Characterization of Dark-Matter-induced anisotropies in the diffuse gamma-ray background

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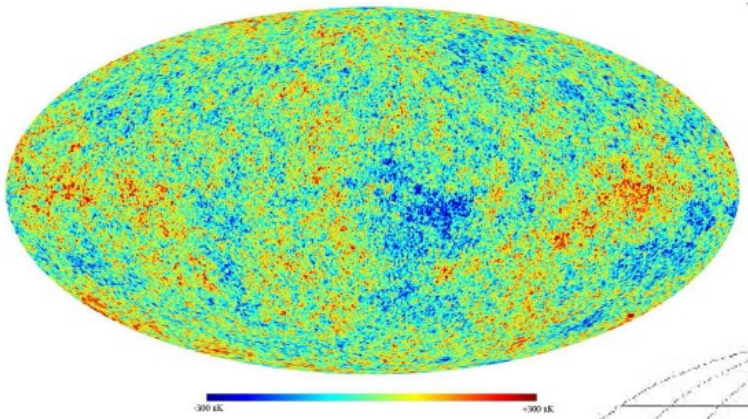
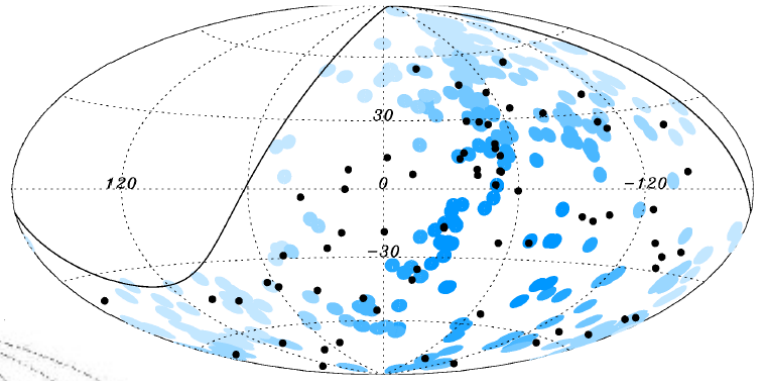
Motivation

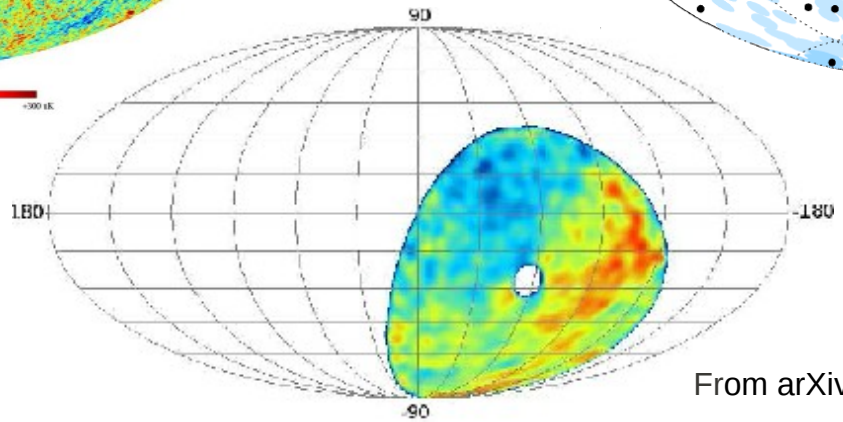
The study of anisotropies has played a fundamental role in modern physics



From http://en.wikipedia.org/wiki/Cosmic_microwave_background_radiation



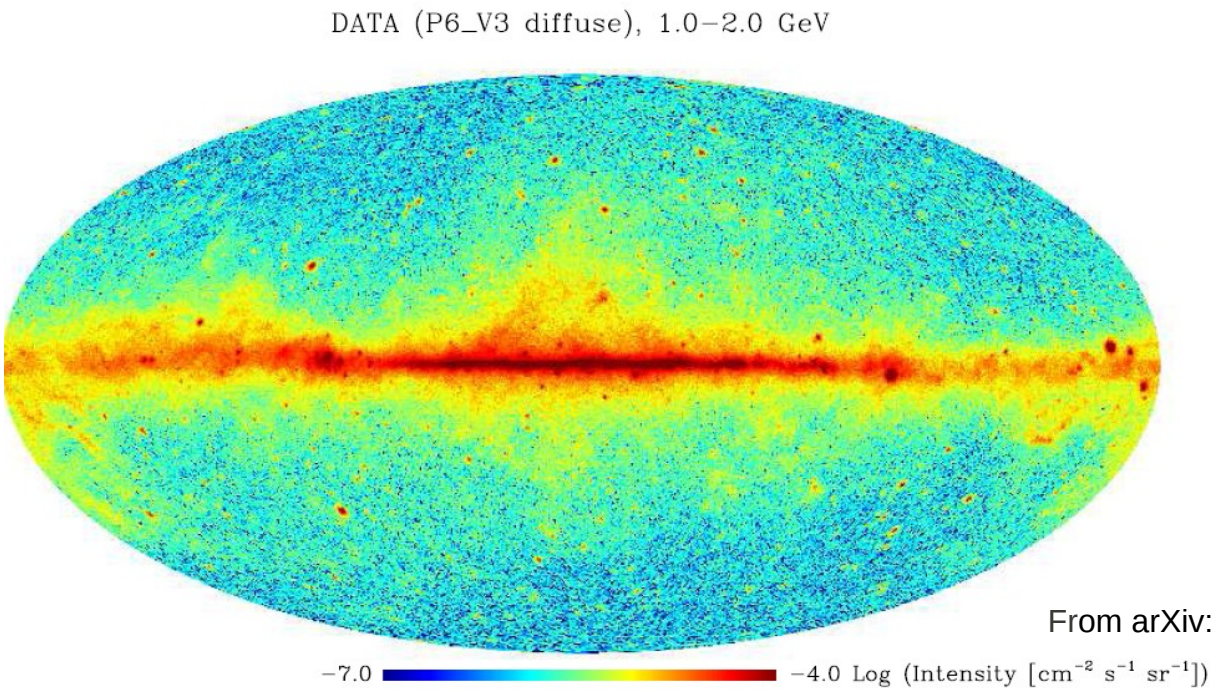
From arXiv:1009.1855



From arXiv:1005.2960

- alternative to the study of point sources
- complementarity with the analysis of the intensity energy spectrum
- APS mainly depends on the spatial distribution of sources
- good prospects for DM detection

Isotropic Gamma-Ray Background (IGRB)

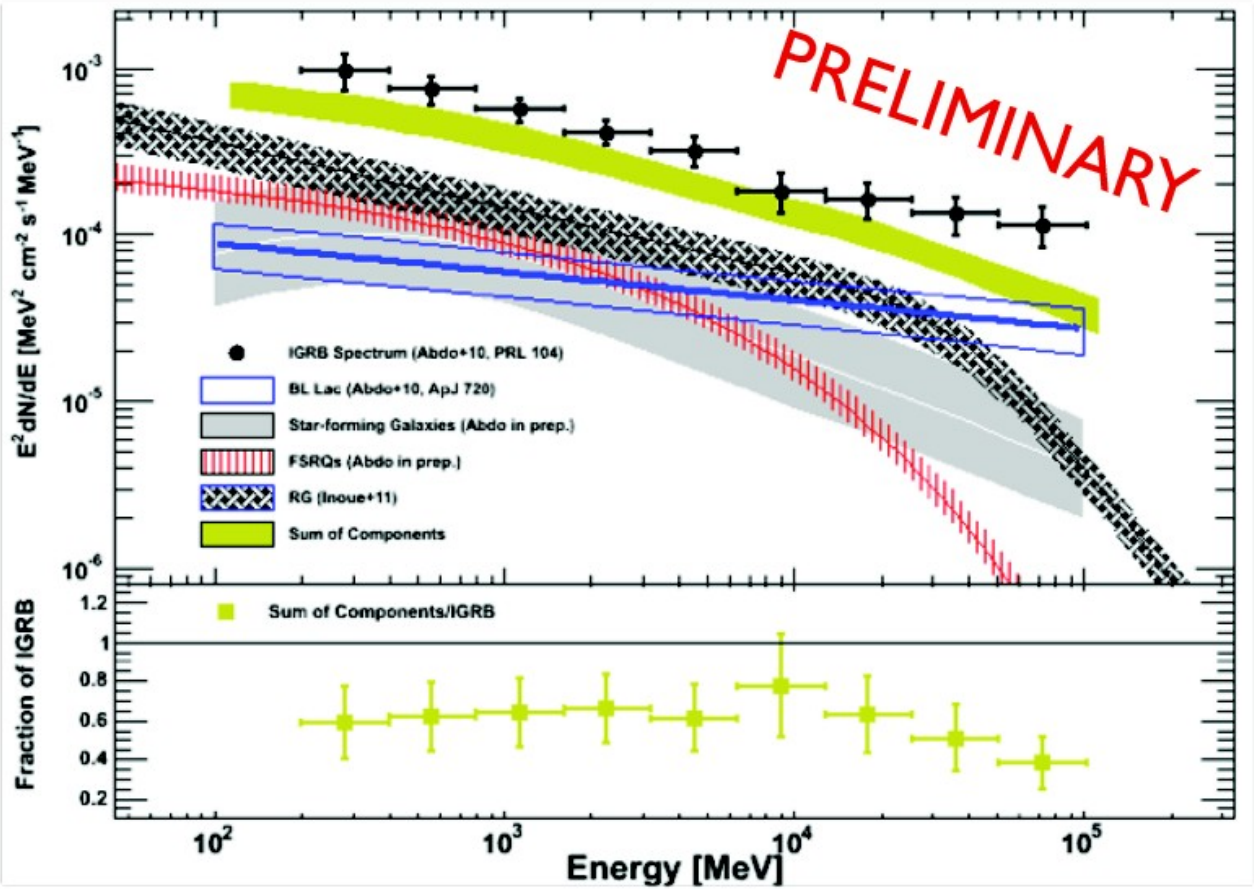


From arXiv:1202.2856

- galactic foreground (due to interactions of cosmic rays with the interstellar medium)
- point sources
- residual emission (IGRB)

Unresolved sources contribute to the IGRB.
Measured by Fermi-LAT between 300 MeV and 100 GeV and found compatible with a power-law with Γ=-2.4

Contribution of unresolved sources

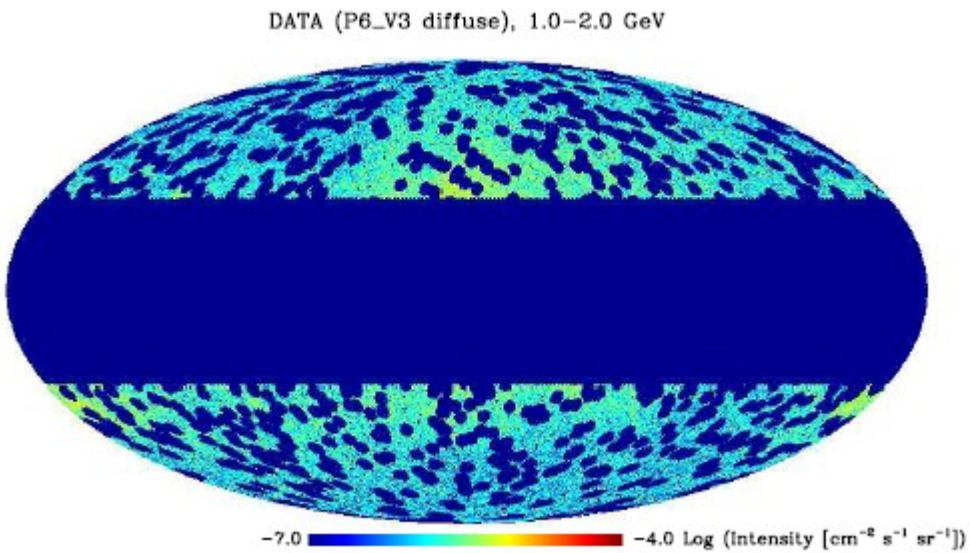


From Ajello's talk at the Fermi Symposium 2011

Known source classes sum up to (at most) 80% of the total IGRB.

Room for new physics.

Fermi-LAT measurement of the APS



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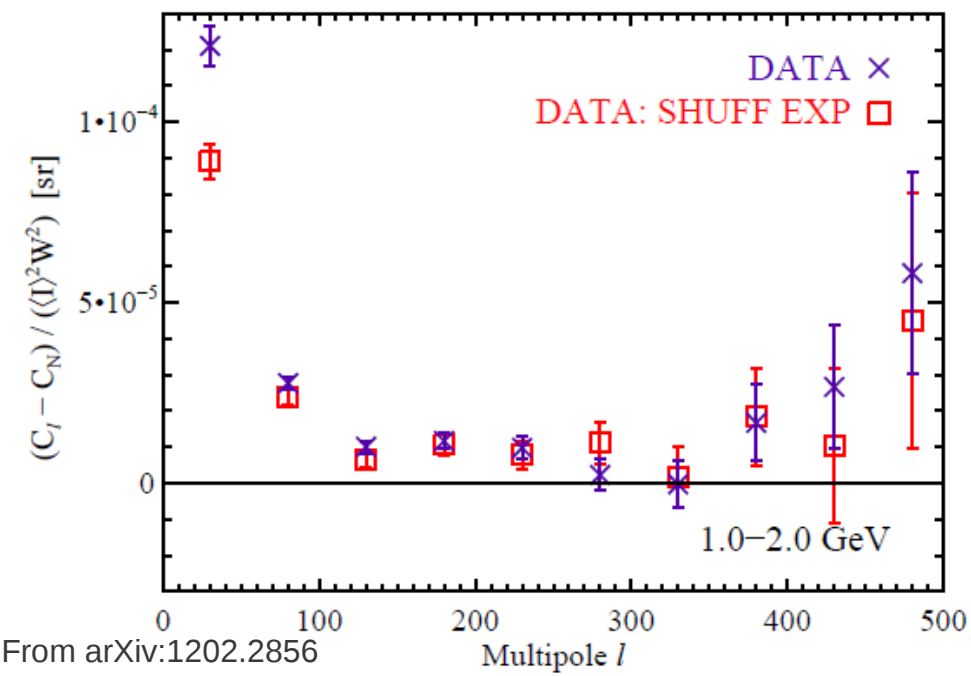
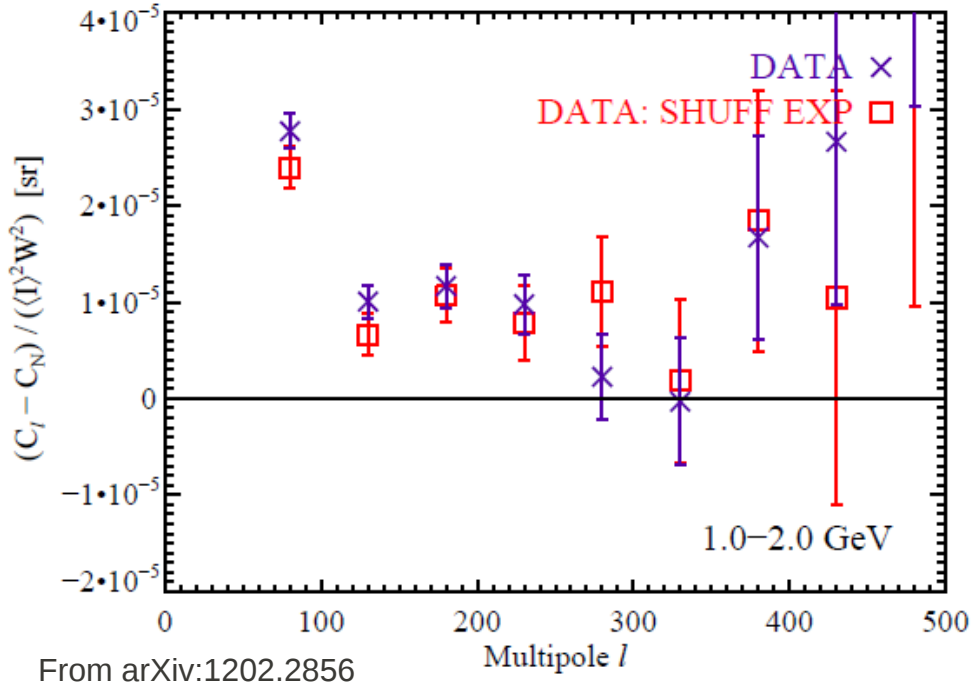


From arXiv:1202.2856

- data from 22 months of data
- 4 energy bins from 1 GeV to 50 GeV
- point sources and Galactic plane (b<30) are masked
- results tested with different foreground models, latitude cuts, etc.
- APS DATA are compared with a source MODEL

Angular power is detected in the multipole range from ℓ=155 to and 504 with a significance of almost 7σ.

Fermi-LAT measurement of the APS



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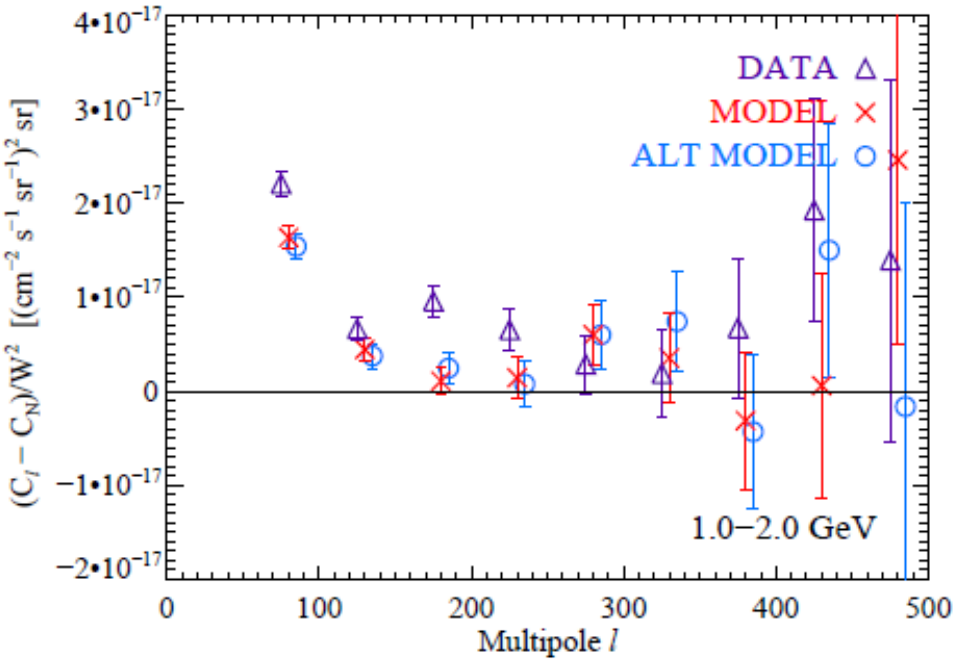


Intensity APS

(dimensionful amplitude of anisotropies)

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

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

Fluctuation APS

(dimensionless, independent of intensity normalization)

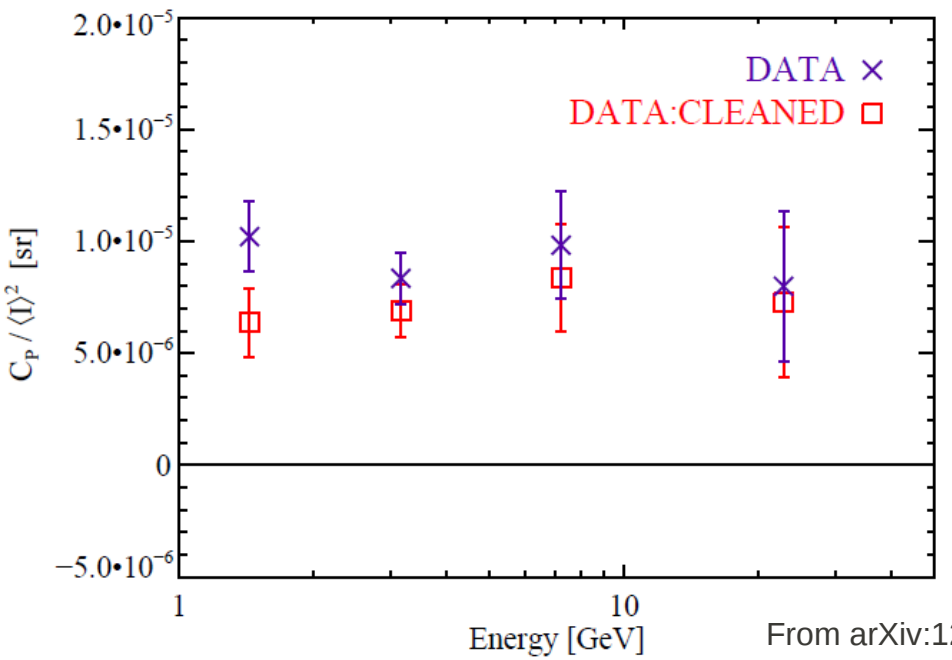
$$\frac{C_\ell}{\langle I \rangle^2}$$

Interpretation of results

1) independent on multipoles: unclustered sources

2) independent on energy (fluctuation APS): one single population of sources contributing

3) shape of the energy dependence of the intensity APS gives you information on the emission of the sources contributing



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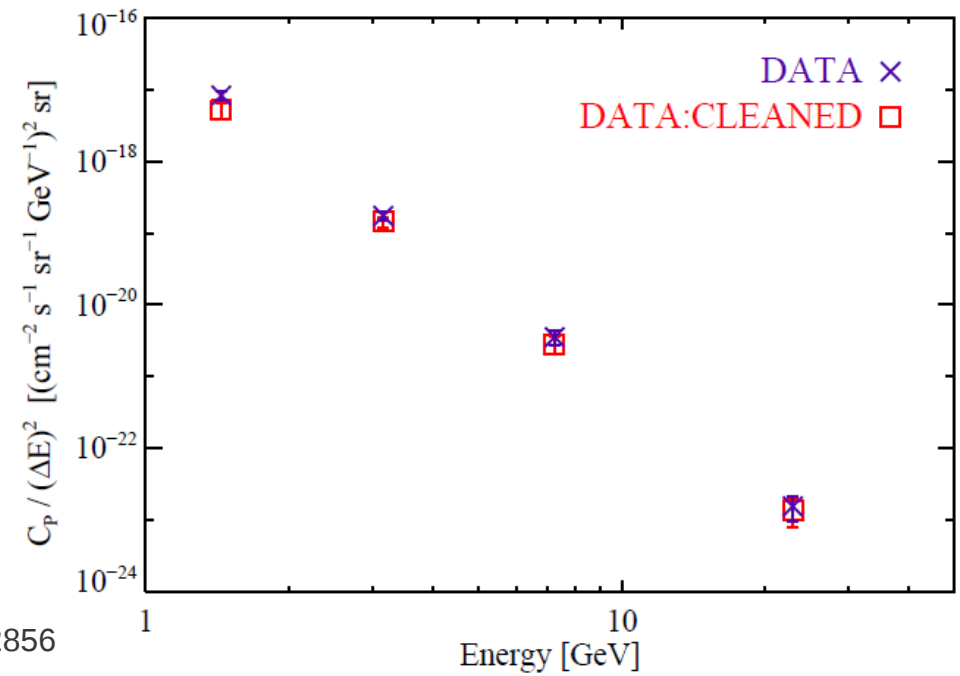


Overview of the project

Build a map of DM distribution around us that is as complete and realistic as possible (arXiv:1207.0502)

- both annihilating DM and decaying DM are considered
- the DM distribution is modeled from the results of the most recent *N*-body simulations (Millennium-II and Aquarius)
- we also account for the contribution of halos and subhalos below M_{res} down to M_{min}
- "theoretical uncertainties" are discussed (and quantified)

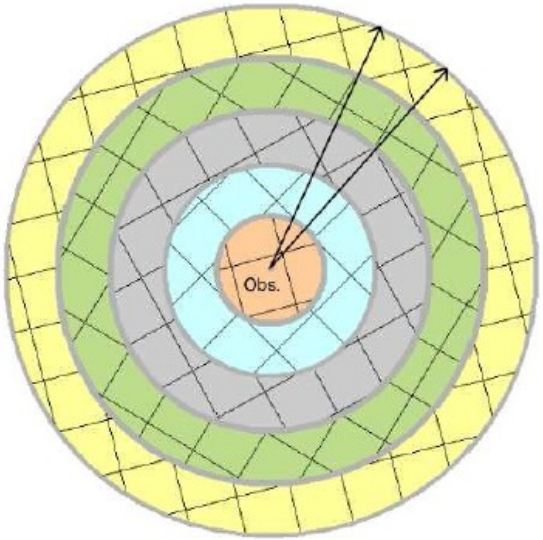
The maps will work as template for DM emission and will be included in the "source model"

- Fermi APS data will be extended to 3 years of data
- DM template maps used to put constraints
- contribution of astrophysical sources will also be considered

Extragalactic DM (sub)halos

“Resolved” (sub)halos

- Millennium-II catalogs of halos and subhalos above the mass resolution of the simulations
- 32 snapshots at different redshifts
- each halo is considered with its own profile



From arXiv:0908.2428

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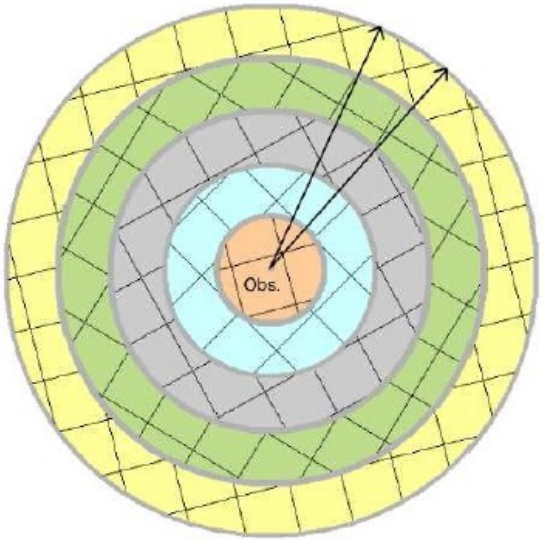

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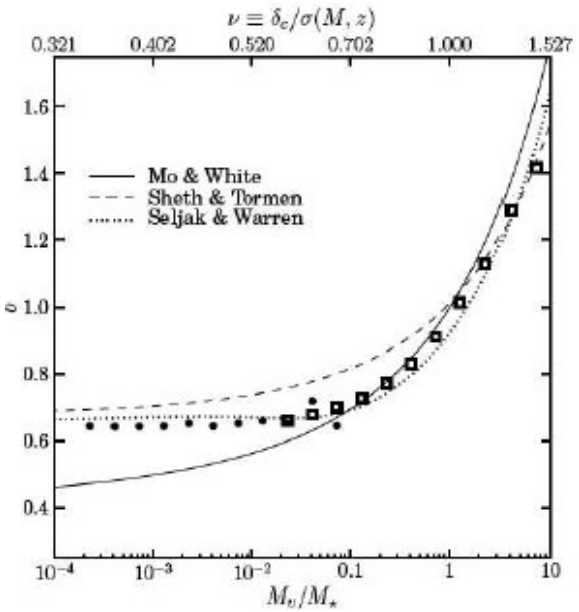

From arXiv:0903.3041

“Unresolved” main halos

- emission produced in main halos below the mass resolution of MS-II down to M_{min} is computed analytically
- used to boost up the flux of the smallest objects in MS-II

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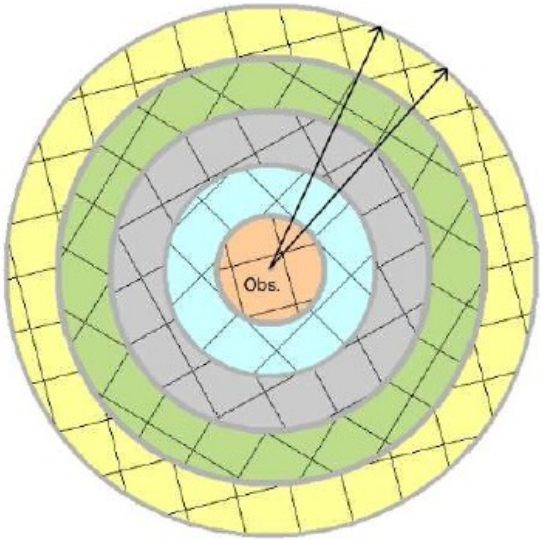

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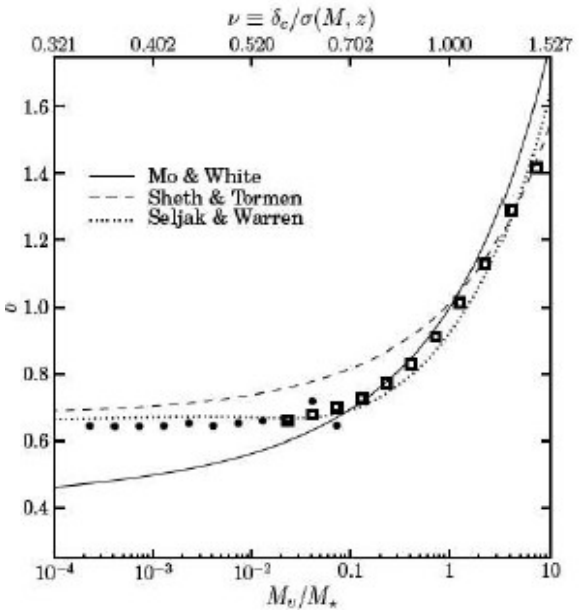

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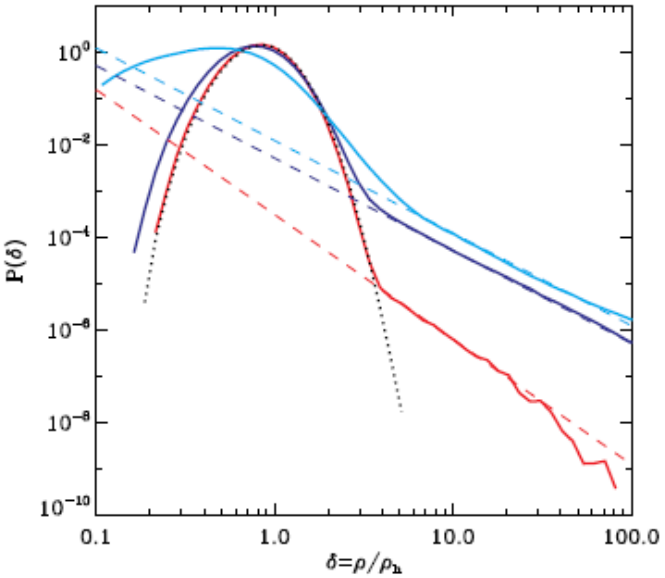


From arXiv:1001.3144

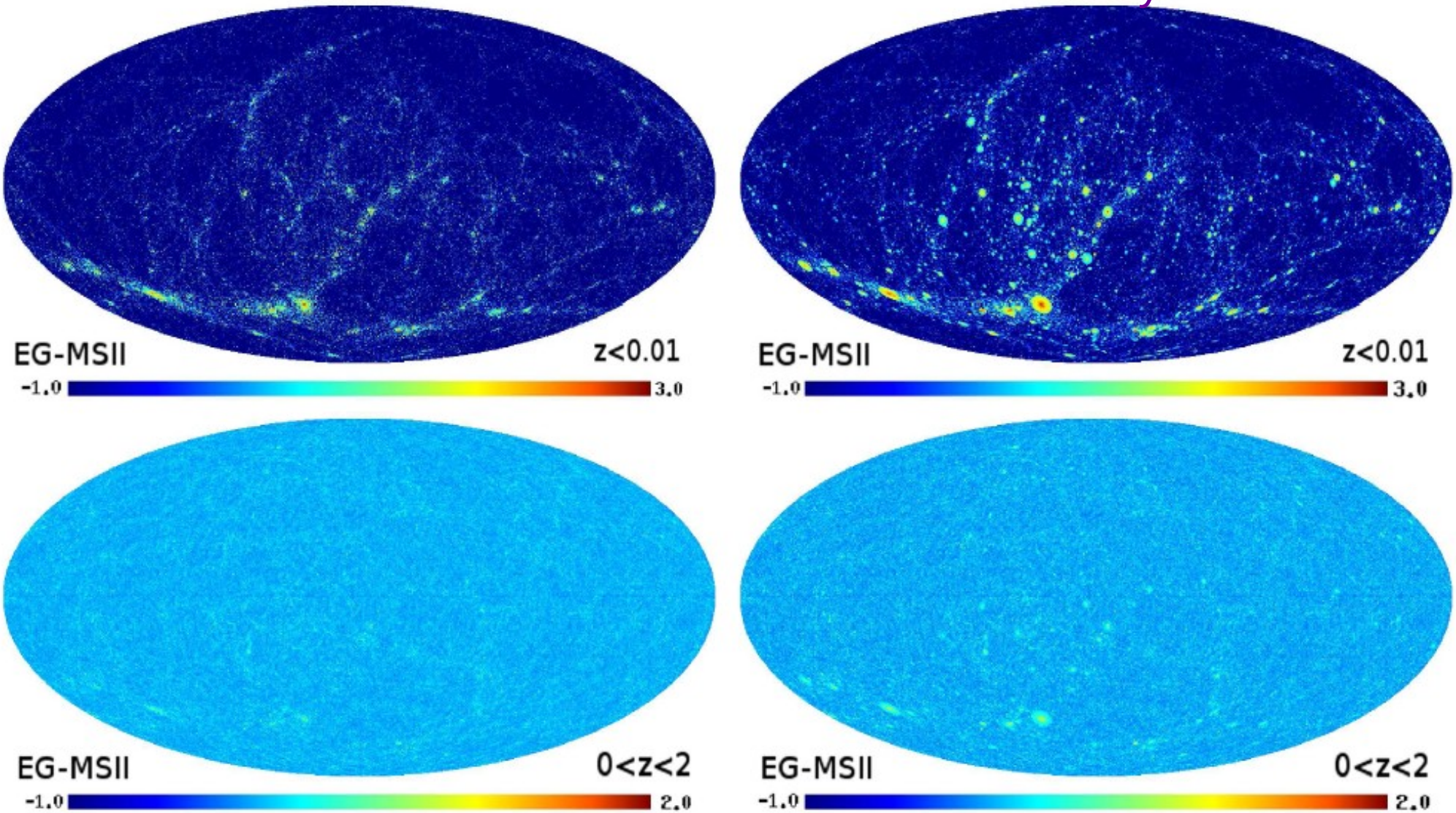
"Unresolved" subhalos

- probability of having subhalos at different distances from the center of halos
- tune the model to account for different subhalo boosts

Extragalactic DM (sub)halos

Annihilation

Decay



E=4 GeV. b channel. M_{min}=10^{-6} solar masses.

Annihilation: m_χ=200 GeV σv=3×10^{-26} cm^3s^{-1}. Decay: m_χ=2 TeV τ=2×10^{27}s

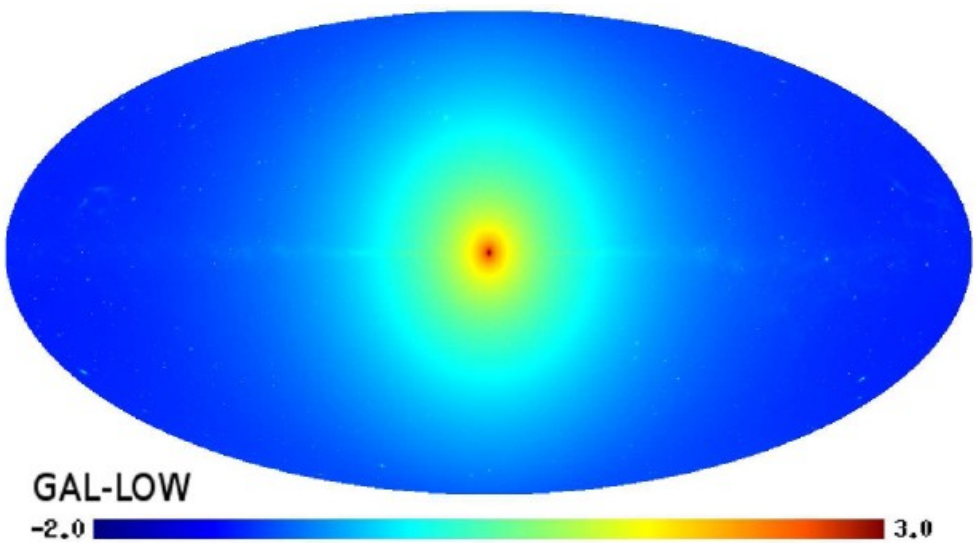
Milky Way smooth halo and its subhalos

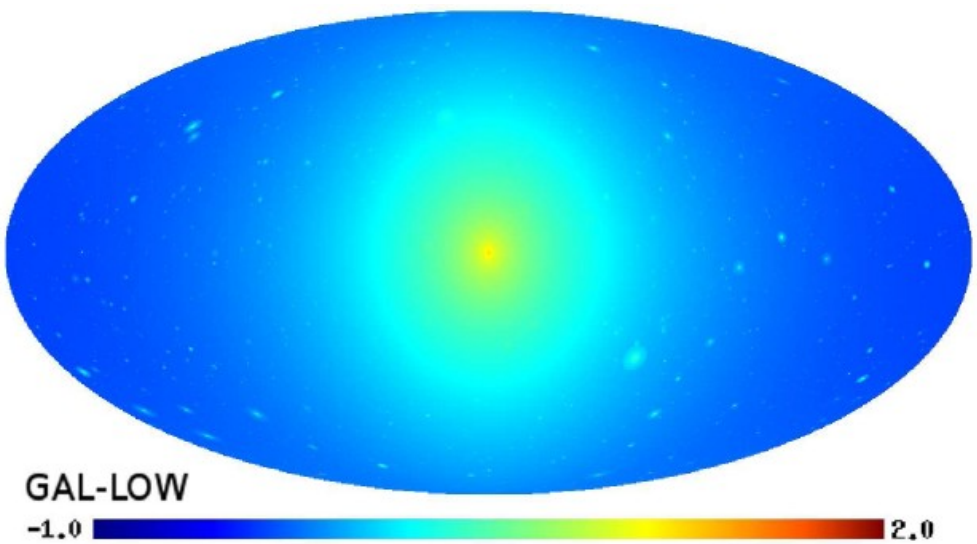
Smooth halo

- parametrized as en Einasto profile (taken from Aquarius)
- local density fixed at 0.3 GeV cm^{-3}

Galactic subhalos (resolved and unresolved)

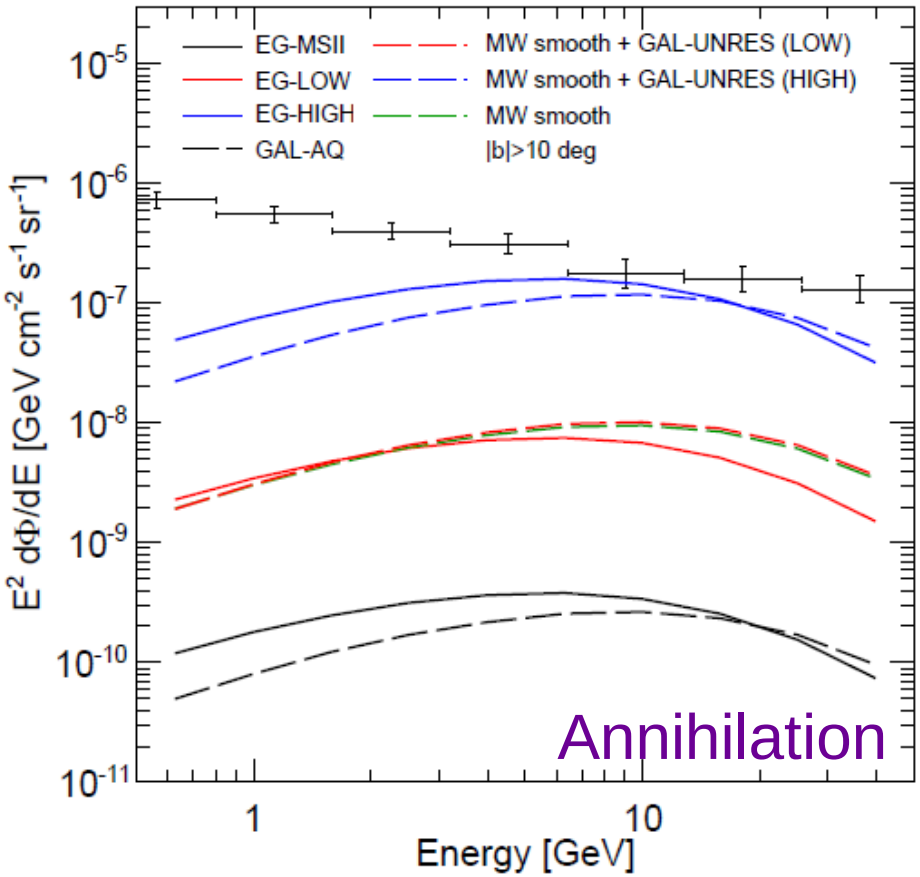
- Aquarius subhalo catalogs are used
- unresolved objects modeled as in the extragalactic case (LOW and HIGH). The contribution of unresolved subhalos to the APS has been proved to be negligeble (analytic model based on Ando 2009)

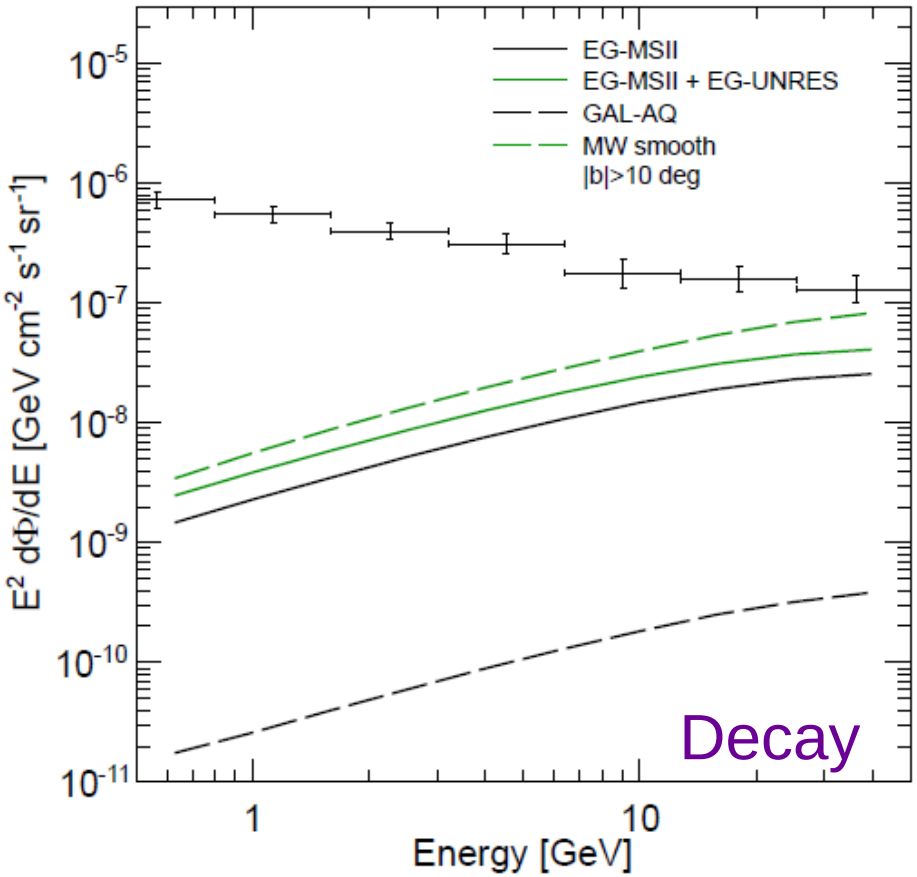




E=4 GeV. Annihilation: m_χ=200 GeV σv=3×10^{-26} cm^3s^{-1}. Decay: m_χ=2 TeV τ=2×10^{27}s. M_{min}=10^{-6} sol,mass

Intensity of the DM-induced emission





- Extragalactic (sub)halos in MS-II catalogs
- Total extragalactic emission (LOW subhalo boost)
- Total extragalactic emission (HIGH subhalo boost)
- Dashed: galactic subhalos in the Aquarius catalogs
- Dashed: MW smooth halo
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Annihilation: m_χ=200 GeV

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b channel. M_{min}=10^{-6} solar masses

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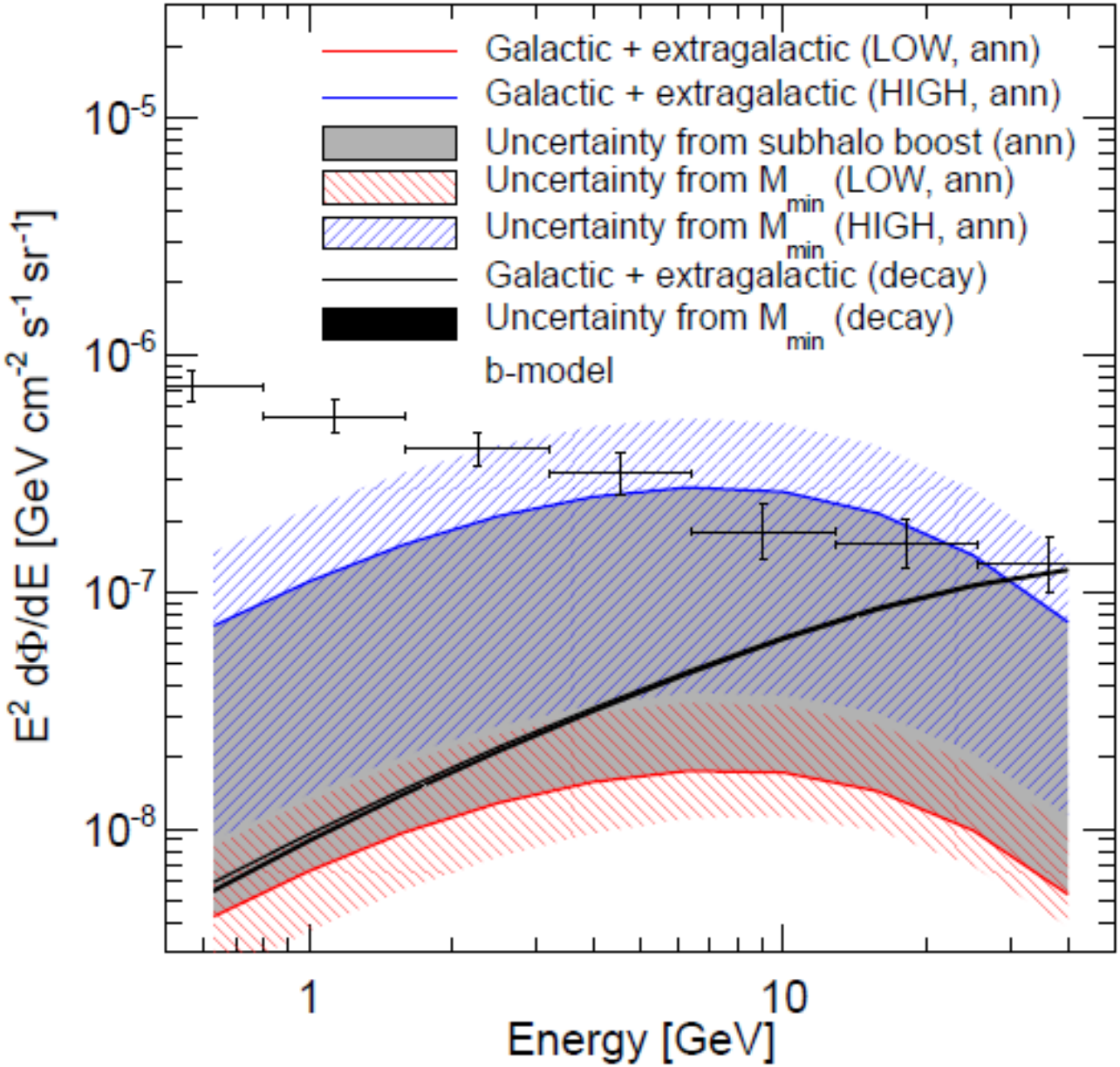

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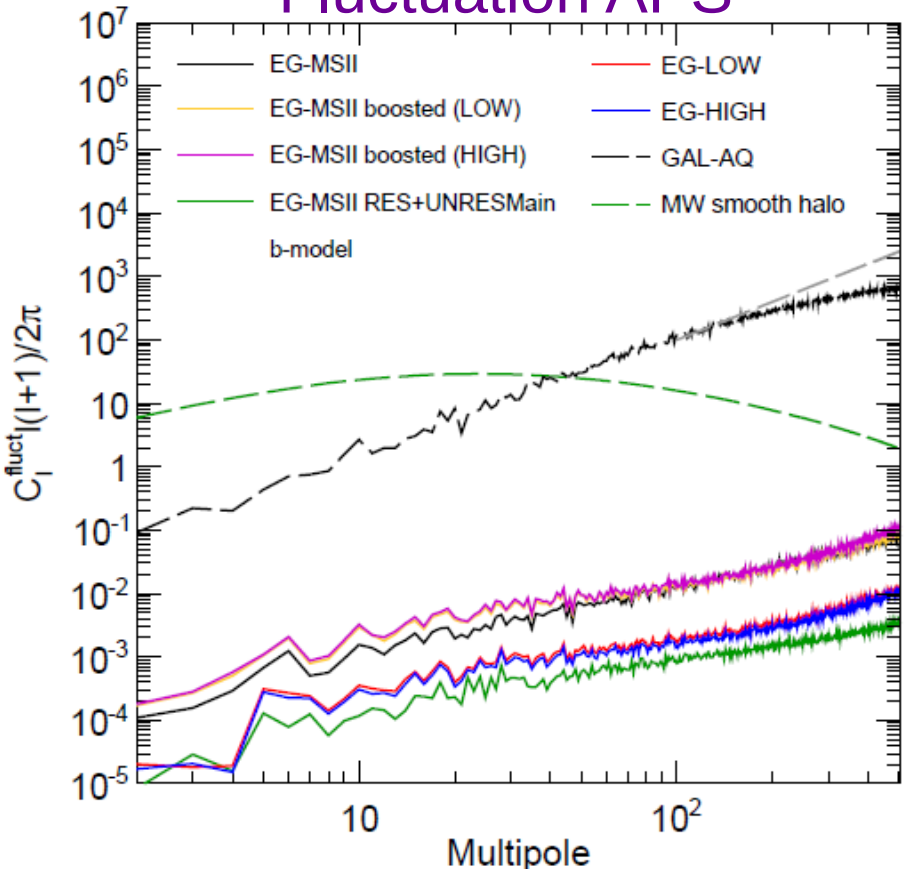
APS of the DM-induced emission

Fluctuation APS



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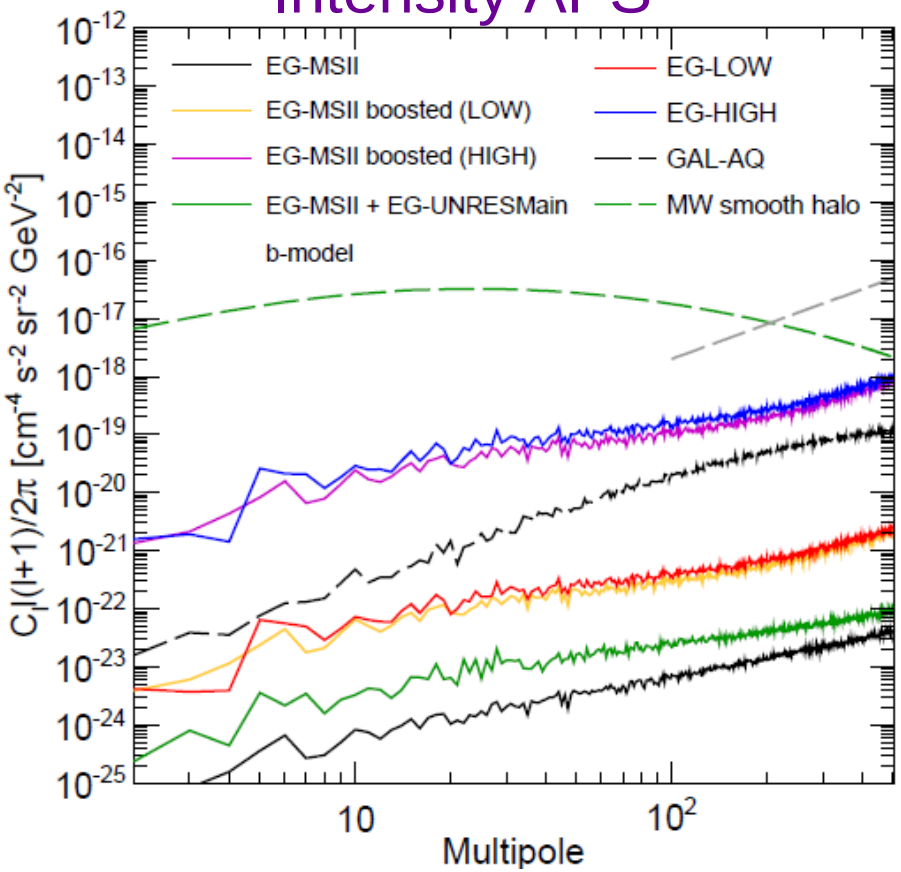

$$C_\ell^{\rm fluct} \equiv \langle \frac{d\Phi}{dE} \rangle^{-2} C_\ell = \sum_i \frac{\langle d\Phi^i/dE \rangle^2}{\langle d\Phi/dE \rangle^2} C_{\ell,i}^{\rm fluct} = \sum_i f_i^2 C_{\ell,i}^{\rm fluct}$$

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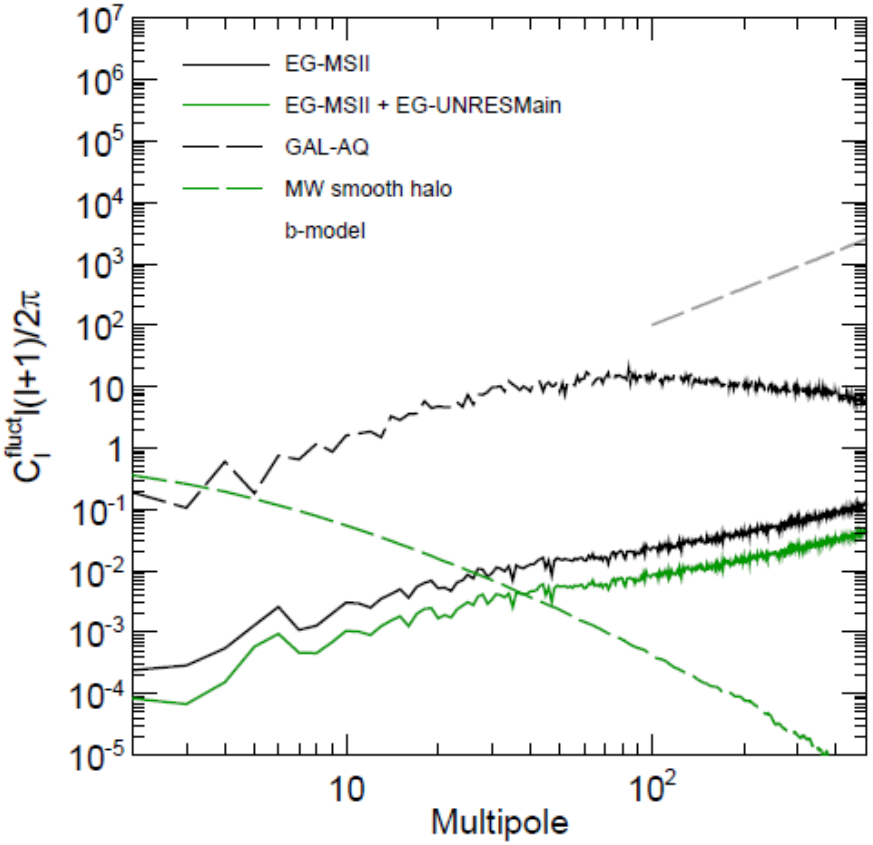

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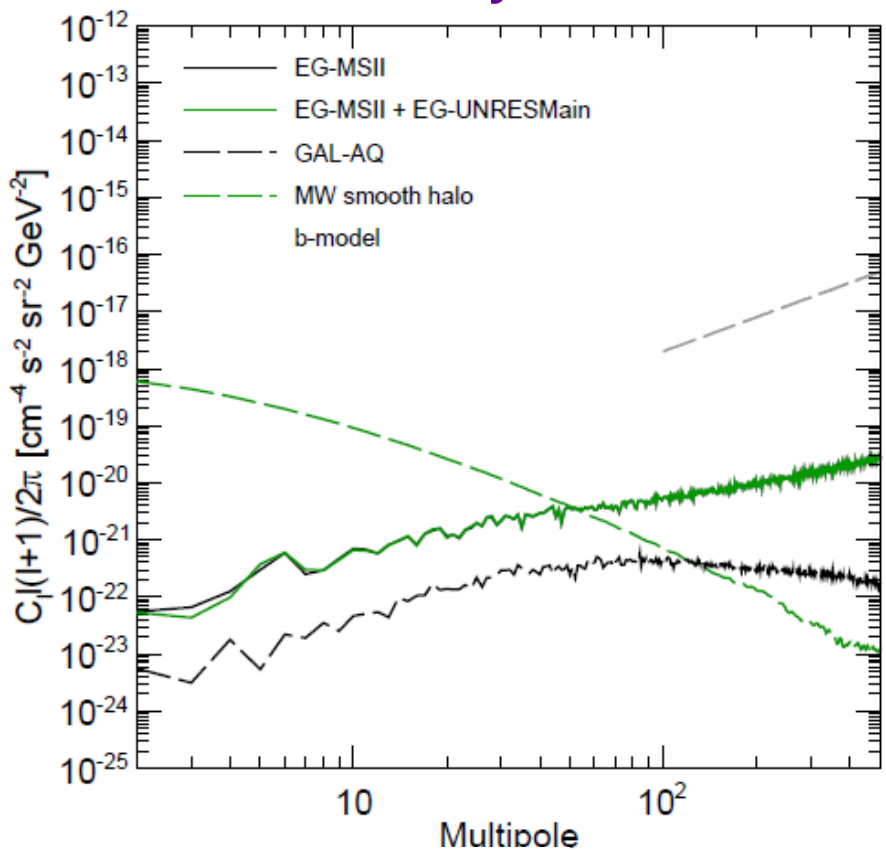

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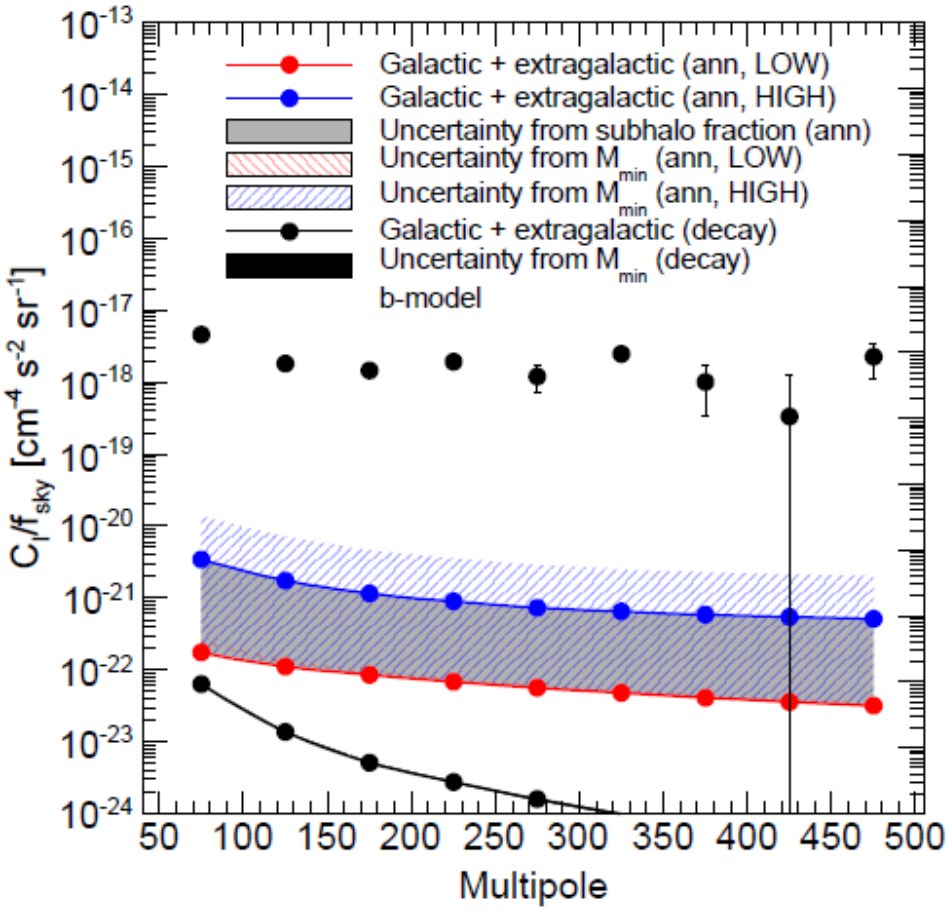

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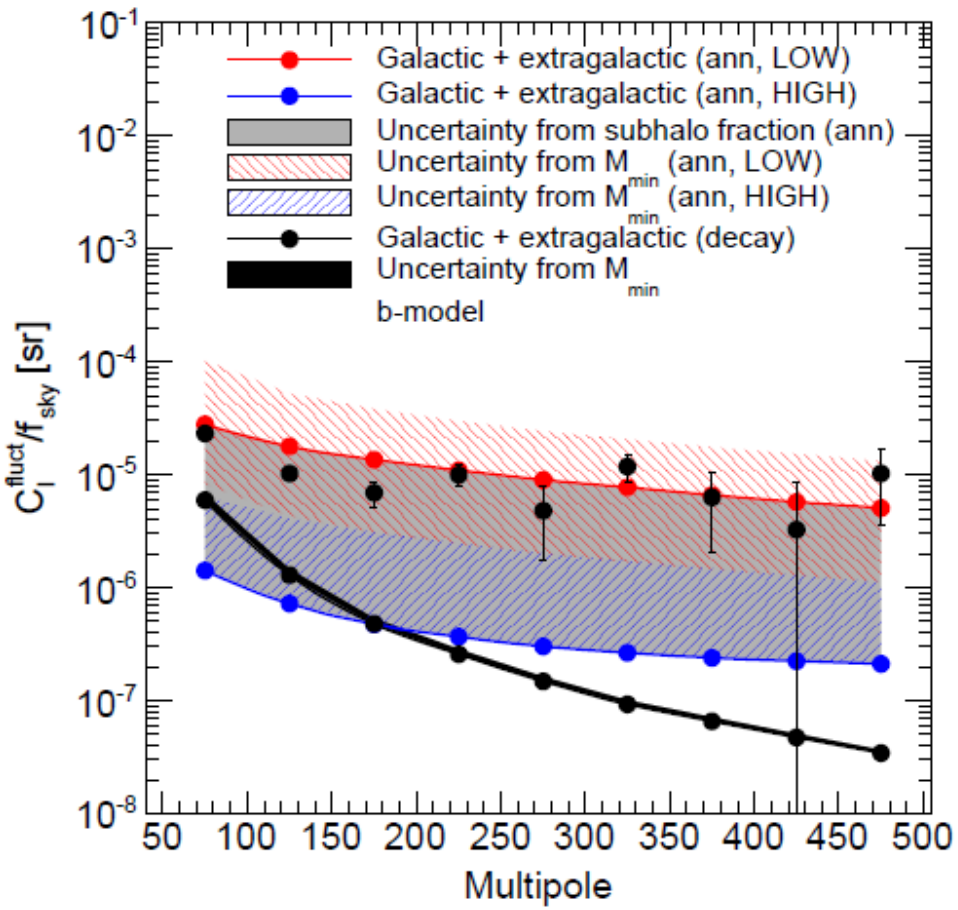

Annihilation: m_χ=200 GeV σv=3×10^{-26} cm^{3}s^{-1}. Decay: m_χ=2 TeV τ=2×10^{27} s. *b* channel.

Conclusions

- Nature of IGRB is still unknown and predictions from known source classes cannot reproduce the whole emission

- Information can be obtained from the study of the IGRB anisotropies

- Fermi-LAT detection of angular power above ℓ=155 from 1 to 50 GeV

- Possibility of extracting constraints on the DM particle from the comparison of template maps of DM emission with the Fermi-LAT data

- Keep a look to the arXiv for our publications!

Energy dependence of the APS

$$\frac{C_{\mathrm{P,tot}}}{\langle I_{\mathrm{tot}}\rangle^2} = f_1^2 \frac{C_{\mathrm{P},1}}{\langle I_1\rangle^2} + f_2^2 \frac{C_{\mathrm{P},2}}{\langle I_2\rangle^2} + \ldots \qquad (5)$$