Effects of Low Boosted Dark Matter Annihilation on Galactic Signals

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Based Upon:
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Dark Matter Interpretation of the Galactic Center Excess (GCE)

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- One possible explanation is that it originates from dark matter interactions.
- However, this explanation is in tension with other similar measurements, in particular, gamma ray measurements from dwarf satellite galaxies.

Dark Matter Galactic Indirect Detection

- Measurements incorporate both particle and galactic properties to calculate the expected flux

$$\frac{\mathrm{d}\Phi}{\mathrm{d}E_\gamma} = \frac{\mathrm{d}N}{\mathrm{d}E_\gamma} \begin{cases} \frac{\langle \sigma_{\mathrm{ann}} v \rangle_0}{8\pi\, m_\chi^2} \times J_{\mathrm{ann}} & \text{(annihilation)} \\ \frac{1}{4\pi\, m_\chi\, \tau_{\chi,0}} \times J_{\mathrm{decay}} & \text{(decay)} \end{cases}$$

- In many cases, the equations are separable into a particle physics portion and an astrophysical part, the J-factor.

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- In practice, J_{ann} incorporates integration over the phase space of both parents.

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- What happens to the galactic signals from these boosted models?

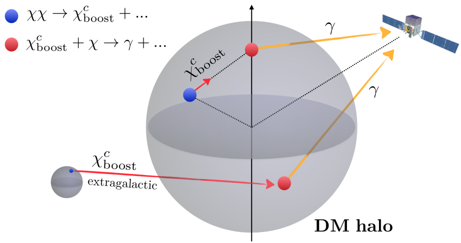
Toy Model

- Two-part dark matter χ_1 and χ_2 with $m_{\chi_1} > m_{\chi_2}$
- χ_1 annihilates to χ_2 with a boost.
  - Rates are similar to thermal dark matter and χ_1 can be viewed as the standard dark matter.
- χ_2 annihilates and produces a SM observable signal.
  - χ_2 rates are much larger than χ_1 annihilation.

$$\chi_1\chi_1 \to \chi_2^{\mathrm{b}} + \chi_2^{\mathrm{b}}$$

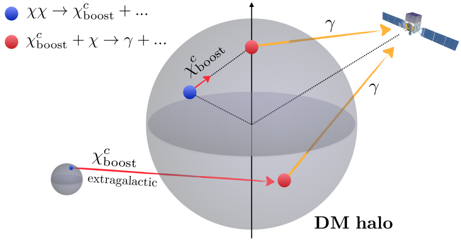
$$\chi_2 + \chi_2 \to \mathrm{SM\ observable}$$

Toy Model



$\chi\chi \to \chi^c_{\rm boost} + \ldots$
$\chi^c_{\rm boost} + \chi \to \gamma + \ldots$
$\chi^c_{\rm boost}$
γ
γ
$\chi^c_{\rm boost}$
extragalactic
DM halo

Toy Model



- If $m_{\chi_1} \gg m_{\chi_2}$, then χ_2 will be highly boosted and escape out of the galaxy. (See Phys. Rev. D 103, 083006 (2021); arXiv:2007.04971 [astro-ph.CO])

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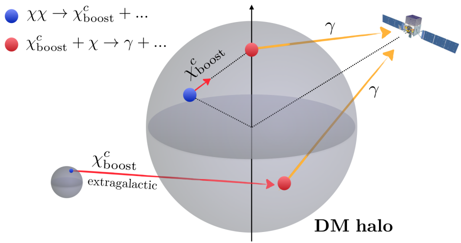

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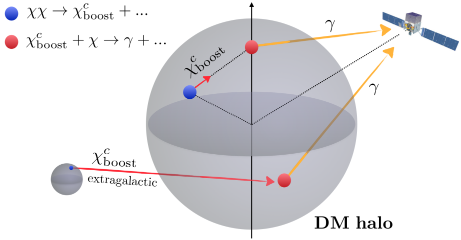

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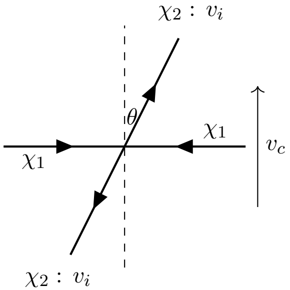
- If $m_{\chi_1} \ll m_{\chi_2}$, the χ_2 population will reach a steady state solution as a combination of χ_1 annihilation products that remain in the galaxy and χ_2 annihilation.
  - The observable signal rate is proportional to the χ_2 capture rate.

Low boost scenario

- For small boosts, parent velocities are no longer negligible leading to a velocity distribution in the galactic frame.



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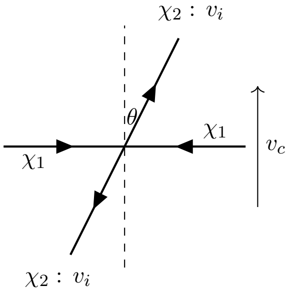

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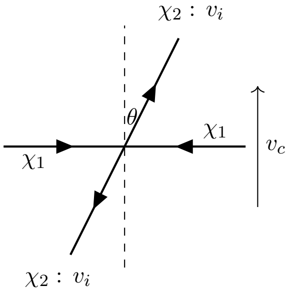

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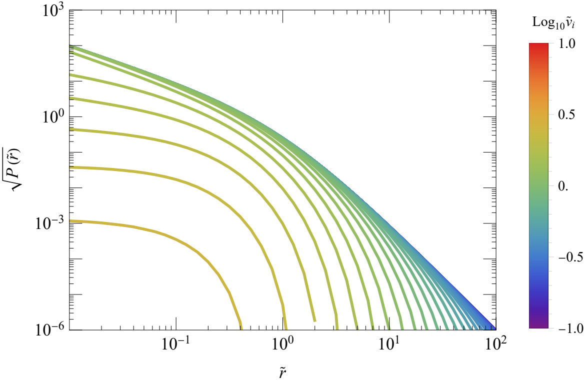
- This leads to the condition

$$\cos\theta < -\frac{2\tilde{\Phi} + \tilde{v}_i^2 + \tilde{v}_c^2}{2\tilde{v}_i\tilde{v}_c}$$

Capture

- For various kick velocities, the capture rate is maximal until a critical speed is reached.
- Afterwards, the rate quickly decreases to no capture.



Galactic Signals

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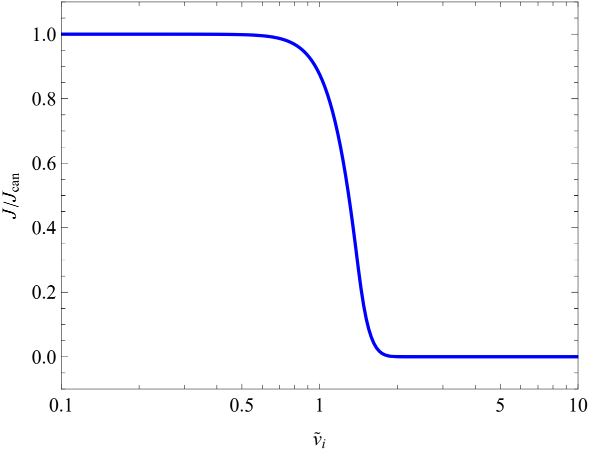
- Due to their size differences, dSphs require a lower boost to achieve escape velocity than the Milky Way.
- This can lead to a dramatically smaller capture percentage and a much smaller expected signal.



Summary

- Boosted dark matter models can lead to additional galactic dependencies for indirect detection methods.
- These dependencies can lead to a transition between no modification to complete suppression of signals within narrow model parameters.
- To identify these properties from other models, observations of a variety of galactic sizes are required.

Thank You!