Discovering Asymmetric Dark Matter with Anti-Neutrinos

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-arxiv:1003.5662
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Where did the DM relic density come from?

-Standard WIMP paradigm is compelling, but it is not the only option.

-Baryonic density arises from an asymmetry between particles and anti-particles.

→ Why not the same for DM?

-The asymmetries could even arise from the same source.

→ The DM must then carry baryon or lepton number, and have a mass O(5 GeV).

-Kaplan, Luty, Zurek

- We assume operators which transfer the asymmetry freeze out at temperatures above m_{DM}.

- The fundamental tests of this scenario:

  -measure the DM mass

  -discover that DM carries baryon or lepton number.

  → This is difficult due to the freezeout requirement!

A possible signature

Since DM is electrically neutral..

→Excess B or L number in DM decays must show up either in neutrinos or in electrons + protons

- For many quantum number assignments the DM carries (anti)-lepton number, and the excess is in (anti)-neutrinos.

→ Would be a striking signal!

(DM annihilations would be too suppressed)

-Unfortunately, no such signal has been seen yet..

→ Leads to constraints on potential decay operators.

-Main limit comes from Super Kamiokande.

→Note that a dedicated analysis is currently underway by SuperK!

The Neutrino Portal

-Falkowski, Juknevich, Shelton

Consider interactions of the form

$$\Delta\mathcal{L} = \frac{\mathcal{O}_{\rm DS}\mathcal{O}_{\rm SM}}{\Lambda^{d-4}}$$

Lowest dimension possibilities:

$$\begin{aligned}
d = 4: \quad \mathcal{O}_1 &= \psi H L \\
d = 5: \quad \mathcal{O}_2 &= X\psi L H \\
d = 6: \quad \mathcal{O}_3 &= \psi L L E^c \\
\mathcal{O}_4 &= \psi L Q D^c \\
\mathcal{O}_5 &= \psi U^c D^c D^c \\
\mathcal{O}_6 &= X_1 X_2 \psi L H \\
\mathcal{O}_{2\nu} &= \tfrac{1}{2} X (LH)^2
\end{aligned}$$

→ many involve the "neutrino portal" operator LH, and have a dominant neutrino signature.

→ others (here with B-L = 1), do not..

Calculating the Constraint

$$\frac{d\Phi}{dE} = \frac{\Gamma_{DM}}{4\pi m_{\rm DM}} \frac{dN}{dE} \int_{\Delta\Omega} \int_0^\infty \rho(x)\, dx$$

($\Delta\Omega \sim 30°$)

- Background is from atmospheric neutrinos.

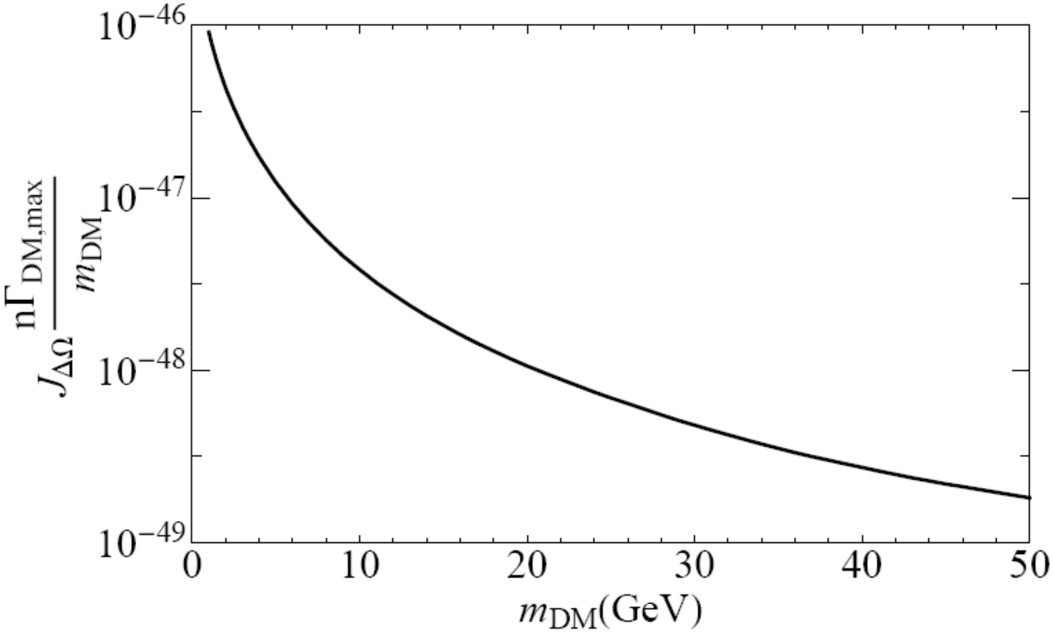
→ We take a conservative constraint: signal < background.

-Yuksel, Horiuchi, Beacom, Ando

(bin width $\Delta \log_{10} E = 0.3$)

-some minor dependence on the halo profile (~ 15%)

Results



($J_{\Delta\Omega}$ ~ 6)

- Dimension 5 operator: $\Lambda_{min} \sim 10^{25}$ GeV
- Dimension 6 operator: $\Lambda_{min} \sim 10^{13}$ GeV

Distinguishing νs from $\bar{\nu}$s

- At water Cherenkov detectors, look for an additional muon in the final state… comes from charged pion decay.

$$\nu_e + P \to P + e^- + \pi^+$$
$$\nu_e + N \to N + e^- + \pi^+$$
$$\bar{\nu}_e + P \to P + e^+ + \pi^-$$
$$\bar{\nu}_e + N \to N + e^+ + \pi^-$$

- A π^- with ~GeV energy tends to become absorbed by a proton before decaying. Gives statistical ability to distinguish neutrinos from anti-neutrinos.

→ Works for DM masses less than ~5-10 GeV.

- Future detectors might have other handles…

Summary

- Asymmetric Dark Matter, with an asymmetry shared between the DM and baryons/leptons, is a compelling framework for producing the DM relic density.

- In such scenarios with DM carrying lepton number, this could lead to anti-neutrino decay products as the dominant detection signature.

- The DM mass must be ~1-10GeV, and thus such a signature would provide striking evidence for the ADM picture.