

Gauge Singlet Dark Matter
and
ATIC/PAMELA e^\mp Excess

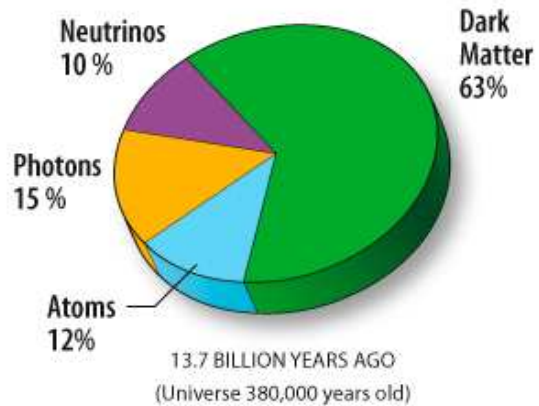
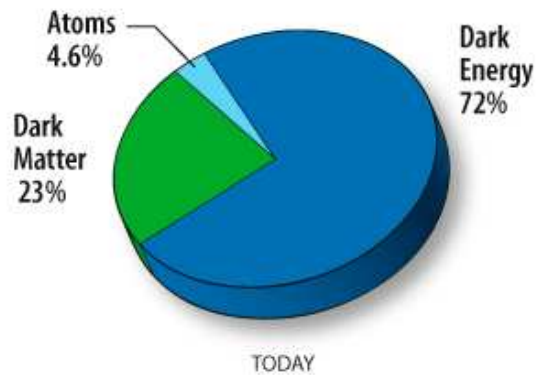
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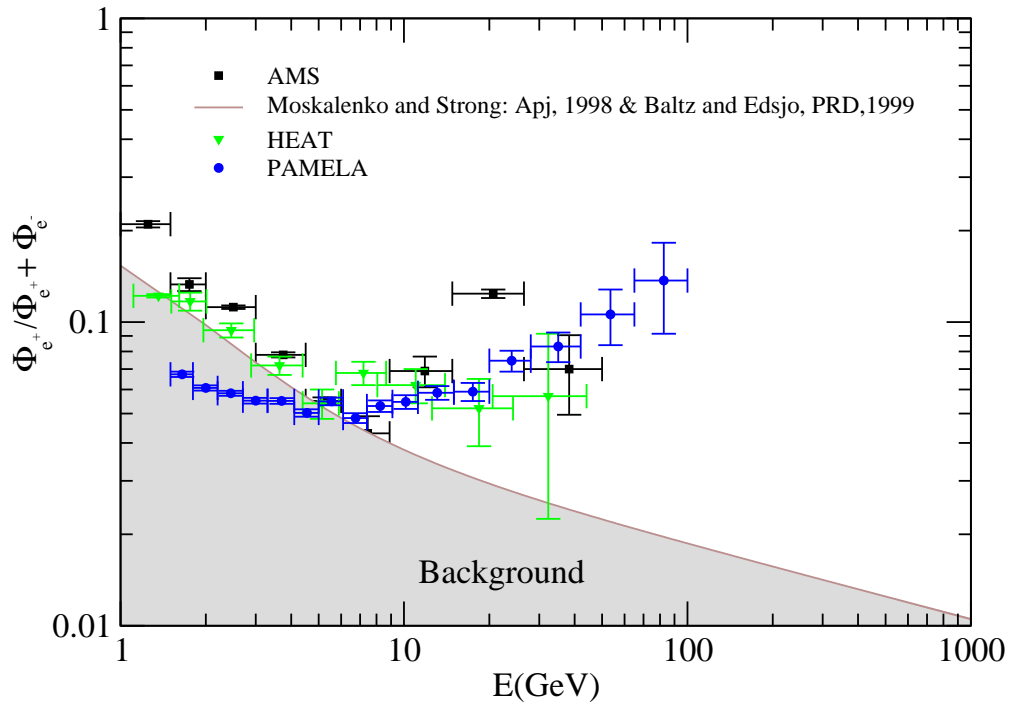
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Talk based on....

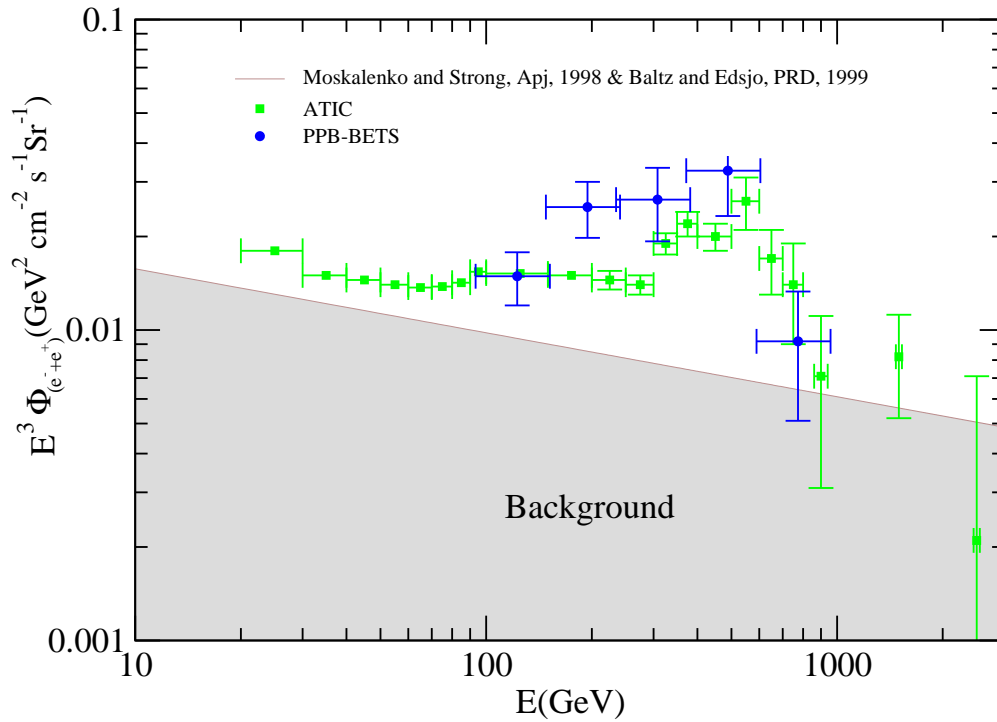
Work done with John McDonald and Kazunori Kohri



Positron Excess



Electron Excess



Questions....

Are those results are true ?

If so, can they be explained by DM ?

Yes !

But the accuracy varies from model to model

Relic density of thermal WIMP

The contribution of a thermal WIMP to DM abundance can be given as:

$$\Omega_{\text{DM}} h^2 = \frac{1.1 \times 10^9 \text{ GeV}^{-1} z_D}{g_*^{1/2} M_{\text{Pl}} \langle \sigma |v| \rangle_{\text{F}}}$$

where

$$z_D = \frac{M_{\text{WIMP}}}{T_D} \approx 25$$

describes the decoupled epoch for thermal WIMP.

Thermal DM Cross-section

Using $\Omega_{\text{DM}} h^2 = 0.101$ and $z_D = 25$ we will get the “canonical cross-section” of WIMP annihilation

$$\langle \sigma |v| \rangle_F \approx 3 \times 10^{-26} \text{cm}^3/\text{sec}$$

and the corresponding velocity at decoupled epoch:

$$v_{\text{DM}} = \sqrt{\frac{3}{z_D}} \approx 0.3$$

Current velocity of DM is:

$$v_{\text{DM}} = 0.001$$

which implies that

$$z_D \approx 3 \times 10^6$$

Boosted DM annihilation cross-section

Current observations of excess of positron and electron can not be explained by the canonical cross-section of DM. We need a larger cross-section:

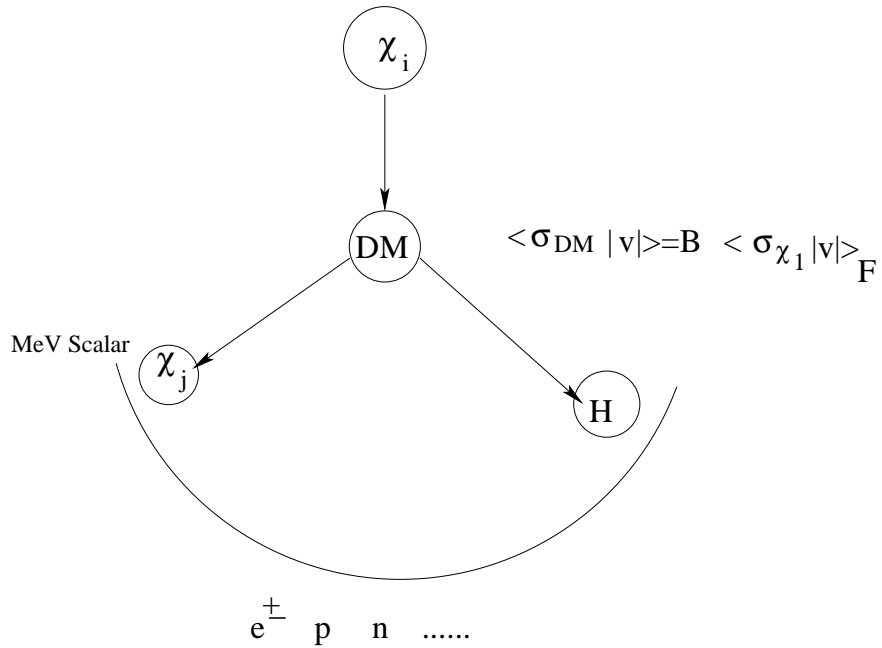
$$\langle\sigma|v|\rangle_{\text{ann}} = B\langle\sigma|v|\rangle_{\text{F}}$$

- (1) Sommerfeld-enhanced s-wave annihilation of thermal DM [Chireli et.al]
- (2) Non-thermal DM [Fairbairn and Zupan:08; Nelson and Spitzer:08]
- (3) Decay of thermal or non-thermal DM with life-time $\mathcal{O}(10^{26})$ sec. [See the next talk]

(4) Breit-Wigner Enhancement of DM annihilation. [Ibe, Murayama and Yanagida]

“One way to resolve this issue is to consider a mechanism where production and annihilation of DM occurs through different channels”.

Gauge Singlet (GS) DM



The Boost Factor

$$\Omega_{\text{DM}} h^2 = (\Omega_{\text{DM}} h^2)_{\text{TH}} + (\Omega_{\text{DM}} h^2)_{\text{NTH}} = 0.101$$

Then the ratio

$$R \equiv \frac{(\Omega_{\text{DM}} h^2)_{\text{NTH}}}{(\Omega_{\text{DM}} h^2)_{\text{TH}}} = \left(\frac{M_{\text{DM}}}{M_{\chi_i}} \right) \left(\frac{z_{\chi_i}}{z_{\text{DM}}} \right) \frac{\langle \sigma_{\text{DM}} | v_{\text{rel}} | \rangle_F}{\langle \sigma_{\chi_i} | v_{\text{rel}} | \rangle_F}$$

If $R \gg 1$ then R gives the boost factor and

$$\langle \sigma_{\chi_i} | v_{\text{rel}} | \rangle_F = 3 \times 10^{-26} \text{cm}^3/\text{s}$$

Positron Flux

The positron flux can be given as:

$$\Phi_{e^+}(E, \vec{r}_{\odot}) = \frac{v_{e^+}}{4\pi b(E)} (n_{\text{DM}})_{\odot}^2$$

$$\int_E^{M_{\text{DM}}} dE' f_{\text{inj}}(E') \cdot I(\lambda_D(E, E'))$$

where $f_{\text{inj}}(E')$ is the injection spectrum and $I(\lambda_D(E, E'))$ is the halo function.

Positron Flux

Diffusion Equation:

$$\frac{\partial}{\partial t} f_{e^+}(E, \vec{r}, t) =$$

$$K(E) \nabla^2 f_{e^+}(E, \vec{r}, t) + \frac{\partial}{\partial t} [b(E) f_{e^+}(E, \vec{r}, t)] + Q(E, \vec{r})$$

where $K(E)$ is the diffusion coefficient; $b(E)$ is the energy loss. The positron source term:

$$Q(E, \vec{r}) = n_{\text{DM}}^2(\vec{r}) f_{\text{inj}}^{e^+}$$

Injection Spectrum

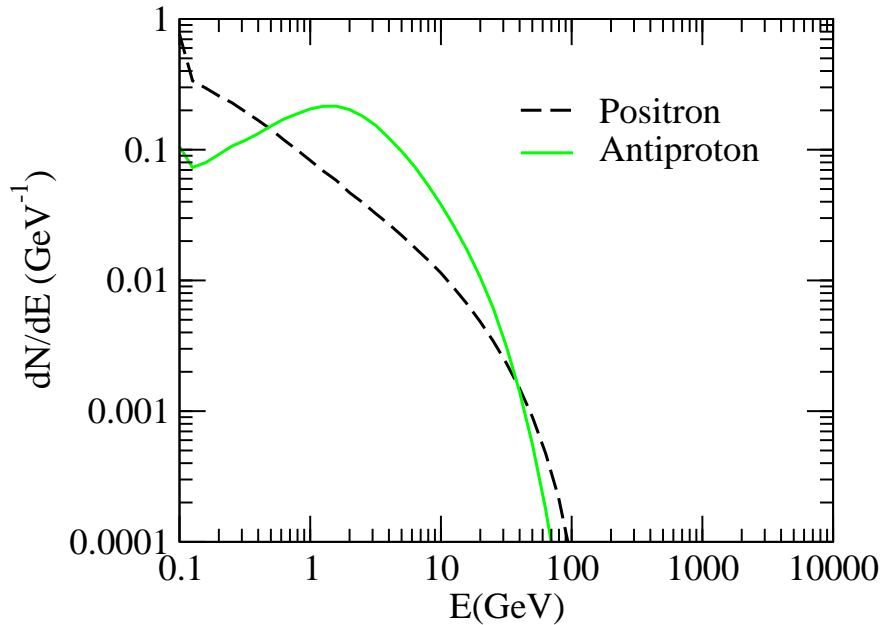
The injection spectrum can be given as

$$f_{\text{inj}}^{e+} = B_{e+} \langle \sigma_{\text{DM}} |v_{\text{rel}}| \rangle_F \frac{dN_{e+}}{dE}$$

$$f_{\text{inj}}^{e+} \approx B_{e+} R \langle \sigma_{\chi_i} |v_{\text{rel}}| \rangle_F \frac{dN_{e+}}{dE}$$

Thus the injection spectrum enhanced by a factor of R .
Therefore, the total flux also enhanced by a factor of R .

Fragmentation function from SM Higgs



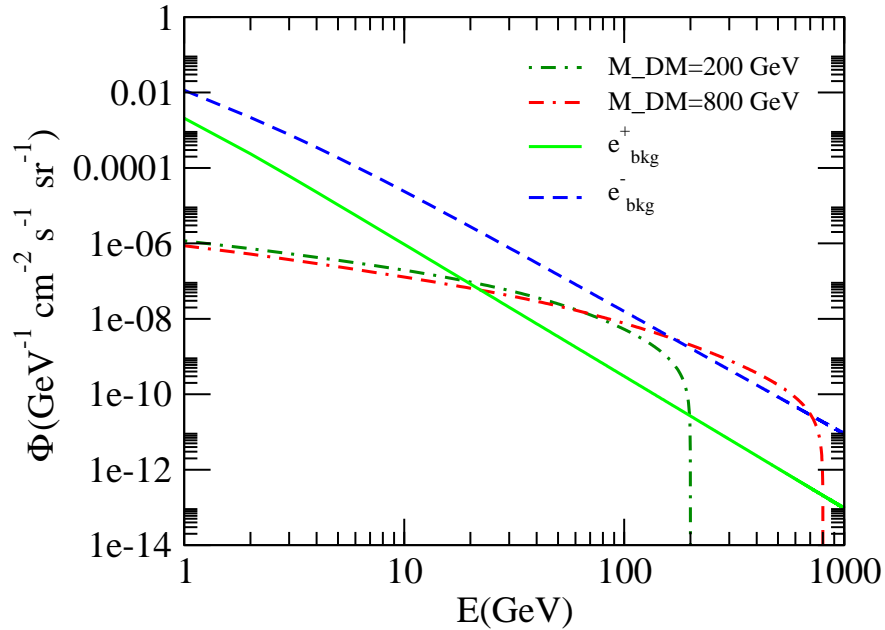
dN/dE from MeV scale scalar

In case of MeV scale particles dN/dE can be $\approx 1/M_{\text{DM}}$

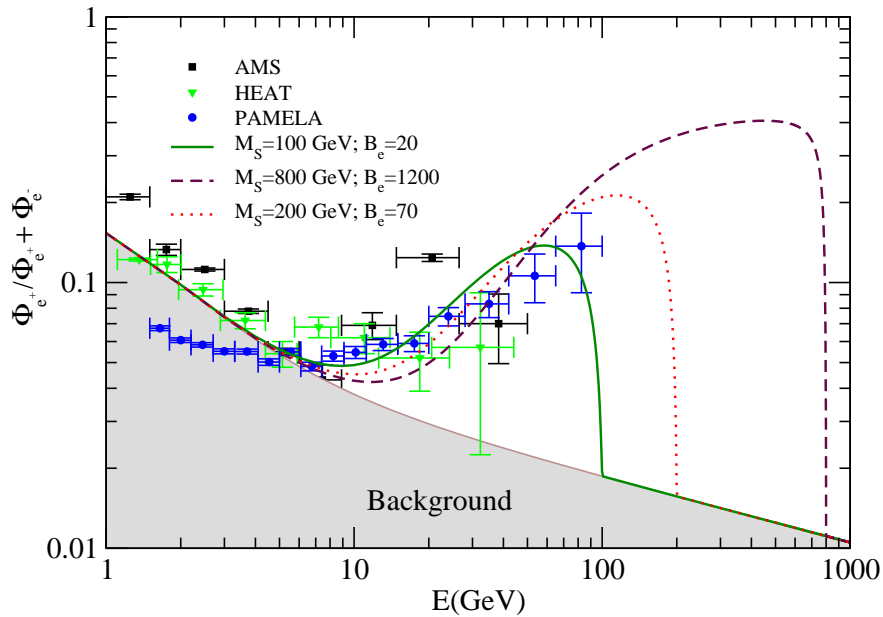
Comparing with dN/dE from Higgs we see that it increases by an order of magnitude if DM annihilates through Higgs channel.

However, this may not rule out the DM annihilation through SM Higgs.

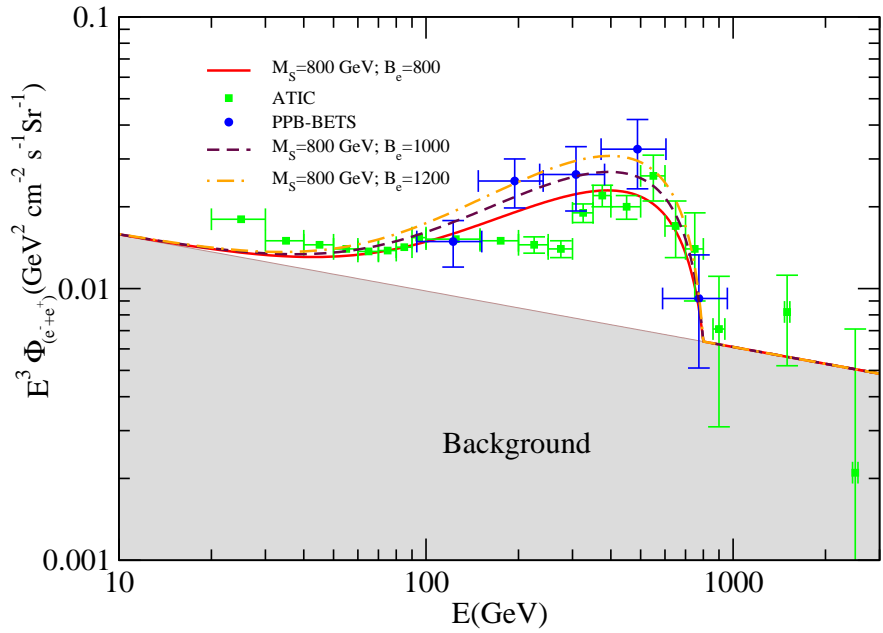
Positron Flux from GS DM



Positron Excess from GS DM



Electron Excess from GS DM



Conclusions and Outlook

A gauge singlet DM, yet a simple model, seems to explain the current observed anomalies at ATIC and PAMELA.

Annihilation of DM to MeV scale scalars is safer, but may not be predictive.

Annihilation of DM through Higgs channel will be reported soon.



THANK YOU