Characterization of the Local Universe via cross-correlations

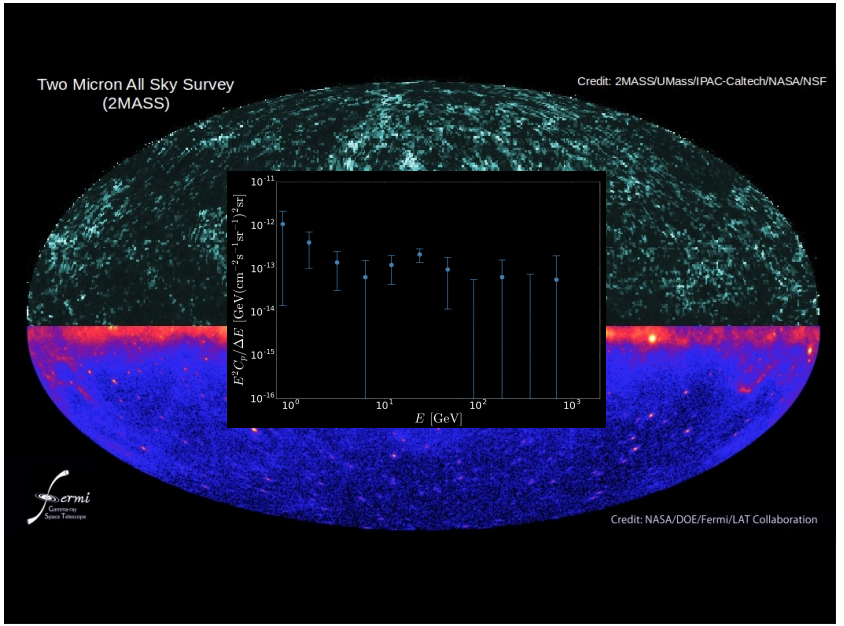
S. Ammazzalorso [1], N. Fornengo [1], S. Horiuchi [2], M. Regis [1]

[1] *Dipartimento di Fisica, Università di Torino and INFN, Torino, Italy*

[2] *Department of Physics, Virginia Tech, Blacksburg, VA 24061, USA*

Abstract

- The Extra-galactic Unresolved Diffuse Emission contains anisotropies due to faint source emission
- The anisotropies of the Local γ-ray Universe can be studied computing the Angular Power Spectrum of the cross-correlation with catalog of galaxies at redshift < 0.1
- The measurement of the angular cross-correlation between Fermi-LAT maps and the 2MPZ catalog allows to constrain different source populations at low z, including particle Dark Matter



Data Selection

Fermi-LAT data:

Public Data Pass8:

- ULTRACLEANVETO
- PSF1+2+3
- 9 years
- 600 MeV – 1 TeV
- 11 logarithmic energy bins

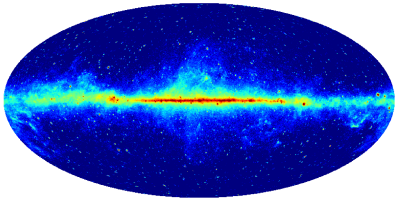


Fig 1. Integrated γ-ray flux above 1 GeV

The 2MASS Photometric Redshift catalogue[1] (2MPZ) is built by cross-matching 2MASS XSC, WISE and SuperCOSMOS all-sky samples.
It reconstructs the galaxy redshift via an artificial network and it contains ~ 10^6 objects.

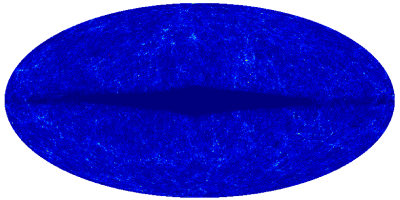


Fig 2. 2MPZ whole sample map

Galaxy subsets:

2MRS	----> subset of 2MPZ peaked at low redshift [2]
Identified mAGNs	----> subset obtained by cross-matching WISE, 2MASS and Rosat [3]
Identified blazars	----> obtained from infrared color-color diagram [4]
Brightest galaxies in B band	----> indicator of star formation
Brightest galaxies in K band	----> correlating with the mass of the object

[1] Bilicki et al., Astrophys.J.Suppl. 210, (2014)
[2] Huchra et al., Astrophys.J.Suppl. 210, (2012)
[3] Edelson, Malkan, Astrophys.J., 751:52, (2012)
[4] Massaro et al., Astrophys.J., 834, (2017)

For a detailed analysis of the redshift dependence of the cross-correlation see: Cuoco et al., Astrophys.J.Suppl. 232, (2017)

Theoretical background

The correlation can be estimated by:

$$\xi(\theta)=\frac{\sum_{i,j}(n_\gamma-\langle n_\gamma\rangle)\frac{(n_{GAL}-\langle n_{GAL}\rangle)}{\langle n_{GAL}\rangle}f_{ij}(\theta)}{\sum_{i,j}f_{ij}(\theta)} \qquad f_{ij}(\theta)=\begin{cases}1 & \theta_1\leqslant\theta\leqslant\theta_2\\ 0 & \theta<\theta_1\vee\theta>\theta_2\end{cases}$$

The relation between the Cross-Correlation Function and the Angular Power Spectrum is:

$$\xi(\theta)=\sum_l\frac{(2l+1)}{4\pi}C_l P_l(\cos(\theta))$$

The theoretical estimation of the correlation can be written [5] as:

$$C_l^{(\gamma GAL)}=\int\frac{d\chi}{\chi^2}W_\gamma(\chi)W_{GAL}(\chi)P_{\gamma GAL}(k=\frac{l}{\chi},\chi)$$

$$W_\gamma(E,z)=\int dL\frac{dN}{dL}F(L)$$ Provided by data Halo Model

The γ-ray emission Window Function can be modeled from the γ-ray luminosity function of each unresolved component:

- Blazars
- mAGNs
- Star Forming Galaxies
- DM

[5] N. Fornengo, M. Regis, Front. Physics 2:6, (2015)

Data preparation & analysis

Photon fluxes

- Likelihood determination and removal of the Galactic Diffuse Emission
- Masking the Galactic Plane (30 deg cut)
- Masking 3FGL and 3FHL sources (above 10 GeV): the radius around each source depends on its brightness and the PSF in the specific energy bin

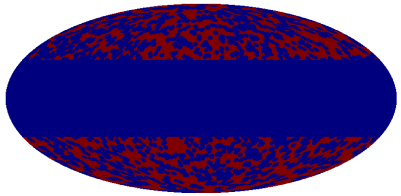
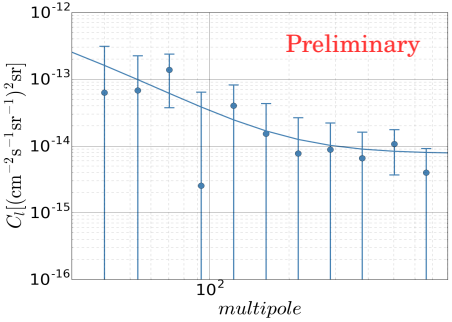


Fig 3. Example of mask in the energy bin 1.2-2.2 GeV. f_{sky} ranges from 0.1 at lower energies to 0.5.

2MPZ

- The mask is built in order to avoid possible systematics [6] (Galactic dust extinction, stars, seeing and sky brightness)



[6] Alonso et al., MNRAS, 449, (2015)

Fig 4. Example of the APS in the energy bin 9.1-17.4 GeV. The correlation is computed using Polspice[7], a statistical tool developed in order to study CMB anisotropies.

[7] www2.iap.fr/users/hivon/software/PolSpice

Results

Redshift dependence

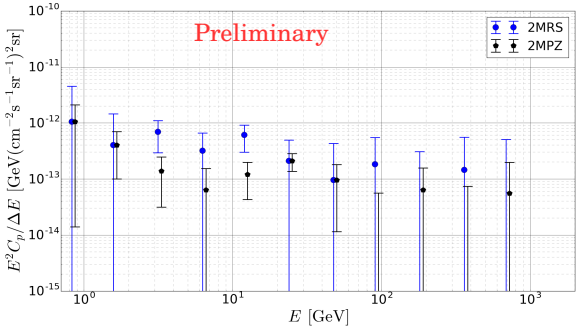


Fig 5. Energy spectrum of the 1halo term (C_p) for the cross-correlation with the 2MPZ and 2MRS subsets.

There is no a clear evidence of a higher trend at lower redshift.

Blazar & AGN signal

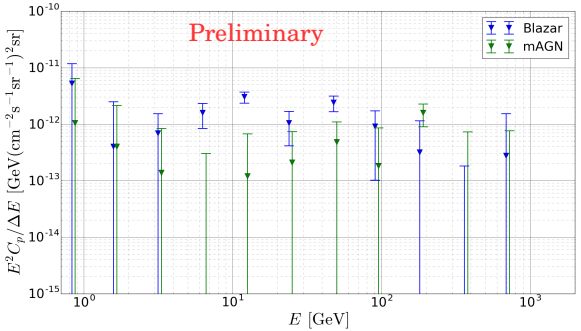


Fig 6. Energy spectrum of the normalized C_p for the mAGNs (W2 subset) and blazars.

We find a good evidence of correlation.

Blazar & AGN contribution

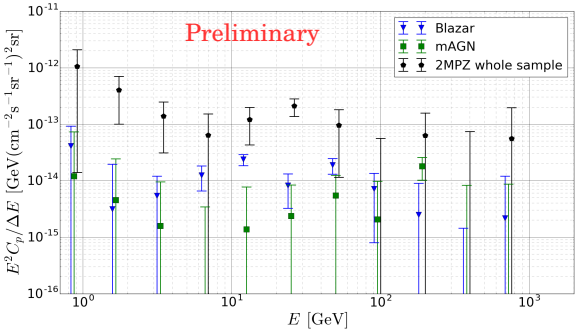


Fig 7. Energy spectrum of the C_p for the mAGNs and blazars respect to the whole 2MPZ sample.

It seems that some other component is required in order to explain the whole correlation.

Ongoing work and future perspectives

- Data interpretation with different source populations to constrain their γ-ray luminosity function at low-z
- Derivation of Dark Matter bounds