

# Cosmology of Gravitino LSP scenario with Right-handed Sneutrino NLSP

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Existence of the Right-handed sneutrino NLSP changes usual Gravitino LSP scenario. Constraints from the BBN is relaxed.

→ New parameter region,  $m_{3/2} < 40$  GeV is allowed!

# SUSY Dark Matter

## Supersymmetric Model

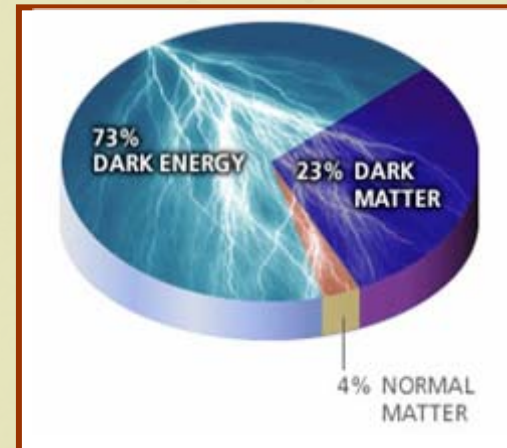
1. most attractive scenario for physics beyond the SM.
2. analyzed in detail from cosmological point of view.

## Supersymmetric Dark Matter

LSP is a candidate for dark matter if R-parity is conserved.

### What is the LSP?

1. Neutralino
2. Gravitino
3. Axino
4. ...

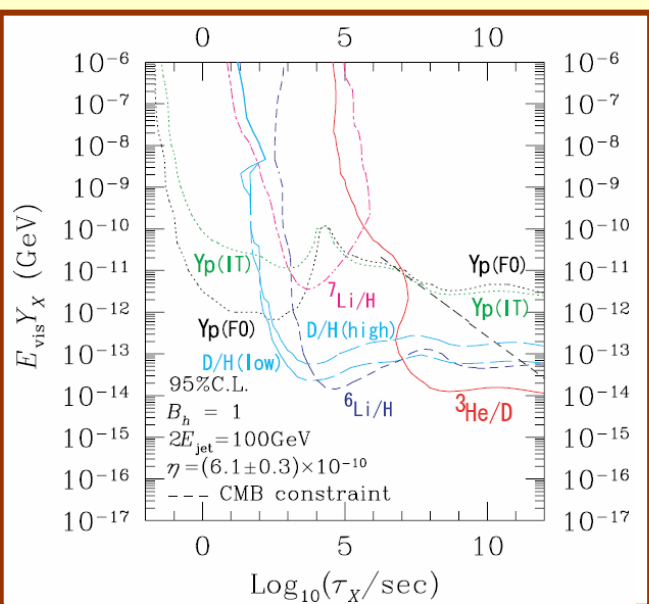


**We consider the Gravitino LSP scenario!**

# Usual Gravitino LSP scenario

Gravitino mass is strictly constrained from the BBN!

Thermally produced NLSP decays into Gravitino at late universe.  
Emitting SM particles spoil successful BBN scenario.



[Kawasaki, Kohri, Moroi (2005)]

$$m_{3/2} \lesssim 0.1 \text{ GeV}$$

[J. Feng, S.Su, F.Takayama (2005) ]

Existence of Right-handed Sneutrino  
NLSP with  $m_{\tilde{B}} > m_{\tilde{\nu}_R} > m_{3/2}$   
BBN constraint is drastically relaxed!

**A new parameter region**

$$m_{3/2} \lesssim 40 \text{ GeV}$$

# Gravitino LSP with R-Sneutrino NLSP

## Model example:

Supersymmetric model with right-handed neutrinos where neutrino masses are *purely Dirac type*.

$$W = W_{\text{MSSM}} + y_\nu \hat{H}_u \hat{L} \hat{\nu}_R^c$$
$$\mathcal{L}_{\text{soft}} = -M_{\tilde{L}}^2 \tilde{L}^\dagger \tilde{L} - m_{\tilde{\nu}_R}^2 \tilde{\nu}_R^* \tilde{\nu}_R + (A_\nu H_u \tilde{L} \tilde{\nu}_R^c + \text{h.c.}) + \dots$$

## Assumptions :

- Three right-handed sneutrino masses are degenerate
- $A_\nu$  is parametrized as  $A_\nu = a_\nu y_\nu M_{\tilde{L}}$  with  $a_\nu \sim \mathcal{O}(1)$
- $y_\nu \sin \beta = 3.0 \times 10^{-13} \times \left( \frac{m_\nu^2}{2.8 \times 10^{-3} \text{ eV}^2} \right)^{1/2}$

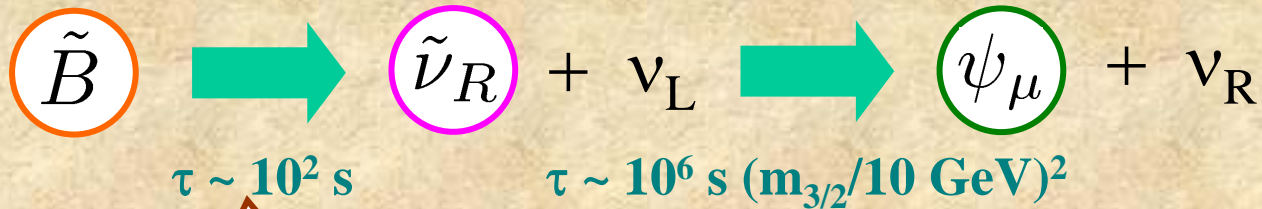
Mass spectrum,  $m_{\tilde{B}} > m_{\tilde{\nu}_R} > m_{3/2}$ , is realized.

- Can be relatively light among super-particles (no EW scale corrections for its mass)
- Never thermalized due to small neutrino Yukawa coupling



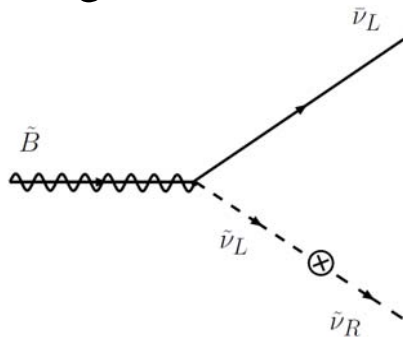
# Cosmology of the scenario

Gravitino LSP, R-Sneutrino NLSP, Bino-like neutralino NNLSP.



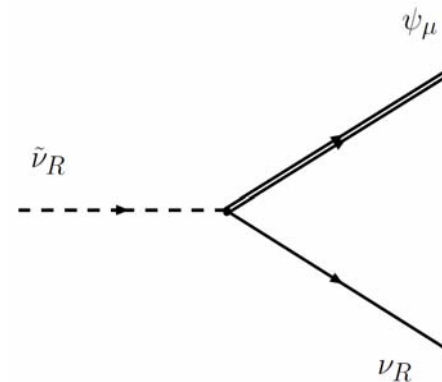
## Bino decay

After freezing out, Bino-like neutralino decays into Right-handed Sneutrino.



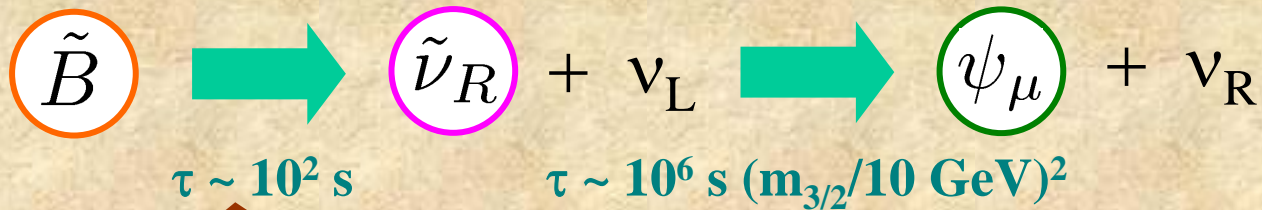
## R-Sneutrino decay

Although the life time is much longer than 1 sec., no visible (charged or colored) particles are emitted in this process.



# Constraints on the scenario

Gravitino LSP, R-Sneutrino NLSP, Bino-like neutralino NNLSP.

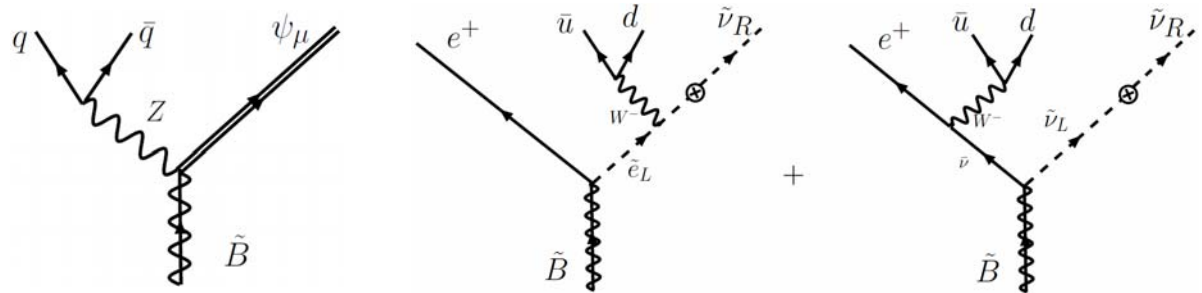


This decay is slightly constrained by the BBN due to sub-leading processes.

$$\tilde{B} \rightarrow \psi_\mu q \bar{q}$$

$$\tilde{B} \rightarrow \tilde{\nu}_R e_L^+ q \bar{q}'$$

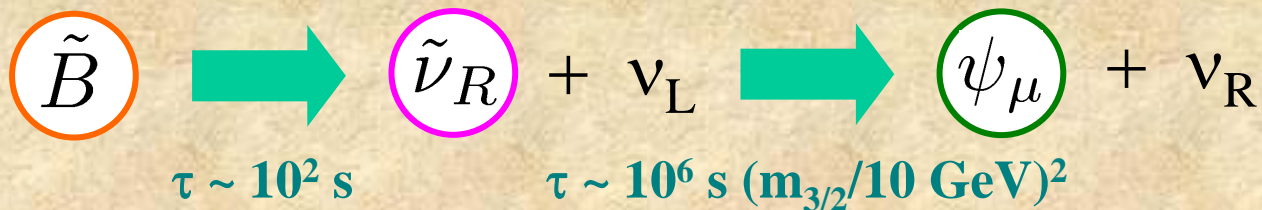
$$\tilde{B} \rightarrow \tilde{\nu}_R \bar{\nu}_L q \bar{q}$$



**Three- or four- body decays to produce hadrons**

# Constraints on the scenario

Gravitino LSP, R-Sneutrino NLSP, Bino-like neutralino NNLSP.



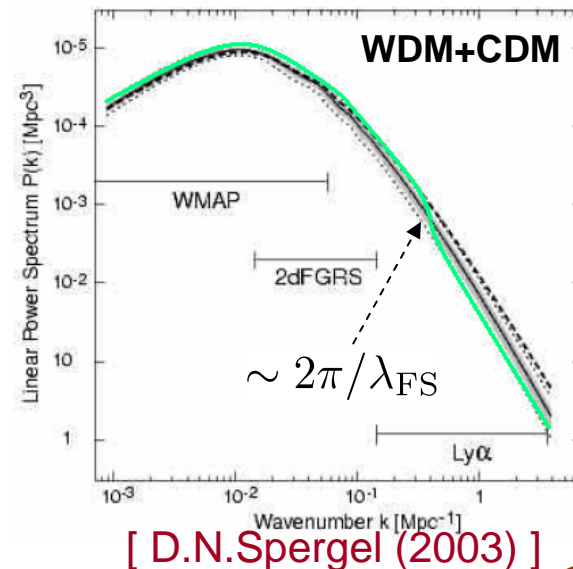
This decay is constrained by the structure formation of our universe.  
 (Emitted gravitino acts as warm dark matter: IFS  $\sim 6$  Mpc)

On the other hand, gravitino is also produced by thermal scattering processes and acts as cold dark matter.

$\rightarrow$  **Constraints on WDM+CDM scenario.**

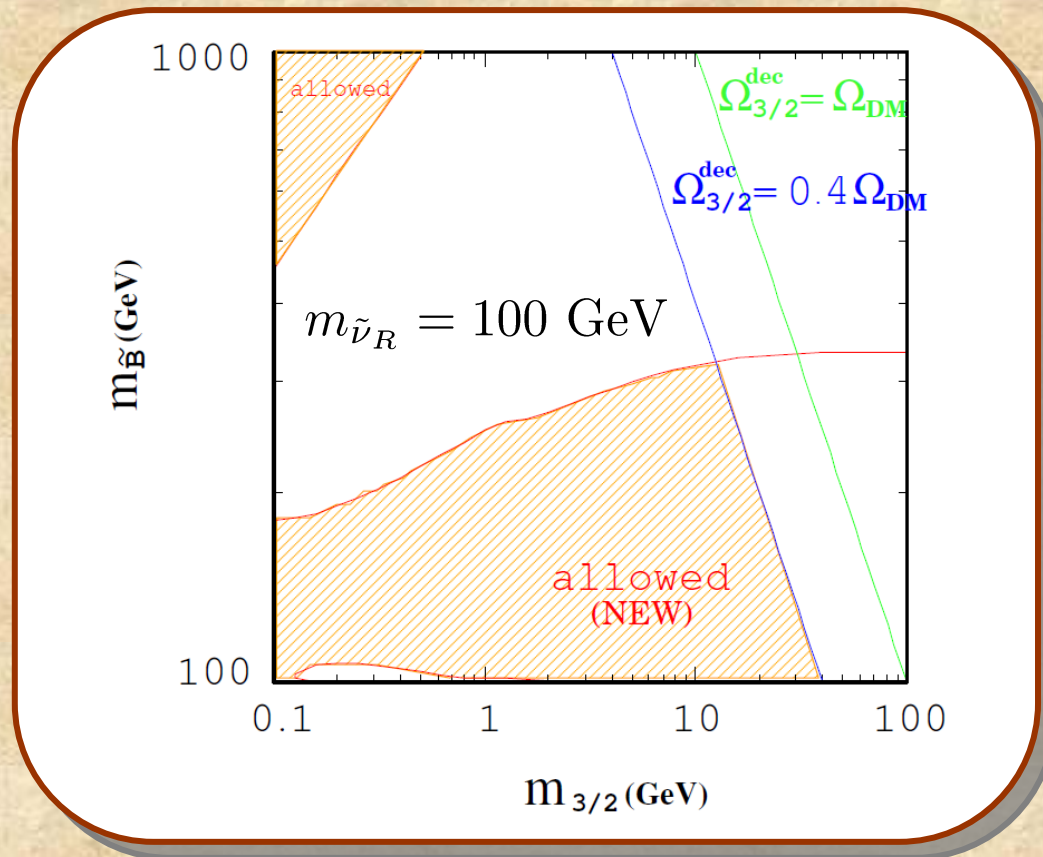
In order not to distort the power spectrum,

$$\Omega_{3/2}^{\text{dec}} \lesssim 0.4 \Omega_{\text{DM}}$$



# Constraints on the Gravitino mass

Constraint on the Gravitino mass is drastically relaxed!



**NEW allowed region:  $m_{3/2} \lesssim 40 \text{ GeV}$  [ Cf.)  $m_{3/2} \lesssim 0.1 \text{ GeV}$  without  $\tilde{\nu}_R$  ]**



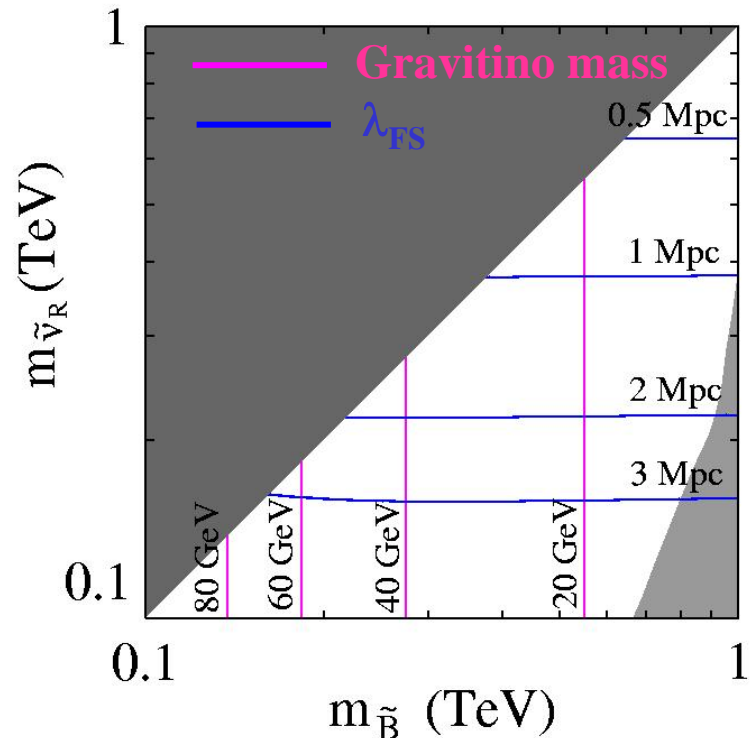
# SuperWIMP scenario

In this model

It is possible to construct the SuperWIMP scenario, even if the LSP in the MSSM sector is Neutralino!!

In the SuperWIMP scenario:  
It is postulated that the all dark matter (gravitino) abundance is coming from the decay of the LSP in the MSSM sector.

(Without the Right-handed Sneutrino, the SuperWIMP scenario is strongly constrained by the BBN.)



**There is a parameter region consistent with BBN and structure formation.**

# Conclusion

1. Constraint on the mass of the Gravitino Dark Matter is drastically relaxed when the Right-handed Sneutrino NLSP exists.
2. For example, in the case of the Bino-like neutralino NNLSP, the constraint is  $m_{3/2} < 40 \text{ GeV}$ .  
[ Cf.)  $m_{3/2} < 0.1 \text{ GeV}$  without the R-Sneutrino ]
3. This scenario also allow us to construct the Super-WIMP scenario, even if the LSP in the MSSM sector is Neutralino.