Scherk-Schwarz SUSY breaking from the viewpoint of 5D conformal supergravity

Yutaka Sakamura (Osaka Univ.)

with Hiroyuki Abe (YITP)

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Introduction

SUSY: a solution of hierarchy problem

- SUSY breaking is necessary
- Scherk-Schwarz SUSY breaking:
  - Basic theory is 5D with U(1) sym.
  - different b.c. on bosons and fermions
- In 5D conformal SUGRA, various properties of SS mechanism can be easily understood.

SS breaking in 5D SUGRA

5D SUGRA on S^1/Z_2 with the radius R

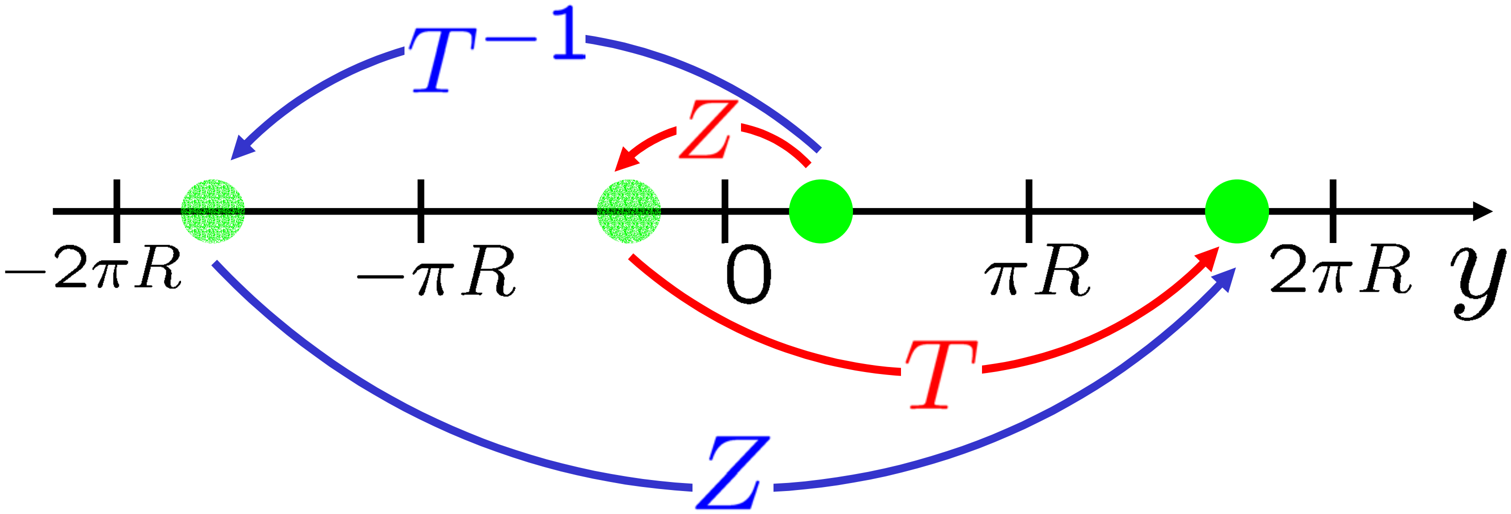
It has $SU(2)_R$ symmetry.

- Orbifold b.c. : $\Phi(x,-y) = \pm Z\Phi(x,y)$

  We choose as $Z = \sigma_3$

- Twisted b.c. for $U(1) \subset SU(2)_R$

$$\Phi(x, y+2\pi R) = T\Phi(x,y),$$
$$T = e^{-2\pi i\vec{\omega}\cdot\vec{\sigma}}$$



- Consistency condition:

$$TZ = ZT^{-1}$$

This requires $\vec{\omega} = (\omega_1, \omega_2, 0)$.

5D conformal supergravity

(Kugo & Ohashi)

- Symmetries:

$$(P_m, M_{mn}, D, U_{ij}, K_m, Q_i, S_i)$$

- Field content:

$SU(2)_U$-indices

  - Weyl multiplet: $(e_\mu{}^m, \psi_\mu^i, V_\mu^{ij}, \cdots)$
  - Hypermultiplet: $\mathcal{H}^\alpha = (\mathcal{A}_i^\alpha, \zeta^\alpha, \mathcal{F}_i^\alpha)$

$$(\alpha = \underbrace{1, 2}_{\text{compensator}}, \underbrace{3, 4, \cdots, 2(n_\mathsf{H} + 1)}_{\text{Physical fields}})$$

  - Vector multiplet: $\mathcal{V}^I = (M^I, \Omega^{Ii}, W_\mu^I, Y^{Iij})$

$$(I = 0, 1, 2, \cdots, n_\mathsf{V})$$

Superconformal gauge fixing

- Extra symmetries: $(\boldsymbol{D}, \boldsymbol{U}, \boldsymbol{S}, \boldsymbol{K})$
- Ordinary gauge fixing conditions

$$\boldsymbol{U}\text{-fixing} \quad : \quad \mathcal{A}^{a}{}_{i} \propto \delta^{a}{}_{i} \quad (a = 1, 2)$$

$$\vdots$$

$$SU(2)_U \times SU(2)_C \to SU(2)_R$$

rotate i rotate a

Combining $\boldsymbol{D}$- and $\boldsymbol{U}$- gauge fixings,

$$\mathcal{A}^{a}{}_{i} = \delta^{a}{}_{i} \sqrt{1 + \mathcal{A}^{\underline{\alpha}}{}_{j}\mathcal{A}_{\underline{\alpha}}{}^{j}}$$

We will modify this as

$$\mathcal{A}^{a}{}_{i} = \left(e^{i\vec{\omega}\cdot\vec{\sigma}f(y)}\right)^{a}{}_{i} \sqrt{1 + \mathcal{A}^{\underline{\alpha}}{}_{j}\mathcal{A}_{\underline{\alpha}}{}^{j}},$$

$$(f(y + 2\pi R) = f(y) + 2\pi)$$

while the physical fields remain periodic.

$SU(2)_U$-gauge field on-shell is given by

$$V_\mu^{ij} = -\mathcal{A}^{a(i}\partial_\mu \mathcal{A}_a{}^{j)} + \mathcal{A}^{\underline{\alpha}(i}\partial_\mu \mathcal{A}_{\underline{\alpha}}{}^{j)} + \cdots$$

V_y^{ij} is shifted and

$$\int_0^{2\pi R} dy\, V_y^i{}_j = 2\pi i\,(\vec{\omega}\cdot\vec{\sigma})^i{}_j + \cdots$$

This corresponds to the nonvanishing F-term of the radion superfield in the superfield formalism.

(G.von Gersdorff,M.Quiros,…)

gravitino gaugino

SUSY breaking terms:

$$e^{-1}\mathcal{L}_{\omega} = f'(y)\,(i\vec{\omega}\cdot\vec{\sigma})_{ij}\left(2i\bar{\psi}_m^{(i}\gamma^{m4n}\psi_n^{j)} + a_{IJ}\bar{\Omega}^{Ii}\gamma_4\Omega^{Jj}\right)$$

$$-2\left(f'(y)\,|\vec{\omega}|\right)^2 \mathcal{A}_{\underline{\alpha}}{}^{i}\mathcal{A}^{\underline{\alpha}}{}_{i} + \cdots$$

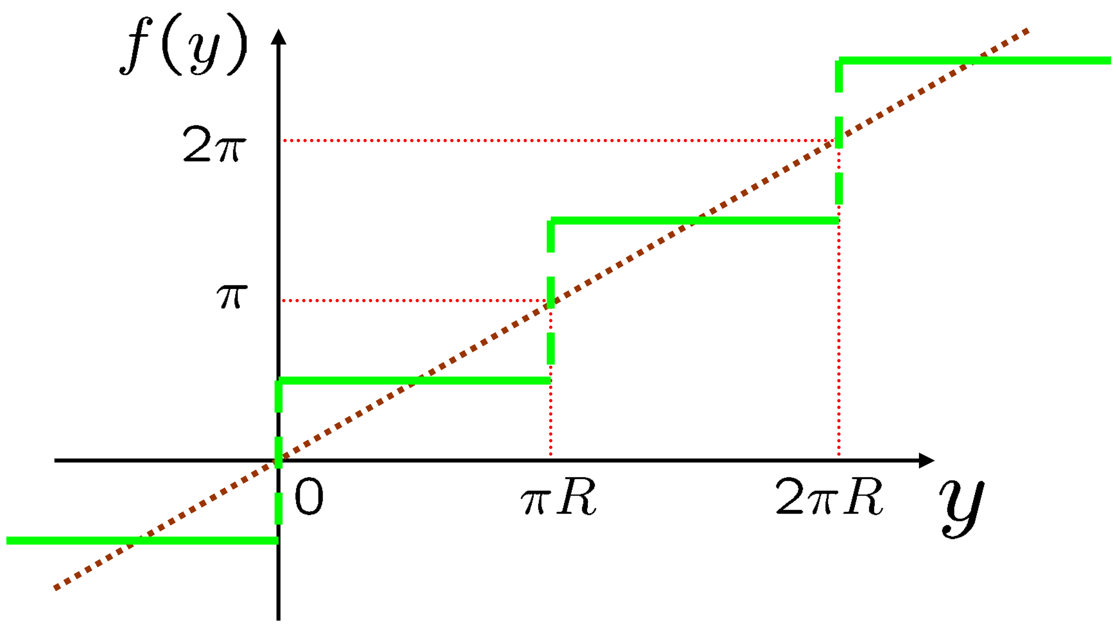
hyperscalar

All ~~SUSY~~ terms are proportional to $f'(y)$.

Singular gauge fixing

We take a gauge fixing parameter as

$$f(y) = \frac{\pi}{2}\sum_n (\mathrm{sgn}(y - n\pi R) - \mathrm{sgn}(-n\pi R))$$



Namely,

$$f'(y) = \pi \sum_n \delta(y - n\pi R)$$

Thus $\mathcal{L}_\omega$ becomes boundary terms.

SS twist

$\Leftrightarrow$ Boundary Constant superpotential

for Z_2- even part of the action

provided that $W = \pi(\omega_2 + i\omega_1)$

SS twist and warped geometry

SS twist yields an inconsistency on the warped geometry. (Hall,Nomura,Okui,Oliver (2004))

- Gauging of $U(1) \subset SU(2)_R$ by graviphoton is necessary to realize AdS_5 geometry.

$$\mathcal{D}_\mu \mathcal{A}^a{}_i = \partial_\mu \mathcal{A}^a{}_i - \mathcal{A}^{aj} V_{\mu ij} - g_R W^R_\mu (\vec{q} \cdot i\vec{\sigma})^a{}_b \mathcal{A}^b{}_i + \cdots$$

- From $\mathcal{D}^\mu \mathcal{A}^a{}_i \mathcal{D}_\mu \mathcal{A}_a{}^i$, a graviphoton mass term appears, which is proportional to $[(\vec{q} \cdot \vec{\sigma}), (\vec{\omega} \cdot \vec{\sigma})]$.

Consistency condition:

$$[(\vec{q}\cdot\vec{\sigma}),(\vec{\omega}\cdot\vec{\sigma})]=0 \quad (\vec{\omega}=(\omega_1,\omega_2,0))$$

- **Models of** (Gherghetta,Pomarol;Falkowski,Lalak,Pokorski)
  gauging $U(1)_R$ with Z_2-odd coupling
  i.e., $\vec{q}=(0,0,q_3) \Longrightarrow \vec{\omega}=0$
- **Model of** (Altendorfer,Bagger,Nemeschansky)
  gauging $U(1)_R$ with Z_2-even coupling
  i.e., $\vec{q}=(q_1,q_2,0) \Longrightarrow \vec{\omega}\propto\vec{q}$
  SS twisting seems possible.
  But this model is not derived from known off-shell SUGRA.

Summary

From the viewpoint of 5D conformal SUGRA,

- SS twisting for $SU(2)_R$ is understood as twisted $SU(2)_U$- gauge fixing.

- SS twist $\Leftrightarrow$ Boundary constant superpotential for Z_2- even part of the Lagrangian

- SS twist in AdS_5 leads to massive graviphoton.

Future works

- The case that both SS twist and boundary constant superpotentials exist (model of Altendorfer,Bagger,Nemeschansky?)
- Extension to two-compensator case (e.g. effective theory of heterotic M theory)