Gravitino dark matter and a high reheating temperature

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Sources of relic gravitinos:

1. Thermal initial abundance

2. Scattering of already thermalized particles

$$\Omega^{\rm TP}h^2 = \left(\frac{T_{\rm RH}}{10^9\,{\rm GeV}}\right)\left[7.4\times10^{-6}\left(\frac{m_{3/2}}{1\,{\rm GeV}}\right)+\left(\frac{m_{\rm NLSP}}{300\,{\rm GeV}}\right)^2\left(\frac{1\,{\rm GeV}}{m_{3/2}}\right)\sum_r \gamma_r\left(\frac{M_r}{m_{\rm NLSP}}\right)^2\right]$$

$$\gamma_3 = 0.48 - 0.56\,(0.62-0.74)\,,\ \gamma_2 = 0.57\,(0.54)\,,\ \gamma_1 = 0.17\,(0.13) \qquad \text{for } T_{\rm RH} = 10^9\,(10^7)\,{\rm GeV}$$

Pradler & Steffen '06; Rychkov & Strumia '07

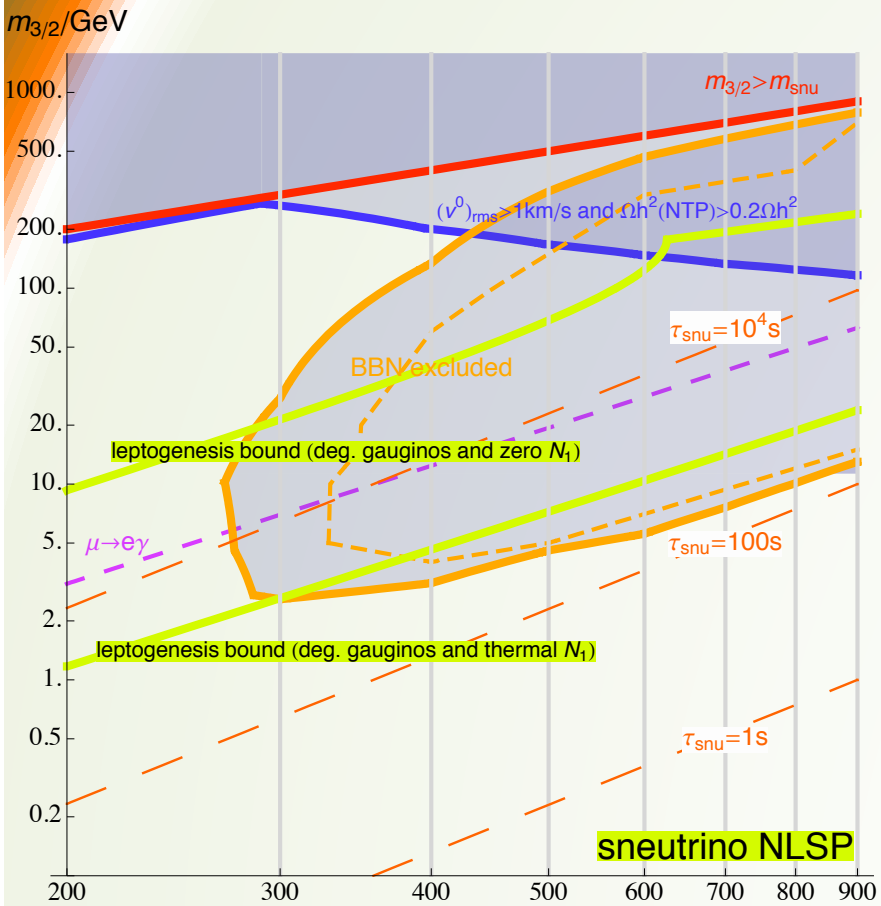
For fixed masses of the gravitino and the NLSP, and the reheating temperature, the r.h.s. is minimized with NLSP/gaugino mass degeneracy.

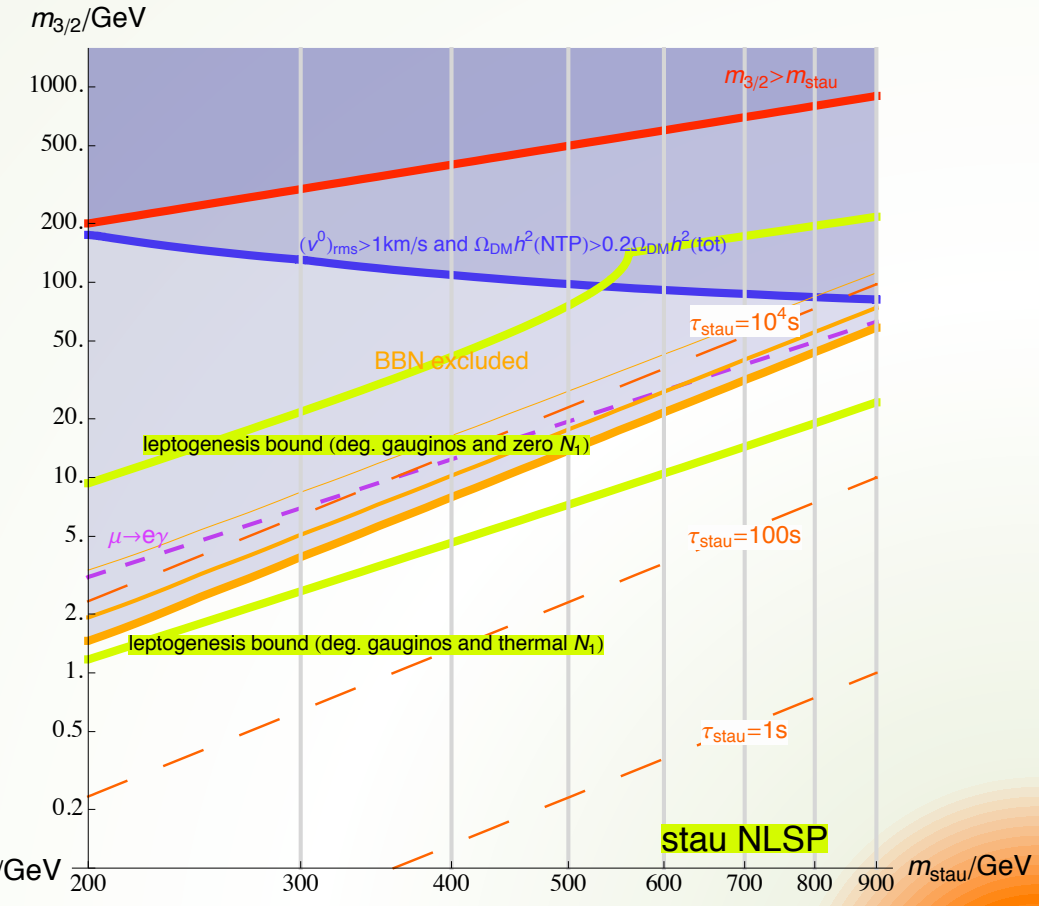
3. Decays of the next-to-lightest supersymmetric particle (NLSP)

$$\tau({\rm NLSP}\to\tilde{G}+{\rm SM}) = 5.9\cdot10^4\,{\rm s}\left(\frac{m_{3/2}}{1\,{\rm GeV}}\right)^2\left(\frac{100\,{\rm GeV}}{m_{\rm NLSP}}\right)^5$$

Bounds from Big Bang Nucleosynthesis and leptogenesis

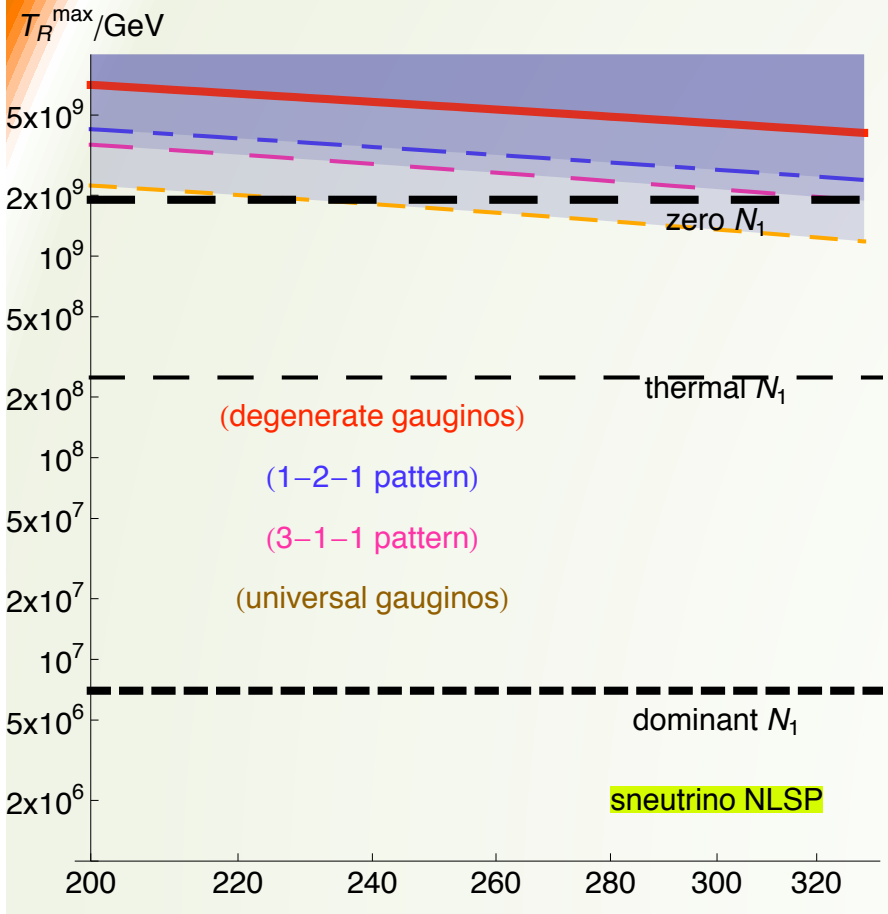
based on: Giudice et al. '03; Kwasaki, Kohri & Moroi '04; Jedamzik, Lemoine & Moultaka '05; Antusch & Teixeira '06; Kanzaki et al. '07; Pradler & Steffen '07; Kawasaki et al. '08; Pradler '08; calculations with micrOMEGAs.2.2 (Belanger et al. '06,'08)

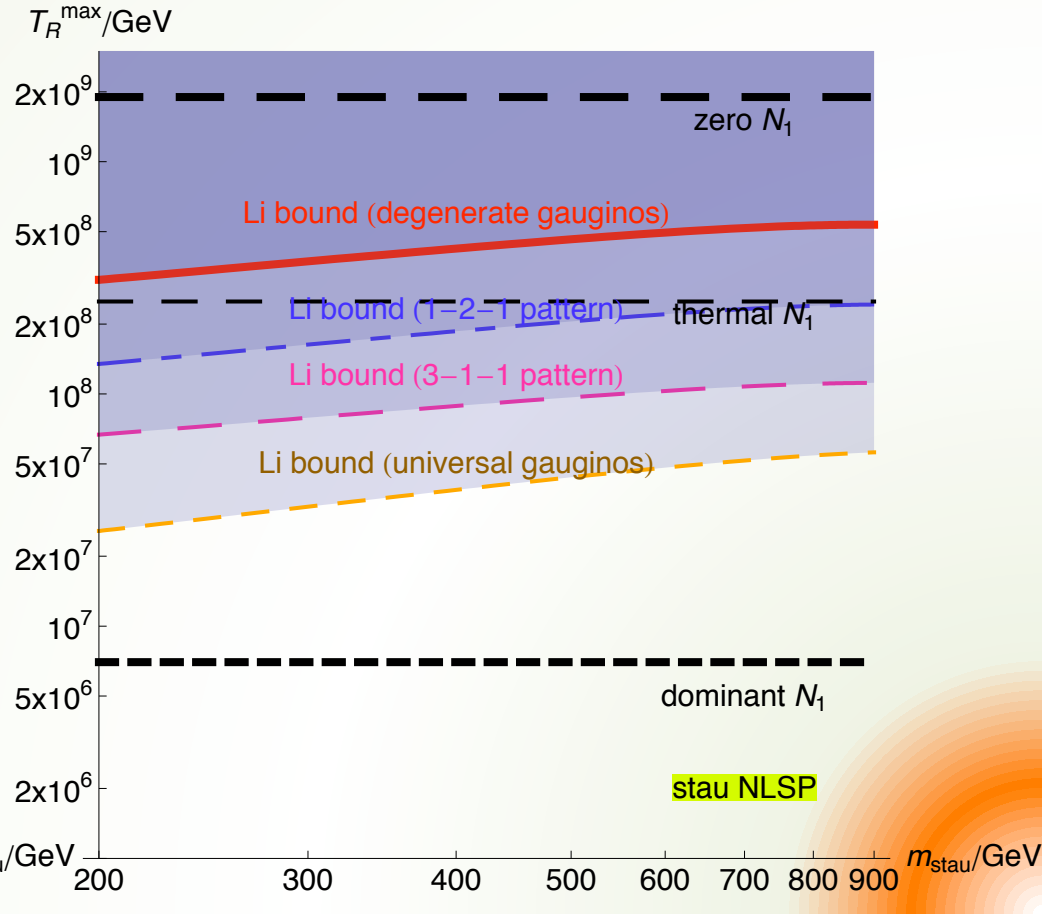




Maximal reheating temperature consistent with the BBN bounds

In models with NLSP/gaugino mass degeneracy
the BBN/leptogenesis tension is alleviated





Minimal gauge mediation of supersymmetry breaking

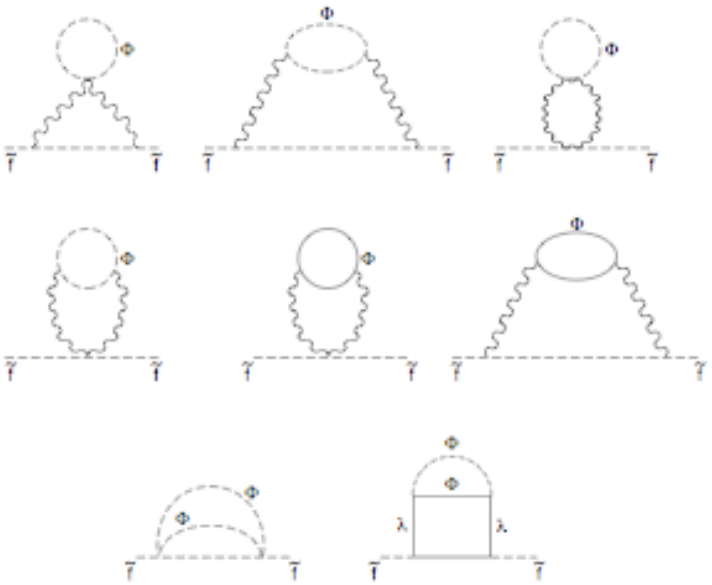
$$w = -\lambda X \tilde{\phi}\phi$$

nonsinglet, e.g. $\bar{\mathbf{5}}, \mathbf{5}$ of $SU(5)$

mass splitting between bosonic and fermionic components

singlet, breaks susy

$$\langle F_X \rangle \neq 0$$



$$M_i = \frac{\alpha_i}{4\pi} N \frac{\langle F_X \rangle}{\langle X \rangle}$$

10^5 GeV

$$m_s^2 = 2 \sum_i \left(\frac{\alpha_i}{4\pi}\right)^2 C_s^{(i)} N \left(\frac{\langle F_X \rangle}{\langle X \rangle}\right)^2$$

Generalized gauge mediation of supersymmetry breaking

Meade, Seiberg & Shih '08; Carpenter et al. '08

SU(5) breaking & higher dim SU(5) irreps (modest) or nonpert. interactions of messengers (courageous)

High-scale input

$$M_{\rm mess} = \left(10^{-3} - 10^{-1}\right) M_{\rm GUT}$$

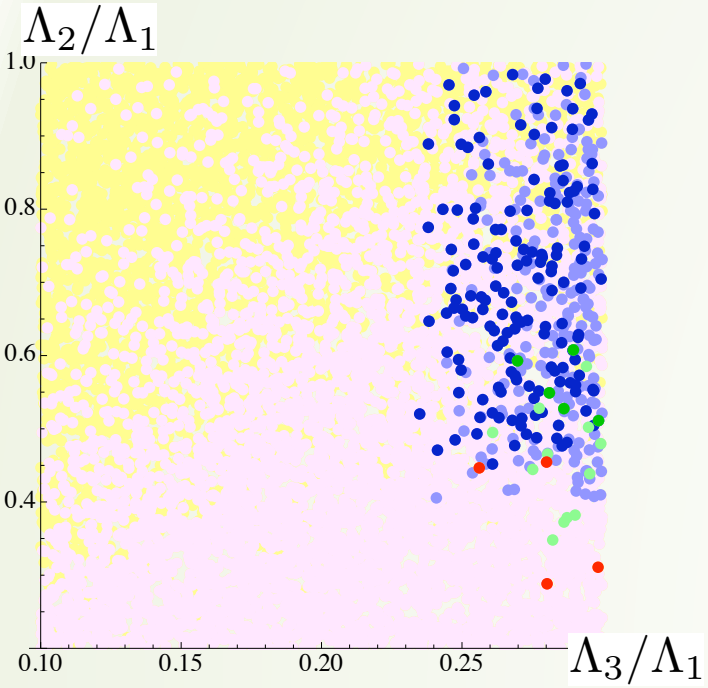
← GeV-scale gravitino

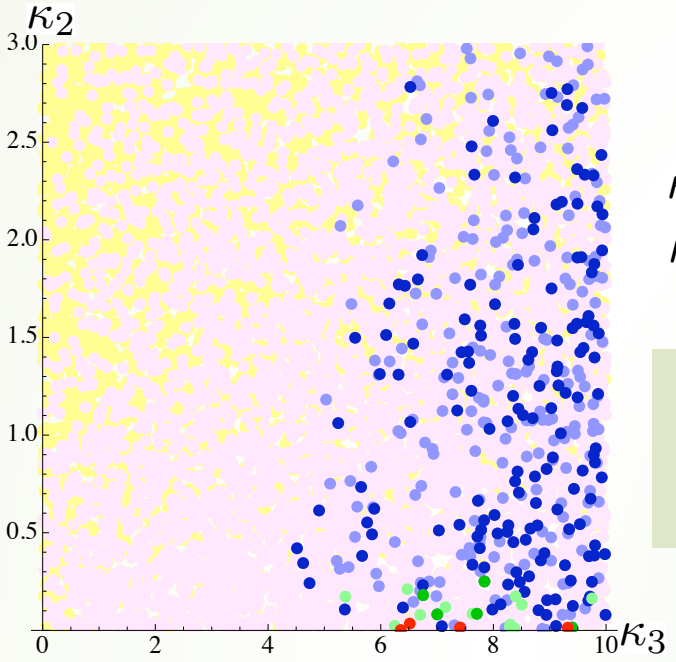
$$M_r = \frac{g_r^2}{16\pi^2}\Lambda_r \qquad m_s^2 = \sum_{r=1}^{3} \frac{g_r^4}{128\pi^4} C_r^{(s)} \kappa_r \Lambda_r^2$$

$r = 1,2,3 \to U(1)_Y,\ SU(2)_L,\ SU(3)_C$
$s = Q, U, D, L, E, H_1, H_2$

Minimal models: $\Lambda_r = \Lambda \qquad \dfrac{1}{\kappa_r} = N_{\rm mess}$

Low-scale output (RG analysis)





$$M_{\rm mess} = 10^{15}\,{\rm GeV}$$

$\Lambda_1 = 3 \cdot 10^5\,{\rm GeV}$ $(M_1 \approx 400\,{\rm GeV})$

$\kappa_1 \ll 1$ stau NLSP

$\kappa_1, \kappa_2 \ll 1$ sneutrino NLSP

- no EWSB
- RH stau NLSP
- RH stau NLSP $\frac{m_{\rm glu}}{m_{\rm stau}} < 2$
- mixed stau NLSP
- sneutrino NLSP $m_{\rm snu} < 400\,{\rm GeV}$
- none of the above

$m_h > 114\,{\rm GeV}$

Summary

Large reheating temperature (leptogenesis) – motivation for studying models with **compressed NLSP/gaugino spectra** (beyond minimal gauge mediation)

The optimal pattern of **GGM** of supersymmetry breaking **at high scale**

	SU(3)	SU(2)	U(1)
gauginos (wrt bino)	small gluino/NLSP degeneracy	medium wino/NLSP degeneracy	---
scalars (wrt gauginos)	LARGE rad. EWSB, higgs mass bound	≤ medium EWSB small sneutrino NLSP	small NLSP lighter than bino

Particle messenger models?

nonstandard SU(5) representations required

examples of O'Raifeartaigh models with 2 pairs $\mathbf{35} + \bar{\mathbf{35}}$