Asymmetric Dark Matter May Not Be Light

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Abstract

It is often said that asymmetric dark matter is light compared to typical weakly interacting massive particles. Here we point out a simple scheme with a neutrino portal and O(60 GeV) asymmetric dark matter which may be "added" to any standard baryogenesis scenario. The dark sector contains a copy of the Standard Model gauge group, as well as (at least) one matter family, Higgs doublet, and right-handed neutrino. After baryogenesis, some lepton asymmetry is transferred to the dark sector through the neutrino portal where dark sphalerons convert it into a dark baryon asymmetry. Dark hadrons form asymmetric dark matter and may be directly detected due to the vector portal. Surprisingly, even dark anti-neutrons may be directly detected if they have a sizeable electric dipole moment. The dark photons visibly decay at current and future experiments which probe complementary parameter space to dark matter direct detection searches. Exotic Higgs decays are excellent signals at future $e^+ e^-$ Higgs factories, in particular, the ILC.

The Dark Sector

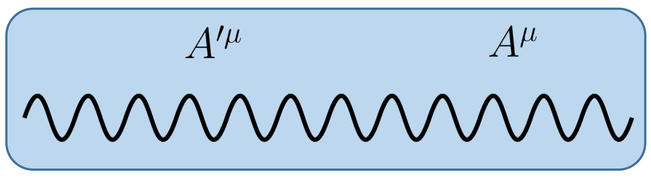
Introduce a minimal dark sector mimicking the SM:

- Gauge group: SU(3)' × SU(2)' × U(1)'
- One matter generation
- One Higgs doublet
- One right-handed Weyl neutrino

Portals

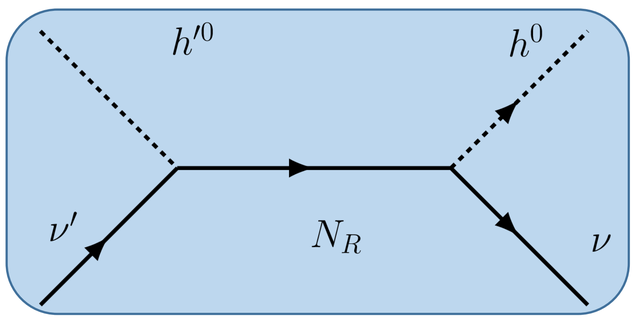
Kinetic Portal

$$\mathcal{L} \subset \frac{\varepsilon}{2} F_{\mu\nu} F'^{\mu\nu} + \frac{1}{2} m_{\gamma'}^2 A'_{\mu} A'^{\mu}$$

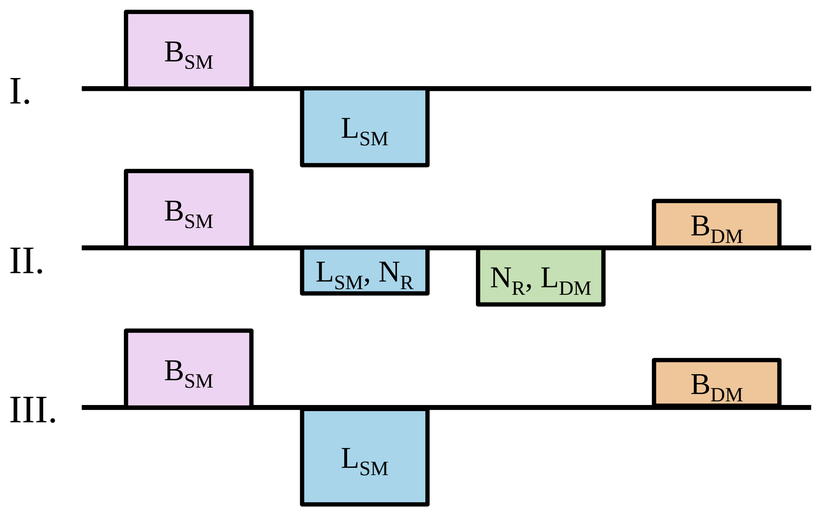


Neutrino Portal

$$\mathcal{L} \subset y'_N \bar{L}' \hat{\mathrm{H}}' N_R + y_N \bar{L} \hat{\mathrm{H}} N_R + c.c$$



Asymmetry Transfer

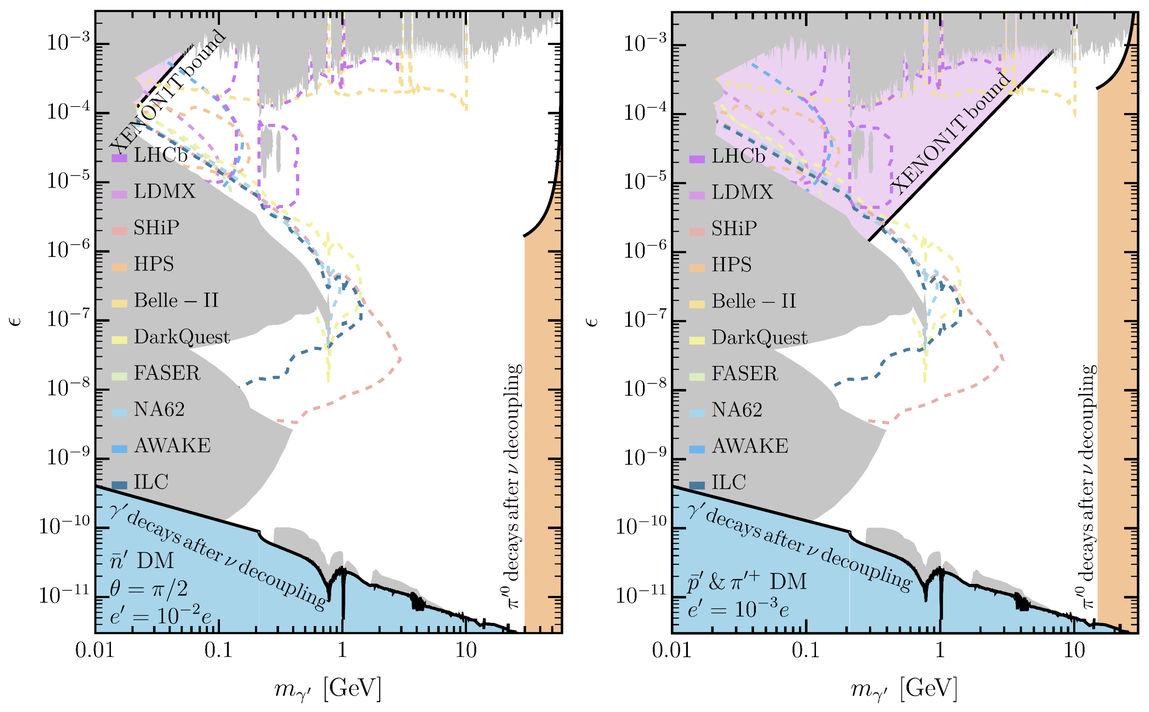


I. SM Electroweak Baryogenesis generates equal B_{SM} and L_{SM} asymmetries
II. The neutrino portal transfers some SM lepton asymmetry over to the dark leptons and dark sphalerons convert it into dark baryon asymmetry
III. Right-handed neutrino decays back into the SM

Dark Matter Masses

Dark Sector Phase Transition	Dark Baryon Number	Dark Lepton Number	Predicted DM Mass	
1st order	$B' = -\frac{72}{535} B$	$L' = \frac{168}{535} B$	$\bar{p}$ & π'	29.9 GeV
			$\bar{n}$	59.9 GeV
Crossover	$B' = -\frac{120}{1427} B$	$L' = \frac{360}{1427} B$	$\bar{p}$ & π'	18.7 GeV
			$\bar{n}$	37.4 GeV

Dark Baryon Detection



The viable ADM parameter space as projected onto dark photon mass versus kinetic mixing. Existing constraints on visibly decaying dark photons are shaded dark gray, while projected sensitivities are dashed. Color-shaded regions are ruled out by too-late decays and direct detection constraints, as discussed in the text. Left: DM is all $\bar{n}'$ and $e' = 10^{-2}$ e. Right: DM is 50% $\bar{p}'$ and 50% π'^+ and $e' = e_{min}$.

Detections at the ILC

Best Detected Through e^+e^- Collider

- Dark photon decays to visible particles [when $m_{\gamma'}$ > O(GeV)]
- Production of dark hadrons through an off-shell dark photon (dark spectroscopy)[4]
- Beam dump experiments reaching heavier dark photon masses[5]
- Exotic Higgs decays through Higgs mixing[6]

Conclusions

- With this new model, we have a simple dark sector which may be "added" onto existing models of electroweak baryogenesis to simultaneously explain DM.
- In the most minimal case, we predict a range of dark matter masses much higher than any previous models of asymmetric dark matter, up to nearly 60 GeV.
- The ILC will probe large swaths of the viable ADM parameter space. It can also probe other predicted interactions such as exotic Higgs decays.

References

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