THE DEGENERATE GRAVITINO SCENARIO

Oscar Vives

L. Boubekeur, K-Y Choi, R. Ruiz de Austri and O.V.,

arXiv:1002.0340, JCAP 1004:005,2010

SUSY 2010

Gravitino problem

- Local SUSY $\Rightarrow$ Supergravity: $g_{\mu\nu} \leftrightarrow \psi_\mu$
- Gravitational couplings $\propto \frac{1}{M_{\text{Planck}}} \Rightarrow \tau_{3/2,NLSP} \ggg$
- Even with inflation, gravitinos re-created at reheating.
- Gravitino abundance $\propto T_{\text{Reheat}}$
- Gravitino(/NLSP) decay upsets success of stand. BBN

GRAVITINO PROBLEM

- Local SUSY $\Rightarrow$ Supergravity: $g_{\mu\nu} \leftrightarrow \psi_\mu$
- Gravitational couplings $\propto \frac{1}{M_{\rm Planck}} \Rightarrow \tau_{3/2,NLSP} \ggg$
- Even with inflation, gravitinos re-created at reheating.
- Gravitino abundance $\propto T_{\rm Reheat}$
- Gravitino(/NLSP) decay upsets success of stand. BBN

$$\Downarrow$$

Strong tension with hight $T_{\rm Reheat}$ required by thermal leptogenesis

Is it possible thermal leptogenesis in a SUSY scenario??...

Gravitino couplings completely fixed in sugra... "free" parameters: $m_{3/2}$, $\Delta M \equiv m_{\rm NLSP} - m_{3/2}$ and NLSP comp.

A.- Reduce the number of NLSP (gravitino) decays:

- Short-lived, or very long-lived NLSP
- NLSP annihilate strongly at decoupling.

B.- Reduce the energy released per NLSP decay

Is it possible thermal leptogenesis in a SUSY scenario??...

Gravitino couplings completely fixed in sugra... "free" parameters: $m_{3/2}$, $\Delta M \equiv m_{\rm NLSP} - m_{3/2}$ and NLSP comp.

A.- Reduce the number of NLSP (gravitino) decays:

- Short-lived, or very long-lived NLSP
- NLSP annihilate strongly at decoupling.

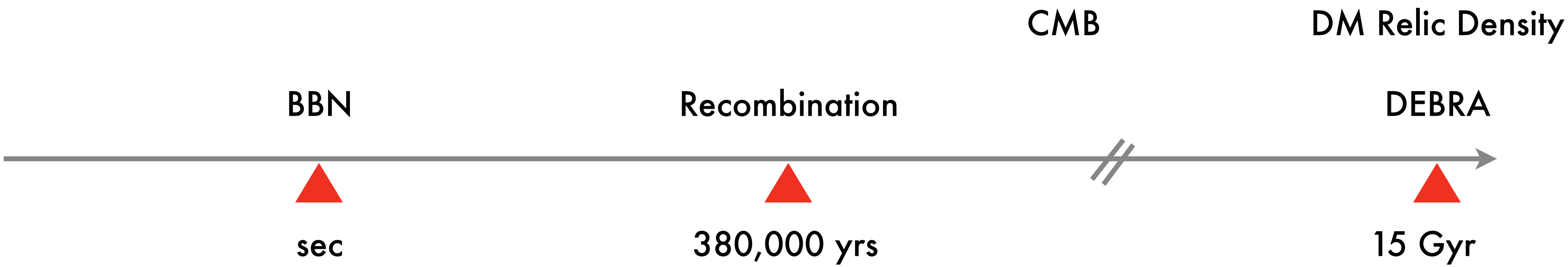
B.- Reduce the energy released per NLSP decay

$$\Downarrow$$

"Degenerate gravitino" scenario, $\Delta M \equiv m_{\rm NLSP} - m_{3/2} << m_{3/2}$.

Constraints on late decay

Different constraints depending on τ_{NLSP} (fixed by $m_{3/2}$ and ΔM)



- Any τ_{NLSP} — Dark matter relic abund.
- $O(10)$ sec $\leq \tau_{\text{NLSP}} \leq 10^7$ sec — BBN constraints
- 10^7 sec $\leq \tau_{\text{NLSP}} \leq 10^{13}$ sec — CMB constraints
- 10^{13}sec $\leq \tau_{\text{NLSP}}$ — Diffuse extragalactic background radiation.

Dark Matter relic abundance

- Total relic abundance must match the observed WMAP abundance

$$\Omega_{\rm CDM}h^2 = \Omega_{\rm LSP}h^2 + \Omega_{\rm NLSP}h^2 \simeq 0.11$$

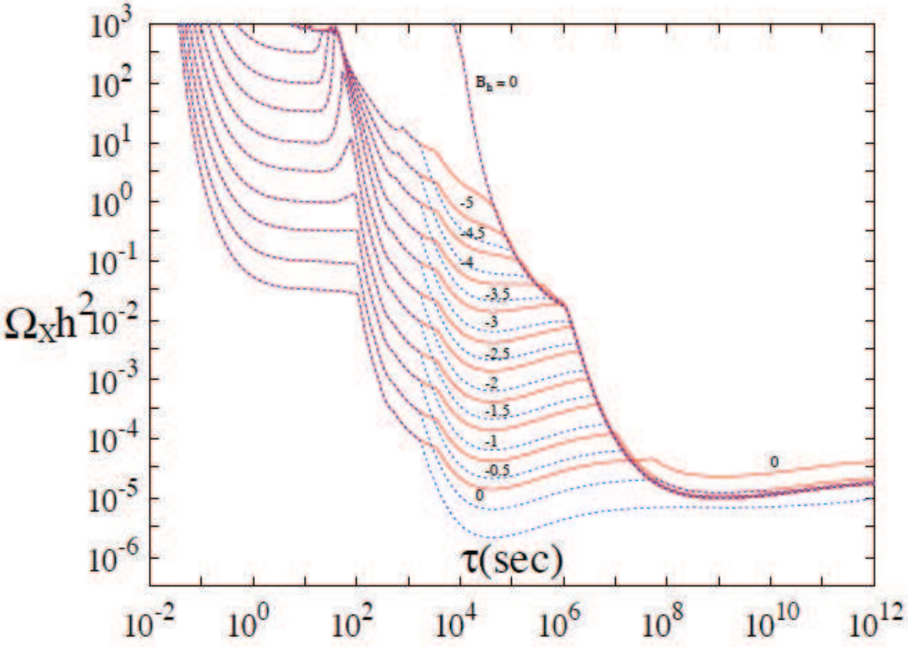
- Define ω to quantify non-thermally produced DM:

$$\omega = \frac{Y_{\rm NLSP}}{Y_{\rm CDM}} = 1 - \frac{\Omega_{\rm LSP}h^2}{\Omega_{\rm CDM}h^2}$$

- The released energy density, ξ_a:

$$\begin{aligned}\xi_{\rm em,had} &= \Delta M\ B_{\rm em,had}\ Y_{\rm NLSP} \equiv \delta m_{3/2}\ B_{\rm em,had}\ Y_{\rm NLSP} \\ &= 4.1 \times 10^{-10}{\rm GeV}\left(\frac{\Omega_{\rm CDM}h^2}{0.11}\right)\omega\ B_{\rm em,had}\ \delta\end{aligned}$$

Big Bang Nucleosinthesis



K. Jedamzik, arXiv:hep-ph/0604251

In our "degenerate gravitino" scenario, $\tau_{\mathrm{NLSP}} \gtrsim 10^7\mathrm{sec}$ or $\Delta M \lesssim 2\mathrm{GeV}$ $\Longrightarrow$ we can consider only em decays.

Cosmic Microwave Background

- CMB spectrum very well described by a Bose-Einstein distribution

$$f_\gamma(E) = \frac{1}{e^{E/(kT)+\mu} - 1}, \quad \text{where } |\mu| < 9 \times 10^{-5} \text{ from FIRAS}$$

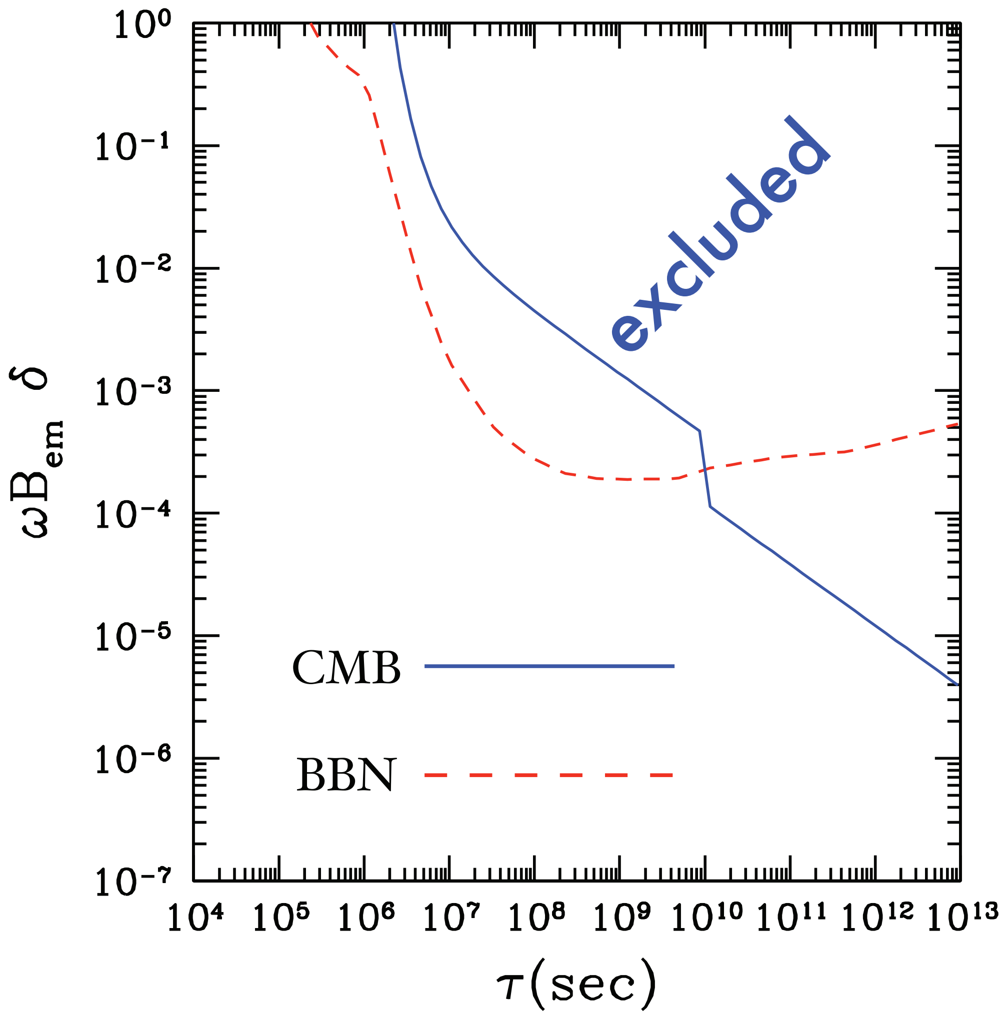
- For $\tau_{\rm NLSP} \lesssim 8.8 \times 10^9$ sec (for $\tau_{dC} = 6.08 \times 10^6$ sec.)

$$\xi_{\rm em} < 1.59 \times 10^{-8} e^{(\tau_{dC}/\tau_{\rm NLSP})^{5/4}} \left(\frac{1\text{sec}}{\tau_{\rm NLSP}}\right) \text{GeV}$$

- For $\tau_{\rm NLSP} \gtrsim 8.8 \times 10^9$ sec

$$\xi_{\rm em} < 4.42 \times 10^{-9} \sqrt{\frac{1\text{sec}}{\tau_{\rm NLSP}}} \text{GeV}$$

BBN + CMB


excluded
CMB
BBN
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
$\omega B_{em}\ \delta$
10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13}
τ(sec)

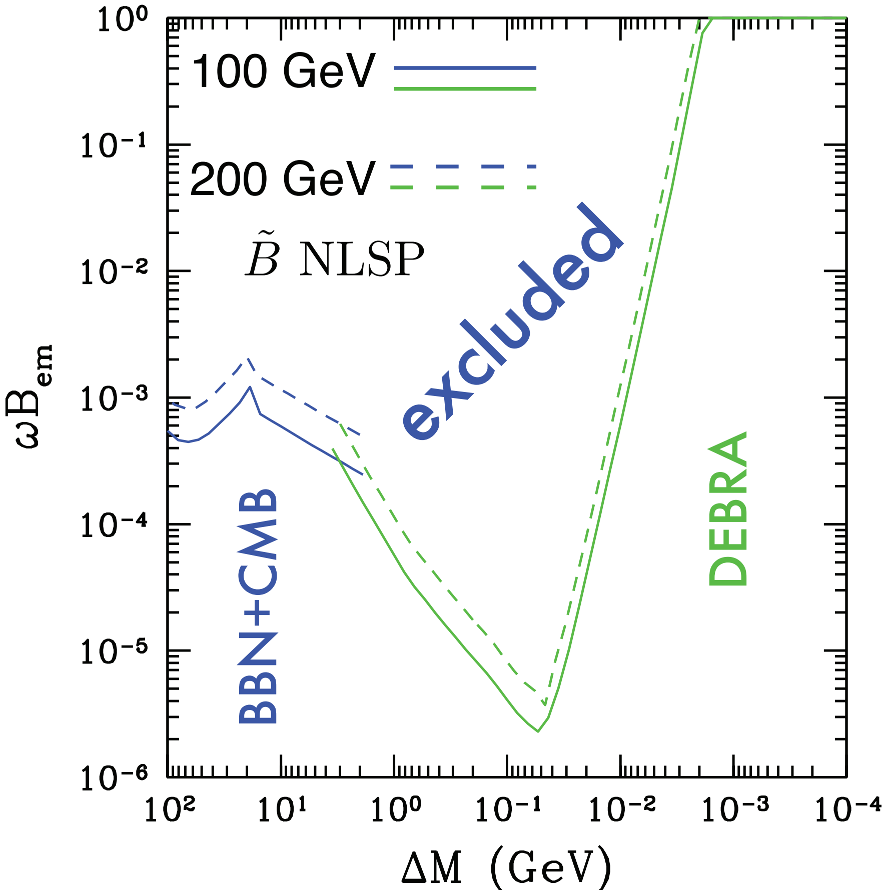
Diffuse gamma rays

$$\frac{d\Phi}{dE_\gamma} = \frac{c}{4\pi\tau_{\rm NLSP}} \int_{t_0}^{t_i} dt\, \frac{\rho_c \Omega_{\rm WMAP} \omega B_{em}}{m_{\rm NLSP}}\, e^{-t/\tau_{\rm NLSP}}\, \delta(E_\gamma - a\, E_{em})$$

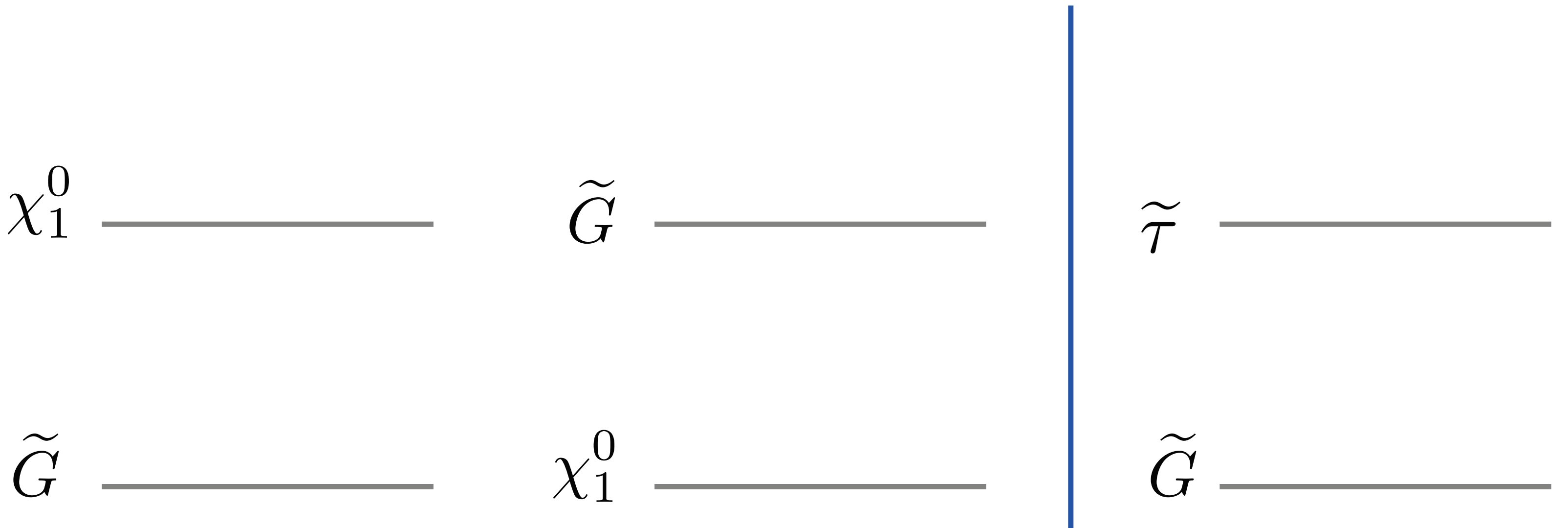
Compare obtained diffuse gamma rays with data from:

1.- SPI
2.- COMPTEL
3.- EGRET

Yuksel & Kistler '07



Three different possibilities:



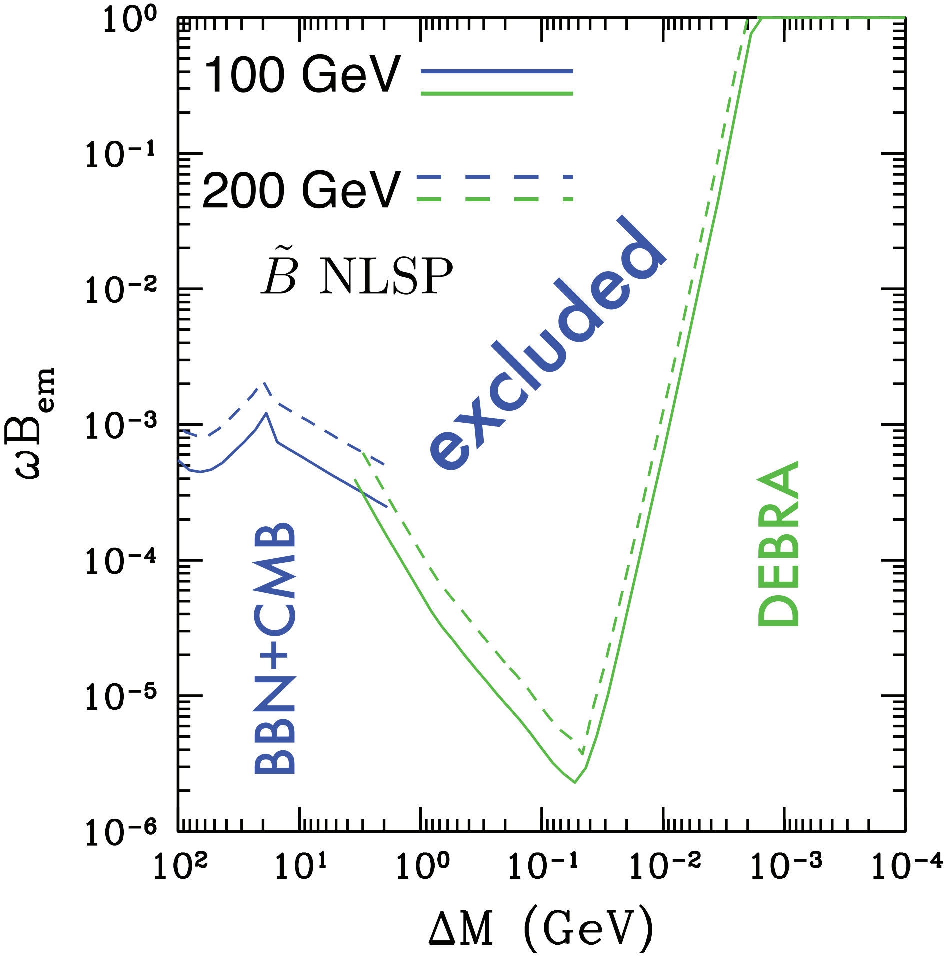
$\tau_{\tilde{\tau}} < \tau_0$ → $\Delta M \gtrsim 2\,\mathrm{GeV}$

$\tilde{\tau}$ abund. today strongly constrained by "heavy water"

$$\omega < 2.2 \times 10^{-27} \left(\frac{m_{\tilde{\tau}}}{100\mathrm{GeV}} \right)$$

χ^0 NLSP

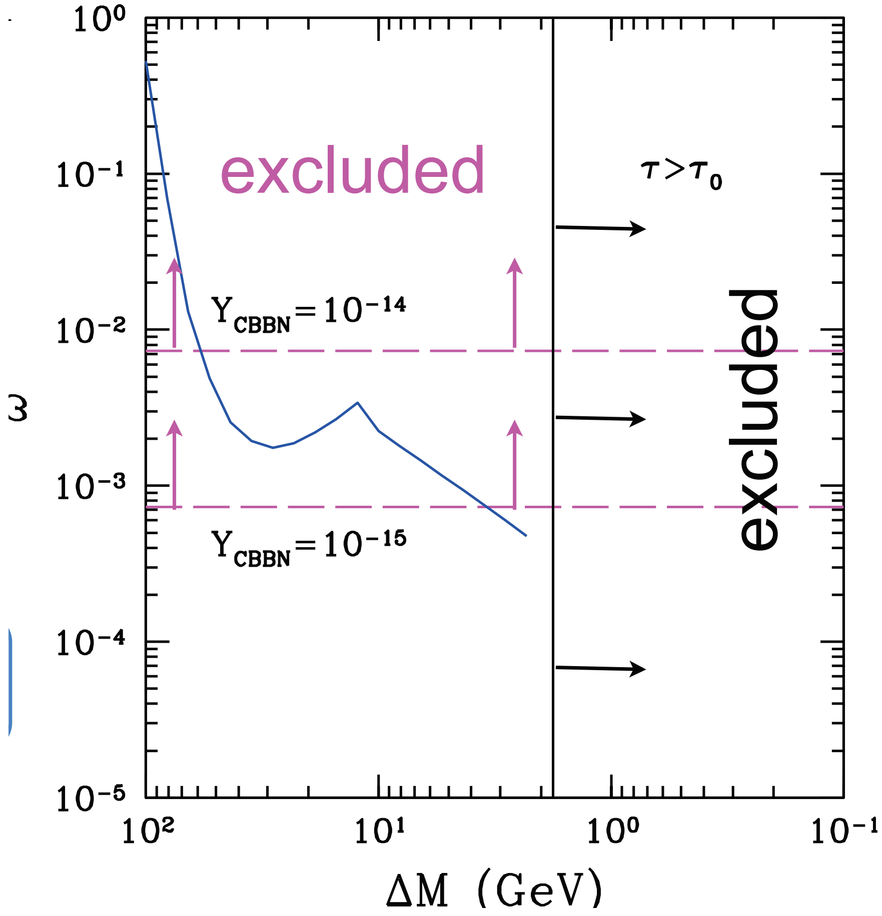
$\tilde{G}$ abundance indirectly constrained by total relic density, $T_{\rm Reheat} \sim O(10^9)$ GeV if strong BBN/CMB/DEBRA constraints on $\tilde{\chi}^0$ satisfied.



$\tilde{\tau}$ NLSP

Long-lived $\tilde{\tau}$ constrained by catalyzed BBN.

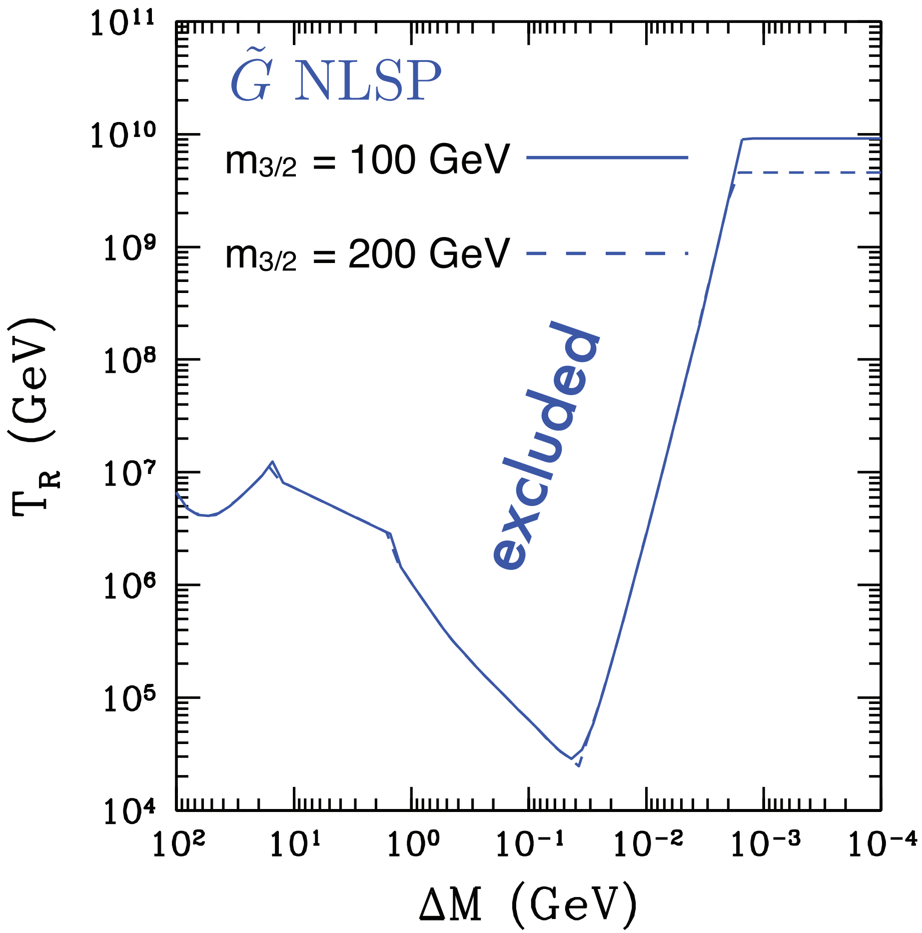
$$Y_{X^-} < 10^{14}\text{–}10^{15} \Rightarrow \omega < 2.44 \times 10^{-3} \left(\frac{m_{\tilde{\tau}}}{100\text{GeV}}\right) \left(\frac{Y_{X^-}}{10^{-14}}\right)$$



$\tilde{G}$ NLSP

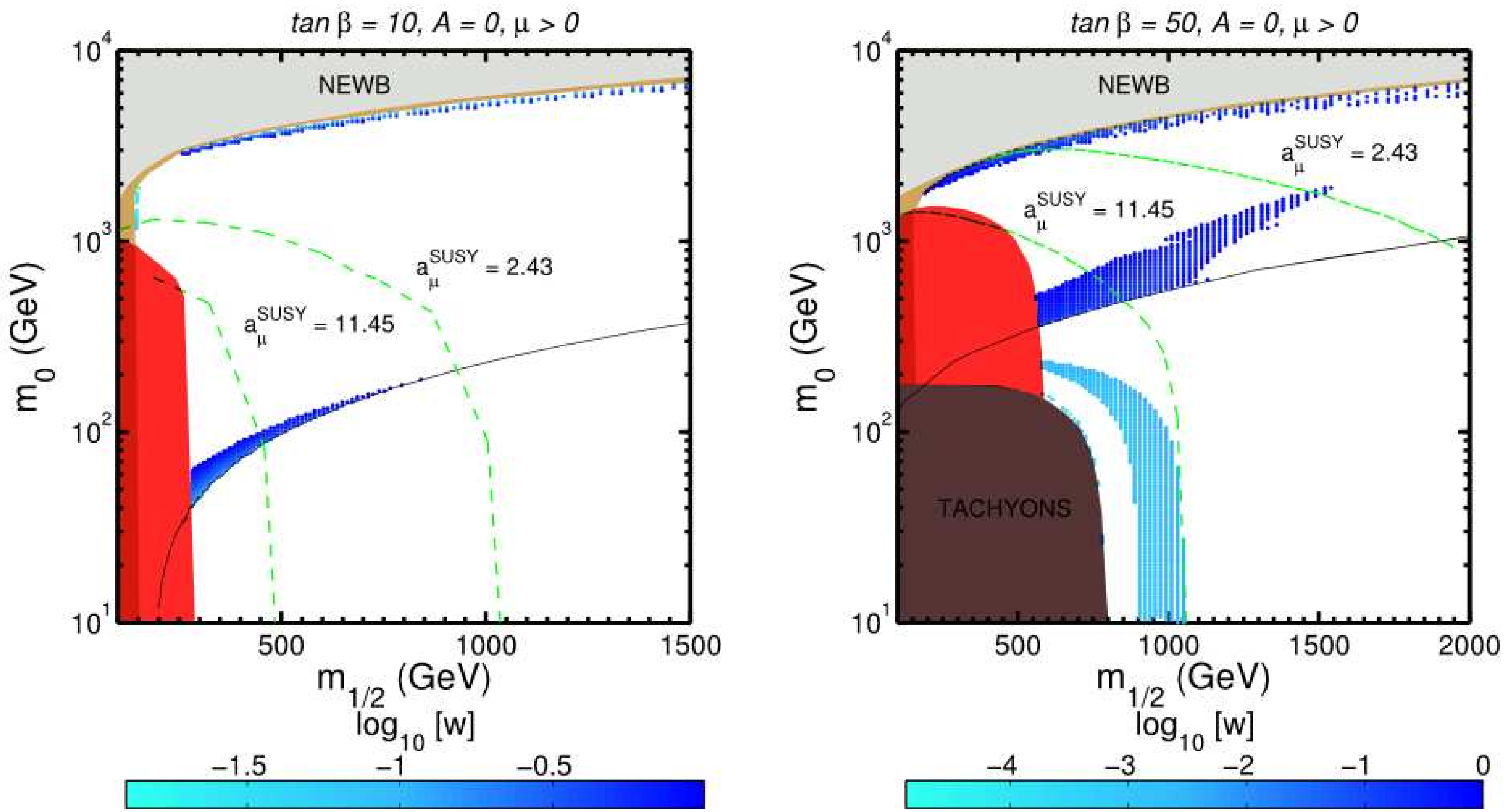
Bound on ω translates directly into $T_{\rm Reheat}$

$$T_{\rm Reheat} \simeq 4.1 \times 10^9 {\rm GeV} \left(\frac{m_{3/2}}{100{\rm GeV}}\right) \left(\frac{1{\rm TeV}}{M_3}\right)^2 \omega$$



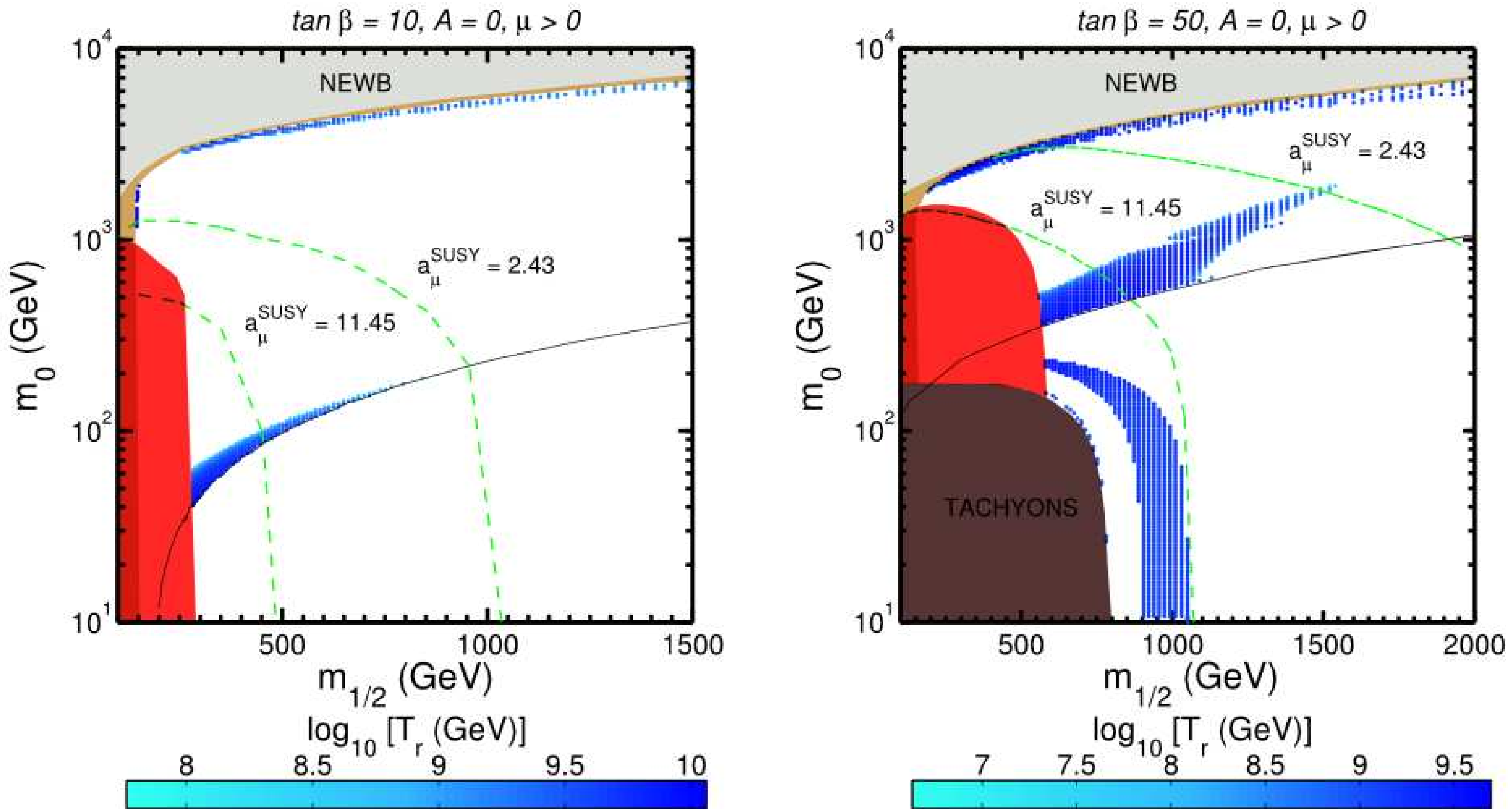
CMSSM REALIZATIONS

In the CMSSM, how low can ω be ???.



CMSSM REALIZATIONS

For $\tilde{G}$ LSP and appropriate $m_{3/2}$



$\Longrightarrow \Delta M < 10^{-2}$ GeV; χ^0 begin to decay now.

CONCLUSIONS

Yes !!, large $T_{\rm Reheat}$ for leptogenesis possible in the MSSM. But...

$\Downarrow$

$A.-$ $\tau_{\rm LNSP} > \tau_0$: A strong degeneracy with the NLSP is required, $\Delta M \lesssim 10$ MeV.

$B.-$ NLSP must annihilate completely at decoupling.

Conclusions

Yes !!, large $T_{\rm Reheat}$ for leptogenesis possible in the MSSM. But...

$\Downarrow$

$A.-$ $\tau_{\rm LNSP} > \tau_0$: A strong degeneracy with the NLSP is required, $\Delta M \lesssim 10$ MeV.

$B.-$ NLSP must annihilate completely at decoupling.

- $\tilde{G}$–χ^0 degeneracy : CDM relic density and direct detection experiments not coincide with density inferred from colliders.
- $\tilde{G}$–$\tilde{\tau}$ degeneracy: charged slow tracks in collider + null results in direct detection experiments.