Radio loud AGN contribution to the Extragalactic Gamma-Ray Background (EGRB)

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Abstract: The origin of extragalactic gamma-ray background (EGRB) detected by Fermi remains poorly understood even today. Unresolved point sources are potential contributors to this emission. Since most of the identified sources in the Fermi catalog are blazars, a significant contribution to the EGRB could come from unresolved blazars. In addition, Fermi has now detected several radio galaxies. According to the unification scenario, radio galaxies can be considered as misaligned blazars.Though jet emission falls rapidly with increasing jet inclination angle, considering the larger population of misaligned blazars compared to nearly-aligned ones, these sources are expected to contribute significantly to EGRB. Our aim is to analyze Fermi data to date on radio galaxies and model it to derive jet parameters and finally to derive the dependency of jet luminosity on inclination angle. Here we present the preliminary results of our work.

Origin of Extragalactic Gamma-ray Background (EGRB)

• Truly diffuse processes (Black hole evaporation, large scale structure formation, etc.)
• Unresolved point source origin
• Most of the identified Fermi sources: **Blazars** [1]. Fermi also detected 11 radio galaxies (**misaligned blazars**) [2].
• In order to find the contribution from any source class their luminosity function has to be constructed. We present the preliminary results of both blazars and misaligned blazars contribution to the EGRB.

Blazar Contribution

Assumptions and Inputs:
• BL Lacs and FSRQs are considered as separate source classes.
• First Fermi γ-ray catalog [1,3].
• Limiting flux is considered as 7E-8 ph cm^{-1} s^{-1} to have a complete sample [4], (81 FSRQs and 26 (18 with known redshift) BL Lacs).

$\frac{V}{V_{max}}$ test

• For BL Lac, $< \frac{V}{V_{max}} >$ = 0.57 $\pm$0.07
$\rightarrow$ No significant evolution
• For FSRQs, $< \frac{V}{V_{max}} >$ = 0.66$\pm$0.03,
$\rightarrow$ strong evolution.
We considered pure luminosity evolution and pure density evolution.

Pure luminosity evolution

$$L(z) = L_0 \times f(z) \qquad (1)$$

where L_0 is the luminosity at zero redshift and $f(z)$ is the luminosity evolution function.
Two types of evolution function($f(z)$):
• exponential (exp(T(z)/τ)), and
• power law (1+z)$^{\beta}$

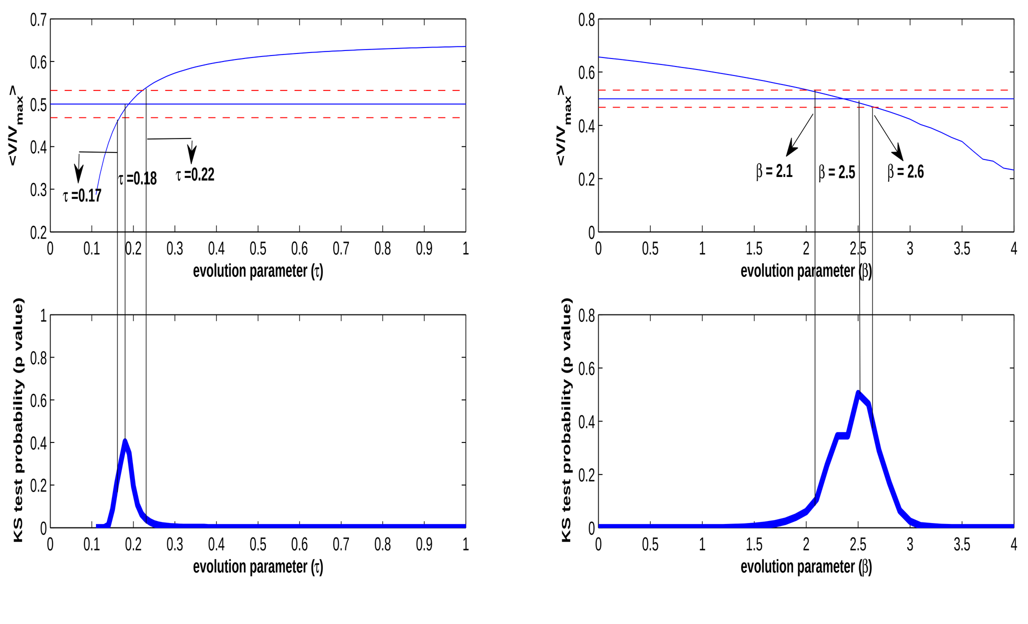

Fig.1 & Fig.2: Upper panel: Variation of $< \frac{V}{V_{max}} >$ with pure luminosity evolution parameter τ (exponential evolution function) and β (power law evolution function) respectively. Lower panel: Variation of KS test probability with evolution parameter τ and β respectively. The best fit parameter value: $\tau = 0.18^{+0.4}_{-0.1}$; $\beta = 2.5^{+0.1}_{-0.4}$

Pure density evolution

$$\phi(L,z) = \phi(L,0) \times g(z) \qquad (2)$$

where $\phi(L,z)$ is the luminosity function at redshift z and $g(z)$ is the density evolution function.
Two types of evolution function($f(z)$):
• exponential (exp(T(z)/τ)), and
• power law (1+z)$^{\beta}$

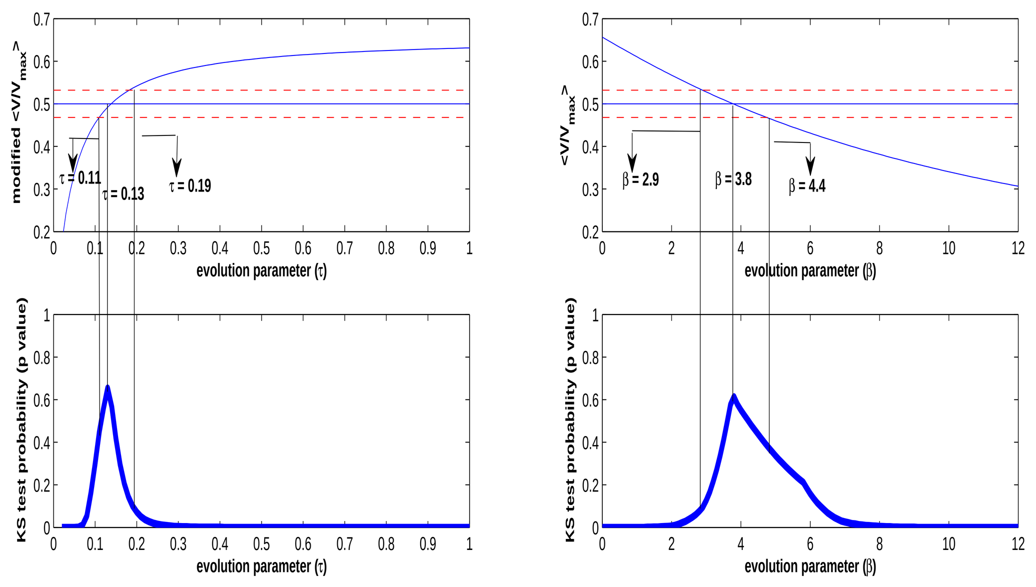

Fig.3 & Fig.4: Upper panel: Variation of $< \frac{V}{V_{max}} >$ with pure density evolution parameter τ (exponential evolution function) and β (power law evolution function) respectively. Lower panel: Variation of KS test probability with evolution parameter τ and β respectively. The best fit parameter value: $\tau = 0.13^{+0.6}_{-0.2}$; $\beta = 3.8^{+0.6}_{-0.9}$

In order to make a choice between pure density evolution and pure luminosity evolution one needs to compare the observed source distribution and the model source distribution (using the derived luminosity function and evolution function). Here, we restrict our discussion to pure luminosity evolution.

De-evolved luminosity function of FSRQs

$$\phi(L_0) = \frac{1}{dL_0}\sum_{i=1}^{N}\frac{1}{V_{max}(i)} \qquad (3)$$

• L_0 and $\phi(L_0)$ are de-evolved luminosity and luminosity function respectively.
• We used $\frac{1}{V_{max}}$ method to derive the luminosity function.

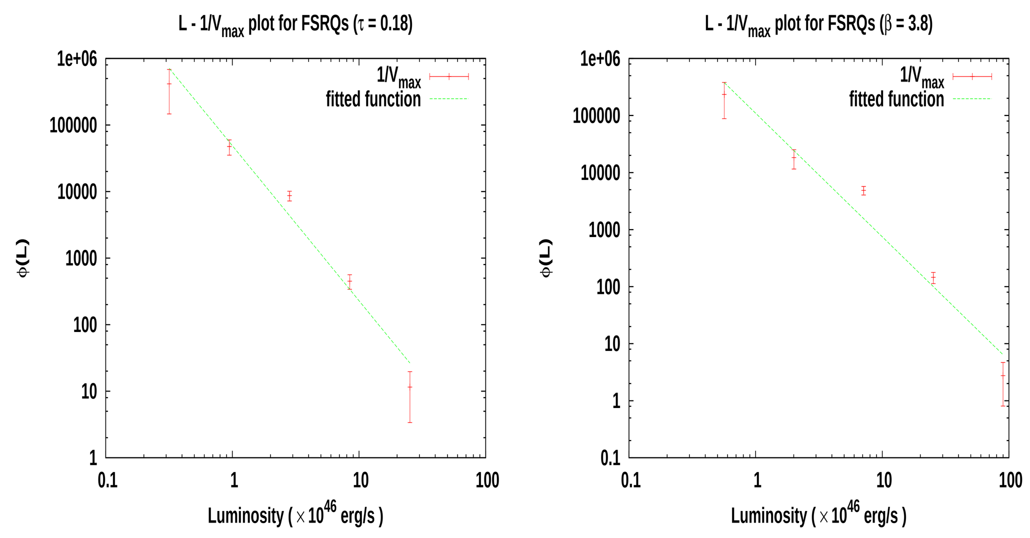

Fig.5 & Fig.6: De-evolved luminosity function for FSRQs from $\frac{1}{V_{max}}$ method. A single power law is fitted with index 2.3 ± 0.2 and 2.2 ± 0.2 for exponential and power law evolution model respectively.

We also constructed the luminosity function of BL Lacs using $\frac{1}{V_{max}}$ method.
In order to have a better constrained luminosity function we consider a broken power law luminosity function and use likelihood analysis to derive the model parameters. This work is in progress.

Misaligned blazar contribution

According to the Unification scenario, FSRQs are the sub class of FR II galaxies whereas, BL Lacs are the sub class of FR I galaxies. The AGN jet emission is expected to fall very rapidly with increasing jet to line-of-sight angle. Nevertheless, considering the large population of these misaligned blazars compared to nearly-aligned ones, these sources are expected to contribute significantly to EGRB. Fermi has already detected 11 misaligned blazars.
Approach One can consider that the observed jet luminosity can be written as

$$L(\theta) = L(0) \times \xi(\theta) \qquad (4)$$

where, θ is the jet to line-of-sight angle. From the knowledge of $\xi(\theta)$ one can in principle, estimate the contribution from off-axis AGNs to the EGRB.

Construction of $\xi(\theta)$

1. We model the SED of these 11 sources.
2. From the knowledge of these SED fittings and VLBI observations we fix the emission processes in the jet and other jet parameters and find the xi(theta) using our model and the Gamma distribution of FSRQs and BL Lacs.
3. From observation: From the observed gamma-ray luminosities of off-axis sources and their jet inclination angle one can construct the $\xi(\theta)$ from observation. The difference in the observed gamma-ray luminosities between two radio galaxies can arise from two different reasons:
a) due to their different jet to line-of-sight angle,
b) due to their different intrinsic luminosities. If one considers that the total radio luminosity is a tracer of unbeamed luminosity, then after an appropriate scaling one can construct the $\xi(\theta)$ from the scaled gamma-ray luminosities and the jet inclination angles of off-axis sources.
We have initiated this work. Our aim is to analyze Fermi data to date on radio galaxies and model it to derive jet parameters. We have completed the analysis and the SED modeling of 3C111 and 3C120.

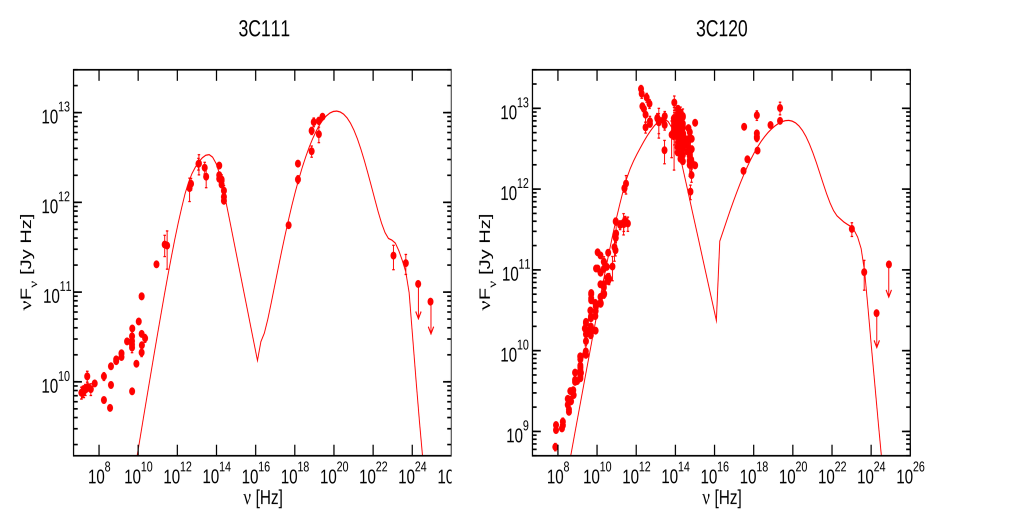

Fig.7 & Fig.8: SED modeling of misaligned blazars 3C 111 and 3C 120 respectively. Both the sources are well fitted with simple SSC emission model. The bulk Lorentz factor (Γ) is also ~5 for both the sources.

Future plan of work

1. SED fitting of all detected off-axis sources.
2. Construct $\xi(\theta)$ from model.
3. Calculate the scaled gamma-ray luminosities for more on-axis sources (both for FR I and FR II) galaxies and construct the $\xi(\theta)$ observationally. Finally from the knowledge of $\xi(\theta)$ we will estimate the contribution from the radio galaxies to the EGRB.

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References:

[1] Abdo, A.A. et al. 2010a, ApJS, 188, 405.
[2] Abdo, A.A. et al. 2010b, ApJ, 720, 912.
[3] Abdo, A.A. et al. 2010c, ApJ, 715, 429.
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