Prospects for a Gravitino LSP in Gaugino Mediation

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Based on
W. Buchmüller, K. Hamaguchi, J.K., hep-ph/0506105

Outline

1. Gaugino Mediation
2. Naive Dimensional Analysis
3. Bounds on Gaugino and Gravitino Masses

Motivation

Gravitino LSP

- Alternative dark matter candidate
- Can allow large enough reheating temperature for thermal leptogenesis
- Decays of a charged NLSP may be observable at colliders

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Gravitino mass in different SUSY-breaking scenarios

- Gauge mediation: $m_{3/2} \ll 1\,\text{GeV} \Rightarrow$ LSP
- Gravity mediation: $m_{3/2} \sim 100\,\text{GeV} - 1\,\text{TeV} \Rightarrow$ maybe LSP
- Anomaly mediation: $m_{3/2} \gtrsim 10\,\text{TeV} \Rightarrow$ not LSP
- Gaugino mediation: ?

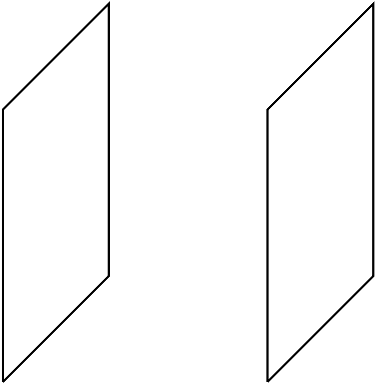
1 Gaugino Mediation

2 Naive Dimensional Analysis

3 Bounds on Gaugino and Gravitino Masses

Setup

Kaplan, Kribs, Schmaltz, Phys. Rev. **D62** (2000)
Chacko, Luty, Nelson, Ponton, JHEP **01** (2000)



- D dimensions
- 4-dimensional branes

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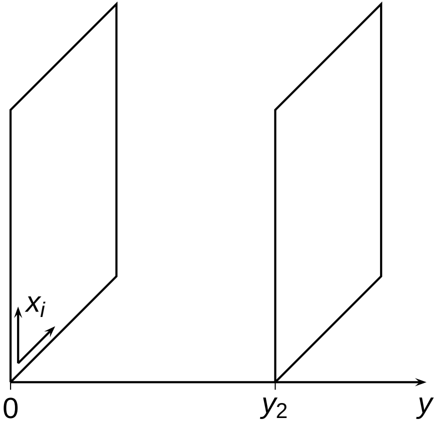

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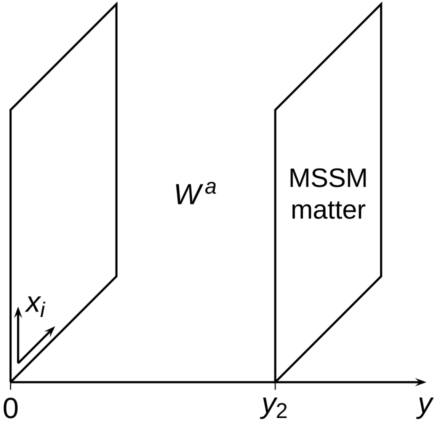

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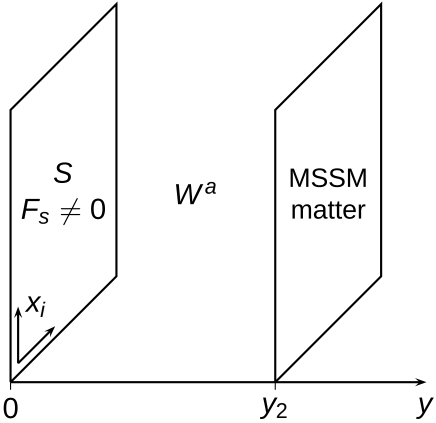

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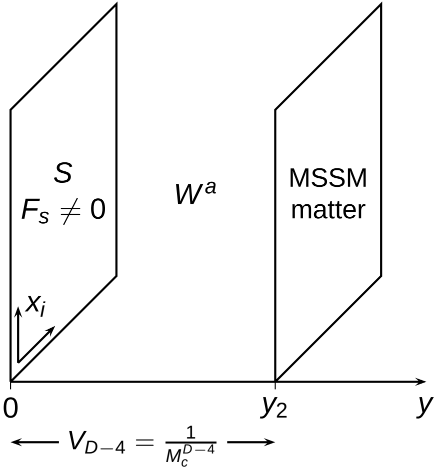

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Coupling of Gauge Fields to S

$$\mathscr{L}_{SWW} = \delta^{(D-4)}(y)\,\frac{h}{4\Lambda}\int \mathrm{d}^2\theta\, S\, W^a W^a + \text{h.c.}$$

- h: dimensionless coupling
- Λ: cutoff

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- h: dimensionless coupling
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- Normalization of gauge fields:

$$\mathscr{L}_{\text{kin}} = \frac{1}{4g_D^2}\int \mathrm{d}^2\theta\, W^a W^a + \text{h.c.} + \ldots$$

SUSY Breaking

Vev F_S for the F-term of S yields

- Gaugino mass

$$m_{1/2} = \frac{g_4^2 h F_S}{2\Lambda}$$

  - g_4: 4-dimensional gauge coupling ($g_4^2 = \frac{g_D^2}{V_{D-4}}$)
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- Squark and slepton masses very small
  $\rightsquigarrow$ solution of the SUSY flavor problem

Restricting the Masses

$$\frac{m_{3/2}}{m_{1/2}} = \frac{2\Lambda}{\sqrt{3}g_4^2 h M_4}$$

- $M_c < \Lambda \lesssim M_D$
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  - Must not be too large to avoid strong coupling below Λ
    $\Rightarrow$ Lower bound on $m_{3/2}/m_{1/2}$
    $\rightsquigarrow$ Estimate by naive dimensional analysis

1. Gaugino Mediation

2. Naive Dimensional Analysis

3. Bounds on Gaugino and Gravitino Masses

Idea

Manohar, Georgi, Nucl. Phys. **B234** (1984); Georgi, Randall, Nucl. Phys. **B276** (1986)
Luty, Phys. Rev. **D57** (1998); Cohen, Kaplan, Nelson, Phys. Lett. **B412** (1997)
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Consider theory with dimensionless bulk fields $\hat{\Phi}(x, y)$ and brane fields $\hat{\phi}(x)$, valid up to a cutoff Λ:

$$\mathscr{L} = \Lambda^D \hat{\mathscr{L}}_{\text{bulk}}(\hat{\Phi}) + \delta^{(D-4)}(y) \Lambda^4 \hat{\mathscr{L}}_1(\hat{\Phi}, \hat{\phi})$$

Loop corrections

- suppressed by loop factor $1/\ell_D$ ($\ell_4 = 16\pi^2$, $\ell_5 = 24\pi^3$, ...)
- enhanced by group theory factor C, typically $C \sim C_2(G)$ (e.g. $C = 5$ for $\mathrm{SU}(5)$)

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Consider theory with dimensionless bulk fields $\hat{\Phi}(x, y)$ and brane fields $\hat{\phi}(x)$, valid up to a cutoff Λ:

$$\mathscr{L} = \frac{\Lambda^D}{\ell_D/C} \hat{\mathscr{L}}_{\text{bulk}}(\hat{\Phi}) + \delta^{(D-4)}(y) \frac{\Lambda^4}{\ell_4/C} \hat{\mathscr{L}}_1(\hat{\Phi}, \hat{\phi})$$

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- enhanced by group theory factor C, typically $C \sim C_2(G)$ (e.g. $C = 5$ for $\mathrm{SU}(5)$)

$\Rightarrow$ With suitable prefactors in $\mathscr{L}$:
All loops of same order of magnitude for $\mathcal{O}(1)$ couplings
$\Leftrightarrow$ Strong coupling

NDA Recipe

1. Express theory in terms of dimensionless fields:

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Example

5D gauge coupling:

$$g_5^2 < \frac{24\pi^3/C}{\Lambda}$$

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$$\Rightarrow\; h < \frac{\ell_D}{4\pi\sqrt{C}g_4^2}\left(\frac{M_c}{\Lambda}\right)^{D-4}$$

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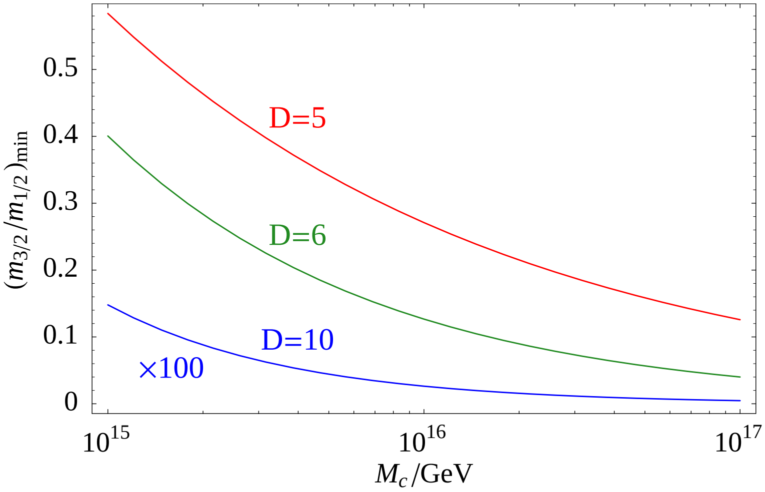
$$\Downarrow$$

Lower Bound on Gravitino to Gaugino Mass Ratio

$$\frac{m_{3/2}}{m_{1/2}} = \frac{2\Lambda}{\sqrt{3}g_4^2 h\, M_4} > \frac{8\pi\sqrt{C}}{\sqrt{3}\ell_D}\left(\frac{\Lambda}{M_c}\right)^{D-4}\frac{\Lambda}{M_4}$$

Lower Bound on $m_{3/2}/m_{1/2}$

Choose cutoff equal to D-dimensional Planck scale and $C = 5$



Lower Bound on $m_{3/2}/m_{1/2}$

Result

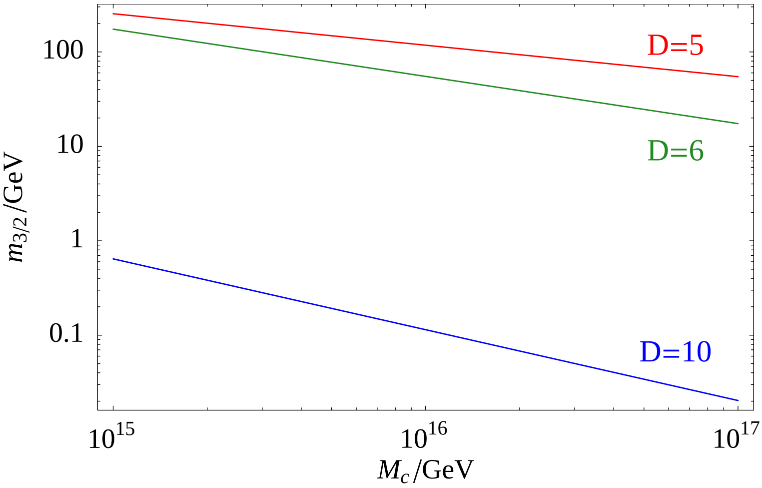
- Gravitino can be the LSP, if gaugino mass sufficiently close to upper bound
- Gravitino can't be much lighter than gauginos for $D = 5, 6$

Note:

- $m_{1/2}$ given at M_c $\rightsquigarrow$ Running to low energies decreases lightest gaugino mass by factor ~ 0.4
- Bound becomes weaker if the cutoff is lowered

Lower Bound on $m_{3/2}$

Fix $m_{\tilde{g}} = 1$ TeV (at low energy) $\Rightarrow$ Lower bound on $m_{3/2}$



Lower Bound on $m_{3/2}$

Typical Bound in Gaugino Mediation

$m_{3/2} > 17$ GeV (for $D = 6$ and $M_c = 10^{17}$ GeV)

$\Rightarrow$ Experimental implications for much lighter gravitino would disfavor gaugino mediation

Scalar Masses

- Initial condition at compactification scale: Squark and slepton masses ≈ 0
- Generated by radiative corrections
- Lightest slepton is a stau
- Typical mass slightly below that of lightest neutralino

$\Rightarrow$ Gravitino LSP $+$ $\tilde{\tau}$ NLSP possible

$\Rightarrow$ $\tilde{\tau}$ decays into gravitinos may be observed at colliders

Buchmüller, Hamaguchi, Ratz, Yanagida, Phys. Lett. **B588** (2004)
Hamaguchi, Kuno, Nakaya, Nojiri, Phys. Rev. **D70** (2004)
Feng, Smith, Phys. Rev. **D71** (2005)
Hamaguchi, Ibarra, JHEP **02** (2005)
Brandenburg, Covi, Hamaguchi, Roszkowski, Steffen, Phys. Lett. **B617** (2005)

Conclusions

For gaugino mediated SUSY breaking:

- Lower bound on mass ratio $m_{3/2}/m_{1/2}$ from naive dimensional analysis
- Gravitino can be the LSP
- Lower bound: $m_{3/2} \gtrsim 10\,\text{GeV}$
- Stau is a good candidate for the NLSP