Cosmology with Dirac (s)neutrinos in the MSSM

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Overview

- Take MSSM, add RH (s)neutrino, but only Dirac mass term (and susy-breaking mass): scalar sector has a ‘sterile’, RH sneutrino; Yukawas are v. small.
- especially interesting for mattergenesis
  - what’s mattergenesis
  - why is ν_R LSP interesting candidate for DM in mattergẽnesis
  - mattergenesis scenarios that make use of small Yukawas

What is mattergenesis

- mattergenesis: explain ratio

$$\frac{\Omega_{DM}}{\Omega_b} \sim \frac{0.19}{0.04} \sim 4.9$$

- usual case: (baryo/lepto)genesis creates baryons, DM is freeze-out relic density
- What if DM and baryons have ‘common origin’
- (baryo/lepto)genesis creates baryons *and* dark matter, ie new ‘mattergenesis’ mechanism

$\tilde{\nu}_R$ and mattergenesis

- *Useful* for mattergenesis: non-thermal DM (no reprocessing of 'early' DM asymmetry)
  - exists ways around, eg. 'late decay' mechanism
- *Necessary* for mattergenesis: outside of new mechanism relic density is low/negligible

- in MSSM+(Dirac) (s)neutrino, both can happen with ν_R $\tilde{\text{LSP}}$
  - **cannot** happen if large Majorana mass!
  - could work with pseudo-Dirac (s)neutrinos, but beware of constraints

$\tilde{\nu}_R$ interactions

Only a handful:

- Superpotential

$$\mathcal{W} \supset \lambda \mathbf{L}^i \epsilon_{ij} \mathbf{H_u}^j \bar{\mathbf{N}}$$

  - 4-point terms
  - higgsino-lepton-sneutrino

- Susy breaking

$$\mathcal{V}_{\mathcal{SB}} = m^2_{\tilde{\nu}_L} \tilde{\nu_L}^* \tilde{\nu_L} + m^2_{\tilde{\nu}_R} \tilde{\nu_R}^{c*} \tilde{\nu_R}^c + \left(a \lambda H_u \tilde{L} \tilde{\nu}^c_R + h.c. \right)$$

  - mass terms
  - higgs-slepton-sneutrino
  - left-right sneutrinos mixing

$\tilde{\nu}_R$ thermalisation

- Annihilations $\tilde{\nu}_R$ - $\bar{\tilde{\nu}}_R$ can go through:
  - 4-points terms ~ λ^4, always out of eq.
  - higgsino exchange (~ λ^2/m_H^2), always out of eq.
  - slepton exchange constrains trilinear coupling

$$a < 10^{-1} m^2_{\tilde{\bar{\nu}}_L} \mathrm{GeV}$$

  - gaug(e/ino) interactions from L-H part constrain

$$\frac{\lambda a v}{\left(m^2_{\tilde{\bar{\nu}}_L} - m^2_{\tilde{\bar{\nu}}_R}\right)} < 3 \times 10^{-10}$$

- **$\tilde{\nu}_R$ doesn't thermalise**

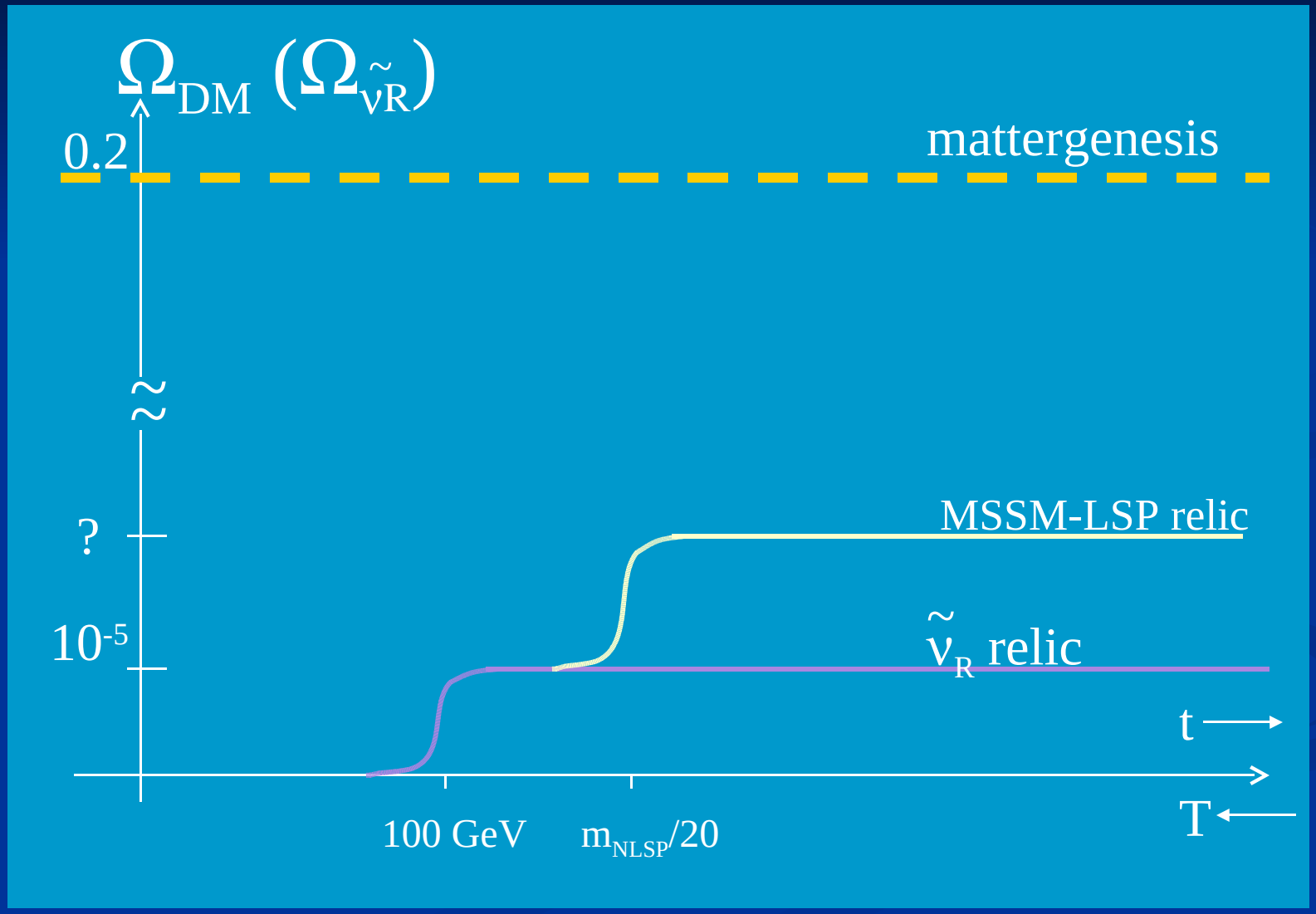
$\tilde{\nu}_R$ relic density I

- $\tilde{\nu}_R$ created by decays of particles in thermal eq., eg higgsino-> lepton+ $\tilde{\nu}_R$
- this creates tiny (10^{-4}-10^{-2} Ω_{DM}) relic density (trilinear coupling not 'large' and sneutrino masses not degenerate)
- enhancement see Asaka, Ishiwata, Moroi, hep-ph/0512118
- point is: easy to make relic density small

$\tilde{\nu}_R$ relic density II

- decaying particle (eg. higgsino) will freeze-out -> dumping of $\tilde{}$ MSSM-LSP density into ν_R
- small neutralino relic a possibility, eg. Arkani-Hamed&al, hep-ph/0601041, Bélanger&al, hep-ph/0604150
- general danger for mattergenesis

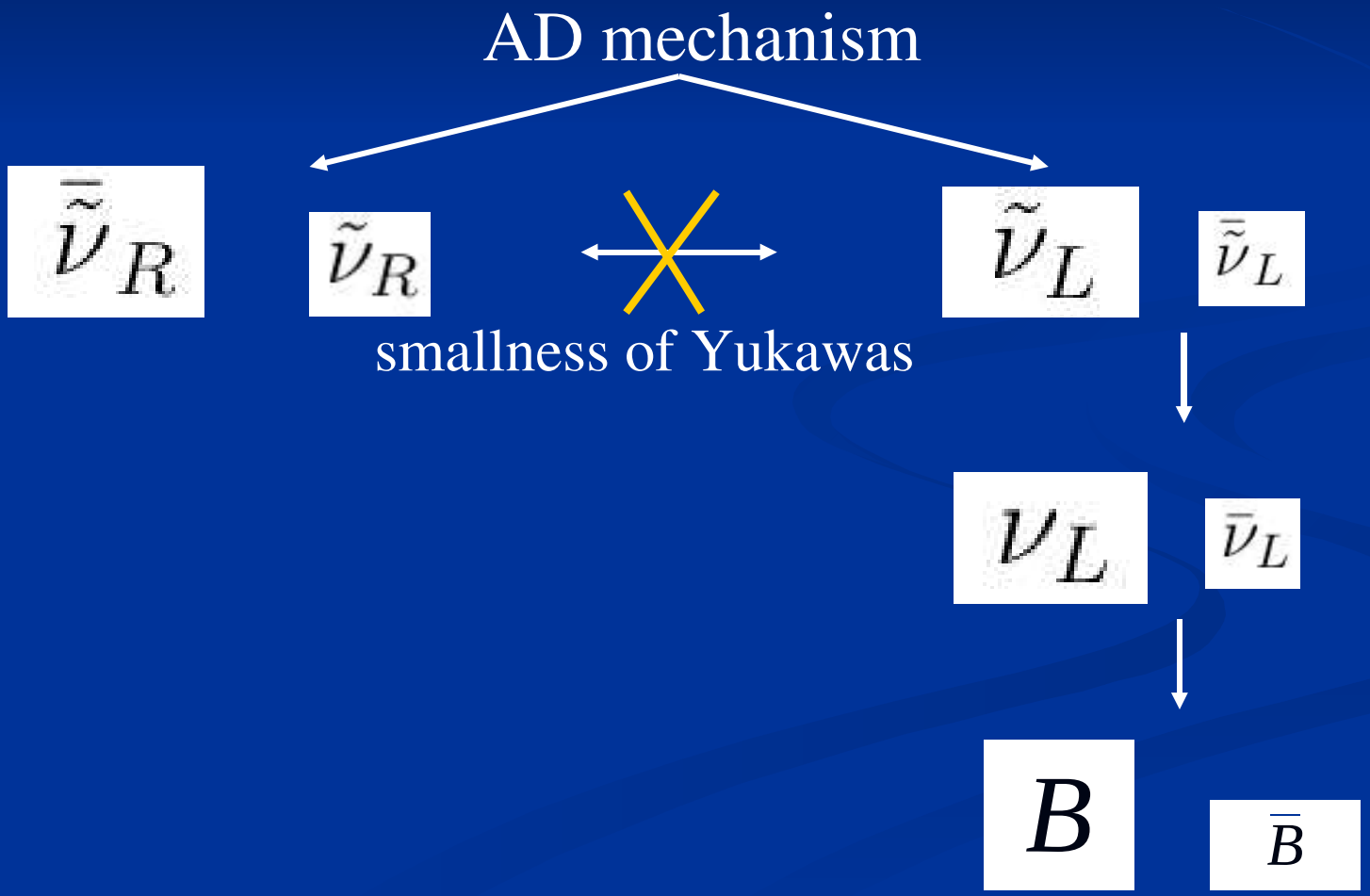
General picture



Mattergenesis scenarios

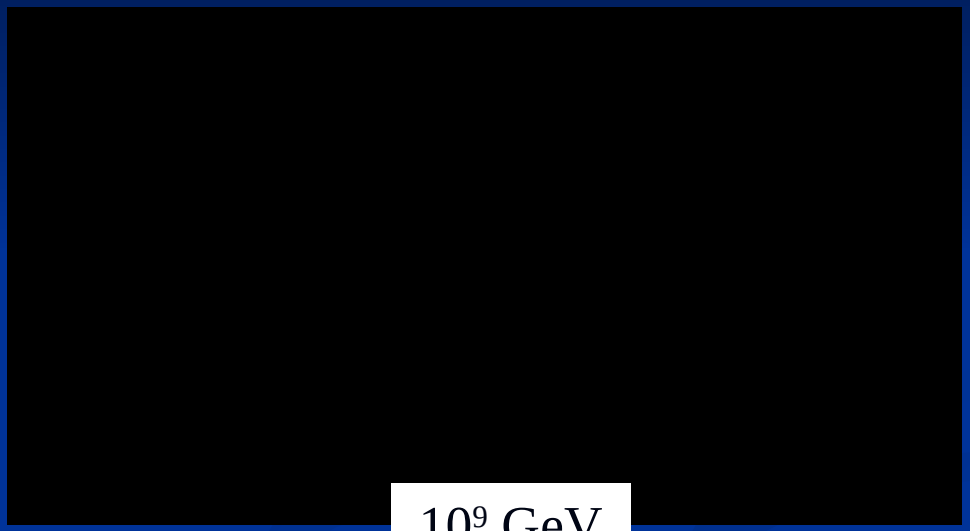
- hep-ph/0601149, Affleck-Dine leptogenesis and DM w ν_R
- J. McDonald, hep-ph/0609126, AD mattergenesis w ν_R
- don't create nett L-number, create L-R polarisation (Dick&al. hep-ph/9907562)
- possible only with Dirac (s)neutrino because left and right don't equilibrate (small Yukawas)

Mattergenesis scenarios

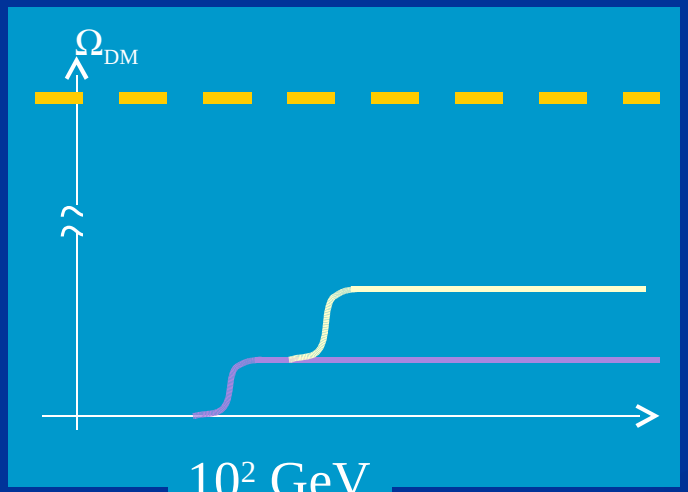


Mattergenesis scenarios

Asymmetry (-> $\tilde{\nu}_R$) created before relic density created



10^9 GeV



$m_{\tilde{\nu}R} \sim 1$ GeV

for correct amounts of dark and baryonic matter

Mattergenesis scenarios

- Kuzmin, hep-ph/9701269: ‘asymmetrization of plasma with respect to B-L distribution between the normal fermionic sector of SM and the new sector R’ … via early decay of new massive X particle
- suggested minimal implementation in MSSM+$\underset{\sim}{\nu}_R$

Overview: cosmology with Dirac $\tilde{\nu}_R$

- MSSM+'Dirac' $\tilde{\nu}_R$
  - give candidate for mattergenesis-DM (non-thermal non-abundant relic)
  - provide mattergenesis mechanism possibilities
  - mattergenesis produces DM
- MSSM+'see-saw' $\tilde{\nu}_R$
  - no candidate for mattergenesis-DM
  - leptogenesis produces baryons
  - LSP freeze-out produces DM