$U(1)_{B-L}$ Dark Matter Provides an Explanation for PAMELA and ATIC Positron Excesses

Katie Richardson-McDaniel

University of New Mexico

Pheno 2009: Universiy of Wisconsin-Madison

arXiv:0812.2196, arXiv:0902.3463 and an upcoming IceCube Analysis
In collaboration with Rouzbeh Allahverdi (UNM),
Sascha Bornhauser (UNM), Bhaskar Dutta (Texas A&M),
Yudi Santoso (University of Durham)

Three Probes of Dark Matter

Direct Detection: CDMS, DAMA/LIBRA, XENON...

- Probes interactions with matter
- Cannot test relic density

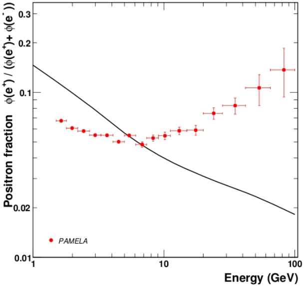
Indirect Detection: PAMELA, Fermi, IceCube...

- Depends on annihilation cross-section
- Astrophysical backgrounds

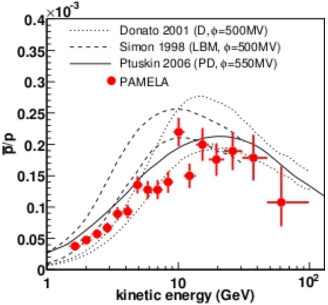
Particle Accelerators: LHC, ILC

- Will determine mass through missing energy from decay chains
- Cannot prove cosmological stability

Motivation for $U(1)_{B-L}$



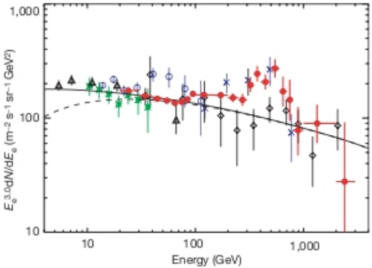
Adriani, et al 0810.4995



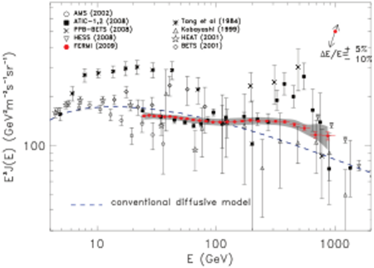
Adriani, et al 0810.4994

Problem: We need to explain a positron excess without an antiproton signal, as seen by PAMELA

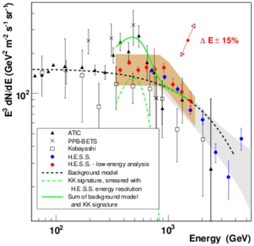
ATIC and Fermi also suggest new physics



Chang, et al Nature 456, 362-365



Abdo, et al 0905.0025



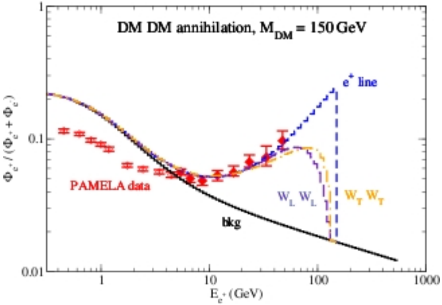
Aharonian, et al 0905.0105

Dark matter annihilation might provide an explanation

PAMELA data requires more than $\langle \sigma v \rangle_f$

For DM annihilation, a boost factor is needed

$$\Gamma_{ann} = Bn\langle \sigma v \rangle_f \propto \langle \sigma v \rangle_0$$



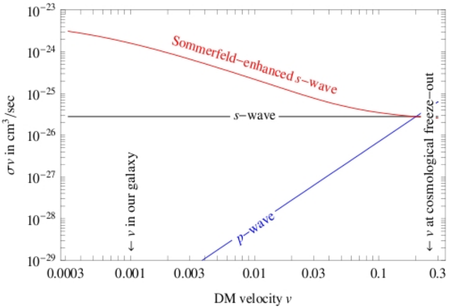
Barger, et al 0809.0162

- e^+, e^-: $B \sim O(10)$
- W: $B \sim O(100)$

χ_0^1 annihilates in p-wave: $\langle \sigma v \rangle_0 \propto v^2 \langle \sigma v \rangle_f \approx 10^{-5} \langle \sigma v \rangle_f$

Ways to Boost $\langle \sigma v \rangle$ Now But Not at Freeze Out

- Local DM substructure O(10), not O(10^4).
- Sommerfeld enhancement achieves large B.



Cirelli, et al 0809.2409

To explain PAMELA

Successful models must exhibit

1. S-wave annihilation
2. A light boson to create an attractive force for Sommerfeld enhancement
3. Annihilation mostly to the leptonic sector

The MSSM alone cannot meet these conditions but the minimal $U(1)_{B-L}$ extension can.

$U(1)_{B-L}$ Model Contents

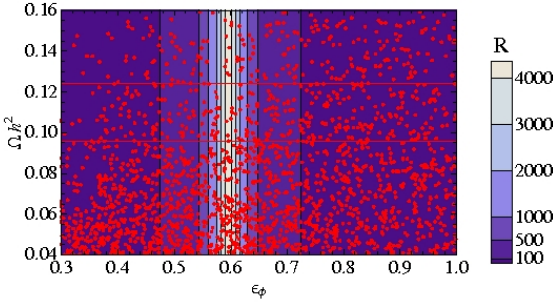
3 right-handed $N + \widetilde{N}$	Needed for anomaly-free theory Explain ν masses
$Z' + \widetilde{Z}'$	Mass limits from TeVatron/ LEP
$H'_1, H'_2 + \widetilde{H'_1}, \widetilde{H'_2}$	Break symmetry, $m_{Z'}$ Light ϕ gives Sommerfeld enhancement

Dark matter candidates in $U(1)_{B-L}$

- New neutralino: $\chi_0'^1$, fermion
- Right-handed sneutrino: $\widetilde{N}$, scalar

B-L provides Sommerfeld enhanced s-wave annihilation

$\chi_0'^1\ \chi_0'^1 \rightarrow \phi\phi$	s-wave	$\widetilde{N}\widetilde{N}^* \rightarrow \phi\phi$	s-wave	(80-90%)
$\chi_0'^1\ \chi_0'^1 \rightarrow f\bar{f}$	p-wave	$\widetilde{N}\widetilde{N} \rightarrow NN$	s-wave	(10-20%)
		$\widetilde{N}\widetilde{N}^* \rightarrow f\bar{f}$	p-wave	

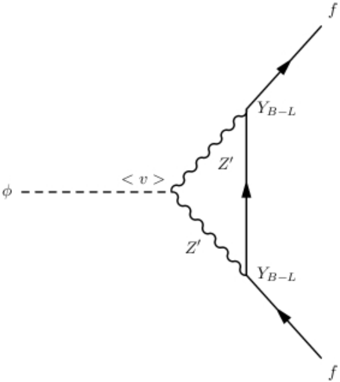


Allahverdi, et al 0812.2196

Light Higgs Decays Preferentially to Leptons

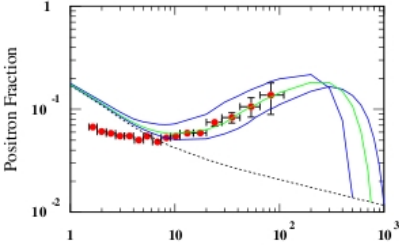
Lepton Annihilation Preferred

$$\Gamma_{\phi \to f\bar{f}} \propto Q_f^4 m_f^2 C_f$$

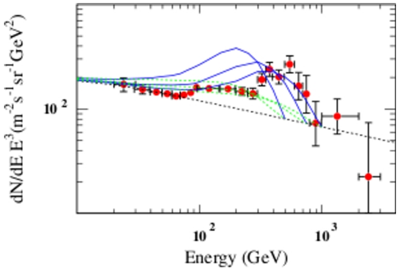


$(Q_L/Q_Q)^4$	3^4
C_L/C_Q	$1/3$
$(m_\tau/m_c)^2$	$(1.4)^2$
τ/c	53

$U(1)_{B-L}$ fits PAMELA and ATIC data



Allahverdi, et al 0812.2196



Allahverdi, et al 0812.2196

PAMELA (left) and ATIC (right) fits for 1, 1.5, 2 TeV annihilating to taus with $R = 10^3$

Other Model Signatures and Properties

- Direct Detection
  - Spin-dependent: None, B-L is non-chiral
  - Spin-independent: $\sigma_{\chi_0'^1}$ too small,
    $\sigma_{\widetilde{N}}$ upcoming experiments can probe $10^{-11} - 10^{-9} pb$

Other Model Signatures and Properties

- Direct Detection
  - Spin-dependent: None, B-L is non-chiral
  - Spin-independent: $\sigma_{\chi_0^{\prime 1}}$ too small, $\sigma_{\widetilde{N}}$ upcoming experiments can probe $10^{-11} - 10^{-9} pb$
- Indirect Detection
  - Distinctive IceCube signature for $\widetilde{N}$, $\delta(E)$ for annihilation to ν
  - Fermi velocity effect

Other Model Signatures and Properties

- Direct Detection
  - Spin-dependent: None, B-L is non-chiral
  - Spin-independent: $\sigma_{\chi_0^{\prime 1}}$ too small,
    $\sigma_{\widetilde{N}}$ upcoming experiments can probe $10^{-11} - 10^{-9} pb$
- Indirect Detection
  - Distinctive IceCube signature for $\widetilde{N}$,
    $\delta(E)$ for annihilation to ν
  - Fermi velocity effect
- Collider Physics
  - New missing energy signals from ϕ

Other Model Signatures and Properties

- Direct Detection
  - Spin-dependent: None, B-L is non-chiral
  - Spin-independent: $\sigma_{\chi_0'^1}$ too small,
    $\sigma_{\widetilde{N}}$ upcoming experiments can probe $10^{-11} - 10^{-9} pb$
- Indirect Detection
  - Distinctive IceCube signature for $\widetilde{N}$,
    $\delta(E)$ for annihilation to ν
  - Fermi velocity effect
- Collider Physics
  - New missing energy signals from ϕ

- Other Implications for Cosmology
  - $\widetilde{N}$ can be part of the inflaton, $\varphi = (\widetilde{N} + H_u + \widetilde{L})/\sqrt{3}$