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Dark matter in a SUSY left-right theory

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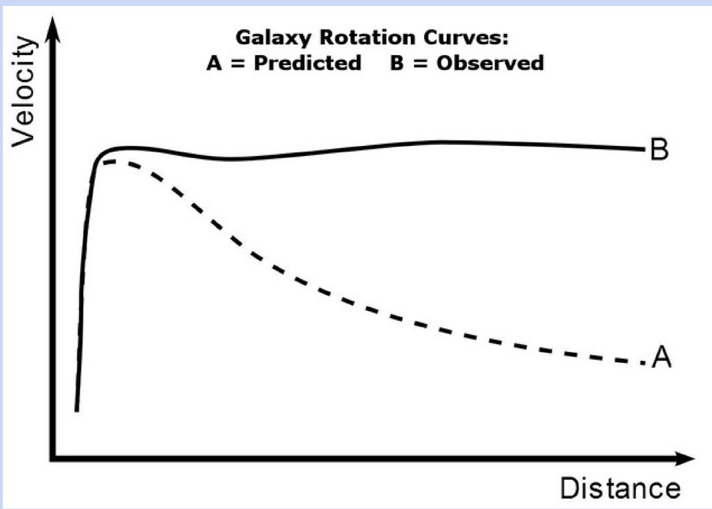
Dark matter and Supersymmetry



- Dark matter is one of the best evidences for physics beyond the SM
- $\Omega_{DM} h^2 \sim 0.1$
- WIMP miracle: A WIMP with $m \sim 100$ GeV can naturally fit the picture

SUSY is the most popular extension of the SM. It provides a solution to the hierarchy problem and has room to accommodate new physics.

- The LSP is stable if R-parity is conserved: DM candidate
- The lightest neutralino is the classic WIMP: cold, electrically neutral and colourless

However . . . open questions:

- Theoretical understanding for the conservation of R-parity
- Neutrino masses
- Link to unified models

A Left-Right symmetric model: ΩLR

Aulakh et al. PRL 79 (1997) 2188 and PRD 58 (1998) 115007

$$SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$

Superfield	$SU(3)_c$	$SU(2)_L$	$SU(2)_R$	$U(1)_{B-L}$
Δ	1	3	1	2
$\bar{\Delta}$	1	3	1	-2
Δ^c	1	1	3	-2
$\bar{\Delta}^c$	1	1	3	2
Ω	1	3	1	0
Ω^c	1	1	3	0

$$\begin{aligned} \mathcal{W} &= Y_Q Q \Phi Q^c + Y_L L \Phi L^c - \frac{\mu}{2}\Phi\Phi + f L \Delta L + f^* L^c \Delta^c L^c \\ &+ a \Delta \Omega \bar{\Delta} + a^* \Delta^c \Omega^c \bar{\Delta}^c + \alpha \Omega \Phi \Phi + \alpha^* \Omega^c \Phi \Phi \\ &+ M_\Delta \Delta \bar{\Delta} + M_\Delta^* \Delta^c \bar{\Delta}^c + M_\Omega \Omega \Omega + M_\Omega^* \Omega^c \Omega^c \end{aligned}$$

- Parity conservation
- Two Higgs bidoublets
- Triplets with even charges under $U(1)_{B-L}$
- mSUGRA-like boundary conditions at the GUT scale
- Type-I seesaw mechanism

Symmetry breaking

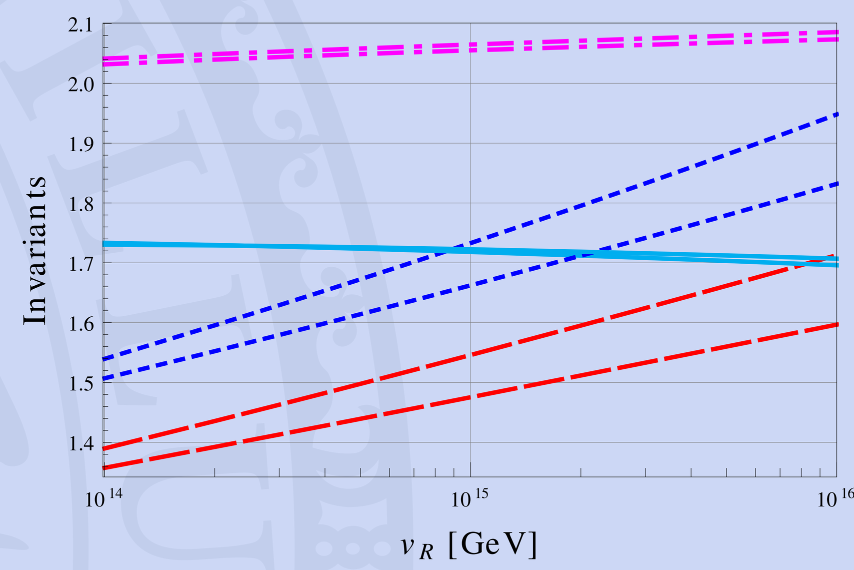
Two steps breaking

$$SU(2)_R \times U(1)_{B-L} \xrightarrow[\langle \Omega^{c\,0} \rangle = \frac{v_R}{\sqrt{2}}]{} U(1)_R \times U(1)_{B-L} \xrightarrow[\langle \Delta^{c\,0} \rangle = \frac{v_{BL}}{\sqrt{2}}]{} U(1)_Y$$

Automatic R-parity conservation at low energies

Low energy phenomenology

- Many changes w.r.t. the CMSSM
- Interesting perspectives for LFV (see *Esteves et al. JHEP 1012 (2010) 077*)
- Deformed spectrum and invariant mass combinations. On the right: $\frac{m_Q^2 - m_{\tilde{u}}^2}{M_1^2}$, $\frac{m_L^2 - m_{\tilde{e}}^2}{M_1^2}$, $\frac{m_{\tilde{d}}^2 - m_L^2}{10 M_1^2}$ and $\frac{m_Q^2 - m_{\tilde{e}}^2}{10 M_1^2}$

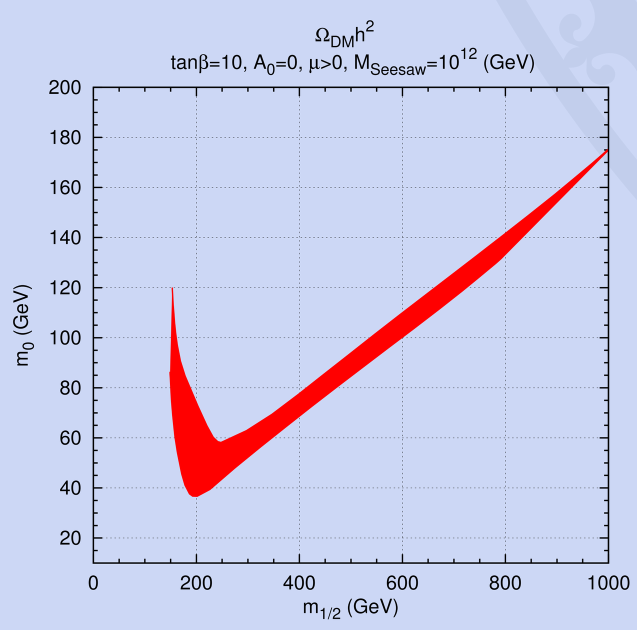


Dark matter in the ΩLR model

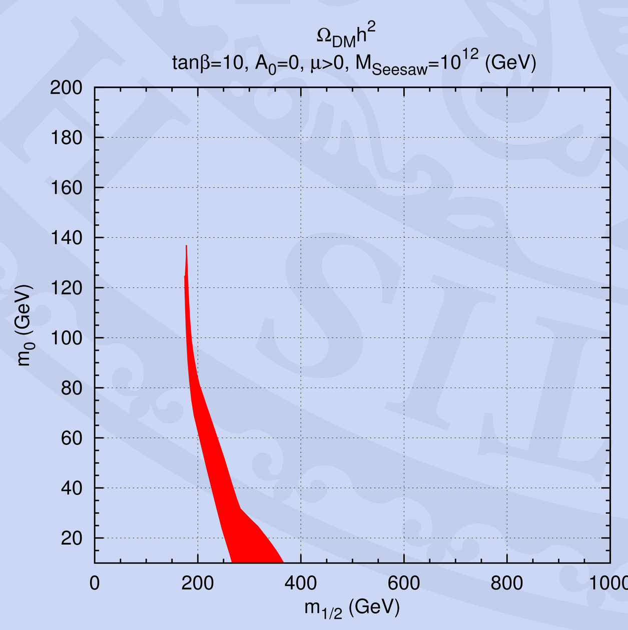
I) Disappearance of DM regions

Even slight changes in the SUSY spectra can lead to sizeable changes in the relic density of the lightest neutralino. Therefore, the usual CMSSM DM regions might vanish in the ΩLR model.

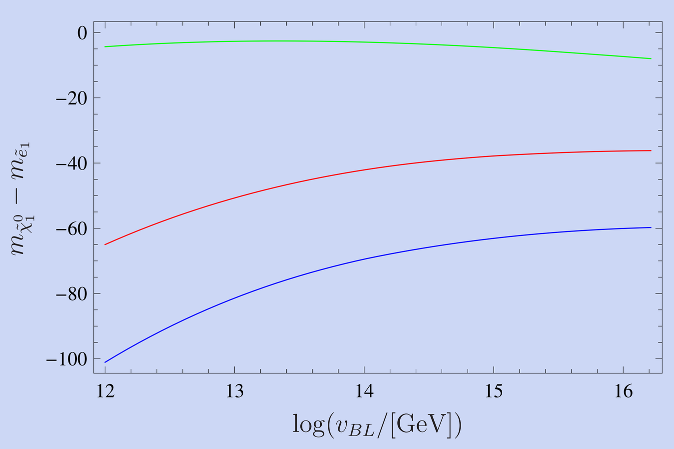
Example: $\tilde{\tau}$-coannihilation region



$v_{BL} = v_R = 10^{16}$ GeV



$v_{BL} = v_R = 10^{15}$ GeV



On the left: $\tilde{\chi}_1^0 - \tilde{\tau}$ mass difference for $v_{BL} = v_R = 10^{12}$ GeV, $v_{BL} = v_R = 10^{14}$ GeV and $v_{BL} = v_R = 10^{16}$ GeV

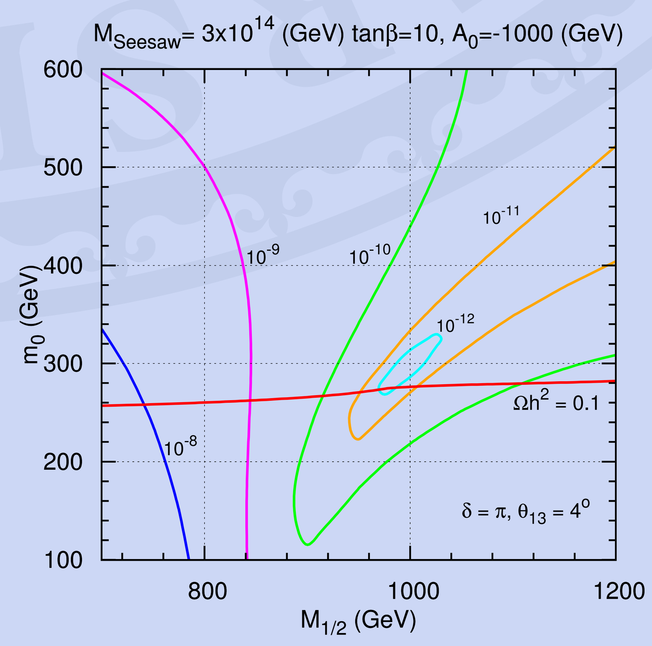
For low v_{BL} or v_R the running of the soft gaugino mass parameters leads to a very light bino, reducing the region where it can be degenerate with the lightest $\tilde{\tau}$.

II) Flavoured coannihilation

Flavour contributions can reduce the $\tilde{\tau}$ mass and enhance the $\tilde{\chi}_1^0 - \tilde{\tau}$ coannihilation x-section. This leads to new DM regions where flavour effects are essential to obtain the correct relic density, see *Chowdhury et al. arXiv:1104.4467*.

$$m_{\tilde{\tau}_1}^2 \simeq m_{\tilde{\tau}_R}^2 (1-\delta) - m_\tau \mu \tan\beta, \text{ with } \delta = \frac{\Delta_{RR}^{i\tau}}{\sqrt{m_{\tilde{l}_R^i}^2 m_{\tilde{\tau}_R}^2}}$$

The ΩLR model has potentially large LFV in the R slepton sector and thus the DM constraint can also be fullfilled using the flavoured coannihilation solution.



On the left: $Br(\mu \to e\gamma)$ and $\Omega_{DM} h^2$ in the $m_0 - M_{1/2}$ plane.

A strong fine-tuning is required to reduce $Br(\mu \to e\gamma)$ below the MEG limit ($Br < 2.4 \cdot 10^{-12}$).

- Flavoured coannihilation DM regions can be found in ΩLR
- Large A_0 values are required
- Large LFV signals at colliders and low energy experiments are expected

Intermediate scales between the GUT and SUSY scales can have a very strong impact on the low energy spectrum and lead to a DM phenomenology totally different from the one in the CMSSM. In the ΩLR model we found that some standard DM regions can disappear due to the stronger running of gaugino mass parameters. We also found regions in parameter space where the correct relic density is obtained thanks to flavoured coannihilation.

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