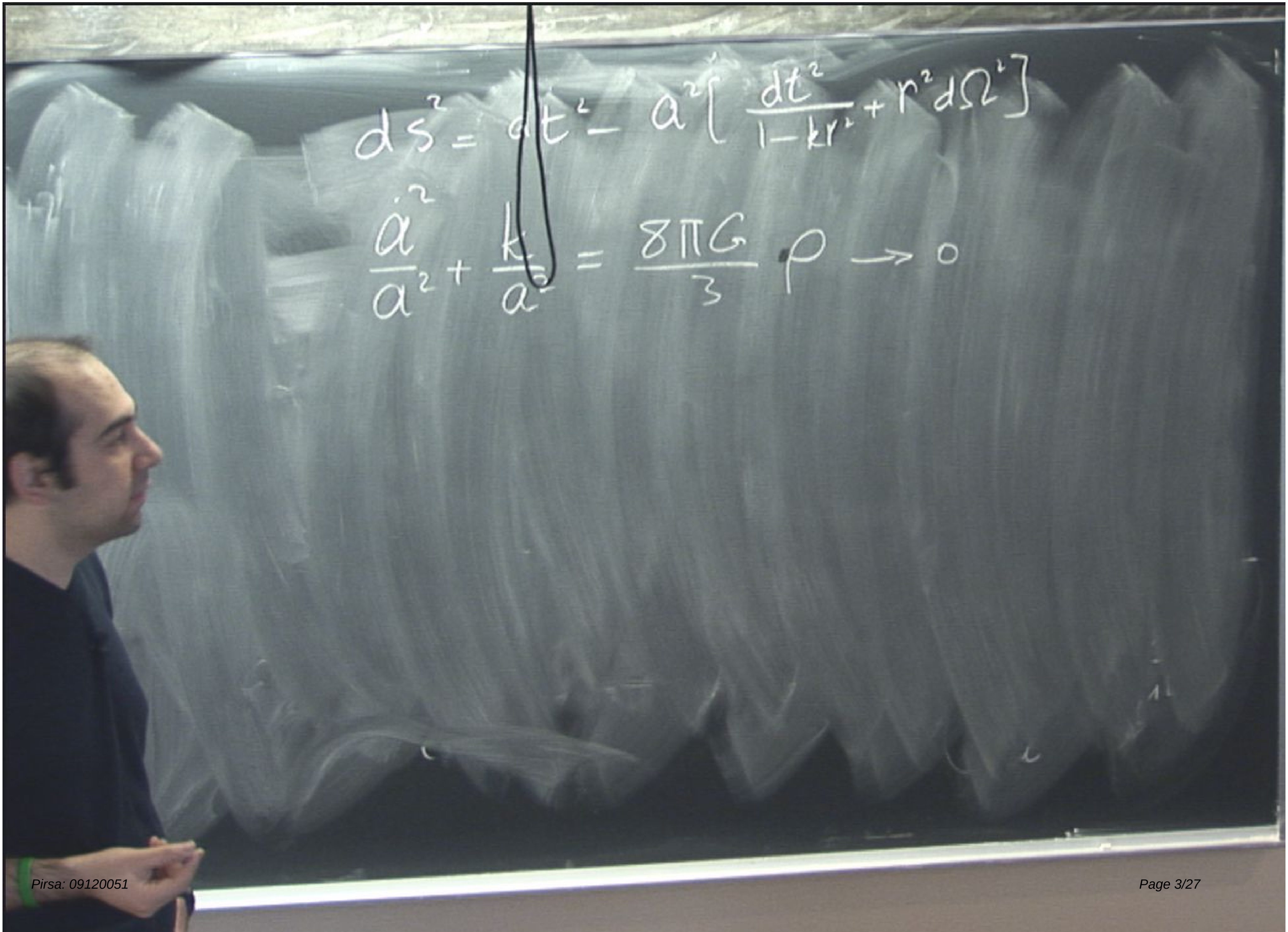
Title: Cosmology - Review (PHYS 621) - Lecture 3

Date: Dec 02, 2009 10:00 AM

URL: http://pirsa.org/09120051

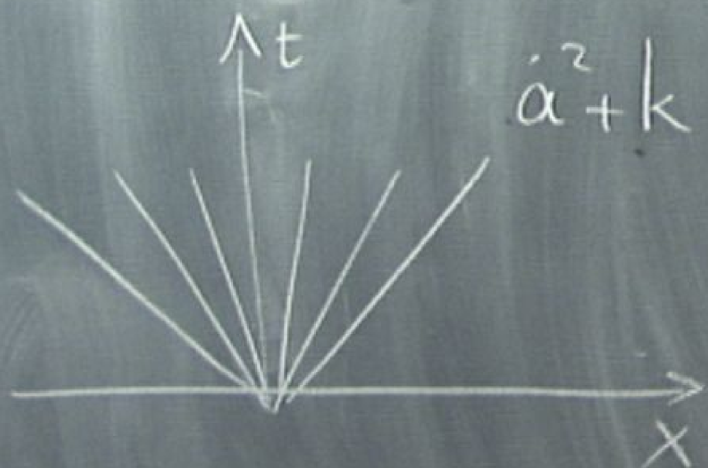
Abstract:

perimeter scholars
international


$ds^2 = dt^2 - a^2\left[\frac{dt^2}{1-kr^2} + r^2 d\Omega^2\right]$
$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \to 0$

$$ds^2 = dt^2 - a^2\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$$

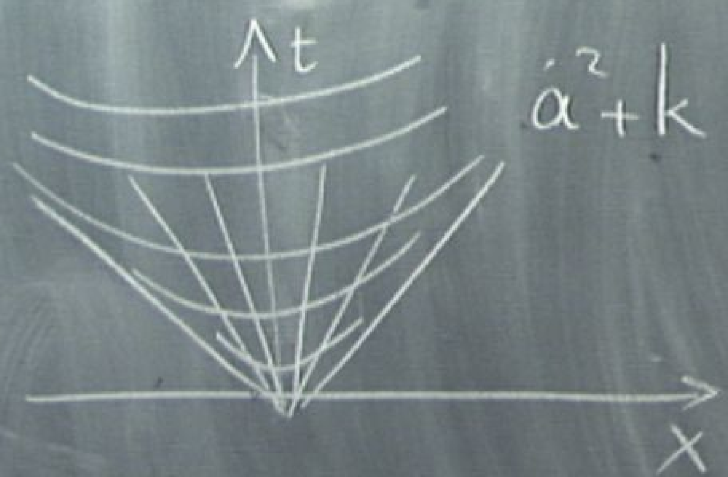
$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \rightarrow 0$$



$$\dot{a}^2 + k = 0 \Rightarrow \dot{a} = 1 \Rightarrow a = t$$

$$ds^2 = dt^2 - a^2\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$$

$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \to 0$$



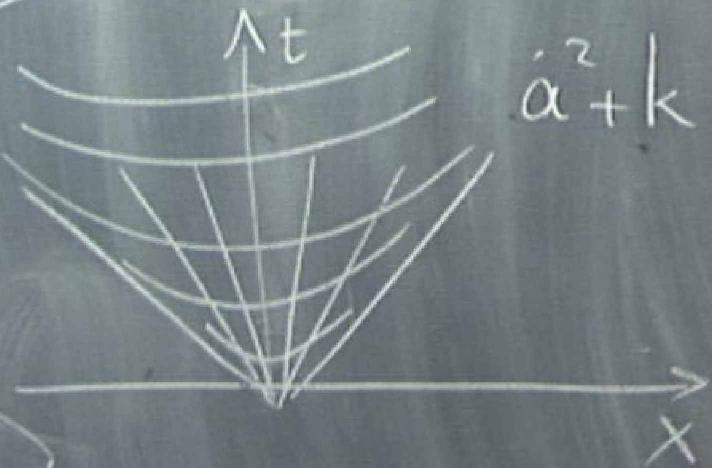
$$\dot{a}^2 + k = 0 \Rightarrow \dot{a} = 1 \Rightarrow a = t$$

$$1 + z = \frac{a_0}{a}$$

$$z = v = Hr$$

$$ds^2 = dt^2 - a^2\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$$

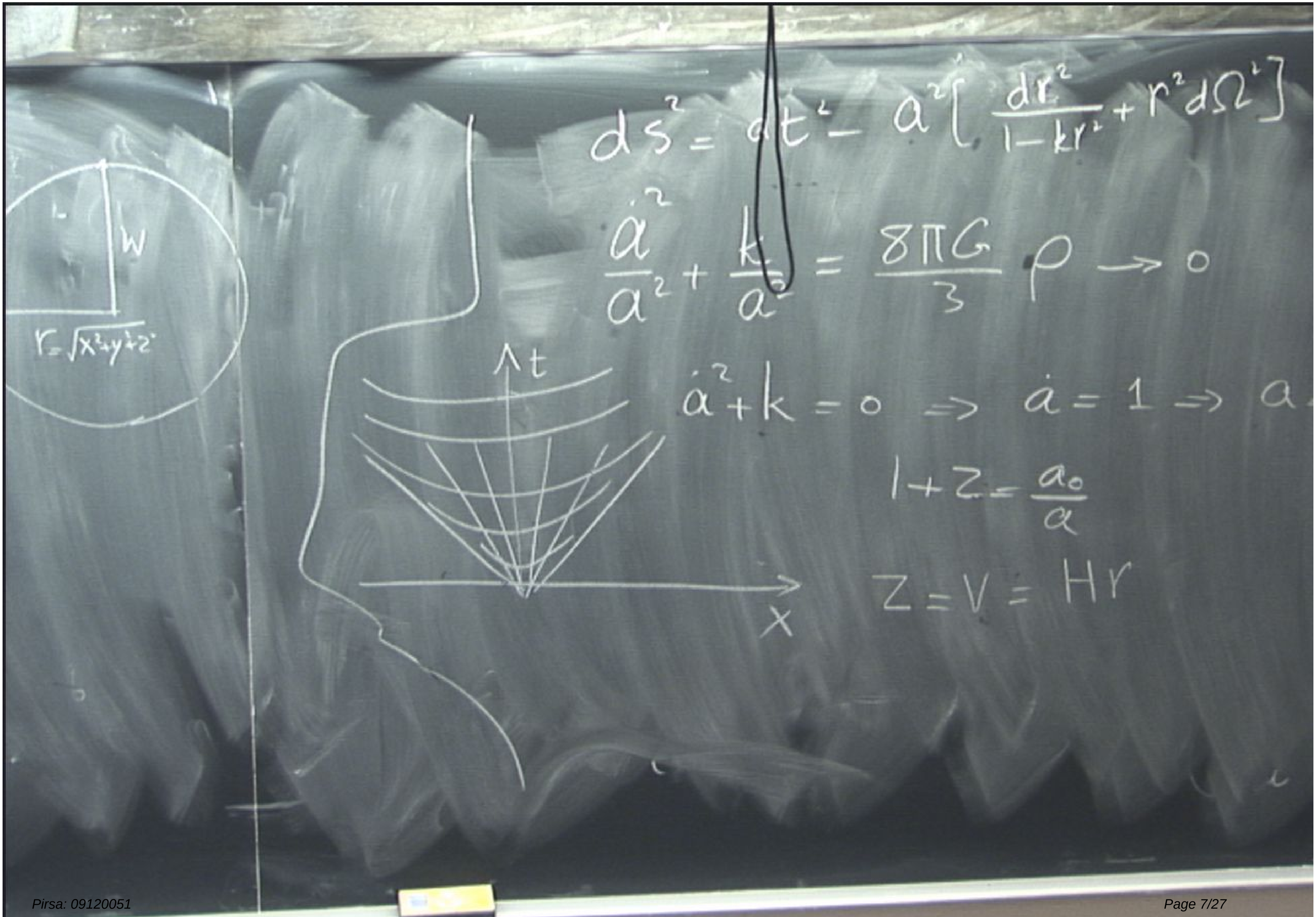
$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \rightarrow 0$$

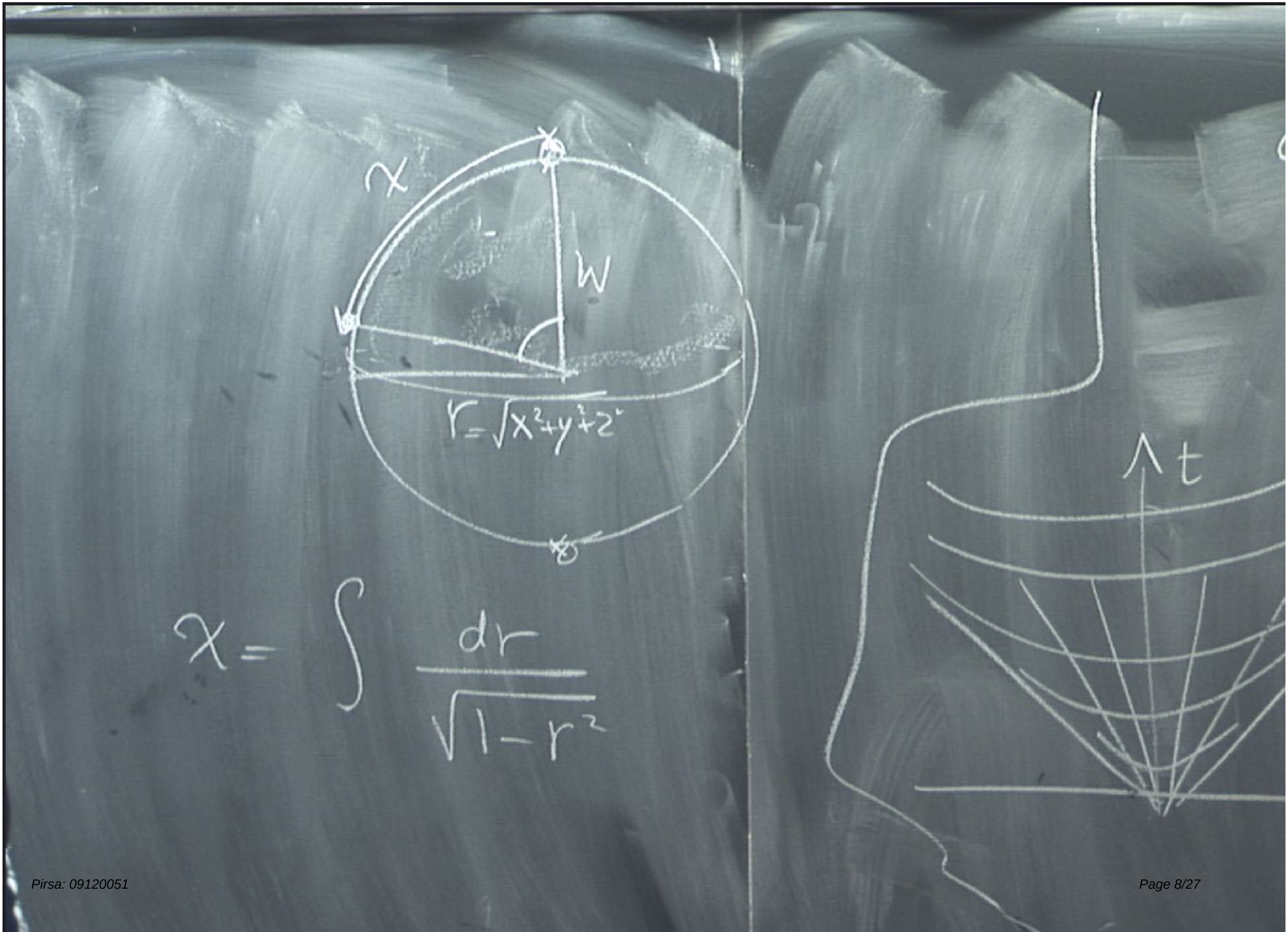


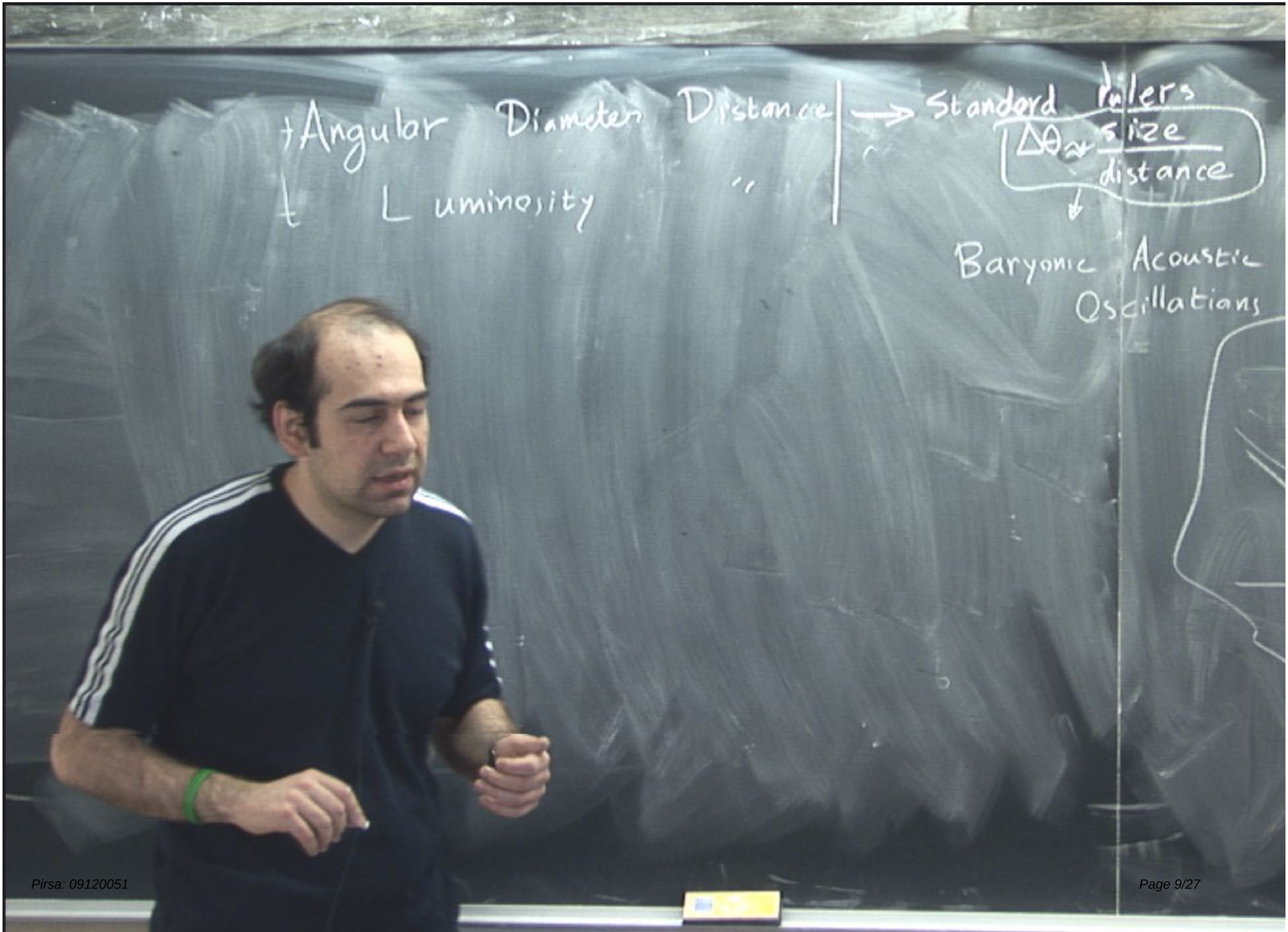
$$\dot{a}^2 + k = 0 \Rightarrow \dot{a} = 1 \Rightarrow a \sim t$$

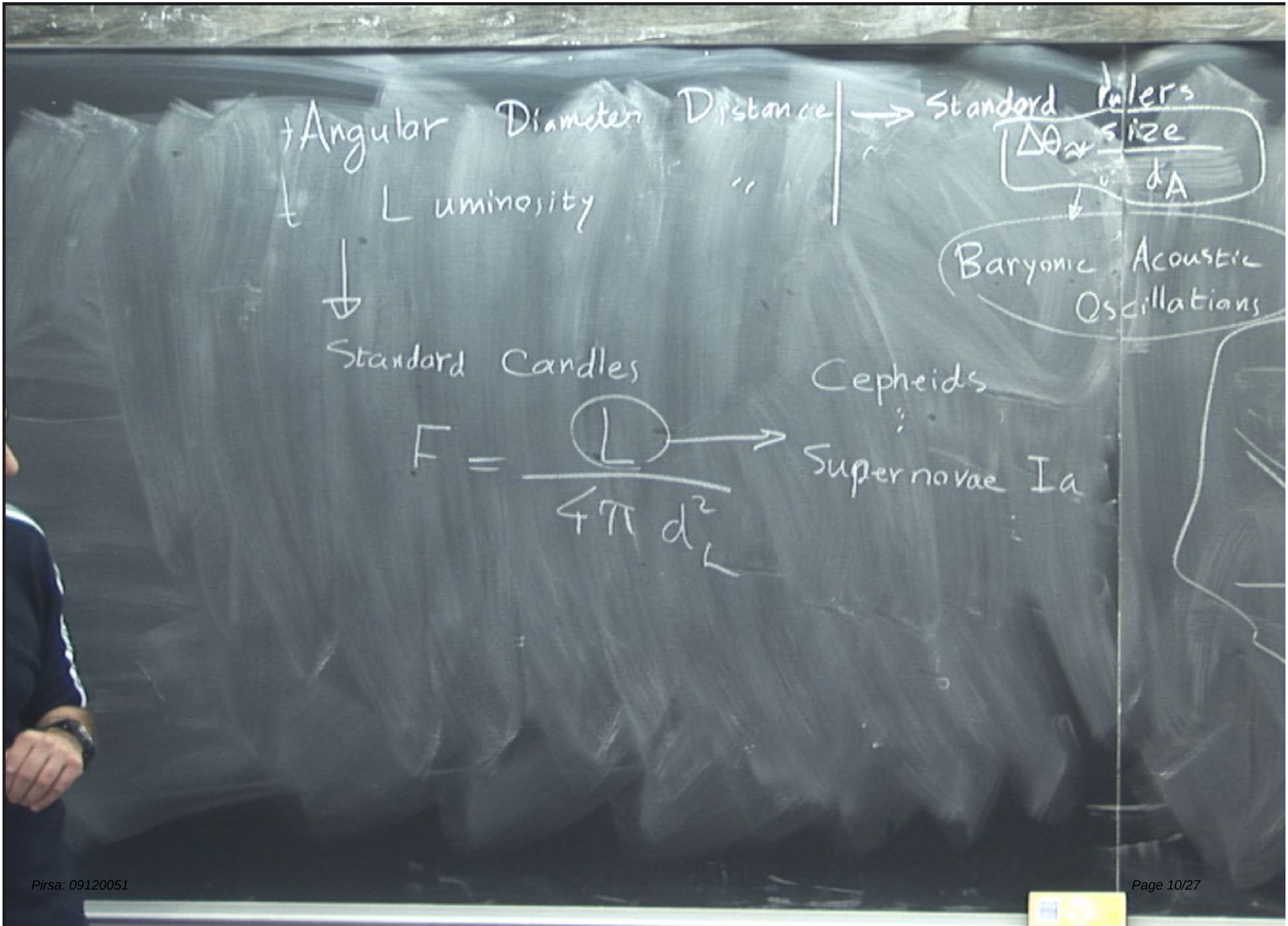
$$1 + z = \frac{a_0}{a}$$

$$z = v = Hr$$


$ds^2 = dt^2 - a^2\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$
$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \to 0$
$\dot{a}^2 + k = 0 \Rightarrow \dot{a} = 1 \Rightarrow a$
$1 + z = \frac{a_0}{a}$
$z = v = Hr$
W
$r = \sqrt{x^2+y^2+z^2}$
t
x


χ
W
$r = \sqrt{x^2+y^2+z^2}$
$\chi = \int \frac{dr}{\sqrt{1-r^2}}$
t


+Angular Diameter Distance
→ Standard Rulers
ΔΘ ≈ size / distance
+ Luminosity "
Baryonic Acoustic Oscillations


Angular Diameter Distance
Standard Rulers
Δθ ≈ size / d_A
Luminosity "
Baryonic Acoustic Oscillations
Standard Candles
Cepheids
F = L / 4π d_L^2
Supernovae Ia

Angular Diameter Distance → Standard Rulers

$$\boxed{\Delta\theta \simeq \frac{\text{size}}{d_A}}$$

Luminosity "

Baryonic Acoustic Oscillations

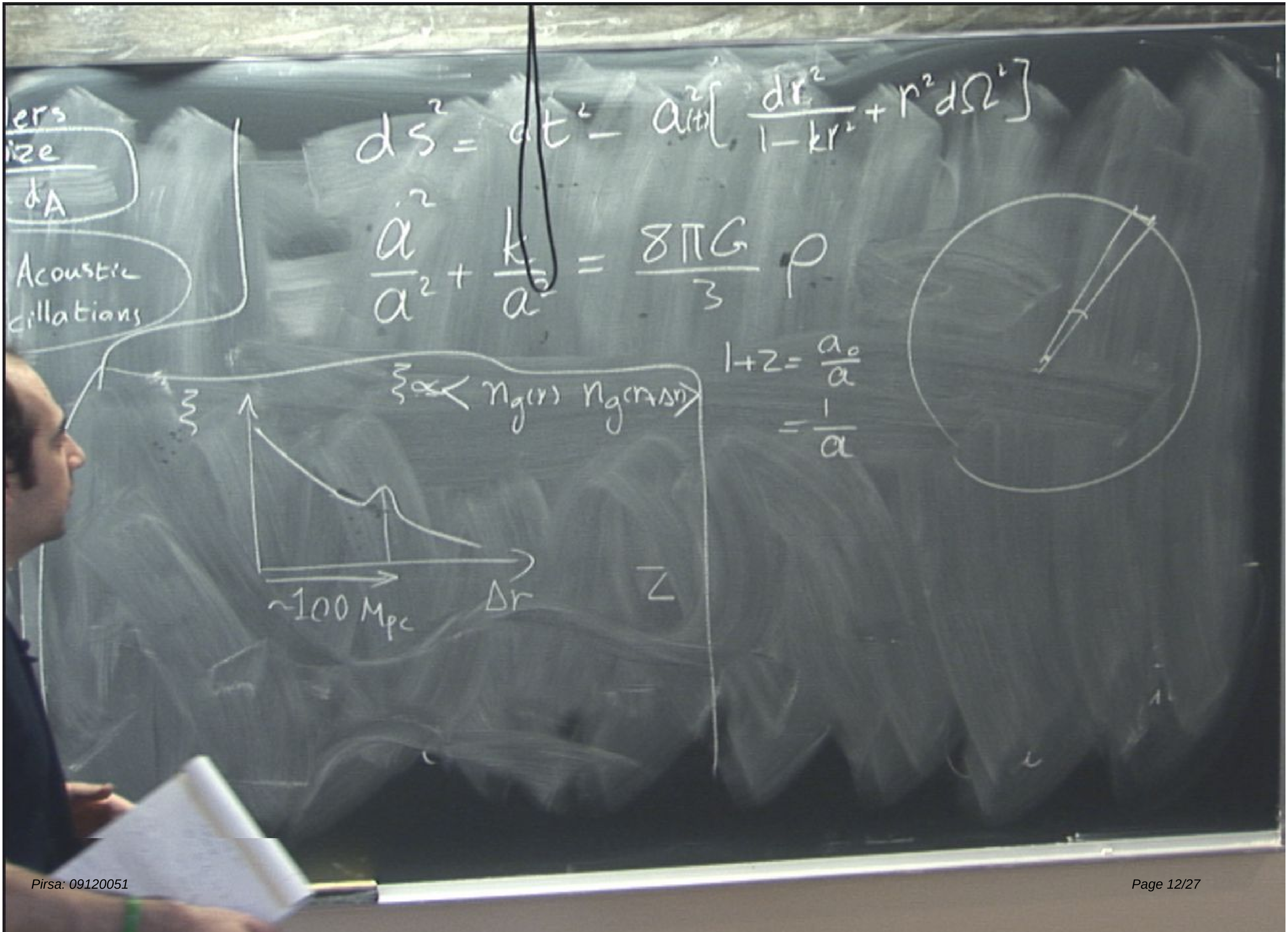
Standard Candles

Cepheids

⋮

$$F = \frac{L}{4\pi d_L^2} \longrightarrow \text{Supernovae Ia}$$

$$d_A = ar$$


ders
size
d_A
Acoustic
oscillations
$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$
$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$
$1+z = \frac{a_0}{a} = \frac{1}{a}$
$\xi \propto \langle n_g(r)\, n_g(r+\Delta r)\rangle$
ξ
$\sim 100\ M_{pc}$
Δr
z

Angular Diameter Distance → Standard Rulers

$$\Delta\theta \approx \frac{\text{size}}{d_A}$$

Baryonic Acoustic Oscillations

Luminosity "

Standard Candles

$$F = \frac{L}{4\pi d_L^2}$$

→ Cepheids

⋮

Supernovae Ia

$$d_A = a r = \frac{r}{1+z}$$

$$d_L = r(1+z)$$

lers
ize
d_A

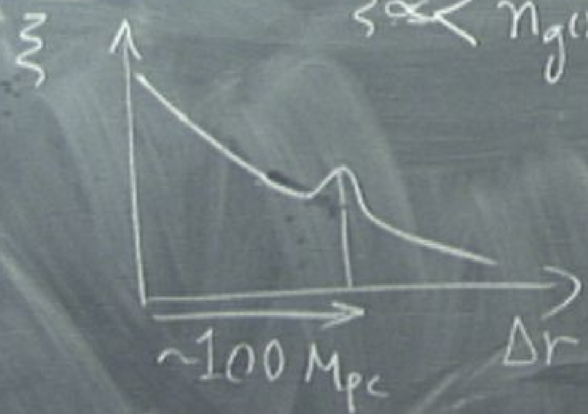
Acoustic
cillations

$$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$$

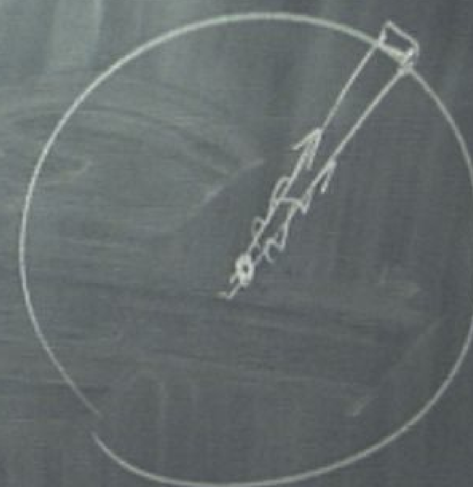
$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$$

$$1+z = \frac{a_0}{a} = \frac{1}{a}$$

$$\xi \propto \langle n_g(r)\, n_g(r+\Delta r)\rangle$$



Z



+ Angular Diameter Distance → Standard

$\Delta\theta \approx$

+ Luminosity "

↓

Standard Candles

$$F = \frac{L}{4\pi d_L^2}$$ → Cepheids

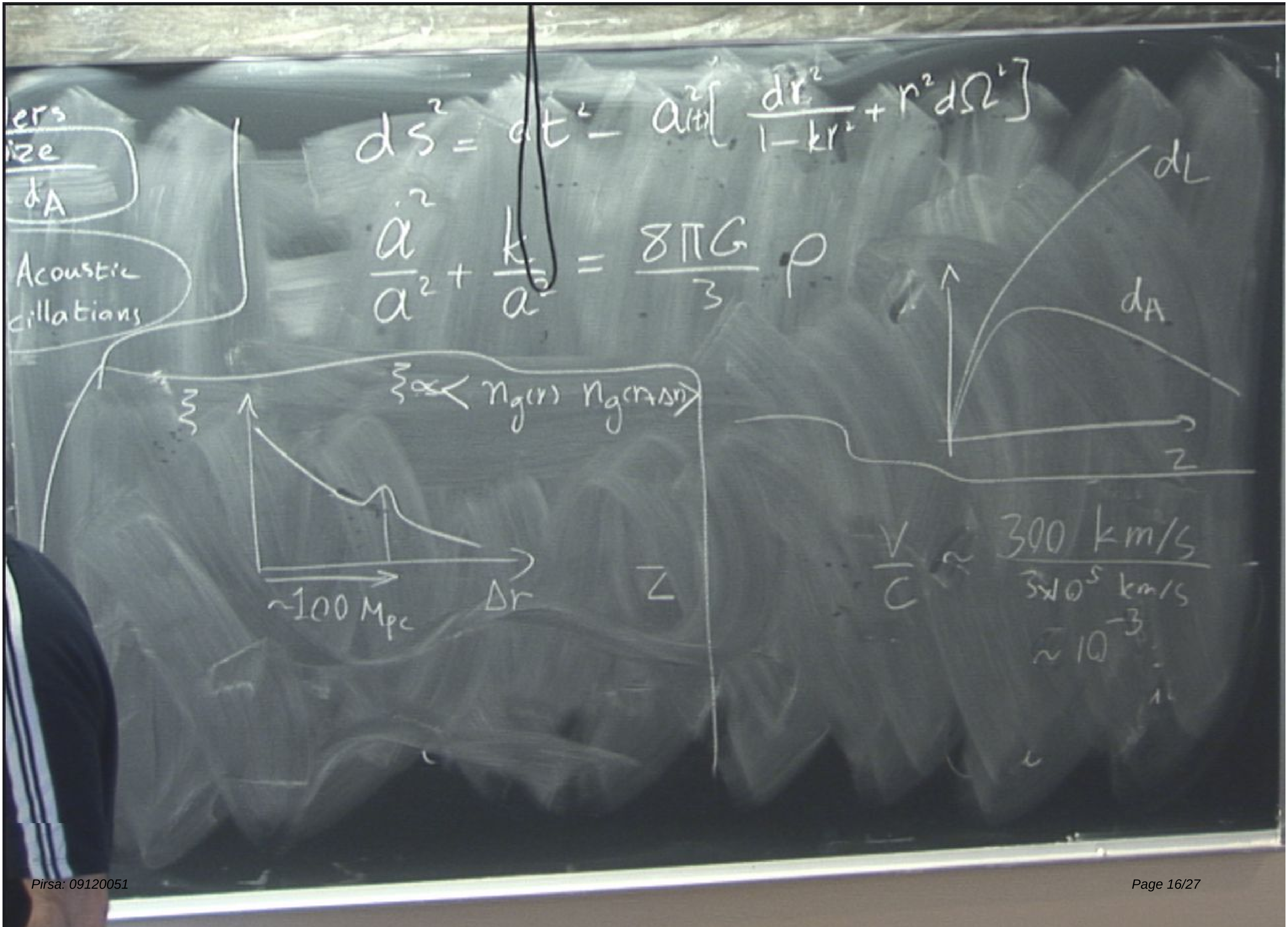
⋮

Supernovae Ia

Baryonic

Osc

$$\boxed{\begin{aligned} d_A &= a r = \frac{r}{1+z} \\ d_L &= r(1+z) \end{aligned}}$$



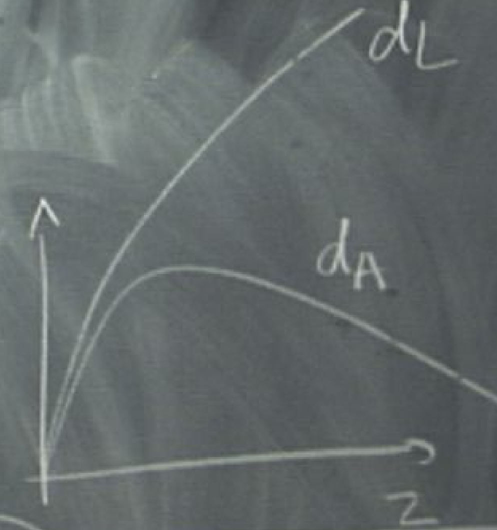
d_A
Acoustic
$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$
$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$
$\xi \propto \langle n_g(r)\, n_g(r+\Delta r)\rangle$
ξ
~ 100 Mpc
Δr
d_L
d_A
z
$\frac{v}{c} \sim \frac{300 \text{ km/s}}{3\times10^5 \text{ km/s}} \sim 10^{-3}$

lers
ize
d_A

Acoustic
cillations

$$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right]$$

$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$$



Hubble Law

$$z \simeq v \simeq H d$$

$$\frac{v}{c} \sim \frac{300\ \mathrm{km/s}}{3\times 10^5\ \mathrm{km/s}} \sim 10^{-3}$$

...lers
...ize
d_A

Acoustic
...cillations

$$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\, d\Omega^2\right]$$

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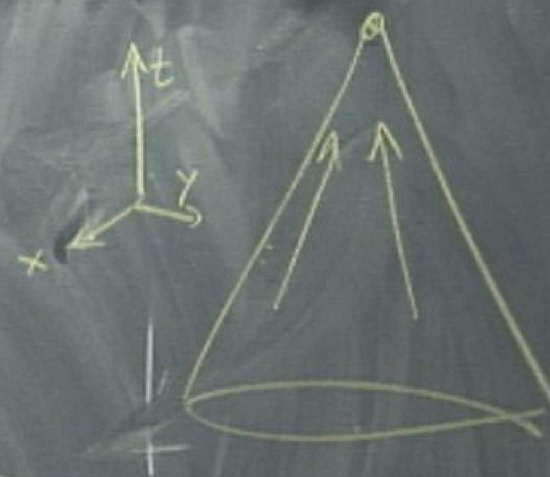


Hubble Law

$k = 0$
assume

$$z \simeq v \simeq H\, d$$

$$dr = \frac{dt}{a}$$

$$\Rightarrow r = \int \frac{dt}{a}$$

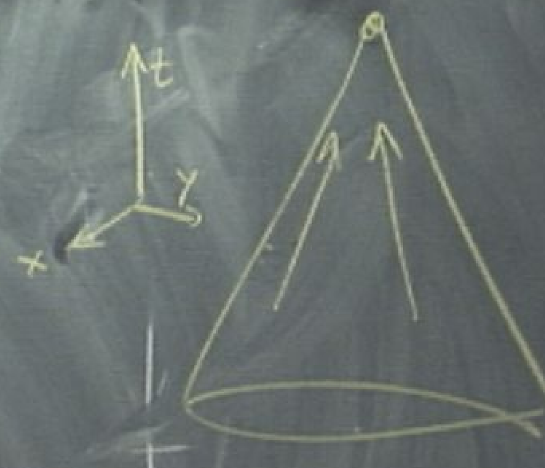
$$\frac{v}{c} \simeq \frac{300\ \mathrm{km/s}}{3\times 10^5\ \mathrm{km/s}} \simeq 10^{-3}$$

...lers
...ize
d_A

Acoustic
...cillations

$$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right] \qquad \boxed{1+z = \frac{1}{a}}$$

$$\frac{\dot{a}^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$$



Hubble Law

$k = 0$
assume

$$z \simeq v \simeq H\, d$$

$$dr = \frac{dt}{a} \qquad H = \frac{\dot{a}}{a}$$

$$\Rightarrow r = \int \frac{dt}{a} \approx \frac{\Delta t}{a} = \frac{H\Delta t}{aH}$$

$$= \frac{\Delta a}{a^2 H} = \frac{\Delta a^{-1}}{H} =$$

$$\frac{v}{c} \approx \frac{300\ \text{km/s}}{3\times10^5\ \text{km/s}} \approx 10^{-3}$$

lers
ize
d_A

Acoustic
cillations

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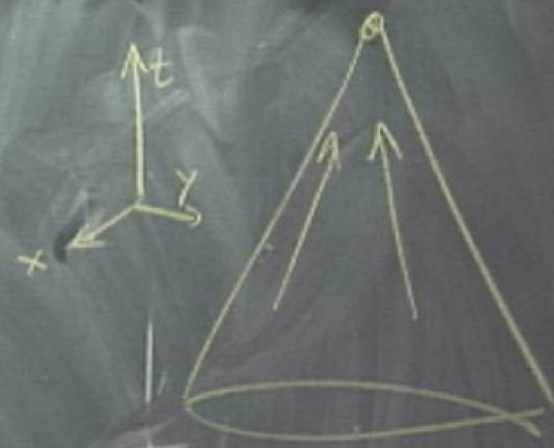

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$k=0$ assume

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$$= \frac{\Delta a}{a^2 H} = \frac{\Delta a^{-1}}{H} = \frac{z}{H}$$

decelleration par.

$$q_0 = -\frac{a\ddot{a}}{\dot{a}^2}\Big|_{t=t_0}$$

$$r = \frac{1}{H_0}\left[z - \frac{1}{2}(1+q_0)z^2 + \dots\right]$$

...lers
...ize
d_A

Acoustic
...cillations

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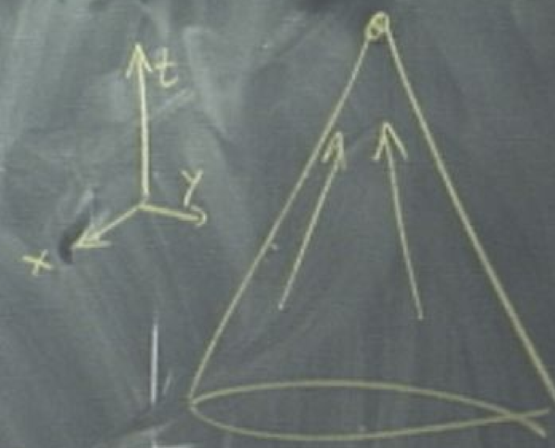

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lers
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d_A

Acoustic
cillations

$$ds^2 = dt^2 - a^2_{(t)}\left[\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right] \qquad \boxed{1+z=\frac{1}{a}}$$

$$\frac{\dot a^2}{a^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho$$

$$\dot\rho + 3H(1+w)\rho = 0$$

eq. of state:

$$w \equiv \frac{P}{\rho}$$

Hubble Law

k = 0
assume

$$z \simeq v \simeq H\, d$$

decelleration par.

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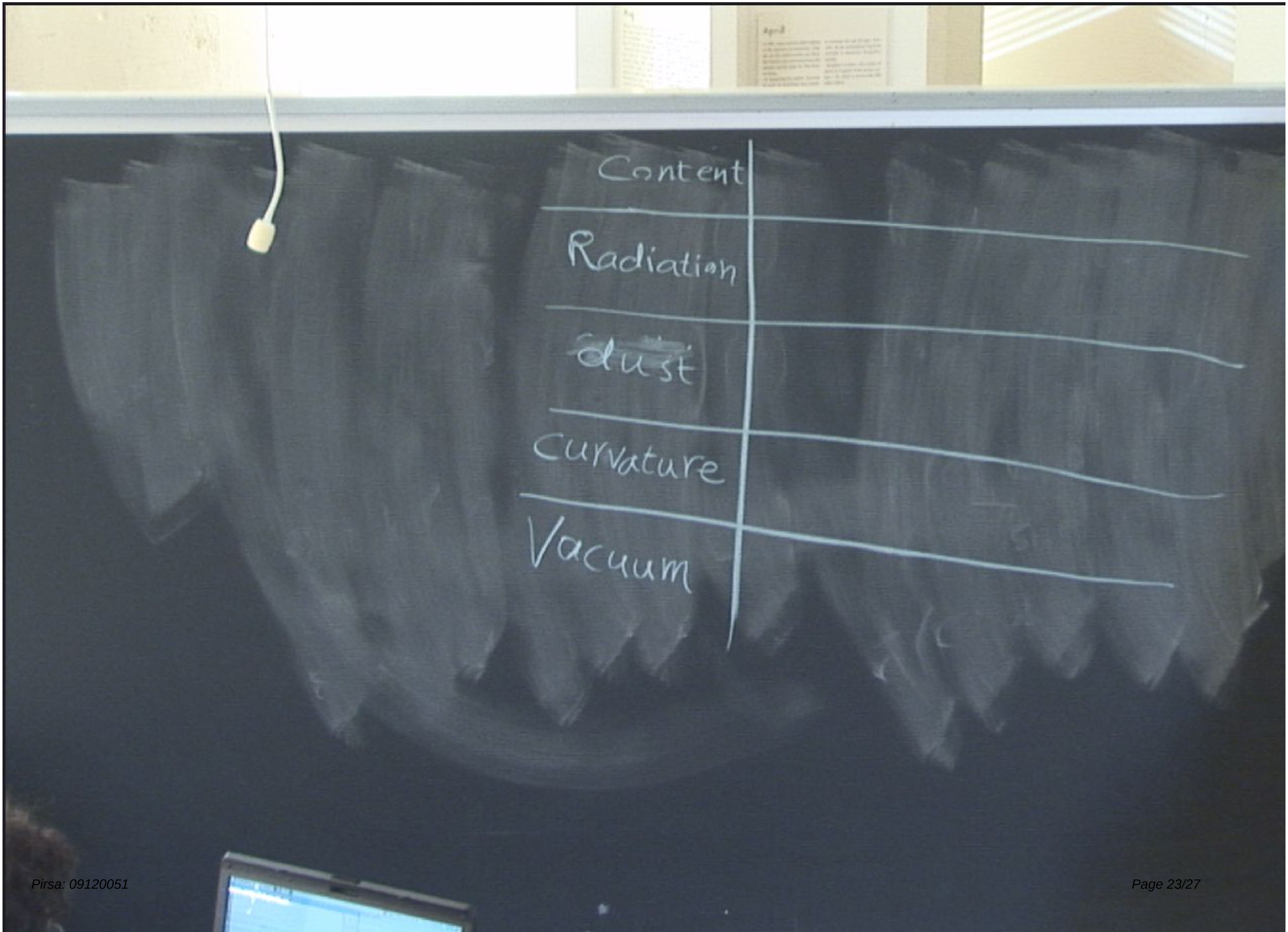
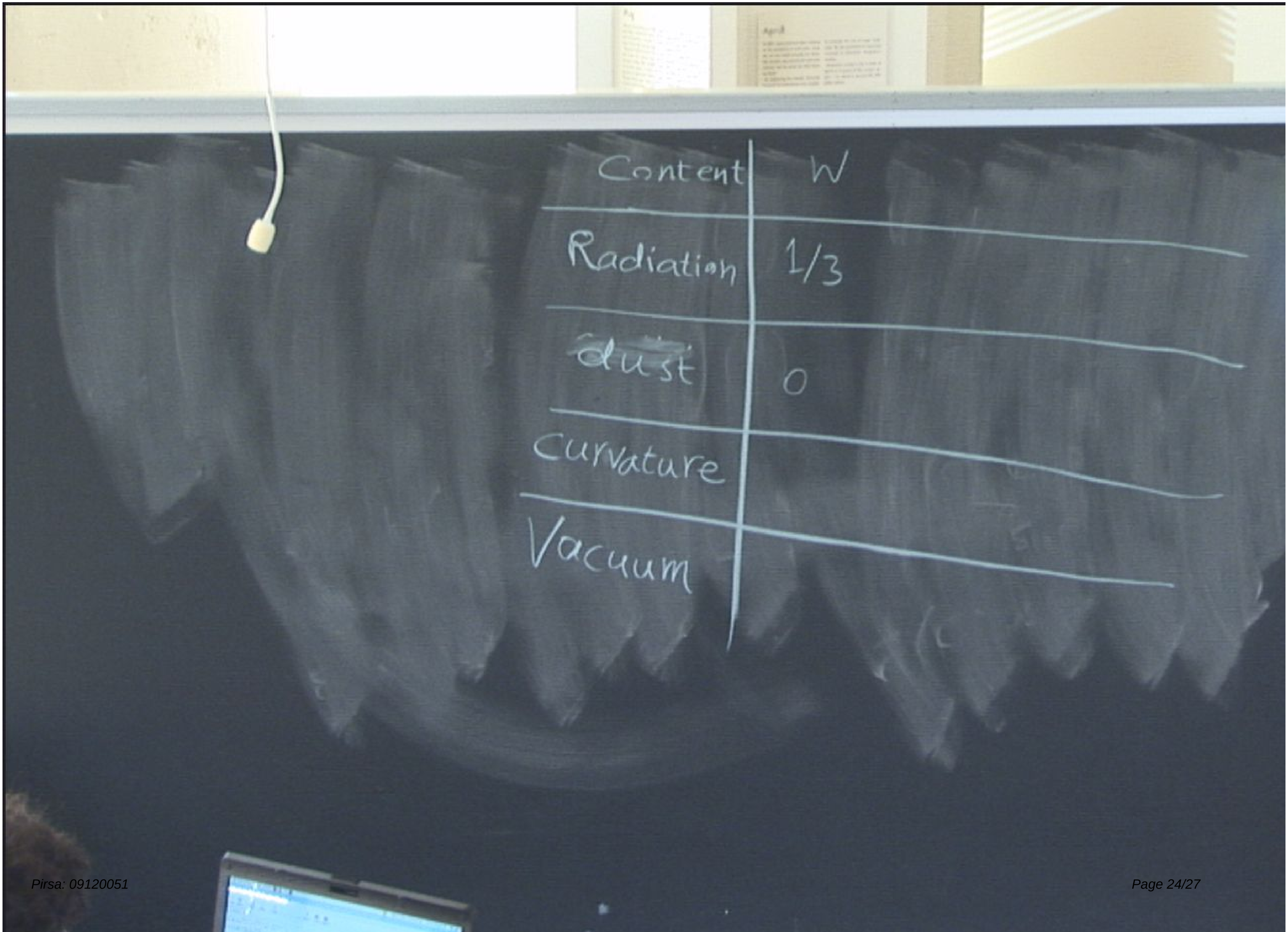
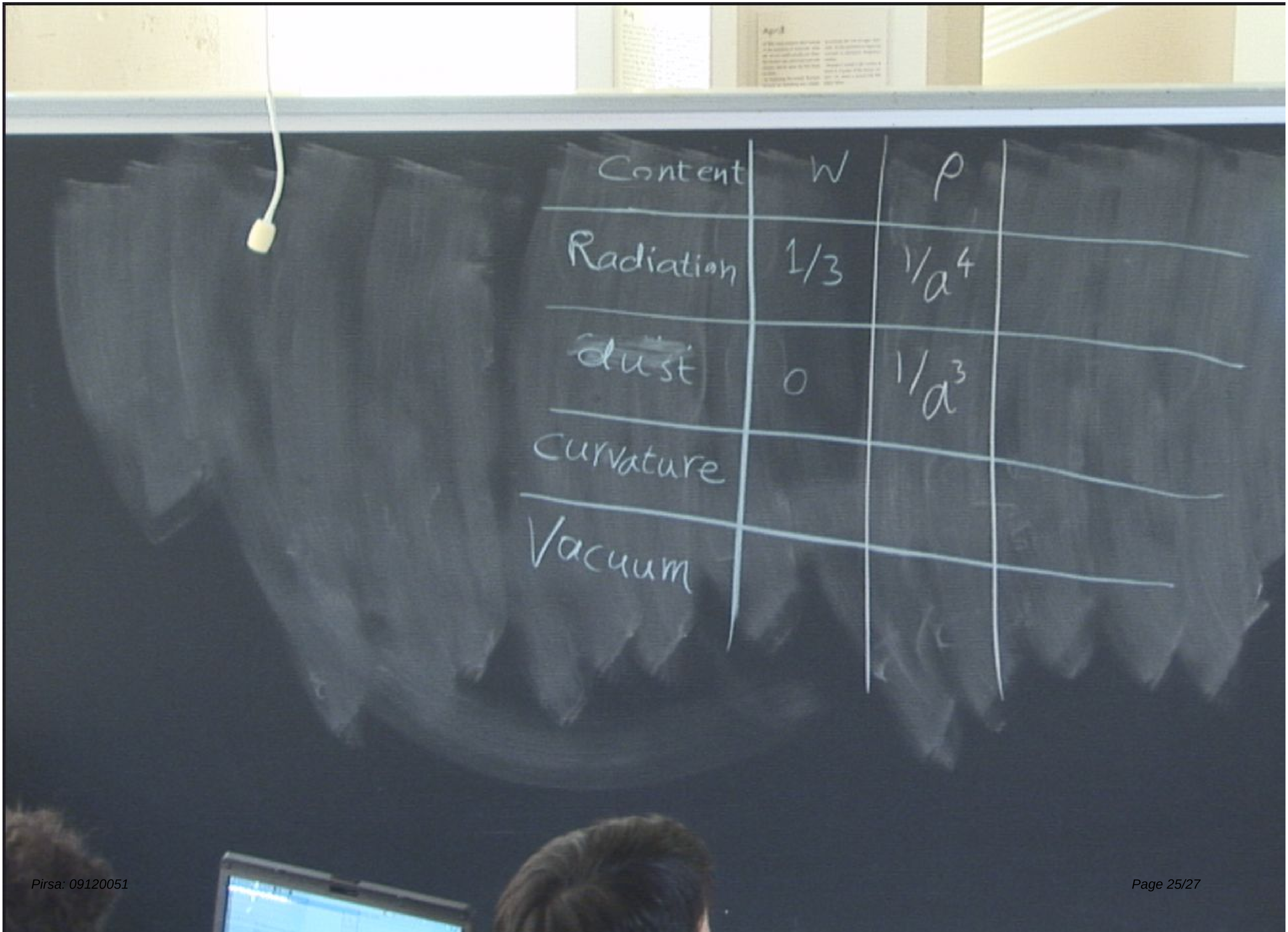
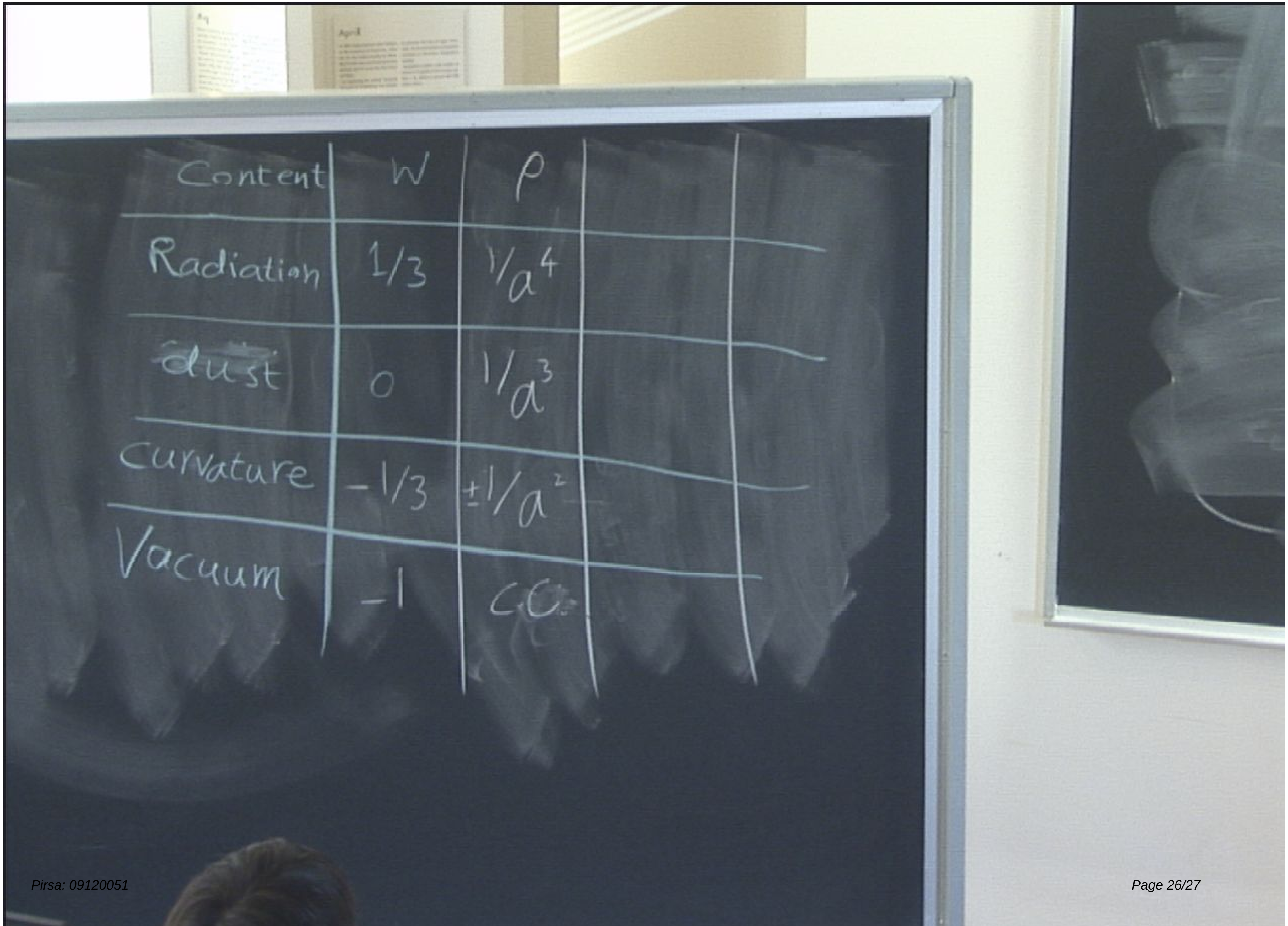

Content
Radiation
dust
curvature
Vacuum


Content
W
Radiation
1/3
~~dust~~
0
Curvature
Vacuum


Content
w
ρ
Radiation
1/3
1/a^4
~~dust~~
0
1/a^3
curvature
Vacuum


Content
W
ρ
Radiation
1/3
1/a^4
dust
0
1/a^3
curvature
-1/3
±1/a^2
Vacuum
-1
c.c.

Content	w	ρ	a
Radiation	$1/3$	$1/a^4$	$t^{1/2}$
dust	0	$1/a^3$	$t^{2/3}$
curvature	$-1/3$	$\pm 1/a^2$	t
Vacuum	-1	c.c.	$e^{H_0 t}$