Strong dark matter constraints on GMSB models

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Gauge Mediated SUSY breaking

GMSB

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SUSY breaking is transmitted from the hidden to the visible sector by Messenger particles due to gauge couplings on loop level.

- The Messenger sector is parametrized by the Messenger Mass M and the SUSY Breaking Scale Λ
- Minimal Model:
  - Messengers transform as $5 + \bar{5}$ under $SU(5)$ (d_R^c-, ν-, e_L-like)
  - After EWSB the ν -like Messenger is the lightest one. If stable $\Omega_\nu h^2 \gg 0.1$!

Gravitino

- The Gravitino is LSP in GMSB with mass

$$m_{3/2} = \frac{M\Lambda}{\sqrt{2}kM_P}, \qquad k \leq 1$$

- $m_{3/2}$ is in keV range for common values :

  $\rightarrow$ Relic density independent of Reheating Temperature:

$$\Omega h^2 \simeq \frac{m_{3/2}}{0.85\text{keV}} \frac{100}{g_*(T_{3/2})}$$

- Lower Bound on $m_{3/2}$ from Lyman-α-forest

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Cosmological Gravitino Problem

The Relic Density for $m_{3/2} > 1.5\text{keV}$ is $\Omega_{3/2}h^2 > 1.2$

$\rightarrow$ One order too high !

Entropy Production - The Solution?

Idea:

- Allow Decays of the lightest Messenger:
- This Decays produce Entropy
- The Entropy dilutes the Relic Density of frozen out particles:

$$\Delta_M \sim \frac{4}{3}\frac{MY_M}{T_D}$$

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Realization:

Mixing term between Messenger and MSSM particles in the superpotential: [a]

$$W_{\not R} = f m_{3/2} \Phi_M \bar{\Phi}_{MSSM},\ \mathcal{O}(f) = 1$$

[a] Baltz/Murayama [astro-ph/0108172v2], Fujii/Yanagida[hep-ph/0208191v2]

The next Problem: Electroweak Symmetry Breaking

- In literature only decays in neutralino and SM fermion assumed:
  Before EWSB Tree Level Decays in massless Gauge Bosons forbidden (Gauge Invariance)
- After EWSB decays in massive Gauge Bosons are possible

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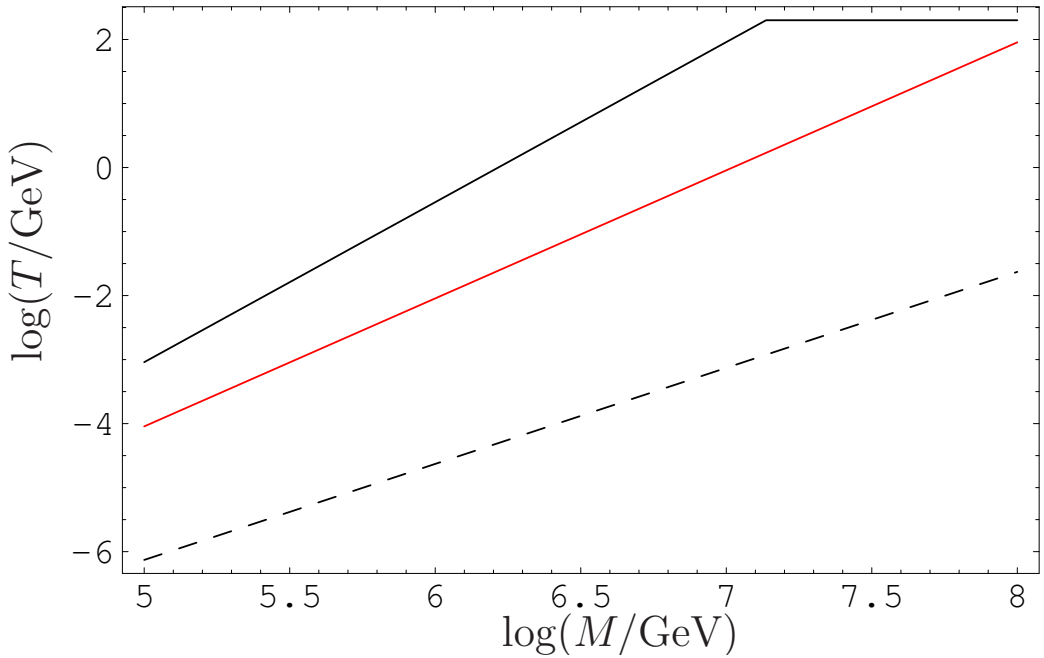
Enhancement

The decay into W-Bosons is enhanced by a factor $\frac{M^2}{M_W^2}$ in comparison to the decay in neutralino and fermion

$\rightarrow$ Messengers decay to fast to produce sufficient entropy!

Freeze out and decay temperature



- Red: Freeze out temperature of gravitino
- Black,solid: Decay temperature including W^--channel
- Black,dashed: Decay temperature without W^--channel

$$k = 1, f = 1, \Lambda = 10^{-3} M$$

Another problem: Big Bang Nucleosynthesis

- Tuning of f leads to later decay of weakly interacting messengers
- But: The strongly interacting messengers decay much later (Decay in Z suppressed by GIM).

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- Tuning of f leads to later decay of weakly interacting messengers
- But: The strongly interacting messengers decay much later (Decay in Z suppressed by GIM).

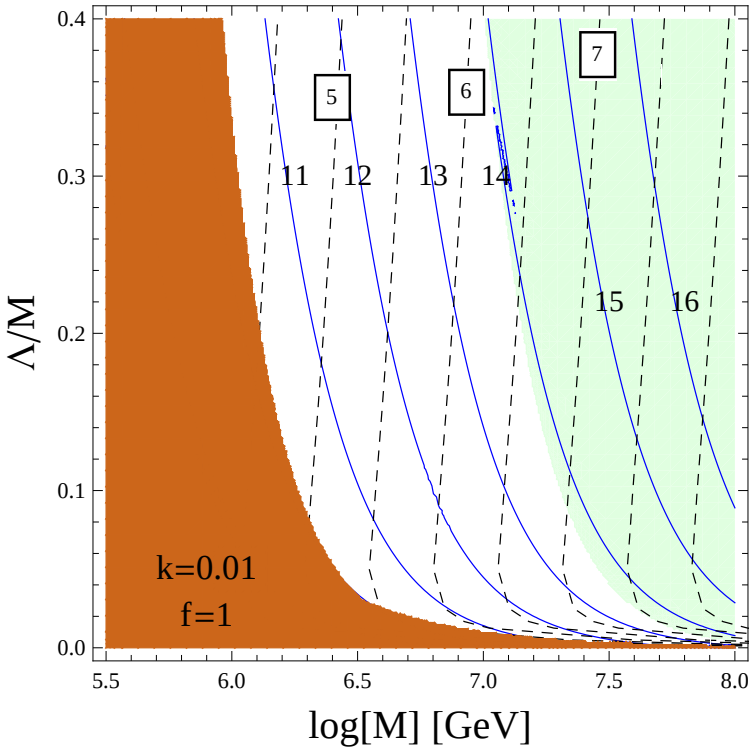
$$\rightarrow \text{Spoiling the results of BBN}$$

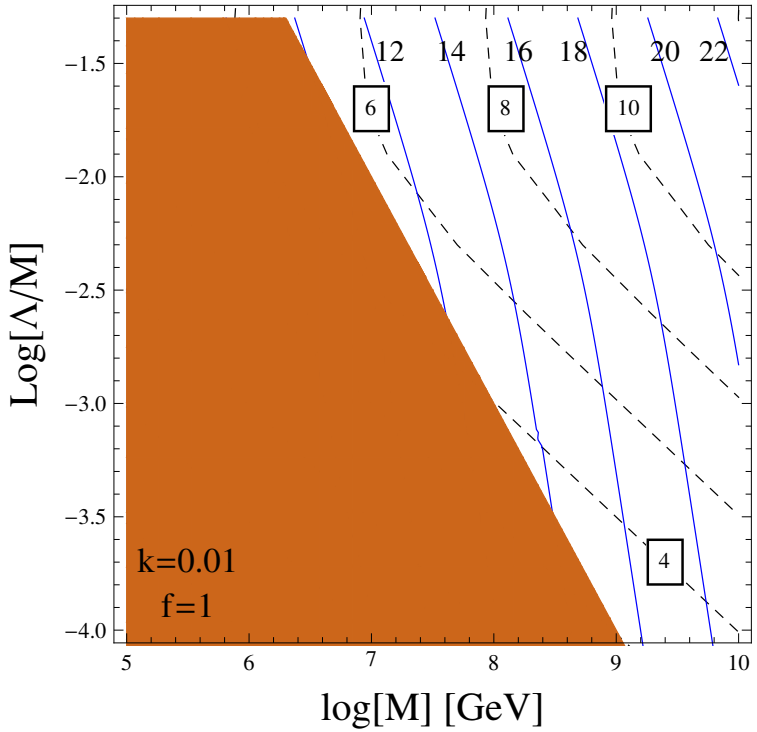
- The relic density of the strongly interacting messengers itself is too low to produce sufficient entropy

Result

Interplay of different types of messengers and different cosmological constraints rule this scenario out!

Relic density of strongly interacting Messengers





Generalization to other Messenger Sectors

- Results hold for other messenger sectors with other/more messenger multiplets or other GUT-groups
- One exception: Messengers transforming under 16 of $SO(10)$
  - Lightest messenger is gauge singlet

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Gauge Singlet Messengers

Have correct life and abundance to dilute Gravitinos without fine tuning

Summary

- Decays of neutral messengers in W enhanced
  $\rightarrow$ Messengers decay often before gravitino is frozen out
- The $SU(3)$-messengers decay much later (GIM suppressed)
  $\rightarrow$ Spoils results of BBN, if neutral messengers decay late
- Entropy production by strongly interacting messengers alone is too small

Different cosmological constraints rule minimal scenario out!

- Holds for many GMSB-models. **16** under $SO(10)$ might work