Gravitino Dark Matter in Brane Cosmology

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Outline

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Introduction

- Our current picture of Universe: Flat, accelerating expansion, dark side dominant component

- Dark energy (70 per cent): CC, Quintessence, Modified Gravity

- Dark matter (25 per cent): Popular candidate the LSP (axino, gravitino, neutralino)

-Brane Cosmology: String-inspired, novel cosmology

The model 1: The brane model

-Model defined by

$$S = \int d^5x\sqrt{-g}\,(M_5^3 R - \Lambda_5) + \int d^4x\sqrt{-h}\,(-T + \text{brane matter}) \quad (1)$$

-Field equations on the brane

$$G_{\mu\nu} + \Lambda_4 g_{\mu\nu} = \frac{8\pi}{m_{pl}^2}\tau_{\mu\nu} + (\frac{1}{M_5^3})^2 \pi_{\mu\nu} - E_{\mu\nu} \quad (2)$$

-4d and 5d quantities are related by

$$m_{pl} = 4\sqrt{\frac{3\pi}{T}}\,{M_5}^3 \quad (3)$$

$$\Lambda_4 = \frac{1}{2M_5^3}\left(\Lambda_5 + \frac{T^2}{6M_5^3}\right) \quad (4)$$

-Friedmann-like equation

$$H^2 = \frac{\Lambda_4}{3} + \frac{8\pi}{3m_{pl}^2}\rho + \frac{1}{36M_5^6}\rho^2 + \frac{C}{a^4} \tag{5}$$

-Randall-Sundrum fine-tuning

$$\Lambda_5 = -\frac{T^2}{6M_5^3} \tag{6}$$

Novel expansion law

$$H^2 = \frac{8\pi G}{3}\rho\left(1 + \frac{\rho}{\rho_0}\right) \tag{7}$$

where

$$\rho_0 = 96\pi G M_5^6 \tag{8}$$

The model 2: The particle physics model

In MSSM: The usual gauge group plus superpatners. For soft SUSY breaking

-Mass terms for the gauginos $\tilde{g}_i$, M_1, M_2, M_3

$$M\tilde{g}\tilde{g} \tag{9}$$

-Mass terms for sfermions $\tilde{f}$

$$m_{\tilde{f}}{}^2 \tilde{f}^\dagger \tilde{f} \tag{10}$$

-Masses and bilinear terms for the Higgs bosons H_u, H_d

$$m_{H_u}{}^2 H_u^\dagger H_u + m_{H_d}{}^2 H_d^\dagger H_d + B\mu(H_u H_d + h.c.) \tag{11}$$

-Trilinear couplings between sfermions and Higgs bosons

$$AY\tilde{f}_1 H \tilde{f}_2 \tag{12}$$

In CMSSM only 4 parameters plus μ sign

-Universal gaugino masses

$$M_1(M_{GUT}) = M_2(M_{GUT}) = M_3(M_{GUT}) = m_{1/2} \tag{13}$$

-Universal scalar masses

$$m_{\tilde{f}_i}(M_{GUT}) = m_0 \tag{14}$$

-Universal trilinear couplings

$$A^u_{ij}(M_{GUT}) = A^d_{ij}(M_{GUT}) = A^l_{ij}(M_{GUT}) = A_0 \delta_{ij} \tag{15}$$

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$$tan\beta \equiv \frac{v_1}{v_2} \tag{16}$$

Analysis

-Compute Gravitino abundance

$$\Omega_{3/2}h^2 = \Omega_{3/2}^{NTP}h^2 + \Omega_{3/2}^{TP}h^2 \tag{17}$$

and impose the CDM constraint

$$0.075 < \Omega_{cdm}h^2 = \Omega_{3/2}h^2 < 0.126 \tag{18}$$

-Take into account collider constraints

$$m_h > 114.4\ GeV \tag{19}$$

$$m_{\tilde{\tau}_1} > 81.9\ GeV \tag{20}$$

$$m_{\tilde{\chi}_1^\pm} > 81.9\ GeV \tag{21}$$

$$BR(b \to s\gamma) = (3.39^{+0.30}_{-0.27}) \times 10^{-4} \tag{22}$$

Consider benchmark models

Model	$m_0\,(GeV)$	$m_{1/2}\,(GeV)$	$tan\beta$	$m_\chi\,(GeV)$	$\Omega_\chi h^2$
A	200	500	15	205.42	0.64
B	400	800	25	337.95	1.82
C	1000	600	30	252.41	7.37
D	350	450	20	184.46	1.2

Table 1: The four benchmark models considered in the analysis

-For TP Gravitino abundance is given by

$$\Omega_{3/2}^{TP} h^2 = 2.75 \times 10^8 \left(\frac{m_{3/2}}{GeV}\right) Y_{3/2}^{TP}(T_0) \quad (23)$$

$$Y = \frac{n}{s} \quad (24)$$

$$Y_{3/2}^{TP} \simeq 10^3 \left(\frac{GeV}{m_{3/2}}\right)^2 \frac{T_R}{M_P} \quad (25)$$

-For NTP $\rightarrow$ NLSP decay

$$\Omega_{3/2} h^2 = \frac{m_{3/2}}{m_{NLSP}} \Omega_{NLSP} h^2 \quad (26)$$

Assume that NLSP=neutralino

-Two more parameters: $T_R, m_{3/2}$

Modifications due to new expansion law

But first: Transition temperature defined

$$\rho(T) = \rho_0 \tag{27}$$

and is given

$$T_t = 1.6 \times 10^7 \left(\frac{100}{g_{eff}}\right)^{1/4} \left(\frac{M_5}{10^{11}\,GeV}\right)^{3/2} GeV \tag{28}$$

Another way of writing Friedman-like equation

$$H = H_{st}(1 + \frac{T^4}{T_t^4}) \tag{29}$$

Then two things are different:

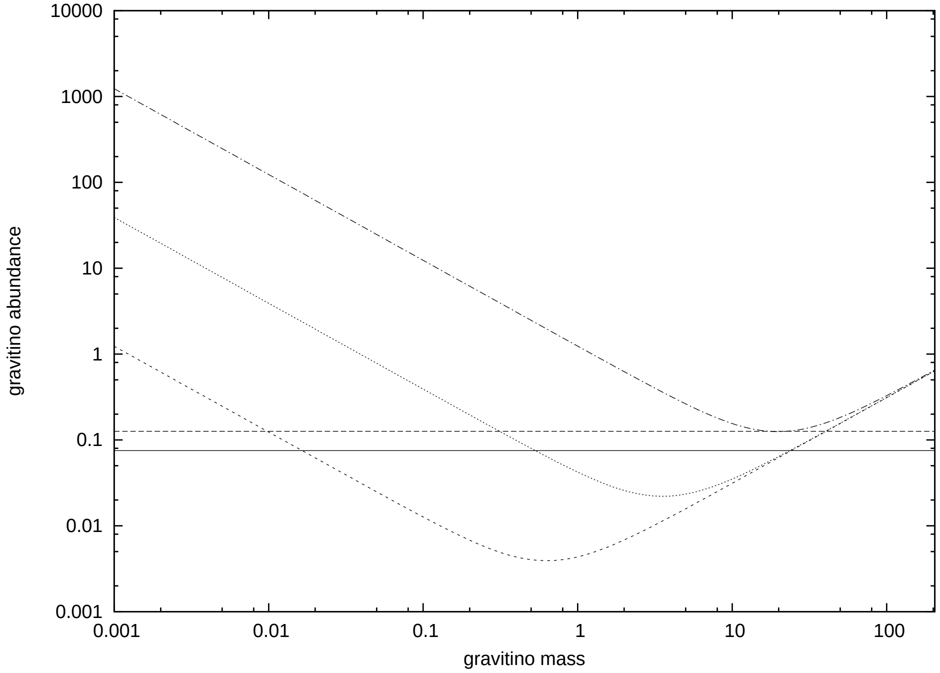
- (TP) Gravitino abundance is now $\sim T_t$ instead of $\sim T_R$

- (NTP) For LSP the abundance changes to

$$\frac{\Omega^{(b)}}{\Omega^{(s)}} = C\,\frac{x_t}{x_d^{(s)}} \tag{30}$$

where

$$\begin{aligned} C &\sim 1 && (31)\\ x_t &= \frac{m}{T_t} && (32)\\ x_d^{(s)} &= \frac{m}{T_d^{(s)}} \simeq 30 && (33) \end{aligned}$$



Gravitino abundance versus gravitino mass (in GeV) for several values of the five-dimensional Planck mass M_5. Values of M_5 used are 10^{10} GeV, 10^{11} GeV and 10^{12} GeV from bottom to top. The strip around 0.1 is the allowed range for cold dark matter.

Conclusions

-We assume that gravitino is the LSP

-We take thermal and non-thermal gravitino production mechanisms into account

-Brane models offer a novel cosmology with a generalized Friedman-like equation

-TH and NTP productions are modified due to novel expansion law

-Gravitino can play the role of dark matter for $m_{3/2} \sim (0.1 - 10)$ GeV and for $M_5 < 10^{12}$ GeV

Thank you