Hidden Sector Dark Matter Models for the Galactic Center Gamma-Ray Excess

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See also:
1405.0272, 1404.6528, 1404.4977

COSMO’14
15-40 GeV Dark Matter… What about LUX?

\[
\sigma_{\text{SI nucleon}} (\text{cm}^2) = 5 \times 10^{-45}
\]

\[
\sigma_{\text{SI nucleon}} (\text{cm}^2) = 4 \times 10^{-45}
\]

\[
\sigma_{\text{SI nucleon}} (\text{cm}^2) = 3 \times 10^{-45}
\]

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\sigma_{\text{SI nucleon}} (\text{cm}^2) = 2 \times 10^{-45}
\]

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\]

\[
m_{\chi} [\text{GeV}]
\]

LUX
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- Intermediate states have small mixing, but large branching fraction to SM states.
- The decay of the intermediate states to SM fermions yields a photon-spectrum. These cascade decays result in a somewhat different fit to the GC excess.
- Nucleon scattering is suppressed, but annihilation is unsuppressed.
A Generic Example
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\[ XX \rightarrow \phi_1 \phi_2 \rightarrow 4b \]
In general, for arbitrary $2m_X > m_{\phi_1} + m_{\phi_2}$, $\phi_1$ and $\phi_2$ are boosted.
Generic Example: \( XX \rightarrow \phi_1 \phi_2 \rightarrow 4b \)

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Compared to direct annihilations, cascade annihilations prefer DM masses about twice as large.
Generic Example:

$XX \rightarrow \phi \phi \rightarrow 4b$

$E_\gamma^2 dN_{\gamma}/dE_\gamma$ [GeV$^2$/cm$^2$/s/sr]

$E_\gamma$ [GeV]

$m_X = 70$ GeV, $m_\phi = 70$ GeV

$m_X = 70$ GeV, $m_\phi = 10$ GeV

$m_X = 70$ GeV, $m_\phi = 40$ GeV
Generic Example:
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$XX \rightarrow \phi_1 \phi_2 \rightarrow 4b$, $m_X = 72$ GeV
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\( \phi \)'s produced at rest

\( m_X = 72 \) GeV

\[ m_{\phi_1} [\text{GeV}] \]

\[ m_{\phi_2} [\text{GeV}] \]
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\(\phi_1\)'s produced at rest

Combined \(\phi\) and \(b\) boost

\(b\)'s produced at rest

\(XX \rightarrow \phi_1 \phi_2 \rightarrow 4b, m_X = 72\, \text{GeV}\)
Generic Example:

**XX → φ₁φ₂ → 4b**

- φ’s produced at rest
- m_X = 60-80 GeV is “good” fit
- Combined φ and b boost
- b’s produced at rest

\[ XX \rightarrow \phi_1 \phi_2 \rightarrow 4b, \quad m_X = 72 \text{ GeV} \]
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- Power (via annihilations) goes as \( \sigma \nu/\text{m}_x \).
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- Hence, reduced intensity for the best-fit cascade annihilations.
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- This suppresses $\sigma v$ (today) relative to $\sigma v$ (at freeze-out). However, with a mass splitting of order 5%, $\sigma v$ (today) only suppressed by a few percent.
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All these factors produce tension in the normalization of the signal, but can be compensated by adjusting mass of Milky way profile (which is uncertain by O(1) factor).
An Actual Model
Dark Photon
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- If $\phi$ has small kinetic mixing with photon, then $\phi$ predominantly decays to SM fermions.

\[ \mathcal{L} = \frac{1}{2} \epsilon F'_{\mu\nu} F^{\mu\nu} \]
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Naturally, $\sim 10^{-4}$, avoiding limits from LUX
Dark Photon

\[ m_x \text{ [GeV]} \]

\[ m_\phi \text{ [GeV]} \]
Thank you
Backup Slides
Neutralino LSP, which is dominantly singlino-like.

If \( m_{h_s} + m_{a_s} < 2m_\chi \), then \( \chi\chi \rightarrow h_s a_s \).

If light singlet-like Higgses have small mass mixing with MSSM Higgses, then they predominantly decay to SM fermions.

\[
W^{\text{Higgs}} = (\mu + \lambda S) \hat{H}_u \hat{H}_d + \xi_F \hat{S} + \frac{1}{2} \mu' \hat{S}^2 + \frac{1}{3} \kappa \hat{S}^3
\]

\( \sim 10^{-4} \), avoiding limits from LUX.
NMSSM

NMSSM, $m_\chi = 67$ GeV, tan$\beta = 5$