Abstract

- The Extra-galactic Unresolved Diffuse Emission contains anisotropies due to faint source emission

- The anisotropies of the Local $\gamma$-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 $\gamma$-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 $\sim 10^6$ 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


For a detailed analysis of the redshift dependence of the cross-correlation see:

Theoretical background

The correlation can be estimated by:

$$\xi(\theta) = \frac{\sum_{i,j} (n_x - \langle n_x \rangle)(n_{\text{Gal}} - \langle n_{\text{Gal}} \rangle)}{\sum_i f_x(\theta)} f_{\gamma}(\theta) = \begin{cases} 1 & 0 < \theta_1 < \theta < \theta_2 \\ 0 & \theta < \theta_1 \vee \theta > \theta_2 \end{cases}$$

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

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

The theoretical estimation of the correlation can be written \[^{[5]}\] as:

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

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

The \(\gamma\)-ray emission Window Function can be modeled from the \(\gamma\)-ray luminosity function of each unresolved component:

- Blazars
- mAGNs
- Star Forming Galaxies
- DM


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

2MPZ
- The mask is built in order to avoid possible systematics \[^{[6]}\] (Galactic dust extinction, stars, seeing and sky brightness)


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

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.tap.fr/~hivon/software/PolSpice
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

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.