# Conformal SUSY Breaking and A Solution to the Polonyi Problem

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# The Polonyi Problem

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SUSY is broken by non vanishing F term of

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

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

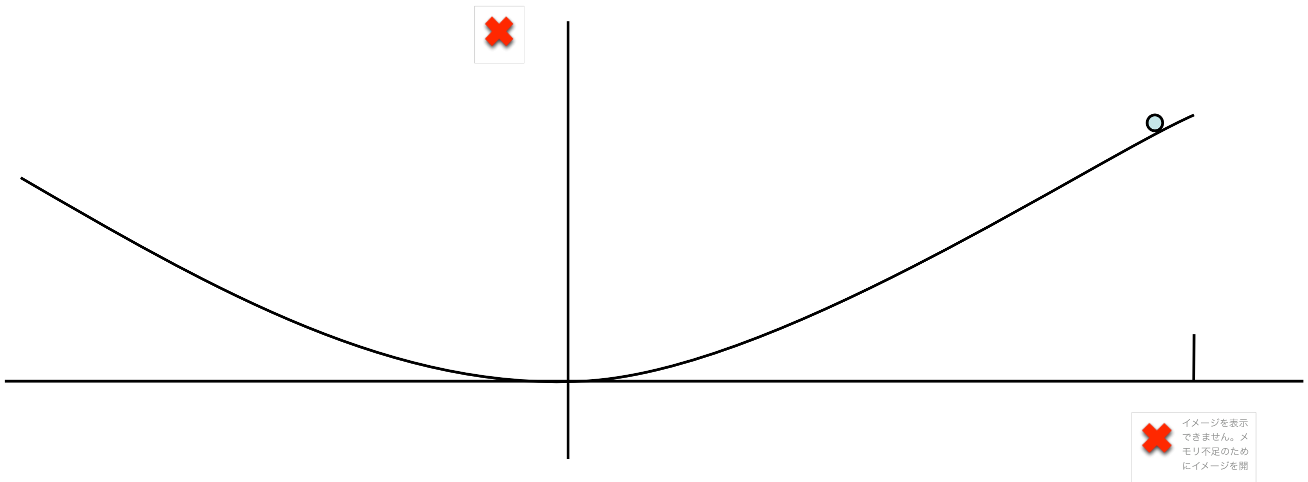
$$f = \frac{S}{M_{\mathrm{PL}}} W_\alpha W^\alpha \quad \rightarrow m_\lambda \simeq \frac{F_S}{M_{\mathrm{PL}}} \simeq m_{3/2}$$

The is neutral of any symmetries

There is no origin for the

The mass is of order $m_{3/2} \ll H_{\rm infl}$

$$< S > |_{\rm infl} \neq < S > |_{\rm present}$$



The S decays into the SSM particles through Planck suppressed operators

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

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

The S (Polonyi field) decays after the BBN

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

The potential for S

$$V = e^K \times (F(S,\Phi)); \quad K = K(S,\Phi)$$

The potential minimum is given by

$$V_S = K_S e^K (F(S,\Phi)) + e^K F_S = 0$$

During the inflation the first term dominates

since $e^K (F(S,\Phi)) \simeq H^2 M_{\mathrm{PL}}^2$

Then we get $K_S \simeq 0$

In the present universe the second term dominates $< S >_{\mathrm{present}} \neq < S >_{\mathrm{inflation}}$

# Solutions

- Introduce a mass term

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

But, SUSY is not broken

- Introduce a Yukawa coupling

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

But, SUSY is not broken

- Increase the SUSY-breaking soft mass

$$m_S \simeq 1\mathrm{TeV} \quad \to \quad 100\mathrm{TeV}$$

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 $H_{\text{infl}} > \Lambda_{\text{comp}} \simeq \Lambda_{\text{SUSY}}$ , the S is resolved into 

and 

during the inflation

The origin of 

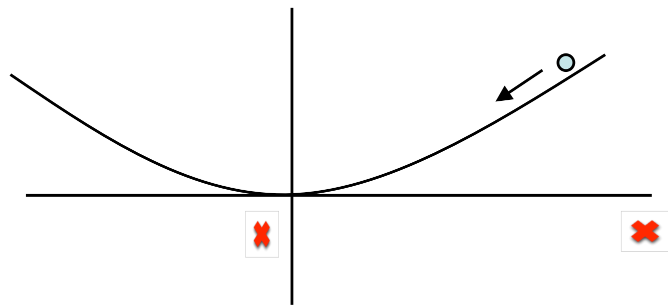
is the unique point where the gauge symmetry is exact

The 

's have Hubble-induced mass during the inflation

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

Then, the and go to their origins during the inflation



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

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

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

But, the gaugino mass is too small

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

A solution is given by superconformal theory

The theory is motivated by the small cosmological constant

# Cosmological Constant

$$\Lambda \simeq M_{\mathrm{PL}}^4 \simeq 10^{73}\mathrm{GeV}^4$$ 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

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

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

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

We need a fine tuning of order 120 still!

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

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

$$W \neq 0$$ 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

Massive quarks

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

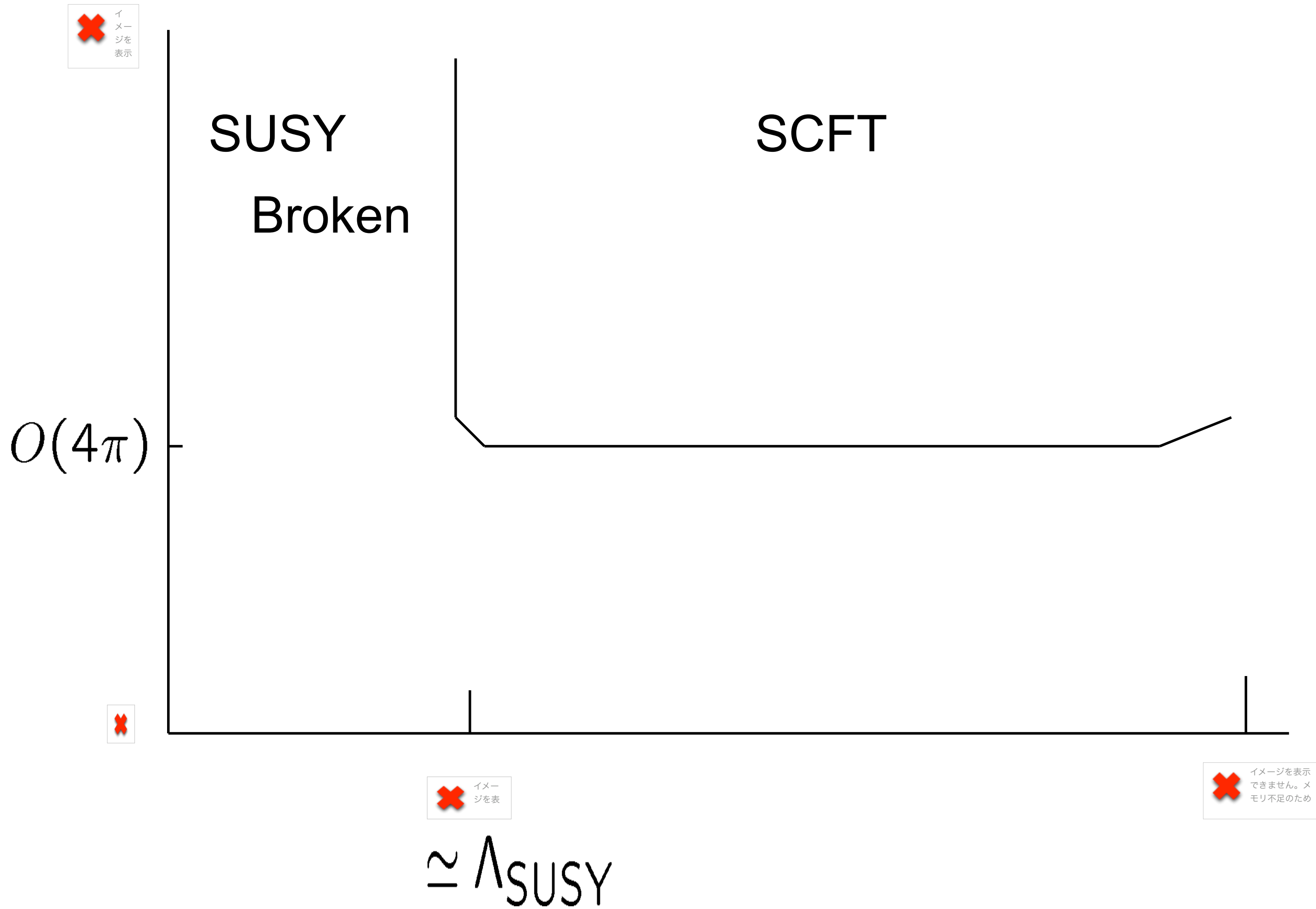
Add massive quarks $P^i(\mathbf{10})$ $i = 1 - N_F$

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

Seiberg

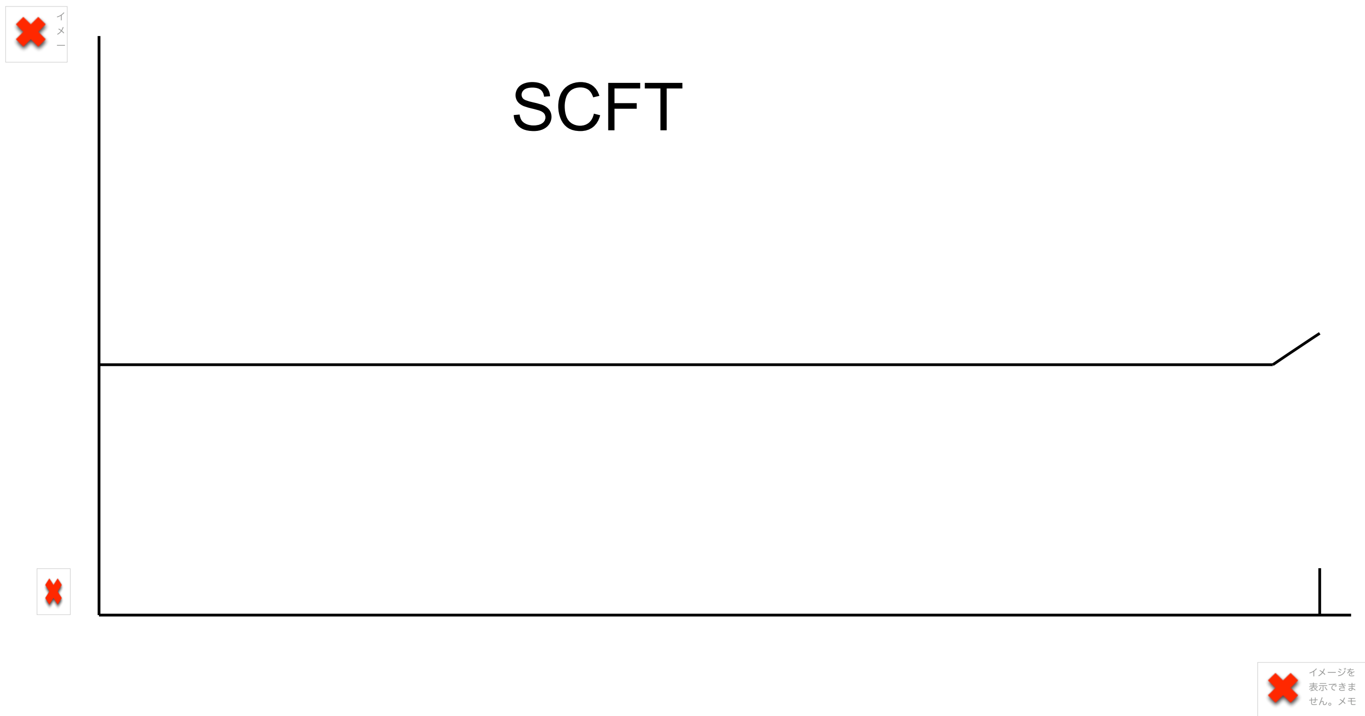
$\gamma_P = -0.97$ for $N_F = 10$

# 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 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

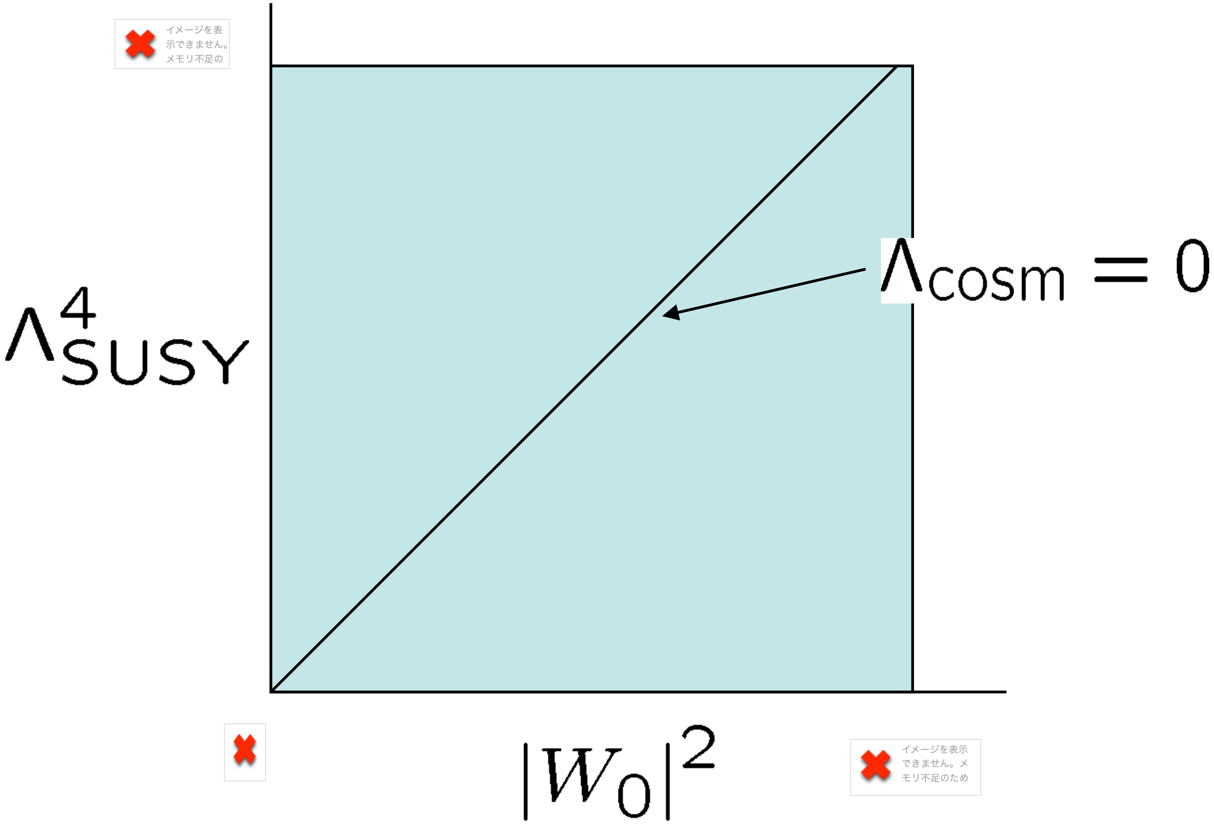
$$m_P(\mu) \simeq \left(\frac{\mu}{M_{\mathsf{PL}}}\right)^{\gamma_P} m_P^0 \qquad (m_P^0 \simeq m_{3/2})$$

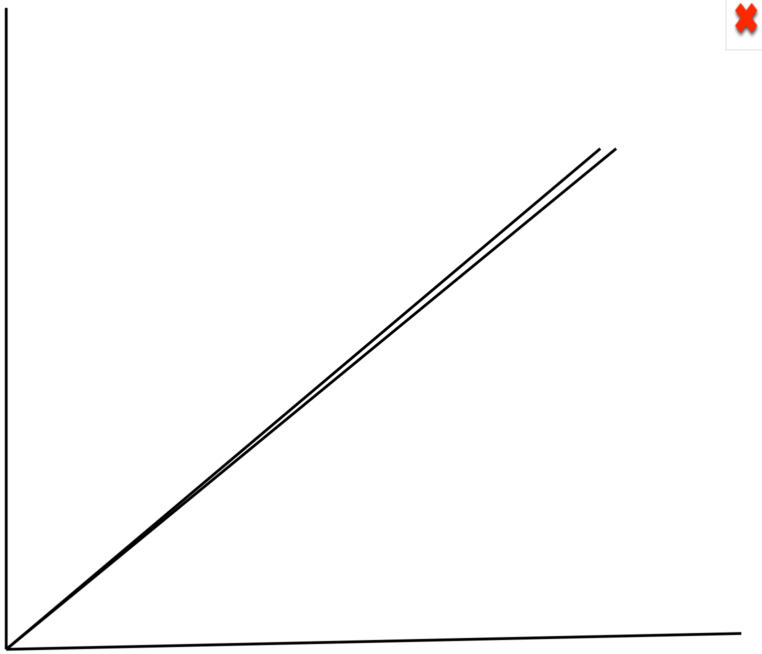
For $\gamma_P = -1$ we obtain

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

We naturally get the cancellation

# Tuning



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

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

$$\gamma_P = -0.97$$

- 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, $\Lambda_{\mathsf{cosm}} \simeq \Lambda^4_{\mathsf{SUSY}} \simeq m^2_{3/2}$

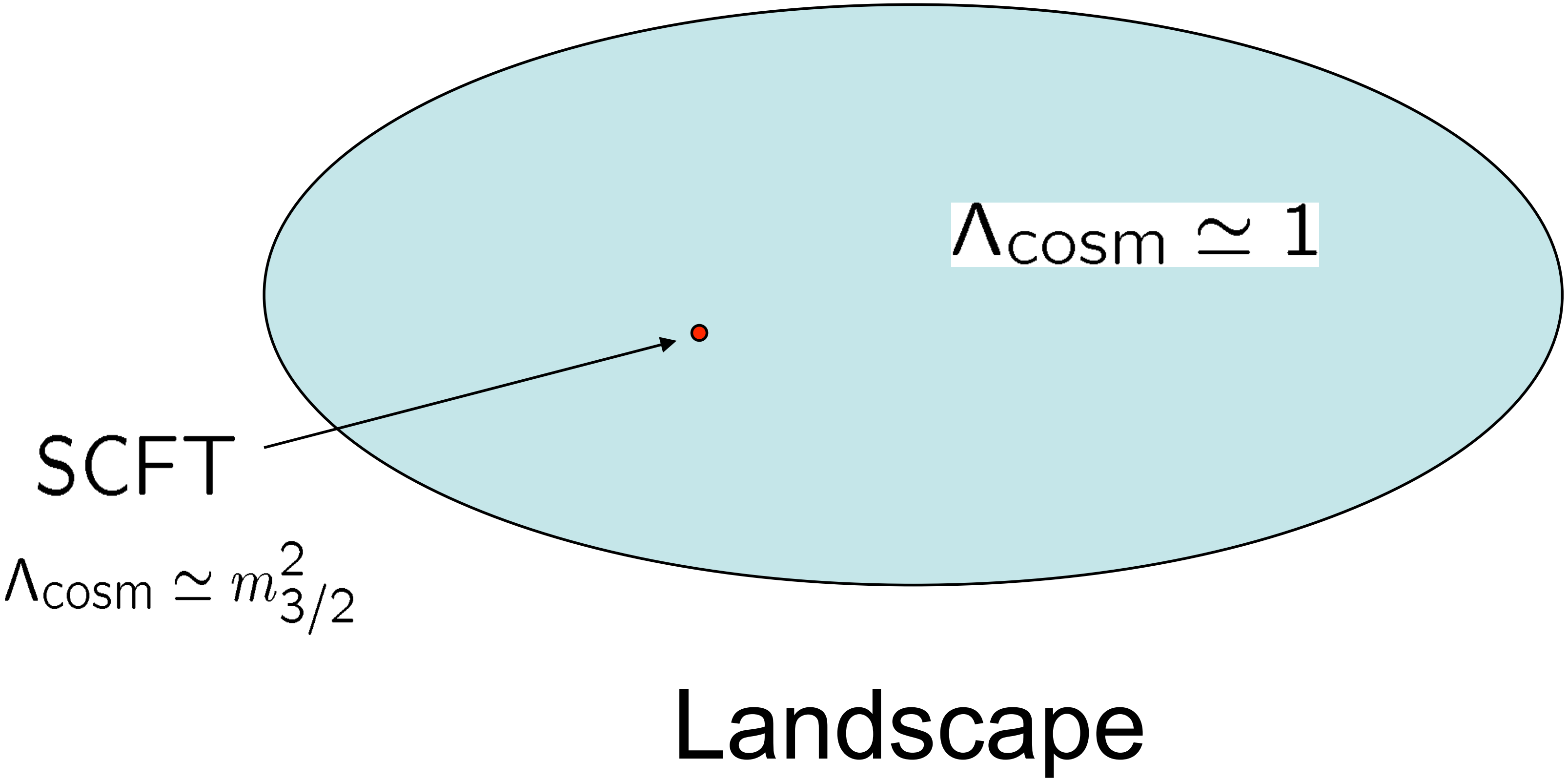
$$\simeq 10^{-30} - 10^{-60}$$

We need further mechanisms to reduce $\Lambda_{\mathsf{cosm}}$

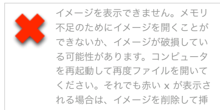
OR

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

Our SCFT's have a candidate of S

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

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

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

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

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

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

# Conclusion

- The SCFT with $\gamma \simeq -1$ is very interesting

$$\Lambda_{\mathrm{cosm}} \simeq m_{3/2}^2$$

It may have more chance to be chosen in the landscape of vacua

- A strong phenomenological motivation for the SCFT with $\gamma \simeq -1$

# The Polonyi (Moduli) problem is solved

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

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

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