Stringy dark matter in the KL moduli stabilization scenario

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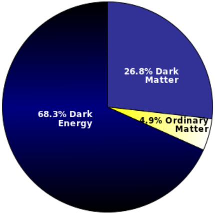
1805.01521
w/ Ernany R. Schmitz

1st Workshop on High Energy Theory and Gender @ CERN

September 27th, 2018

Why dark matter in the KL moduli stabilization scenario?

Baryonic matter $\sim 5\%$ of the Universe content!



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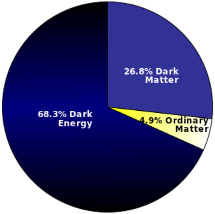

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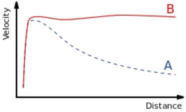

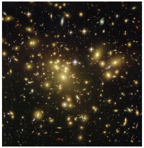

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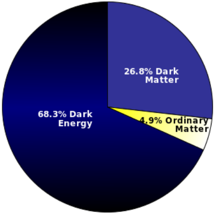

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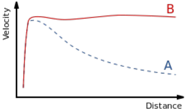

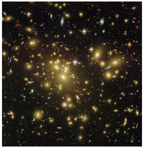

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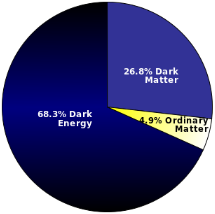

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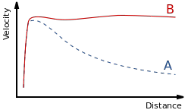

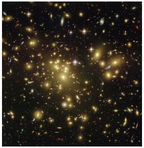

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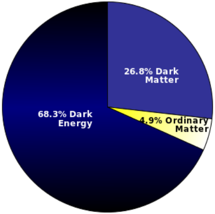

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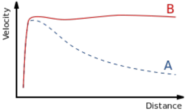

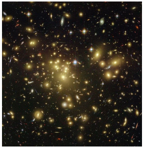

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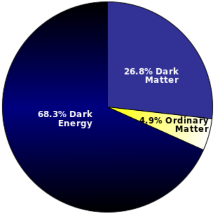

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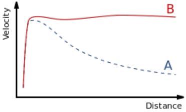

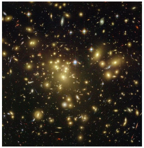

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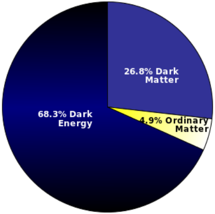

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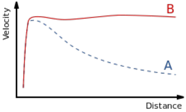

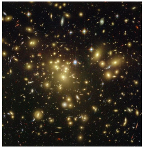

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- Moduli dynamics can create problems for consistent evolution of the Universe. **Here**: Avoid them + dark matter!

Outline

- KL moduli stabilization scenario + ISS uplifting sector
- Evolution of the Universe
- Dark matter production
- Conclusions

KL moduli stabilization scenario

[Kallosh and Linde '04]

- Low-scale SUSY breaking + high-scale inflation.
- IIB on orientifolded Calabi-Yau 3-folds $\Rightarrow$ 4d $\mathcal{N} = 1$ SUGRA for volume modulus ρ

$$K_{\mathrm{KL}} = -3\ln(\rho + \bar{\rho})$$
$$W_{\mathrm{KL}} = W_0 + Ae^{-a\rho} - Be^{-b\rho}, \quad W_0 < 0,\ A, B, a, b > 0$$

- $V = e^K(K^{\rho\bar{\rho}} D_\rho W \bar{D}_{\bar{\rho}} \overline{W} - 3|W|^2) < 0 \Rightarrow \Lambda < 0$ **(AdS SUSY)**.

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ISS sector

[Intriligator, Seiberg and Shih '06]

- 4d $\mathcal{N}=1$ SU(N_c) SQCD in $N_c+1 \ \leq\ N_f \ <\ 3N_c/2$.
  - **Chiral superfields**: $q_i^a, \tilde q_b^j, S_j^i,\ \ i,j=1,\ldots,N_f$ and $a,b=1,\ldots,N=N_f-N_c$.

$$K_{\rm ISS} = |q|^2 + |\tilde q|^2 + |S|^2$$
$$W_{\rm ISS} = h({\rm Tr}\tilde q S q - M^2 {\rm Tr} S)$$

h = dimensionless coupling and M = ISS energy scale.

  - **Here**: $N=1$ and $N_f=4$.

[**TG** and Schmitz '18]

Uplifting

- V becomes positive $\Rightarrow \Lambda > 0$ **(dS SUSY)** with

$$m_{3/2} \equiv \left\langle e^{K/2} W \right\rangle \simeq \frac{h}{\left(2 \langle \rho \rangle / M_{\mathrm{P}}\right)^{3/2}} \left(\frac{M}{M_{\mathrm{P}}}\right)^2 M_{\mathrm{P}}$$

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Decay rates

- Largest contributions from

$$\begin{aligned}
\mathrm{Re}S_1 &\rightarrow \chi_{S1} + \bar{\chi}_{S1} \\
\mathrm{Re}S_2 &\rightarrow \psi_{3/2} + \psi_{3/2} \\
\mathrm{Re}Q_1 &\rightarrow \left(\psi_{3/2} + \psi_{3/2}, \quad \chi_{S1} + \bar{\chi}_{S1} + \mathrm{Im}Q_2, \quad \chi_{S1} + \bar{\chi}_{S1} + \mathrm{Re}Q_2\right) \\
\mathrm{Re}Q_2 &\rightarrow \left(\psi_{3/2} + \psi_{3/2}, \quad \chi_{S1} + \bar{\chi}_{S1} + \mathrm{Im}Q_2\right)
\end{aligned}$$

ISS scalars: S and Q and **ISS fermions**: χ_S

Evolution of the Universe

[**TG** and Schmitz '18]

- **Moduli and gravitino problems:**
  - • decays after BBN
    ⇒ unacceptable entropy diluting BBN products,
  - • decays to large number of unstable gravitinos or lighter ISS fields
    ⇒ large DM relic density.

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- Oscillations after inflationary phase (inflaton η)

  $\Rightarrow$ Neglect: modulus ρ and ReQ_2,

  $\Rightarrow$ Relevant (amplitude $\neq 0$): ReS_1, ReS_2 and ReQ_1.

Dark matter production

[**TG** and Schmitz '18]

- **Dark matter:** LSP neutralino χ.
  - Thermal: freeze-out from η plasma.
  - Non-thermal: decays of $\psi_{3/2}$ or χ_{S1} (followed or not by neutralino co-annihilation).

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Constraint	Meaning
Numerical and $M < 4.80 \times 10^{-2} h M_{\mathrm{P}}$	$s_\eta > s_{\phi_{\mathrm{ISS}}}$ and $\rho_\eta > \rho_{\phi_{\mathrm{ISS}}}$
$M \gtrsim 3.82 \times 10^{-6} h^{-1/2} M_{\mathrm{P}}$ and $M \lesssim 2.56 \times 10^{-5} h^{-1/2} M_{\mathrm{P}}$	$\psi_{3/2}$ decays before BBN and $\psi_{3/2}$ decays after neutralino freezeout
$M \gtrsim 1.75 \times 10^{-3} h^{-1/2} M_{\mathrm{P}}$ and $M \lesssim 9.12 \times 10^{-3} h^{-1/2} M_{\mathrm{P}}$	χ_{S1} decays before BBN and χ_{S1} decays after neutralino freezeout

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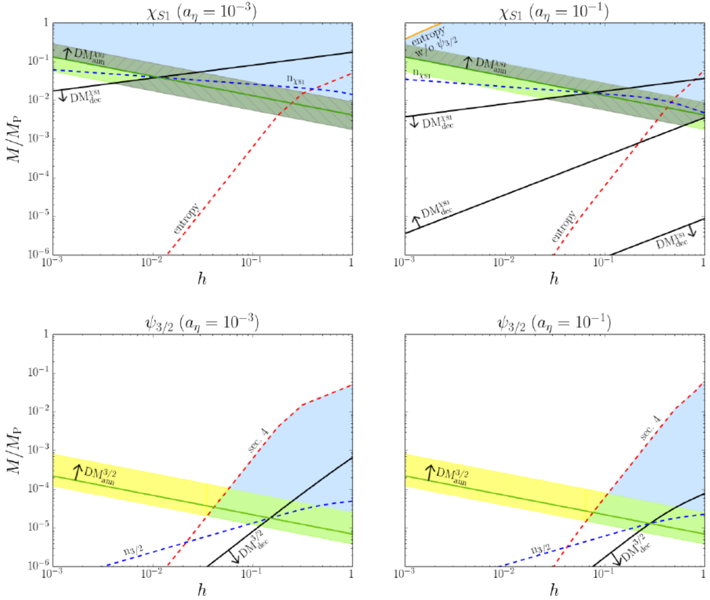
- Acceptable production: $\Omega_{DM} h^2 \lesssim 0.12$ [Planck 2018]. 10% thermal + 90% non-thermal without moduli/gravitino problems.

- $m_\chi = 100$ GeV, $\langle \sigma_{\rm ann} v_{\rm M\o l} \rangle = 10^{-7} {\rm GeV}^{-2}$ [TG and Schmitz '18]
  $a_\eta = 10^{-1} \times$ coupling η-MSSM gauge bosons.



Conclusions

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- Fruitful string derived scenario with myriad of particles.
- Decay rates + evolution of Universe.
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Thank you for your attention!