PSEUDO-GOLDSTINI IN FIELD THEORY

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SUSY breaking '11, CERN, 16 May 2011

with Riccardo Argurio and Zohar Komargodski (arXiv:1102.2386)

Plan of the talk

- Mediation of SUSY breaking: reminder
- Goldstino and its interactions

- Multiple susy breaking sectors
- Goldstino and Pseudo-Goldstino

- Pseudo-Goldstino in Gauge Mediation
- Pseudo-Goldstino mass
- Phenomenology and Conclusions

MEDIATION OF SUSY BREAKING

- MSSM is a promising candidate for BSM physics
- Supersymmetry must be softly broken in the MSSM
- Standard paradigm: mediation mechanism

MEDIATION OF SUSY BREAKING

- Hidden sector with spontaneous (dynamical) susy breaking (scale $\Lambda_{susy} \equiv \sqrt{F}$)
- Visible sector MSSM with gauge group G_{SM}
- Interactions lead to soft terms in the MSSM, e.g. mass m_{soft} to sparticles

Gauge vs Gravity mediation

Gravity mediation

- Soft terms as Planck suppressed operators
- $m_{soft} \sim \frac{\Lambda_{susy}^2}{M_{Pl}}$
- $\Lambda_{susy} \sim 10^{10-11} GeV$
- Hard predictivity, can lead to FCNC

Gauge mediation

- Typically messengers field charged under G_{SM} and with mass M
- Soft terms via loops of SM gauge fields and messenger fields
- $\Rightarrow m_{soft} \sim \frac{g^2}{16\pi^2} \frac{\Lambda_{susy}^2}{M}$
- (Generically M is a supersymmetric scale s.t.: $\Lambda_{weak} \ll M \ll M_{Pl}$)
- Calculable model, Flavour blind, μ/B_μ problem, ...

Goldstino

- What do we know about hidden sector?
- Spontaneous susy breaking $\Rightarrow$ Massless fermion Goldstino
- Eaten via superHiggs mechanism: $m_{3/2} \sim \frac{F}{M_{Pl}}$

Gauge Mediation

$$m_{3/2} \ll m_{soft}$$

Gravity Mediation

$$m_{3/2} \simeq m_{soft}$$

- Very light gravitino behaves like a Goldstino
- Interactions with MSSM are fixed by supersymmetry

Goldstino couplings

- Goldstino can be described as constrained superfield Komargodski, Seiberg '10

$$X_{NL}^2 = 0 \qquad \Rightarrow \qquad X_{NL} = \frac{G^2}{2F} + \sqrt{2}\theta G + \theta^2 F$$

- Then the couplings to the MSSM results

$$\mathcal{L} \supset \int d^2\theta \frac{m_\lambda}{2f} X_{NL} \mathcal{W}^2 = \frac{1}{2} m_\lambda \lambda^2 + \frac{i m_\lambda}{\sqrt{2} f}\left(G\lambda D - \frac{i}{2}\lambda\sigma^\mu\bar{\sigma}^\nu G F_{\mu\nu}\right) + \dots$$

- Encodes both soft terms and Goldstino couplings

Multiple susy breaking sectors

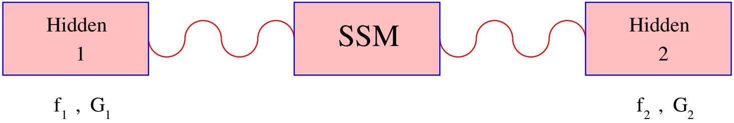
?? What happens if there is more than one susy breaking sector ??

- Suppose to have two susy breaking sectors completely decoupled except for their interaction with the MSSM
- What are the pheno consequences?

Every sector has its own Goldstino, but ...

- True Goldstino is massless in the ridig limit and is eaten by the gravitino in supergravity
- Others are extra fermionic particles (Pseudo-Goldstini) Benakli, Moura '07

TWO SUSY BREAKING SECTORS



$$G = \frac{1}{f}(f_1 G_1 + f_2 G_2) \qquad \text{True-Goldstino} \qquad m_G = m_{3/2}$$

$$G' = \frac{1}{f}(-f_2 G_1 + f_1 G_2) \qquad \text{Pseudo-Goldstino} \qquad m_{G'} = ???$$

where $f = \sqrt{f_1^2 + f_2^2}$

Observe: soft terms are induced by both sectors, e.g. $m_\lambda = m_\lambda^{(1)} + m_\lambda^{(2)}$

Pseudo-Goldstino mass

Gravity mediation

Cheung, Nomura, Thaler '10

- $m_{G'} = 2m_{3/2} \qquad \sim \qquad m_{soft}$

??? Gauge Mediation ???

R.Argurio, Z.Komargodski, A.M. '11

- Contribution from gravity are negligible ($m_{3/2} \ll m_{soft}$)
- PseudoGoldstino can get mass from radiative corrections
- Radiative corrections will be the dominant contribution
- Can we give a universal estimate ?

COMPUTATION OF $m_{G'}$

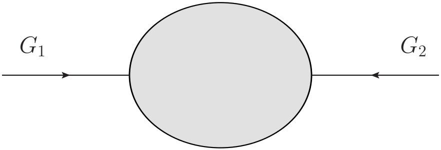
- Mass matrix for the Goldstini (one zero eigenvalue)

$$\mathcal{L} \supset \begin{pmatrix} G_1 & G_2 \end{pmatrix} \begin{pmatrix} -(f_2/f_1)\mathcal{M}_{12} & \mathcal{M}_{12} \\ \mathcal{M}_{12} & -(f_1/f_2)\mathcal{M}_{12} \end{pmatrix} \begin{pmatrix} G_1 \\ G_2 \end{pmatrix}$$

- Pseudo Goldstino mass determined by $\mathcal{M}_{12}$

$$m_{G'} = (\frac{f_1}{f_2} + \frac{f_2}{f_1})\mathcal{M}_{12}$$

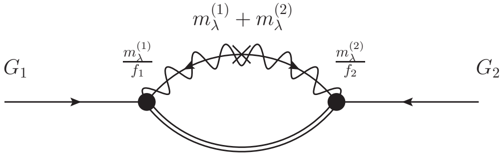
- We have to compute



Effective theory computation

- Leading contribution from interaction with gaugino

$$\mathcal{L} = \frac{m_\lambda}{2} \int d^2\theta \left(\frac{\alpha_1}{f_1} X_1 + \frac{\alpha_2}{f_2} X_2 \right) W_\alpha^2 \,, \qquad \alpha_1 + \alpha_2 = 1$$



- Divergent contribution ($f_1 = f_2 = f$, $\alpha_1 = \alpha_2$)

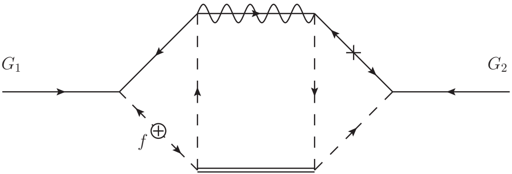
$$m_{G'} \simeq \frac{1}{16\pi^2} \frac{m_\lambda^3}{f^2} \Lambda_{UV}^2$$

- $\Rightarrow$ Effective theory is not predictive
- Need to invoke microscopic physics

TOY MODEL: TWO MINIMAL GAUGE MEDIATION

$$W = \int d^2\theta \sum_{i=1}^{2} (X_i + M_i)\Phi_i\tilde{\Phi}_i$$

- Leading contribution at 3 loops



- Two different effective vertices
  - $G\lambda D$
  - $F^\dagger G\partial\bar{\lambda}D$
- Only first vertex is captured in the low energy lagrangian

?? Can we provide a model independent answer in gauge mediation ??

Microscopic theory: general gauge mediation

- GGM Lagrangian Meade Seiberg Shih '08

$$\frac{1}{g^2}\mathcal{L}_{GGM} = \frac{1}{2}C_0 D^2 - iC_{1/2}\lambda\sigma^\mu\partial_\mu\bar{\lambda} - \frac{1}{4}C_1 F^2_{\mu\nu} - \frac{1}{2}\left(B_{1/2}\lambda^2 + h.c.\right)$$

- We supersymmetrize it by adding term linear in the Goldstino

$$\mathcal{L}_{eff} = \mathcal{L}_{GGM} - \frac{G^\alpha}{\sqrt{2}f}[Q_\alpha, \mathcal{L}_{GGM}] + O(G^2)$$

$$\frac{1}{g^2}\mathcal{L}_{Gold} = \frac{iB_{1/2}}{\sqrt{2}f}\left(G\lambda D - \frac{i}{2}\lambda\sigma^\mu\bar{\sigma}^\nu G F_{\mu\nu}\right) + \frac{1}{\sqrt{2}f}(C_0 - C_{1/2})G\sigma^\mu\partial_\mu\bar{\lambda}D + \frac{i}{\sqrt{2}f}(C_1 - C_{1/2})G\sigma_\nu\partial_\mu\bar{\lambda}F^{\mu\nu} + \dots$$

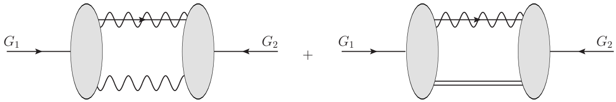
- $B_{1/2}$ and ΔC_i are functions of the momentum which die off at large p^2
- Momentum dependent vertices with cut off
- Several checks on $\mathcal{L}_{eff}$ (e.g. $O(G^2)$ terms $\Rightarrow$ massless Goldstino)

Pseudo-Goldstino mass

- Lagrangian for the two susy breaking sector case

$$\mathcal{L}(G_1, G_2, B_{1/2}^{(1,2)}, C_i^{(1,2)}) = \mathcal{L}_{GGM}^{(1)} + \mathcal{L}_{GGM}^{(2)} + \mathcal{L}_{Gold}^{(1)} + \mathcal{L}_{Gold}^{(2)} + \ldots$$

- We have the vertices to compute $\mathcal{M}_{12} \Rightarrow m_{G'}$
- Leading contribution at order g^4



⇒ Pseudo-Goldstino mass

$$m_{G'} = \frac{g^4}{2}\left(\frac{1}{f_1^2} + \frac{1}{f_2^2}\right) \int \frac{d^4p}{(2\pi)^4} B_{1/2}^{(1)} \left(C_0^{(2)} - 4C_{1/2}^{(2)} + 3C_1^{(2)}\right) + 1 \leftrightarrow 2$$

- We can check that True Goldstino remains massless
- We can check the expression in toy model (two copies of MGM)

Pseudo-Goldstino mass: comments

- Estimate $m_{G'}$, assuming same susy scale M in the two sectors

$$m_{G'} \simeq \frac{g^4}{(16\pi^2)^3}\left(\frac{f_1}{f_2}+\frac{f_2}{f_1}\right)\left(\frac{f_1}{M}+\frac{f_2}{M}\right)$$

- For $f_1 \sim f_2 \sim f$ and typical gauge mediation scenario

$$m_{G'} \simeq \frac{g^4}{(16\pi^2)^3}\frac{f}{M} \simeq \frac{g^2}{(16\pi^2)^2} m_{soft} \simeq 1 GeV$$

- $m_{G'}$ is enhanced if susy breaking scales are different

$$f_1 \gg f_2 \qquad \Rightarrow \qquad m_{G'} \simeq \frac{g^2}{(16\pi^2)^2} m_{soft}\left(\frac{f_1}{f_2}\right) \simeq 100 GeV$$

- But we cannot unbalance too much the two sector scales

!!! Typical mass scale of Pseudo Goldstino in gauge mediation is GeV !!!

Pseudo-Goldstino in gauge med: summary

- More hidden sectors with susy breaking
- $\Rightarrow$ New fermionic light particle: Pseudo-Goldstino
- Probe of the hidden sector

- We extracted its MSSM couplings in Gauge mediation
- We computed its mass
- Pseudo Goldstino mass

$$m_{G'} \simeq 1GeV - 100GeV$$

- Our computation dominates over gravity as long as $\sqrt{f} \leq 10^9 GeV$
- Typically Pseudo Goldstino is the NLSP (the LSP is the gravitino)

Phenomenology and outlook

- G' candidate for NLSP in gauge mediated models
- Couples to the MSSM particles similarly to the True Goldstino
- LSP is the gravitino
- G' decays to G
- Lifetime of G': from few seconds to cosmologically time scale

Collider signatures

- Lightest Observable sector Supersymmetric Particle (LOSP) can decay both to pseudo-Goldstino and to Gravitino with different branching ratios
- Decay to G' (GeV mass particle), or to G (eV mass particle)