Contribution of Gamma-ray Loud Radio Galaxies to the Extragalactic Gamma-ray Background Radiation

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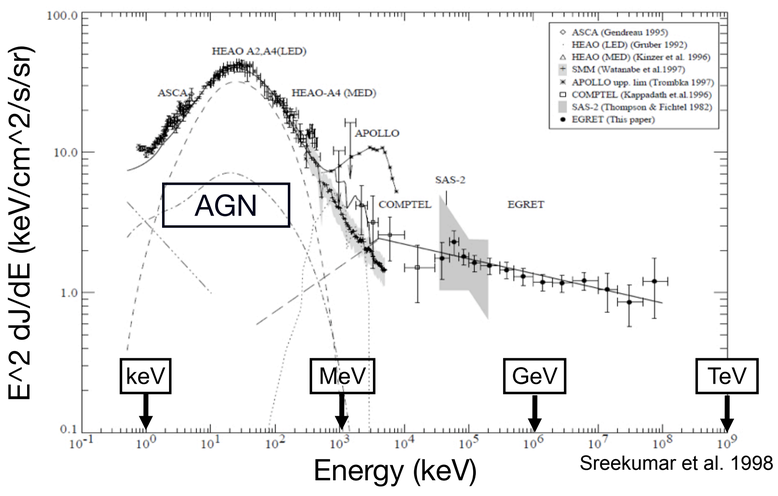
The Fermi gamma-ray satellite has recently detected gamma-ray emissions from radio galaxy cores. From these samples, we first examine the correlation between the luminosities at 5 GHz and at 0.1-10 GeV of these gamma-ray loud radio galaxies. We find that the correlation is significant based on a partial correlation analysis. Using this correlation and the radio luminosity function (RLF) of radio galaxies, we further explore the contribution of gamma-ray loud radio galaxies to the unresolved extragalactic gamma-ray background (EGRB). The gamma-ray luminosity function is obtained by normalizing the RLF to reproduce the source count distribution of the Fermi gamma-ray loud radio galaxies. We find that gamma-ray loud radio galaxies will explain ~25% of the unresolved Fermi EGRB flux above 100 MeV and will also make a significant contribution to the EGRB in the 1-30 MeV energy band. Since blazars explain 22% of the EGRB above 100 MeV, radio loud active galactic nuclei (AGNs) population explains ~47% of the unresolved EGRB. We further make an interpretation on the origin of the EGRB. The observed EGRB spectrum at 0.2-100 GeV does not show an absorption signature by the extragalactic background light. Thus, the dominant population of the origin of EGRB at very high energy (>30 GeV) might be nearby gamma-ray emitting sources or sources with very hard gamma-ray spectrum.

1:Extragalactic Gamma-ray Background (EGRB)



Sreekumar et al. 1998

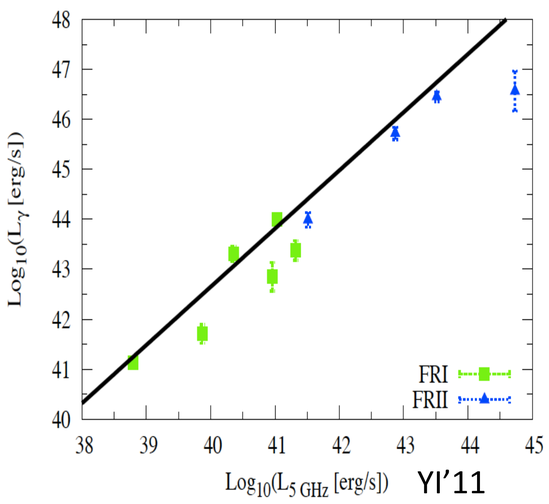
- It is thought that blazars are would make a significant contribution to the EGRB (see e.g. YI & Totani '09).
- Recent study based on Fermi result shows that blazars explain ~22% of EGRB (Abdo+'10, see the talk by Ajello).

- ***~78% of EGRB is still unknown.***
- Various candidates have been suggested
  - Radio quiet AGNs (YI, Totani, & Ueda '08)
  - Starburst galaxies (Fields+ '10, Makiya+'11)
  - Dark matter annihilation/decay (Ando+'07)

2:A New Promising Candidate: Gamma-ray Loud Radio Galaxy

- Fermi detected 11 radio galaxies (Abdo+'10)

Correlation between Radio & Gamma-ray Luminosities



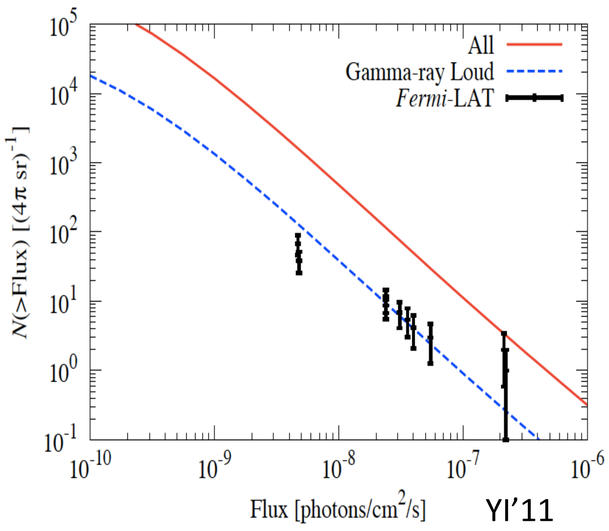
YI'11

- Radio galaxies would also contribute to EGRB
  - Gamma-ray luminosity function (GLF) is required.
  - but, too few samples.
  - Radio luminosity function is well studied (Willot+'01)
  - Gamma-ray and radio luminosities are well correlated.

$$L_\gamma \propto L_{5\mathrm{GHz}}^{1.16}$$

  - similar to that of blazars.
- GLF is determined using the luminosity correlation and RLF.

3:Source Count Distribution

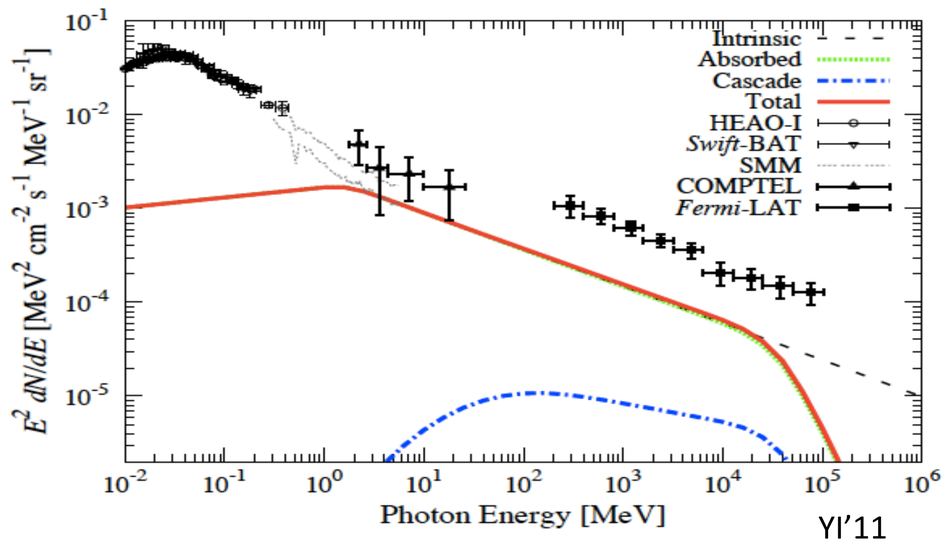


YI'11

- Willot +'10 RLF is adopted in our model.
- GLF is normalized to the number of Fermi radio galaxies.
  - Detection efficiency of Fermi-LAT is corrected following Abdo +'10.
- Gamma-ray loud population is ~8 % of radio galaxies.

4:EGRB from Radio Galaxies

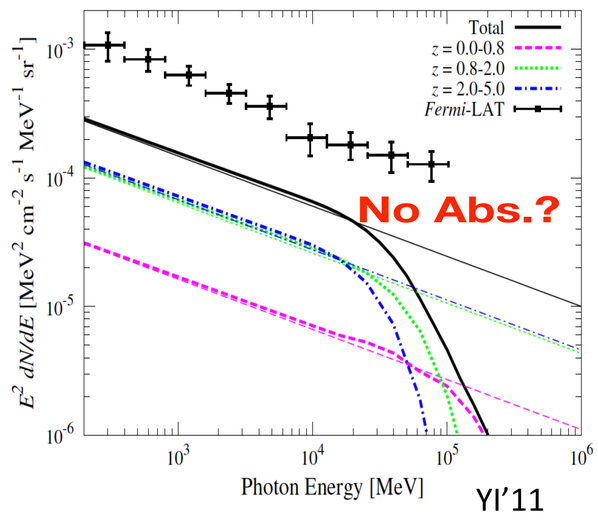
EGRB Spectrum from Radio Galaxies



YI'11

- A broken power-law SED is assumed. Average photon index of radio galaxies is adopted.
- For EBL model, we use Finke+'10.
- EBL absorption and cascade emission are included.
- ~25 % of "unresolved" Fermi EGRB will be explained by radio galaxies.
- Due to small sample size, there is a factor of ~2.5 uncertainty.
- ~47% of "unresolved" Fermi EGRB will be explained by radio loud AGNs, 22% from blazars and 25 % from radio galaxies.

5:Implication to the origin of EGRB



YI'11

- No EBL absorption signature in the Fermi EGRB spectrum up to 100 GeV.
- Cosmological sources (AGN and cosmic star formation rate) have their evolution peak at z~1-2 (Ueda +'03, Hopkins & Beacoms '06).
- EBL models predict that optical depth is ~1 at 100 GeV for z=1 (Kneiske+'04, Franceschinie+'08, Gilmore+'09, Finke+'10)
- Nearby sources or sources with hard spectrum?
- EGRB information at higher energy is required. Fermi and CTA observation will be keys to understanding this.

6:Conclusion

- Radio & Gamma-ray luminosities of radio galaxies are correlated.
- ~8% of radio galaxies are the gamma-ray emitting population
- ~25% of the unresolved EGRB would be explained by radio galaxy population.
- Radio loud AGN population (blazars & radio galaxies) can account of ~50% of the unresolved EGRB.