Stringy dark matter in the KL moduli stabilization scenario

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w/ Ernany R. Schmitz

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Why dark matter in the KL moduli stabilization scenario?

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- Moduli stabilization: flat directions of \(V\) stabilized by giving masses to moduli. **Here:** Kallosh-Linde scenario (KL)!

- 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**  

- Low-scale SUSY breaking + high-scale inflation.
- IIB on orientifolded Calabi-Yau 3-folds \(\Rightarrow\) 4d \(\mathcal{N} = 1\) SUGRA for volume modulus \(\rho\)
  
  \[
  K_{KL} = -3 \ln(\rho + \bar{\rho}) \\
  W_{KL} = W_0 + A e^{-a\rho} - B e^{-b\rho}, \quad W_0 < 0, \; A, B, a, b > 0
  \]

- \(V = e^K (K^{\rho \bar{\rho}} \partial_{\rho} W \partial_{\bar{\rho}} \bar{W} - 3|W|^2) < 0 \Rightarrow \Lambda < 0\) (AdS SUSY).
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ISS sector

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

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

  $h$ = dimensionless coupling and $M$ = ISS energy scale.

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

Uplifting

- $V$ becomes positive $\Rightarrow \Lambda > 0 \text{ (dS SUSY)}$ with

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

- Largest contributions from

\[
\begin{align*}
\text{Re} S_1 & \rightarrow \chi S_1 + \bar{\chi} S_1 \\
\text{Re} S_2 & \rightarrow \psi_{3/2} + \psi_{3/2} \\
\text{Re} Q_1 & \rightarrow (\psi_{3/2} + \psi_{3/2}, \chi S_1 + \bar{\chi} S_1 + \text{Im} Q_2, \chi S_1 + \bar{\chi} S_1 + \text{Re} Q_2) \\
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\end{align*}
\]

**ISS scalars**: $S$ and $Q$ and **ISS fermions**: $\chi_S$
Evolution of the Universe

Moduli and gravitino problems:

- decays after BBN
  ⇒ unacceptable entropy diluting BBN products,

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  ⇒ large DM relic density.
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Oscillations after inflationary phase (inflaton $\eta$)

⇒ Neglect: modulus $\rho$ and $\text{Re}Q_2$,

⇒ Relevant (amplitude $\neq 0$): $\text{Re}S_1$, $\text{Re}S_2$ and $\text{Re}Q_1$. 
Dark matter production

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

[ TG and Schmitz ‘18]
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<td>$s_\eta &gt; s_{\phi IS} \quad \text{and} \quad \rho_\eta &gt; \rho_{\phi IS}$</td>
<td>$M \lesssim 4.80 \times 10^{-2} h M_p$</td>
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<td>$\psi_{3/2}$ decays before BBN and $\psi_{3/2}$ decays after neutralino freezeout</td>
<td>$M \gtrsim 3.82 \times 10^{-6} h^{-1/2} M_p$ and $M \lesssim 2.56 \times 10^{-5} h^{-1/2} M_p$</td>
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<td>$\chi_{S1}$ decays before BBN and $\chi_{S1}$ decays after neutralino freezeout</td>
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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, $\langle \sigma_{\text{ann}} v_{\text{Mol}} \rangle = 10^{-7}$ GeV$^{-2}$

$a_\eta = 10^{-1} \times$ coupling $\eta$-MSSM gauge bosons.

[ TG and Schmitz '18]
Conclusions

* KL+ISS+MSSM+inflaton scenario

- Fruitful string derived scenario with myriad of particles.
- Decay rates + evolution of Universe.
- Dark matter candidates with relic density $\Omega_{DM} h^2 \lesssim 0.12$ and no moduli/gravitino problems.

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Thank you for your attention!