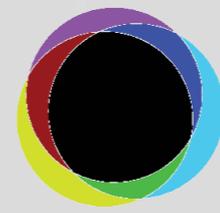


GRAPPA x
x
x



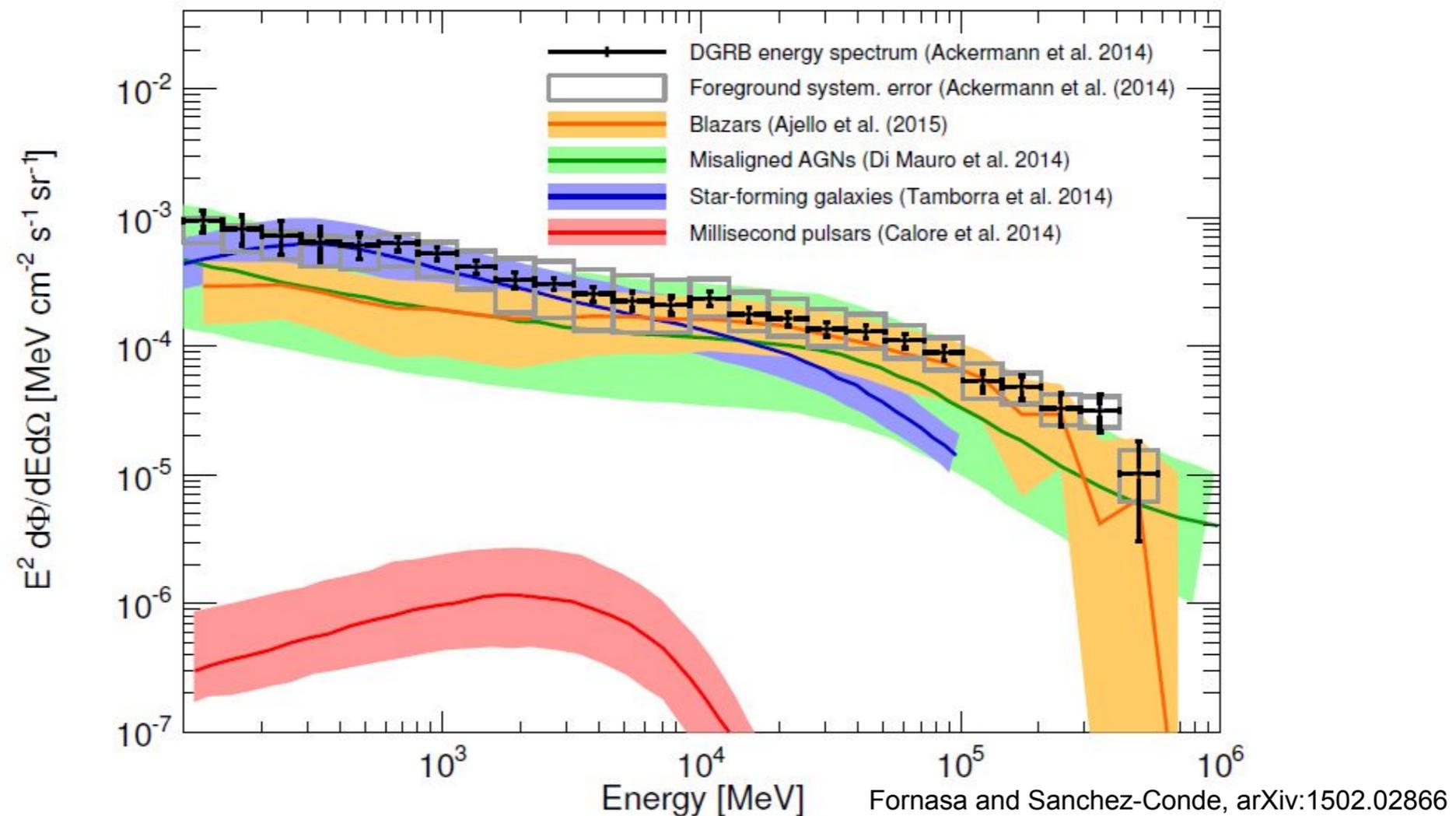
GRavitation AstroParticle Physics Amsterdam

Dissecting the Diffuse Gamma-Ray Background

Mattia Fornasa

work in collaboration with A. Cuoco, J. Gaskins, G. Gomez-Vargas,
T. Linden, F. Prada, M. Sanchez-Conde, F. Zandanel and J. Zavala

Intensity of the Diffuse Gamma-Ray Background



- cumulative emission of unresolved sources (blazars, star-forming galaxies, misaligned AGNs, millisecond pulsars, DM-induced emission)
- data-driven model describing the DGRB intensity
- limits on DM from the comparison with new Fermi-LAT data

Di Mauro and Donato, Phys. Rev. D19 (2015) 12, 123001

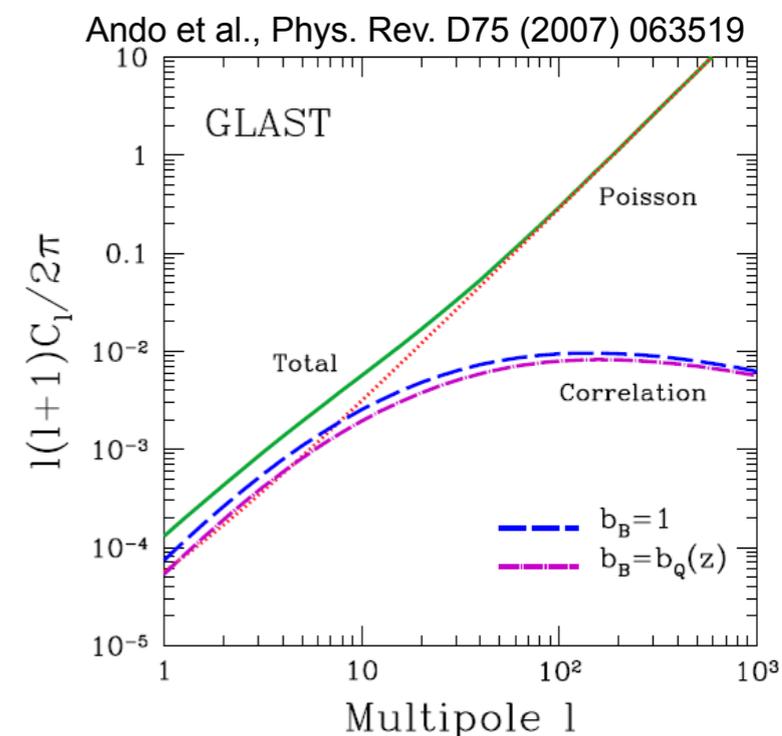
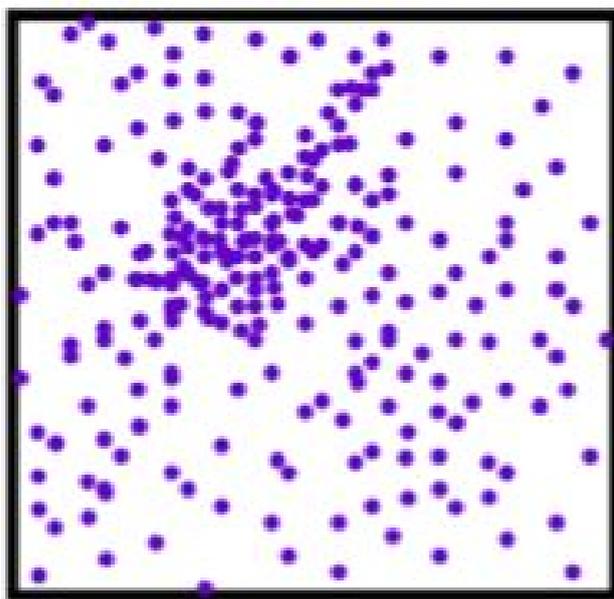
Anisotropies and angular power spectrum

$$a_{\ell,m} = \int d\Omega_{\mathbf{n}} [I(\mathbf{n}) - \langle I \rangle] Y_{\ell,m}^*(\mathbf{n})$$

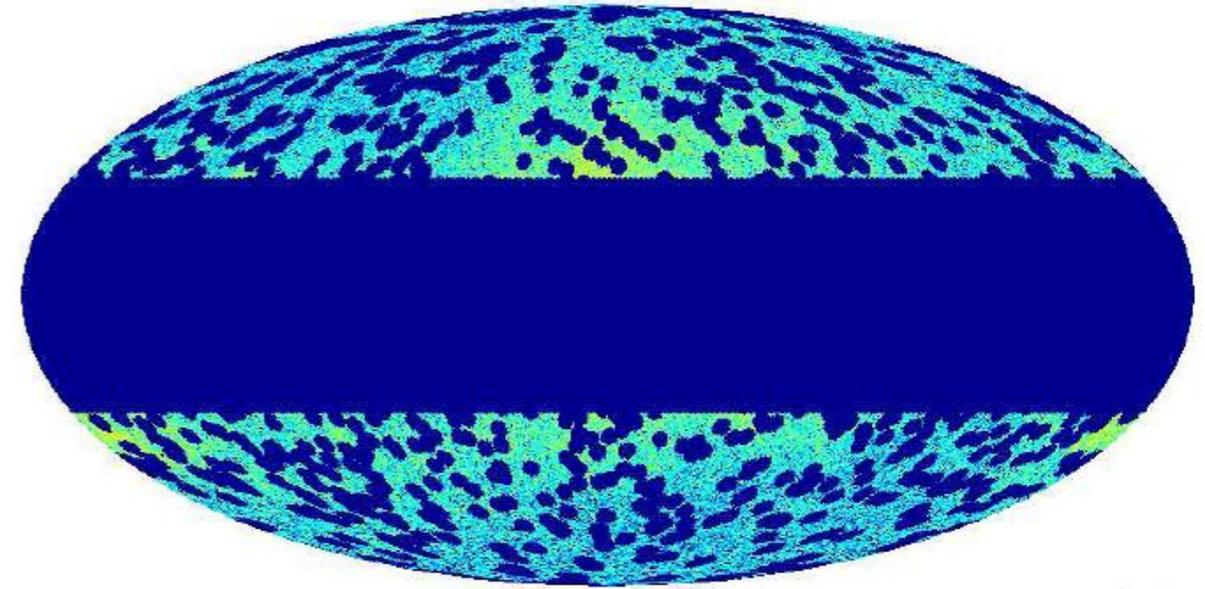
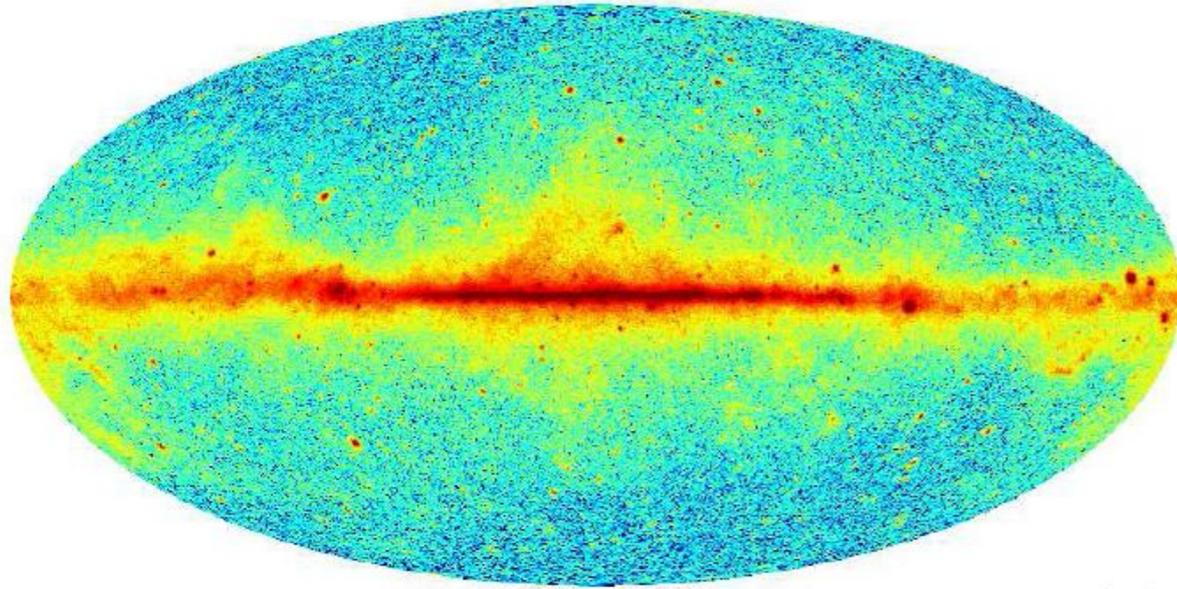
$$C_{\ell} = \frac{\sum_{|m| \leq \ell} |a_{\ell,m}|^2}{2\ell + 1}$$

- measure the angular power spectrum (APS) of anisotropies and model it as a sum of different components (as done for the DGRB intensity)
- derive constraints on the nature of DM
- Poissonian APS CP, i.e. independent on multipole

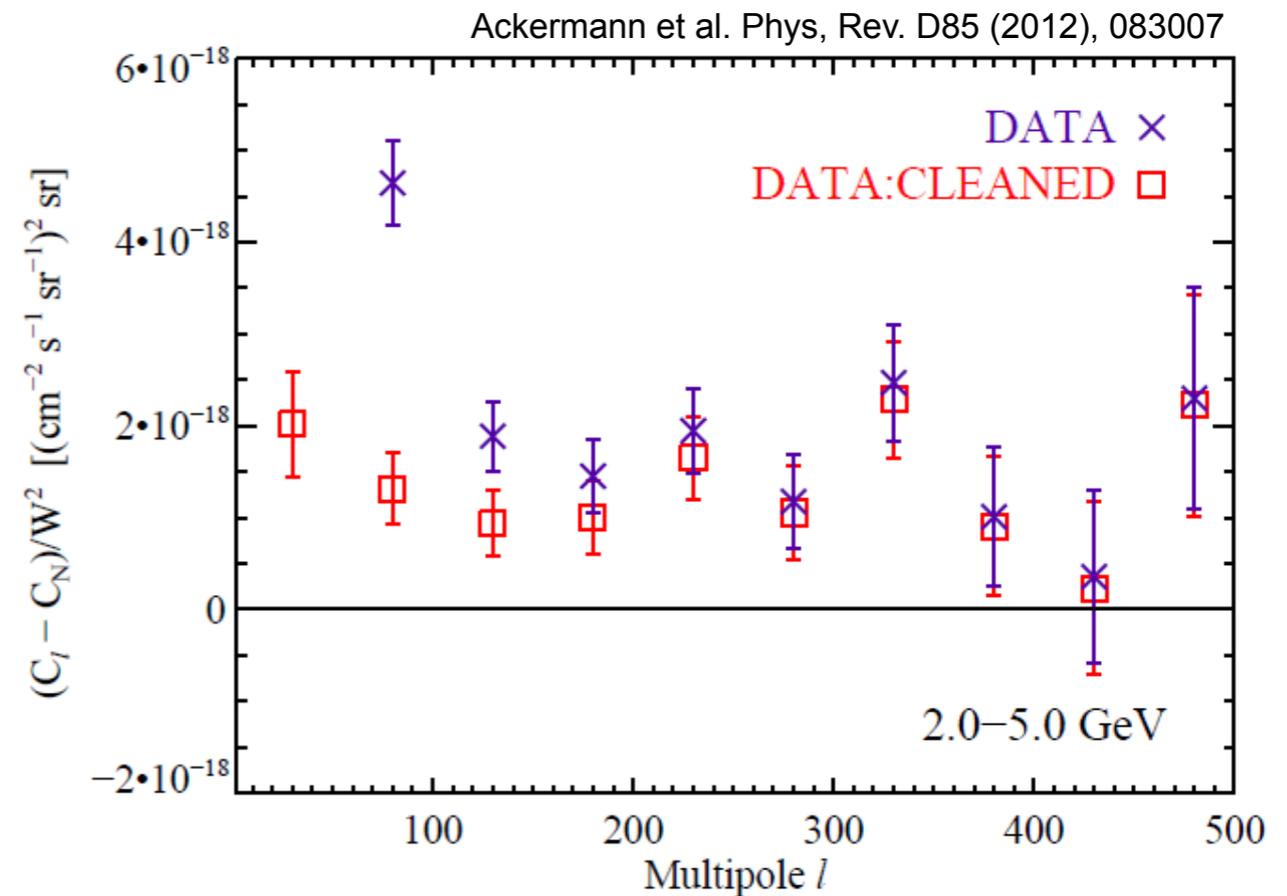
$$C_P = \int_0^{S_t} \frac{dN}{dS} S^2 dS$$



Fermi-LAT anisotropy measurement

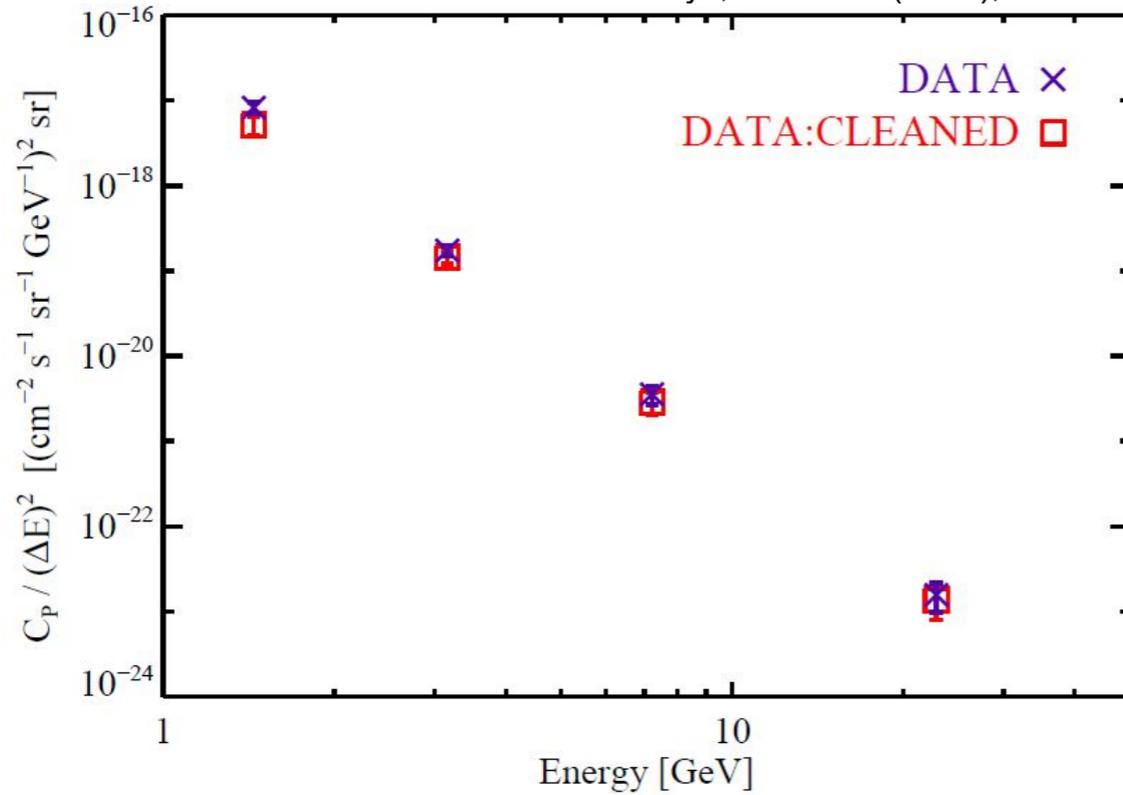


- Galactic foreground and sources are masked (not fitted)
- 22 months of data, 4 energy bins between 1 and 50 GeV
- signal region between a multipole of 155 and 504
- photon noise subtracted from the data



Fermi-LAT anisotropy measurement

Ackermann et al. Phys. Rev. D85 (2012), 083007



| E_{\min} [GeV] | E_{\max} [GeV] | Significance |
|------------------|------------------|--------------|
| 1.04 | 1,99 | 6.5σ |
| 1.99 | 5.00 | 7.1σ |
| 5.00 | 10.4 | 4.1σ |
| 10.4 | 50.0 | 2.4σ |

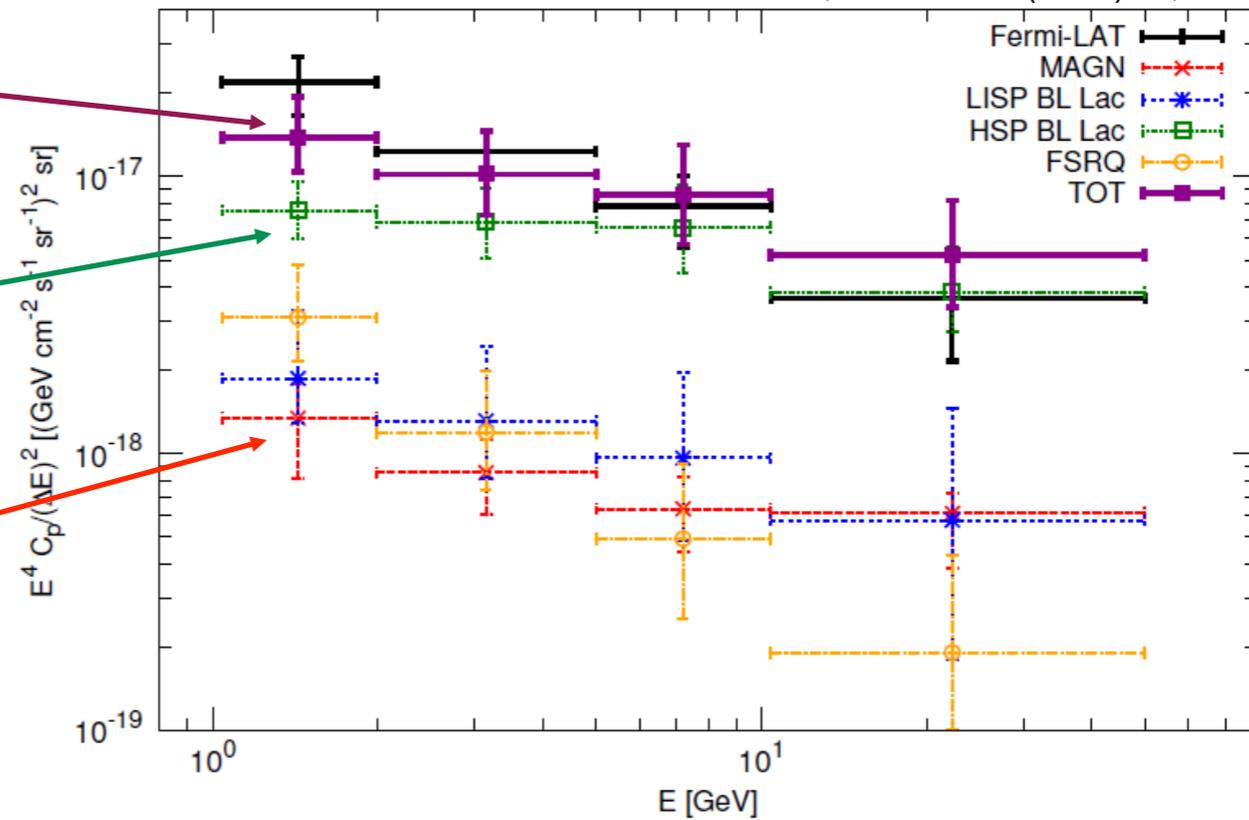
$$C_P = \int_0^{S_t} \frac{dN}{dS} S^2 dS$$

Di Mauro et al., JCAP 1411 (2014) 11, 021

Total astrophysics

Blazars (HSP BL Lacs)

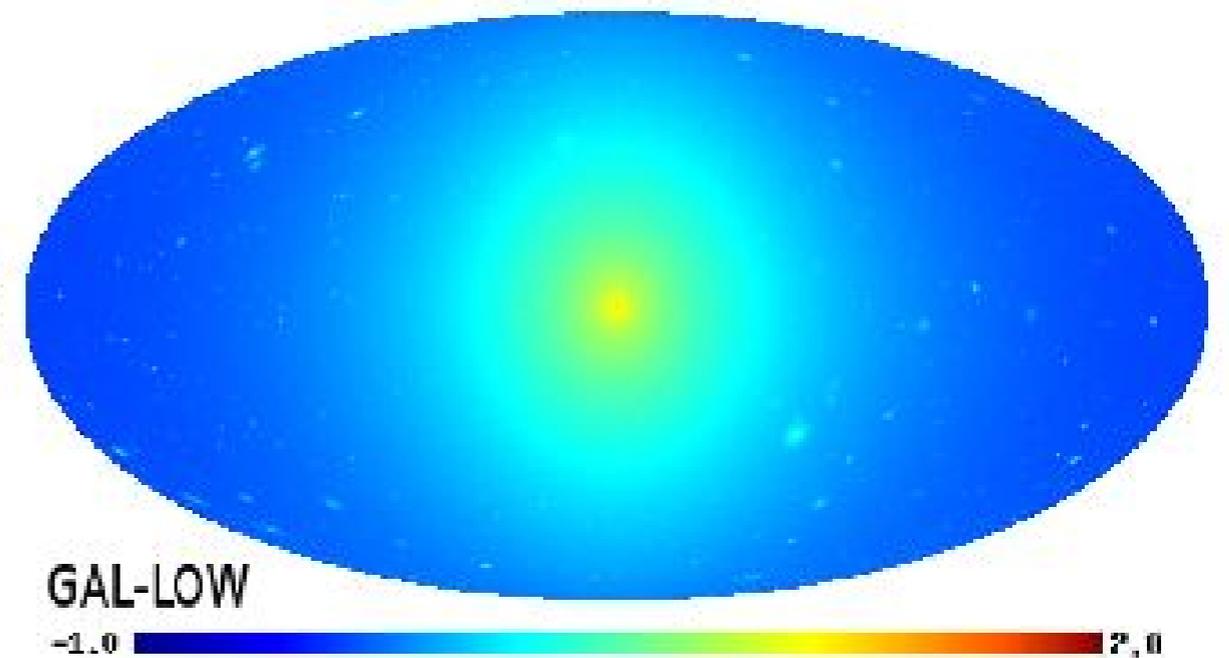
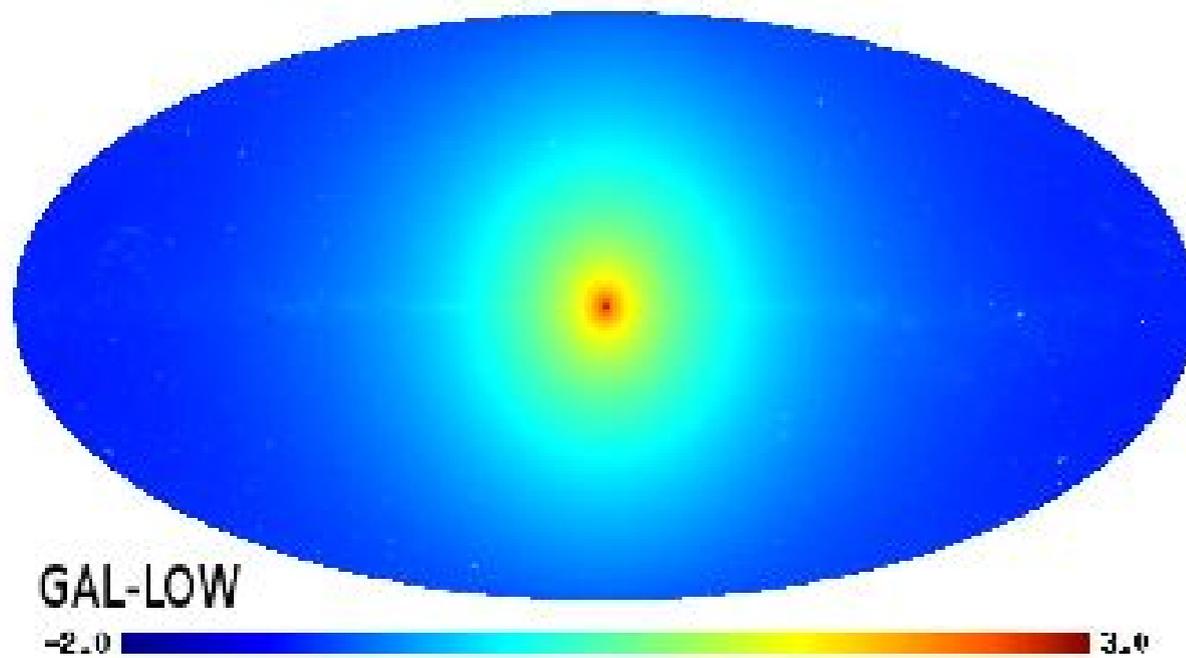
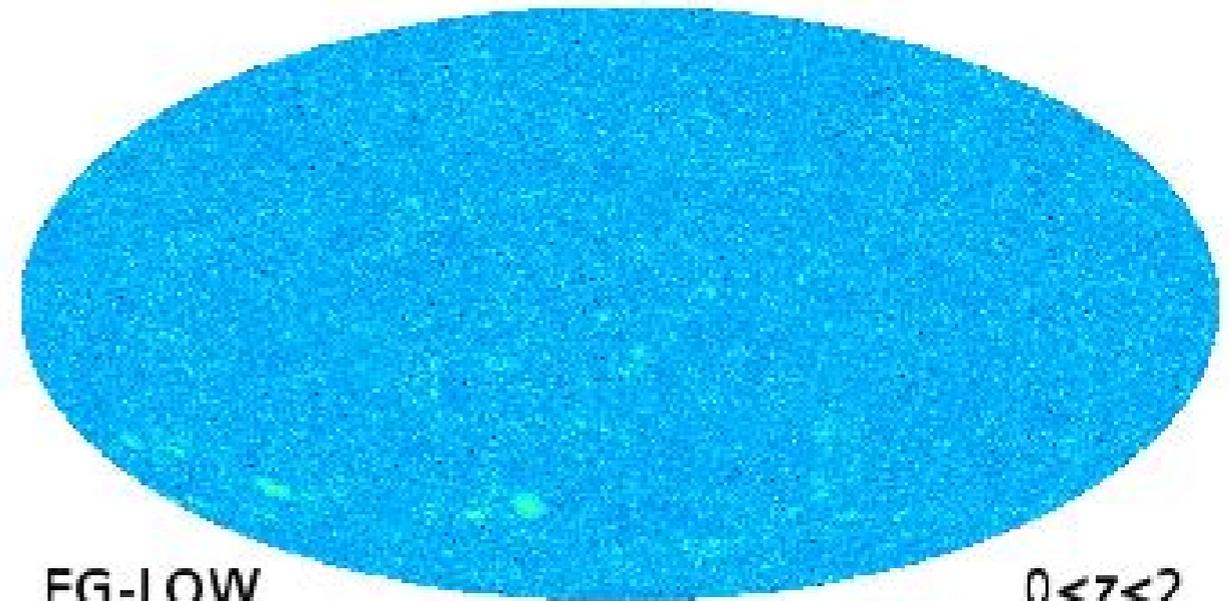
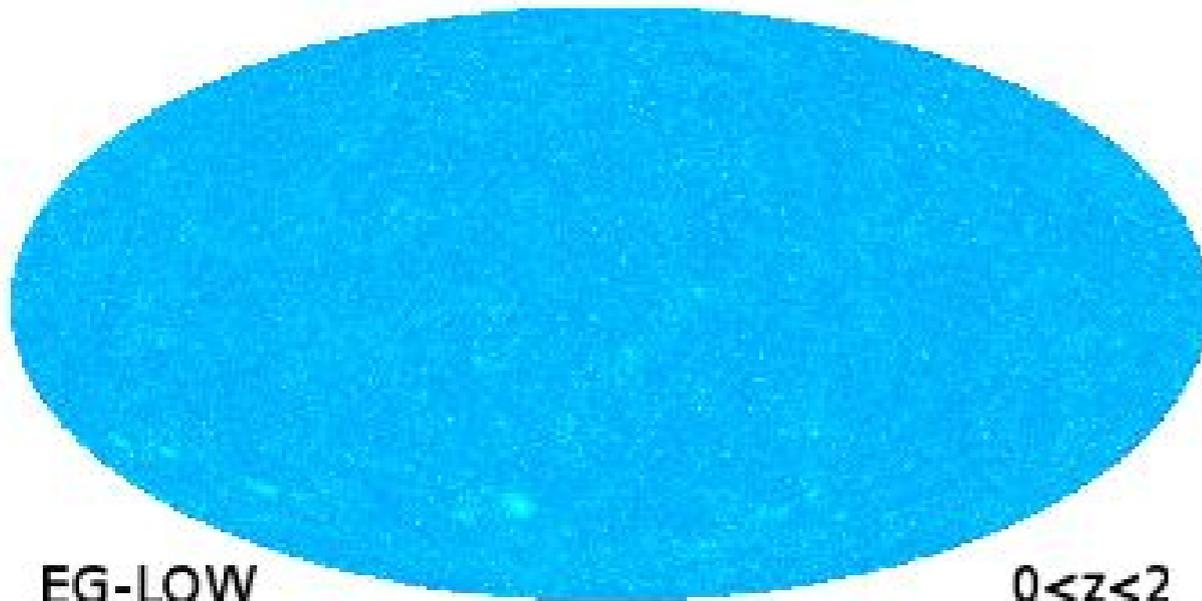
Misaligned AGNs



Gamma-ray anisotropies from Dark Matter

Annihilation

Decay

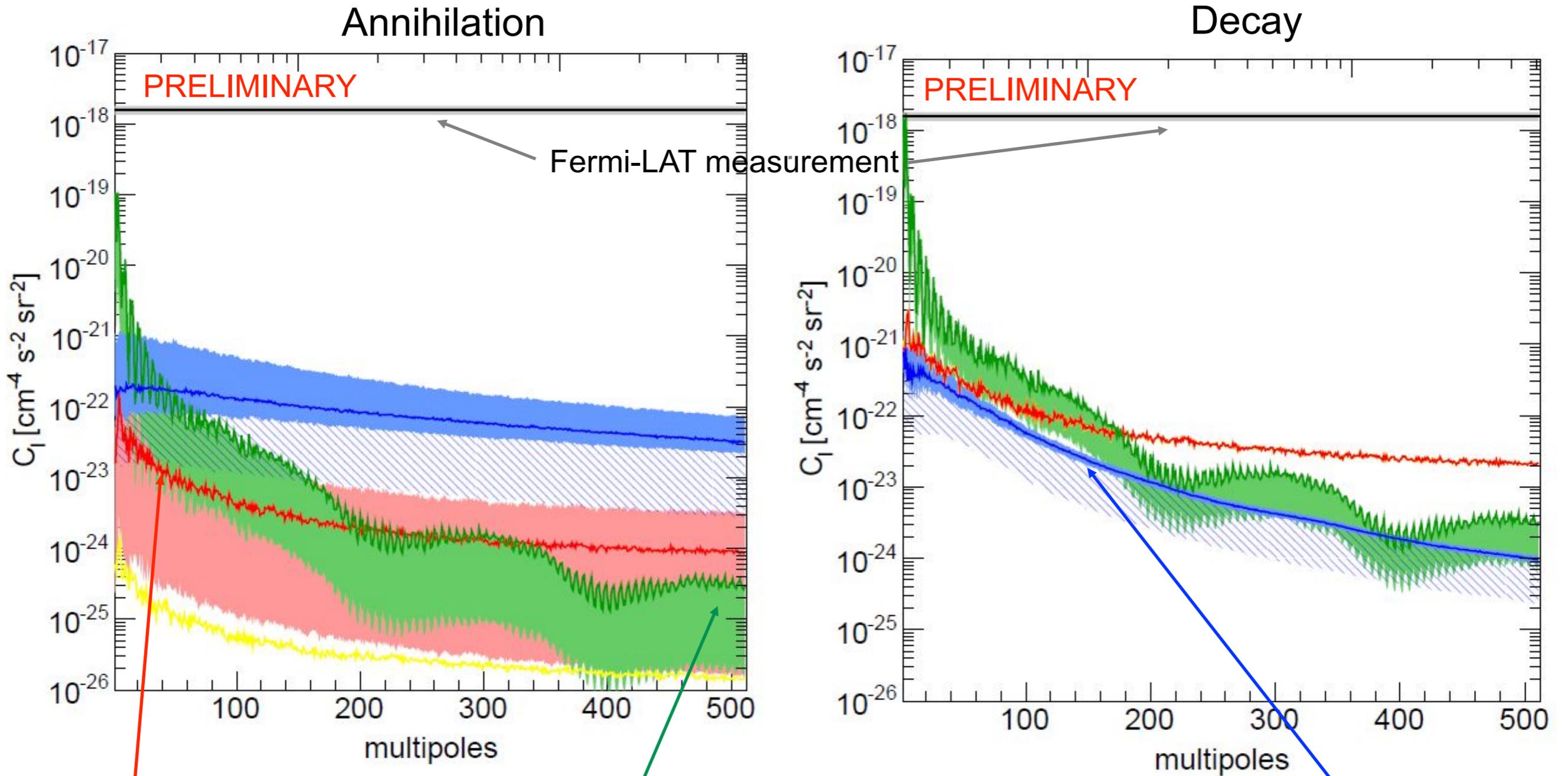


Fornasa et al., MNRAS 1529 (2013)

$E=4$ GeV, $M_{\min}=10^{-6} M_{\odot}$, b quarks

$m_{\chi}=200$ GeV, $\sigma v=3 \times 10^{-26} \text{cm}^3 \text{s}^{-1}$ (annihilation), $m_{\chi}=2$ TeV, $\tau=2 \times 10^{27}$ s (decay)

Gamma-ray anisotropies from Dark Matter



Extragalactic component
with uncertainty on M_{\min}

Smooth MW halo with uncertainty
on the total mass of the MW

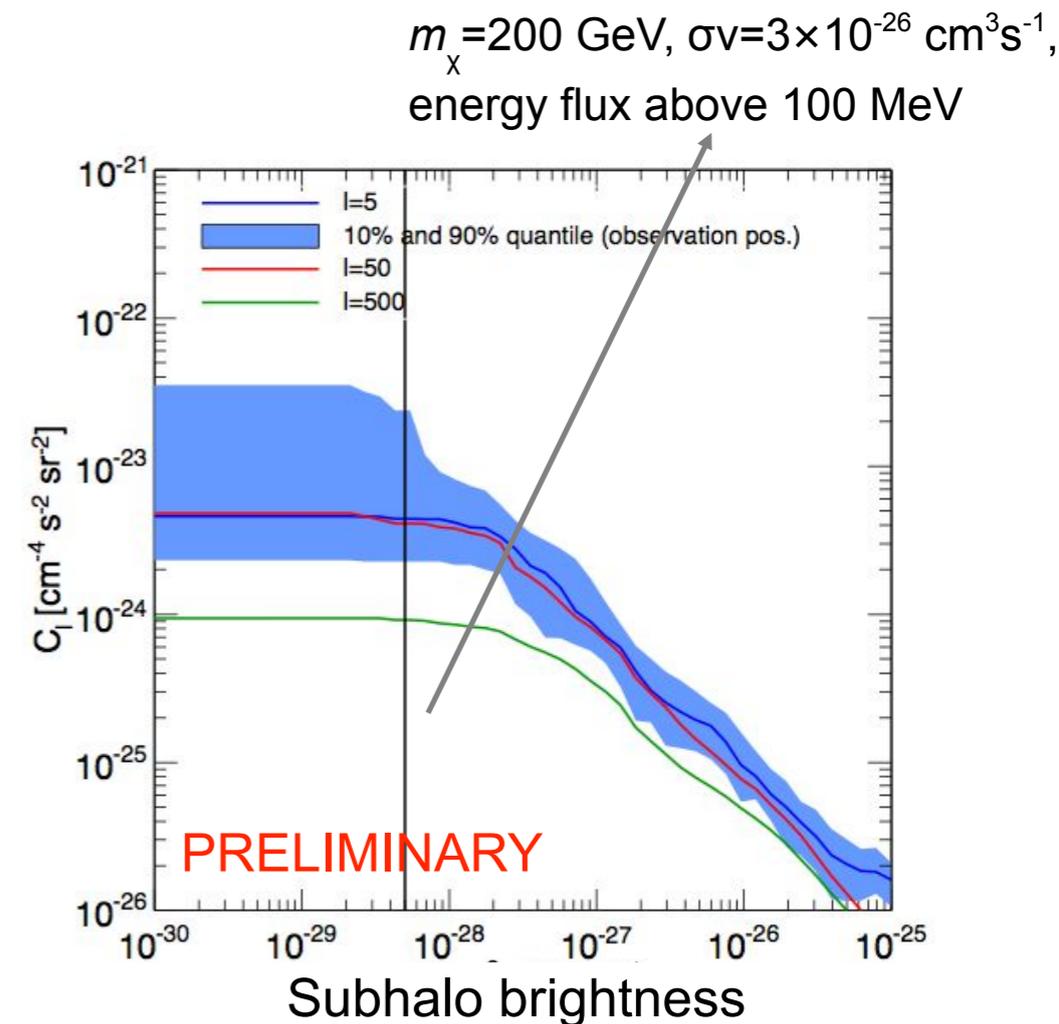
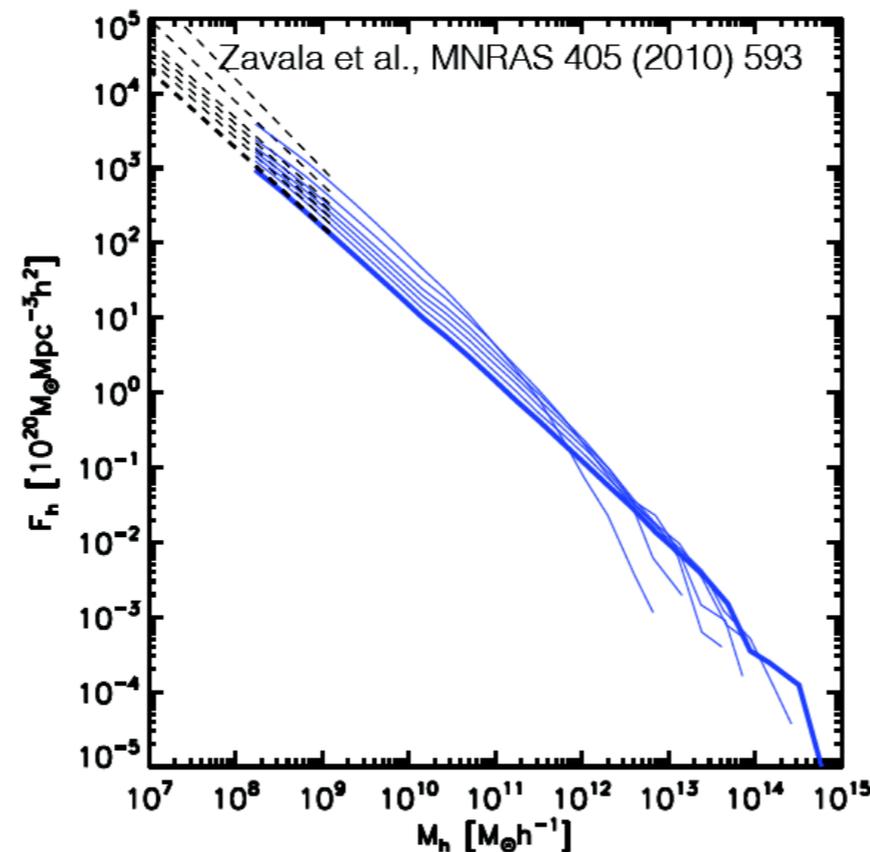
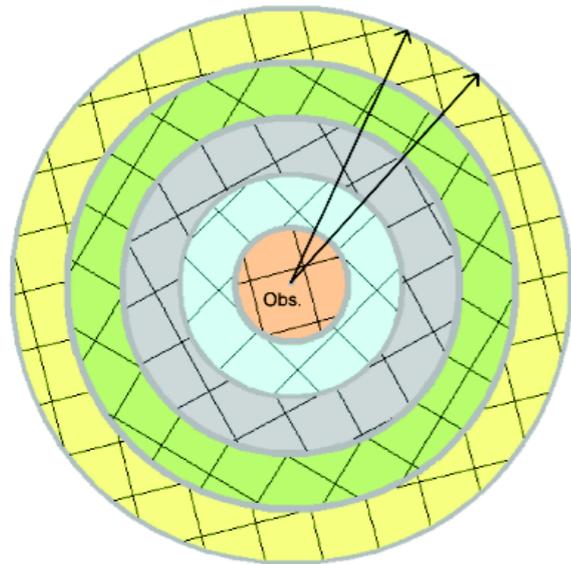
Galactic subhalos with
uncertainty on the location of
the observer and on the total
MW mass

$E=[2,5]$ GeV, $M_{\min}=10^{-6} M_{\odot}$, b quarks

$m_{\chi}=200$ GeV, $\sigma v=3 \times 10^{-26} \text{cm}^3 \text{s}^{-1}$ (annihilation), $\tau=2 \times 10^{27}$ s (decay)

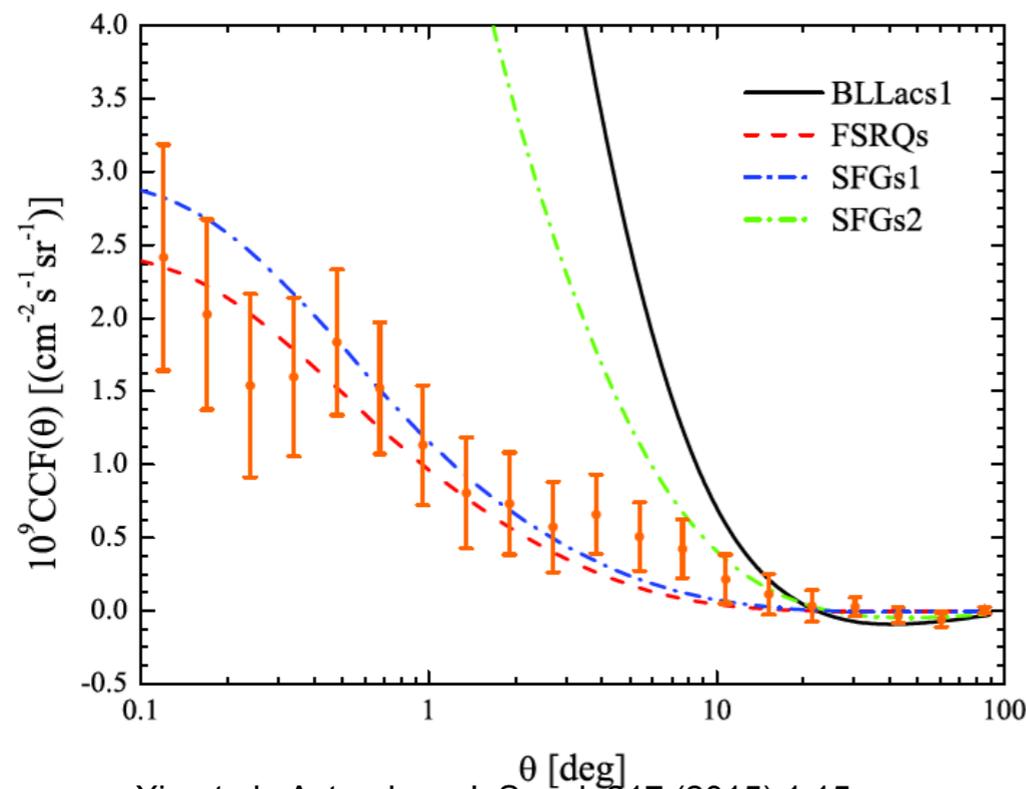
Simulate the DM-induced gamma-ray sky

- repetition of the Millennium-II box to cover a large portion of the Universe
- extrapolation below the mass resolution of the Millennium-II
- Galactic subhalos that are too bright are neglected
- uncertainty on the mass of the MW induces an uncertainty on the amount of Galactic subhalos

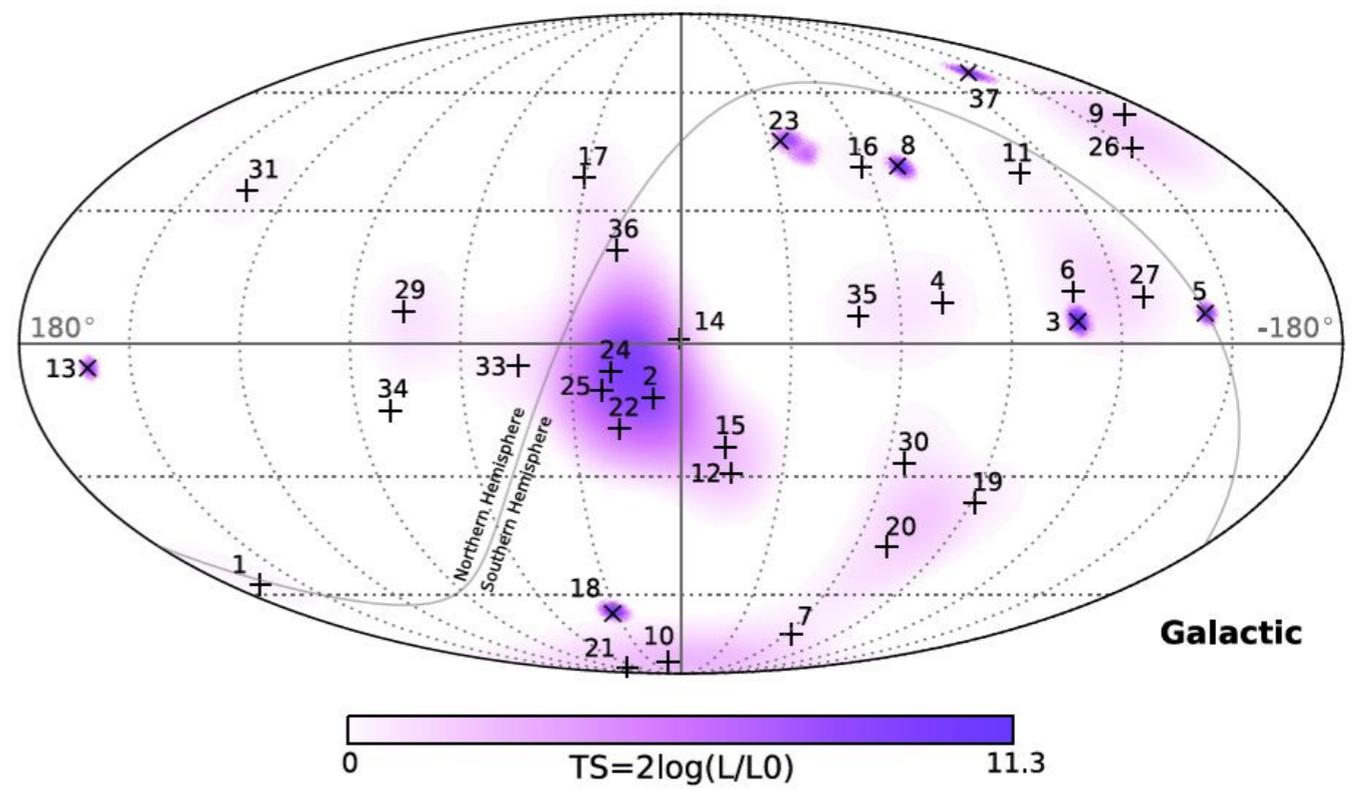


Conclusions

- DGRB is a very informative observable, able to constrain (unresolved) astrophysical sources and DM-induced emission
- not only intensity: importance of anisotropies
- not only auto-correlation: the novelty of cross-correlation
- not only gamma rays: extra-terrestrial neutrinos from IceCube



Xia et al., *Astrophys. J. Suppl.* 217 (2015) 1,15



Aartsen et al., *Phys. Rev. Lett* 113 D90 (2014) 101101

Intensity vs. fluctuation APS

- Fluctuation APS: dimension-less quantity (independent on energy)

$$a_{\ell,m}^{\text{fluct}} = \int d\Omega_{\mathbf{n}} \frac{I(\mathbf{n}) - \langle I \rangle}{\langle I \rangle} Y_{\ell,m}^*(\mathbf{n}) \quad C_{\ell}^{\text{fluct}} = \sum_{|m| \leq \ell} |a_{\ell,m}^{\text{fluct}}|^2$$

- Intensity APS: dimension-ful quantity (scaling with energy like $\langle I \rangle^2$)

$$C_{\ell}^{\text{int}} = C_{\ell}^{\text{fluct}} \langle I \rangle^2$$

- summation rule

$$C_{\ell}^{\text{int}} = C_{\ell,1}^{\text{int}} + C_{\ell,2}^{\text{int}}$$

$$C_{\ell}^{\text{fluct}} = \frac{\langle I_1 \rangle^2}{\langle I \rangle^2} C_{\ell,1}^{\text{fluct}} + \frac{\langle I_2 \rangle^2}{\langle I \rangle^2} C_{\ell,2}^{\text{fluct}}$$

