

Title: Conformal SUSY Breaking and Cosmological Constant

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Abstract:

# Conformal SUSY Breaking and Cosmological Constant

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# Cosmological Constant

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

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

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

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

# Supergravity

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

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

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

We need a fine tuning of order 120

still!

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

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

$W \neq 0 \longleftarrow$  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:

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

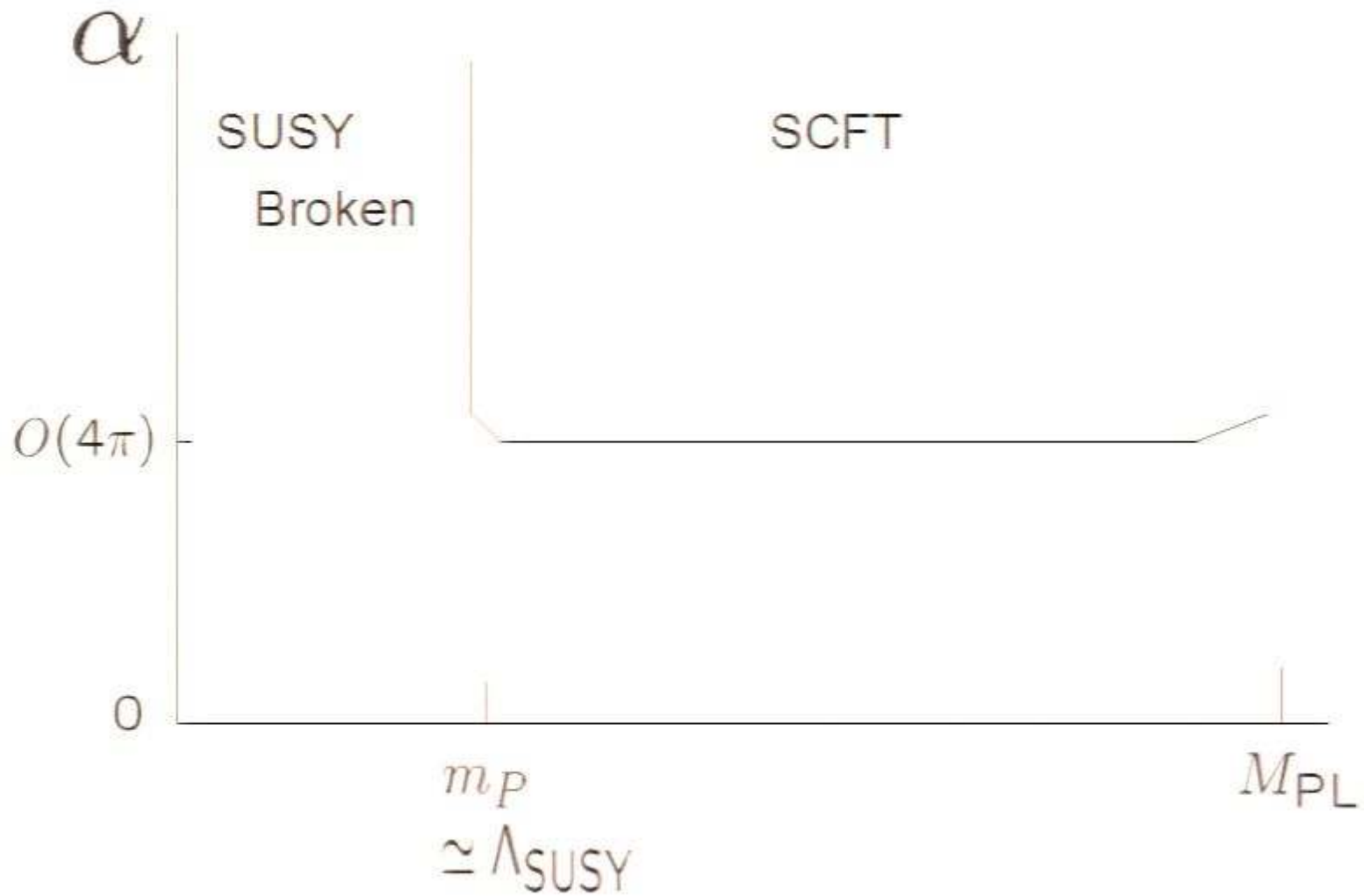
Affleck, Dine, Seiberg  
Murayama

Add massive quarks  $P^i(10)$   $i = 1 - N_F$

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

$$\gamma_P = -0.97 \quad \text{for } N_F = 10$$

# 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

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

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

$$\begin{aligned} W &= c_0 \times PP && (M_{\text{PL}} = 1) \\ &= m_{3/2} PP \end{aligned}$$

We have

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

Too small

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

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

$$m_P(\mu) \simeq \left(\frac{\mu}{M_{\text{PL}}}\right)^{\gamma_P} m_P^0 \quad (m_P^0 \simeq m_{3/2})$$

For  $\gamma_P = -1$  we obtain

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

We naturally get the cancellation  $V \simeq 0$

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## Examples for $\gamma_P \simeq -1$ theory

- $SO(10)$  with one  $Q(16) + 10 P(10)$

$$\gamma_P = -0.97$$

- $SP(3) \times SP(1) \times SP(1)$  with

$$8 Q(6, 1, 1) + 1 P(6, 2, 1) + 1 P(6, 1, 2)$$

$$\gamma_P = -1$$

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

But,  $\Lambda_{\text{cosm}} \simeq \Lambda_{\text{SUSY}}^4 \simeq m_{3/2}^2$   
 $\simeq 10^{-30} - 10^{-60}$

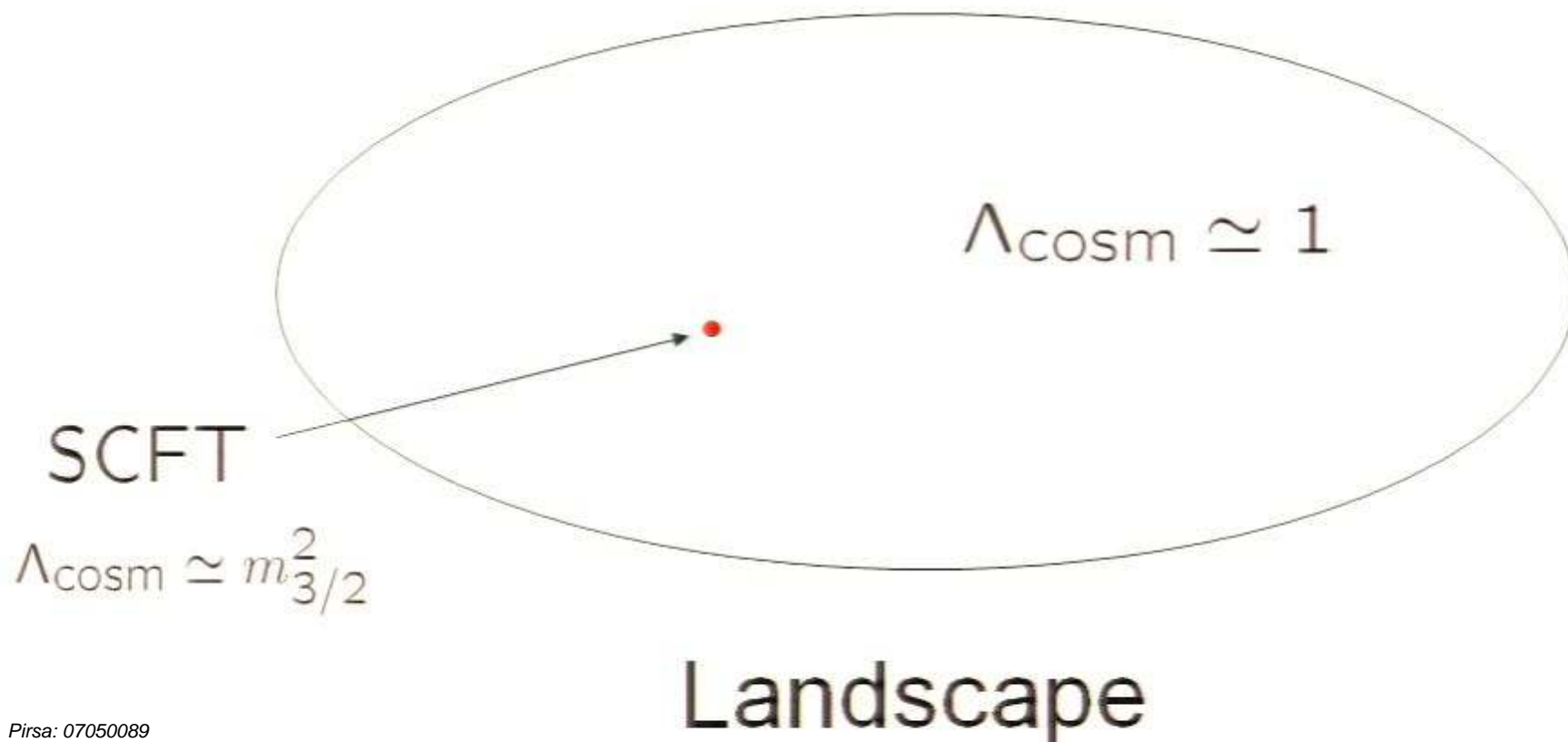
We need further mechanisms to reduce

$\Lambda_{\text{cosm}}$

OR

to invoke the anthropic principle

A phenomenological reason why we believe the SCFT was chosen



The SCFT with  $\gamma_P \simeq -1$

→ 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  $S$

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

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

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

The  $S$  decays into the SSM particles through Planck suppressed operators

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

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

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

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

But, SUSY is not broken

- Introduce a Yukawa coupling

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

But, SUSY is not broken

- Increase the SUSY-breaking soft mass

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

The Polonyi S decays before the BBN

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

Endo, Hamaguchi, Takahashi  
Nakamura, Yamaguchi

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- Composite S :  $S = (\psi_a \psi^a)$

If  $H_{\text{infl}} > \Lambda_{\text{comp}} \simeq \Lambda_{\text{SUSY}}$ , the S is resolved into  $\psi_a$  and  $\psi^a$  during the inflation

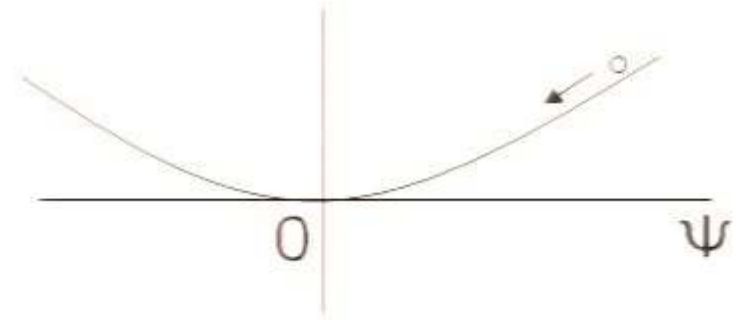
The origin of  $\psi_a$  is the unique point where the gauge symmetry is exact

The  $\psi_a$ 's have Hubble-induced mass during the inflation

$$V = (H_{\text{infl}})^2 \psi_a^\dagger \psi_a$$

Then, the  $\psi_a$  and  $\psi^a$  go to their origins during the inflation

$$S = (\psi_a \psi^a) \rightarrow 0$$



$$\langle S \rangle |_{\text{imfl}} \simeq \langle S \rangle |_{\text{present}}$$

$$\rho_S \simeq 0 \quad \leftarrow \quad \text{no Polonyi problem}$$

But, the gaugino mass is too small

$$\frac{\psi_a \psi^a}{M_{\text{PL}}^2} W_\alpha W^\alpha \rightarrow m_\lambda \simeq \frac{\Lambda_{\text{SUSY}}}{M_{\text{PL}}} m_{3/2}$$

Our SCFT's have a candidate of S

$$S = (PP) \quad ; \quad F_S \simeq \Lambda_{\text{SUSY}}^2$$

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

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

But it becomes large at the SUSY-breaking scale  $\Lambda_{\text{SUSY}}$

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

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

The  $S$  decays into the SSM particles through Planck suppressed operators

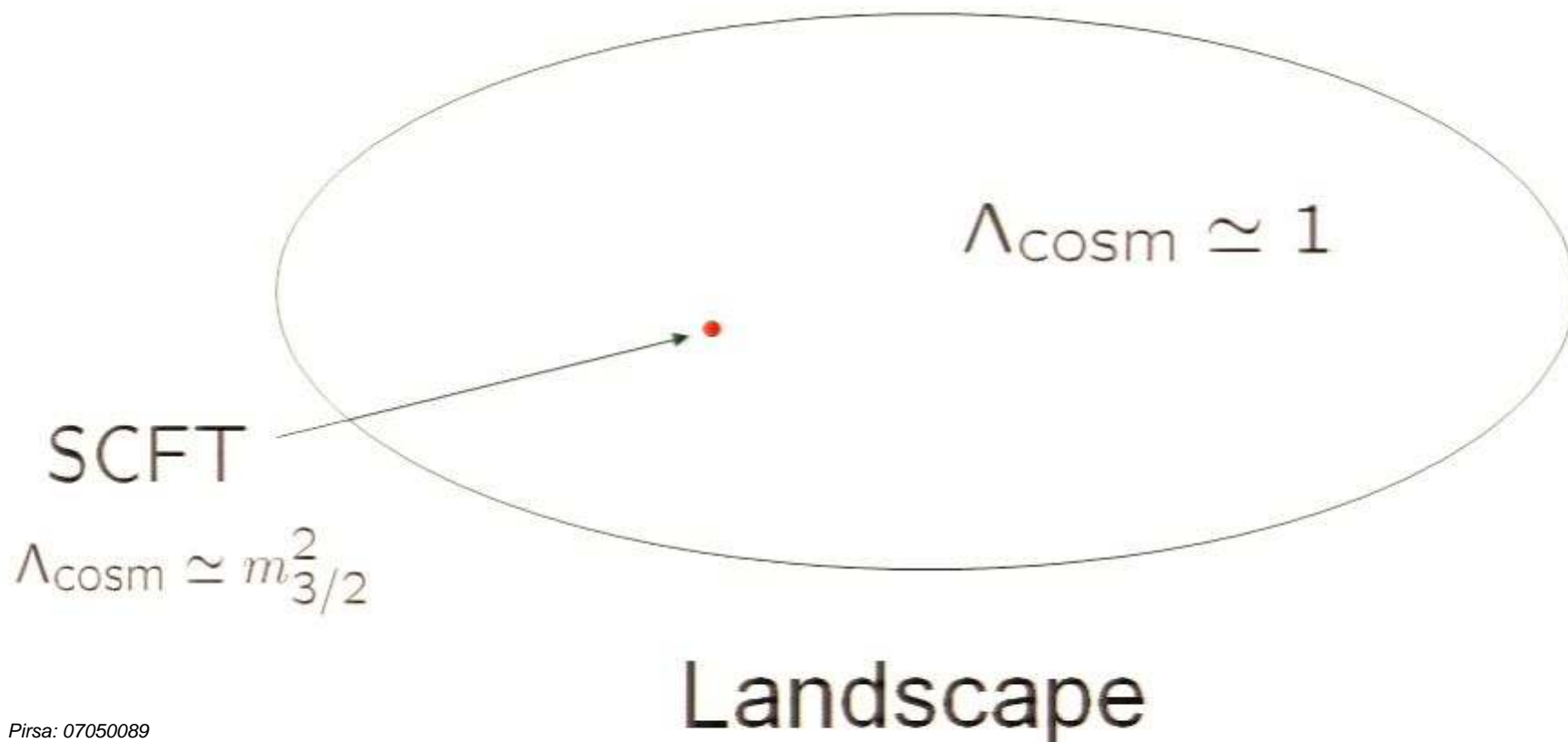
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$$\gamma_P = -1$$

LED

red

660

$$f = \frac{PPW_a W_b}{\lambda}$$

$$E = h\nu$$

K

energy of photon

E

$$K = \frac{2\pi}{\lambda}$$



LED red

$$f = \frac{PP W_a W_a}{\lambda_{nm}}$$

660

$$E = h\nu$$

$$K = \frac{(PP)^T (PP)}{8\pi\epsilon_0}$$

of photon

$$E$$

$$K = \frac{2\pi}{\lambda}$$

$$\sum_{\mu=0}^7 z_{\mu}^2$$

$x)X)$

$$\sum_{\mu=0}^7 z^{\mu}$$

$$|x\rangle\langle x|$$

LED red

$$f = \frac{P}{W} = \frac{P}{W \lambda}$$

660

$$E = h\nu$$

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In

energy of photon E

$$K = \frac{2\pi}{\lambda}$$

$$10^{-4} \text{ s}$$

The Polonyi (Moduli) problem is solved

The Polonyi field  $S$  is a composite state  
of the hidden quarks  $P$   $\langle S \rangle |_{\text{infl}} \simeq 0$

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

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