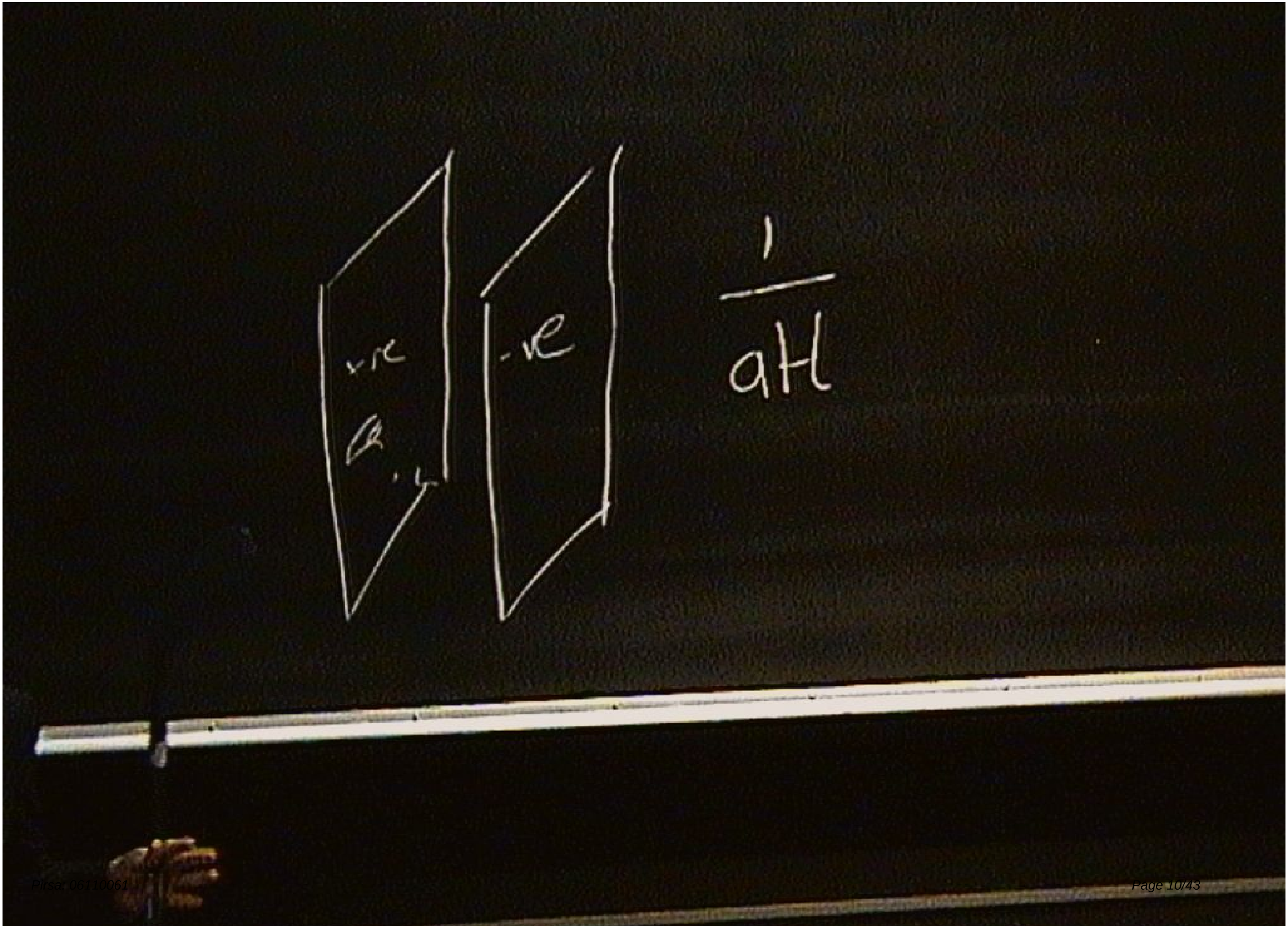




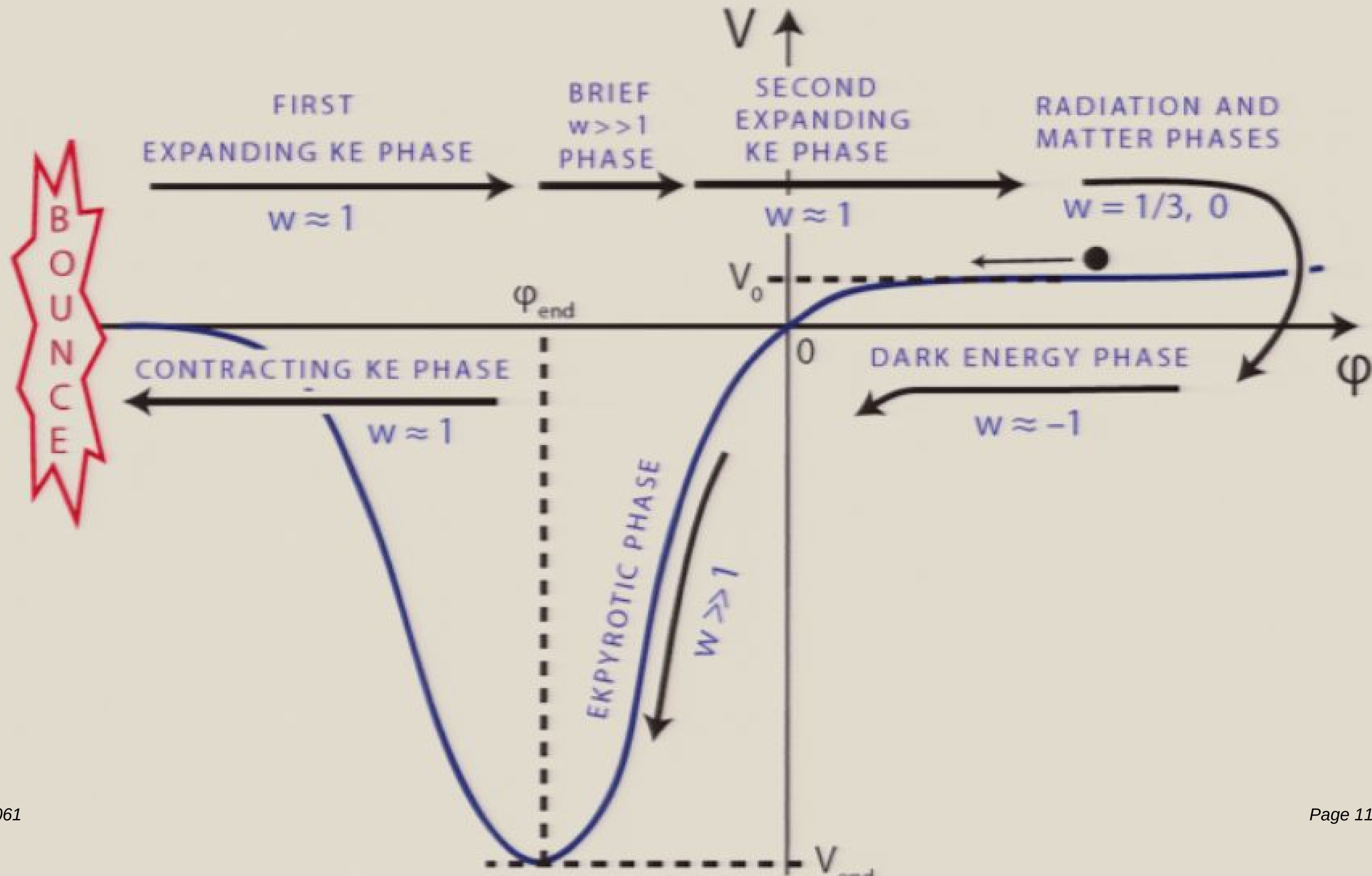

+ve
-ve

THE POTENTIAL




+ve
-ve
1
aH

THE POTENTIAL



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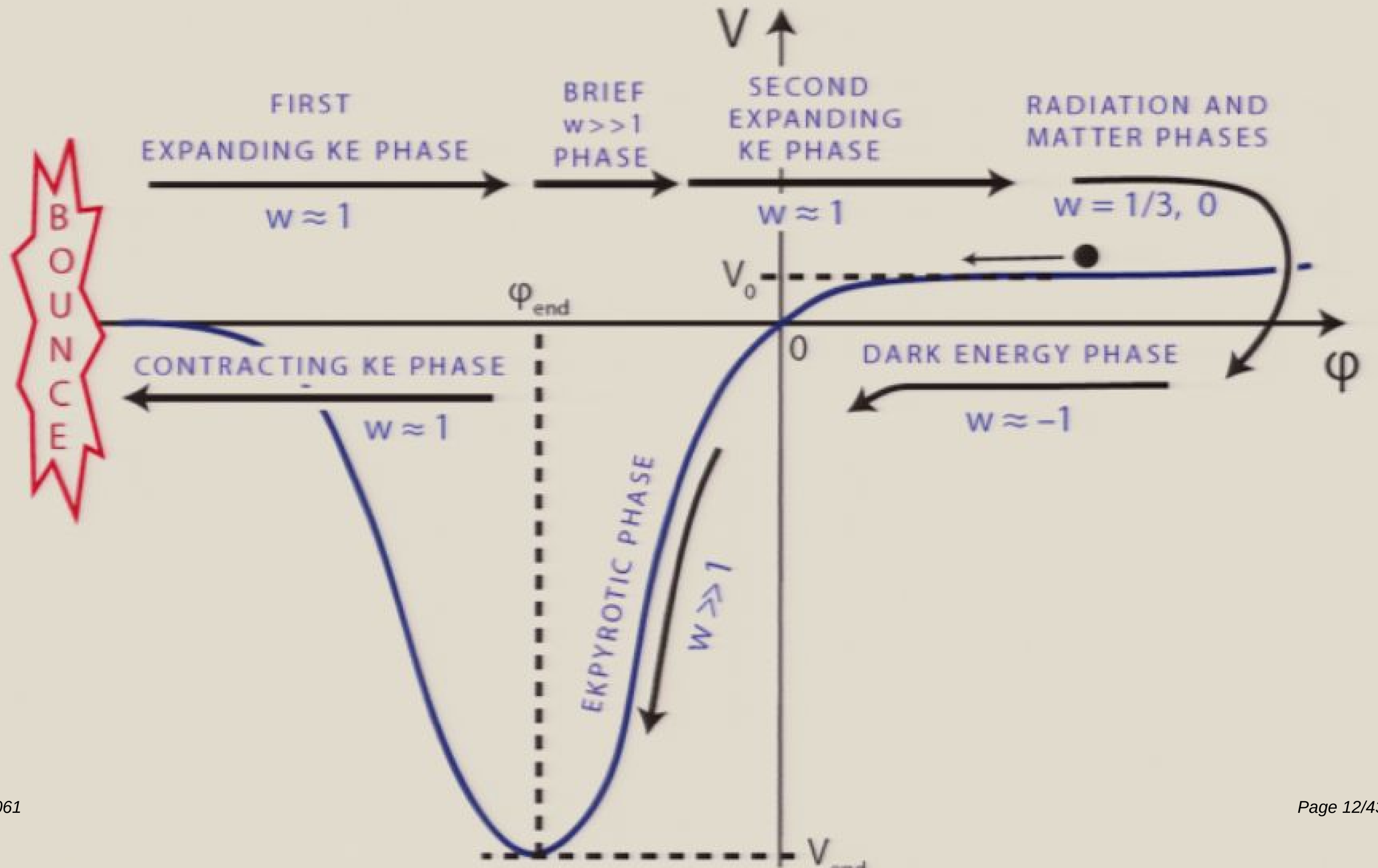
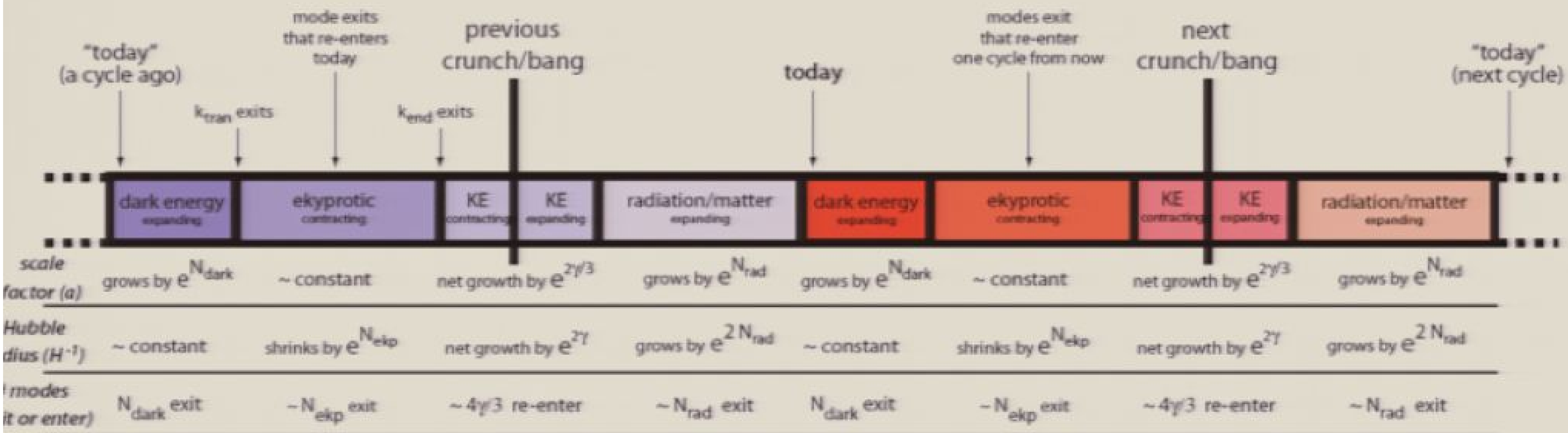


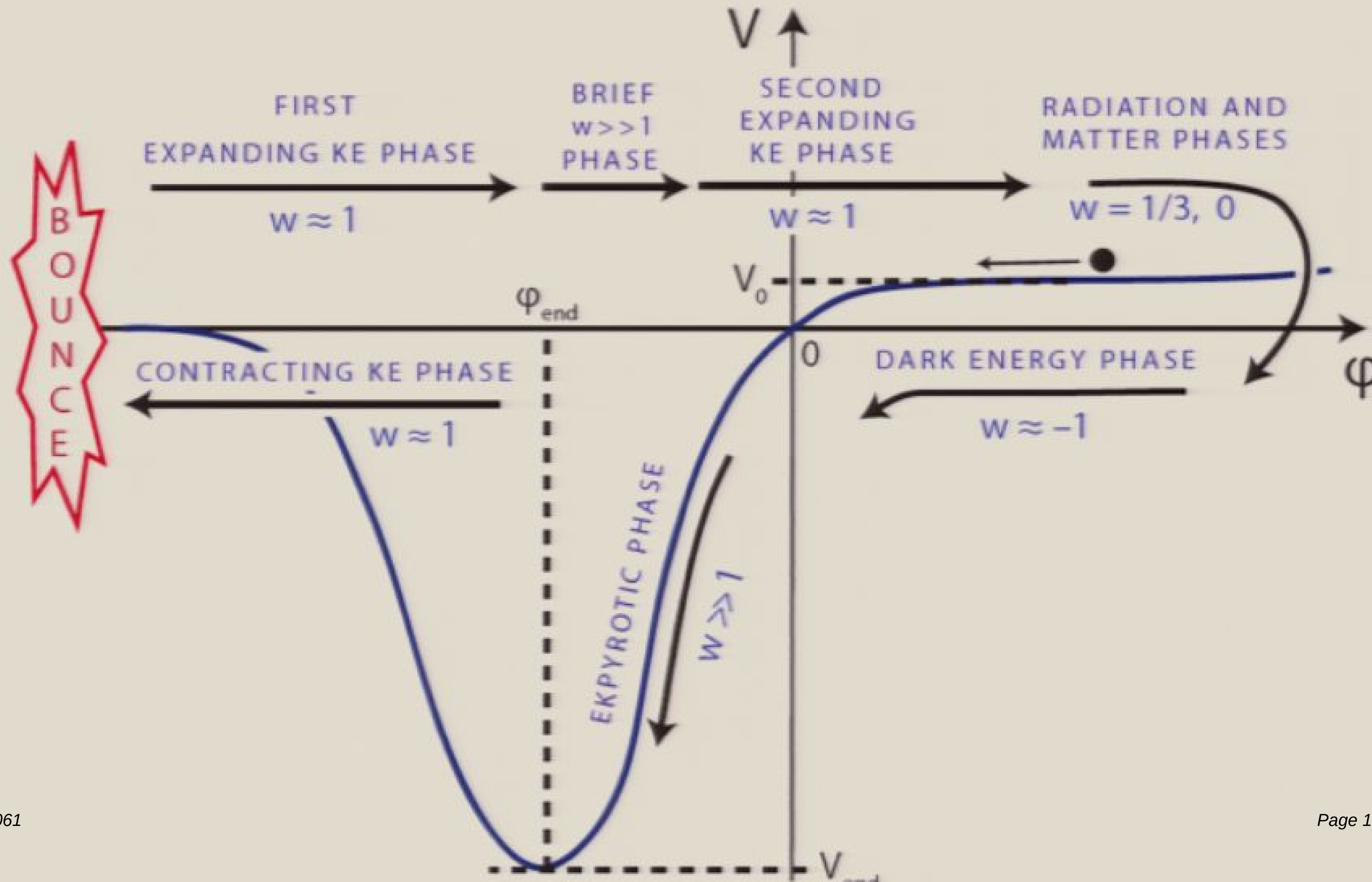
SCALES I



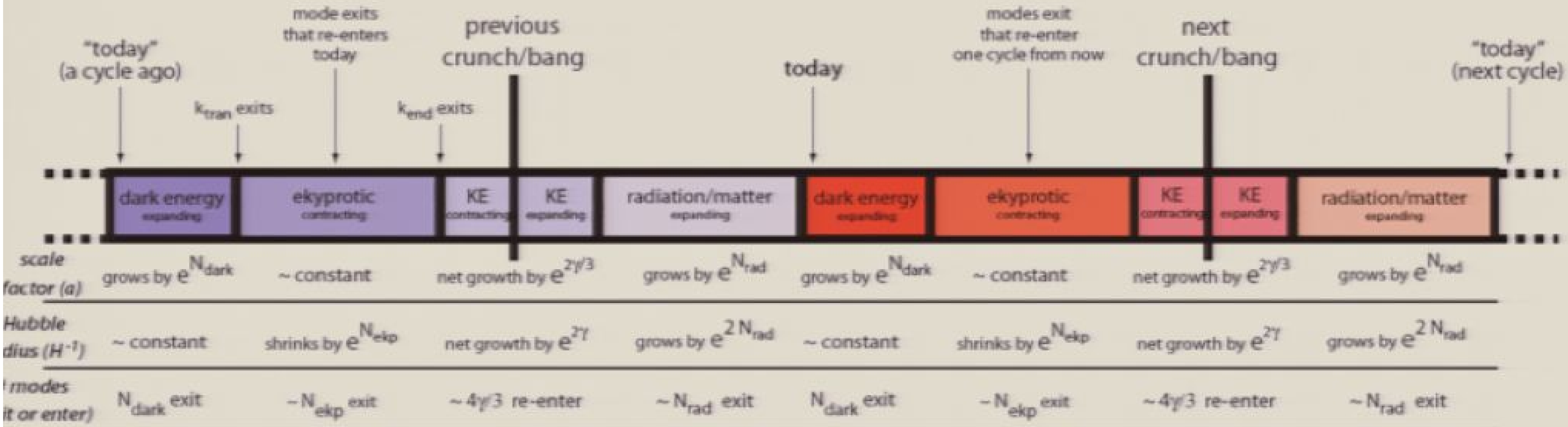
$$\gamma = \log \frac{(-V_{\rm end})^{1/4}}{T_{\rm reheat}}, \quad N_{\rm ekp} = \log \sqrt{\frac{-V_{\rm end}}{V_0}}, \quad N_{\rm rad} = \log \frac{T_{\rm rh}}{T_0}$$

$$N_{\rm ekp} = 2(\gamma + N_{\rm rad})$$

THE POTENTIAL



SCALES I



$$\gamma = \log \frac{(-V_{\rm end})^{1/4}}{T_{\rm reheat}}, \quad N_{\rm ekp} = \log \sqrt{\frac{-V_{\rm end}}{V_0}}, \quad N_{\rm rad} = \log \frac{T_{\rm rh}}{T_0}$$

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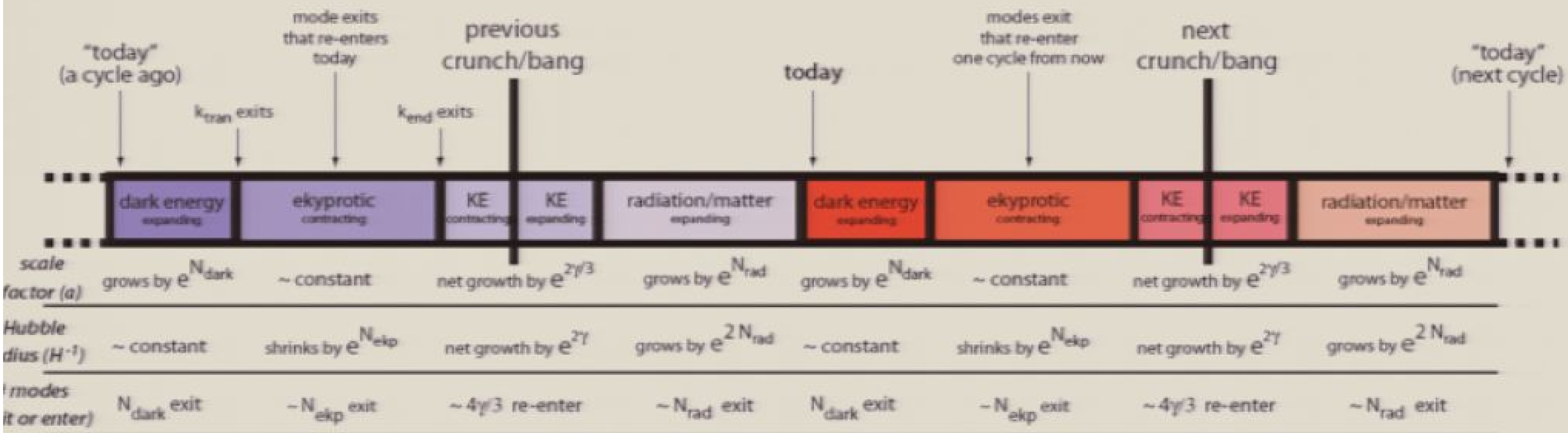
SCALES I



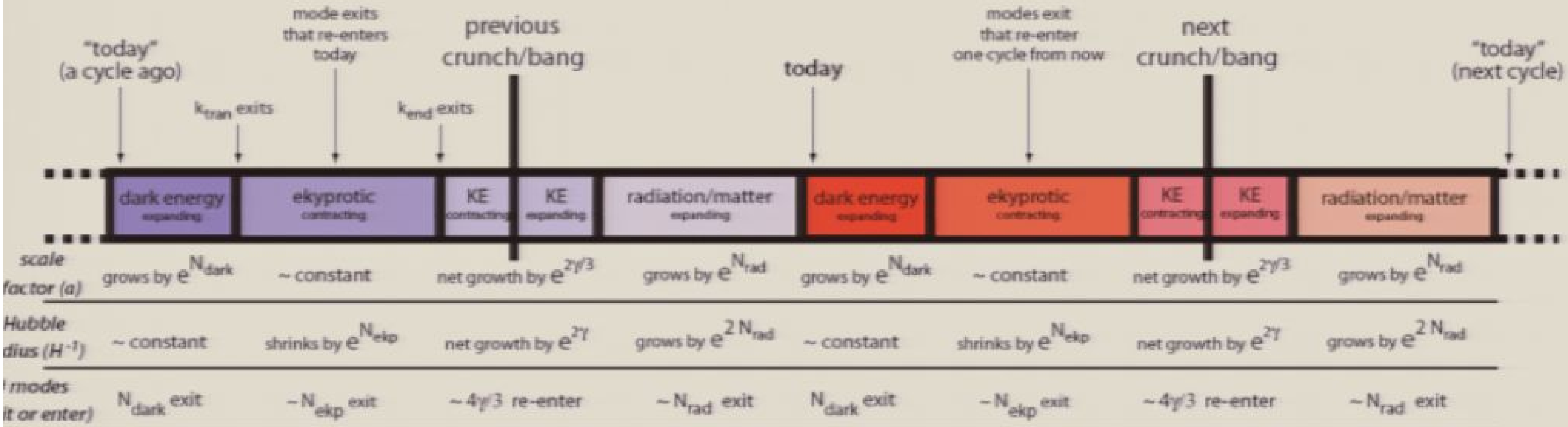
$$\gamma = \log \frac{(-V_{\rm end})^{1/4}}{T_{\rm reheat}}, \quad N_{\rm ekp} = \log \sqrt{\frac{-V_{\rm end}}{V_0}}, \quad N_{\rm rad} = \log \frac{T_{\rm rh}}{T_0}$$

$$N_{\rm ekp} = 2(\gamma + N_{\rm rad})$$

$H \sim \sqrt{V}$

$a \sim \text{const}$

SCALES I



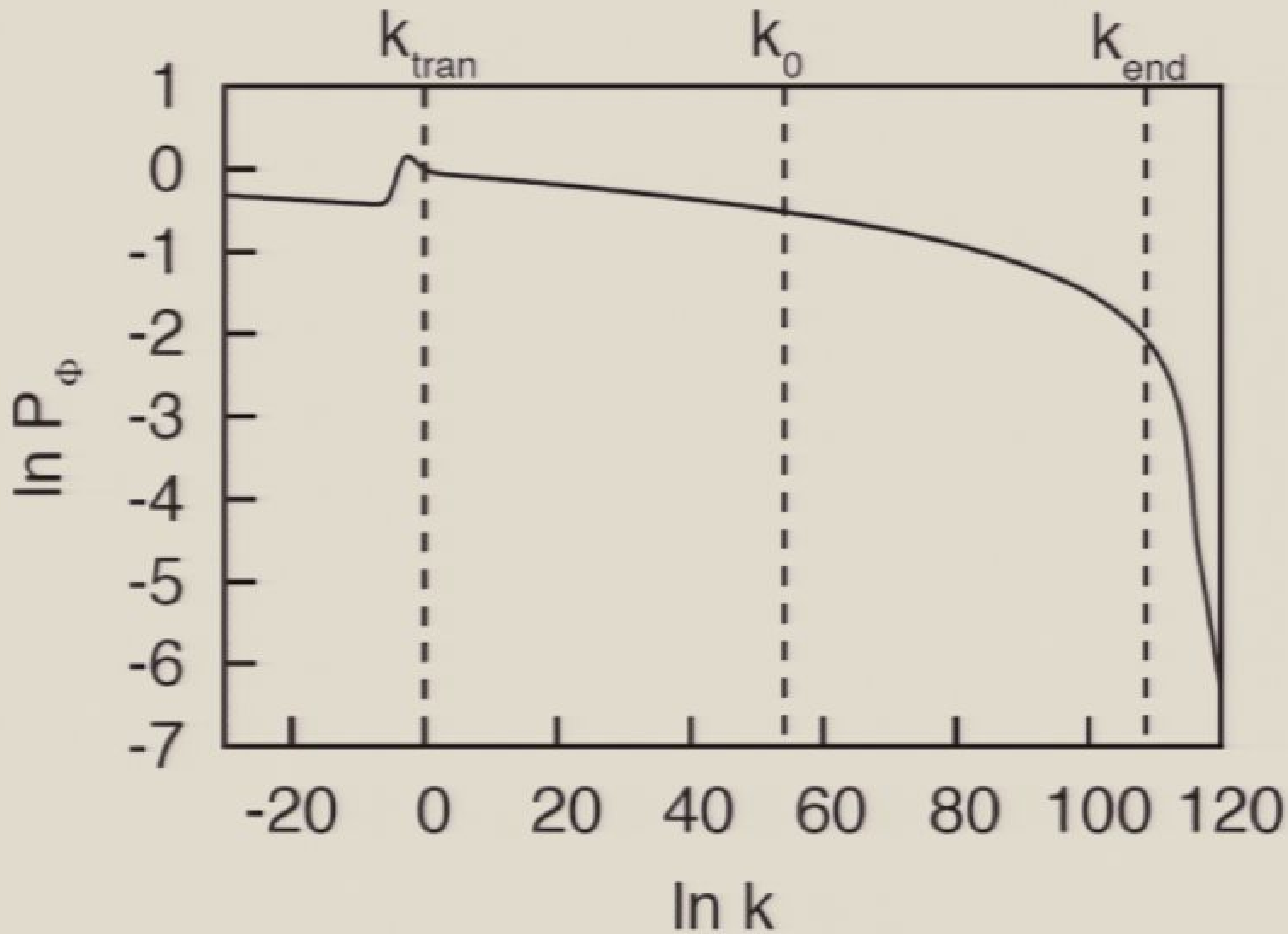
$$\gamma = \log \frac{(-V_{\rm end})^{1/4}}{T_{\rm reheat}}, \quad N_{\rm ekp} = \log \sqrt{\frac{-V_{\rm end}}{V_0}}, \quad N_{\rm rad} = \log \frac{T_{\rm rh}}{T_0}$$

$$N_{\rm ekp} = 2(\gamma + N_{\rm rad})$$

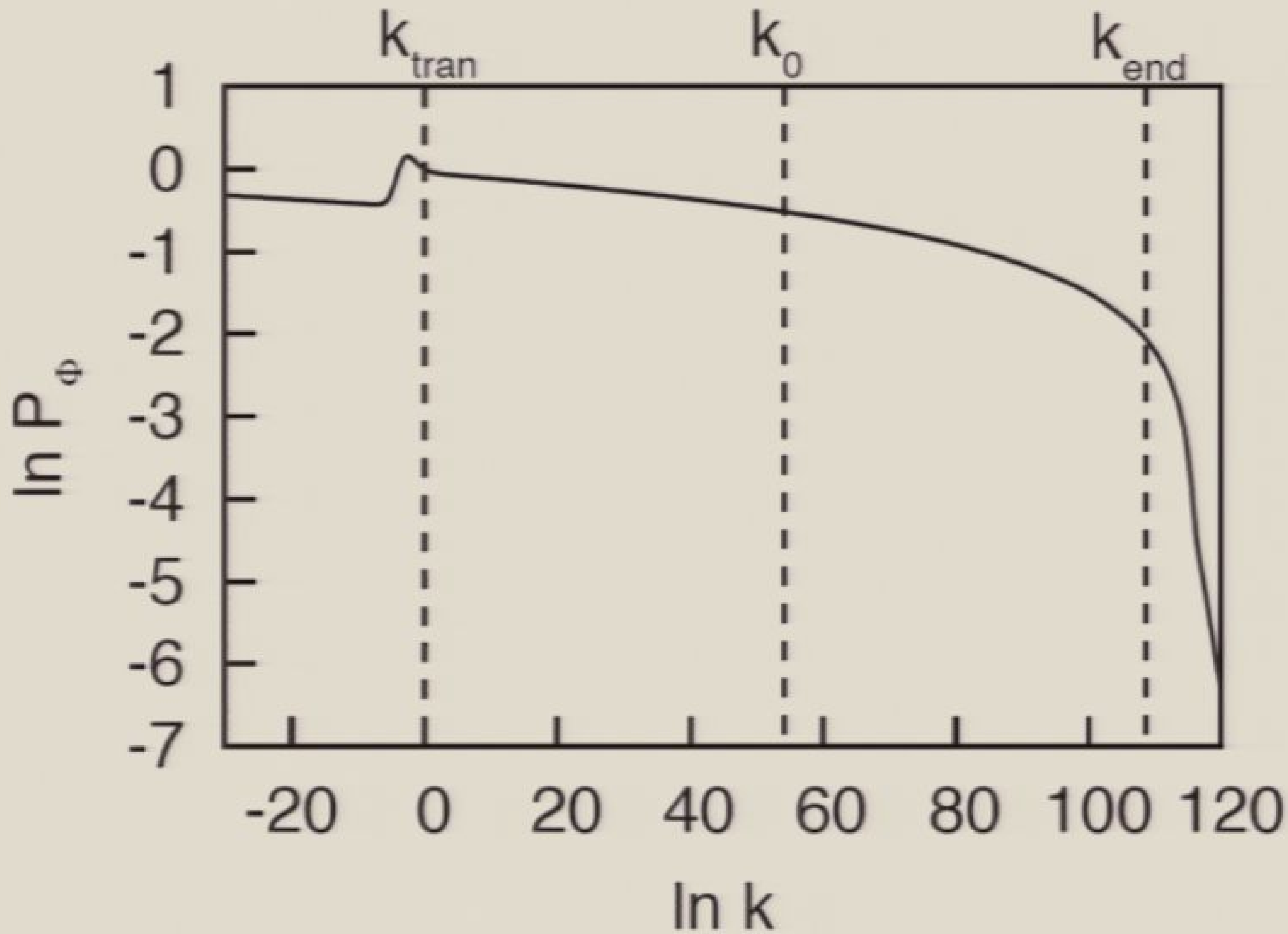
SCALES II

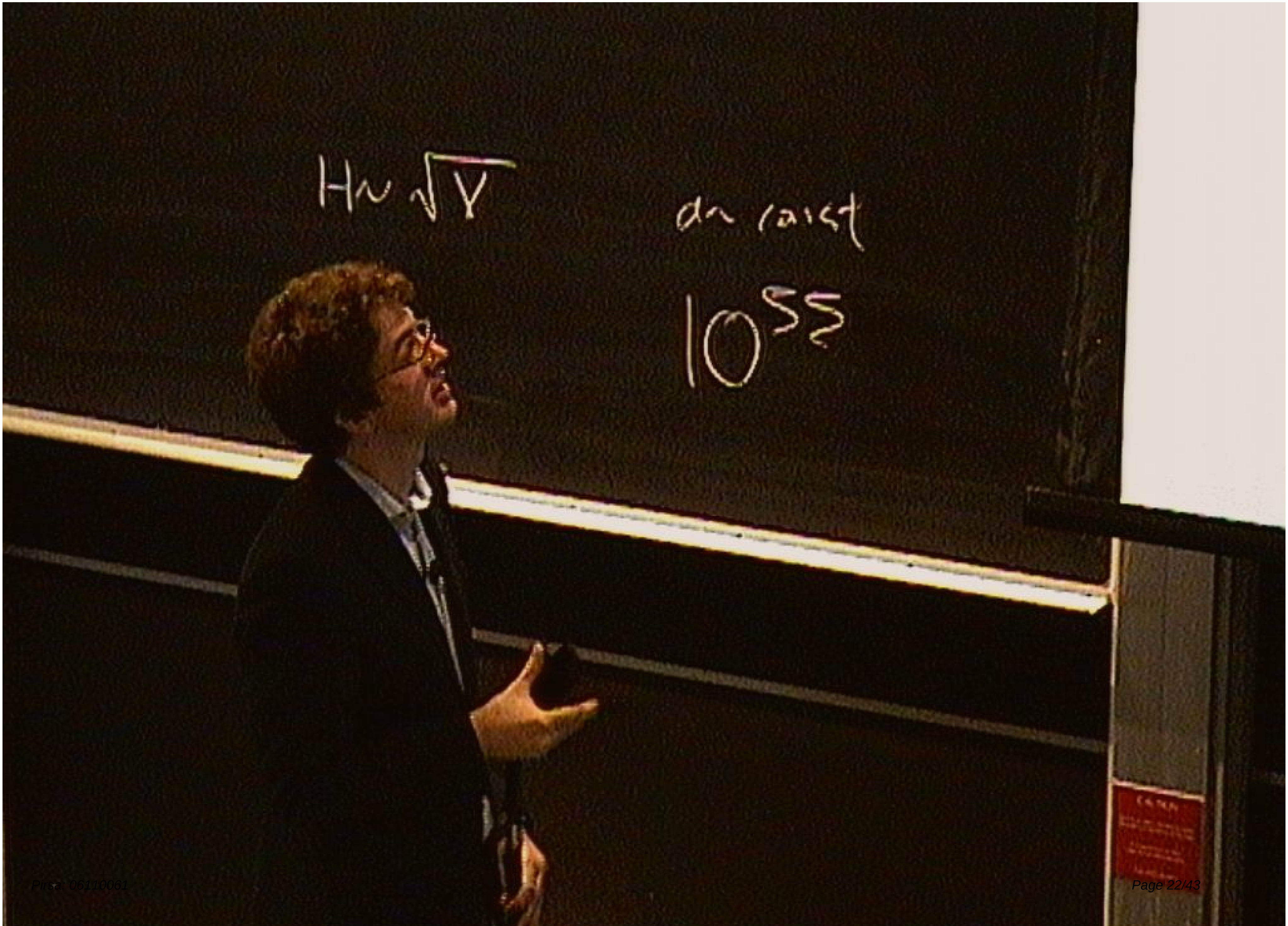
Length scale	Size relative to today's horizon
Today's horizon	1
Current wavelength of the modes that:	
…were on the horizon one cycle ago	$e^{N_{\rm dark}+2\gamma/3+N_{\rm rad}}$
…will be on the horizon one cycle from now	$e^{-N_{\rm dark}-2\gamma/3-N_{\rm rad}}$
…were the first ones to go ultralocal during the ekpyrotic phase one cycle ago	$e^{2\gamma/3+N_{\rm rad}}$
…were the last ones to go ultralocal during the ekpyrotic phase one cycle ago	$e^{-N_{\rm ekp}+2\gamma/3+N_{\rm rad}}$
…will be the first ones to go ultralocal during the coming ekpyrotic phase of this cycle	$e^{-N_{\rm dark}}$
…will be the last ones to go ultralocal during the coming ekpyrotic phase of this cycle	$e^{-N_{\rm dark}-N_{\rm ekp}}$

POWER SPECTRUM

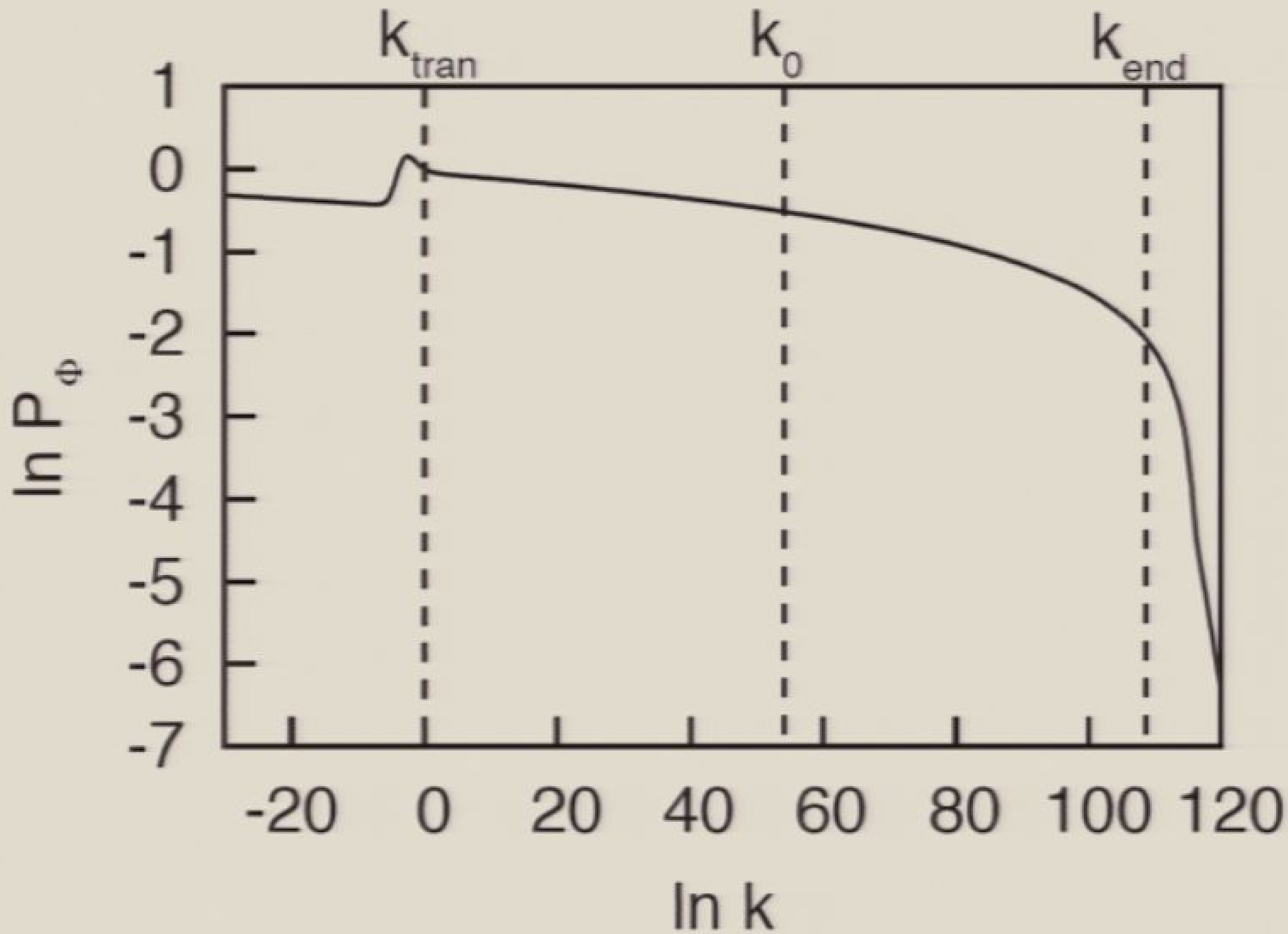


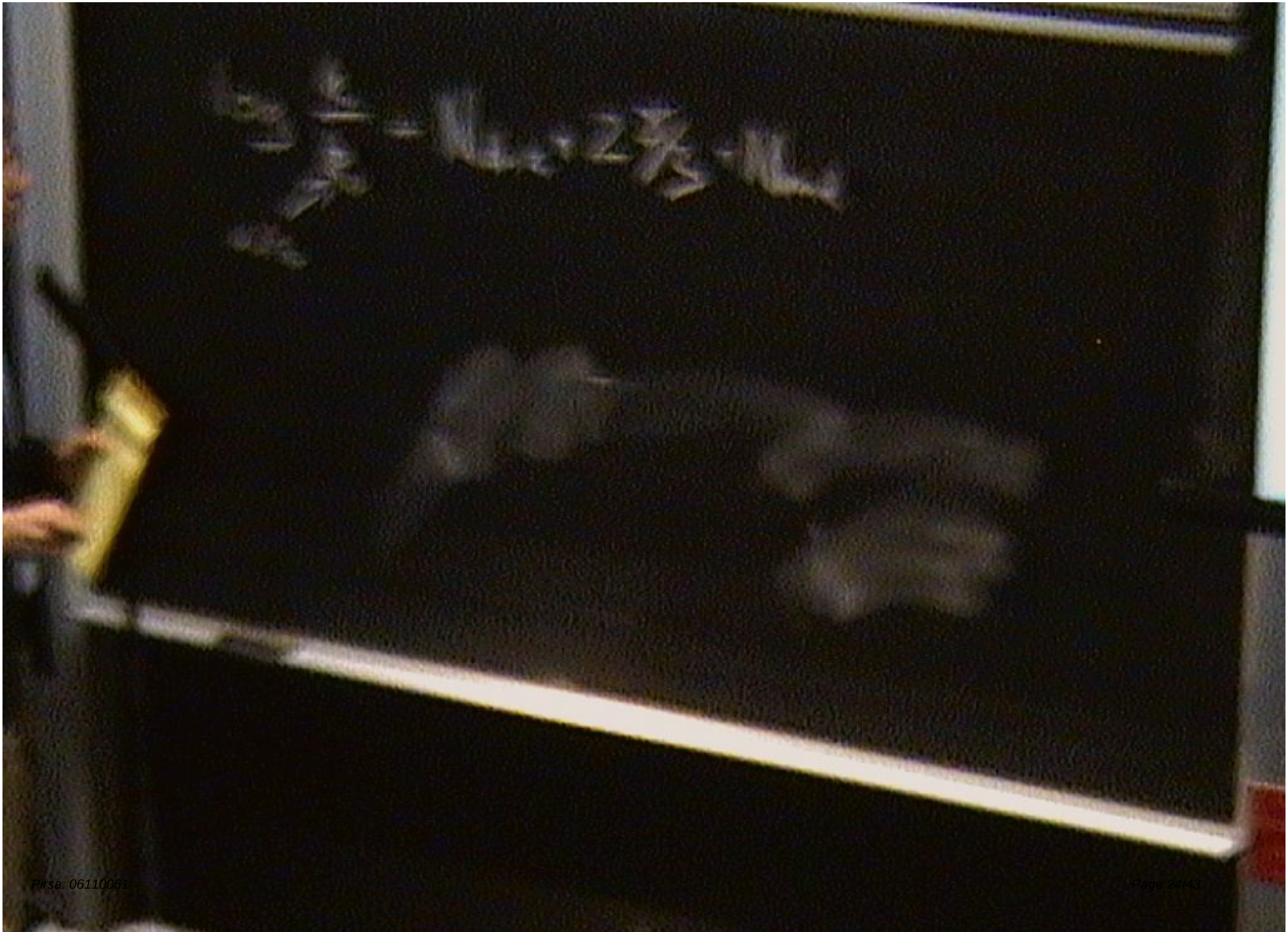
POWER SPECTRUM

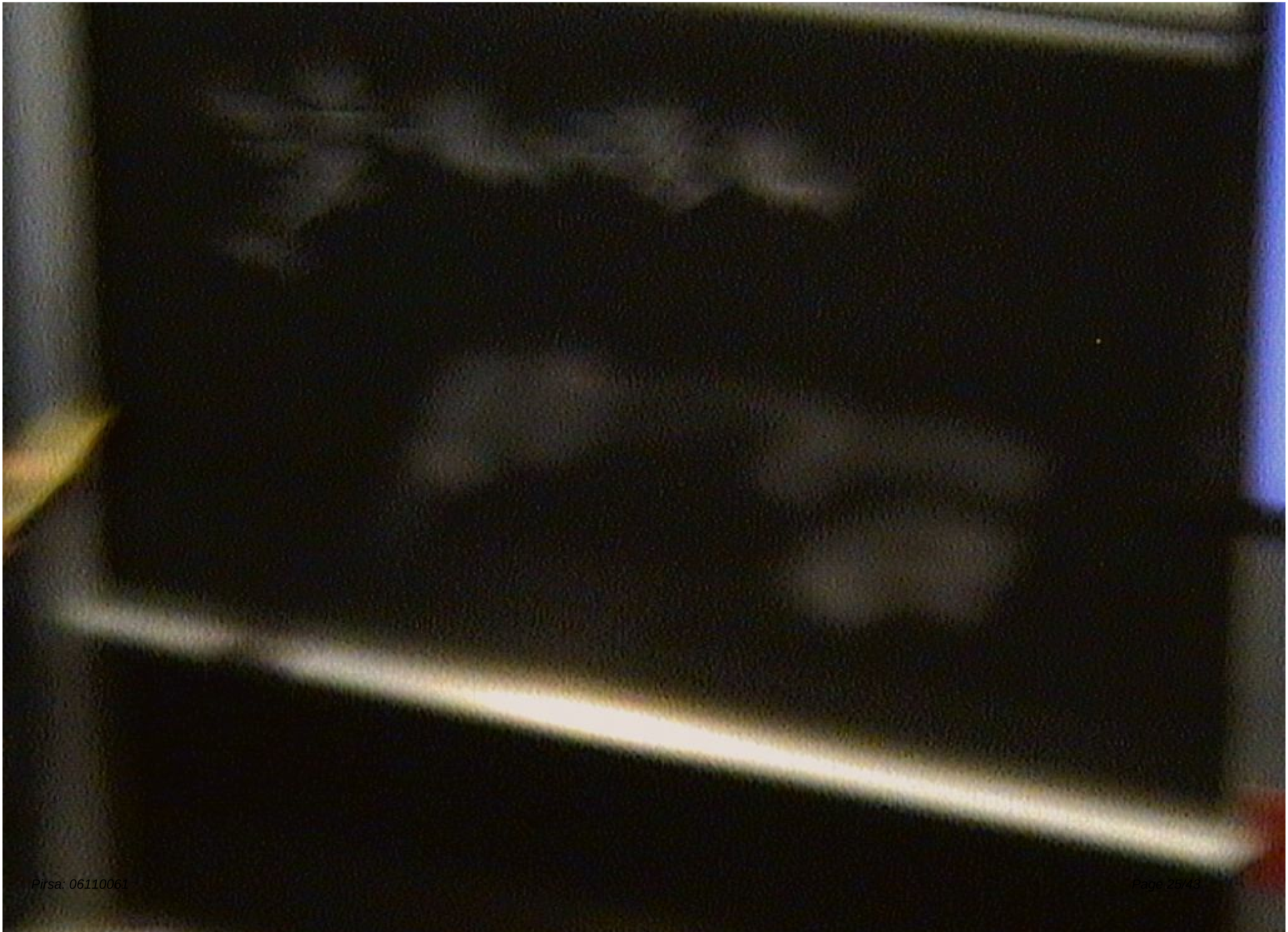


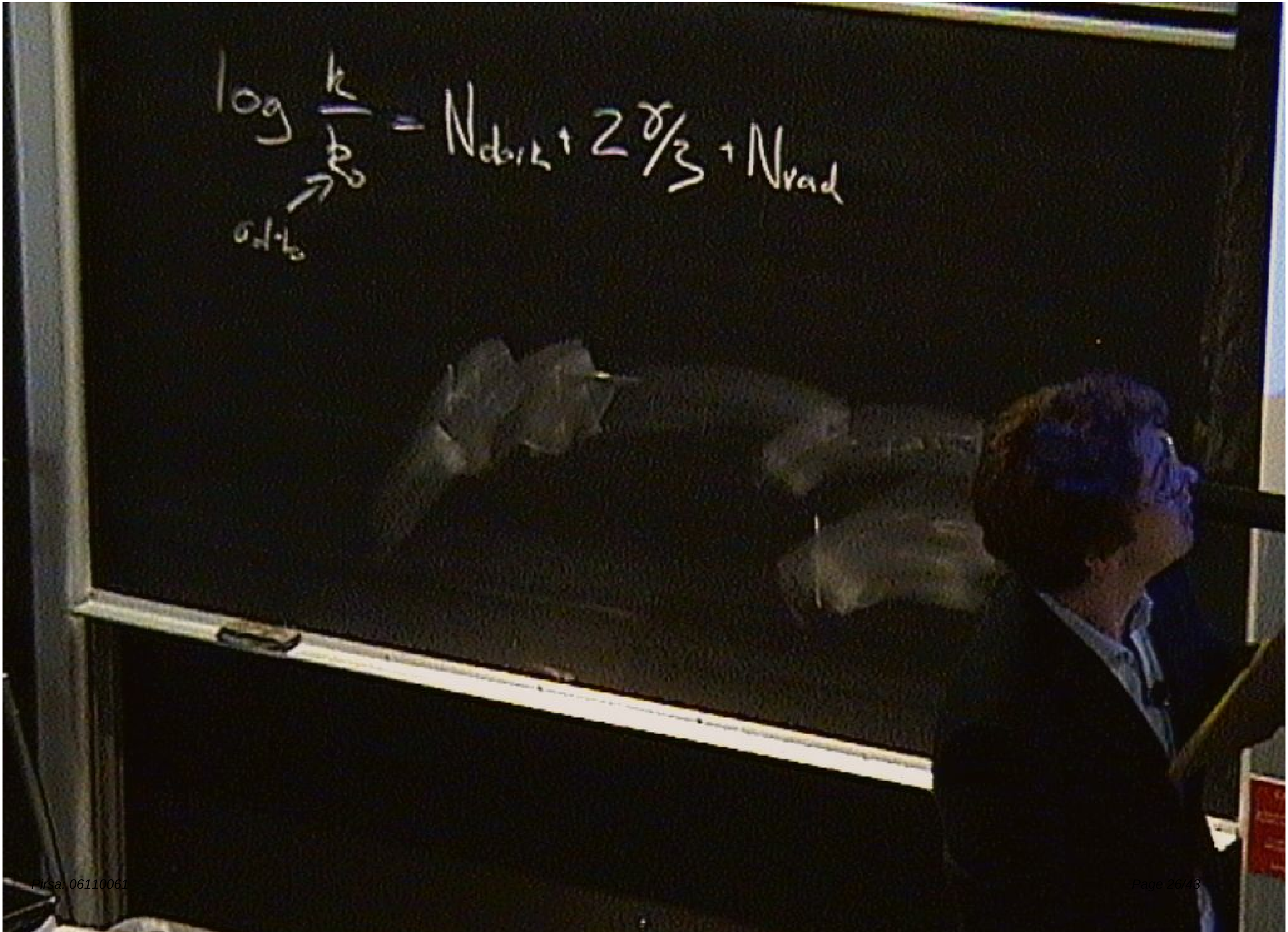

H ~ √Y
10^55

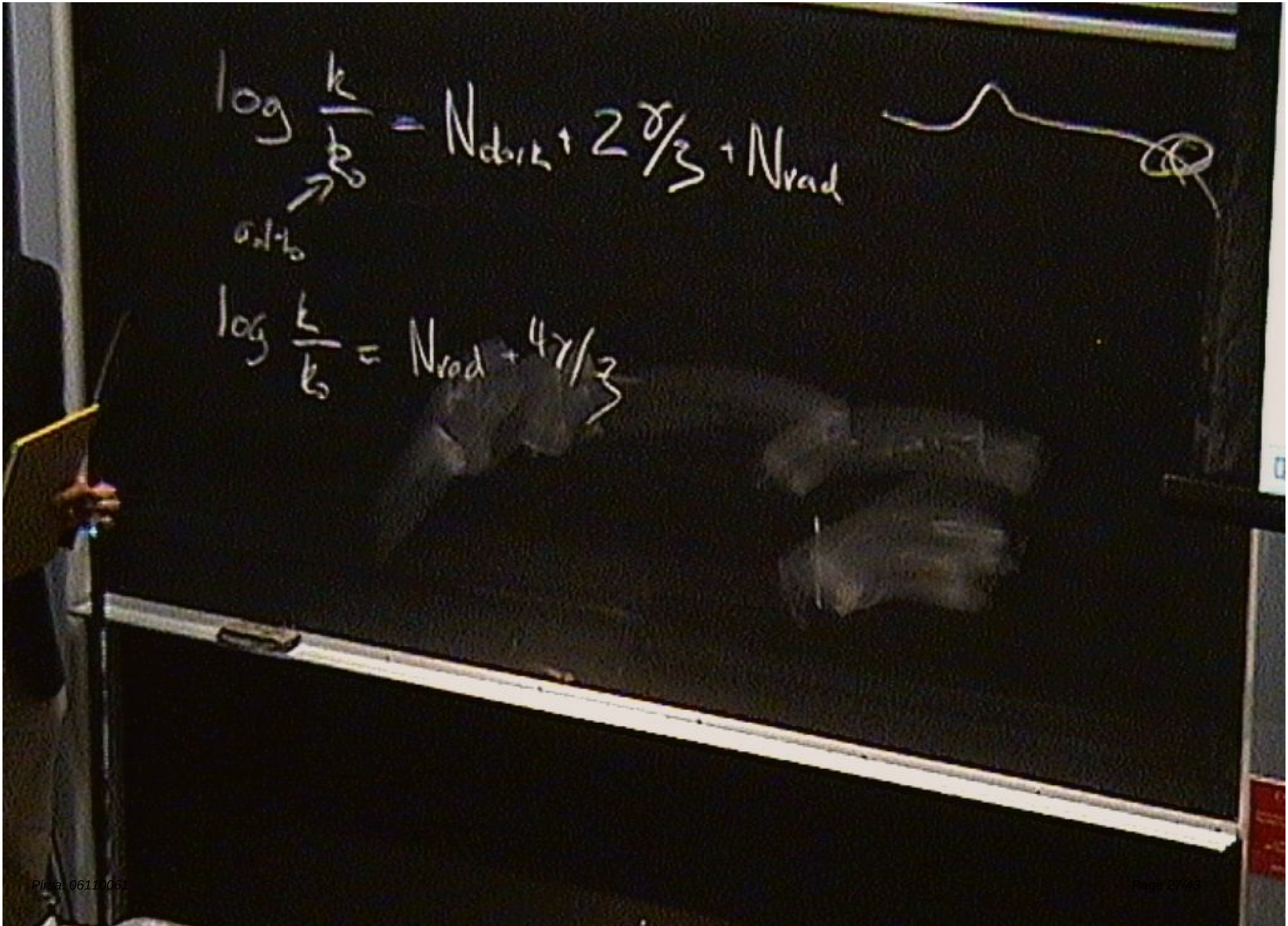
POWER SPECTRUM

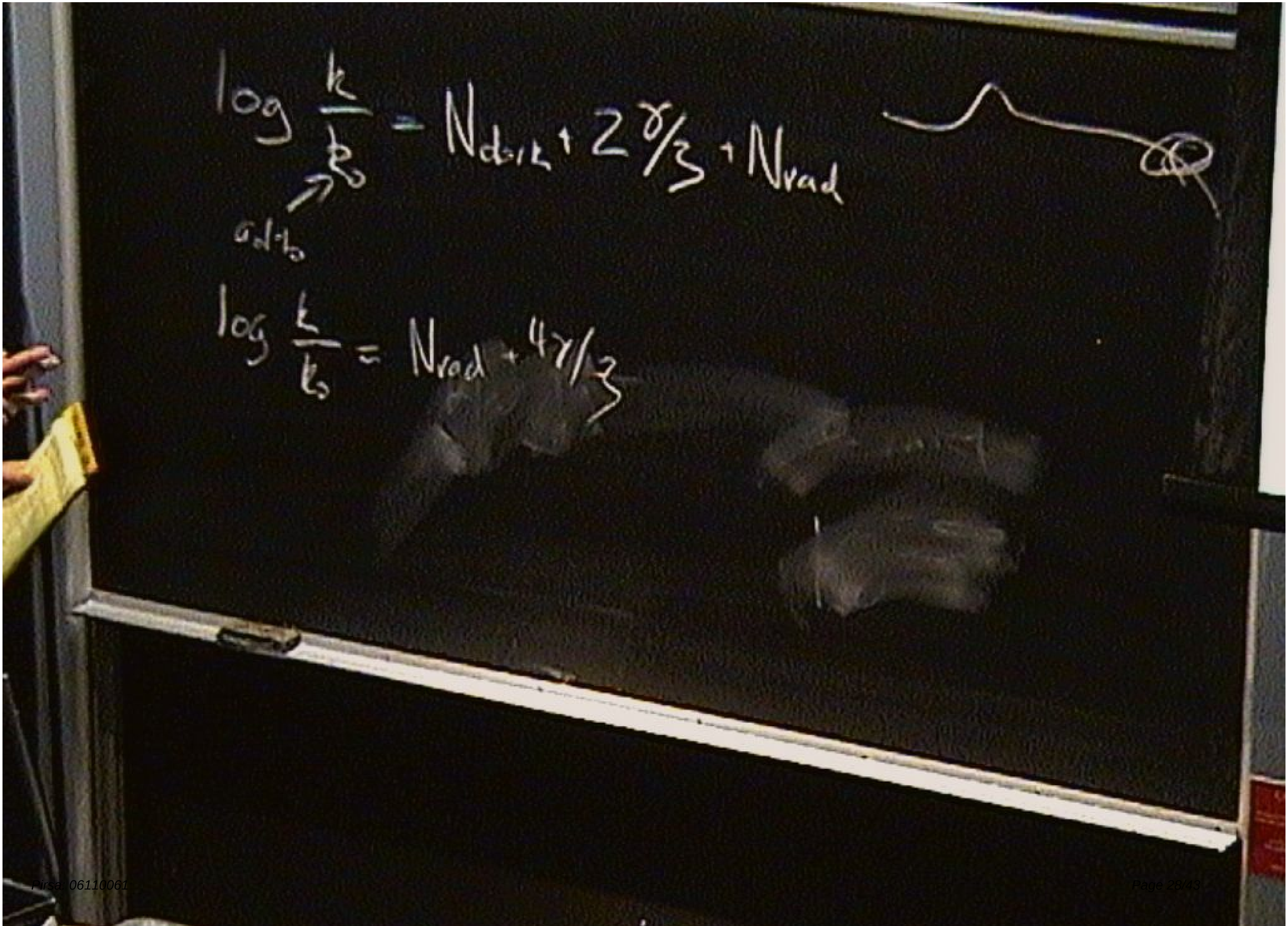




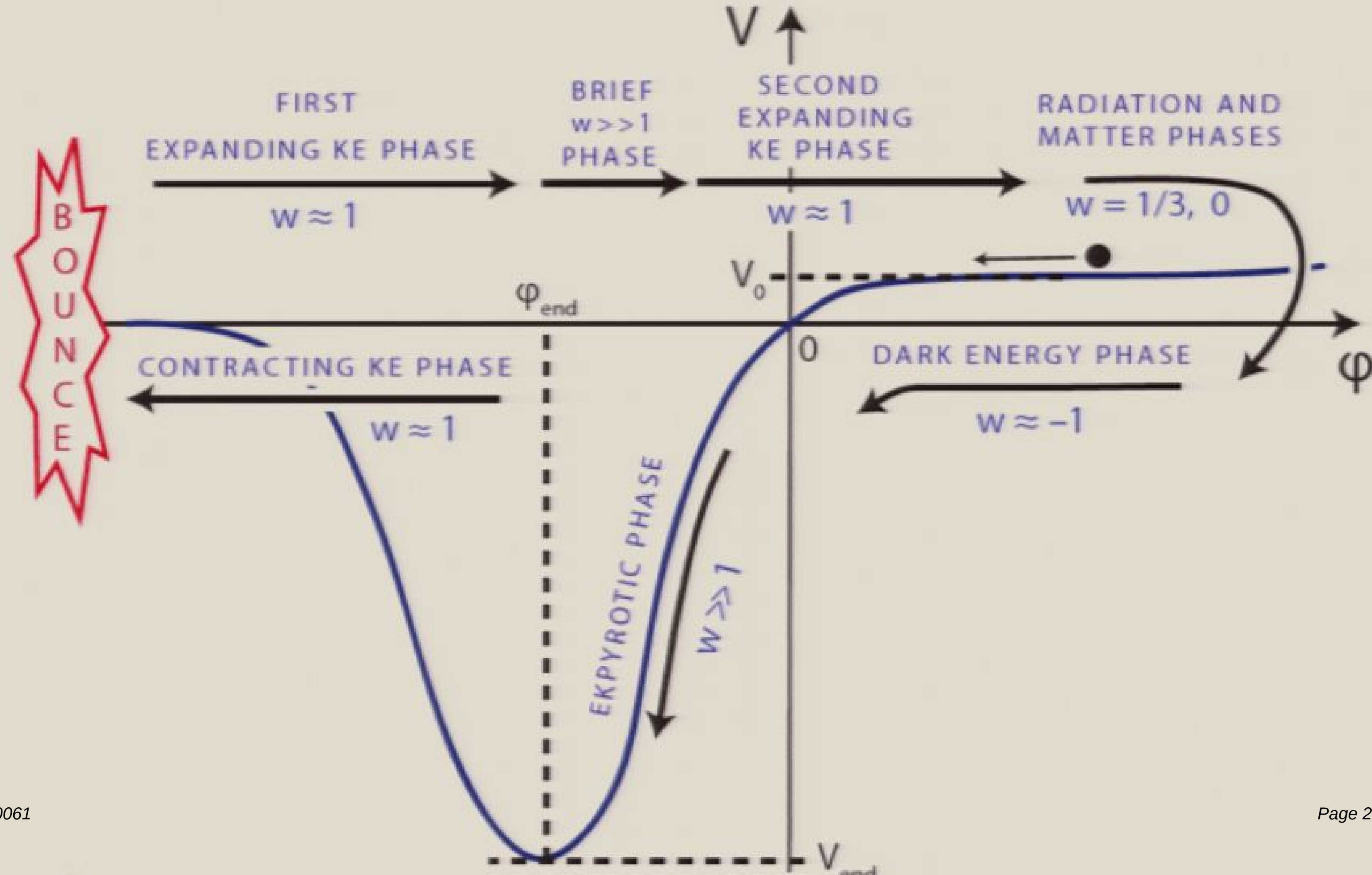


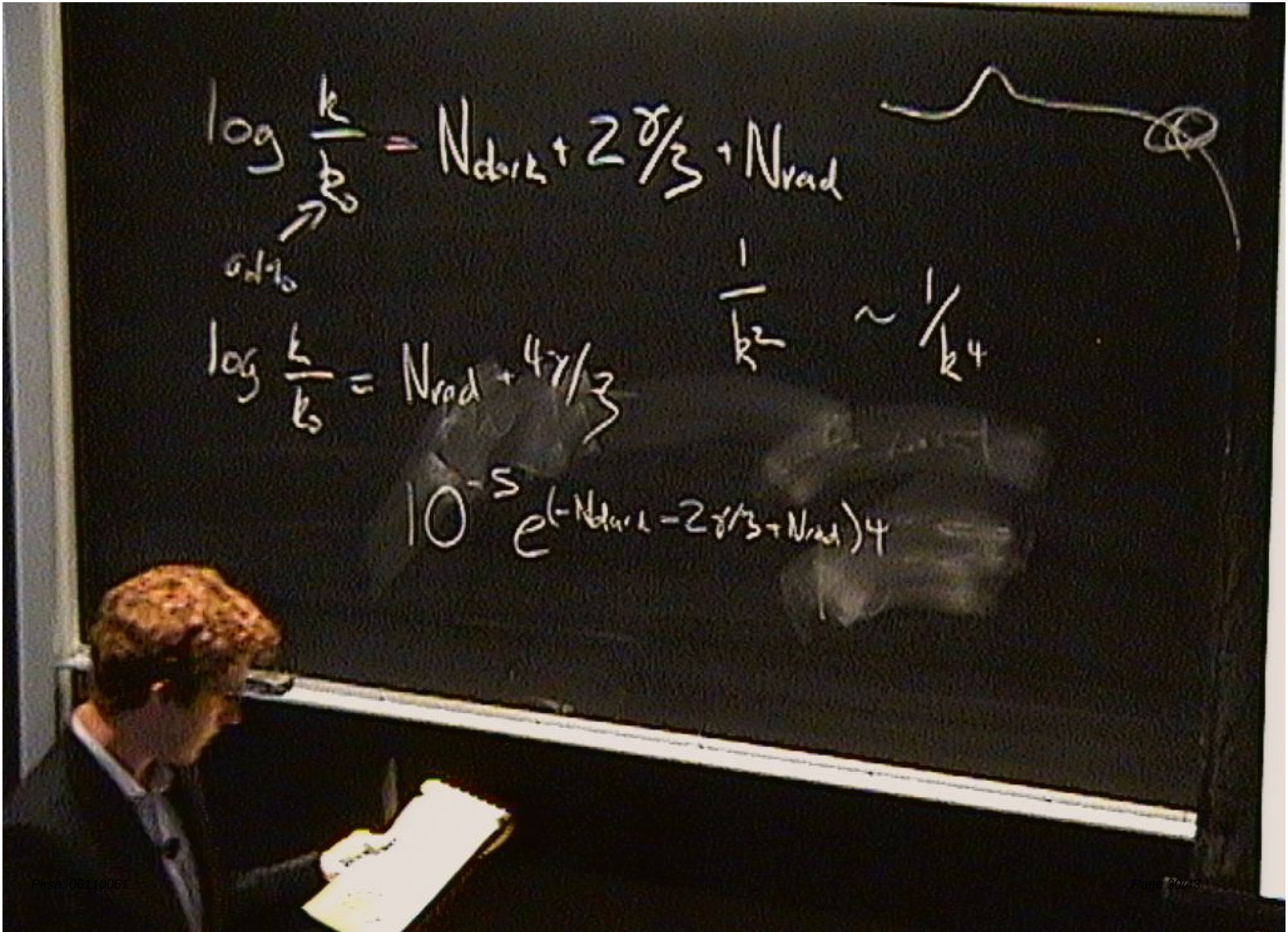

log k/k0 = Ndark + 2γ/3 + Nrad


$\log \frac{k}{k_0} = N_{dark} + 2\gamma/3 + N_{rad}$
$\log \frac{k}{k_0} = N_{rad} + 4\gamma/3$


log k/k0 = Ndark + 2γ/3 + Nrad
adiab
log k/k0 = Nrad + 4γ/3

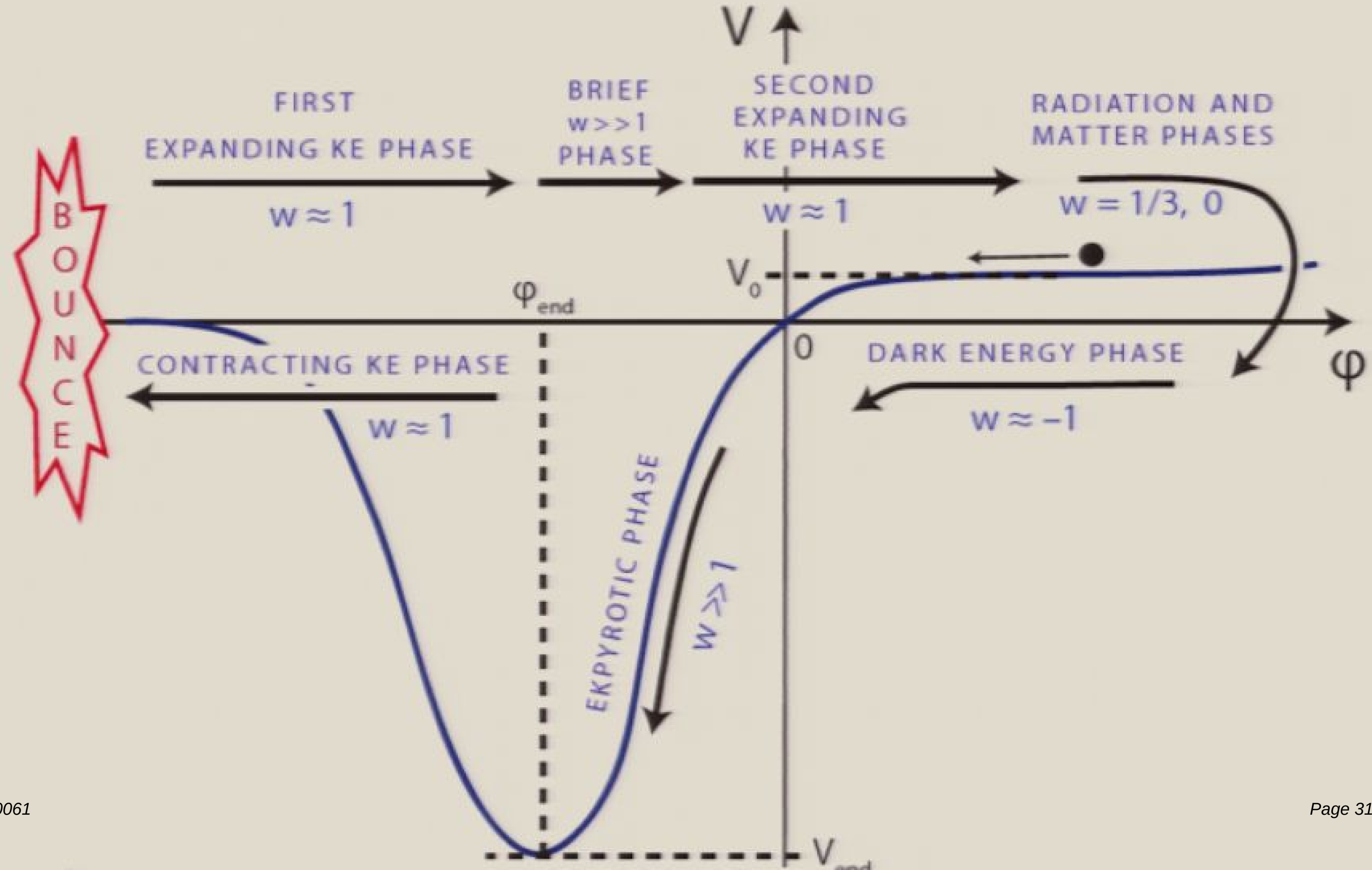
THE POTENTIAL

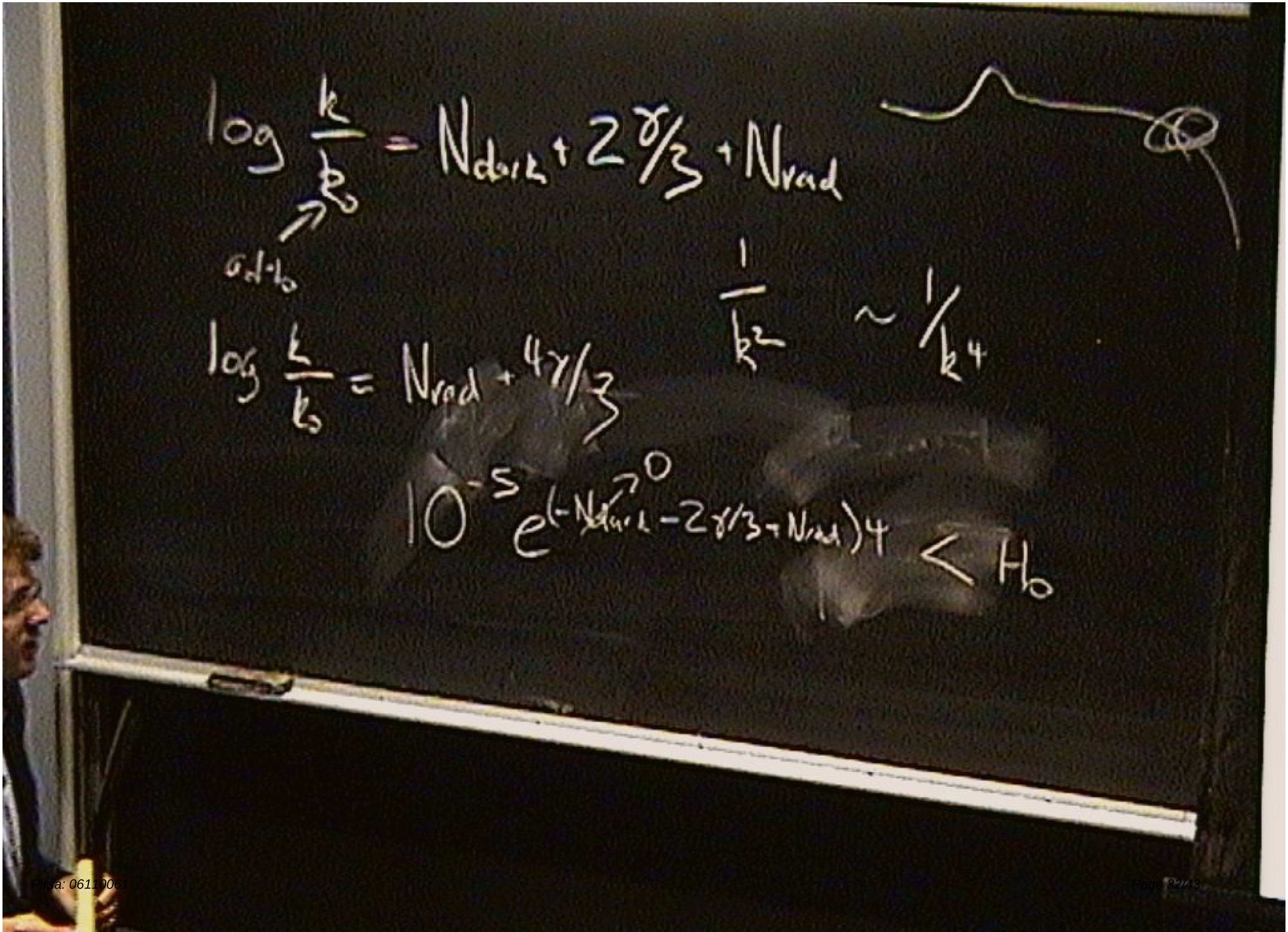




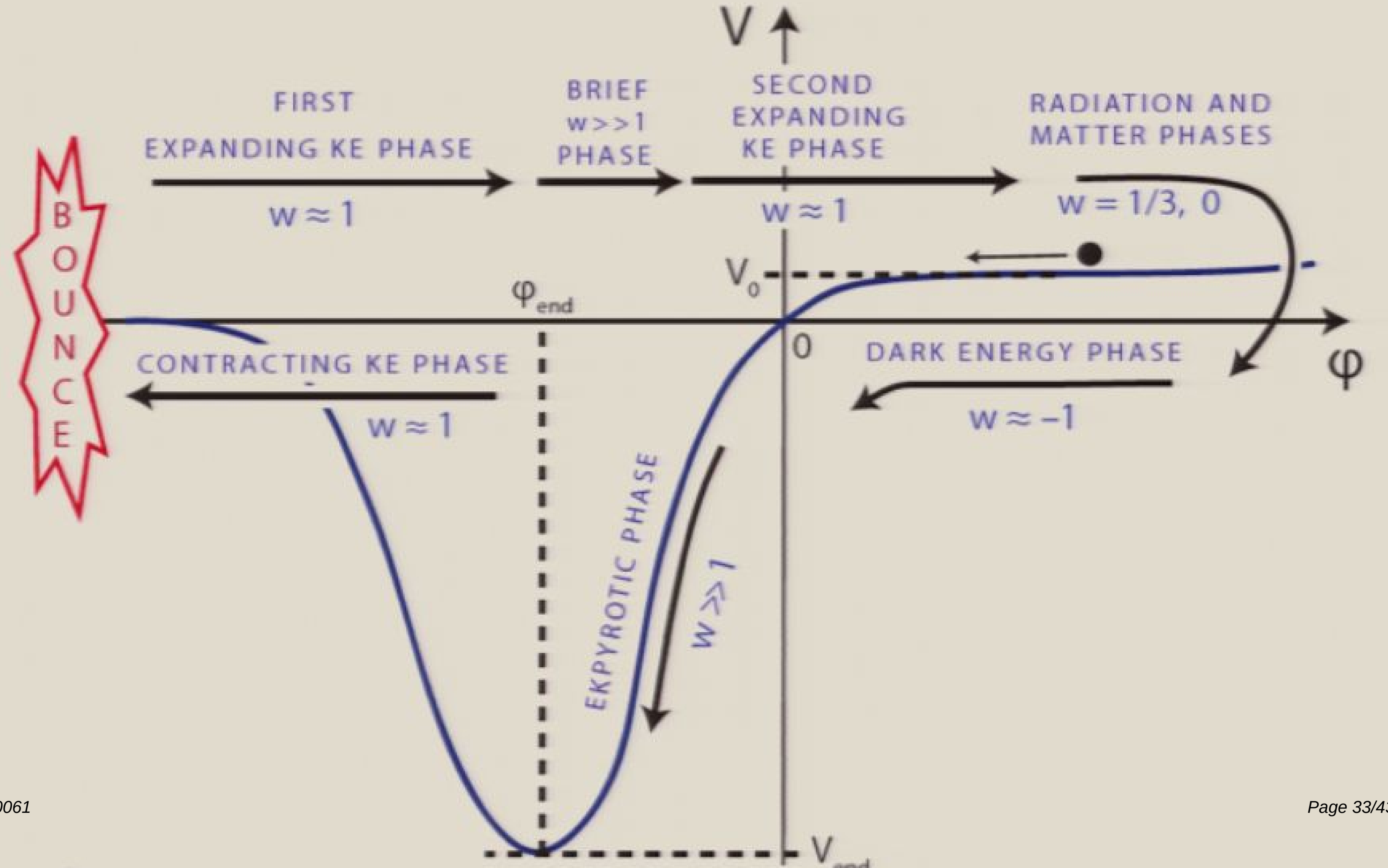
$\log \frac{k}{k_0} = N_{dark} + 2\gamma/3 + N_{rad}$
$\log \frac{k}{k_0} = N_{rad} + 4\gamma/3$
$\frac{1}{k^2} \sim 1/k^4$
$10^{-5} e^{(-N_{dark} - 2\gamma/3 + N_{rad})4}$

THE POTENTIAL

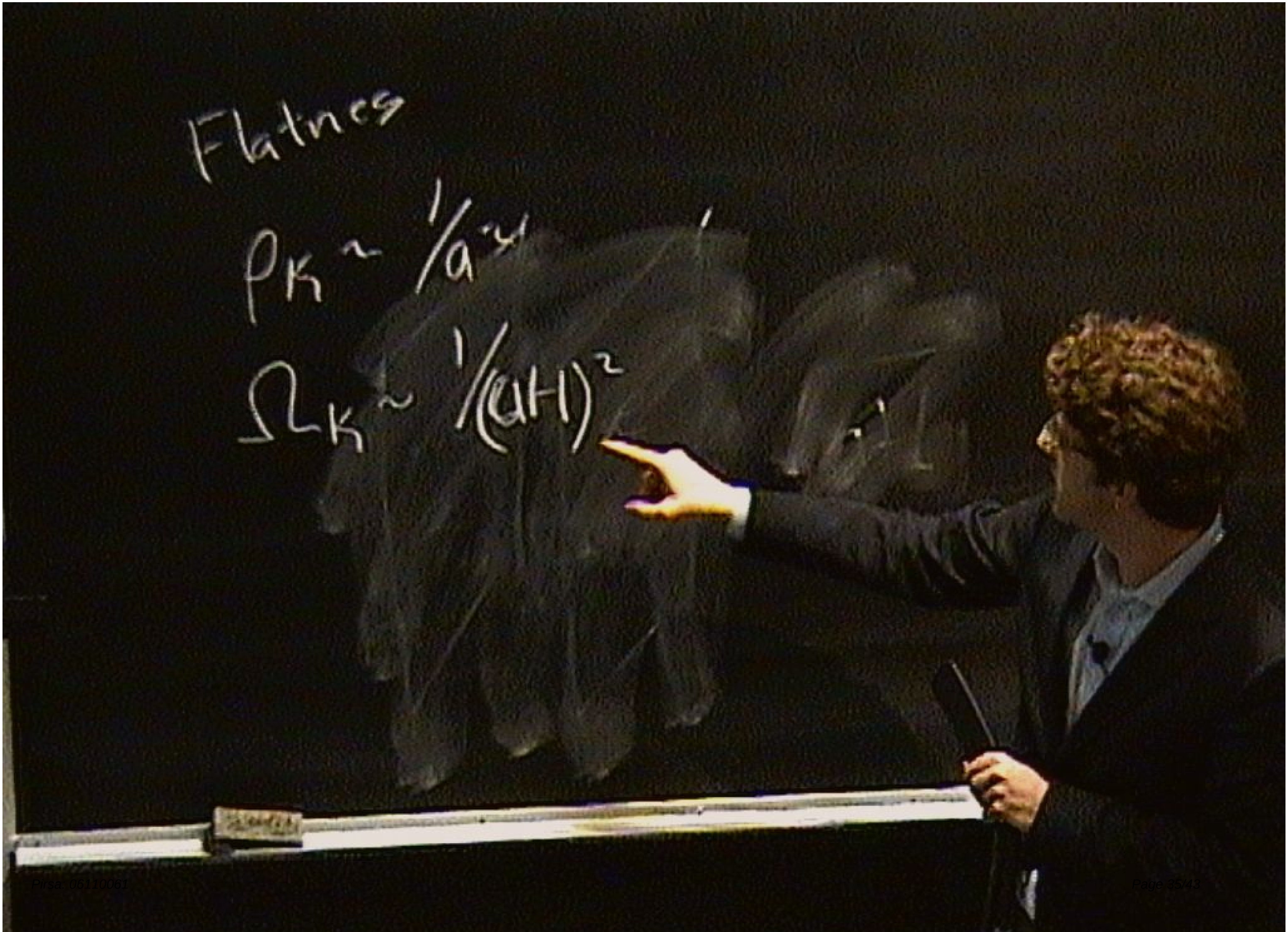


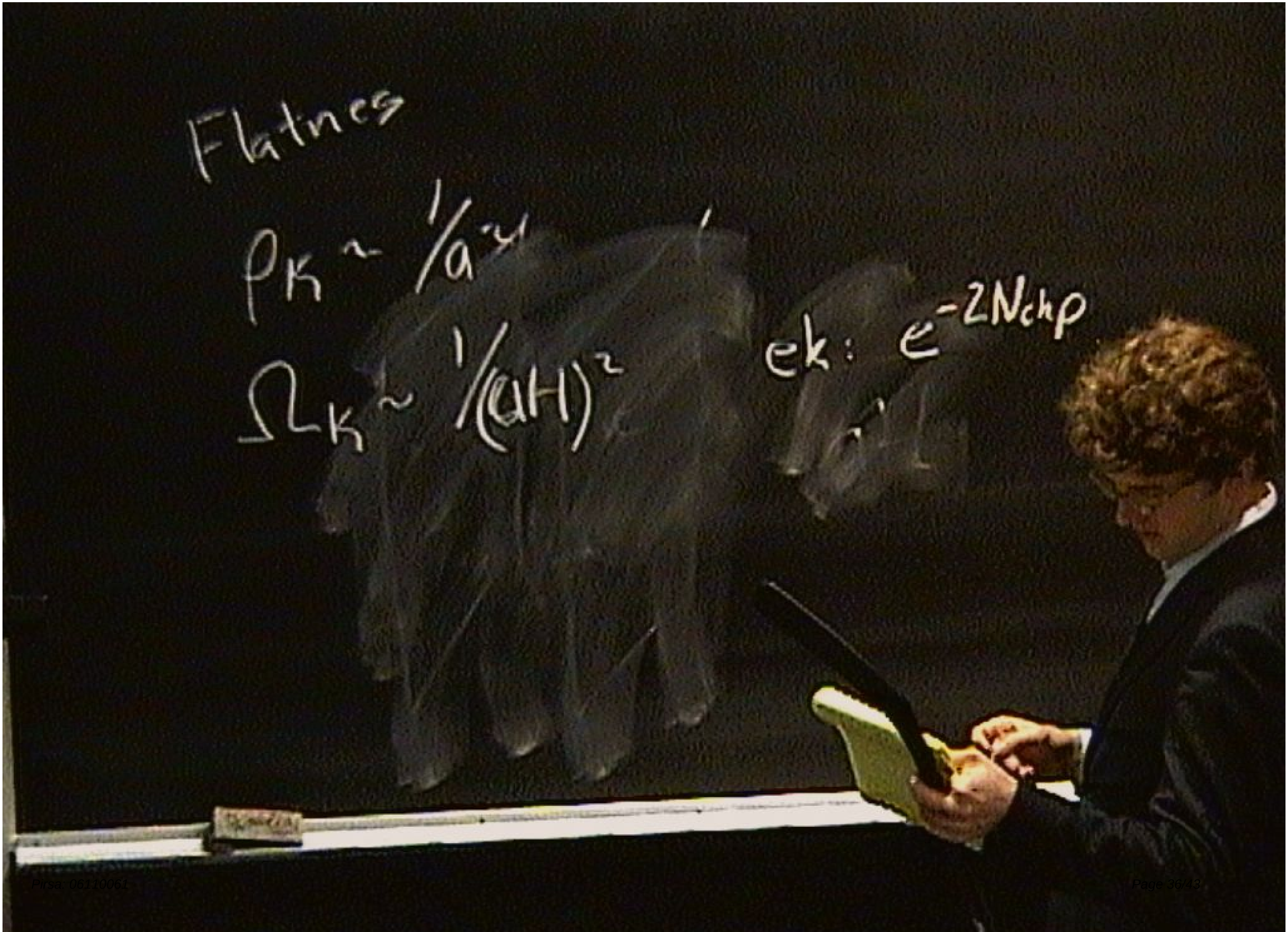

log k/k0 = Ndark + 2γ/3 + Nrad
ad·b
1/k²
~ 1/k⁴
log k/k0 = Nrad + 4γ/3
10^-5 e^(-Ndark - 2γ/3 + Nrad)4 < H0
0

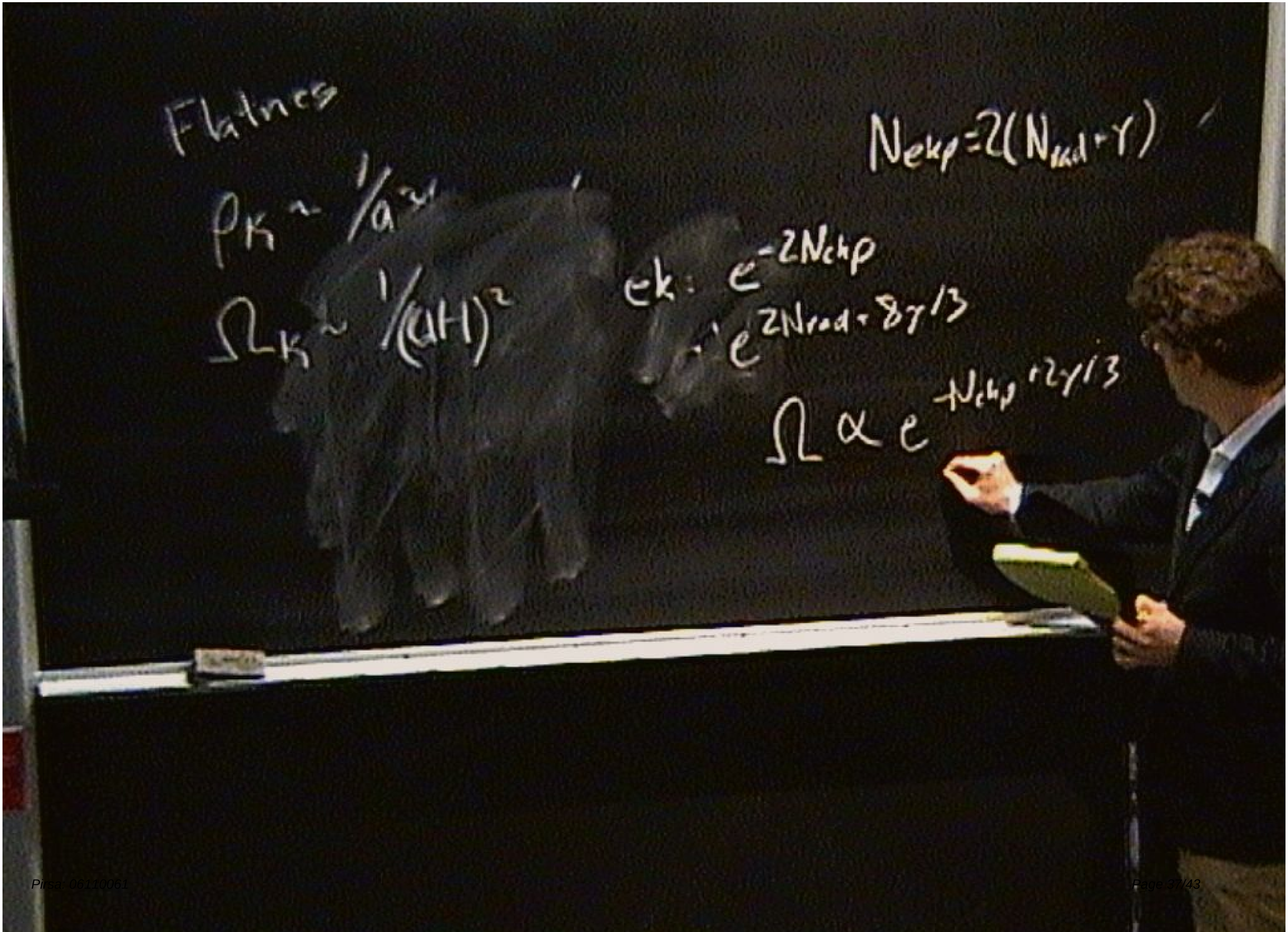
THE POTENTIAL

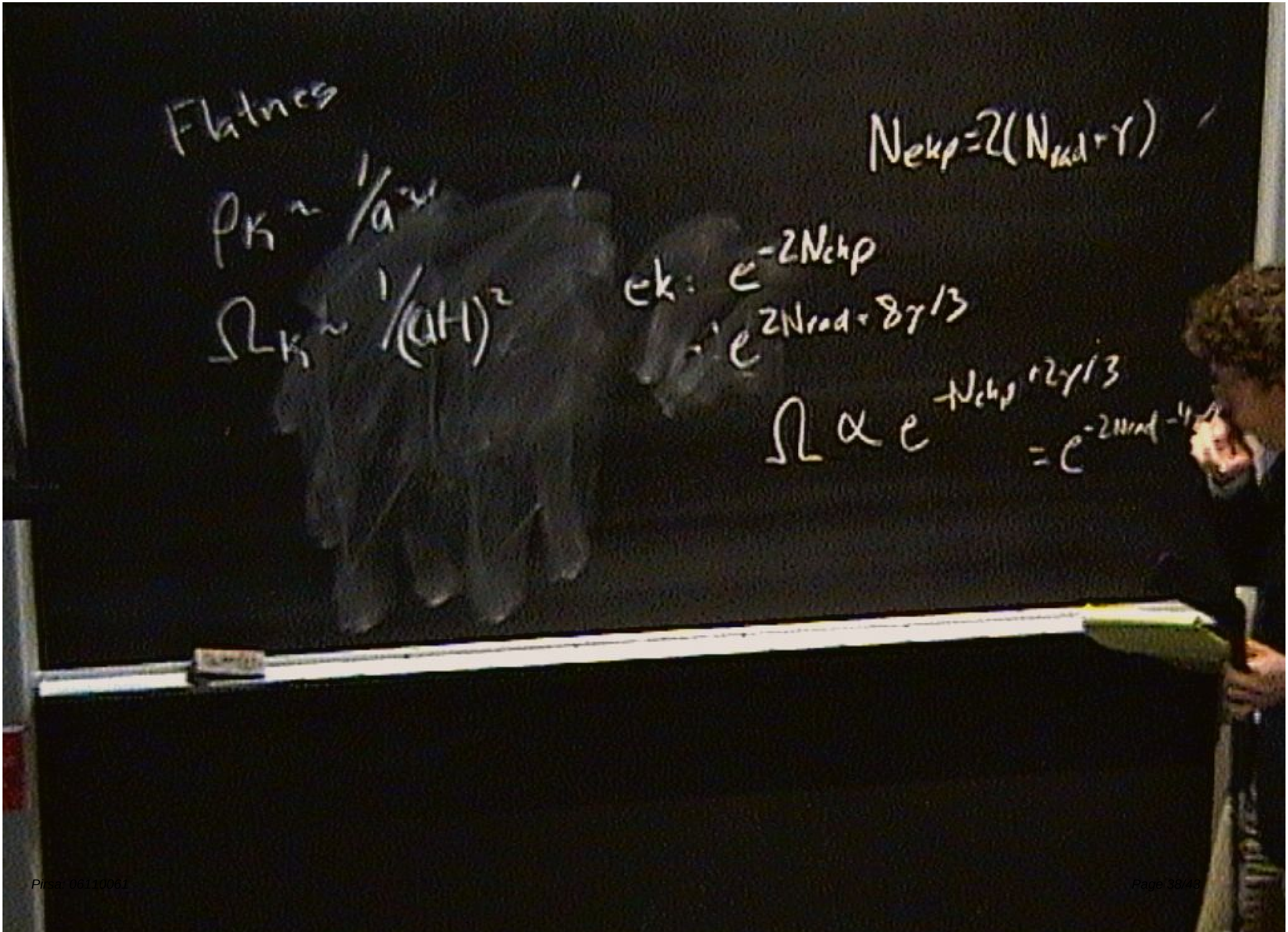


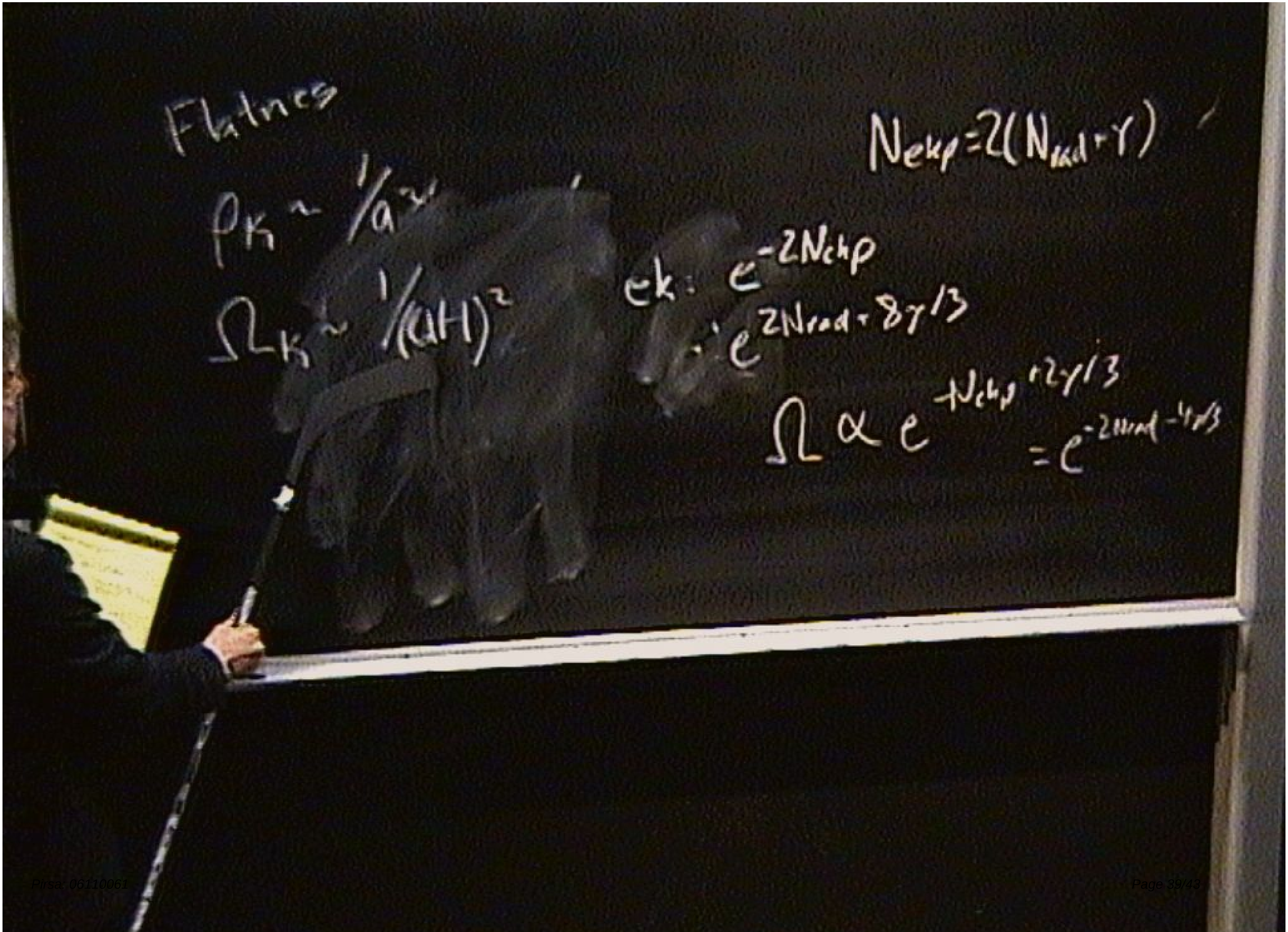

Flatnes


Flatness
ρK ~ 1/a
ΩK ~ 1/(aH)²

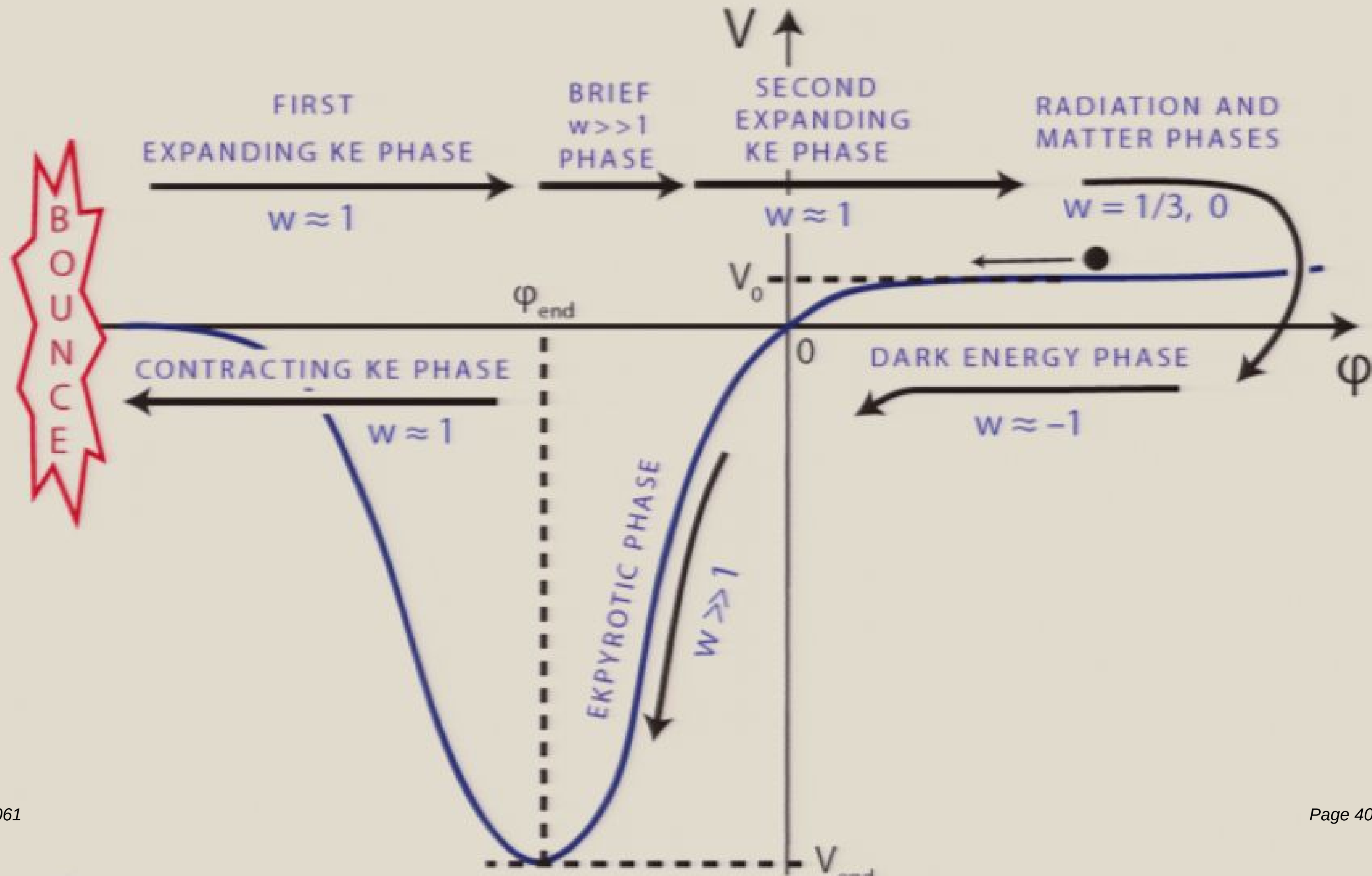

Flatnes
ρK ~ 1/a²
ΩK ~ 1/(aH)²
ek: e^-2Nchp

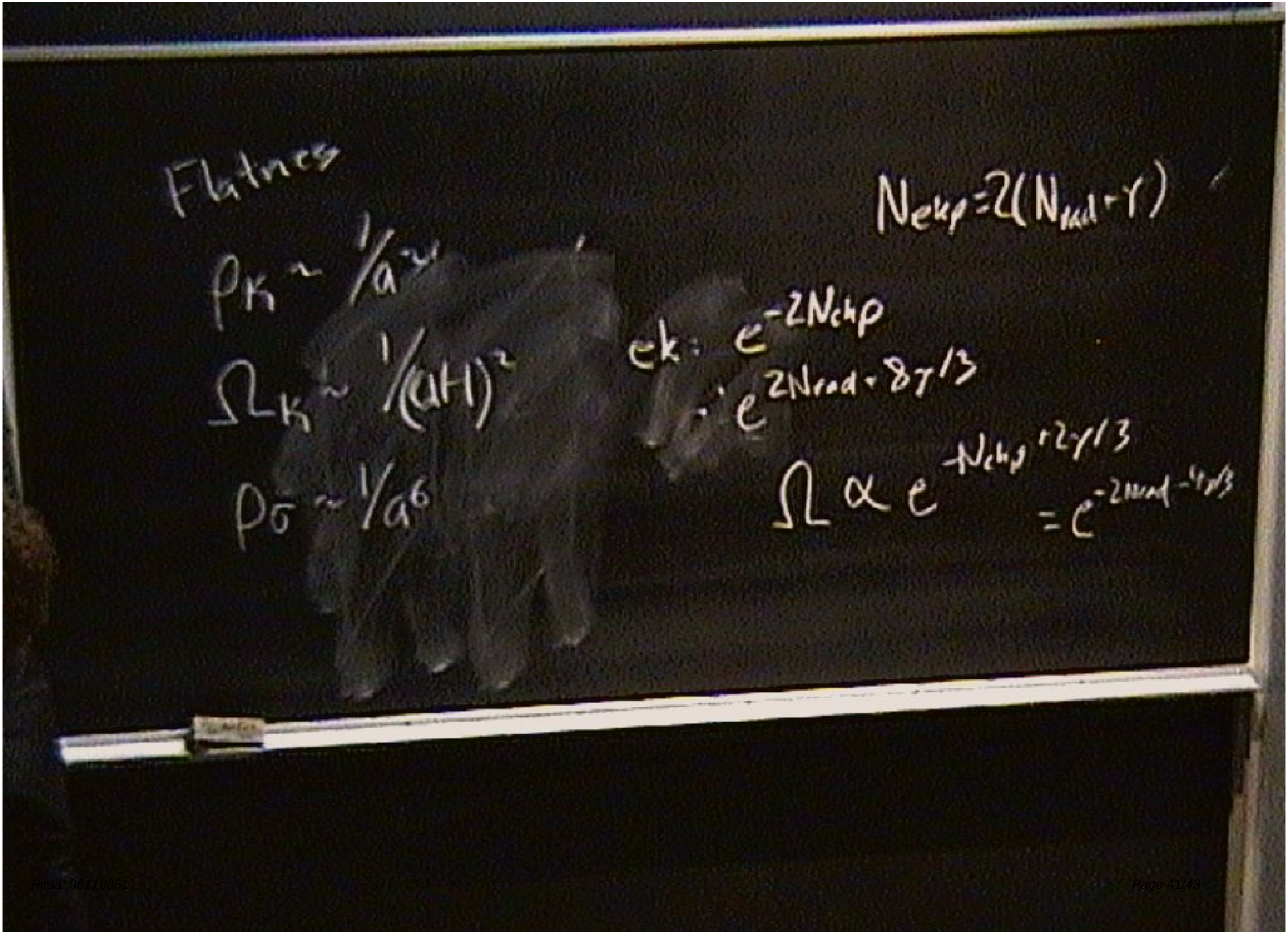

Flatness
ρK ~ 1/a²
ΩK ~ 1/(aH)²
Nexp = 2(Nrad + γ)
ek: e^-2Nexp
e^2Nrad + 8γ/3
Ω ∝ e^-Nexp + 2γ/3


Flatnes
Nexp=2(Nrad+γ)


Flatnes
ρK ~ 1/a²
ΩK ~ 1/(aH)²
Nexp = 2(Nrad + γ)
εk: e^-2Nexp
e^2Nrad + 8γ/3
Ω α e^-Nexp + 2γ/3
= e^-2Nrad - 4γ/3

THE POTENTIAL




Flatness
ρK ~ 1/a^2
ΩK ~ 1/(aH)^2
ρσ ~ 1/a^6
Nexp = 2(Nrad - γ)
eK = e^-2Nexp
= e^2Nrad - 8γ/3
Ω α e^-Nexp + 2γ/3
= e^-2Nrad - 4γ/3

NO HAIR THEOREM

$$3\left(\frac{\dot{a}}{a}\right)^2 = \Lambda + \frac{k}{a^2} + \frac{\rho_m}{a^3} + \frac{\rho_r}{a^4} + \frac{\sigma}{a^6} + \frac{\rho_\phi}{a^{-3(1+w)}}$$

- Λ: cosmological constant, inflaton
- $\frac{k}{a^2}$: curvature, gradients, domain walls
- $\frac{\rho_m}{a^3}$: dust, monopoles
- $\frac{\rho_r}{a^4}$: radiation
- $\frac{\sigma}{a^6}$: anisotropy
- $\frac{\rho_\phi}{a^{-3(1+w)}}$: scalar field

In expansion, smallest w dominates (inflation)

In contraction, largest w dominates (ekpyrosis)

hep-th/0312009

CONCLUSIONS

I. Large-scale structure in the cyclic universe is generated by quantum fluctuations from the previous cycle, without interference from older structure.

II. The ekpyrotic phase is sufficient to make the universe homogeneous, isotropic and flat. Dark energy is superfluous.

III. The global structure of the cyclic universe cannot be described by a uniform FRW picture.