Title: Conformal SUSY Breaking and Cosmological Constant

Date: Jun 02, 2008 11:15 AM

URL: http://pirsa.org/07050089

Abstract:

Conformal SUSY Breaking and Cosmological Constant

T.T.Yanagida

Tokyo, IPMU

Cosmological Constant

$$\Lambda \simeq M_{\mathrm{PL}}^4 \simeq 10^{73}\,\mathrm{GeV}^4 \quad \text{theory}$$

$$\Lambda_{\mathrm{observation}} \simeq 10^{-47}\,\mathrm{GeV}^4$$

We need a Fine Tuning of about order 120 of magnitude!!!

Anthropic principle

Weinberg

Before accepting it, we try to find out

underlying physics for

$$\Lambda \ll M_{\rm PL}^4$$

Supergravity

$$\Lambda_{\mathrm{cosm}} \equiv V = (\Lambda_{\mathrm{SUSY}})^4 - \frac{3}{M_{\mathrm{PL}}^2}|W|^2$$

$$|W| \simeq M_{\mathrm{PL}}^3$$

$$\Lambda_{\mathrm{cosm}} \simeq -M_{\mathrm{PL}}^4$$

We need a fine tuning of order 120

still!

$$\Lambda_{\mathrm{cosm}} = 0 \longrightarrow \Lambda^4_{\mathrm{SUSY}} = 3|W|^2$$

$$(M_{\mathrm{PL}} = 1)$$

$W \neq 0 \quad \longleftarrow \quad$ R-symmetry breaking

The SUSY and R-symmetry breakings should be closely linked

Superconformal Theory

Conformal SUSY Breaking

Ibe, Nakayama, T.T.Y

SUSY breaking sector Q

$$+$$

Massive quarks P

In the massless limit the hidden gauge theory has an infrared fixed point

An example

SUSY breaking sector:

SO(10) + one $Q(\mathbf{16})$

Affleck, Dine, Seiberg

Murayama

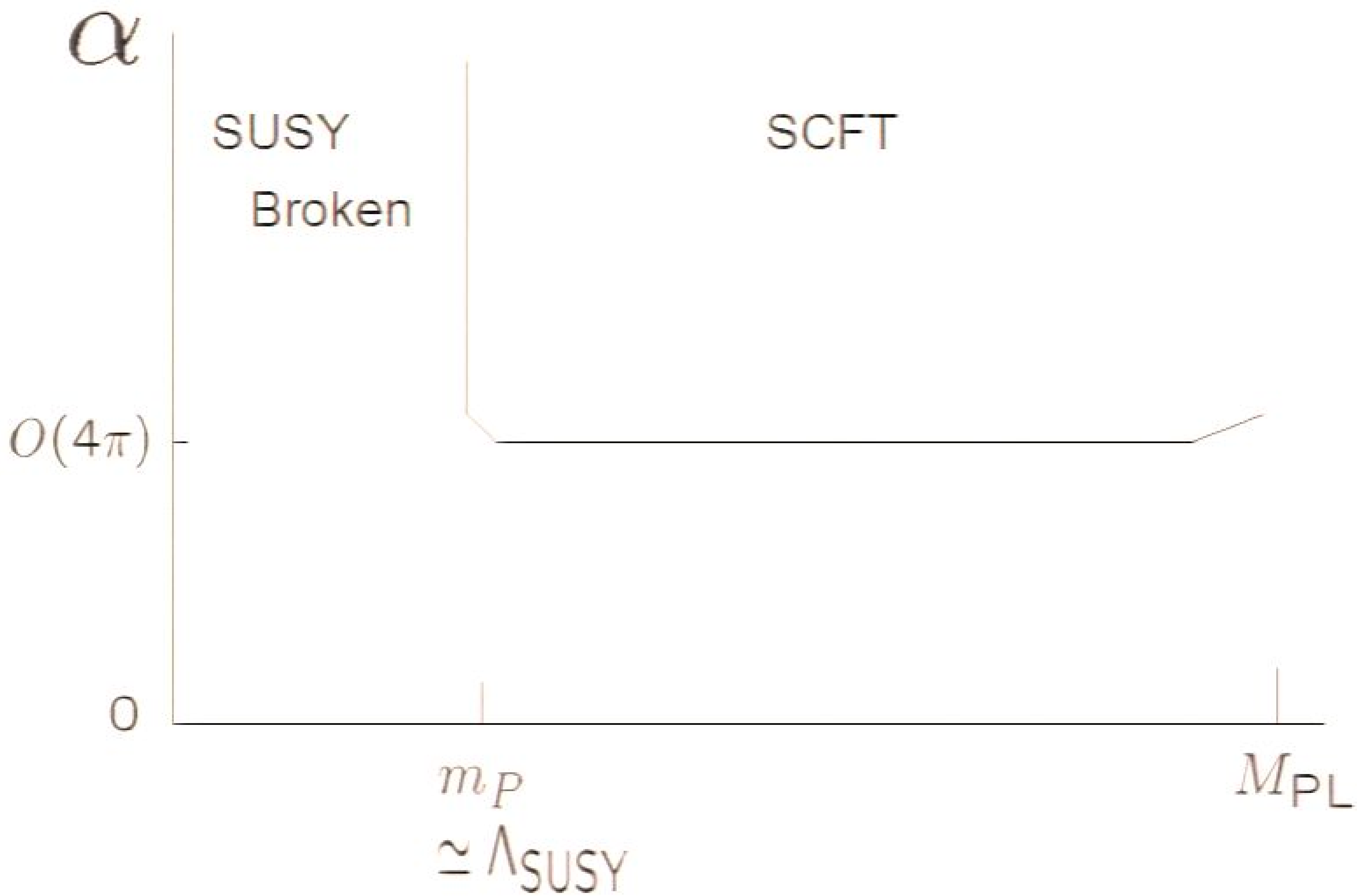
Add massive quarks $P^i(\mathbf{10})$ $\quad i = 1 - N_F$

For $7 < N_F < 21$ the theory is in a conformal window

Seiberg

$\gamma_P = -0.97$ for $N_F = 10$

The gauge coupling running



We take R charge =0 for P, then we have no mass parameter, as long as W=0

In the limit of vanishing W, the theory is just a SCFT and no dynamical SUSY breaking occurs

Now we introduce a small constant term in W that is a R breaking

$$W = c_0 = m_{3/2} M_{\mathrm{PL}}^2$$

Then, the quarks P have a small mass through a possible superpotential

$$W = c_0 \times PP \qquad (M_{\mathrm{PL}} = 1)$$
$$= m_{3/2} PP$$

We have

$$\Lambda_{\mathrm{SUSY}} \simeq m_P = m_{3/2}$$

Too small

$$V = \Lambda^4_{\mathsf{SUSY}} - 3m^2_{3/2}M^2_{\mathsf{PL}} \neq 0$$

But the mass $m_P(\mu)$ rapidly increases at low energies due to the large anomalous dimension γ_P

$$m_P(\mu) \simeq (\frac{\mu}{M_{\mathsf{PL}}})^{\gamma_P} m^0_P \qquad (m^0_P \simeq m_{3/2})$$

For $\gamma_P = -1$ we obtain

$$\Lambda_{\mathsf{SUSY}} \simeq m_P \simeq \sqrt{m_{3/2}M_{\mathsf{PL}}}$$

We naturally get the cancellation $V \simeq 0$

Now we introduce a small constant term in W that is a R breaking

$$W = c_0 = m_{3/2} M_{\mathrm{PL}}^2$$

Then, the quarks P have a small mass through a possible superpotential

$$W = c_0 \times PP \qquad (M_{\mathrm{PL}} = 1)$$
$$= m_{3/2} PP$$

We have

$$\Lambda_{\mathrm{SUSY}} \simeq m_P = m_{3/2}$$

Too small

$$V = \Lambda_{\mathsf{SUSY}}^4 - 3m_{3/2}^2 M_{\mathsf{PL}}^2 \neq 0$$

But the mass $m_P(\mu)$ rapidly increases at low energies due to the large anomalous dimension γ_P

$$m_P(\mu) \simeq (\frac{\mu}{M_{\mathsf{PL}}})^{\gamma_P} m_P^0 \qquad (m_P^0 \simeq m_{3/2})$$

For $\gamma_P = -1$ we obtain

$$\Lambda_{\mathsf{SUSY}} \simeq m_P \simeq \sqrt{m_{3/2} M_{\mathsf{PL}}}$$

We naturally get the cancellation $V \simeq 0$

Examples for $\gamma_P \simeq -1$ theory

- SO(10) with one $Q(\mathbf{16}) + 10\ P(\mathbf{10})$

$$\gamma_P = -0.97$$

- SP(3)×SP(1)×SP(1) with

$$8\ Q(\mathbf{6}, \mathbf{1}, \mathbf{1}) + 1\ P(\mathbf{6}, \mathbf{2}, \mathbf{1}) + 1\ P(\mathbf{6}, \mathbf{1}, \mathbf{2})$$

$$\gamma_P = -1$$

$\gamma_P \simeq -1$ theory is interesting !!

But, $\Lambda_{\text{cosm}} \simeq \Lambda_{\text{SUSY}}^4 \simeq m_{3/2}^2$

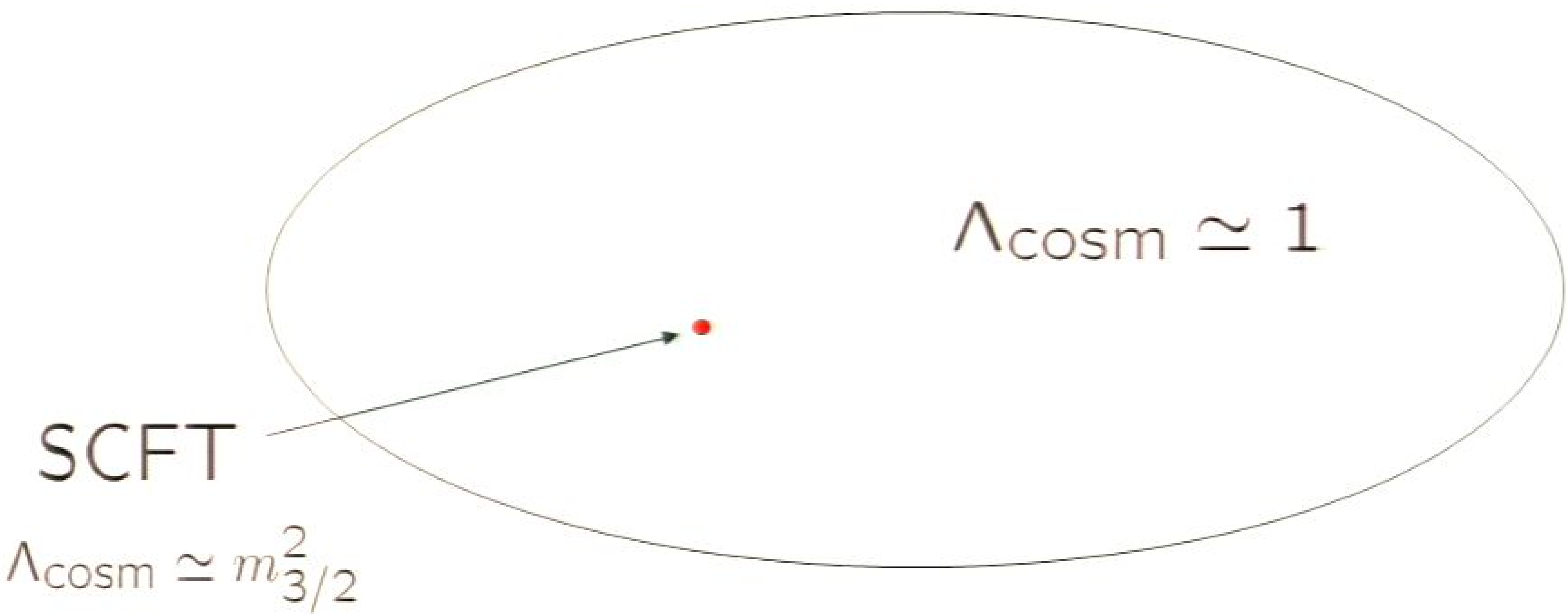
$$\simeq 10^{-30} - 10^{-60}$$

We need further mechanisms to reduce Λ_{cosm}

OR

to invoke the anthropic principle

A phenomenological reason why we believe the SCFT was chosen



Landscape

The SCFT with $\gamma_P \simeq -1$

$\longrightarrow$ Solution to the Polonyi (Moduli) Problem in SUSY breaking vacua

The Polonyi Problem

C.F.K.R.R.

SUSY is broken by non vanishing F term of S

$$W_{\text{eff}} = \Lambda^2_{\text{SUSY}} S \quad \rightarrow F_S = \Lambda^2_{\text{SUSY}}$$

$$K = \frac{S^\dagger S}{M^2_{\text{PL}}} q^\dagger q \quad \rightarrow m_q^2 \simeq \frac{F_S^2}{M^2_{\text{PL}}} \simeq m^2_{3/2}$$

$$f = \frac{S}{M_{\text{PL}}} W_\alpha W^\alpha \quad \rightarrow m_\lambda \simeq \frac{F_S}{M_{\text{PL}}} \simeq m_{3/2}$$

The S decays into the SSM particles through Planck suppressed operators

$$\Gamma \simeq \frac{m_S^3}{M_{PL}^2}$$

$$\rightarrow \tau \simeq 10^3 \text{sec} \quad \text{for } m_{3/2} \simeq 1\text{TeV}$$

The S (Polonyi field) decays after the BBN

The decay produces high energy particles which destroy the light nuclei produced by BBN

Solutions

- Introduce a mass term

$$W_{\text{eff}} = \Lambda^2_{\text{SUSY}} S + mS^2$$

But, SUSY is not broken

- Introduce a Yukawa coupling

$$W_{\text{eff}} = \Lambda^2_{\text{SUSY}} S + ySH\bar{H}$$

But, SUSY is not broken

- Increase the SUSY-breaking soft mass

$$m_S \simeq 1\text{TeV} \quad \rightarrow \quad 100\text{TeV}$$

The Polonyi S decays before the BBN

But, it decays dominantly into a pair of gravitinos………… Even worse

Endo, Hamaguchi, Takahashi
Nakamura, Yamaguchi

- Increase the SUSY-breaking soft mass

$$m_S \simeq 1\,\text{TeV} \quad \rightarrow \quad 100\,\text{TeV}$$

The Polonyi S decays before the BBN

But, it decays dominantly into a pair of gravitinos………… Even worse

Endo, Hamaguchi, Takahashi
Nakamura, Yamaguchi

- Composite S : S= $(\Psi_a \Psi^a)$

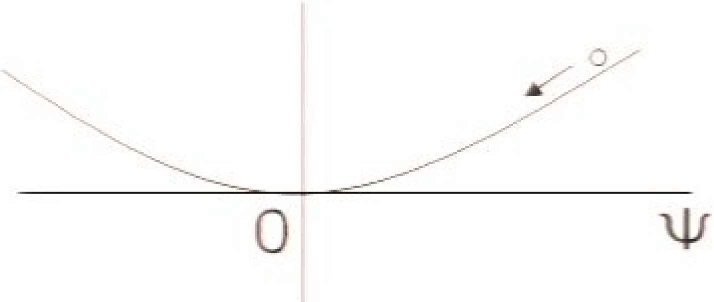
If $H_{\rm infl} > \Lambda_{\rm comp} \simeq \Lambda_{\rm SUSY}$, the S is resolved into Ψ_a and Ψ^a during the inflation

The origin of Ψ_a is the unique point where the gauge symmetry is exact
The Ψ_a's have Hubble-induced mass during the inflation

$$V = (H_{\rm infl})^2 \Psi_a^\dagger \Psi_a$$

Then, the Ψ_a and Ψ^a go to their origins during the inflation

$$S = (\Psi_a \Psi^a) \to 0$$



$$< S > |_{\text{imfl}} \simeq < S > |_{\text{present}}$$

$\rho_S \simeq 0 \quad \leftarrow \quad$ no Polonyi problem

But, the gaugino mass is too small

$$\frac{\Psi_a \Psi^a}{M_{\text{PL}}^2} W_\alpha W^\alpha \to \quad m_\lambda \simeq \frac{\Lambda_{\text{SUSY}}}{M_{\text{PL}}} m_{3/2}$$

Our SCFT's have a candidate of S

$$S = (PP) \quad ; \; F_S \simeq \Lambda^2_{\mathrm{SUSY}}$$

The S has a coupling with $W_\alpha W^\alpha$

$$f = \frac{PP}{M^2_{\mathrm{PL}}} W_\alpha W^\alpha \quad \text{at Planck scale}$$

But it becomes large at the SUSY-breaking scale Λ_{SUSY}

$$f \simeq \frac{M_{\mathrm{PL}}}{\Lambda_{\mathrm{SUSY}}} \times \frac{PP}{M^2_{\mathrm{PL}}} W_\alpha W^\alpha \quad \text{for } \gamma_P \simeq -1$$

$$\rightarrow m_\lambda \simeq m_{3/2}$$

The S decays into the SSM particles through Planck suppressed operators

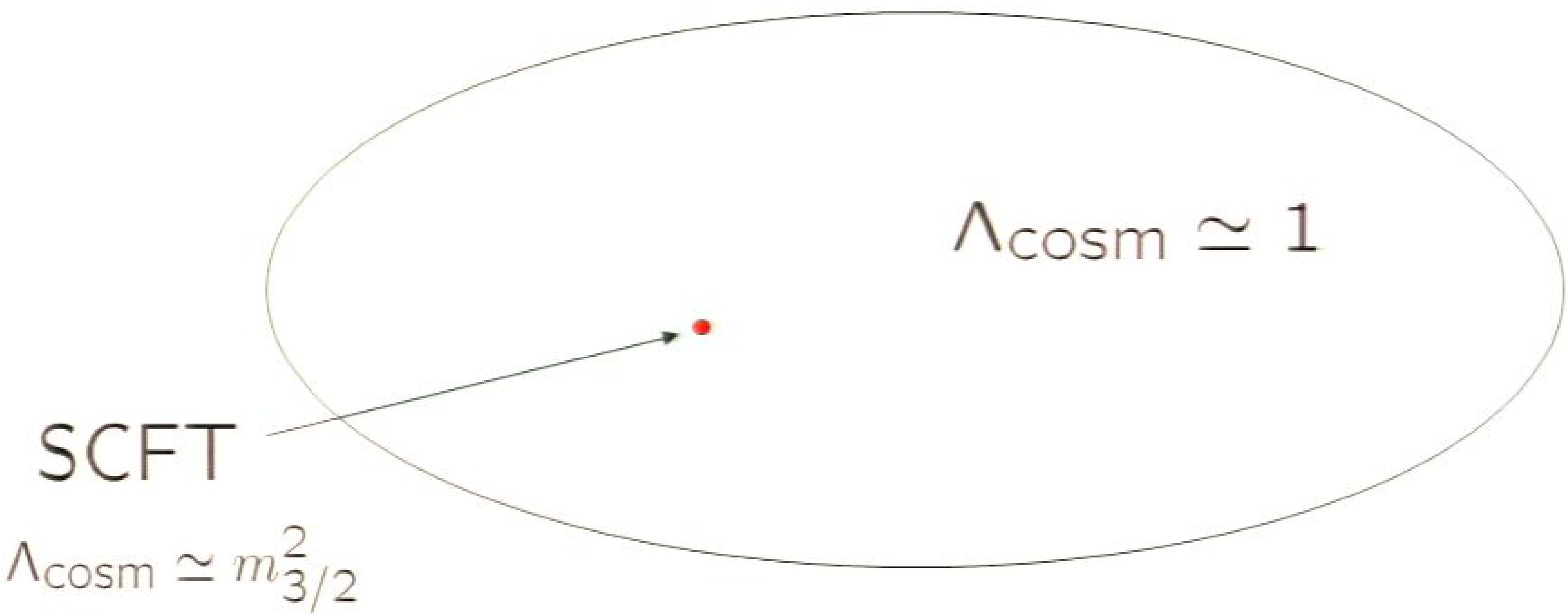
$$\Gamma \simeq \frac{m_S^3}{M_{\mathrm{PL}}^2}$$

$$\to \tau \simeq 10^3 \mathrm{sec} \quad \text{for } m_{3/2} \simeq 1\,\mathrm{TeV}$$

The S (Polonyi field) decays after the BBN

The decay produces high energy particles which destroy the light nuclei produced by BBN

A phenomenological reason why we believe the SCFT was chosen



Landscape

Solutions

- Introduce a mass term

$$W_{\text{eff}} = \Lambda^2_{\text{SUSY}} S + mS^2$$

But, SUSY is not broken

- Introduce a Yukawa coupling

$$W_{\text{eff}} = \Lambda^2_{\text{SUSY}} S + ySH\bar{H}$$

But, SUSY is not broken

Examples for $\gamma_P \simeq -1$ theory

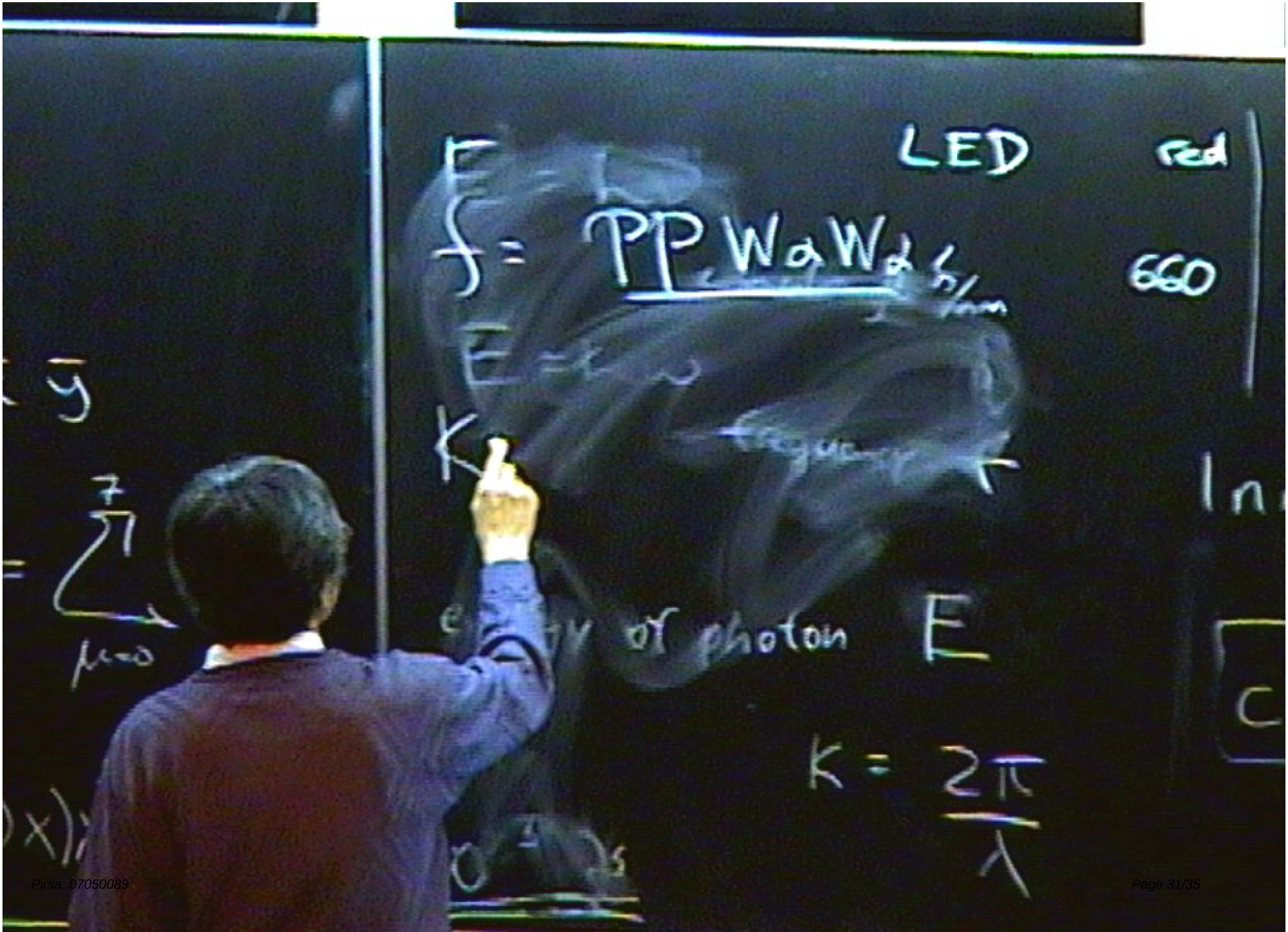
- SO(10) with one $Q(\mathbf{16}) + 10\ P(\mathbf{10})$

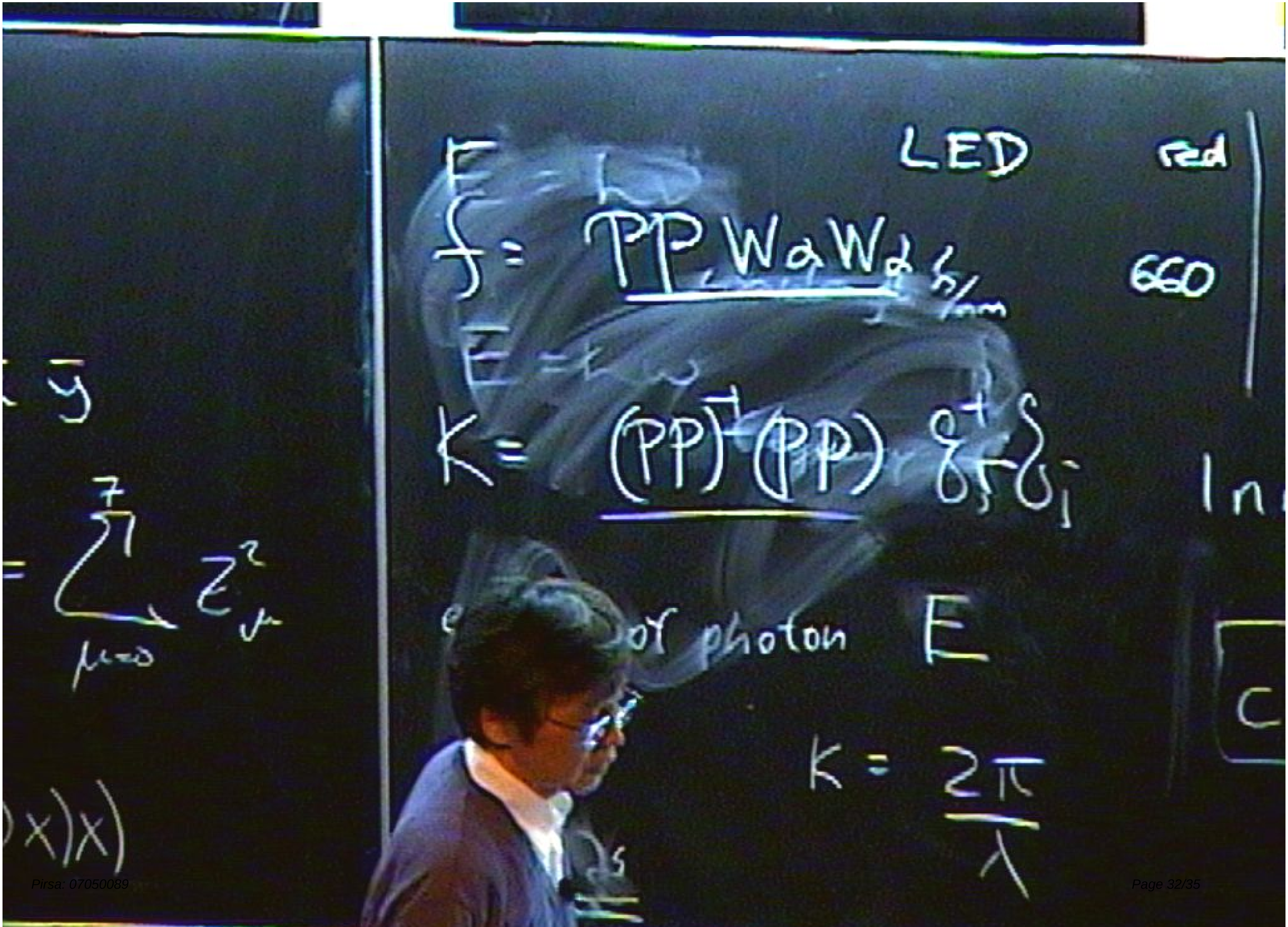
$$\gamma_P = -0.97$$

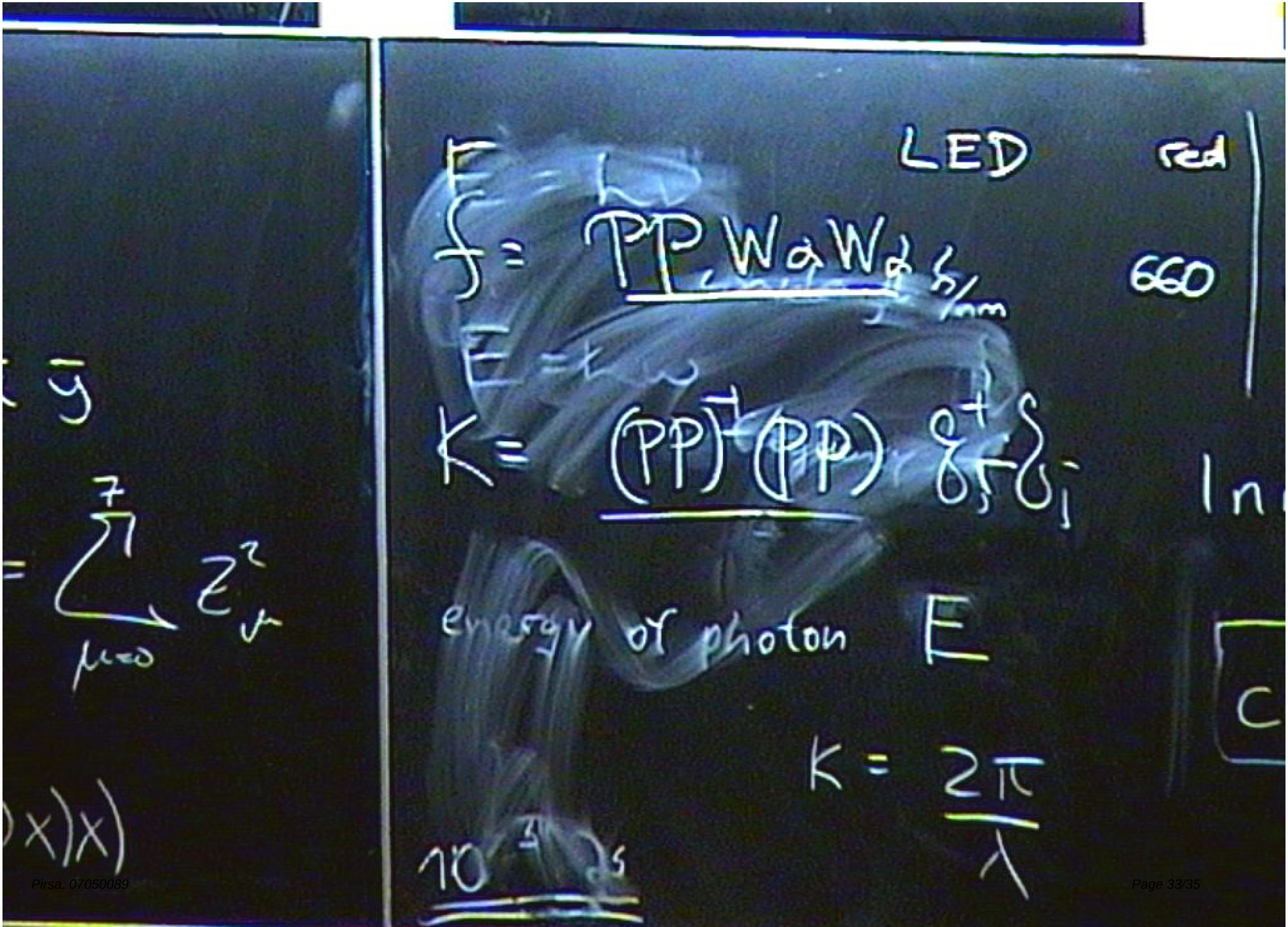
- SP(3)×SP(1)×SP(1) with

$$8\ Q(\mathbf{6}, \mathbf{1}, \mathbf{1}) + 1\ P(\mathbf{6}, \mathbf{2}, \mathbf{1}) + 1\ P(\mathbf{6}, \mathbf{1}, \mathbf{2})$$

$$\gamma_P = -1$$


LED
red
660
of photon
E
K = 2π
λ


LED
red
660
or photon
E
K = 2π / λ


LED
red
660
energy of photon
E
K = 2π / λ
In

The Polonyi (Moduli) problem is solved

The Polonyi field S is a composite state of the hidden quarks P

$$< S > |_{\text{infl}} \simeq 0$$

The important higher-dimensional operator $\frac{PP}{M_{\text{PL}}^2} W_\alpha W^\alpha$ is enhanced by the large anomalous dimension $\gamma_P \simeq -1$

The Polonyi (Moduli) problem is solved

The Polonyi field S is a composite state of the hidden quarks P

$$< S > |_{\text{infl}} \simeq 0$$

The important higher-dimensional operator $\frac{PP}{M_{\text{PL}}^2} W_\alpha W^\alpha$
is enhanced by the large anomalous dimension $\gamma_P \simeq -1$