# Geometry mediated SUSY breaking

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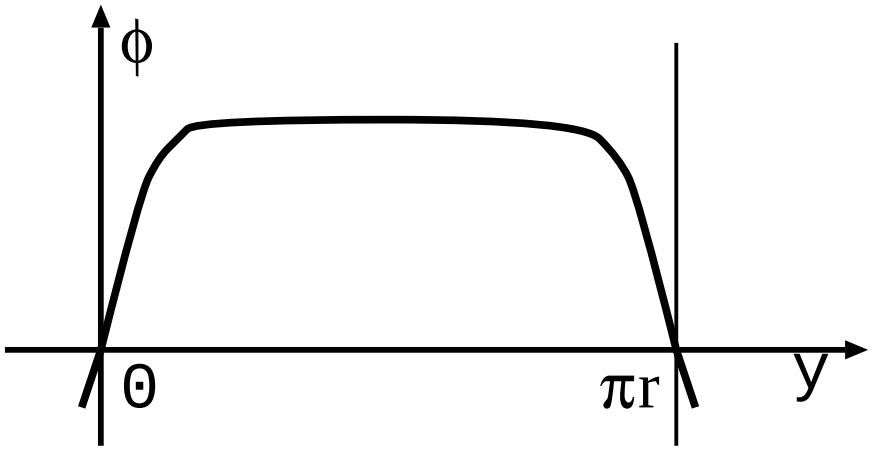
# 1 Introduction

## SUSY brane-world models:

- Origin of ~~SUSY~~
- Stabilization of the radius moduli
  - Nontrivial configuration of bulk scalar fields
  - Casimir energy
  - Non-perturbative gauge dynamics




Nontrivial scalar configuration

$\Downarrow$

Space-time deviates from the BPS background.

$\Downarrow$

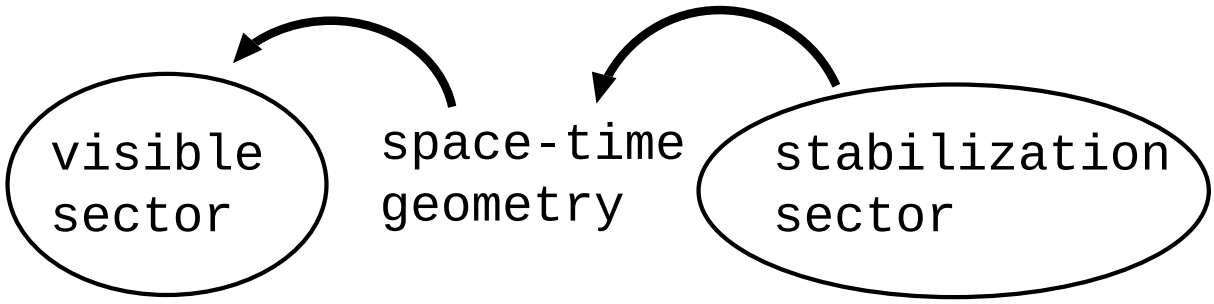
~~SUSY~~ terms are induced through the deformation of the space-time.

## Purpose

We will derive the effective action on the deformed background in terms of superfields.

**Assumption:**

(1) We have found a non-BPS solution (that stabilizes the radius).
(2) Stabilization sector is decoupled from our visible sector.




To illustrate the qualitative features, we will work with a simplified toy model in which the bulk is 4D.

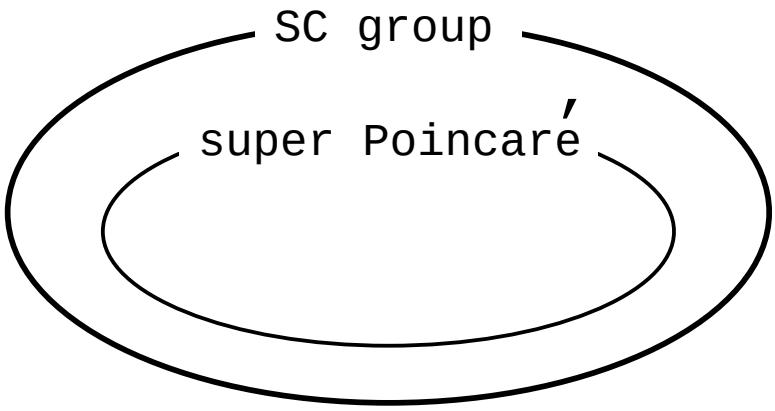
**Obstacle:**

SUSY cannot be defined on the non-BPS background.

Superconformal approach of SUGRA is useful.

## Superconformal formulation of 4D SUGRA

1. Extend the symmetry of the theory to SC group.
2. Construct an invariant action.
3. Remove the extra symmetries by the gauge fixing.




We can define the 3D global SUSY using the extended symmetry **even on the deformed space-time**.

**Strategy**

Define 3D superfields by using the global SUSY.

$\Downarrow$

Rewrite the invariant action on the gravitational background in terms of the superfields.

$\Downarrow$

Fix the extra gauge and derive the effective action.
(SUSY is broken at this step.)

## 2 Field contents and background

### SC generators and gauge fields

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| generator: | $P_a$ | $M_{ab}$ | $Q_\alpha$ | $D$ | $A$ | $S_\alpha$ | $K_a$ |
| gauge field: | $e_\mu{}^a$ | $\omega_\mu{}^{ab}$ | $\psi_\mu$ | $b_\mu$ | $A_\mu$ | $\varphi_\mu$ | $f_\mu{}^a$ |

### Chiral multiplets

$$\Phi^I = \left[\phi^I, \chi^I_\alpha, \mathcal{F}^I\right], \quad (I = 0, 1, 2, \cdots)$$

$$\begin{aligned} \Sigma &\equiv \Phi^{I=0} \quad \text{(Compensator)} \\ \Phi^{\rm h} &\equiv \Phi^{I=1} \quad \text{(Hidden sector field)} \\ \Phi^i &\equiv \Phi^{I>1} \quad \text{(Matter fields)} \end{aligned}$$

### (Internal) Gauge multiplet

$$V = [B_\mu, \lambda_\alpha, D]$$

### Gravitational background:

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu = e^{2K(y)}\eta_{mn}dx^m dx^n + dy^2.$$
$$(m, n = 0, 1, 3; \quad y = x^2)$$

$$\begin{aligned} \langle e_\mu{}^a \rangle &= \mathrm{diag}\left(e^K, e^K, 1, e^K\right), \\ \langle \psi^\alpha_\mu \rangle &= 0, \\ \langle A_m \rangle &= 0, \\ \langle A_y \rangle &= \frac{\kappa^2}{2}\mathrm{Im}\left(\bar{\phi}^{\rm h}_{\rm bg}\dot{\phi}^{\rm h}_{\rm bg}\right) \end{aligned}$$

($\kappa$: Gravitational coupling)

# 3 Global SUSY and superfields

## Global SUSY:

In the case that $\langle A_y \rangle = 0$, we can define the 3D global SUSY that preserves the gravitational background.

$$\delta \equiv \delta_Q(\epsilon) + \delta_S(\eta),$$

where

$$\epsilon_\alpha = \frac{i}{\sqrt{2}} e^{\frac{K}{2}} \epsilon_{0\alpha}, \quad (\epsilon_0\text{: 3D Majorana})$$
$$\eta_\alpha = \frac{1}{2} \dot{K} \left(\sigma^2 \bar{\epsilon}\right)_\alpha .$$

## 3D Superfields:

$$\varphi^I(x,\theta) \equiv \phi^I + e^{\frac{K}{2}} \theta \chi^I + \frac{e^K}{2} \theta^2 f^I,$$
$$\rho_\alpha(x,\theta) \equiv -i e^{\frac{K}{2}} \left(\gamma^m_{(3)} \theta\right)_\alpha B_m - e^K \theta^2 \lambda_{2\alpha},$$
$$\sigma(x,\theta) \equiv -B_y + e^{\frac{K}{2}} \theta \lambda_1 - \frac{1}{2} e^K \theta^2 D,$$

where

$$f^I \equiv i \left(\partial_y \phi^I + i g B_y \phi^I + \mathcal{F}^I + w \dot{K} \phi^I\right),$$
$$\lambda^\alpha \equiv \frac{1}{\sqrt{2}} \left(\lambda_1^\alpha + i \lambda_2^\alpha\right).$$

# 4 3D effective action

$$
\begin{aligned}
&S_{\rm vis} = \\
&\int d^4x \int d^2\theta \left[ e^K \sum_i D^\alpha \bar{\varphi}^{\bar{i}} D_\alpha \varphi^i + \frac{4}{3} e^{2K} \langle A_y \rangle \sum_i \bar{\varphi}^{\bar{i}} \varphi^i \right. \\
&\qquad + 4e^{2K} {\rm Im} \left\{ \frac{1}{2} \sum_i \bar{\varphi}^{\bar{i}} \nabla_y \varphi^i + e^{\frac{\kappa^2}{2} \left| \phi^{\rm h}_{\rm bg} \right|^2} P_{\rm vis}(\varphi^i) \right\} \\
&\qquad \left. + \frac{e^{2K}}{2} {\rm tr} \left\{ u^2 - w^2 \right\} \right] \\
&+ \kappa^2 \int d^4x \, e^{3K} \left[ {\rm Im} \left\{ -2 \sum_i f^G_{\rm bg} \phi^i \bar{f}^{\bar{i}} + 6 \hat{f}^\Sigma_{\rm bg} P_{\rm vis} \right. \right. \\
&\qquad \left. - \frac{4 \langle A_y \rangle}{3\kappa^2} \left( 3P_{\rm vis} - \sum_i \phi^i \frac{\partial P_{\rm vis}}{\partial \phi^i} \right) \right\} \\
&\qquad \left. - \frac{\langle A_y \rangle}{2\kappa^2} {\rm tr} \left\{ (\lambda_1)^2 + (\lambda_2)^2 \right\} + \cdots \right] + \mathcal{O}(\kappa^4),
\end{aligned}
$$

where $f^G_{\rm bg}(y)$ and $\hat{f}^\Sigma_{\rm bg}(y)$ are functions that will vanish in the BPS limit.

After performing the mode-expansion and $y$-integral, we can obtain the 3D effective theory.

## 5 SUSY breaking scales in EFT

$M_{\rm pl}$ : 4D Planck mass, $\Lambda$ : hidden sector scale,
$m_i$ : bulk mass for $\Phi^i$, $\tau$ : boundary tension.

**Scalar masses:**

$$m_S^2 = \frac{\Lambda^3 m_i}{M_{\rm pl}^2}\alpha(m_i, \Lambda, r),$$

where $\alpha$ is a dimensionless function.

**Gaugino mass:**

$$m_g = \int dy \frac{e^{3K}\langle A_y \rangle}{2\pi r} \sim \frac{\Lambda^3}{M_{\rm pl}^2},$$

$\arg(\phi_{\rm bg}^{\rm h})$ is assumed to vary with $\mathcal{O}(1)$ amplitude.

## 6 Summary

- We have discussed SUSY breaking mediated through the deformation of the space-time geometry.
- A systematic method for deriving the effective action on the deformed space-time is proposed.
- SUSY is broken by the SC gauge fixing in our method.
- This work provides a basic strategy for an extention of our method to 5D SUGRA.