Spotting imprints of dark matter in the extragalactic Fermi sky with photon counts statistics

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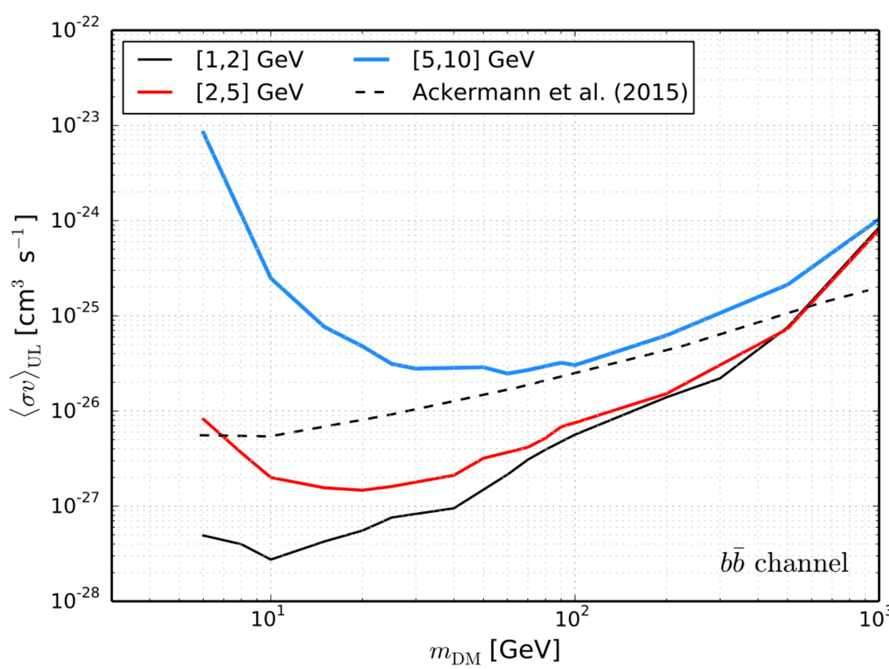
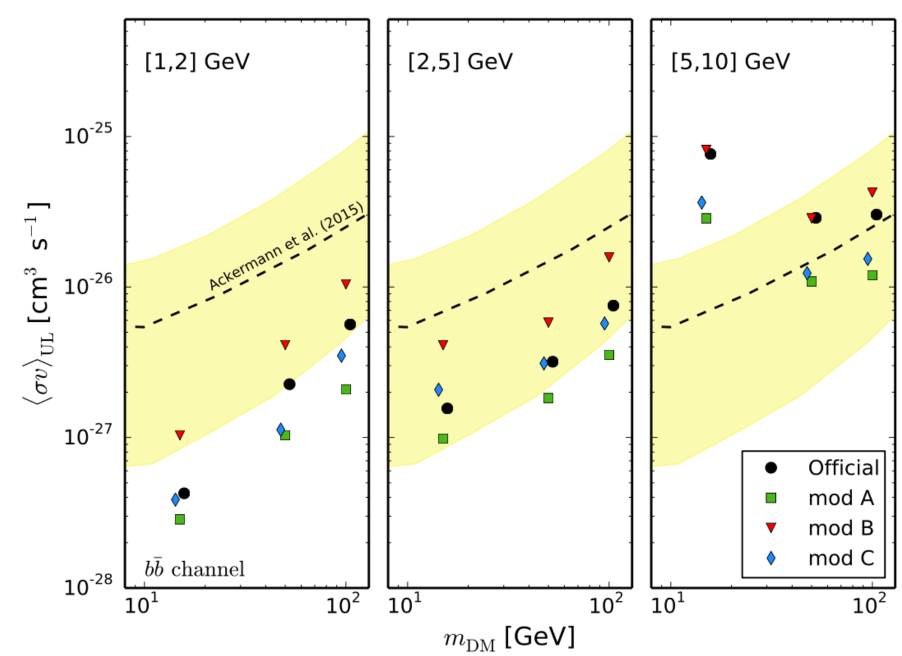
Gamma-ray searches for dark matter (DM) are often driven by investigating the composition of the extragalactic gamma-ray background (EGB). Statistical methods have recently been proven to outperform the sensitivity of classic approaches in finding unresolved point-source populations and EGB decomposition. We employ the 1-point photon counts statistics of eight years of Fermi data to decompose the EGB for latitudes |b| > 30 deg, between 1 and 10 GeV. We extend the analysis to incorporate a potential contribution from annihilating DM. Given different interstellar emission models, we set upper bounds on the DM self-annihilation cross section which are competitive with constraints obtained by other indirect detection methods.

- statistical analysis (1-point PDF)
- 8 yrs Pass 8 data, 1 to 10 GeV
- high Galactic latitudes
- smooth Galactic DM halo

- **upper limits on DM competitive with dSphs**

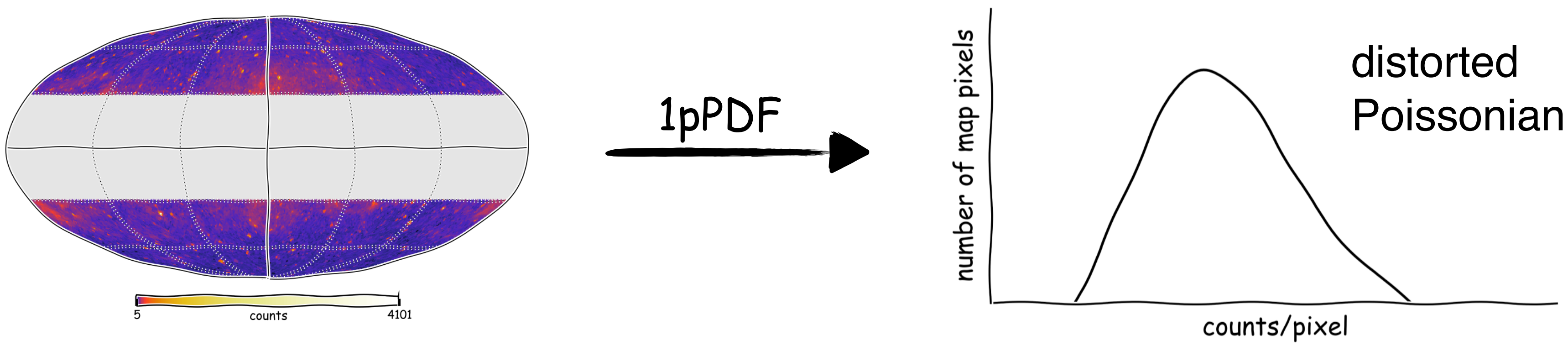




Zechlin, Manconi, Donato, arXiv:1710.01506

I. Introduction and 1pPDF [1-4]

We consider the celestial region of interest (ROI) to be partitioned into N_{pix} pixels of equal area Ω_{pix} . The probability p_k of finding k photons in a given pixel is by definition the 1-point probability distribution function (1pPDF). In the simplest scenario of purely isotropic emission, p_k follows a Poisson distribution with an expectation value equal to the mean photon rate. The imprints of more complex diffuse components and a distribution of point sources alter the shape of the 1pPDF, in turn allowing us to investigate these components by measuring the 1pPDF of the data.



- 1pPDF can be modeled with probability generating functions

$$\mathcal{P}^{(p)}(t) = \sum_{k=0}^{\infty} p_k^{(p)} t^k, \qquad p_k^{(p)} = \frac{1}{k!} \frac{\mathrm{d}^k \mathcal{P}^{(p)}(t)}{\mathrm{d}t^k}\bigg|_{t=0}$$

- **Model for the high-latitude gamma-ray sky**
  - isotropic distribution of gamma-ray point sources (dN/dS)
    —> multiply broken power law (MBPL); **parameters freely adjustable**
  - diffuse component of Galactic foreground emission
    —> official Fermi template [5]; models A, B, C from [6]; **free normalization A_{gal}**
  - diffuse isotropic background emission
    —> power law (index 2.3); free normalization
  - smooth distribution of Galactic DM
    —> Galactic DM halo, Einasto profile with $\rho(r_\odot) = 0.4\,\mathrm{GeV\,cm^{-3}}$; **free normalization A_{DM}**

- **pixel-dependent likelihood function**
  (full exploitation of spatial templates)

$$\mathcal{L}(\boldsymbol{\Theta}) = \prod_{p=1}^{N_{\mathrm{pix}}} P(k_p), \quad \text{where } P(k_p) \text{ is given by the } p_k^{(p)} \text{ coefficients}$$

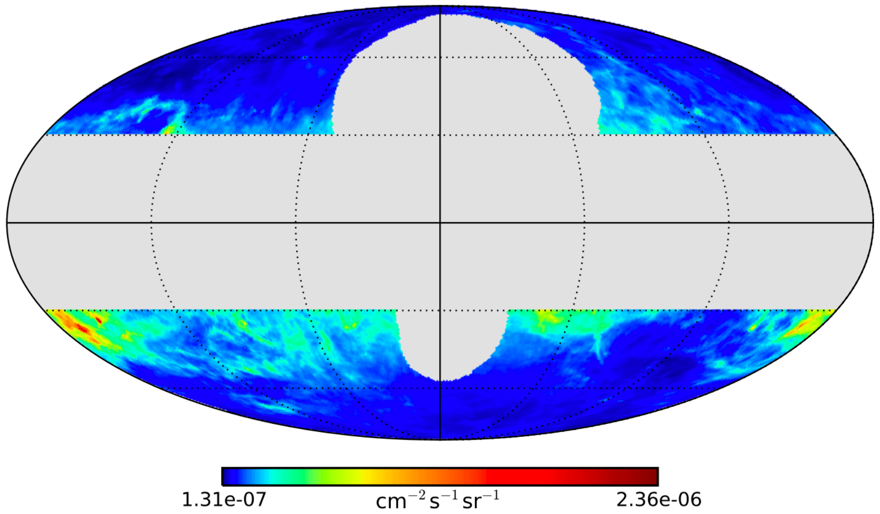
  In this way, qualitatively, diffuse components are treated as classic template fits, while a distribution of point sources, dN/dS, adds non-Poissonian components.

- **parameter estimation**
  —> profile likelihood from Bayesian posterior (MCMC sampling: MultiNest)

- **data set**
  —> **Fermi-LAT**: Pass 8, 8 years, 1 to 10 GeV (3 energy bins), UCV, PSF3
  —> **ROI**: |b| > 30 deg, with Fermi Bubbles and Galactic Loop I masked

- **analysis objective**
  —> investigate 1pPDF sensitivity reach for additional DM component
  —> provide upper limits (ULs) on DM self-annihilation cross section $\langle \sigma v \rangle$, given $A_{\mathrm{DM}} \propto \langle \sigma v \rangle$

- **Galactic foreground (GF) systematics**
  —> GF models equipped with high systematic uncertainties
  —> possible dependencies on or degeneracies of the DM component with GF (in particular with inverse Compton emission) need to be accounted for properly
  —> issues mitigated by focusing on high Galactic latitudes only, and ROI optimization
  —> systematic uncertainties of ULs estimated by using 4 different GF models

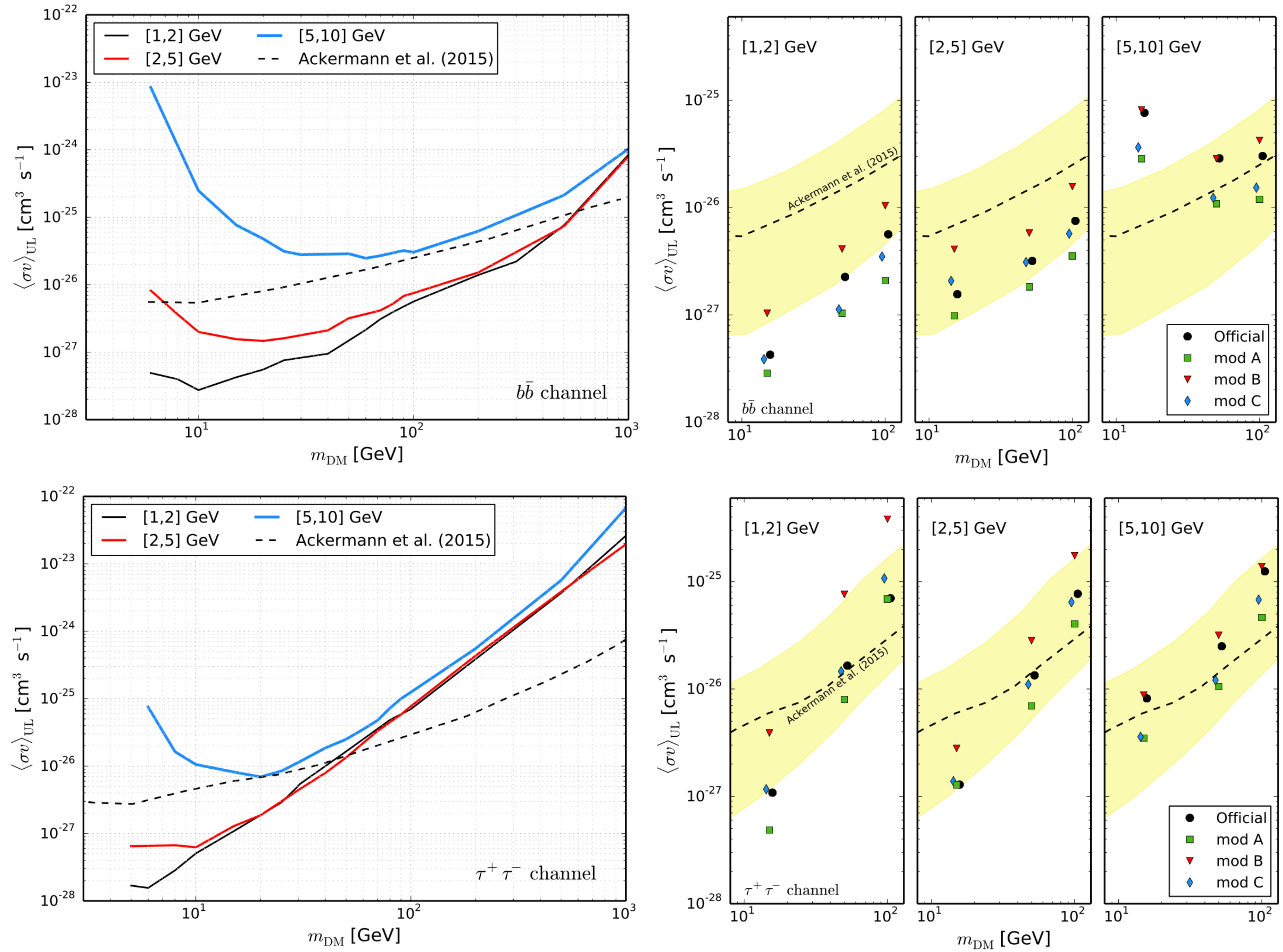


Integrated Galactic foreground emission between 1.99 and 5.0 GeV in the considered ROI.

II. Results [4]

- **upper limits obtained using the official Fermi GF model and models A, B, C**
- moderate systematic scatter

➡ **ULs competitive with bounds recently obtained from dSphs**



References

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