Minimal model of torsion mediated dark matter

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Crux of the matter : NEW dark matter portal

- We propose a minimal model of Torsion mediated dark matter annihilations
- Torsion: Antisymmetric part of the Affine connection in the Einstein-Cartan extension of **General Relativity**
- Observations in DM phenomenology

  • Particle content: A SM singlet Dirac fermion ψ, SM and Torsion : DM DM−Torsion−SM SM

  • The DM is naturally stable without any imposition of ad-hoc symmetry like e.g., $\mathcal{Z}_2$

  • Torsion in phenomenology $\Rightarrow$ like a massive gauge boson (like Z') having only axial coupling

  • The stringent bounds on the SI DM-nucleon direct detection cross-section relaxed due to its axial nature of the torsion.

  • Mixings with SM Gauge bosons can be considered to be absent

Spacetime Torsion : useful properties

- The covariant derivative of a vector field A^ν is a tensor $\Rightarrow$ $\nabla_\mu A^\nu = \partial_\mu A^\nu + \Gamma^\nu{}_{\mu\lambda} A_\lambda$ ($\Gamma^\nu{}_{\mu\lambda} \Rightarrow$ Affine connection)
- Affine connection$\Rightarrow$ Christoffel Connection in Einstein **GR** $\Gamma^\lambda{}_{\mu\nu} = \frac{1}{2} g^{\lambda\alpha} \left(\partial_\mu g_{\nu\alpha} + \partial_\nu g_{\mu\alpha} - \partial_\alpha g_{\mu\nu}\right)$
- In the Einstein-Cartan extension of **GR**, the affine connection can have an **anti-symmetric part** $\tilde{\Gamma}^\lambda{}_{\mu\nu} = \Gamma^\lambda{}_{\mu\nu} + C^\lambda{}_{\mu\nu}$
  Useful parametrization (**arXiv:hep-th/0103093**):

$$T^\lambda{}_{\mu\nu} = \tilde{\Gamma}^\lambda{}_{\mu\nu} - \tilde{\Gamma}^\lambda{}_{\nu\mu},$$

$$T_{\mu\nu\lambda} = \frac{1}{3}\left(T_\nu\, g_{\mu\lambda} - T_\lambda\, g_{\mu\nu}\right) - \frac{1}{6}\,\varepsilon_{\mu\nu\lambda\sigma}\, S^\sigma + q_{\mu\nu\lambda},$$

  Definitions of the irreducible components:
  - $S^\lambda = \varepsilon^{\mu\nu\alpha\lambda}\, T_{\mu\nu\alpha}$ is axial vector mode
  - $q_{\mu\nu\alpha} \Rightarrow$ tensor satisfies $q^\mu{}_{\nu\mu} = 0$ and $\varepsilon^{\mu\nu\alpha\sigma}\, q_{\mu\nu\alpha} = 0$.
  - $T_\mu = T^\alpha{}_{\mu\alpha} \Rightarrow$ the vector (trace) mode

Torsion interactions with DM and SM fermions

- For simplicity we consider Torsion characterized by S_μ only
- Relevant and New parts in Action:
  - S_μ-SM interactions:

$$\mathcal{S}_D = \int d^4x \, \{ i\bar{f}\gamma^\mu(\partial_\mu - i\eta_1 \gamma^5 S_\mu) f \} ,$$

  - S_μ-DM interactions:

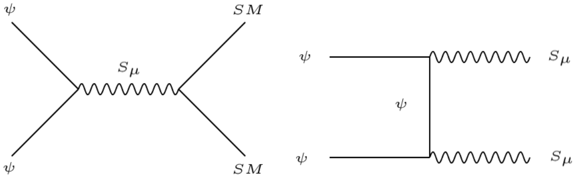
$$\mathcal{S}_{DM} = \int d^4x \, \{ i\bar{\psi}\gamma^\mu(\partial_\mu - i\eta \gamma^5 S_\mu)\psi - m_\psi \bar{\psi}\psi \} .$$

  - Kinetic terms:

$$\mathcal{S}_{torsion} = \int d^4x \left\{ -\frac{1}{4} S_{\mu\nu} S^{\mu\nu} + \frac{1}{2} m_s^2 S_\mu S^\mu \right\}$$

$S_{\mu\nu} = \partial_\mu S_\nu - \partial_\nu S_\mu$ and m_s is the torsion mass

Dominant channels (Universal coupling : $\eta_1 = \eta$)



$$\langle \sigma v \rangle_{\bar{f} f} \sim \eta^4 \frac{m_f^2}{m_s^4} \left(\frac{\left(m_s^2 - 4 m_\psi^2\right)^2}{\left(m_s^2 - 4 m_\psi^2\right)^2 + \Gamma_s^2 m_s^2} \right) + v^2 \frac{\eta^4 m_\psi^2}{\left(4 m_\psi^2 - m_s^2\right)^2} \times \cdot\cdot$$

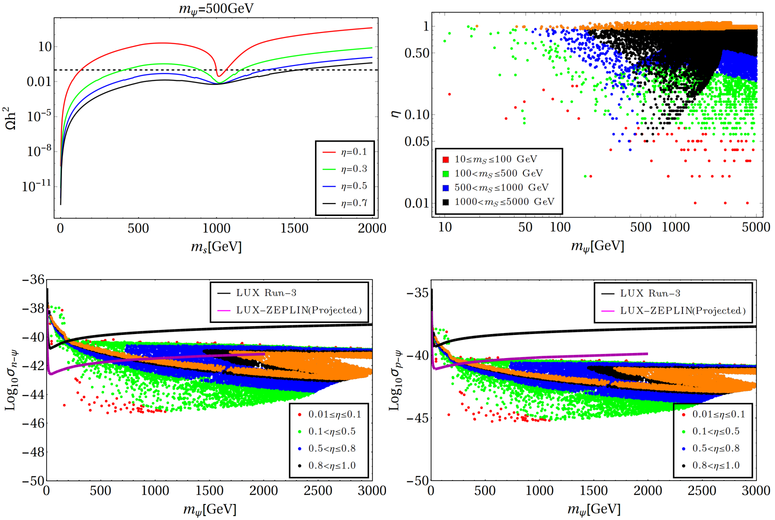
$$\langle \sigma v \rangle_{ss} \sim \frac{\eta^4}{m_\psi^2} \left(1 - \frac{m_s^2}{m_\psi^2}\right)^{3/2} \left(1 - \frac{m_s^2}{2 m_\psi^2}\right)^{-2} + \mathcal{O}\left(v^2\right)$$

Torsion(s_μ)-DM(ψ) phenomenology

Contributions to relic abundance:

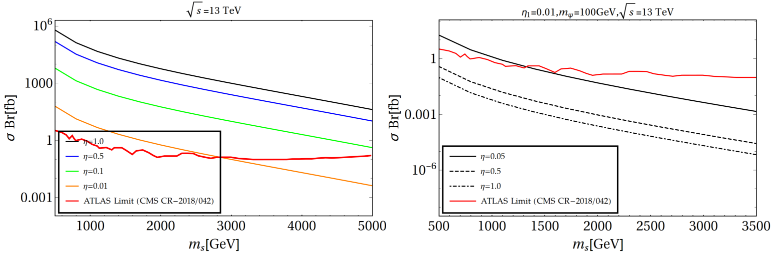
- A resonance at $m_\psi \simeq \frac{m_s}{2}$ can be observed
- For moderate or small m_s, (when Γ_s can be ignored), the **leading order term** in the s-channel process may not be sensitive to **Breit-Wigner type narrow width resonance**
- The **dominant** v^2 contribution carries the **resonance effect**, specially important in relic density calculation when the DM is lighter than top quark
- $DM\ DM \rightarrow t\bar{t} \sim \frac{m_f^2}{m_s^4}$ for $m_s \sim m_\psi$ can produce significant contributions
- Similarly t-channel contributions, free from v^2 suppression, are also important for $m_s \lesssim m_\psi$

Universal Coupling scenario ($\eta = \eta_1$):



LHC constraints and Nonuniversal coupling scenario

- $\sigma(pp \to S_\mu) \times Br(S_\mu \to l^+ l^-)$ $(l \in e, \mu)$ vs. m_s in the universal and nonuniversal coupling (NU) scenario



- $\eta \simeq 1$ may lead to $\Gamma_s/m_s \geq 0.5$ narrow width approximation breaks down $\Rightarrow$ **LHC constraints relaxed**
- NU scenario$\Rightarrow$ DM phenomenology mostly unchanged

Torsion Portal- **GR** connection successfully explain DM phenomena

THANK YOU