Uncertainties of the Antiproton Flux from Dark Matter Annihilation in Comparison to the EGRET Excess of diffuse Gamma Rays

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Conventional Model and DMA

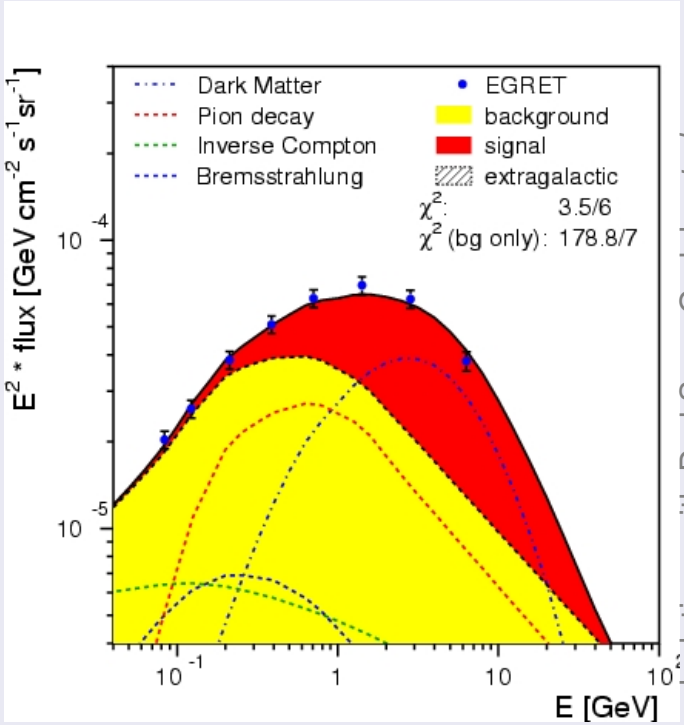
Yields from DMA (expected from LEP data)

$$n_\gamma = \frac{37}{annihilation} \text{ and } n_{\bar{p}} = \frac{0.03}{annihilation} \rightarrow \frac{n_{\bar{p}}}{n_\gamma} = 0.001$$

DarkSUSY predicts

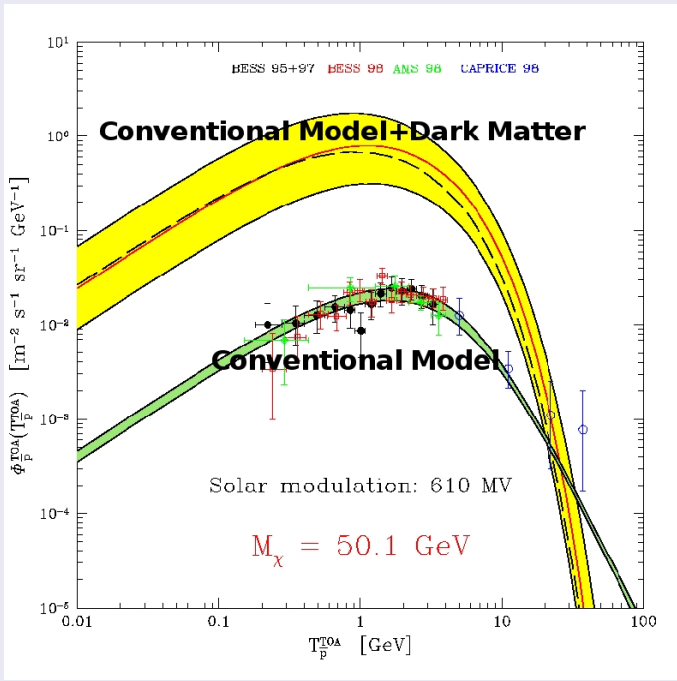
$$\frac{n_{\bar{p}}}{n_\gamma} = 0.5 - 1!$$

Gammas



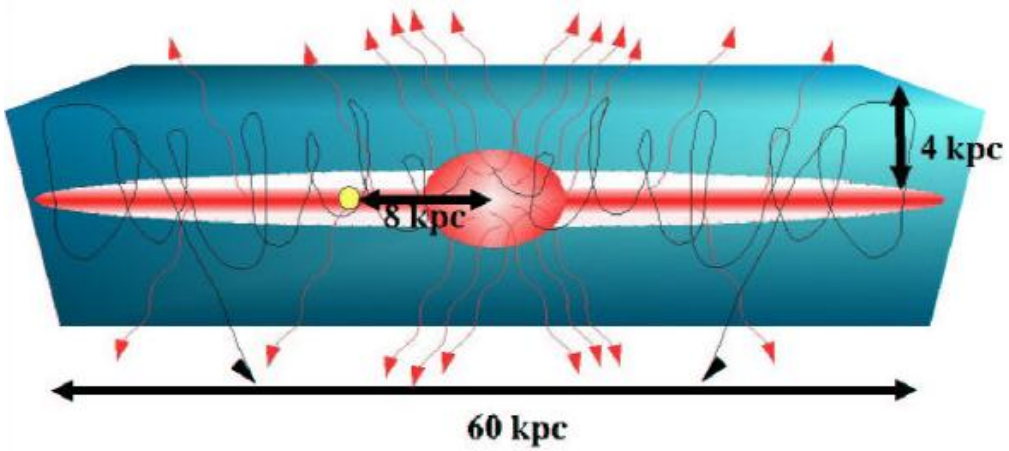
calculations with DarkSusy, Godolo *et al.*

Antiprotons



Bergström *et al.*
astro-ph/0602632v2

Conventional Model



Priors

- no static magnetic field
- gas not clumpy
- isotropic propagation (same in halo and disk)

  → galaxy acts as a **storage box for antiprotons, gammas escape**

Transport parameters

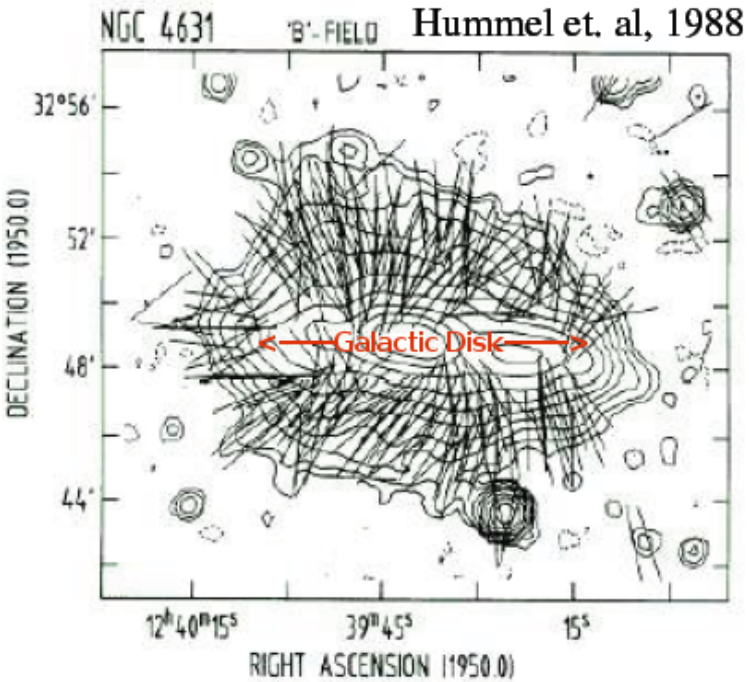
- **Radioactive instable/stable isotopes** $\frac{10Be}{9Be}$ → Age of Cosmic Rays $T_{esc} \approx 10^7\,a$

  "cosmic clocks"
- **Secondary/Primary ratio (B/C)** grammage $X(p) = v \cdot n_H \cdot T_{esc}(p)$

  → $n_H \approx \frac{0.3 atoms}{cm^3}$ → where CR spend their time

  → ratios determine halo size and diffusion coefficient
- **Gammas** insterstellar milieu
- **Charged Species** local environment

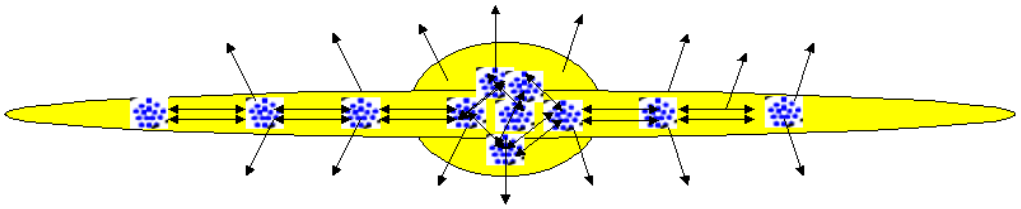
Magnetic field component in z-direction



Anisotropic diffusion/convection

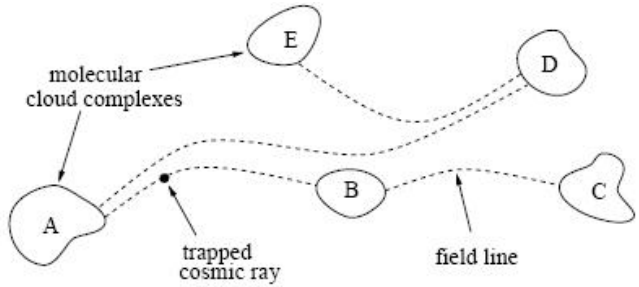
- Anisotropy in galactic magnetic field suggests anisotropic diffusion: $D_{\perp} > D_{||}$
- Escape probability for high z increases $\longrightarrow$ once particles move to higher z values they just escape $\longrightarrow$ plays role when we look at different source distributions as in the case of CR and DM

Molecular Cloud Complexes



multiple reflection between magnetic mirrors

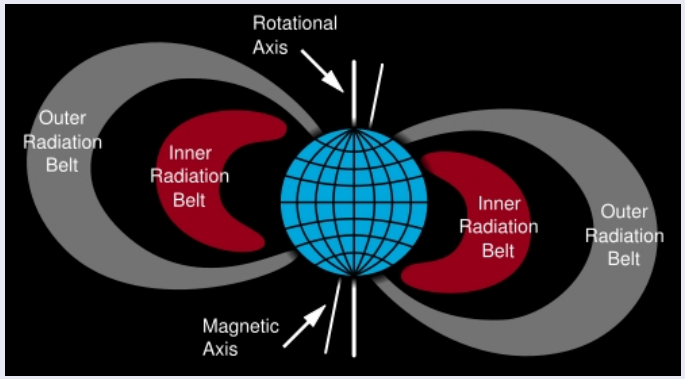
B. Chandran, 2000ApJ...529..513C



Impact on CR transport

- $T_{esc} \approx 10^7\,a$ not by large halo, but by trapping
- grammage obtained by multiple reflection between molecular clouds, particles age in disk-> B/C and Be correct
- **particles are stored**
- **CR collected from smaller area, but particles are OLD**

Van-Allen-Belt



Implementation in GalProp

Transport equation for CR:

$$\frac{\delta\Psi}{\delta t} = \vec{\nabla}\cdot(D\vec{\nabla}\Psi - \vec{V}\Psi) + \frac{\delta}{\delta p}p^2 D_{pp}\frac{\delta}{\delta p}\frac{1}{p^2}\Psi - \frac{\delta}{\delta p}[\dot{p}\Psi - \frac{p}{3}(\vec{\nabla}\cdot\vec{V})\Psi] - \frac{\Psi}{\tau_f} - \frac{\Psi}{\tau_r} + q(\vec{r},t)$$

GalProp, available on http://www.mpe.mpg.de/ aws/propagate.html. Solves transport equation numerically.

Problems with GalProp

- GalProp does not include DM species (e^+, e^-, p, $\bar{p}$, γ)
- GalProp does not allow for anisotropic propagation
- GalProp assumes homogeneous gas distribution

algorithm for solution of transport equation can now handle non-equidistant grid and anisotropic diffusion

	GalProp		Modified Code
spatial grid	equidistant	$\longrightarrow$	arbitrary spacing
diffusion	$D = const.$	$\longrightarrow$	$D_r(\vec{r}) \neq D_z(\vec{r})$
Convenction	V(z)	$\longrightarrow$	$V(\vec{r})$

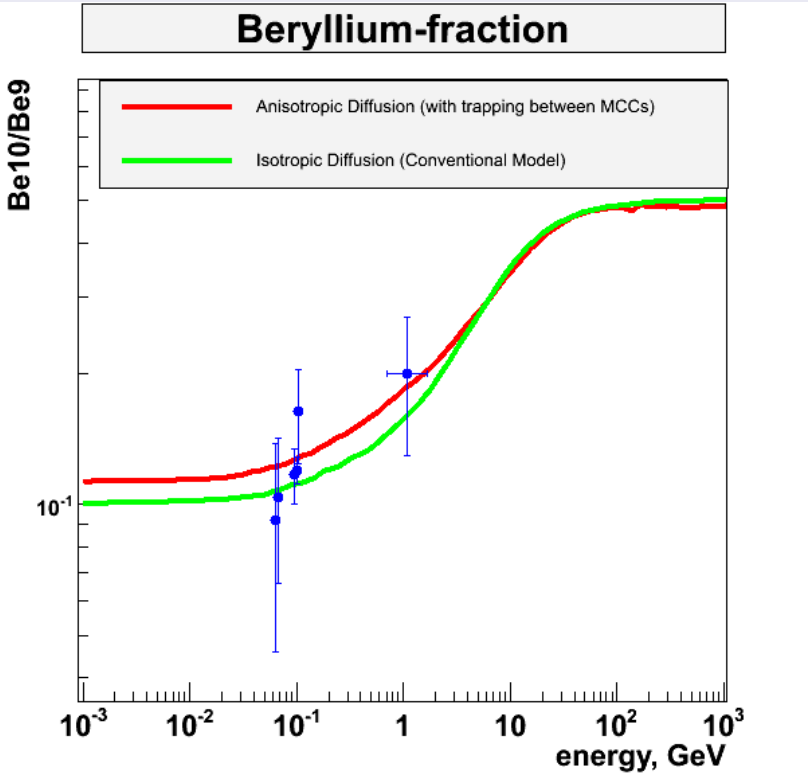
code parallelized for faster computation

Propagation in Chandran Model

charged particles from smaller collection area, but trapping between magnetic mirrors

..leads to large escape time

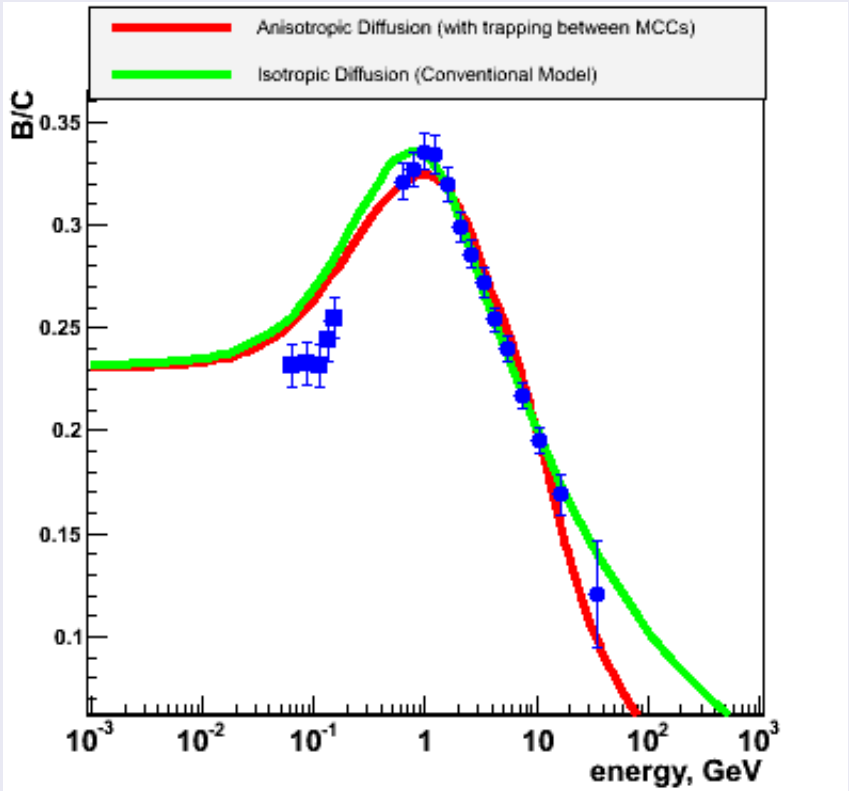
Beryllium $\longrightarrow$ $T_{esc} \approx 10^7\, a$



computation based on GalProp

..leads to large grammage

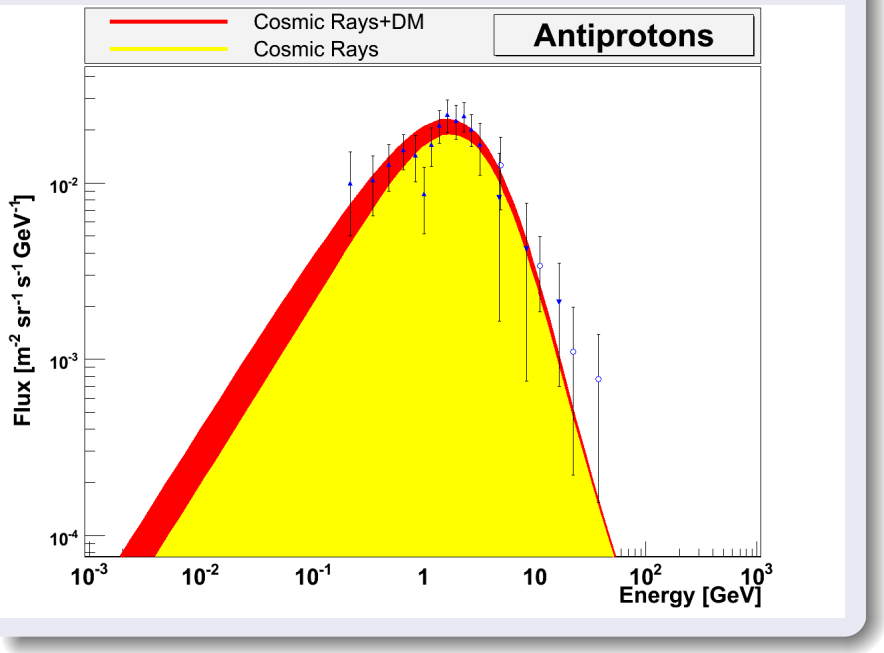
Secondary to Primary ratio (B/C) $\longrightarrow$ grammage ok



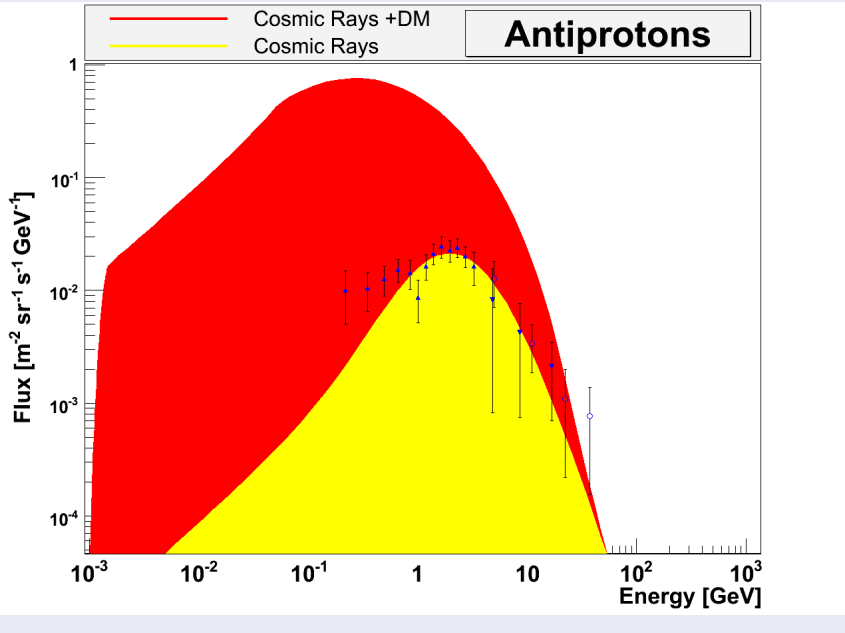
computation based on GalProp

Propagation in Chandran Model

Propagation in Chandran Model



Conventional Model



PARAMETER	CHANDRAN MODEL	CONVENTIONAL MODEL
Diffusion in disk	trapping	$\sim 10^{28}\ \frac{cm^2}{s}$
Diffusion in halo parallel to disk	$\sim 10^{28}\ \frac{cm^2}{s}$	$\sim 10^{28}\ \frac{cm^2}{s}$
Diffusion in z-direction	$\sim 10^{30}\ \frac{cm^2}{s}$	$\sim 10^{28}\ \frac{cm^2}{s}$
Convection	$V(z) = 250\,\frac{km}{s} + 37\,\frac{km}{s \cdot kpc} \cdot z$	$V(z) = 0\,\frac{km}{s}$

- *diffusion reduces both components*
- *additional secondary source only for CR*

Summary

Problem

DarkSUSY claims DMA interpretation of EGRET excess excluded because of too large antiproton flux.
However, DarkSUSY is based on isotropic diffusion
$\rightarrow$ **Galaxy is a large storage box for antiprotons**

Solution

Anisotropic propagation based on Chandran Model
$\rightarrow$ **consistent γ-rays and antiproton fluxes possible**

In contrast to gammas antiproton flux from DMA has order of magnitude uncertainty due to propagation