Title: Quantum Gravity and the Quest for Unification

Date: Jul 15, 2008 01:30 AM

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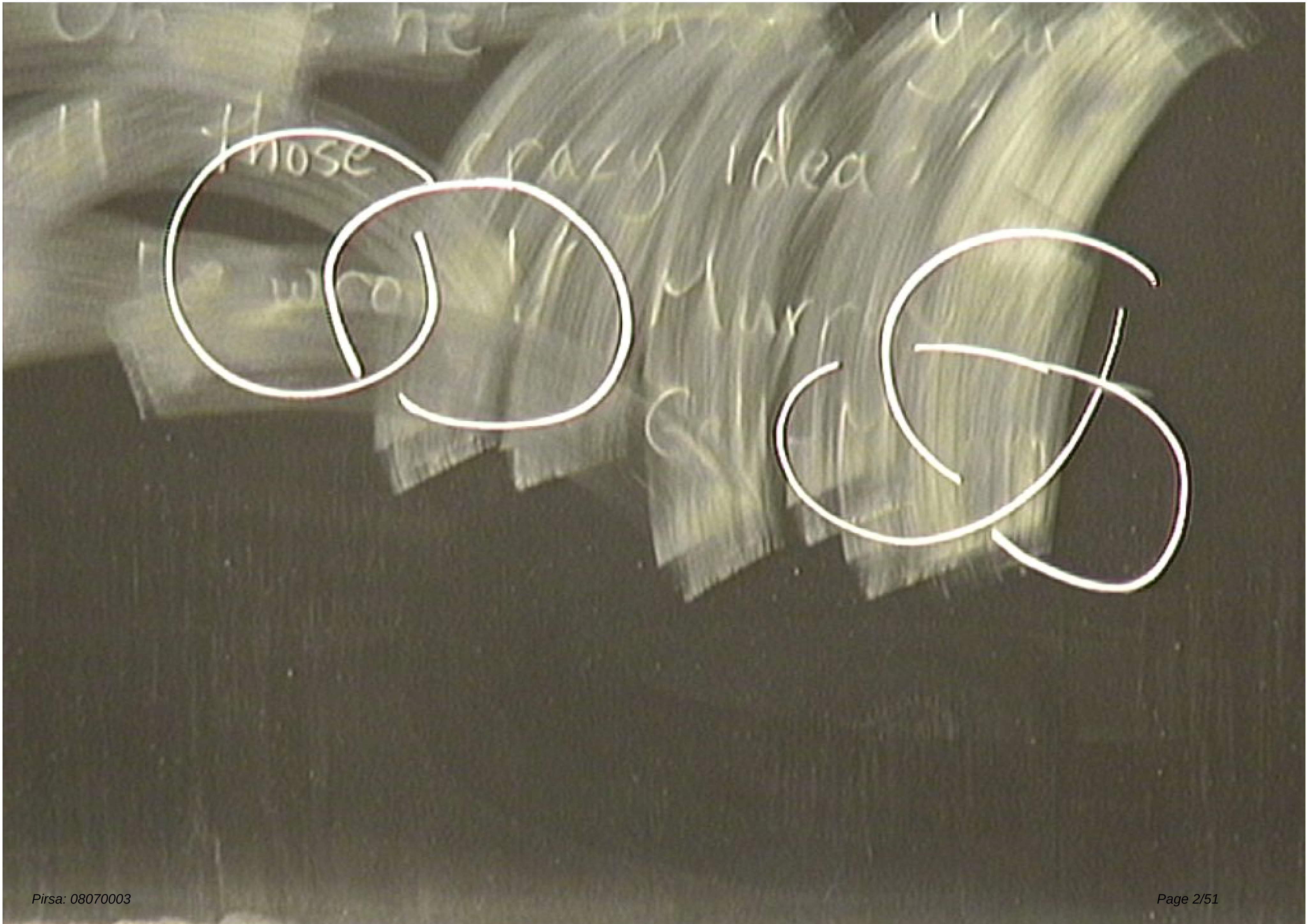
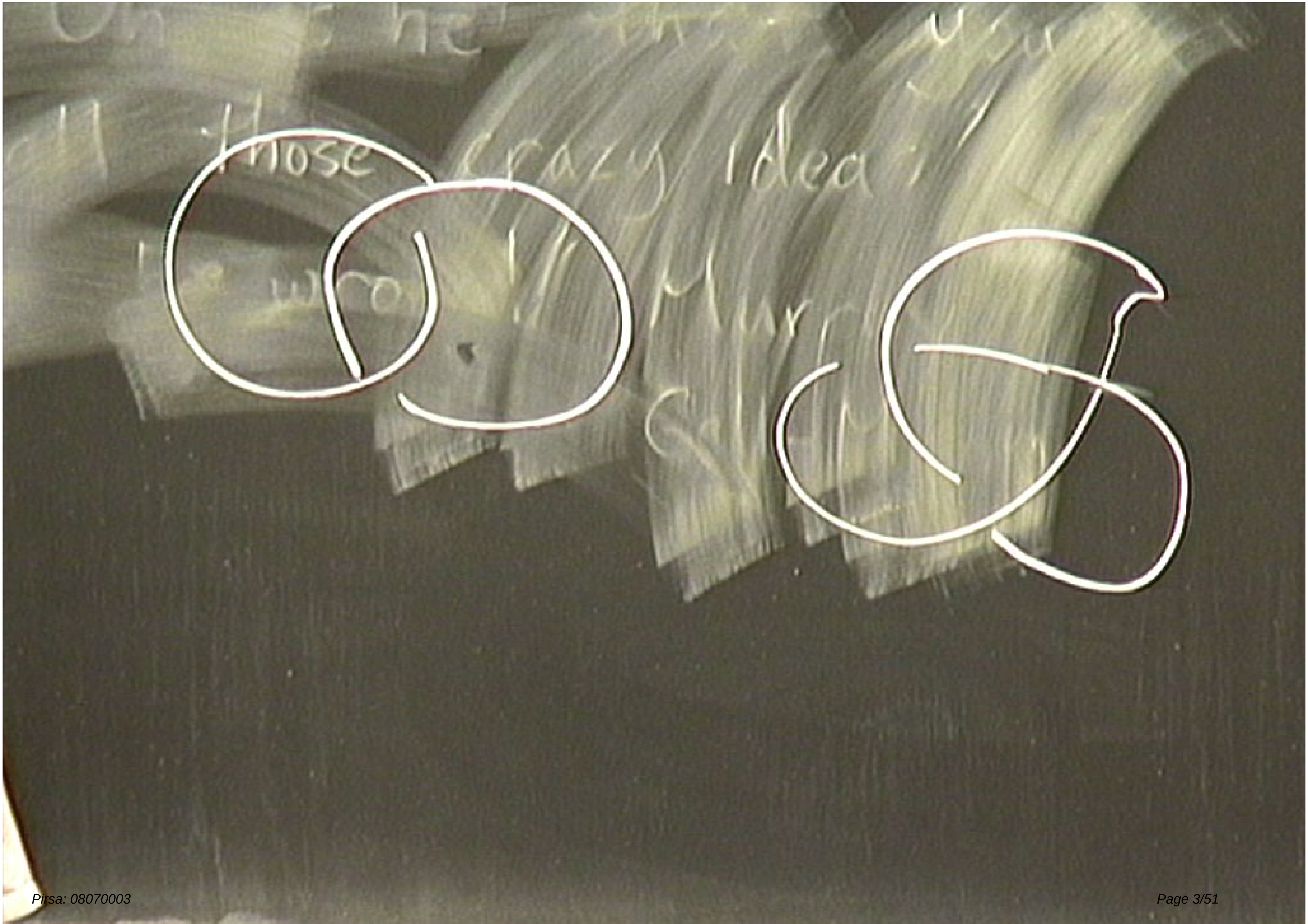
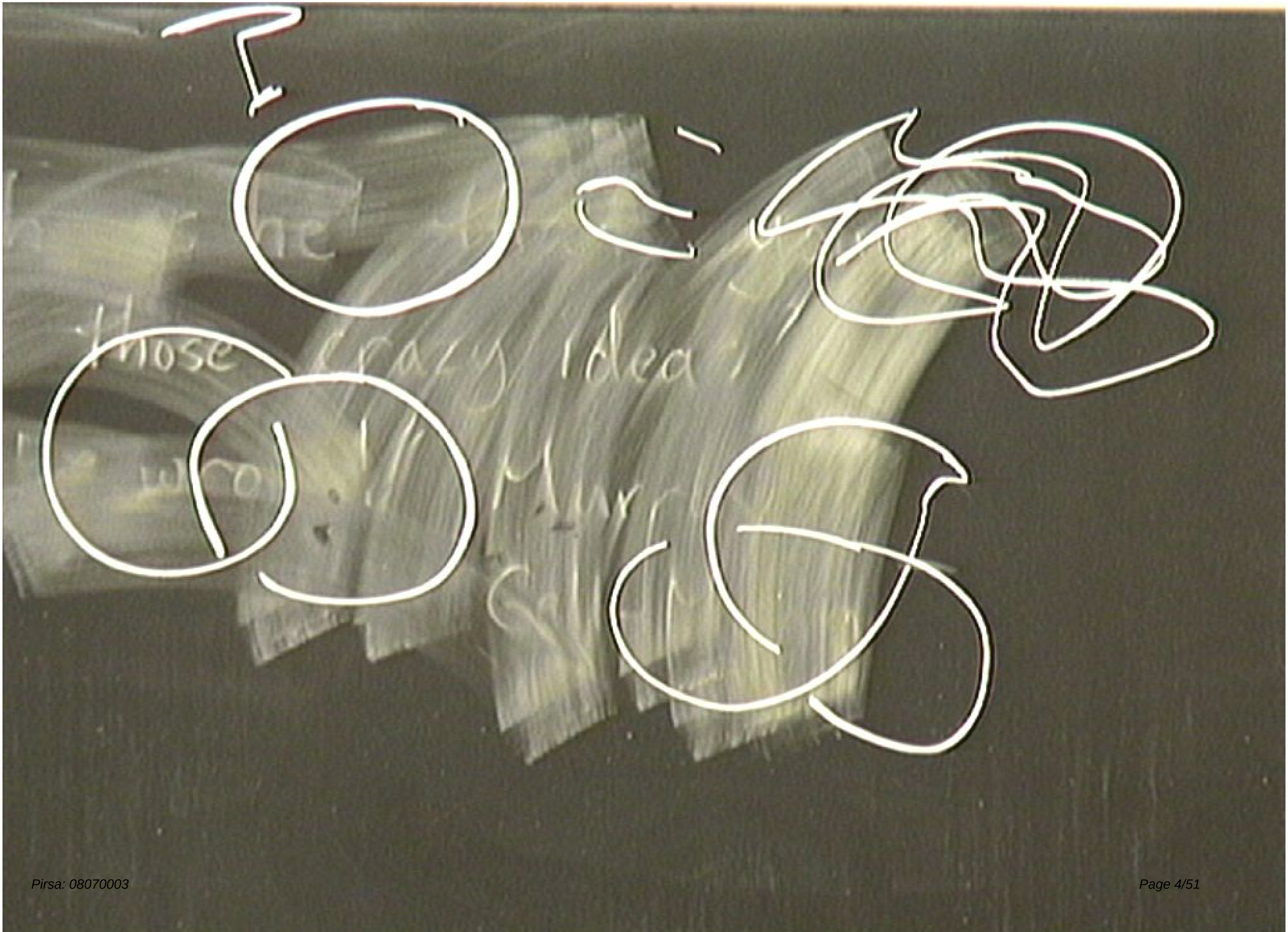
Abstract: Arguably, the most important issue in physics today is trying to unify the twin pillars of modern physics, quantum theory and general relativity, into a single theory known as quantum gravity. This introductory presentation will discuss various aspects of quantum gravity.


those crazy idea

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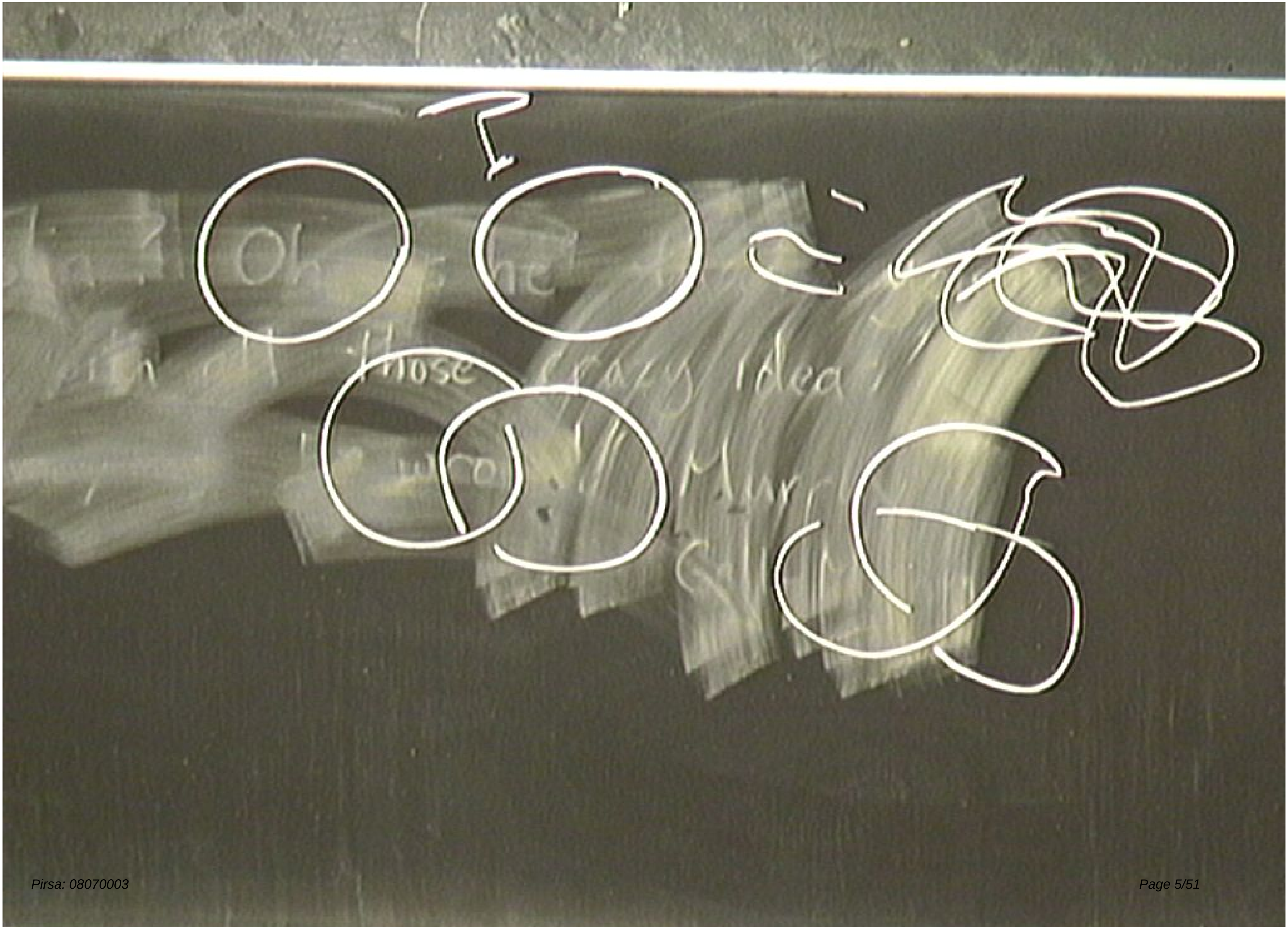


Theory of Principle

Theory of Principle

Framework & language for everything

Theory of Principle

Framework + language for everything

QM ✓

GR ✓

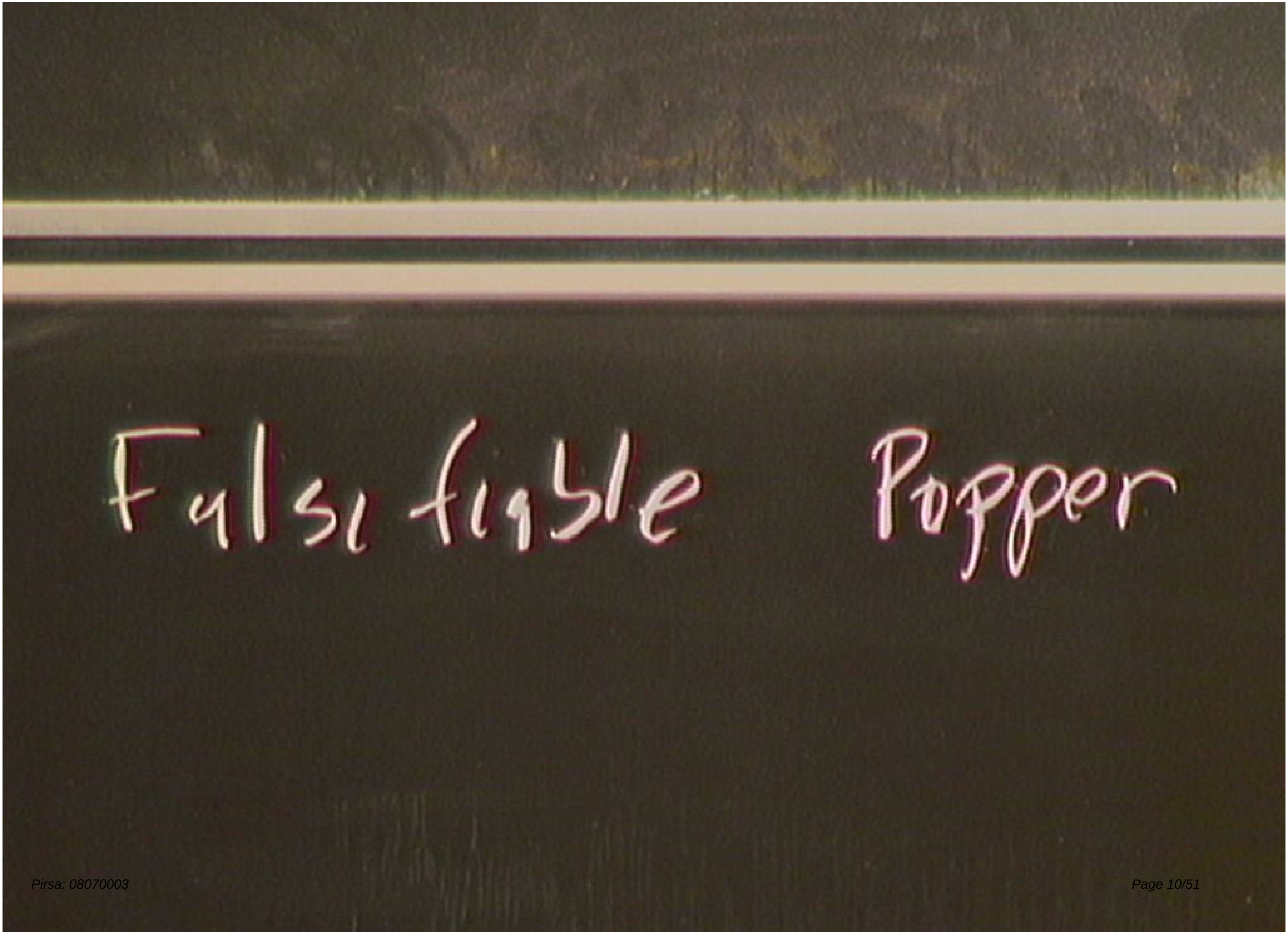
Theory of Principle

Framework & language for everything

QM ✓

GR ✓

⇒ replace/unify these into a single Theory of Principle


Falsifiable Popper

Theory of Principle

Framework + language for everything

QM ✓ – $\hbar$

GR ✓ G c

⇒ replace/unify these into a single Theory of Principle

Falsifiable Popper

$$\text{Pl length} = \sqrt{\frac{\hbar G}{c^3}} \approx 1.6 \times 10^{-33}\ \text{cm}$$

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Falsifiable Popper

$L_{Pl} =$

Pl length $= \sqrt{\frac{\hbar G}{c^3}} \approx 1.6 \times 10^{-33}$ cm $\sim 10^{-20}$ nuclei (fermi)

$T_{Pl} = \frac{L_{Pl}}{c} \sim 10^{-43}$ sec

$M_{Pl} c^2 \sim \frac{\hbar}{T_{Pl}} \sim 10^{19}$ Gev $\sim 10^{16}$ Tev $\sim$ LHC

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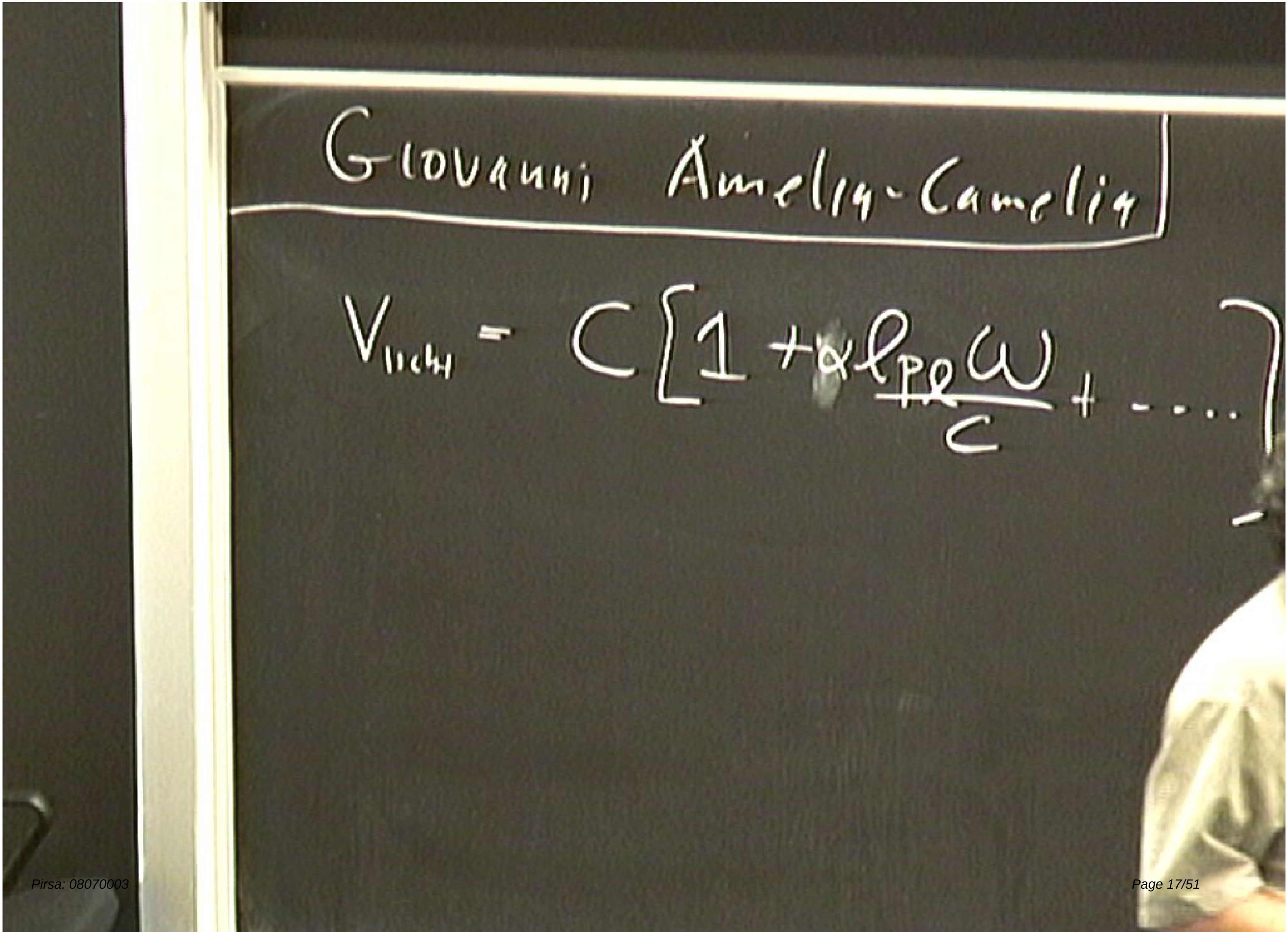
$M_{Pl} \sim 10^{-5}$ gm $\sim$ bacterium

Giovanni Ámelia-Camelia


Giovanni Amelia-Camelia
$V_{light} = c\left[1 + \alpha \frac{l_{Pl}\,\omega}{c} + \dots\right]$

Giovanni Amelia-Camelia

$$V_{light} = c\left[1 + \alpha \frac{l_{PL}\,\omega}{c} + \ldots\right]$$

Giovanni Amelia-Camelia

$$V_{light} = C\left[1 + \alpha \frac{l_{Pl}\,\omega}{c} + \beta \frac{l_{Pl}^2\,\omega^2}{c^2} + \dots\right]$$

ΔT

L

$\Delta \omega$

$$T = \frac{L}{V} = \frac{L}{c}\left(1 - \frac{\alpha \, l_{Pl}\, \omega}{c}\right)$$

$$\Delta T = -\frac{\alpha L \, l_{Pl} \, \Delta \omega}{c^2}$$

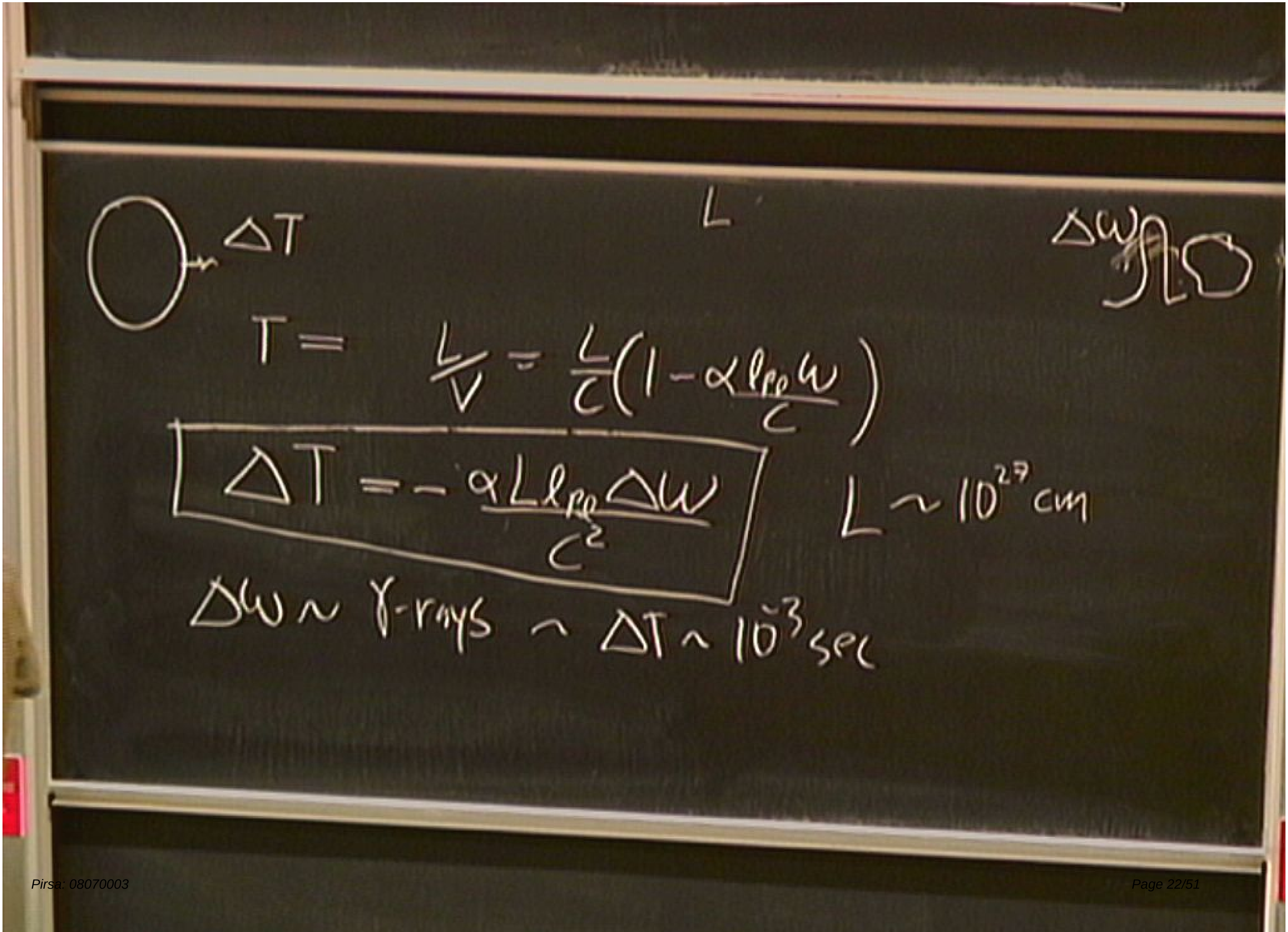
ΔT

L

$\Delta\omega$

$$T = \frac{L}{v} = \frac{L}{c}\left(1 - \alpha \frac{l_{Pl}\,\omega}{c}\right)$$

$$\boxed{\Delta T = -\frac{\alpha L\, l_{Pl}\, \Delta\omega}{c^2}}$$


ΔT
L
$\Delta\omega$
$T = L/V = \frac{L}{c}\left(1 - \alpha \frac{l_{Pl}\,\omega}{c}\right)$
$\Delta T = -\frac{\alpha L l_{Pl} \Delta\omega}{c^2}$
$L \sim 10^{27}$ cm
$\Delta\omega \sim \gamma$-rays $\sim \Delta T \sim 10^{-3}$ sec

Giovanni Amelino-Camelia

special relativity?

$$V_{light} = c\left[1 + \alpha \frac{l_{Pl}\,\omega}{c} + \beta \frac{l_{Pl}^2\,\omega^2}{c^2} + \dots\right]$$

10^{10} 10^{7} 10^{10}

L

ΔT

$\Delta\omega$

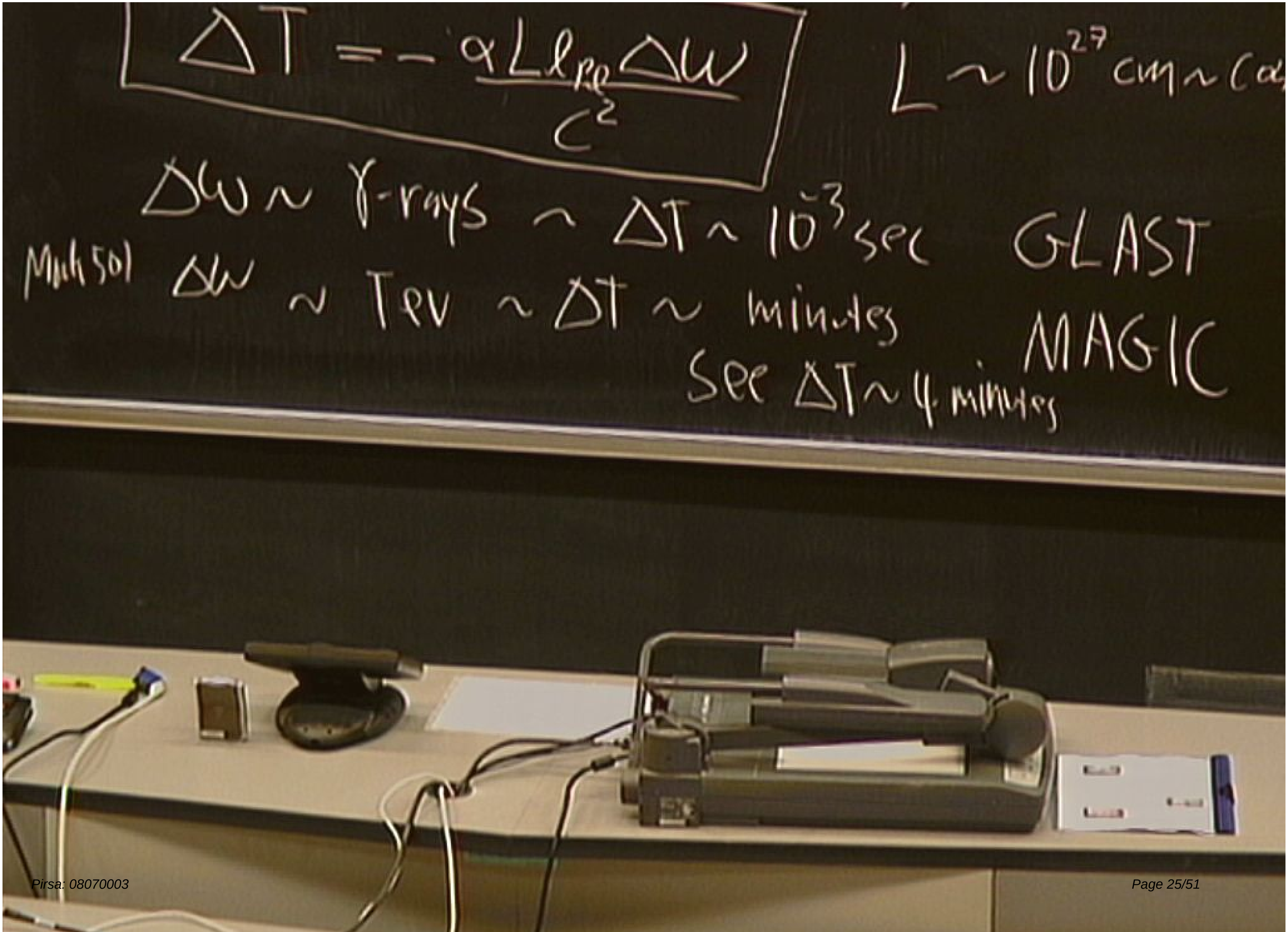
$$T = \frac{L}{V} = \frac{L}{c}\left(1 - \alpha \frac{\ell_{Pl}\,\omega}{c}\right)$$

$$\Delta T = -\alpha \frac{L\,\ell_{Pl}\,\Delta\omega}{c^2}$$

$L \sim 10^{27}$ cm $\sim$ Cosmology

$\Delta\omega \sim \gamma$-rays $\sim \Delta T \sim 10^{-3}$ sec GLAST

Mrk 501 $\Delta\omega \sim$ TeV $\sim \Delta T \sim$ minutes


$\Delta T = -\frac{\alpha L \ell_{Pl} \Delta W}{c^2}$
$L \sim 10^{27}$ cm ~
$\Delta W \sim \gamma$-rays ~ $\Delta T \sim 10^{-3}$ sec
GLAST
Mrk 501 ΔW ~ TeV ~ ΔT ~ minutes
MAGIC
See $\Delta T \sim 4$ minutes

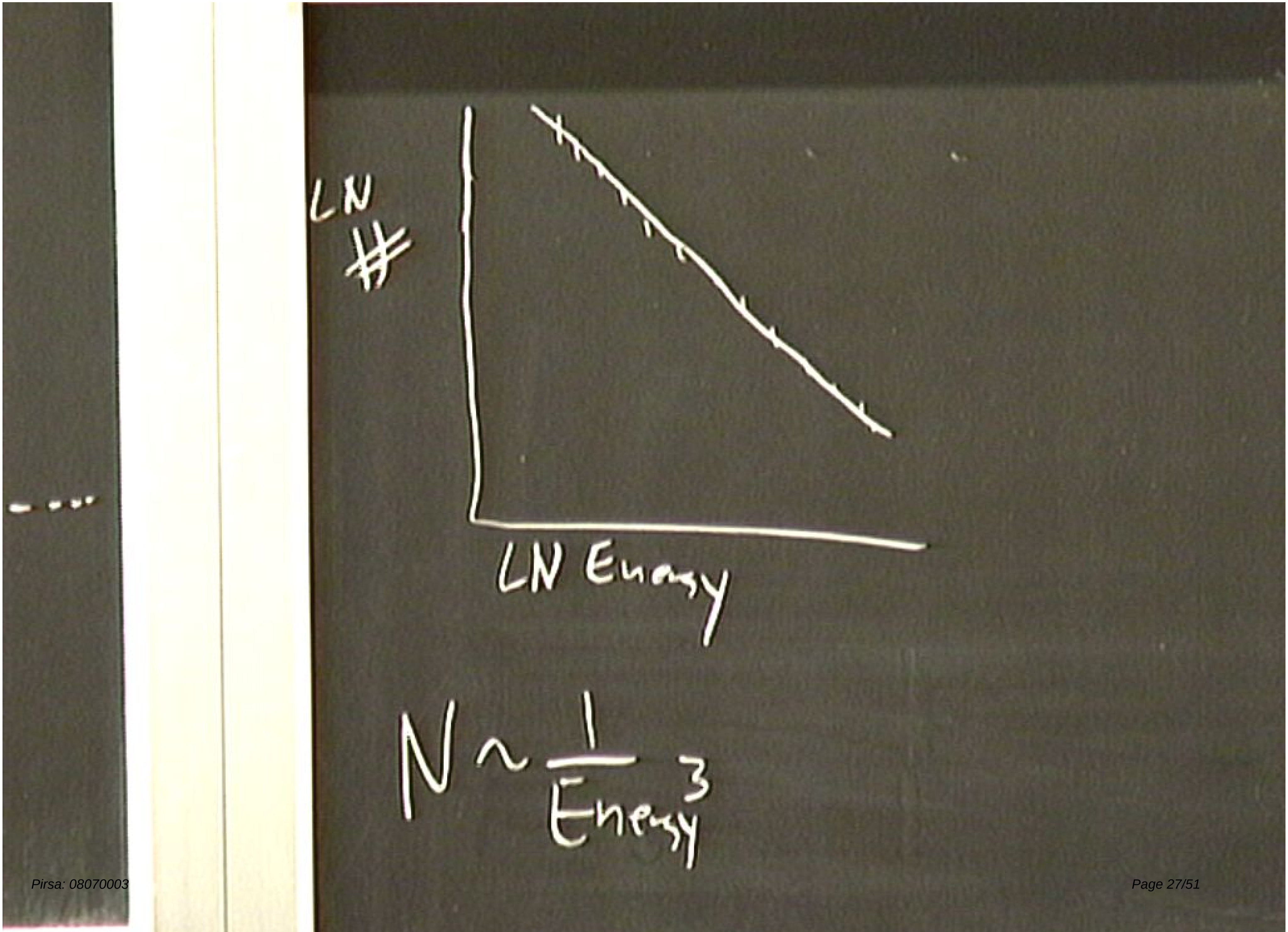
Giovanni Amelino-Camelia

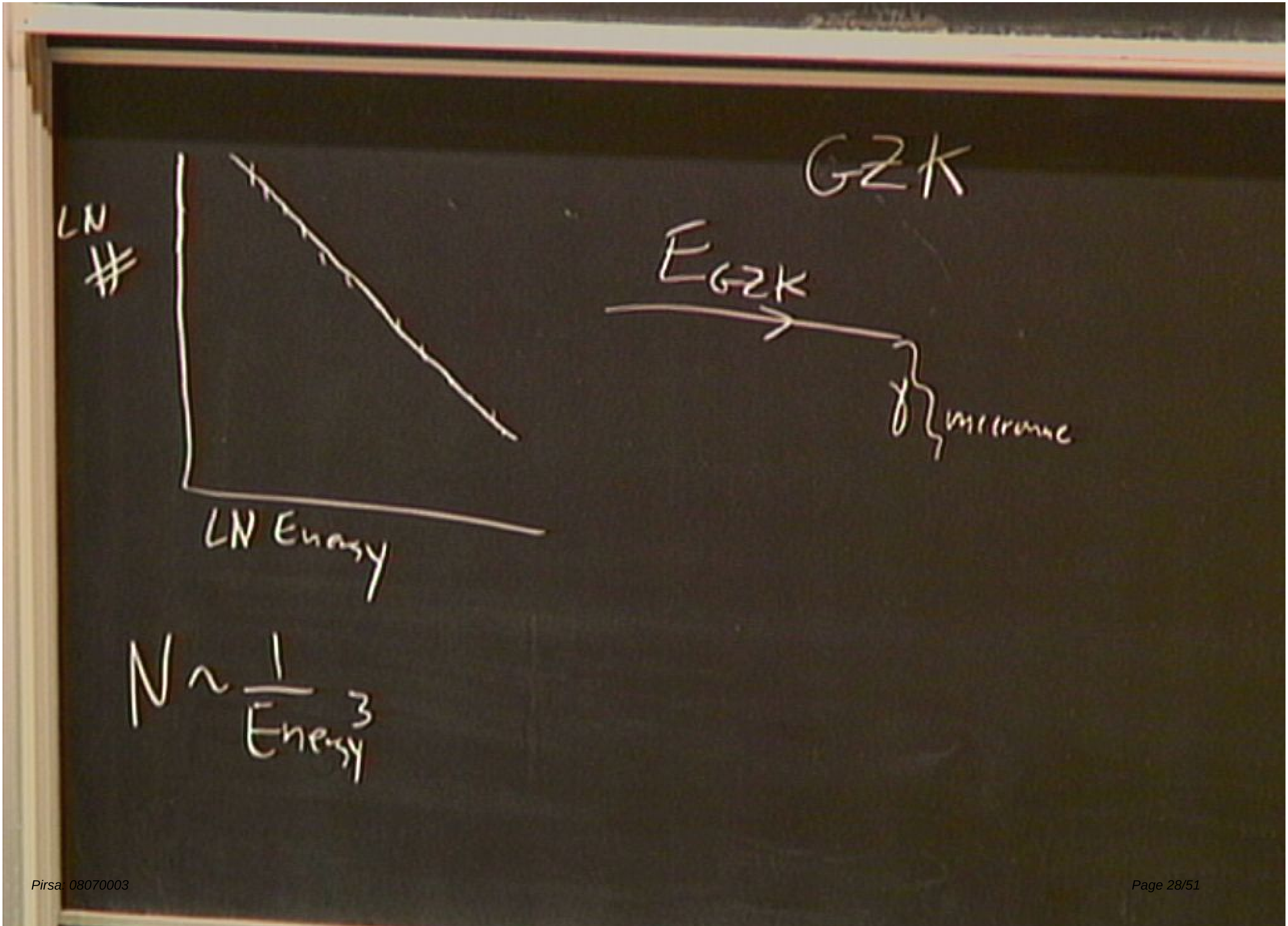
special relativity?

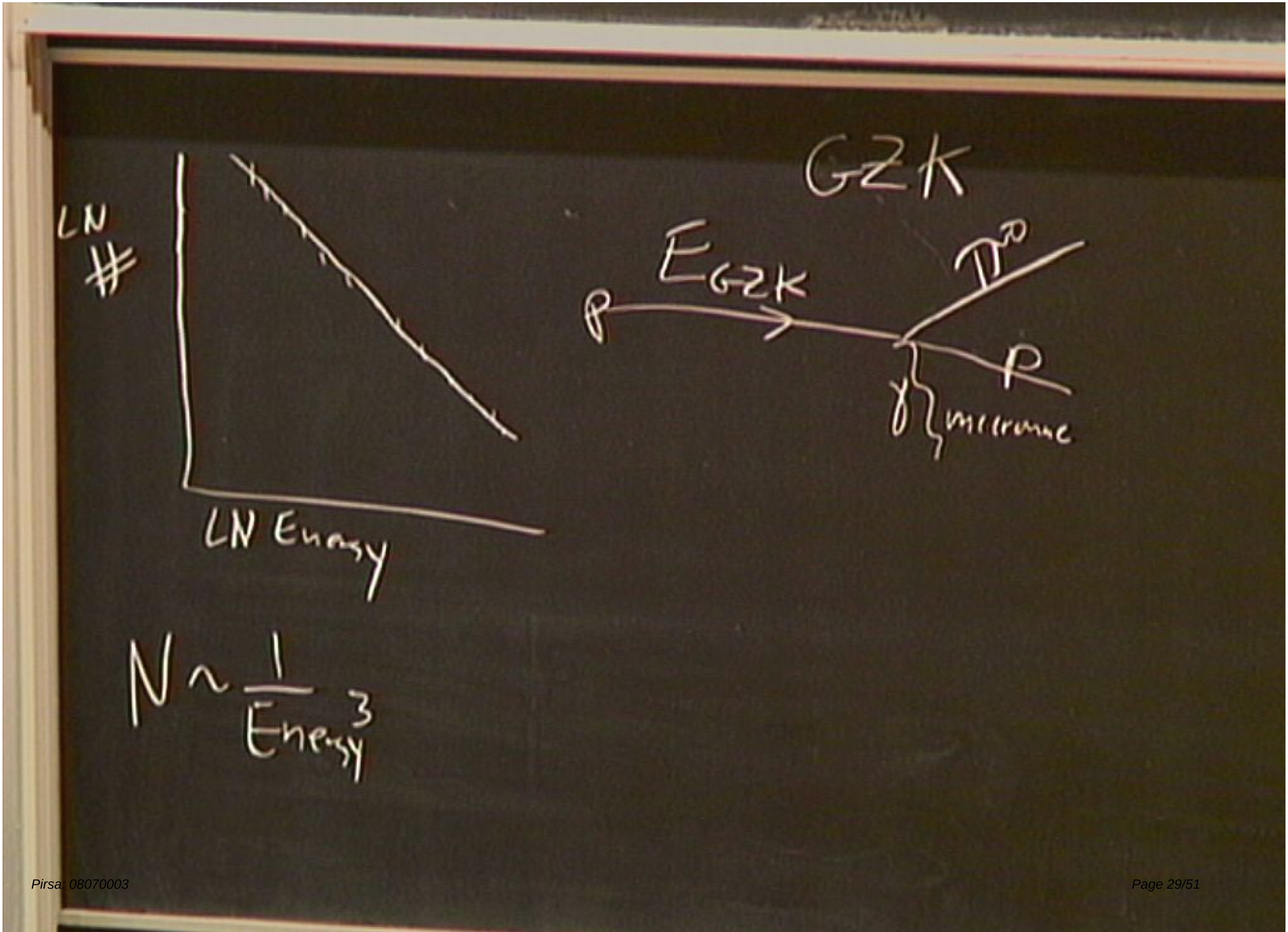
$$V_{light} = c\left[1 + \alpha \frac{l_{Pl}\,\omega}{c} + \beta \frac{l_{Pl}^2\,\omega^2}{c^2} + \dots\right]$$

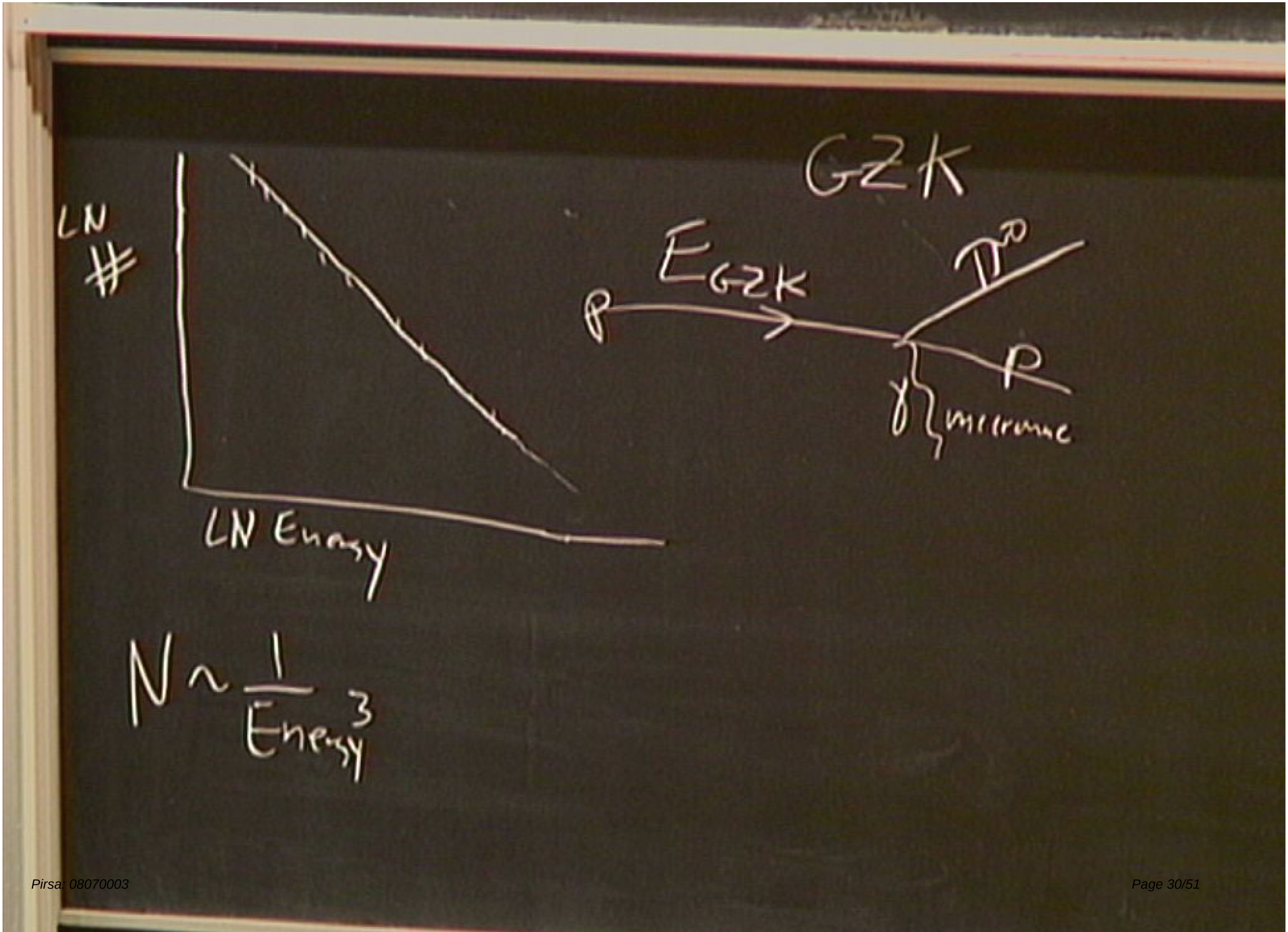
$$E^2 = p^2c^2 + m^2c^4 + \alpha \frac{l_{Pl}E^3}{\hbar} + \beta \frac{l_{Pl}^2 E^4}{\hbar^2} + \dots$$

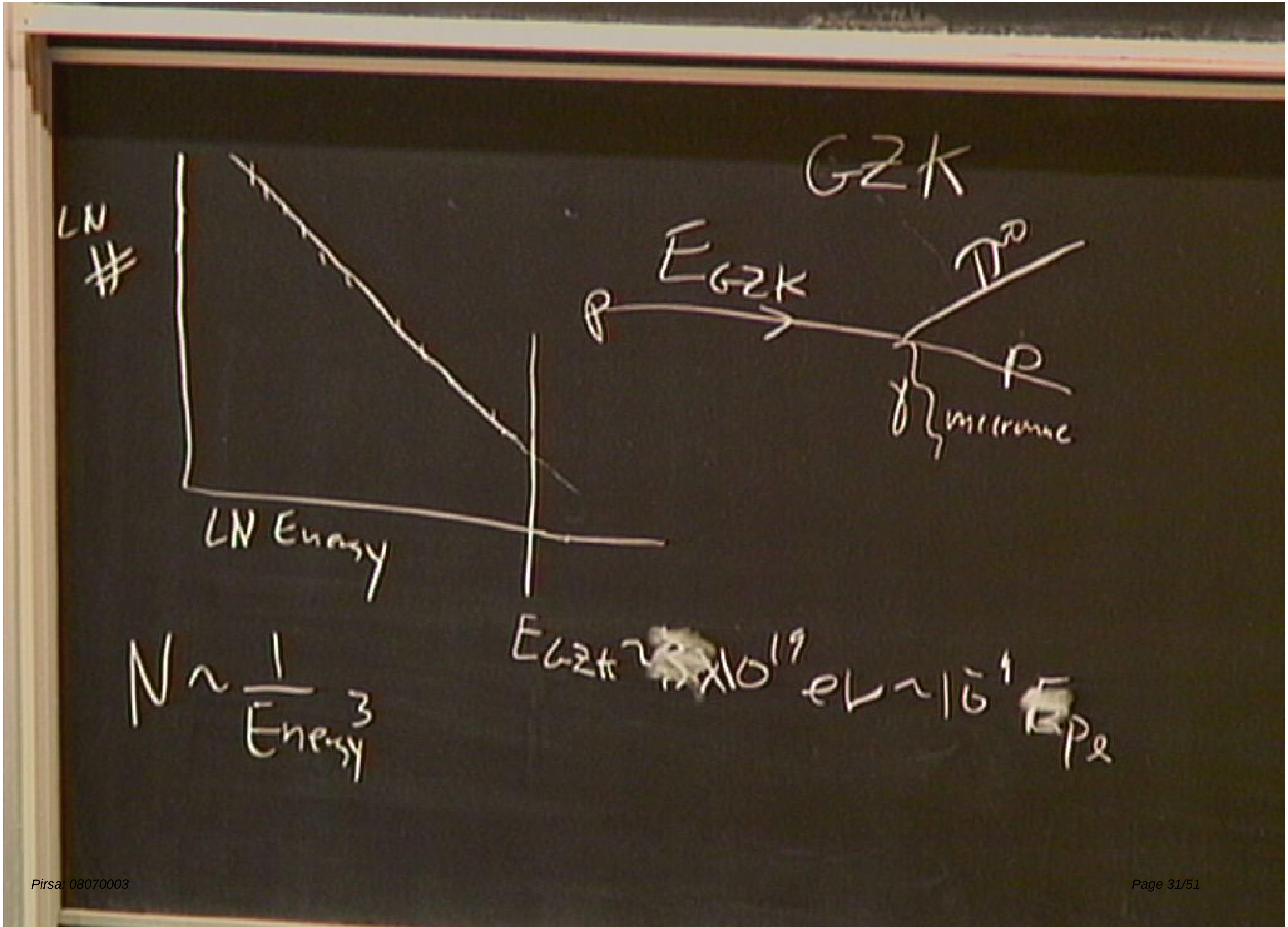
$$\text{speed} = \frac{dE}{dp} \qquad E = \hbar\omega$$

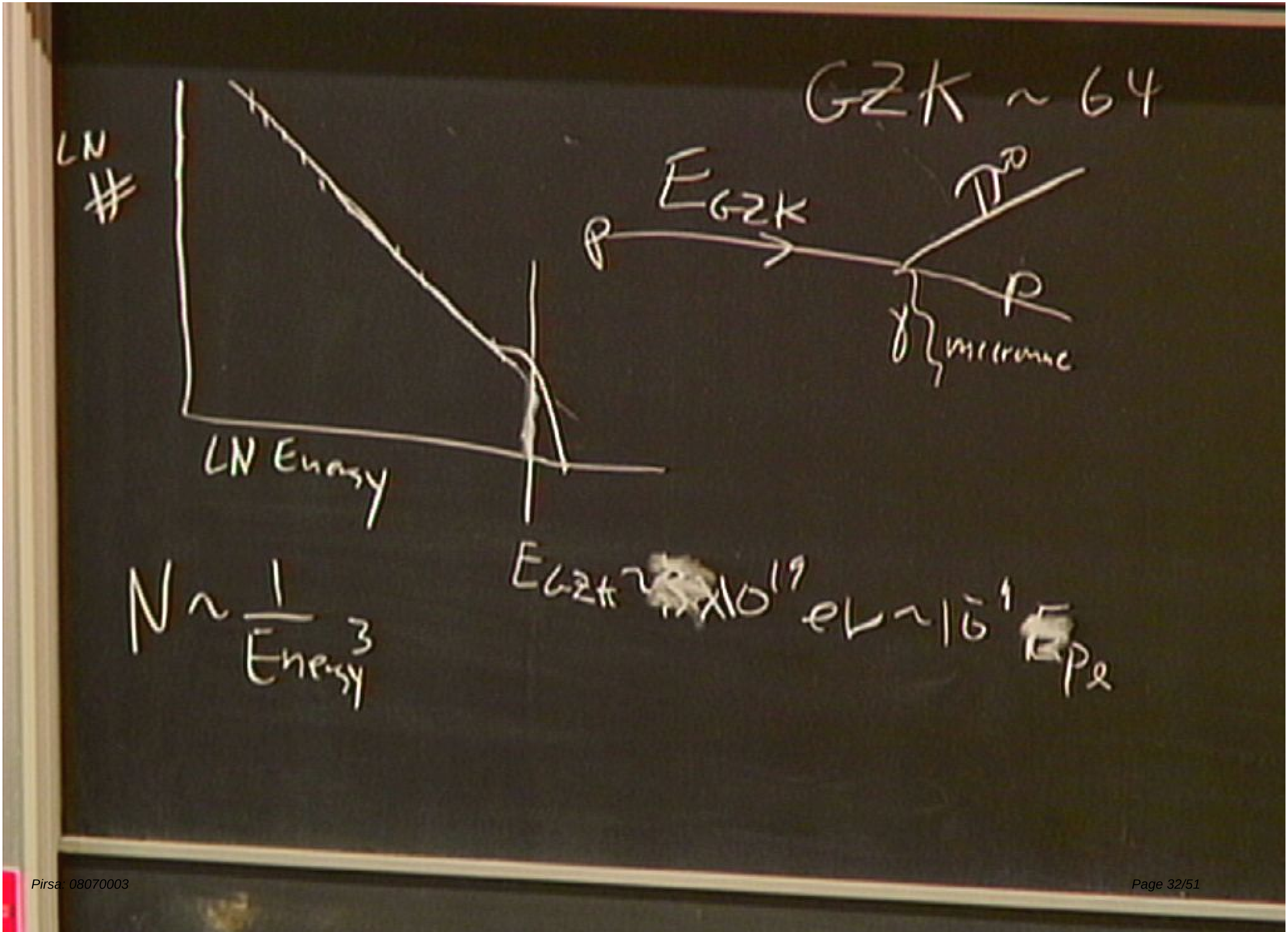

LN #
LN Energy
N ~ 1/Energy³

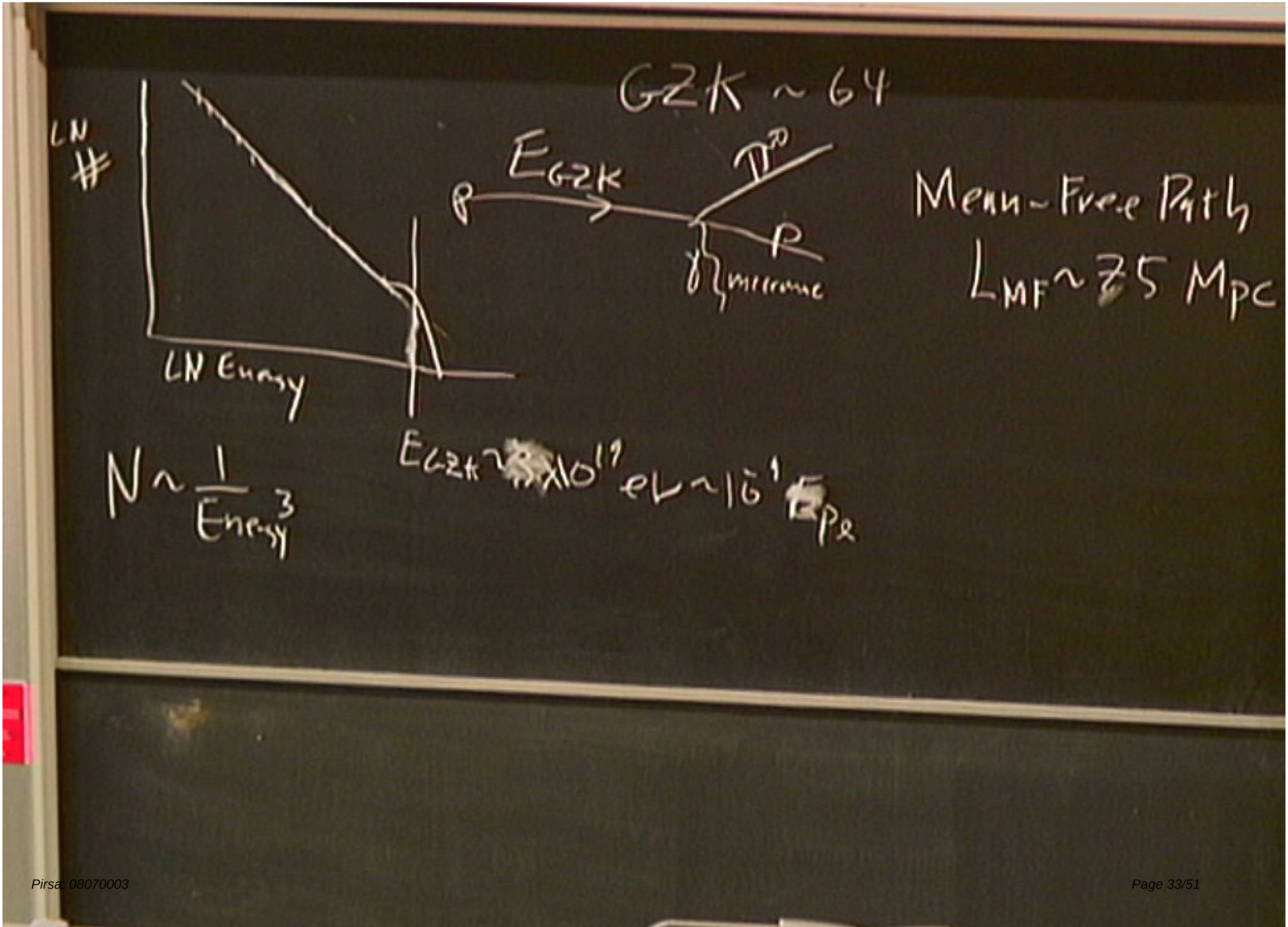

LN #
LN Energy
GZK
E_{GZK}
γ microwave
$N \sim \frac{1}{Energy^3}$

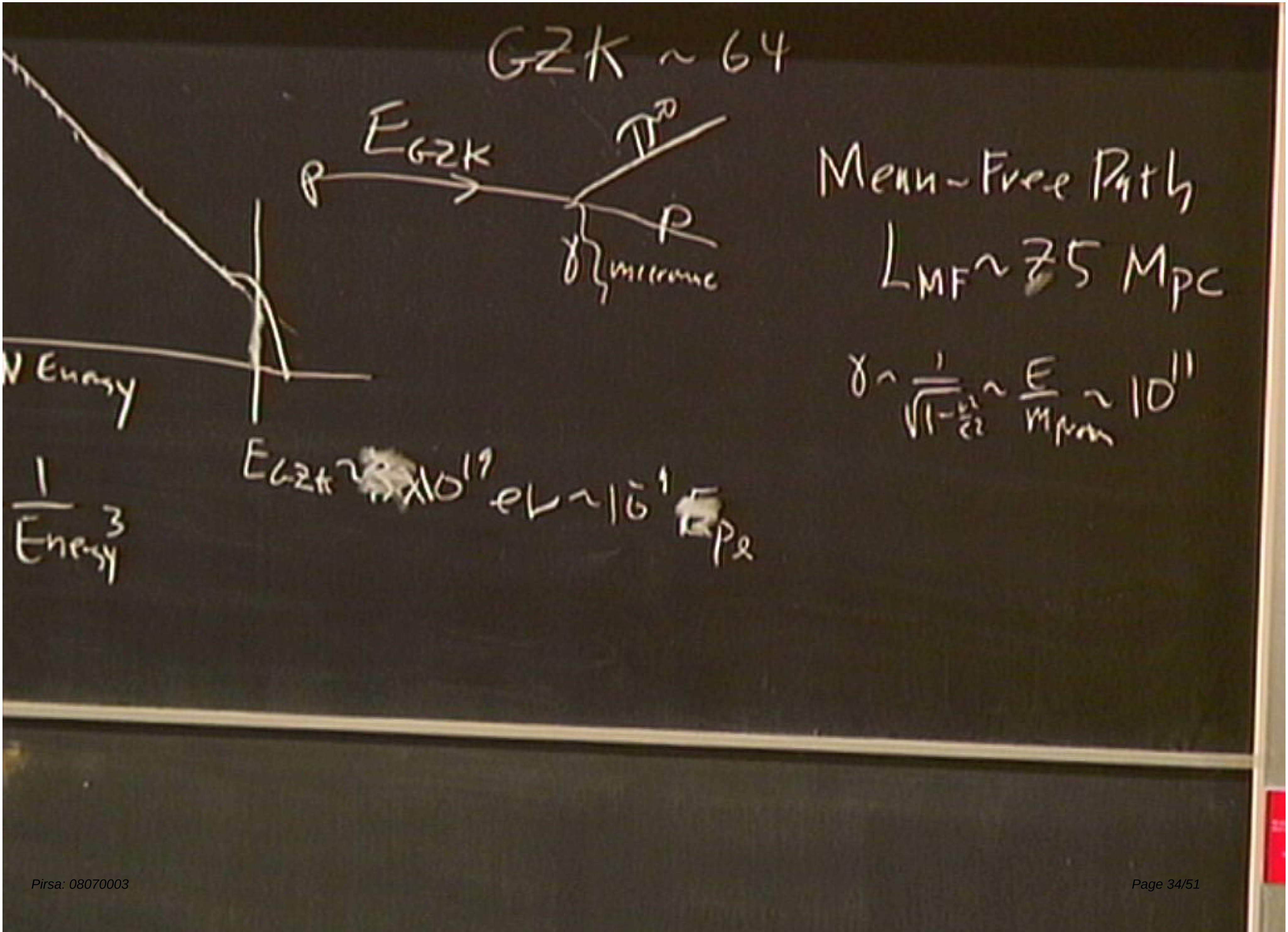

LN #
LN Energy
GZK
E GZK
p
π0
p
γ
microwave
N ~ 1/Energy 3

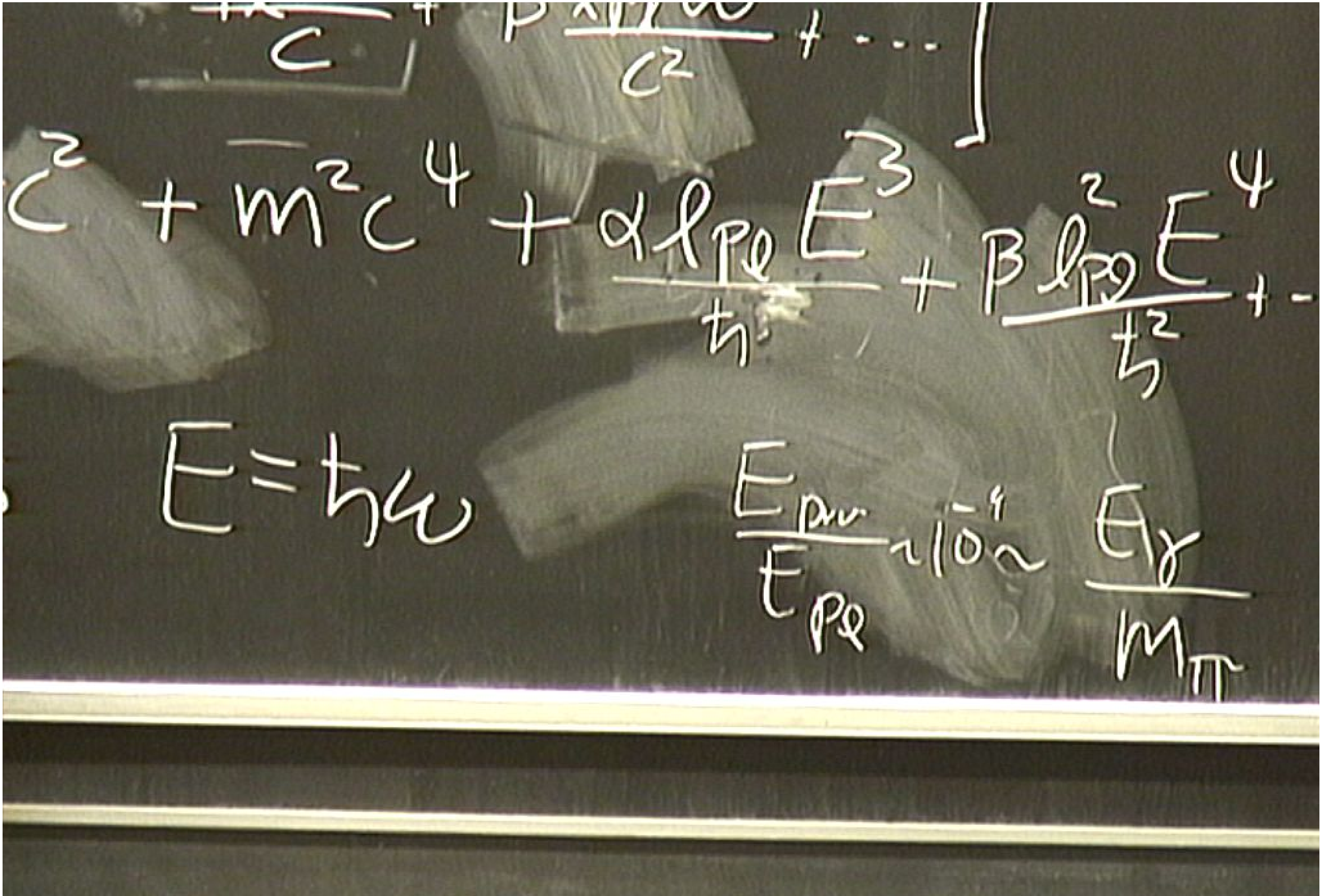

GZK
E GZK
p
π0
p
γ
microwave
LN #
LN Energy
N ~ 1 / Energy3

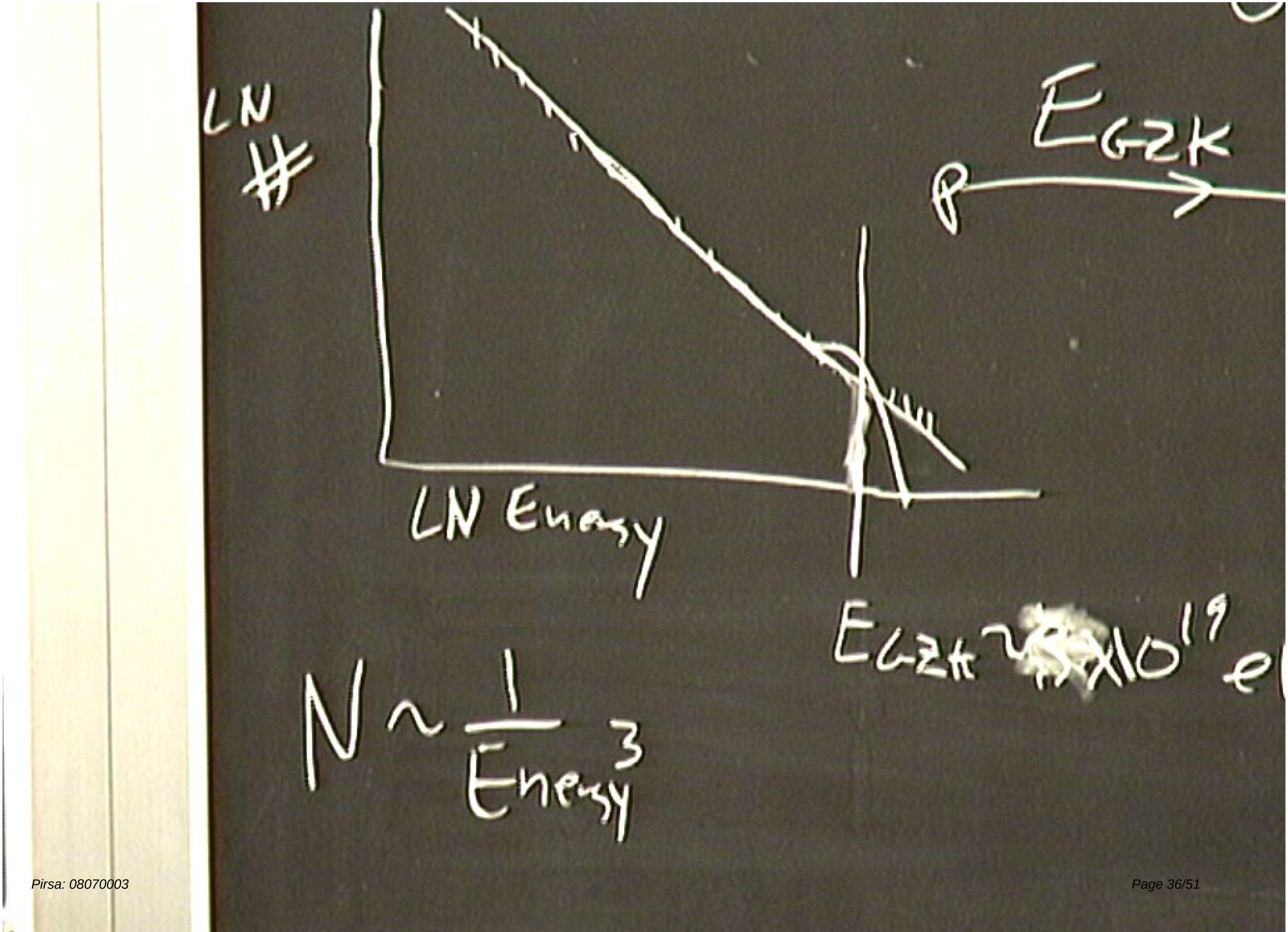

GZK
LN #
LN Energy
E GZK
p
π0
p
γ
microwave
N ~ 1/Energy^3
E GZK ~ x10^19 eV ~ 10^-9 E Pl

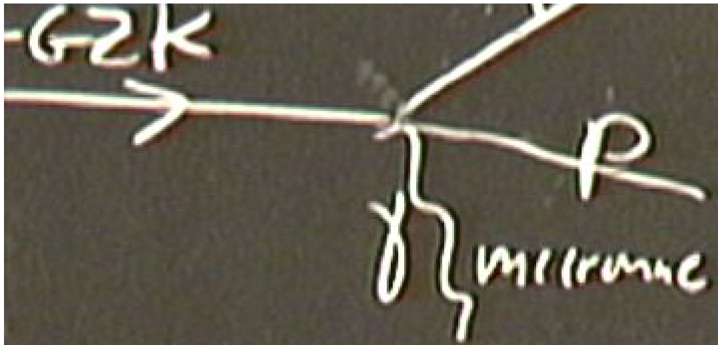

GZK ~ 64
LN #
LN Energy
E GZK
p
π0
p
γ microwave
N ~ 1 / Energy3
EGZK ~ x10^19 eV ~ 10^-9 Pl


GZK ~ 64
LN #
LN Energy
E_GZK
p
π⁰
p
γ microwave
Mean-Free Path
Mpc
N ~ 1/Energy³


GZK ~ 64
E GZK
p
π0
p
γ microwave
Mean-Free Path
L MF ~ 75 Mpc
γ ~ 1/√(1 - v²/c²) ~ E/m prot ~ 10^11
Energy
1/Energy^3
E GZK ~ x10^19 eV ~ 10^-9 E Pl


$c^2 + m^2c^4 + \alpha \frac{l_{Pl} E^3}{\hbar} + \beta \frac{l_{Pl}^2 E^4}{\hbar^2} + \cdots$
$E = \hbar\omega$


LN
#
EGZK
p
LN Energy
EGZK ~ x10^19 e
N ~ 1/Energy^3



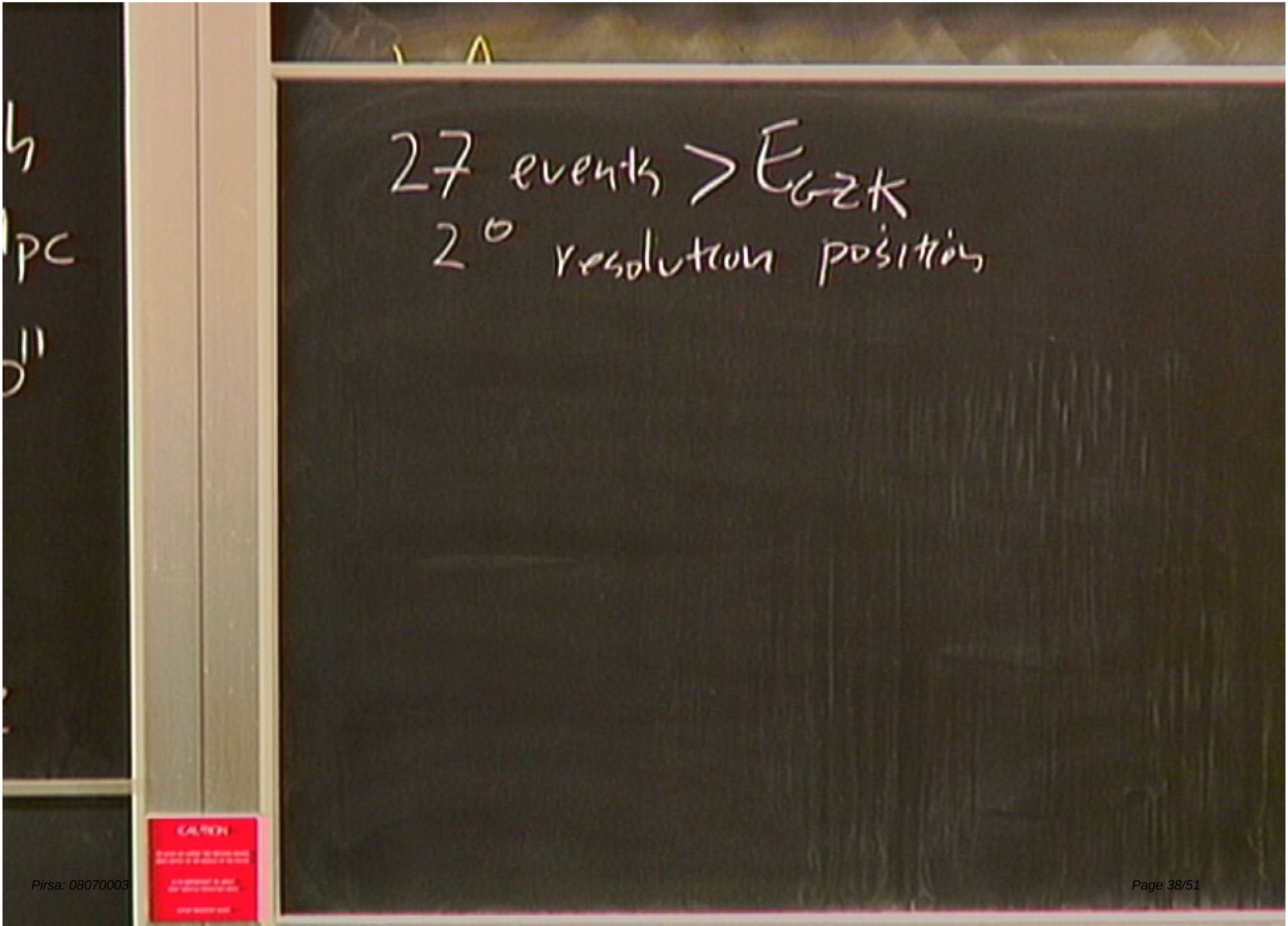
Mean-free path

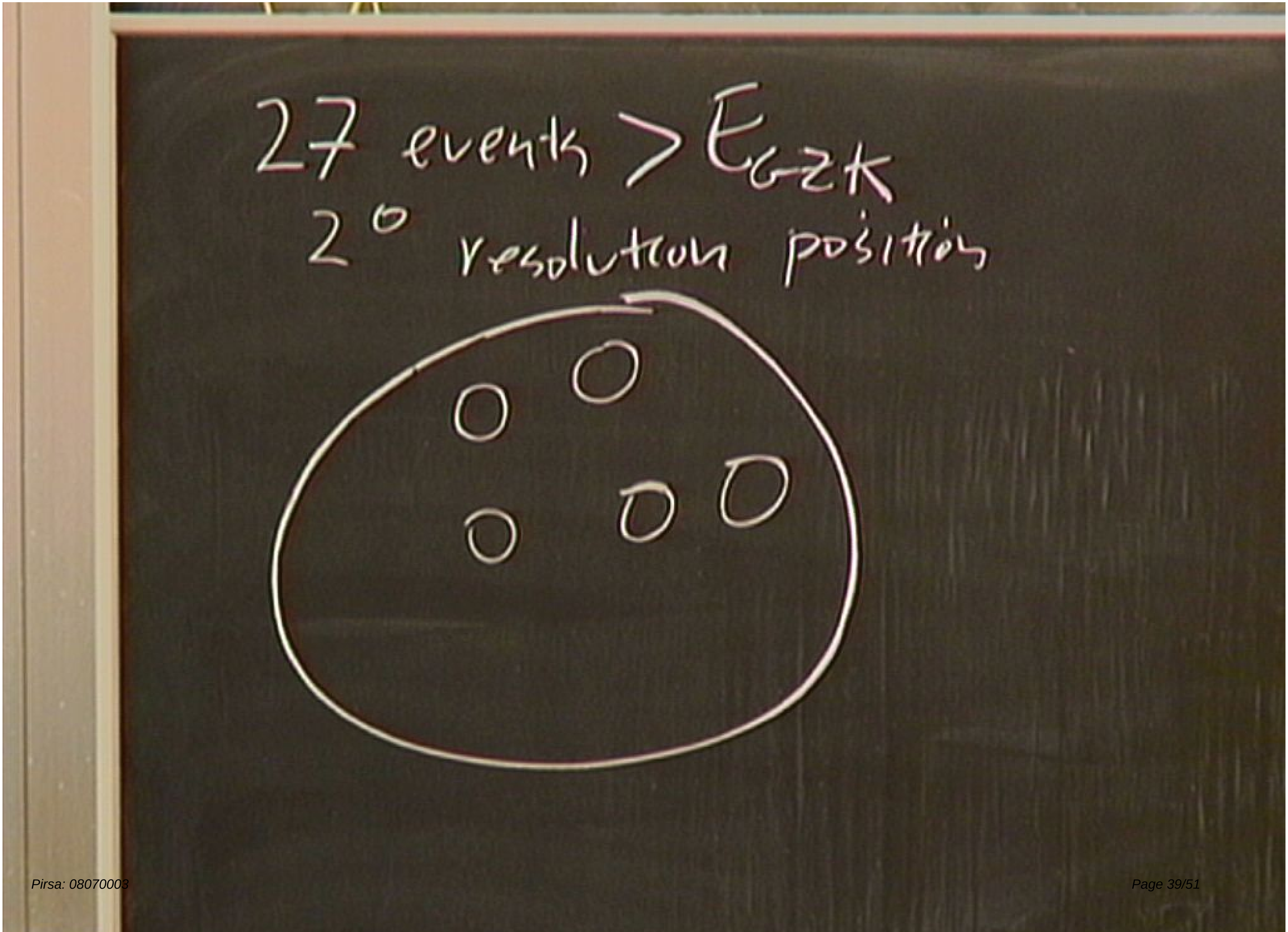
$L_{MF} \sim 75$ Mpc

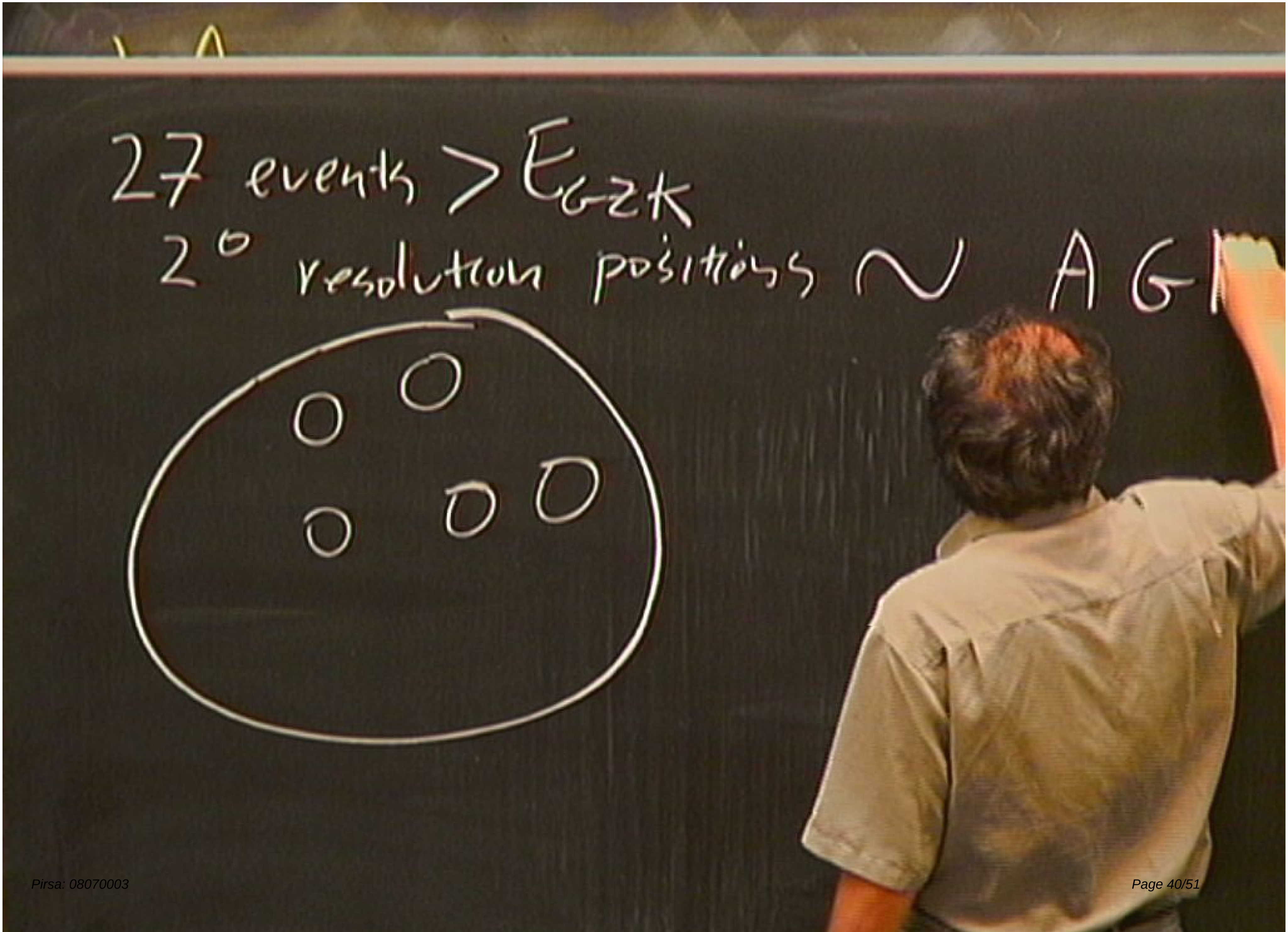
$\gamma \sim \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \sim \frac{E}{m_{proton}} \sim 10^{11}$

$\times 10^{19}$ eV $\sim 10^{-4} E_{Pl}$

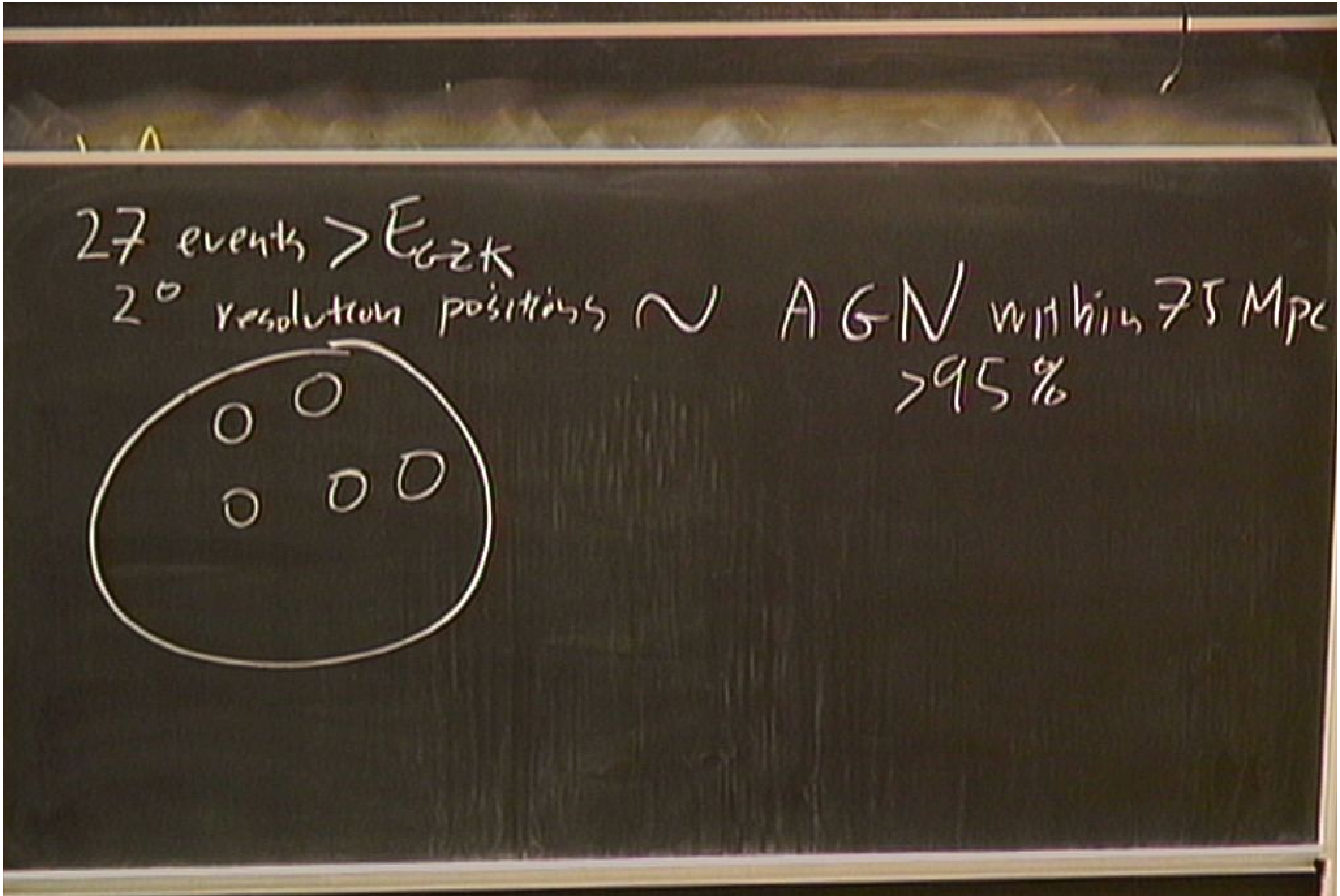
AUGER


27 events > E GZK
2° resolution position


27 events > E_GZK
2° resolution position



27 events > E_GZK
2° resolution positions ~ AG


27 events > E_GZK
2° resolution positions ~ AGN within 75 Mpc
>95%

Prin of SR

1 The relativity of inertial frames

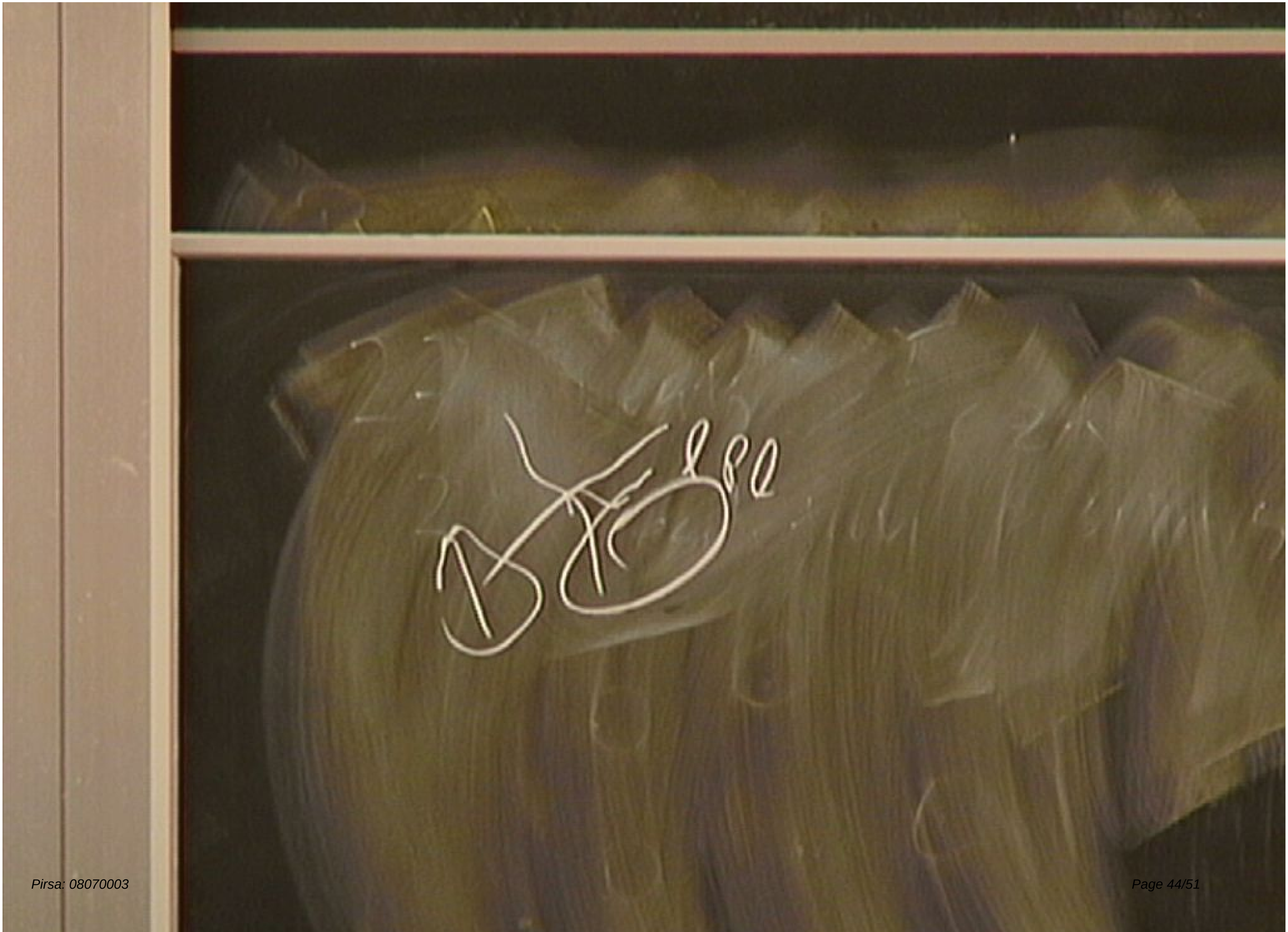
2 "the speed of light" is a universal constan[t]

Prin of SR

1 The relativity of inertial frames

2 "the speed of light" is a universal constant

3 ? is also a universal constant?



Prin of SR

1 The relativity of inertial frames

2 "the speed of light" is a universal constant

3 L_{Pl}, T_{Pl}, E_{Pl} be universal?

Prin of SR

1. The relativity of inertial frames
2. "the speed of light" is a universal constant
3. L_{Pl}, T_{Pl}, E_{Pl} be universal? $\frac{l_P \omega}{c} = \frac{l_P}{\lambda}$
4. c is the speed of a photon in the limit as $\frac{l_{Pl}}{\lambda} \to 0$

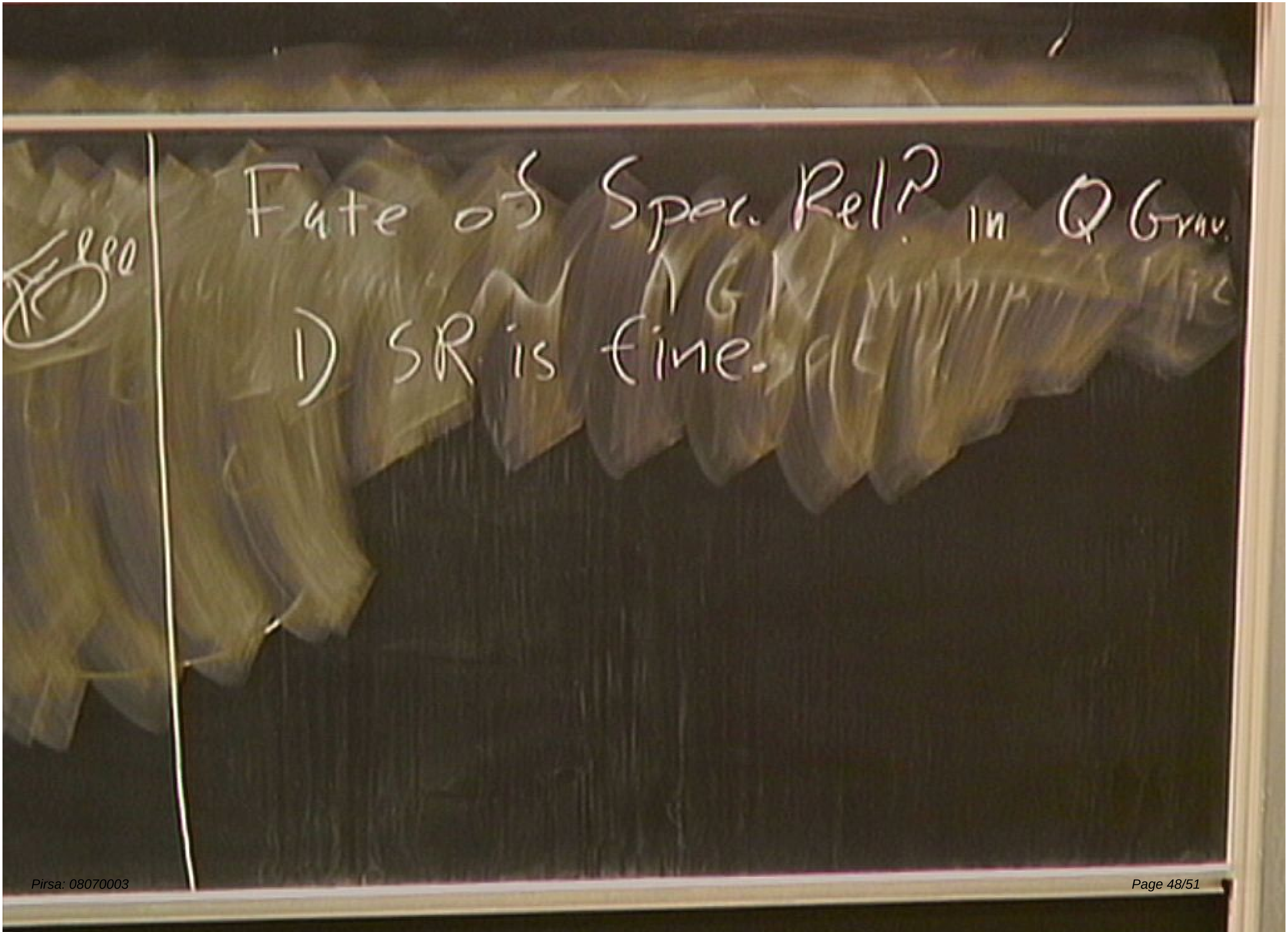
Prin of DSR

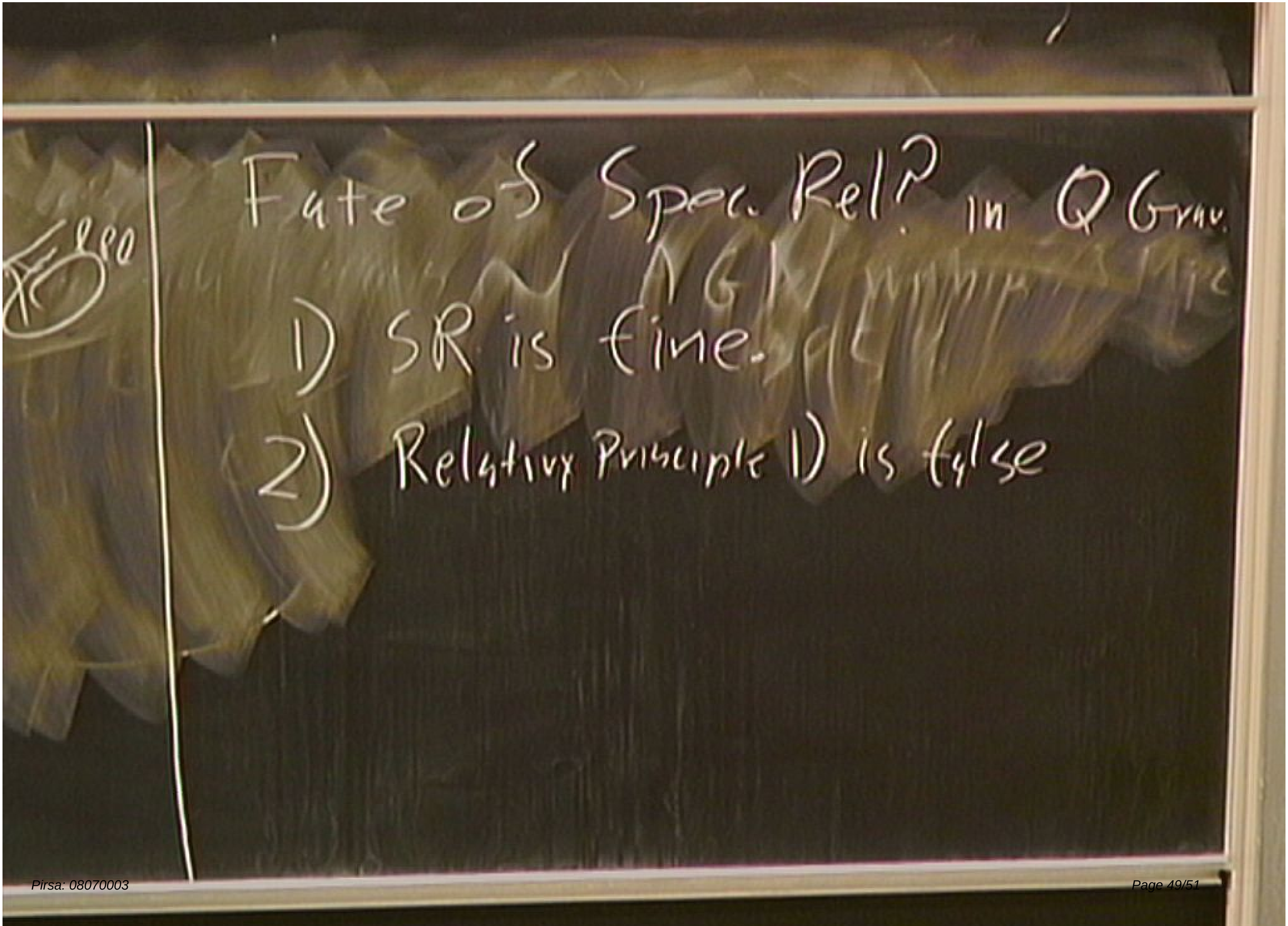
1. The relativity of inertial frames

2. "the speed of light" is a universal constant

3. L_{Pl}, T_{Pl}, E_{Pl} be universal? $\frac{l_P \omega}{c} = \frac{l_P}{\lambda}$

4. c is the speed of a photon in the limit as $\frac{l_{Pl}}{\lambda} \to 0$


Fate of Spec. Rel? in Q Grav.
1) SR is fine.


Fate of Spec. Rel? in Q Grav.
1) SR is fine.
2) Relativity Principle 1) is false

Fate of Spec. Rel? in Q Grav.

1) SR is fine.

2) Relativity Principle 1) is false

3) DSR

Fate of Spec. Rel? in Q Grav.

1) SR is fine.

2) Relativity Principle 1) is false
⇓ no GZK

3) DSR