Constraints on dark matter annihilation in the Milky Way halo

A. Cuoco, J. Conrad, Z. Yang (Stockholm University)
and G. Zaharijas (Stockholm Univesity and CEA/IPhT Saclay)
on behalf of the Fermi Large Area Telescope Collaboration

Abstract

Diffuse gamma-rays are expected to be a powerful tool in constraining dark matter properties. In this presentation, I will report up-to-date limits on dark matter annihilation in the Milky Way halo and comment on the uncertainty introduced by the modeling of the Galactic diffuse emission.

Introduction

The Dark matter (DM) annihilation in *the Milky Way halo* is one of the prime targets for DM search due to the large dark matter density expected in the vicinity of the Galactic Center and the proximity of the region.

The Fermi Large Area Telescope (LAT) is well suited for *DM searches in the diffuse gamma-ray emission*, due to its *good angular and energy resolution*, *wide field of view* and *good charge particle identification*.

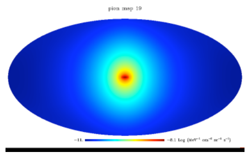
The bulk of the diffuse emission is produced in interactions of cosmic rays (produced in astrophysical sources such as SNRs) with the Galactic radiation field and gas. *The modeling of the astrophysical diffuse emission, and estimates of the systematic uncertainty involved* represents the main difficulty in setting DM limits.

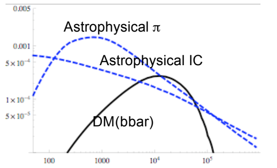
Our approach in this analysis is to use *a maximum likelihood fit in each pixel and energy bin* in a chosen region of interest (ROI) to search for a DM signal. In this way, *by using both, spectral and spatial features* we can, to some extent, break degeneracy between DM and astrophysical diffuse emission.

DM maps

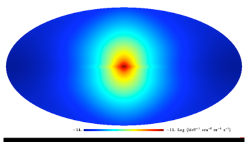
To set DM constraints, we produce DM template sky maps for various DM masses and two representative channels:

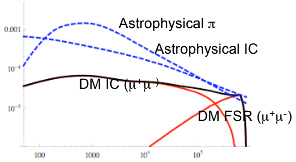
DM DM → b bar and





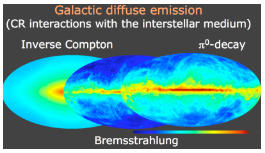
DM DM → μ+μ-.

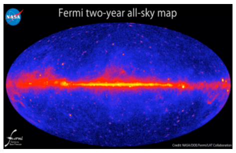




Astrophysical diffuse emission

We deal with the astrophysical diffuse emission fitting at the same time the DM model described above together with a set of astrophysical models produced with GALPROP which have been derived by the Fermi-LAT team map (see talk by J.M., Casandjian and poster by G. Jóhannesson). We leave some freedom to the diffuse model allowing in the fit a free normalization for the HI and HII+H2 gas components, for the Inverse Compton component and the Isotropic component.





Analysis procedure

For this analysis we use p6_v3_dataclean event selection and 21 months data, in the 1-100 GeV energy range.

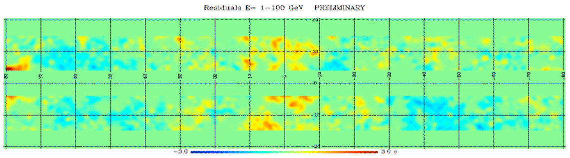
We set *two types* of limits:

1) Limits using a *'reference' astrophysical model* (purple line in figures below). We choose it among the models described above as the one which allows for the biggest contribution of DM (i.e. weakest DM limits). The limits are derived with *a maximum likelihood fit* as described above, with HEALPix order 6 (~1º) spatial binning.
2) In addition, we set conservative DM limits using the *data alone*, without any modeling of the background (blue line in figures below). The expected counts from DM n_{DM} are compared with the observed counts n_{data} and the upper limits at 3(5) sigmas is set from the requirement: $\mathbf{n_{DM} - 3(5)\sqrt{n_{DM}} > n_{data}}$, in at least one energy bin. In this case. We choose in this case a larger pixel size, HEALPix order 3 (~8º), in order to reduce the (relative) Poisson error $\mathbf{\sqrt{n_{DM}} / n_{DM}}$.

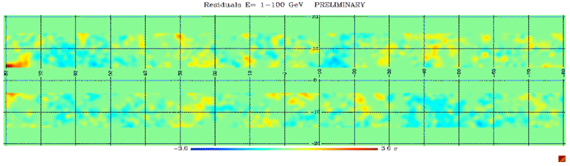
Region of Interest

For this study we choose a low latitude region *5º <|b|<15º and |l|<80º*.

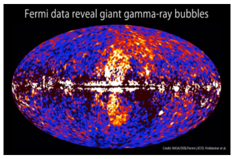
Residuals of the reference model



Residuals of the reference model+DM



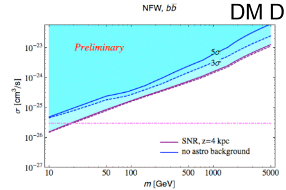
This choice is motivated by the need to minimize residual effects from unmodeled structures in the sky, most notably the *Fermi lobes* (see the talk of M.Su). In addition we leave out the outer Galaxy which is also difficult to model and at the same time does not affect much searches for DM annihilation in the smooth Milky Way halo.

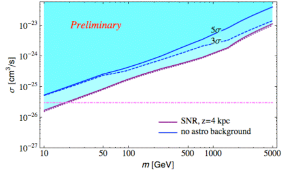


Dark Matter limits

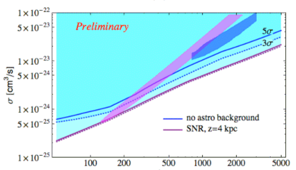
To the left we show the limits when NFW profile is assumed (rs=20 kpc, r0=0.43 GeV/cm3) and to the right, are the limits when Isothermal profile is considered instead (rs=20 kpc, r0=0.43 GeV/cm3).

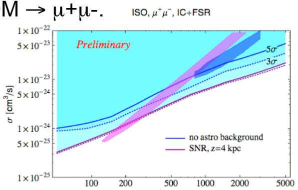
DM DM → b bar

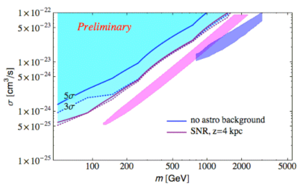


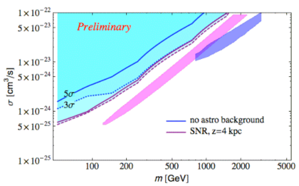


DM DM → μ+μ-.









With magenta we show the region favored for DM interpretation of the PAMELA positron fraction data. Blue is the region favored for DM interpretation of e+e- Fermi-LAT data.

The dependencies of DM limits on various parameters of the diffuse emission was checked by varying one parameter at a time, while keeping others fixed to a reference value. The table below shows values for the mu channel and 150 GeV DM mass (and are representative for both channels and considered masses).

Parameters	δσ/σ [%]
Alfven velocity [30; 44; 50] km/s	[5; REF; 1]
Nucleon injection index I [1.75; 2; 2.2; 2.4]	[REF; 0.5; 2; 5]
Gas maps [Ts=10^5K, MagCut=5; Ts=150K, MagCut=2]	[REF; 8]
Electron injection index II [1.8; 2; 2.2; 2.4]	[41; 33; 18; REF]
Diffusion coefficient [5e28; 7e28; 1e29]	[13; REF; 11]
Halo Height [4; 10] kpc	[REF; 20]
CR source distribution [SNR; Yusifov]	[REF; 35]
Galactic Wind [0; 800] km/h	[REF; 31]