Indirect Detection of Secluded Supersymmetric Dark Matter

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https://arxiv.org/abs/2003.13744
https://arxiv.org/abs/2106.XXXXX
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Brief Outline

Secluded WIMPS and Indirect Detection

The WIMP paradigm remains a popular model of dark matter.

Traditional WIMP candidates, such as MSSM neutralinos, are increasingly bounded by direct detection experiments.

WIMP dark matter within a secluded sector with small portal couplings to the Standard Model can evade direct detection and collider bounds.

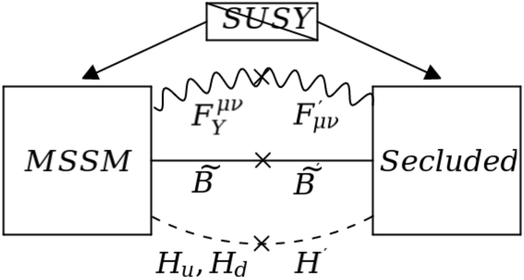
Indirect detection signals, however, will not be suppressed.

Supersymmetric Secluded Sectors and Portals

Supersymmetry can explain why the secluded particles are at the weak scale.

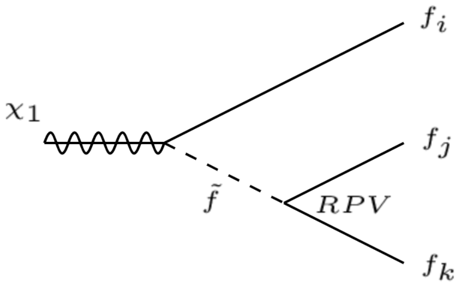
A SUSY kinetic mixing provides a gauge, gaugino, and Higgs portal,

$$\frac{\epsilon}{2}\int d^2\theta\, W_Y W' + h.c. = \epsilon D_Y D' - \frac{\epsilon}{2} F_Y^{\mu\nu} F'_{\mu\nu} + i\epsilon \tilde{B}\sigma^\mu \partial_\mu \tilde{B}'^\dagger + i\epsilon \tilde{B}'\sigma^\mu \partial_\mu \tilde{B}^\dagger.$$



R-Parity Violation

R-Parity is sometimes postulated in the MSSM to stabilize the LSP.



We can add R-Parity violating couplings and investigate the results of different ones on our annihilation spectra.

Photon Spectra from Annihilation

For R-Parity even final states, we have Dirac DM ψ, a dark photon Z', and dark Higgs H'. We do not assume supersymmetry.

$\psi\bar{\psi} \to Z'H'$ (Higgs Mechanism)

$\psi\bar{\psi} \to Z'Z'$ (Stueckelberg)

Branching ratios set by

$$\mathcal{L} = \xi|H'|^2|H|^2 - \frac{\epsilon}{2}F_Y^{\mu\nu}F'_{\mu\nu}. \tag{1}$$

R-Parity Even Final States

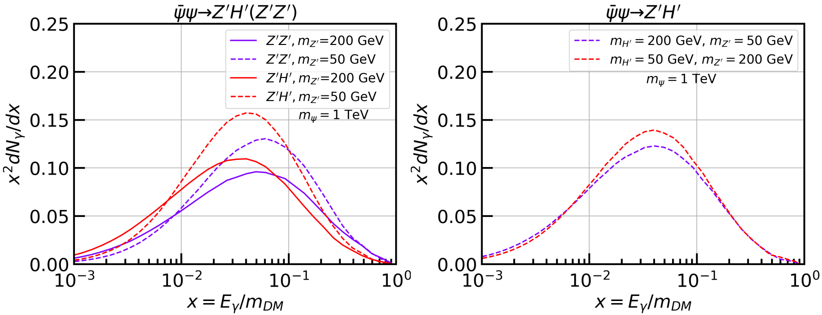


Figure 1: **Left:** Spectra for $\psi\bar{\psi}$ annihilation to either $Z'Z'$, or $Z'H'$ in the degenerate case $m_{Z'} = m_{H'}$. **Right:** We now allow $m'_H \neq m_{Z'}$.

$H' \to b\bar{b}$ or W^+W^-

$Z' \to u\bar{u}$

R-Parity Odd Final States

If the secluded sector is supersymmetric, annihilation to neutralinos, $\psi\bar{\psi} \to \chi_1'\chi_1'$, is possible.

We assume H' is charged under $U(1)'$, so the Higgsino and gaugino mix to form Majorana mass eigenstates χ_1' and χ_2'.

These neutralinos will decay to SM states through the gaugino portal.

LSP in the Visible Sector

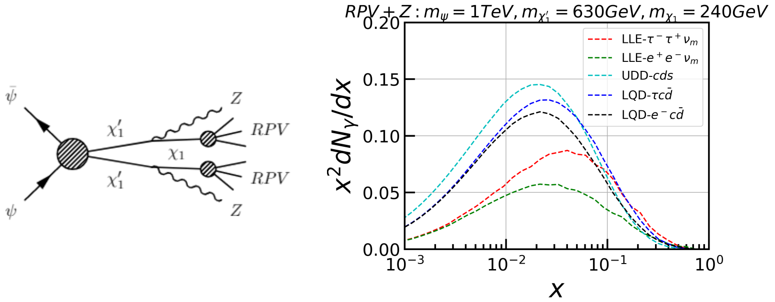


Figure 2: **Left:** Effective DM annihilation through a neutralino cascade. “RPV” indicates the three fermion final state from RPV χ_1 decay, which differs based on the dominant RPV coupling. **Right:** The resulting spectra for specific examples of non-zero RPV couplings.

$$W_{RPV} = \frac{1}{2}\lambda_{ijk} L_i L_j E_k + \lambda'_{ijk} L_i Q_j D^c_k + \frac{1}{2}\lambda''_{ijk} U^c_i D^c_j D^c_k. \qquad (2)$$

LSP in the Secluded Sector

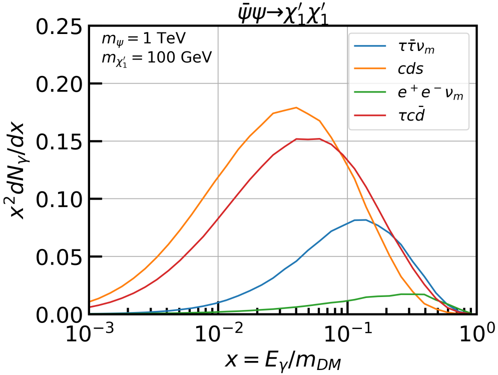


Figure 3: The photon spectra for direct ψ annihilation to χ_1', shown for multiple potential RPV mediated χ_1' decays.

If the χ_1' is lighter than its MSSM counterparts, it may decay directly to the SM via RPV couplings.

Analysis

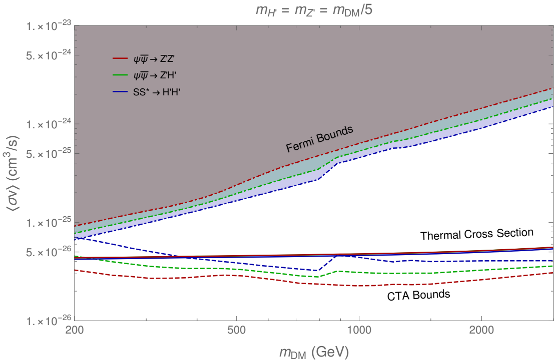
Fermi-LAT

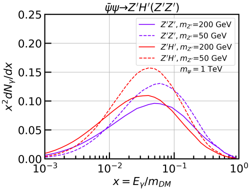
6 years of data
15 dSph galaxies
https://arxiv.org/abs/1503.02641

CTA

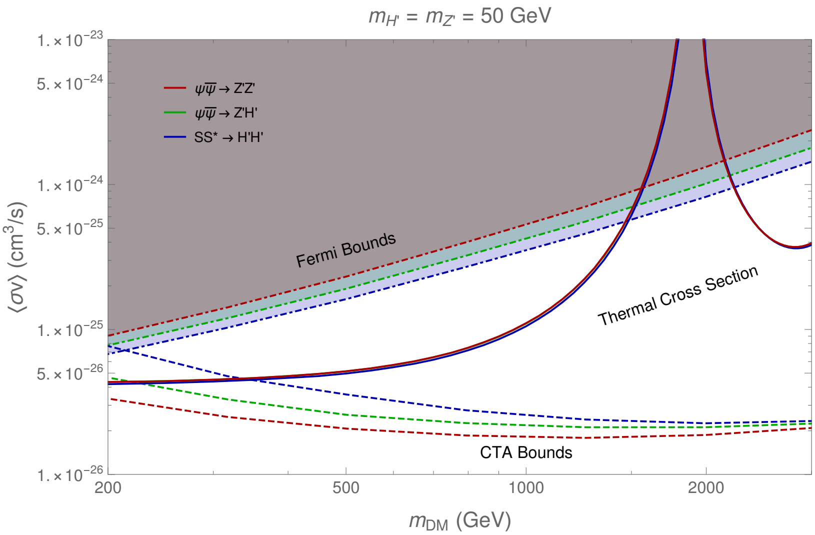
Projected 525 hours
Milky Way galactic center
https://arxiv.org/abs/2007.16129

R-Parity Even Final States

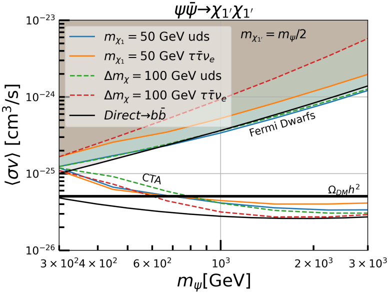


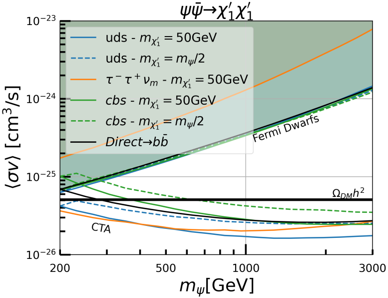


R-Parity Even Final States



R-Parity Odd Final States





Takeaways

Indirect detection can provide a robust probe of DM models where small couplings will suppress direct and collider signals.

A well motivated example is a supersymmetric secluded sector.

For large areas of parameter space, CTA will probe the thermal relic cross section for such a model.