Neutralino dark matter in 5D SUGRA

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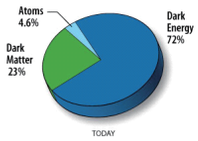
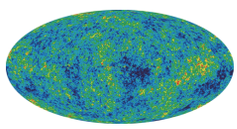
Motivation (Problems in the Standard Model)

Dark matter・・・no candidates in the Standard Model



Inflation・・・no mechanism to realize in the Standard model



No gravity interaction

Yukawa hierarchies between elementary particles

Set up : 5(=4+1)D SUGRA models with multi moduli

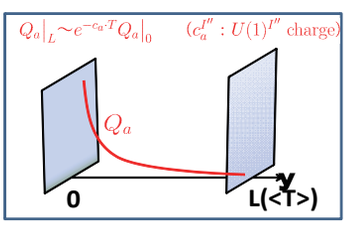
H. Abe, H.O., Y. Sakamura and Y. Yamada Eur. Phys. C 72 2012 (2018)

- Low energy effective theory of Superstring theory (Type IIB SUGRA compactified on the warped throat ?)
- We can determine the structure of the Kahler potential
- Solution to the following problems in the SM

SUSY	⟹	Dark matter
Moduli	⟹	Flat potential (Inflation)
Wave function profile	⟹	Yukawa hierarchies

5D SUGRA models on S^1/Z_2

Yukawa hierarchies are determined by the U(1) charge



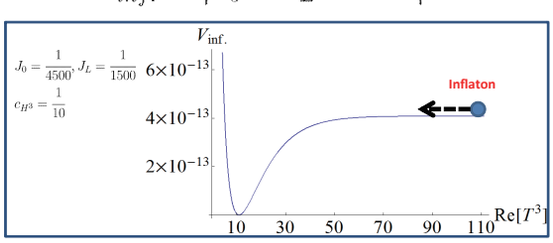
$T^i \cdots$ Fifth components of $U(1)$ (moduli)$(i = 1, 2, 3)$

Moduli inflation

$$W_{inf.} = (J_{03} - J_{L3} e^{-c_{H^3} T^3}) H^3$$

$$\mathrm{Re}[T^3] \cdots \text{inflaton.}$$

$$V_{inf.} \sim |J_0 - J_L e^{-c_{H^3} T^3}|^2$$



Moduli oscillation

$$W = W_{inf.} + (J_{01} - J_{L1} e^{-c_{H^1} T^1}) H^1 + (J_{02} - J_{L2} e^{-c_{H^2} T^2}) H^2 + w + \mu X$$

$$K = Z_X |X|^2 - \tfrac{1}{\Lambda^2} |X|^4 + \cdots$$

- **Moduli mass:** $c_{H^i} J_L e^{-c_{H^i} T^i}$

T^1, T^2, H^1, H^2	; 3×10^{15}[GeV]
X	; 4.8×10^{12}[GeV]
T^3, H^3	; 3.6×10^{12}[GeV]

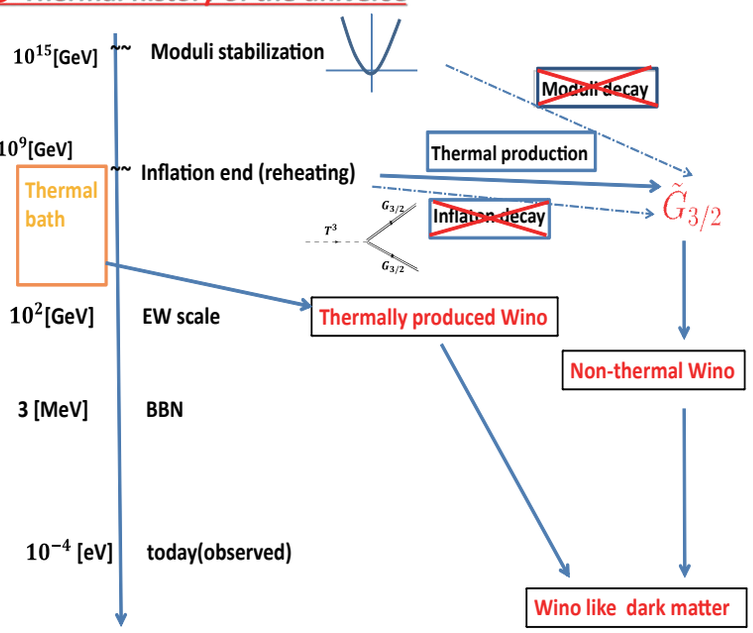
T^1, T^2, H^1, H^2, X does not so oscillate during the inflation.
We also checked that H^3 does not dominate the universe.

- **Gravitino mass:** 1.4×10^5[GeV]
- **Gaugino masses are generated by the anomaly mediation.**
- **Soft masses are generated by the F term of the singlet field.**

Sparticle masses, Higgs mass

	mass[GeV]		mass[GeV]
$\tilde{u}_1$	1.3×10^6	$\tilde{e}_1$	1.2×10^6
$\tilde{u}_2$	1.2×10^6	$\tilde{e}_2$	9.3×10^5
$\tilde{c}_1$	9.1×10^5	$\tilde{\mu}_1$	1.0×10^6
$\tilde{c}_2$	8.9×10^5	$\tilde{\mu}_2$	9.0×10^5
$\tilde{t}_1$	7.0×10^5	$\tilde{\tau}_1$	9.0×10^5
$\tilde{t}_2$	4.1×10^5	$\tilde{\tau}_2$	8.6×10^5
$\tilde{d}_1$	1.3×10^6	$\tilde{\nu_{e_1}}$	1.2×10^6
$\tilde{d}_2$	1.3×10^6	$\tilde{\nu_{e_2}}$	1.4×10^5
$\tilde{s}_1$	1.3×10^6	$\tilde{\nu_{\mu_1}}$	1.0×10^6
$\tilde{s}_2$	8.9×10^5	$\tilde{\nu_{\mu_2}}$	1.4×10^5
$\tilde{b}_1$	6.7×10^5	$\tilde{\nu_{\tau_1}}$	8.6×10^5
$\tilde{b}_2$	4.1×10^5	$\tilde{\nu_{\tau_2}}$	1.4×10^5
$\tilde{\chi}_1^0$	7.3×10^5	$\tilde{\chi}_1^\pm$	371
$\tilde{\chi}_2^0$	7.3×10^5	$\tilde{\chi}_2^\pm$	7.3×10^5
$\tilde{\chi}_3^0$	1227	$m_{3/2}$	1.4×10^5
$\tilde{\chi}_4^0$	371	m_h	125.5

Thermal history of the universe

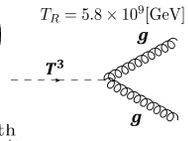


Relic abundance of the Wino like neutralino

J. Pradler and F. D. Steffen, Phys. Rev. D 75 (2007) 023509.

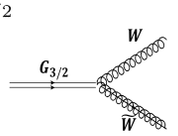
$$\Omega_{3/2}^{TP} h^2 = \sum_{i=1}^{3} \left(1 + \frac{M_i(T_R)^2}{3m_{3/2}^2}\right) w_i g_i(T_R)^2 \ln\left(\frac{k_i}{g_i(T_R)}\right) \left(\frac{m_{3/2}}{100GeV}\right) \left(\frac{T_R}{10^{10}GeV}\right)$$

$T_R = 5.8 \times 10^9$[GeV]



$$Y_{\tilde{W}}^{\text{non-th}} \simeq \min[Y_{3/2}^{\text{th}}, \sqrt{\frac{45}{8\pi^2 g_*}} \frac{1}{M_{Pl} T_{3/2} \langle \sigma_{\text{ann}} v \rangle}] = Y_{3/2}^{\text{th}}$$

$$\Omega_{\tilde{W}}^{\text{non-th}} h^2 \simeq \frac{m_{\tilde{W}}}{m_{3/2}} \Omega_{3/2}^{\text{th}} h^2 \simeq 0.112$$



$$\Omega_{\tilde{W}}^{th} h^2 \simeq \sqrt{\frac{45}{8\pi^2 g_*}} \frac{m_{\tilde{W}}}{T_d} \frac{1}{M_{Pl} \langle \sigma_{\text{ann}} v \rangle} \simeq 4.0 \times 10^{-3}$$

$$\Omega_{\tilde{W}} h^2 = \Omega_{\tilde{W}}^{\text{th}} h^2 + \Omega_{\tilde{W}}^{\text{non-th}} h^2 \simeq \Omega_{\tilde{W}}^{\text{non-th}} h^2$$

Summary

- We can realize the Wino like DM in 5D SUGRA.
- In 5D SUGRA, Kahler structure of the field is exactly determined.
- Relic abundance of the Wino is determined by non-thermal production of the gravitino.
- We estimate the inflaton decay, moduli decay into the gravitino during the reheating era.
- Yukawa hierarchies are determined by the wave function localization.