Dark Matter implications of Fermi-LAT measurement of anisotropies in the diffuse gamma-ray background

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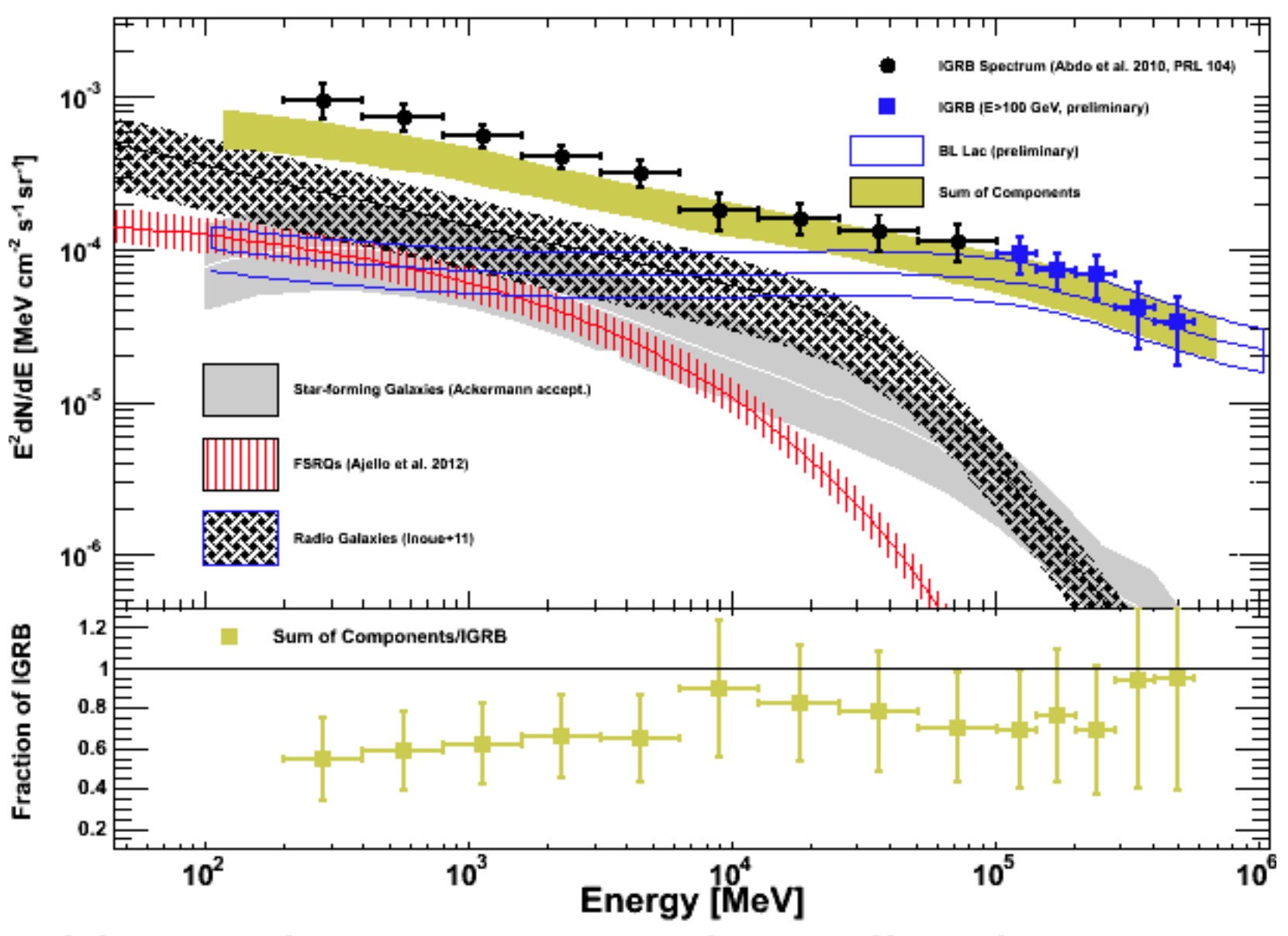
The detailed origin of the diffuse gamma-ray background is still unknown. However, the contribution of unresolved sources is expected to induce small-scale anisotropies in this emission, which may provide a way to identify and constrain the properties of its contributors. Recent studies have predicted the contributions to the angular power spectrum (APS) from extragalactic and galactic dark matter (DM) annihilation or decay. We are currently updating the Fermi-LAT APS measurement using ~ 45 months data, and using accurate predictions for DM anisotropies from state-of-the-art cosmological simulations as presented in [1]. For these preliminary results the already published Fermi-LAT APS measurements [2] are compared to the DM predictions to derive constraints on different DM candidates.

Motivation for anisotropies



The diffuse gamma-ray background is characterized by an isotropic or nearly isotropic distribution and is therefore known as the Isotropic Gamma-ray Background (IGRB) [3].
It is constituted by gamma rays produced by various sources, including blazars, pulsars, and possible DM structures, not yet detected due to the limited angular resolution and photon statistics of the Fermi-LAT.
The panel above shows the IGRB spectrum and the estimated contributions from unresolved blazars, star-forming and radio galaxies. The angular distribution of photons in the diffuse background may contain information about the presence and the nature of these unresolved source populations.

Angular Power Spectrum

For an intensity map *I(Ψ)*, with *Ψ* the sky direction, decomposed in spherical harmonics:

$$I(\psi) = \sum_{\ell m} a_{\ell m} Y_{\ell m}(\psi)$$

The APS is given by the coefficients:

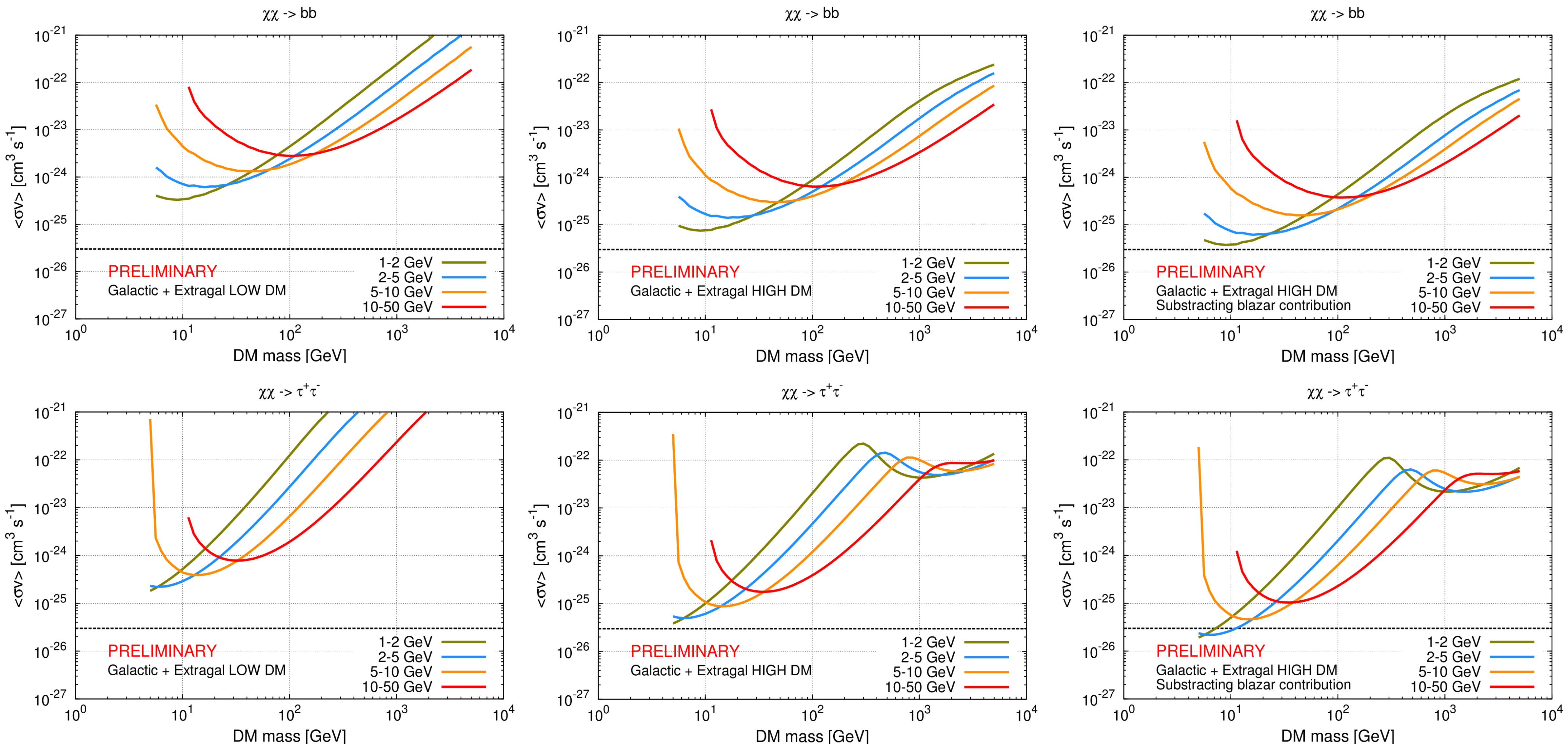
$$C_\ell \;=\; \langle |a_{\ell m}|^2 \rangle$$

The measurement [2]
22 months data, 4 energy bins (from 1GeV to 50 GeV), Masking point sources in 1FGL and |b|<30 deg. A Galactic diffuse model is subtracted from the data, and then the APS of the residual map is computed. Results are shown in the table below.

$E_{\rm min}$ [GeV]	$E_{\rm max}$ [GeV]	$C_{\rm P}$ $[({\rm cm}^{-2}\ {\rm s}^{-1}\ {\rm sr}^{-1})^2\ {\rm sr}]$	Significance
1.04	1.99	$4.62 \pm 1.11 \times 10^{-18}$	4.2σ
1.99	5.00	$1.30 \pm 0.22 \times 10^{-18}$	6.0σ
5.00	10.4	$8.45 \pm 2.46 \times 10^{-20}$	3.4σ
10.4	50.0	$2.11 \pm 0.86 \times 10^{-20}$	2.4σ

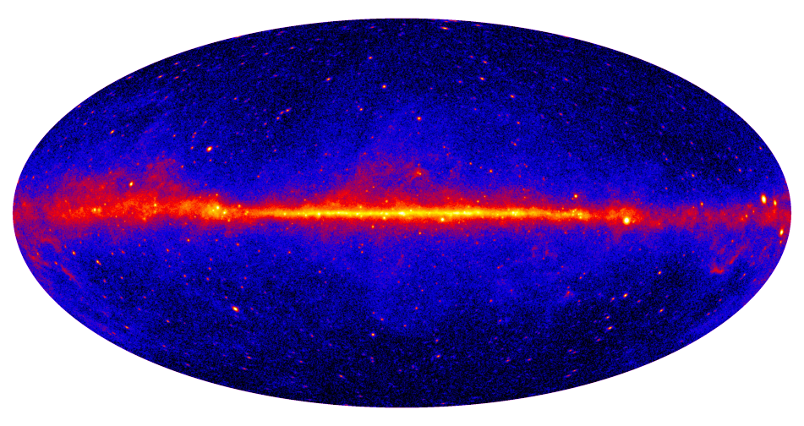
Setting constraints

* To set constraints we use the angular power (Cp) values from the table for multipoles *155<l<504* presented in [2].
* We use the measured Cp values (foreground-cleaned data measurement).
* We require that the DM-induced APS averaged in *155<l<204* does not overshoot the measured Cp in the *155<l<504* multipole range at *95% CL*. This method is used to set the constraints in the first and second columns in this figure.
* We know that the IGRB anisotropy has multiple contributors, therefore these constraints are conservative. Other contributors to IGRB anisotropy are not well known, but we already have constraints on the contribution of blazars [8]. We subtract this contribution from the measured Cp and require that the DM-induced APS does not overshoot this new limit. This method is implemented in the third column of this figure.

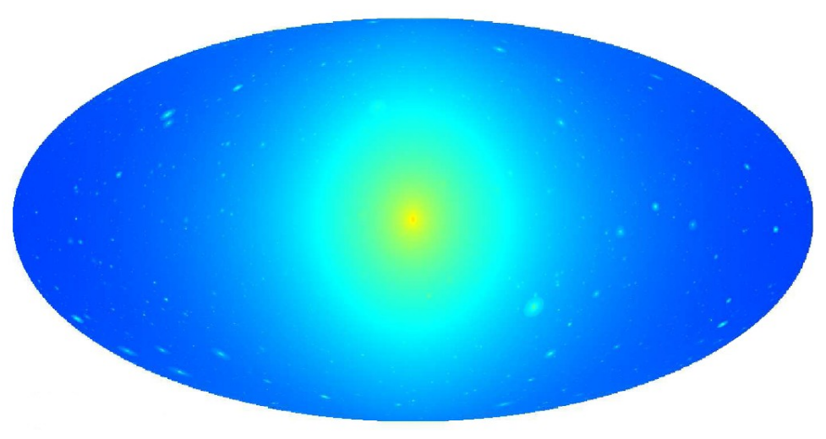


The main uncertainty in the predictions obtained in [1] lies in the characteristics of the low-mass subhalos, below the mass resolution of the simulations. Different values of the "subhalo boost" strongly affect the prediction for the DM-induced gamma-ray intensity and its anisotropies. The authors of [1] considered two benchmark scenarios for subhalos, assuming that the uncertainties can be modeled by changing the subhalo abundance: i) the LOW case, where halos are relatively poor in subhalos, according to the predictions of [5] and [6], and ii) the HIGH case, with large subhalo boosts, compatible with what was found by [7, 8].

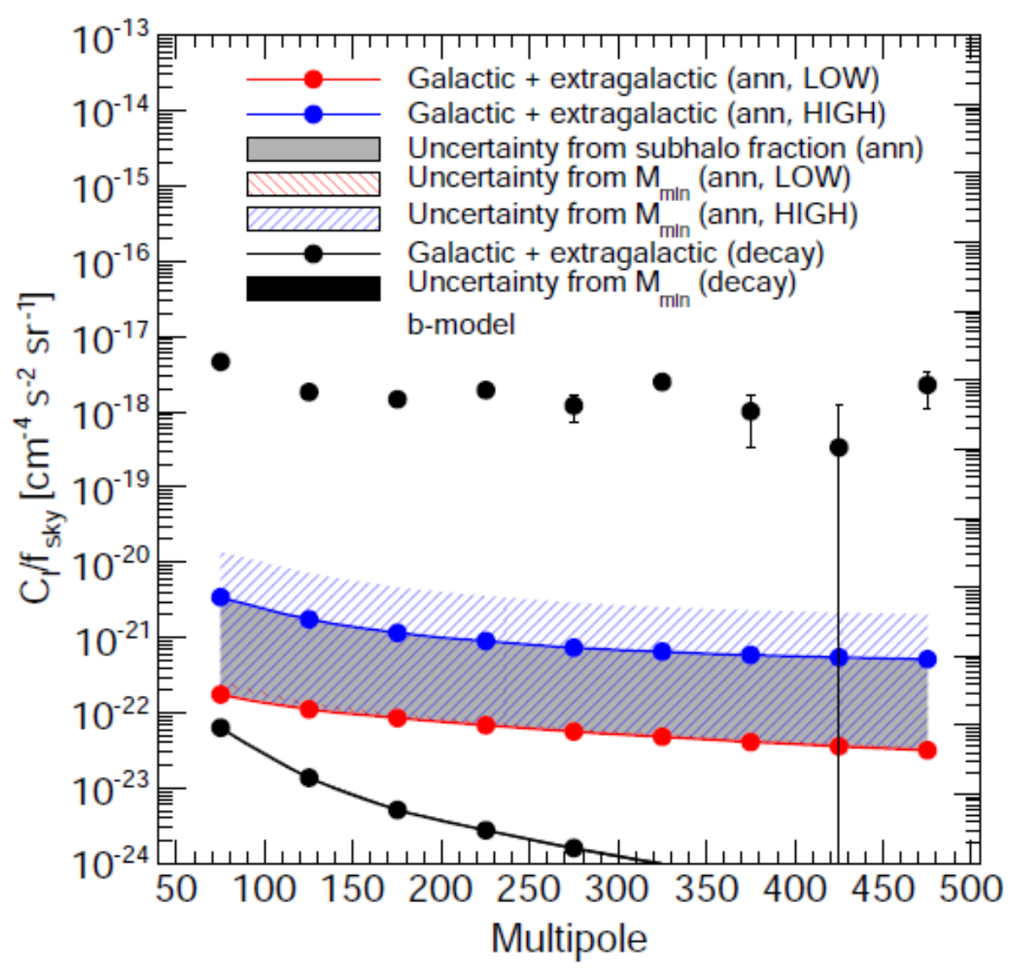
DM predictions



36 months Fermi-LAT data



Galactic DM annih. map from fig 4 of [1]



Total intensity APS of the gamma-ray emission from DM annihilation (color lines) or decay (black line) in extragalactic and galactic (sub)halos.

The APS is measured in the energy bin between 2 to 5 GeV. The observational data points with error bars refer to the measurement of the APS as given in [2].

The APS of gamma rays from DM annihilations or decays has been computed from the all-sky template maps produced in [1].
The authors of [1] used the Millennium-II N-body simulation to model the abundance and the clustering of extragalactic DM halos and subhalos. The technique presented in [4], based on the random repetition of copies of the Millennium-II simulation box, is implemented to probe the universe up to *z=2*. The emission from DM halos with a mass smaller than the resolution of the simulation was estimated assuming that the halo number density and the mass-luminosity relation obtained from the halos in Millennium-II remain unchanged below the resolution, down to the minimal self-bound halo mass *Mmin*. On the other hand, the contribution of low mass subhalos was modeled following the technique described in [5] and extended in [6].
The smooth DM halo of the Milky Way was parametrized in [1] as an Einasto profile, since this provides the best fit to the Milky Way-like halo obtained in the Aquarius N-body simulation. Galactic subhalos down to *10^5 Msun* were modeled directly from the Aquarius simulation, while we use the same procedure as before (based on [5]) to account for the contribution of unresolved subhalos. It has been shown that such objects do not contribute significantly to the total intensity APS.
The authors of [1] also estimated the effect of the assumptions made in the modeling of the DM distribution, looking for their effect both on the intensity of the DM-induced emission and on its APS. The two most relevant sources of uncertainties are the amount of substructures hosted by DM halos and the value of *Mmin*. The first accounts for an uncertainty of a factor *20-30* both in the average intensity and in the intensity APS; when the uncertainty on the value of *Mmin* is taken into account, these factors build up to *40* and *100* for the average intensity and the intensity APS, respectively.

References

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