Anisotropies in the gamma-ray sky

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γ-rays from WIMP Dark Matter (DM)

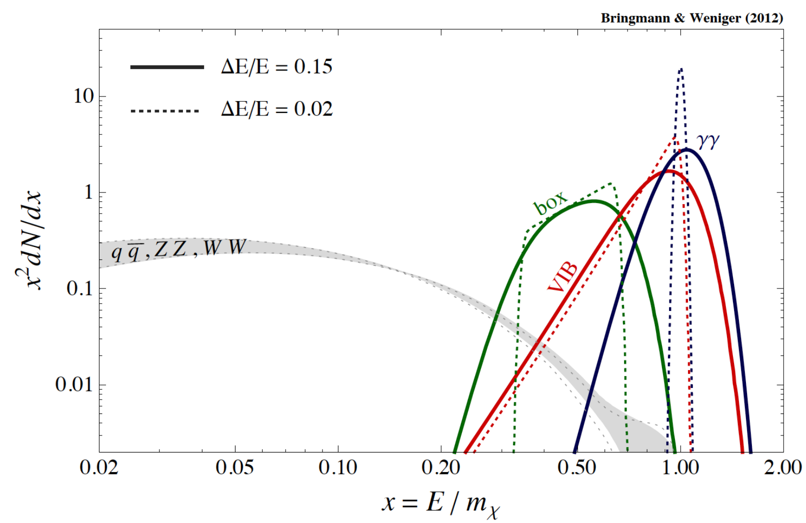
$$\Phi_\gamma = \frac{1}{4\pi} \frac{<\sigma_{ann} v>_0}{2m_\chi^2} \frac{dN_\gamma}{dE_\gamma} I(\Psi)$$

- Particle Physics term (ENERGY information):

$$\frac{\langle \sigma v \rangle}{m_\chi^2}$$ acts as a normalization

$$\frac{dN_\gamma}{dE_\gamma}$$

XX→π^0→2γ
XX→1-loop→γ γ, Zγ
Radiative correrctions
Inverse Compton



- Cosmological term (SPACE information)

$$I(\Psi) = \int_{l.o.s.} \rho^2(r(\lambda,\psi))d\lambda$$

Integral along the line-of-sight of DM density distribution ρ→ Derived from numerical simulations of cosmological structures

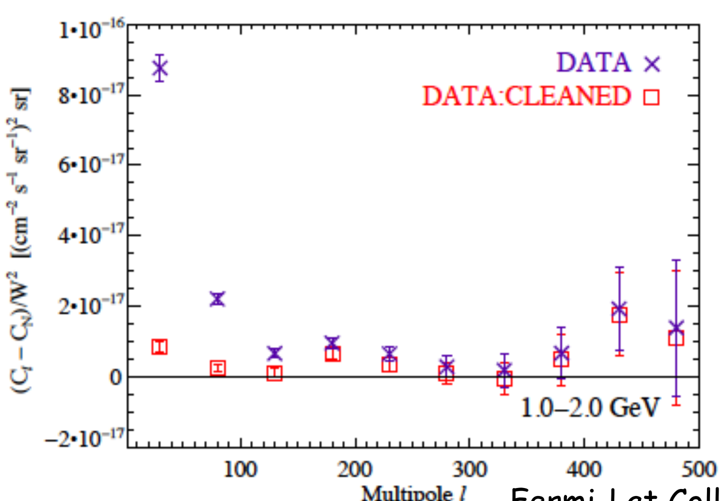
Spatial information: Anisotropies in γ-rays

Peculiar DM over-dense regions may imprint spatial signatures in high resolution data

$$\Delta_{\rm flux}(\Psi) = \frac{d\Phi}{dE}(\Psi) - \left\langle \frac{d\Phi}{dE} \right\rangle = \sum_{l=0}^{\infty} \sum_{m=-l}^{m=l} a_{lm} Y^*_{lm}(\Psi)$$

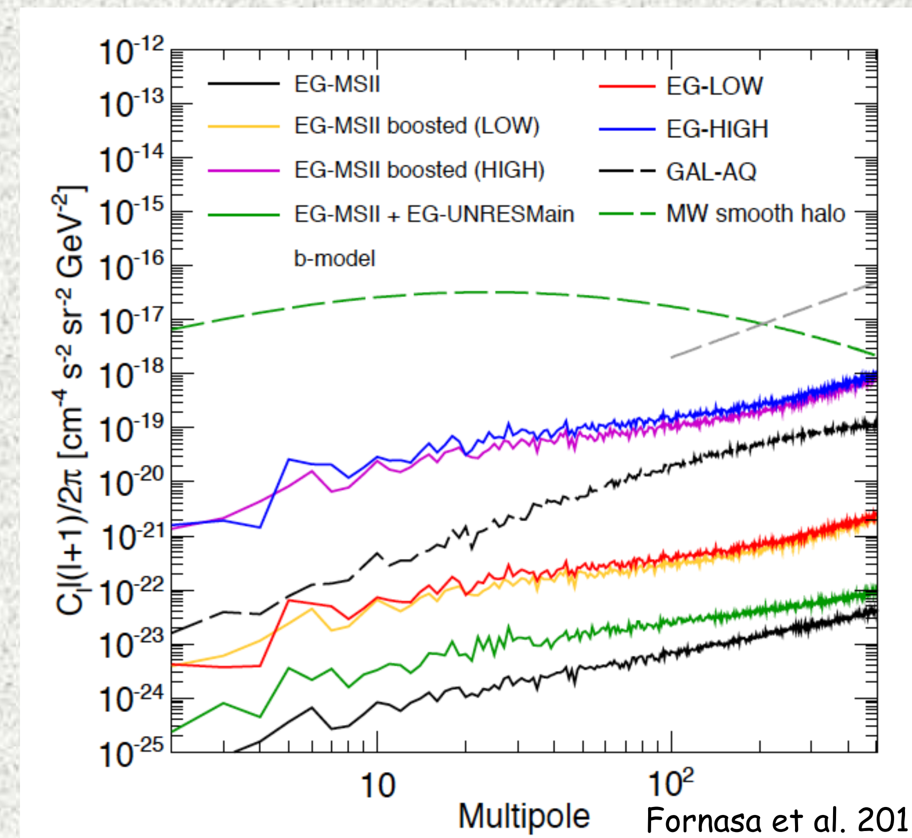
$$C_\ell = \frac{1}{2\ell+1} \left(\sum_{|m|\geqslant \ell} |a_{\ell m}|^2 \right),$$

Fermi-LAT: detected angular power >3σ in 1-10 GeV range at high l



Fermi-Lat Coll. 2012

Predicted angular power spectrum: galactic and extragalactic



Fornasa et al. 2012

Anisotropies in γ-rays from Dark Matter annihilation in the Galactic Halo

Calore, De Romeri, Di Mauro, FD, Herpich, Macciò, Maccione MNRAS 2014

We simulate the formation of a Milky-Way like galactic halo with pure-DM N-body counterparts of the MAGICC simulation suite

(Stinson et al. MNRAS 2013, Di Cintio et al. MNRAS 2014)

- The galaxy has a mass of $1.48 \cdot 10^{12}\ M_\odot$
- We resolve a total of 27 substructures in the range $10^{8.6}$- $10^{9.6}$ $M_\odot$
- We choose 3 different radial profiles to describe DM distribution:
-

$$\rho(r) = \rho_0 \left[\left(\frac{r}{R_c} \right) \left(1 + \frac{r}{R_c} \right)^2 \right]^{-1} \quad \text{(NFW)}$$

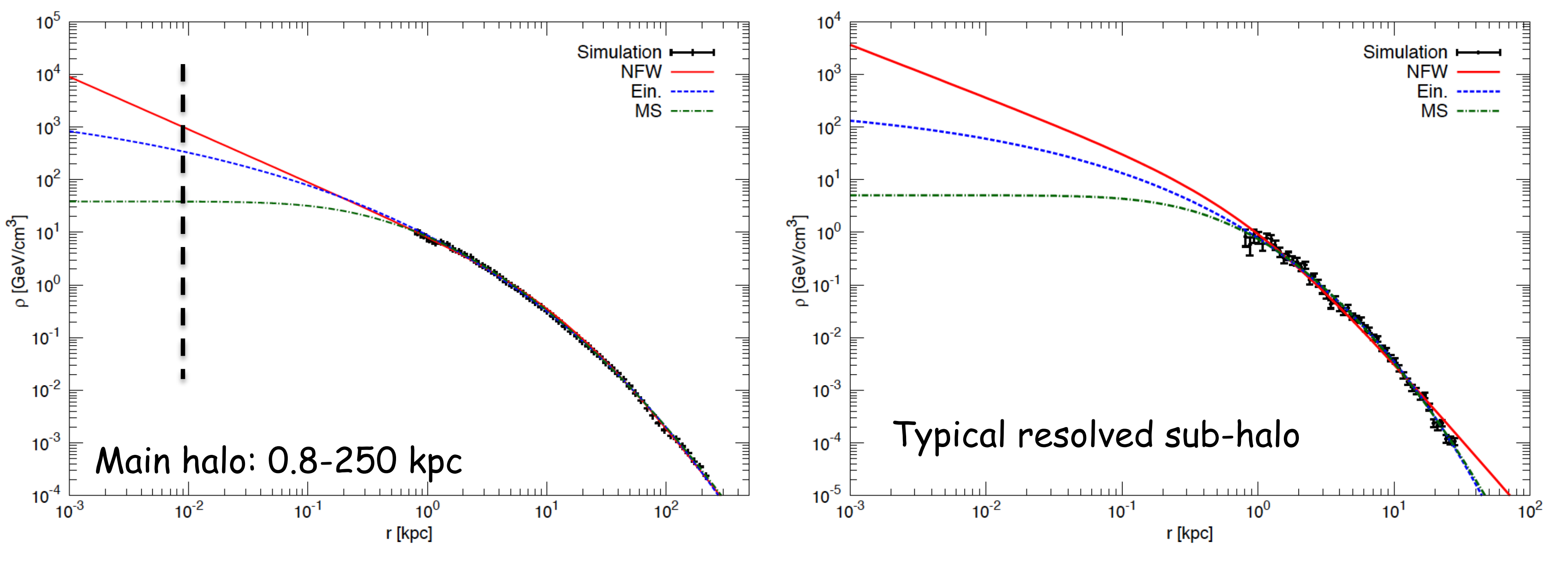
$$\rho(r) = \rho_0 \exp\left(-\frac{2}{\alpha_E} \left[\left(\frac{r}{R_s} \right)^{\alpha_E} - 1 \right] \right) \quad \text{(Ein)}$$

$$\rho(r) = \rho_0 \exp\left(-\lambda \left[\ln\left(1 + \frac{r}{R_\lambda} \right) \right]^2 \right) \quad \text{(MS)}$$

- The function MS is very flexible and can reproduce at the same time cuspy and cored profiles

Anisotropies in γ-rays: the role of the galactic DM radial profile

Calore, De Romeri, Di Mauro, FD, Herpich, Macciò, Maccione MNRAS 2014



1. The main halo is well fitted by all the profiles

2. **Below numerical resolution**
10 pc typical scale for γ-ray production at the GG: difference of 50 among profiles

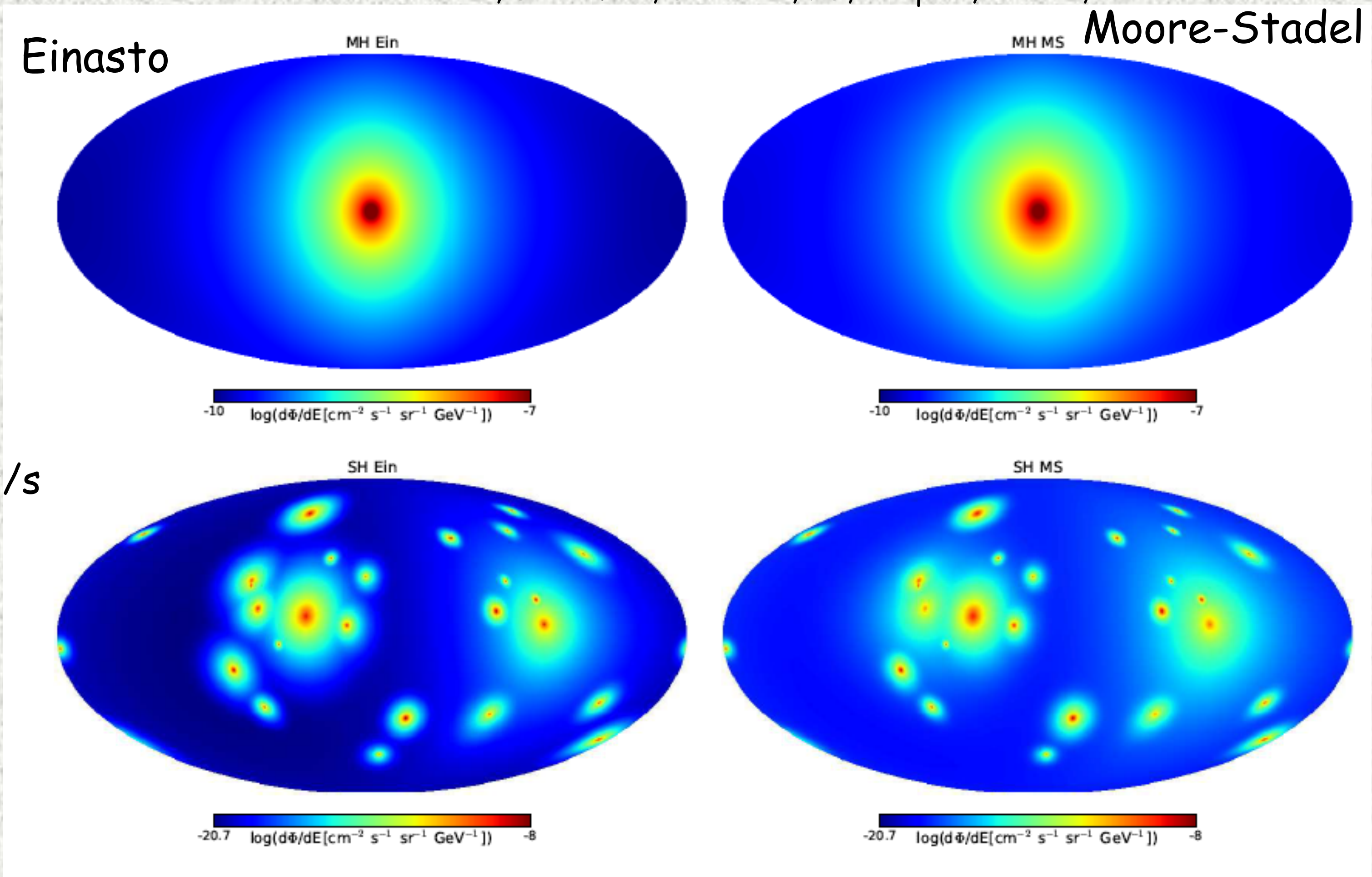
1. For sub-haloes, NFW profile shows tension with the data at large radii

2. The 3 profiles for sub-haloes differ by 100 at 10 pc

Simulated all-sky maps

Calore, De Romeri, Di Mauro, FD, Herpich, Macciò, Maccione MNRAS 2014

E=4 GeV
m_{DM}=200 GeV
$\langle\sigma v\rangle = 3\times10^{26}$ cm^3/s



Emission from Einasto profile is more clustered.

MS profile shows more extended cores

Anisotropies in γ-rays: the role of the galactic DM radial profile

Calore, De Romeri, Di Mauro, FD, Herpich, Macciò, Maccione MNRAS 2014

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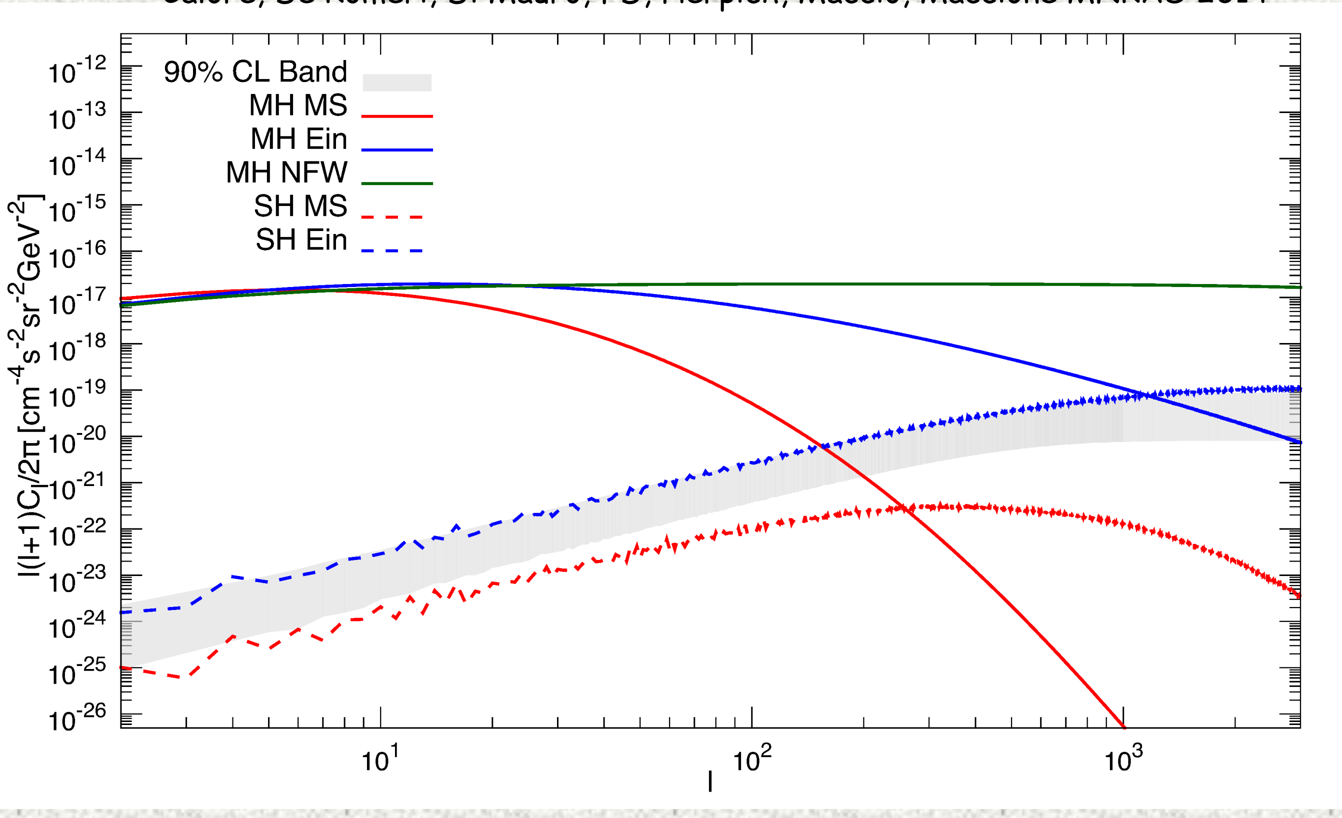
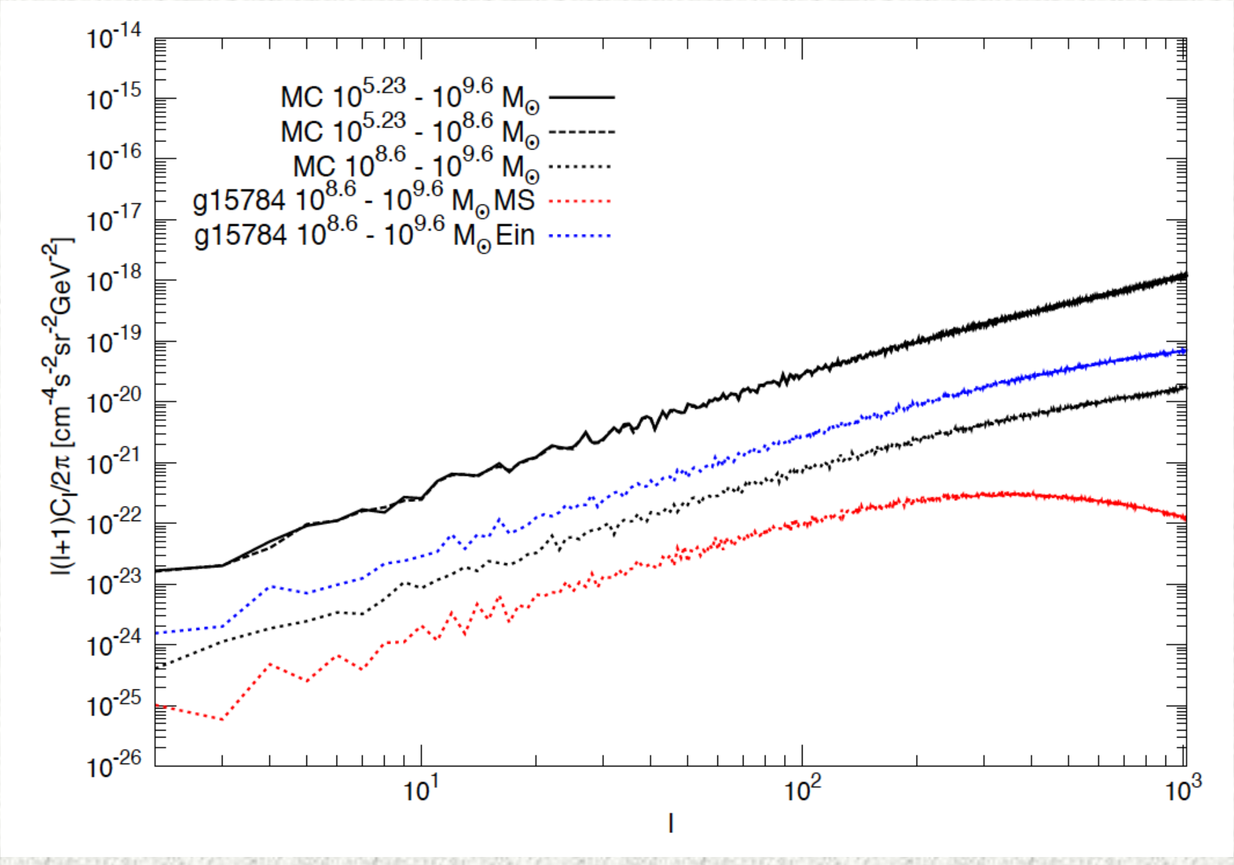


- Main halo dominates the low multipole intensity spectrum
- Einasto profile gives more anisotropy power at high multipoles (or small radii; e.g. l=1000 ~ r=30 pc)
- If halo is cored → lower intensity but higher probability for DM sub-haloes to emerge (N.B. no background included; no low latitude mask).

Effect of unresolved (smaller) sub-haloes

Calore, De Romeri, Di Mauro, FD, Herpich, Macciò, Maccione MNRAS 2014



- Black lines: Aquarius Aq-A-1 simulated sub-haloes, Einasto profile (Springer+2008)
- More massive and cored haloes give a flattening at high l (red line)
- The smaller haloes give more power and a Poisson-like trend

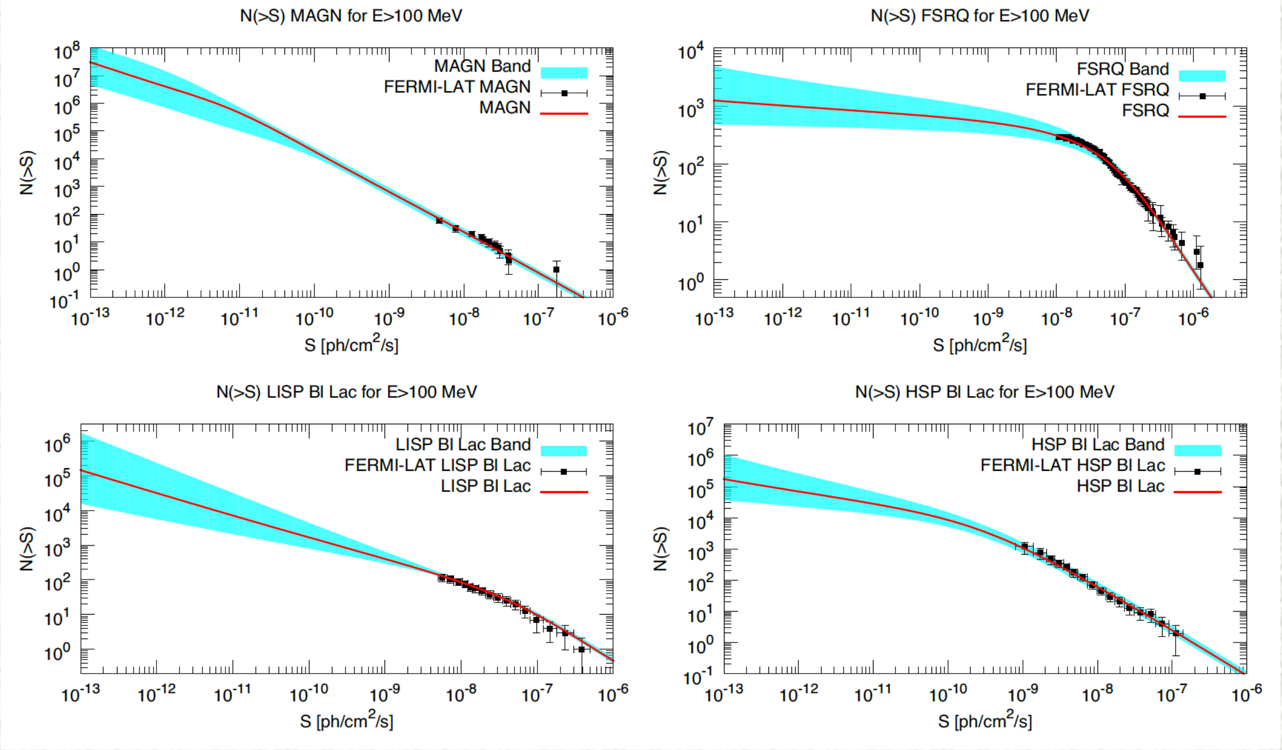
Anisotropy power spectra from astrophysical sources

Cuoco, Di Mauro, FD, Siegal-Gaskins 1407.3275, JCAP subm.

We study angular power for classes of AGN:

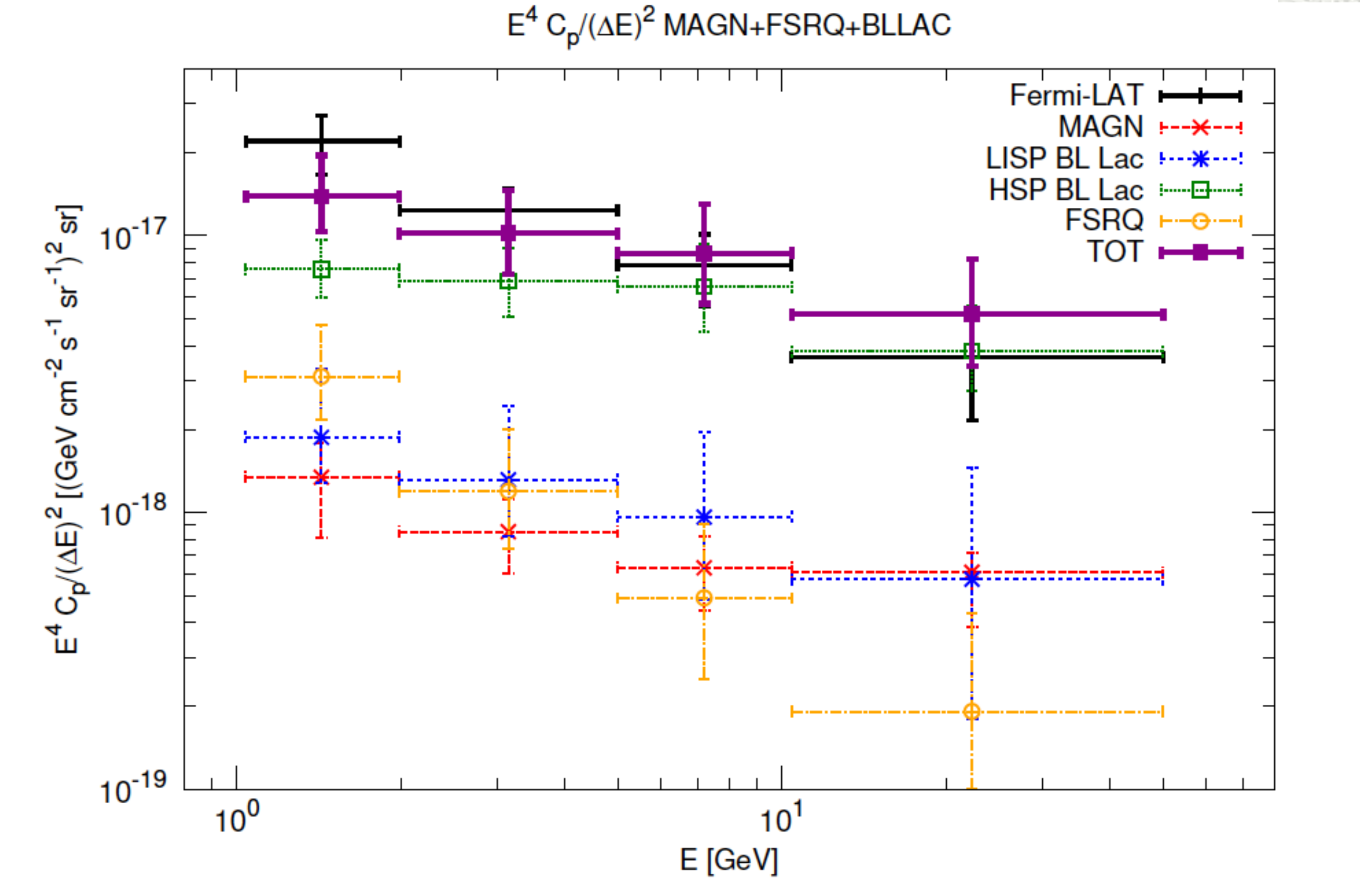
- BL Lacs: LISP and HSP (Low, Intermediate and High Synchrotron Peak)
- Misaligned AGN (MAGN)
- Flat Spectrum Radio Quasar (FSRQ)

See talk by M. Di Mauro



AGN angular power and Fermi-LAT data

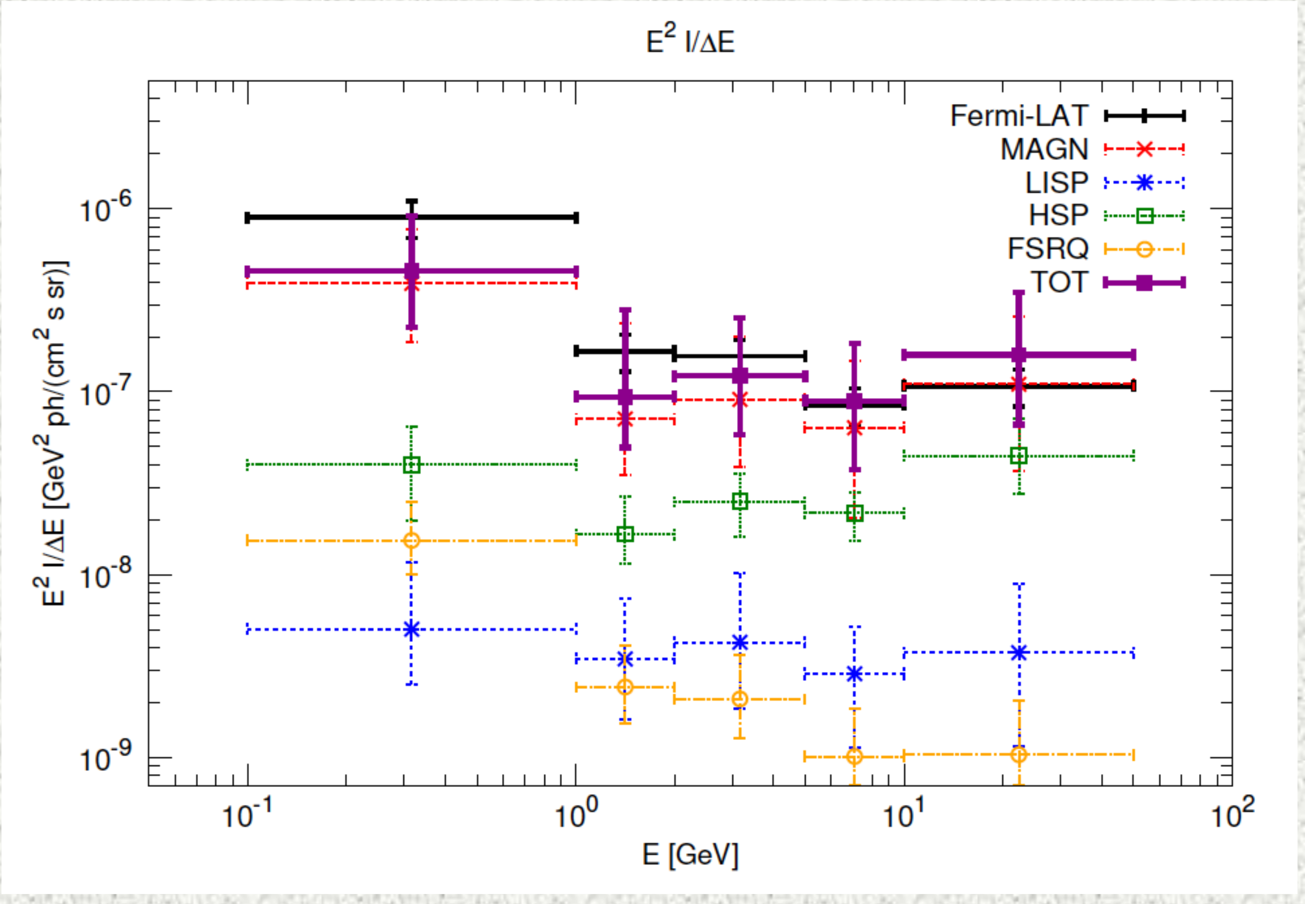
Cuoco, Di Mauro, FD, Siegal-Gaskins 1407.3275, JCAP subm.



HSP BL Lacs contribute the most to the anisotropy;
high energy spectrum MAGN are very numerous by faint, little amount of AP

Fermi-LAT data explained by AGN!!!

The anisotropy - integrated flux consistency



MAGN contribute the most to the IGRB, being very numerous whilst faint
HSP BL Lacs get relevant to the highest energies, but sub-dominant

Our emission models for AGN are compatible with Fermi-LAT data on anisotropy AND diffuse emission

Conclusions

- The anisotropies from DM in the galactic halo depend significantly from the **radial profile**: cuspy haloes → higher anisotropy power spectrum
- Extrapolation of DM radial distribution to sub-resolution radii is dangerous, also for anisotropy studies
- High multipoles are the most sensitive to the geometry of the DM halo
- We have computed the anisotropy for different AGN classes
- Our predictions explain Fermi-LAT data with no need for extra-terms