Cosmological implication of the NMSSM domain wall decay

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§ Introduction

§§ next-to-minimal supersymmetric standard model (NMSSM)

- MSSM suffers from so-called μ-problem.
- A singlet extended model, NMSSM, with Z_3 parity solves the μ-problem. [Fayet (1975), Nilles et al (1983), …]

$$W_{\rm Higgs} = \lambda S H_u H_d + \frac{\kappa}{3} S^3$$

- This Z_3 parity is problematic for cosmology.
- Cosmological domain wall problem [Zeldovich et al (1974)]

§§ next-to-minimal supersymmetric standard model (NMSSM)

- Cosmological domain wall problem [Abel et al (1995)]
- Tiny explicit breaking of Z_3 is favoured from cosmology

Free from DW problem

Gravitational wave generation [Kadota et al (2015)]

Models, e.g., Panagiotakopoulos and Tamvakis (1999), Hamaguchi et al (2012)

§ § next-to-minimal supersymmetric standard model (NMSSM)

- Tiny explicit breaking of Z3 has no effect on phenomenology?

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The Next-to-Minimal Supersymmetric Standard Model

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ABSTRACT

We review the theoretical and phenomenological aspects of the Next-to-Minimal Supersymmetric Standard Model: the Higgs sector including radiative corrections and the

Subsequently solutions of this problem hav
$\mathbb{Z}_3$-symmetry breaking non-renormalisable inter
symmetries, such that $\mathbb{Z}_3$-symmetry breaking *ren*
but with very small coefficients. These $\mathbb{Z}_3$-symmetry breaking terms can still solve the domain wall problem of the otherwise $\mathbb{Z}_3$-invariant NMSSM, without having a visible impact on its phenomenology.

§ Assumed cosmic history

- Primordial inflation
- Reheating
- Electroweak phase transition with domain wall formation
- Domain wall network evolution
- Domain wall decay

  with entropy production [Kawasaki and Takahashi (2005)]
- Big bang nucleosynthesis
- …

§ Domain wall evolution

- Domain wall networks relax so-called scaling solution [Press et al (1989), Hindmarsh (2003), Leite et al (2011, 2013), Hiramatsu et al (2014), …]

$$\rho_{\rm DW} \simeq \sigma H$$

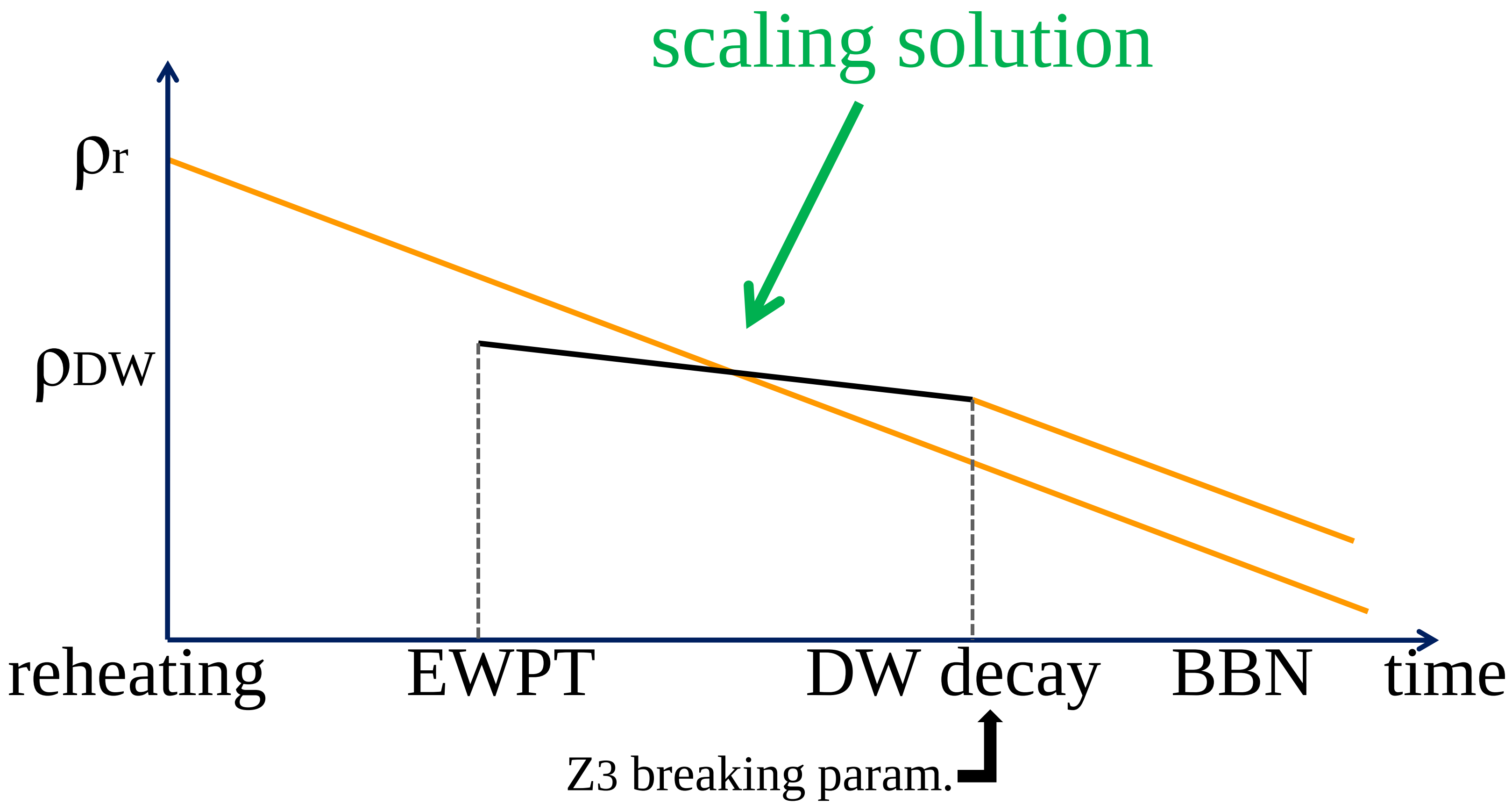
- The tension $\sigma \simeq \frac{16}{3\sqrt{3}} v_s^2 \sqrt{\kappa A_\kappa v_s} = \frac{16}{3\sqrt{3}} \frac{\mu^2}{\lambda^2} \sqrt{\frac{\kappa}{\lambda} A_\kappa \mu}$

- At $H_{\rm eq} \simeq \frac{\sigma}{3M_P^2}$

  the energy density of domain wall becomes comparable to that of background radiation.

§ Domain wall evolution

- Thermal history after inflation



§ § Entropy production

- Entropy ratio before to after DW decay

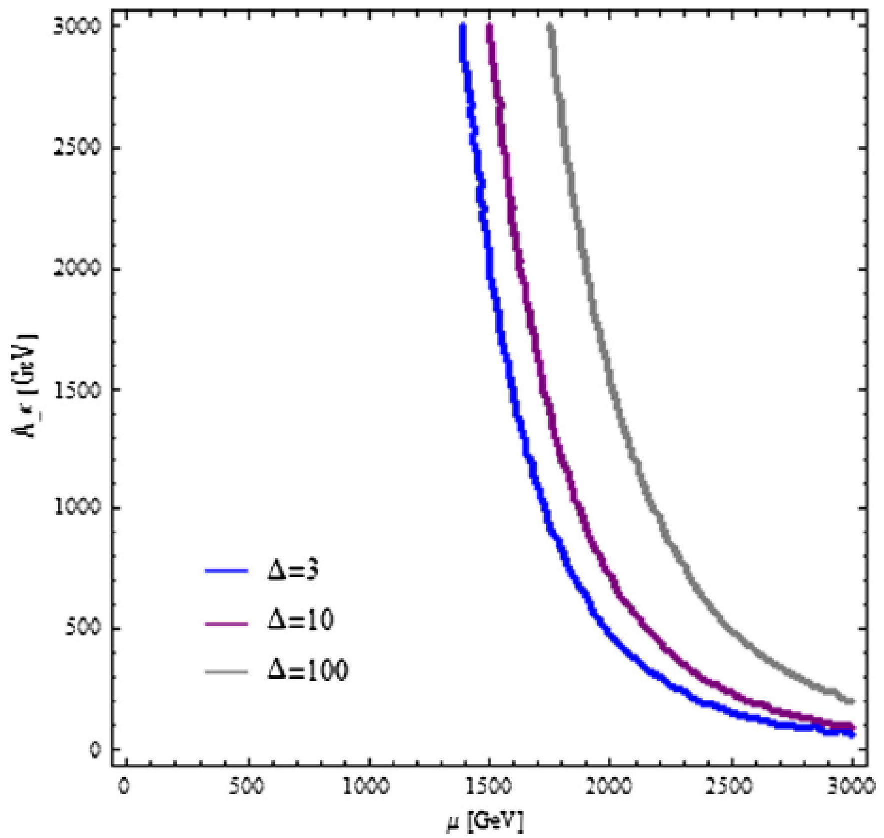
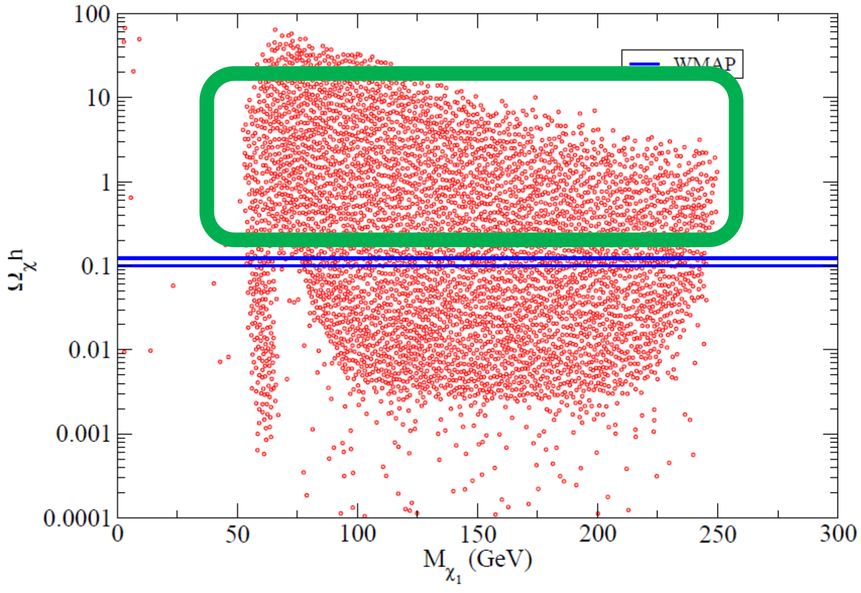


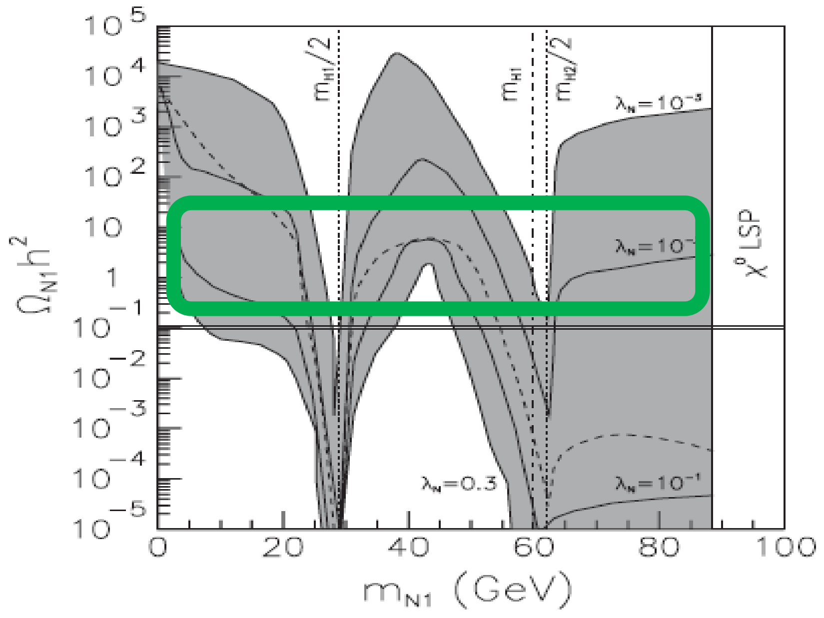
FIG. 3 (color online). The entropy density ratio Δ of after to before domain wall decay in the radiation-dominated era to domain wall dominated era for $\lambda = \kappa = 0.01$, $T_d = 3$ MeV.

- Ratio of entropy increase Δ
- DW Decay temperature T_d

§ § Entropy production

(1) Thermal WIMP relic abundance

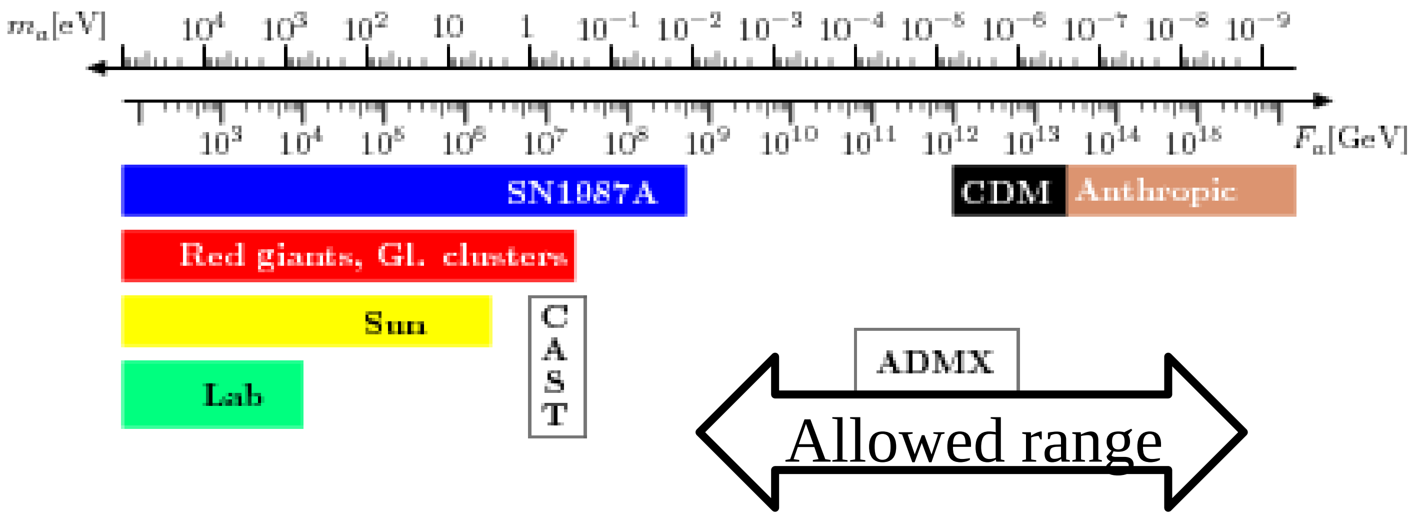




Neutralino [Bager et al (2007)]   RH sneutrino [Cerdeno et al (2009)]

§ § Entropy production

(2) Axion abundance : axion window



Larger *Fa* could be allowed.

§ § Entropy production

(3) LSP abundance for mirage mediation models

$M_{\text{moduli}} \sim 10^2\, M_{3/2} \sim (10^2)^2\, M_\chi$

Decay chain

``Moduli ⟶ gravitino ⟶ neutralino''

produces too much LSP…

[Endo et al (2006)]

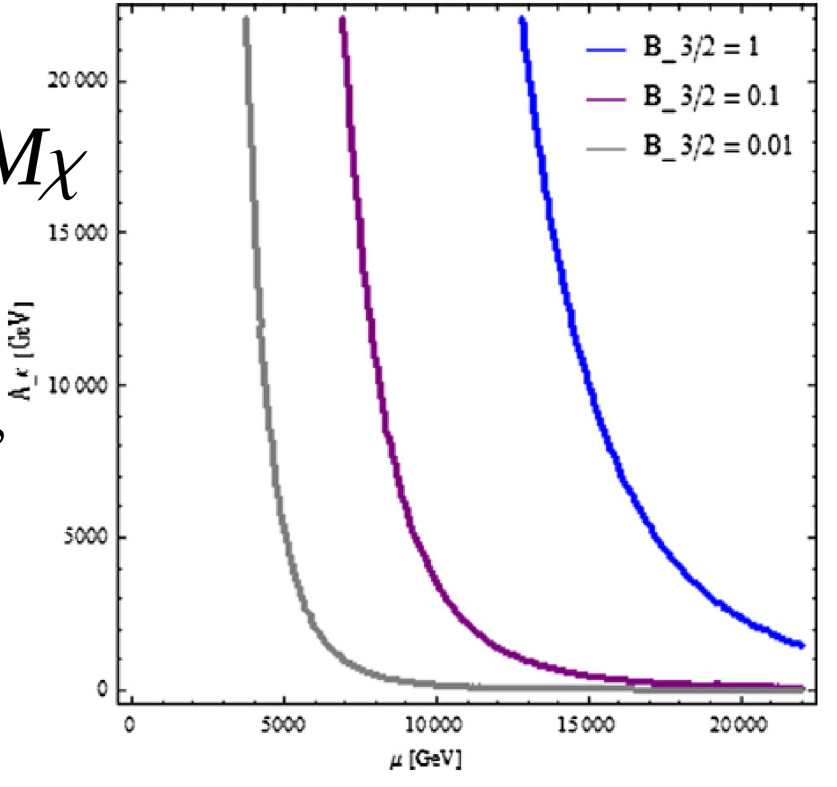


FIG. 4 (color online). The required branching ratio contour to keep $\Omega_{\rm LSP}h^2 = 0.1$ in the mirage mediation scenario for $\lambda = \kappa = 0.01$, $T_d = 3$ MeV, $m_{\rm LSP} = 100$ GeV, $m_{\rm moduli} = 1000$ TeV. Above each curve, the relic abundance is smaller than $\Omega_{\rm LSP}h^2 = 0.1$.

§ Summary

- We have studied cosmological implication of unstable domain wall in the NMSSM.

- The decay of domain wall in the NMSSM may dilute cosmological unwanted relics

  or

  regulate dark matter relic abundance.