

Gaugino mass in tree level R-symmetry breaking models

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Based on arXiv:1412.0183 and more works in progress.

Outline

SUSY breaking and R-symmetry breaking

Gaugino mass in gauge mediation models

No-go for tree level R-breaking and attempts to bypass

Supersymmetry (SUSY)

What is SUSY?

- ▶ Supersymmetry: **bosons** \leftrightarrow **fermions**. e.g.:

chiral fields: $\Phi = \phi + \sqrt{2}\theta\psi + \theta\theta F + \dots$,

vector fields: $V_{WZ} = \bar{\theta}\bar{\sigma}^\mu\theta A_\mu + \bar{\theta}\bar{\theta}\lambda + \theta\theta\bar{\lambda} + (1/2)\theta\theta\bar{\theta}\bar{\theta}D$.

- ▶ Using these fields \rightarrow Lagrangian \rightarrow EOM, quantization, Feynman diagram, etc. \rightarrow phenomenology calculation.
- ▶ Motivations from both math and phenomenology.

SUSY breaking and mediation

- ▶ No superpartner observed \Rightarrow (spontaneous) SUSY breaking.
- ▶ Models: **SUSY breaking** \leftrightarrow **messengers (mediation)** \leftrightarrow **SSM**.

SUSY breaking and R-symmetries

F-term SUSY breaking

- ▶ Superpotential $W(\Phi_i) \rightarrow$ Lagrangian $L \rightarrow$ find the vacuum.
- ▶ **SUSY breaking** $\Leftrightarrow F_i = \partial_i W = 0$ **unsatisfied** at the vacuum.
- ▶ Simple EFT for many SUSY breaking dynamics.

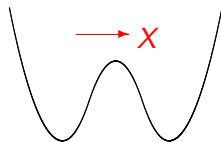
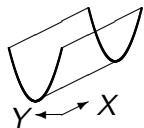
SUSY and R-symmetries

- ▶ R-symmetries: $\theta \rightarrow e^{i\alpha}\theta$, $z_i \rightarrow e^{i\alpha r_i} z_i$, $W \rightarrow e^{2i\alpha} W$.
- ▶ Nelson-Seiberg: **SUSY breaking needs R-symmetries.**
- ▶ In gauge mediation models, **gaugino masses need R-breaking.**
- ▶ Loop level R-breaking: $F_X \neq 0$, $r_X \neq 0$ and $\langle X \rangle \neq 0$ (after loop corrections), many literatures.
- ▶ Tree level R-breaking: $F_X \neq 0$, $r_Y \neq 0$ and $\langle Y \rangle \neq 0$, models more complicated.

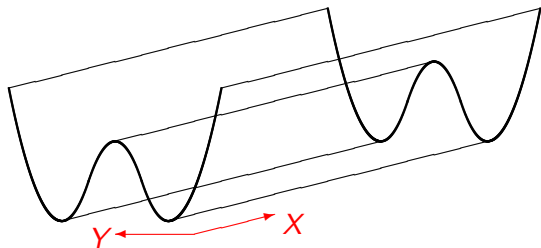
Loop level and tree level R-breaking

Plots of the potential

- ▶ Loop level R-breaking: $F_X \neq 0, \langle X \rangle \neq 0$.



- ▶ Tree level R-breaking: $F_X \neq 0, \langle Y \rangle \neq 0$.



- ▶ Is tree level R-breaking viable for gaugino masses?

Couple to gauge mediation

Gauge mediation with loop level R-breaking

- ▶ SUSY breaking sector \rightarrow spurion X ($r_X = 2$).
- ▶ X breaks both SUSY and R-symmetry: $X = \langle X \rangle + \theta\theta F_X$.
- ▶ SUSY breaking \leftrightarrow messengers: $W = X\tilde{\Phi}_i\Phi_j$:
- ▶ In the Lagrangian: $\langle X \rangle\tilde{\psi}_i\psi_j + F_X\tilde{\phi}_i\phi_j + \text{c.c.}$.
- ▶ Messengers \leftrightarrow SM gauge fields: $\Phi_i^\dagger(e^{2g_a T^a V})\Phi_i$.
- ▶ In the Lagrangian: $-\sqrt{2}(\phi_i^* T^a \psi_i)\lambda^a + \text{c.c.}$.

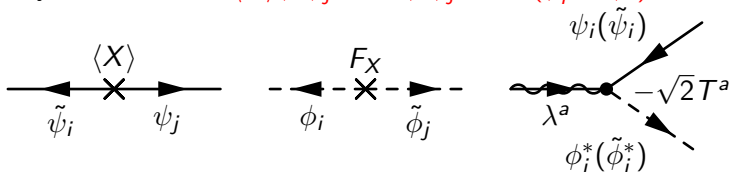
Gauge mediation with tree level R-breaking

- ▶ $X = \theta^2 F_X$ breaks SUSY, $Y = \langle Y \rangle$ breaks R-symmetry.
- ▶ $W = X\tilde{\Phi}_i\Phi_j + Y\tilde{\Phi}_i\Phi_j \rightarrow \langle Y \rangle\tilde{\psi}_i\psi_j + F_X\tilde{\phi}_i\phi_j + \text{c.c.}$.
- ▶ $\Phi_i^\dagger(e^{2g_a T^a V})\Phi_i \rightarrow -\sqrt{2}(\phi_i^* T^a \psi_i)\lambda^a + \text{c.c.}$.

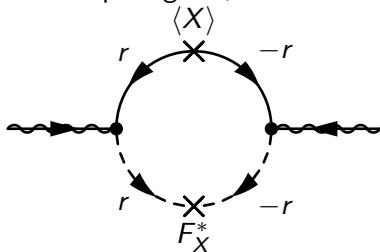
Gaugino masses from loop level R-breaking

One loop gaugino masses

- Feynman rules $\leftarrow \langle X \rangle \tilde{\psi}_i \psi_j + F_X \tilde{\phi}_i \phi_j - \sqrt{2}(\phi_i^* T^a \psi_j) \lambda^a + \text{c.c.}$



- The loop diagram, with R-charges labeled ($r_X = 2$).

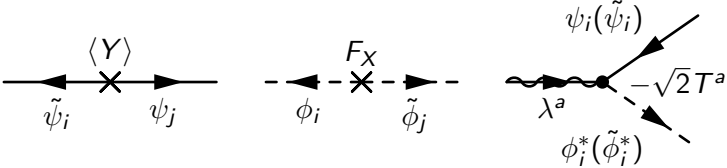


- Loop computation \rightarrow the gaugino mass: $M_{\tilde{g}} \sim \frac{\alpha}{4\pi} \frac{F_X}{\langle X \rangle}$.

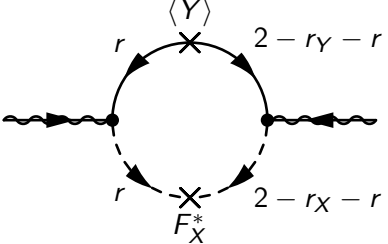
Gaugino masses from tree level R-breaking

One loop gaugino masses

- Feynman rules $\leftarrow \langle Y \rangle \tilde{\psi}_i \psi_j + F_X \tilde{\phi}_i \phi_j - \sqrt{2}(\phi_i^* T^a \psi_i) \lambda^a + \text{c.c.}$



- The loop diagram, with R-charges labeled.



- Loop computation \Rightarrow the gaugino mass: $M_{\tilde{g}} \sim \frac{\alpha}{4\pi} \frac{F_X}{\langle Y \rangle} \cdot (?)$

No-go for tree level R-breaking

Checking R-charge conservation

- ▶ $r_X \neq r_Y \Rightarrow$ R-charge unconserved on the right vertex \Rightarrow the loop diagram does not exist \Rightarrow no-go for $M_{\tilde{g}}$.
- ▶ $r_X = r_Y \Rightarrow X$ and Y are indistinguishable.
- ▶ \Rightarrow generically $\langle X \rangle$ is comparable to $\langle Y \rangle$.
- ▶ $\Rightarrow M_{\tilde{g}}$ has loop level R-breaking contribution $\sim \frac{F_X}{\langle X \rangle}$.
- ▶ \Rightarrow tree level R-breaking is redundant (no-go again).

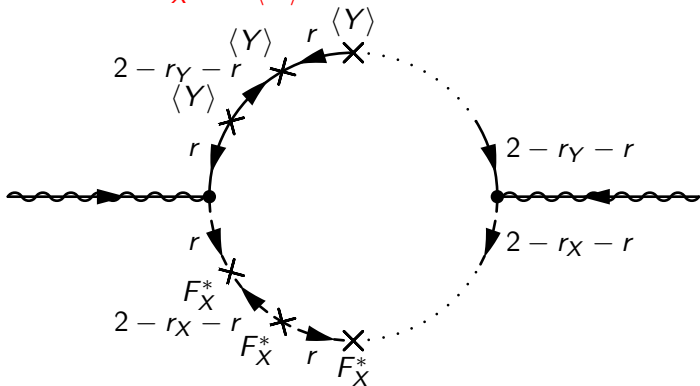
Conclusion

- ▶ Tree level R-symmetry breaking is no-go for gaugino mass (which is the purpose to have R-breaking).
- ▶ Forget about tree level R-breaking(?)

Bypassing the no-go

Bypassing in more complicated models(?)

- ▶ Insert more F_X and $\langle Y \rangle$ vertexes.



R-charge conservation $\Rightarrow r_X = r_Y \Rightarrow$ no-go again.

- ▶ Multiple spurions plausible (works in progress).