Spontaneous R-symmetry Breaking with Multiple Pseudomoduli

arXiv: 1202.5331

Yuhsin Tsai

In collaboration with David Curtin, Zohar Komargodski, and David Shih

PHENO 2012, May 8

Take home message: Previous result

D. Shih, JHEP 0802, 091 (2008)

For a generalized O'Raifeartaigh model with

- only 0 or 2 R-charge
- single pseudo-modulus

Take home message: Previous result

D. Shih, JHEP 0802, 091 (2008)

For a generalized O'Raifeartaigh model with

- only 0 or 2 R-charge
- single pseudo-modulus

It is IMPOSSIBLE to have

radiatively-induced R-symmetry breaking at one-loop level

Take home message: New result

D. Curtin, Z. Komargodski, D. Shih and YT arXiv: 1202.5331

For a generalized O'Raifeartaigh model with

- only 0 or 2 R-charge
- ARBITRARY number of pseudo-moduli

It is IMPOSSIBLE to have

radiatively-induced R-symmetry breaking at one-loop level

WHY DO WE CARE?

The R-symmetry breaking is important

Generic SUSY-breaking models need R-symmetry
(Nelson-Seiberg)

Gauginos don't like R-symmetry
(forbids the Majorana mass term)

The R-symmetry breaking is important

Generic SUSY-breaking models need R-symmetry
(Nelson-Seiberg)

Gauginos don't like R-symmetry
(forbids the Majorana mass term)

Need to break the R-symmetry spontaneously!

- Tree-level breaking: problematic, requires tuning and more complicated potential (Komargodski & Shih, 09')
- Radiatively-induced breaking: pseudomodulus gets a loop-induced tachyonic mass which breaks the R-symmetry

The R-symmetry breaking is important

Generic SUSY-breaking models need R-symmetry
(Nelson-Seiberg)

Gauginos don't like R-symmetry
(forbids the Majorana mass term)

Need to break the R-symmetry spontaneously!

- Tree-level breaking: problematic, requires tuning and more complicated potential (Komargodski & Shih, 09')
- Radiatively-induced breaking: pseudomodulus gets a loop-induced tachyonic mass which breaks the R-symmetry

The R-symmetry breaking is important

Generic SUSY-breaking models need R-symmetry
(Nelson-Seiberg)

Gauginos don't like R-symmetry
(forbids the Majorana mass term)

Need to break the R-symmetry spontaneously!

- Tree-level breaking: problematic, requires tuning and more complicated potential (Komargodski & Shih, 09')
- Radiatively-induced breaking: pseudomodulus gets a loop-induced tachyonic mass which breaks the R-symmetry

Fields with only 0 or 2 R-charge

Models in the form

$$W = X_i\, f_i(\phi_a), \qquad \text{e.g. } W = f\, X + \lambda_{ij}\phi_i X \phi_j$$

have only 0 or 2 R-charge. (e.g. ISS)

- No tree-level R-breaking in this type of models. (Komargodski & Shih, 09')
- Radiatively-induced breaking?

Single PM: it doesn't work!

D. Shih, JHEP 0802, 091 (2008)

The potential can be parametrized as

$$W = f\,X + \tfrac{1}{2}(M_{ij} + N_{ij}X)\phi_i\phi_j.$$

The mass matrix of X at the origin from the one-loop $V_{\rm CW}$ is always positive-definite.$\Rightarrow$ No spontaneous R-breaking

Single PM: it doesn't work!

D. Shih, JHEP 0802, 091 (2008)

The potential can be parametrized as

$$W = f\,X + \tfrac{1}{2}(M_{ij} + N_{ij}X)\phi_i\phi_j.$$

The mass matrix of X at the origin from the one-loop $V_{\rm CW}$ is always positive-definite.$\Rightarrow$ No spontaneous R-breaking

Maybe...

This is because X couples to SUSY-breaking directly?

Single PM: it doesn't work!

D. Shih, JHEP 0802, 091 (2008)

The potential can be parametrized as

$$W = f\,X + \tfrac{1}{2}(M_{ij} + N_{ij}X)\phi_i\phi_j.$$

The mass matrix of X at the origin from the one-loop $V_{\rm CW}$ is always positive-definite.$\Rightarrow$ No spontaneous R-breaking

Maybe...

This is because X couples to SUSY-breaking directly?

How about having

additional PM not coupling to SUSY-breaking directly but break the R-symmetry?

Multiple PM?

- Few R-symmetry breaking attempts have been made by introducing multiple-PM.

  J. Evans, et. al. (1103.4549), Y. Shadmi (1107.3565)

Multiple PM?

- Few R-symmetry breaking attempts have been made by introducing multiple-PM.

  J. Evans, et. al. (1103.4549), Y. Shadmi (1107.3565)

The idea still doesn't work.

Multiple PM?

- Few R-symmetry breaking attempts have been made by introducing multiple-PM.

  J. Evans, et. al. (1103.4549), Y. Shadmi (1107.3565)

The idea still doesn't work.

WHY?

1103.4549 gave a proof of one extra PM, we extend the result to arbitrary many PM.

A sketch of the proof

General O'R model containing R-charges only 0 and 2

$$W = f\,X + \lambda_{ab} X \rho_a \rho_b + \widetilde{\lambda}_{nab}\, Y_n \rho_a \rho_b + m_{ai} \rho_a \sigma_i + \widetilde{\lambda}'_{iab} \sigma_i \rho_a \rho_b$$

- $R[X,\ Y,\ \sigma] = 2, \quad R[\,\rho\,] = 0.$
- Tree-level R-symmetry breaking is impossible
- The $\widetilde{\lambda}'$-term never contributes to the $V_{\rm CW}$ of $X,\ Y$ at 1-loop.
- Write $N_{ab} = \lambda_{ab}\, X + \widetilde{\lambda}_{nab}\, Y_n$.

A sketch of the proof

General O'R model containing R-charges only 0 and 2

$$W = f\,X + \lambda_{ab} X \rho_a \rho_b + \widetilde{\lambda}_{nab}\, Y_n \rho_a \rho_b + m_{ai} \rho_a \sigma_i + \widetilde{\lambda}'_{iab} \sigma_i \rho_a \rho_b$$

- $R[X,\ Y,\ \sigma] = 2, \quad R[\,\rho\,] = 0.$
- Tree-level R-symmetry breaking is impossible
- The $\widetilde{\lambda}'$-term never contributes to the V_{CW} of $X,\ Y$ at 1-loop.
- Write $N_{ab} = \lambda_{ab}\, X + \widetilde{\lambda}_{nab}\, Y_n$.

A sketch of the proof

General O'R model containing R-charges only 0 and 2

$$W = f\,X + \lambda_{ab} X \rho_a \rho_b + \widetilde{\lambda}_{nab}\, Y_n \rho_a \rho_b + m_{ai} \rho_a \sigma_i + \widetilde{\lambda}'_{iab} \sigma_i \rho_a \rho_b$$

- $R[X,\ Y,\ \sigma] = 2, \quad R[\,\rho\,] = 0.$
- Tree-level R-symmetry breaking is impossible.
- The $\widetilde{\lambda}'$-term never contributes to the V_{CW} of $X,\ Y$ at 1-loop.
- Write $N_{ab} = \lambda_{ab}\, X + \widetilde{\lambda}_{nab}\, Y_n$.

A sketch of the proof

General O'R model containing R-charges only 0 and 2

$$W = f\,X + \lambda_{ab} X \rho_a \rho_b + \widetilde{\lambda}_{nab}\, Y_n \rho_a \rho_b + m_{ai} \rho_a \sigma_i + \widetilde{\lambda}'_{iab} \sigma_i \rho_a \rho_b$$

- $R[X,\ Y,\ \sigma] = 2, \quad R[\,\rho\,] = 0.$
- Tree-level R-symmetry breaking is impossible.
- The $\widetilde{\lambda}'$-term never contributes to the V_{CW} of X, Y at 1-loop.
- Write $N_{ab} = \lambda_{ab}\, X + \widetilde{\lambda}_{nab}\, Y_n$.

A sketch of the proof

General O'R model containing R-charges only 0 and 2

$$W = f\,X + m_{ai}\rho_a\sigma_i + N_{ab}\rho_a\rho_b$$

- $R[X,\ Y,\ \sigma] = 2, \quad R[\,\rho\,] = 0.$
- Tree-level R-symmetry breaking is impossible.
- The $\widetilde{\lambda}'$-term never contributes to the $V_{\rm CW}$ of X, Y at 1-loop.
- Write $N_{ab} = \lambda_{ab}\,X + \widetilde{\lambda}_{nab}\,Y_n$.

A sketch of the proof

$$W = f\,X + m_{ai}\rho_a\sigma_i + N_{ab}\rho_a\rho_b, \quad N_{ab} = \lambda_{ab}\,X + \widetilde{\lambda}_{nab}\,Y_n$$

The 1-loop Coleman-Weinberg potential $V_{\text{eff}}^{(1)}$

$$= \frac{1}{64\,\pi^2}\,STr\,M^4 \ln\frac{M^4}{\Lambda^2}$$

A sketch of the proof

$$W = f\,X + m_{ai}\rho_a\sigma_i + N_{ab}\rho_a\rho_b, \quad N_{ab} = \lambda_{ab}\,X + \widetilde{\lambda}_{nab}\,Y_n$$

The 1-loop Coleman-Weinberg potential $V_{\text{eff}}^{(1)}$

$$= \frac{1}{64\,\pi^2}\,STr\,M^4 \ln\frac{M^4}{\Lambda^2} = \frac{-1}{192\,\pi^2}\int_0^{\Lambda} dv^6\; Tr\left(\frac{1}{v^2+M_B^2} - \frac{1}{v^2+M_F^2}\right)$$

A sketch of the proof

$$W = f\,X + m_{ai}\rho_a\sigma_i + N_{ab}\rho_a\rho_b, \quad N_{ab} = \lambda_{ab}\,X + \widetilde{\lambda}_{nab}\,Y_n$$

The 1-loop Coleman-Weinberg potential $V_{\text{eff}}^{(1)}$

$$= \frac{1}{64\,\pi^2}\,STr\,M^4 \ln\frac{M^4}{\Lambda^2} = \frac{-1}{192\,\pi^2}\int_0^{\Lambda} dv^6\; Tr\left(\frac{1}{v^2+M_B^2} - \frac{1}{v^2+M_F^2}\right)$$

Expand the integrand, get the $N^\dagger N$ term

$$V_{\text{eff}}^{(1)}\Big|_{N^2} = \frac{1}{48\,\pi^2}\int_0^{\infty} dv^6\; Tr\left(\frac{\hat{\lambda}^\dagger\hat{\lambda}}{1-\hat{\lambda}^\dagger\hat{\lambda}}\,\hat{N}^\dagger\hat{N}\right),$$

$$\hat{\lambda} = (v^2 + mm^\dagger)^{-1/2}\lambda f^*(v^2 + m^T m^*)^{-1/2}$$

$$\hat{N} = (v^2 + mm^\dagger)^{-1/2}N(v^2 + m^T m^*)^{-1/2}$$

A sketch of the proof

$$V_{\text{eff}}^{(1)}\Big|_{N^2} = \frac{1}{48\,\pi^2}\int_0^\infty dv^6\; Tr\left(\frac{\hat{\lambda}^\dagger\hat{\lambda}}{1-\hat{\lambda}^\dagger\hat{\lambda}}\,\hat{N}^\dagger\hat{N}\right)$$

The mass matrix is positive semi-definite!

- No spontaneous R-breaking at one-loop
- Can show the zero-modes are fields decoupled from SUSY-breaking at one-loop

Conclusion

When building a model with multiple pseudomuduli

For a generalized O'Raifeartaigh model with

- only 0 or 2 R-charge
- ARBITRARY number of pseudo-moduli

It is IMPOSSIBLE to have

Radiatively-induced R-symmetry breaking at one-loop level

- Zero-modes may exist at one-loop, but they are decoupled from SUSY-breaking at this loop level.