Detecting the EBL Attenuation of Blazars with GLAST

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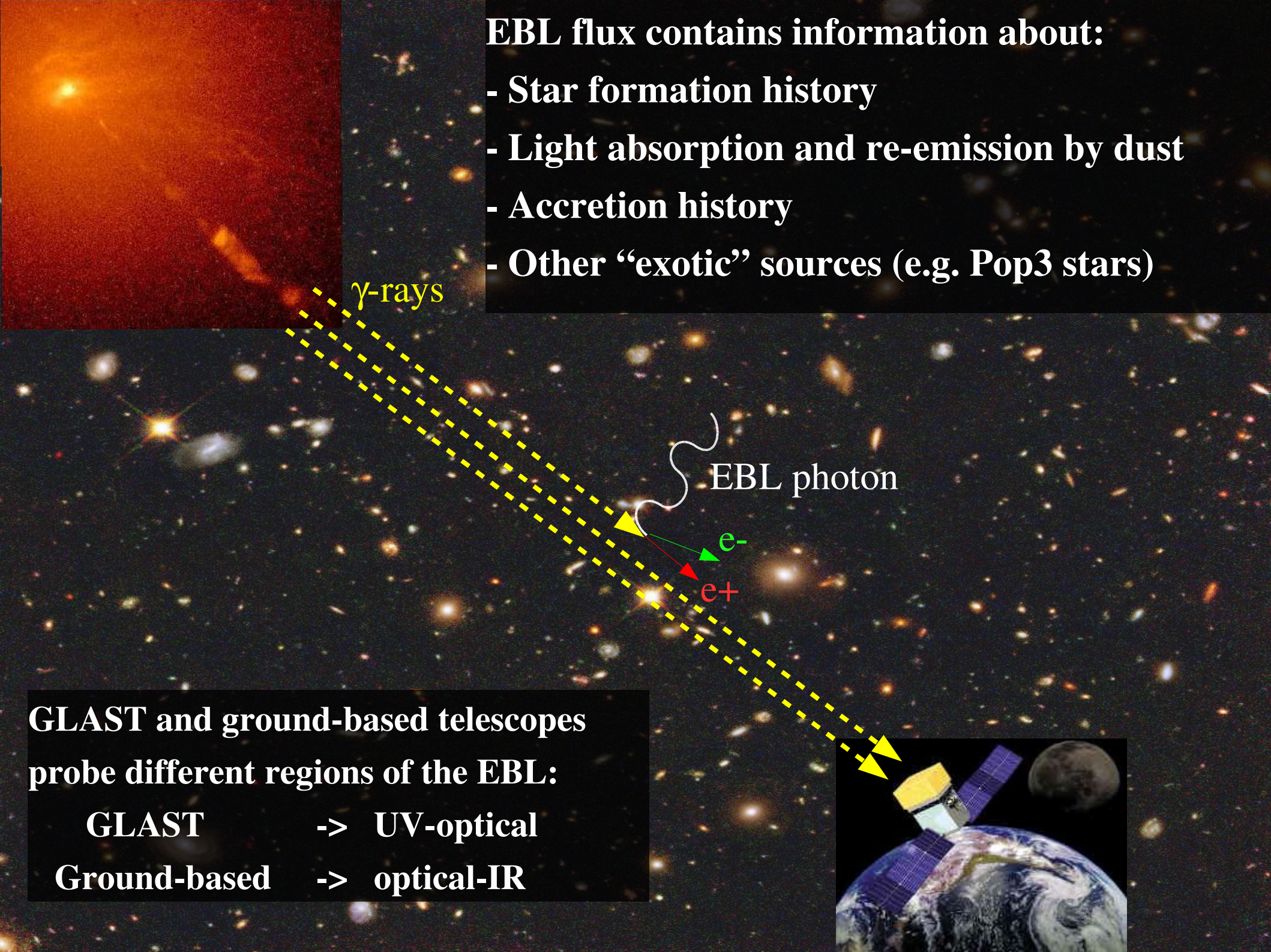
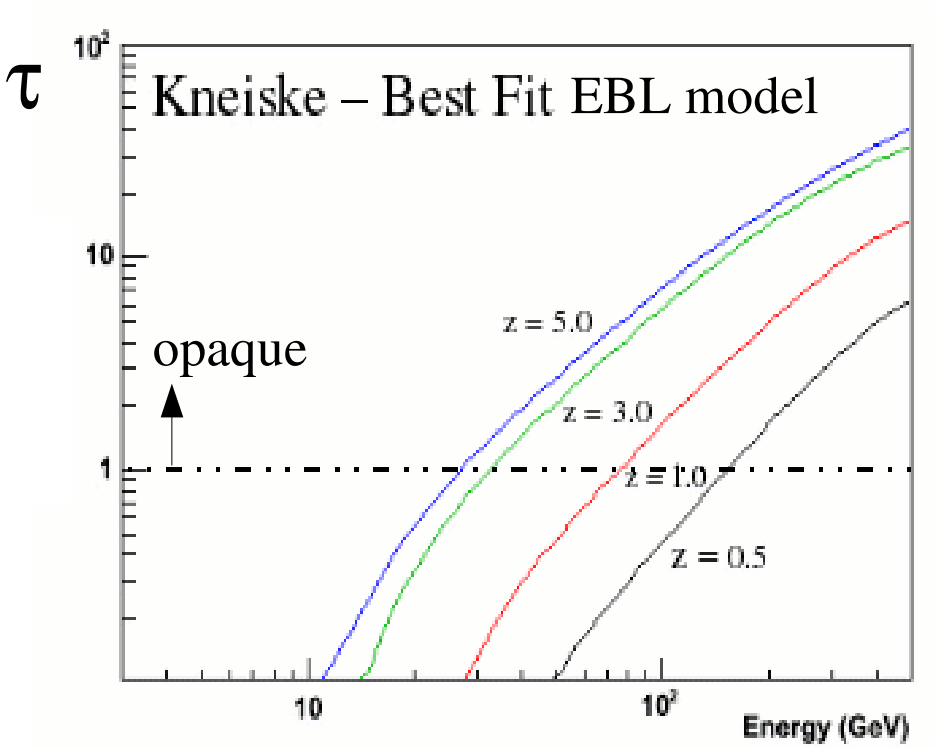

EBL flux contains information about:
- Star formation history
- Light absorption and re-emission by dust
- Accretion history
- Other "exotic" sources (e.g. Pop3 stars)
γ-rays
EBL photon
e-
e+
GLAST and ground-based telescopes
probe different regions of the EBL:
GLAST -> UV-optical
Ground-based -> optical-IR

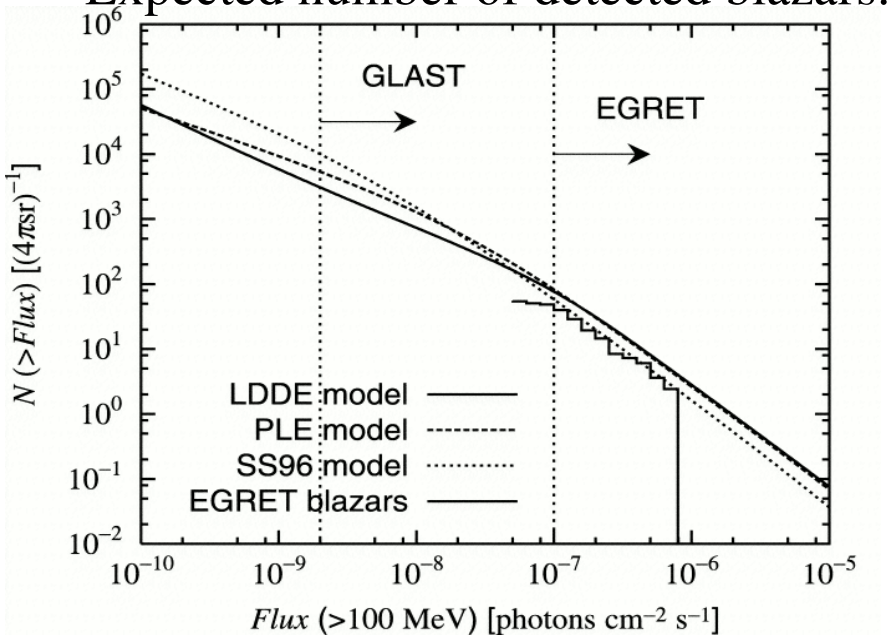
EBL Attenuation



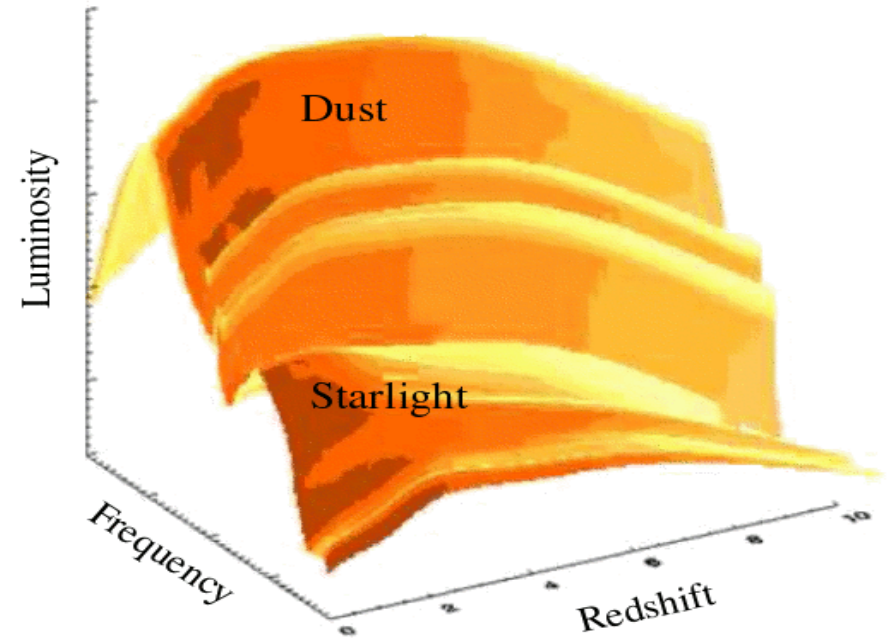
- Only $e^{-\tau}$ of the original flux is observed
- The attenuation is strongly energy dependent:
  - universe is transparent to γ-rays with energy < 10 GeV
  - universe is highly opaque to γ-rays with energy > 1 TeV
- Gamma-ray instruments with energy threshold well below 100 GeV are needed to detect high-redshift sources

The impact of GLAST on EBL studies

Expected number of detected blazars:



Narumoto & Totani (2006)



- In general, GLAST's improved performance with respect to EGRET will lead to more and better understood blazars

- GLAST-detected blazars will be distributed over a wide range of redshifts, thus GLAST will probe the evolution of the EBL.

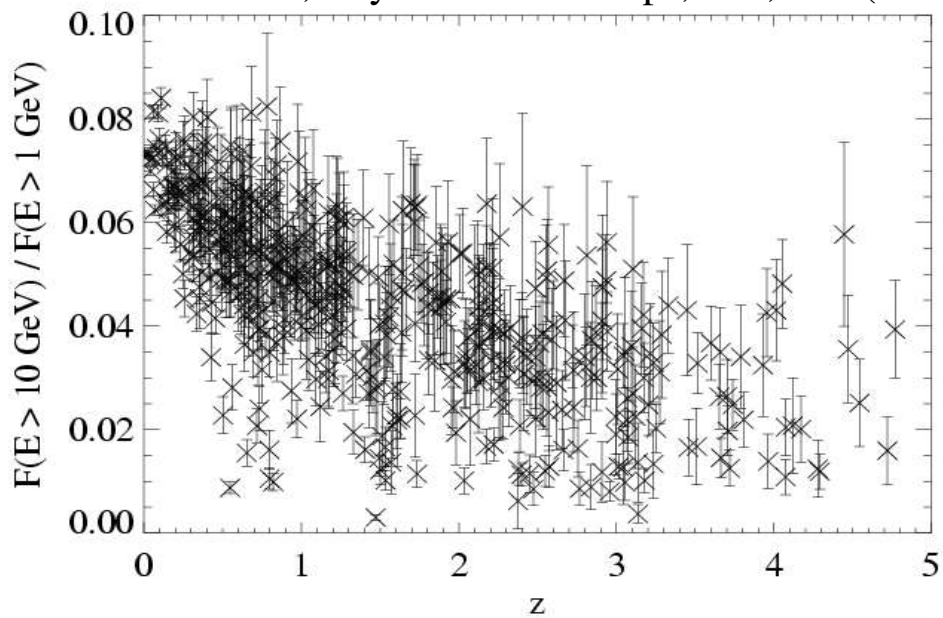
For the first time: study the systematic effect of EBL attenuation in a large number of sources

Method 1: Flux-ratio

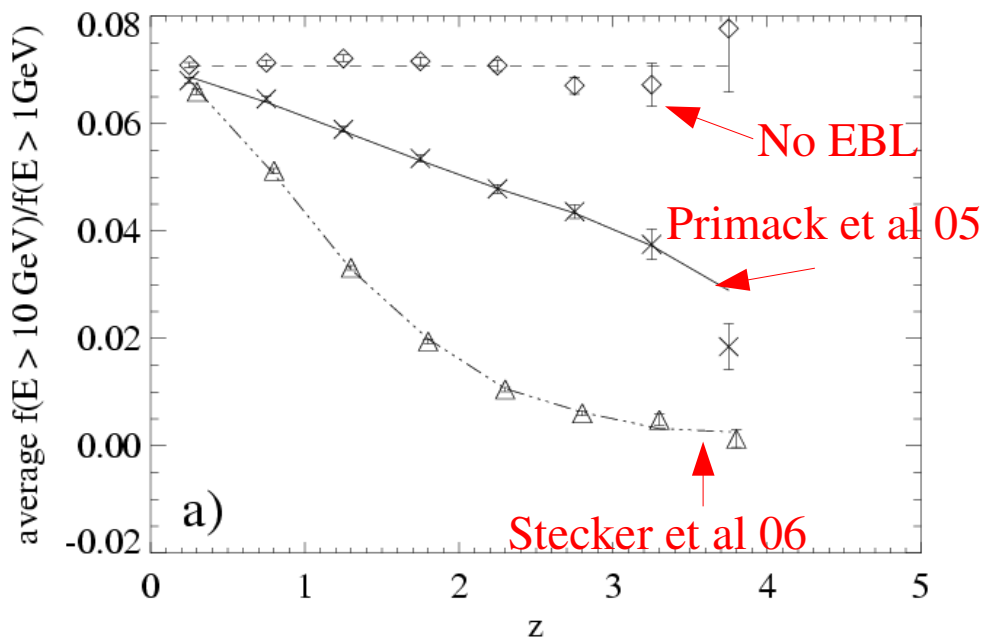
To measure the attenuation of γ-ray emission by EBL absorption the following ratio is calculated:

$$\frac{F\,(E\,>\,10\,GeV)}{F\,(E\,>\,1\,GeV)}$$

Chen, Reyes and Ritz. ApJ, 608, 686 (2004)

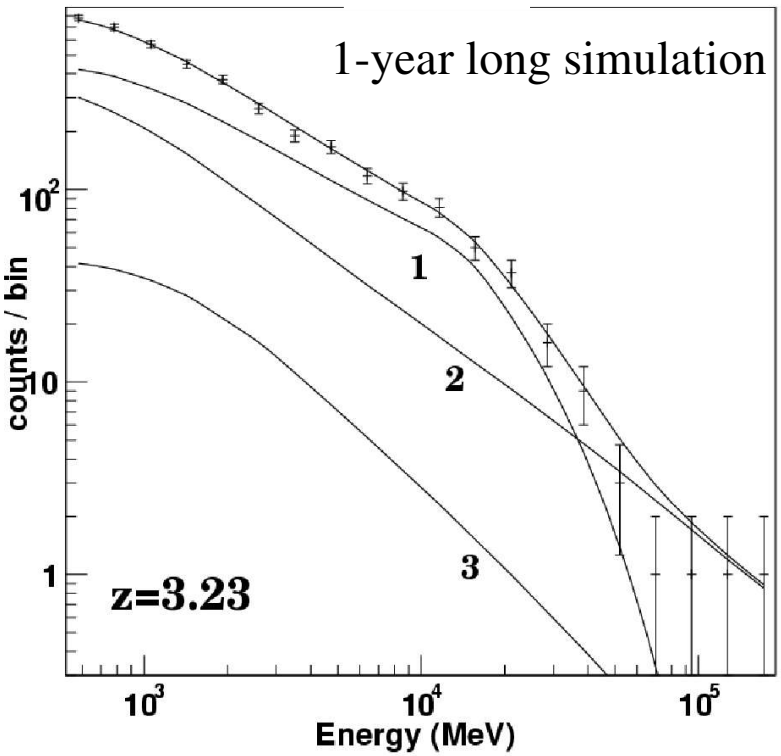


- The effects of EBL attenuation are evident
- The technique can distinguish between different EBL models
- If sources are available, EBL absorption can probe the high-redshift universe.



Method 2: Spectral Analysis of bright blazars

Blazar spectrum in "LAT space" (photon counts):

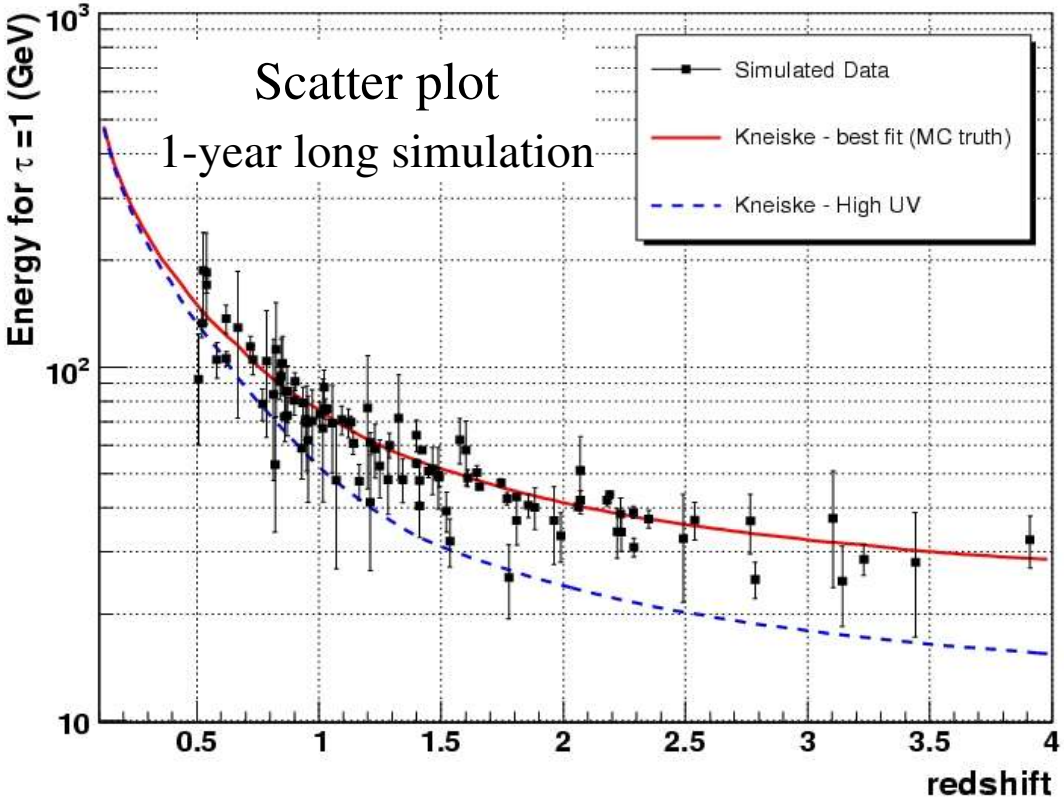


1. Blazar spectrum with exponential cutoff
2. Extragalactic diffuse
3. Galactic diffuse

- The blazar spectrum is assumed to be a simple power law times a modified exponential cutoff:

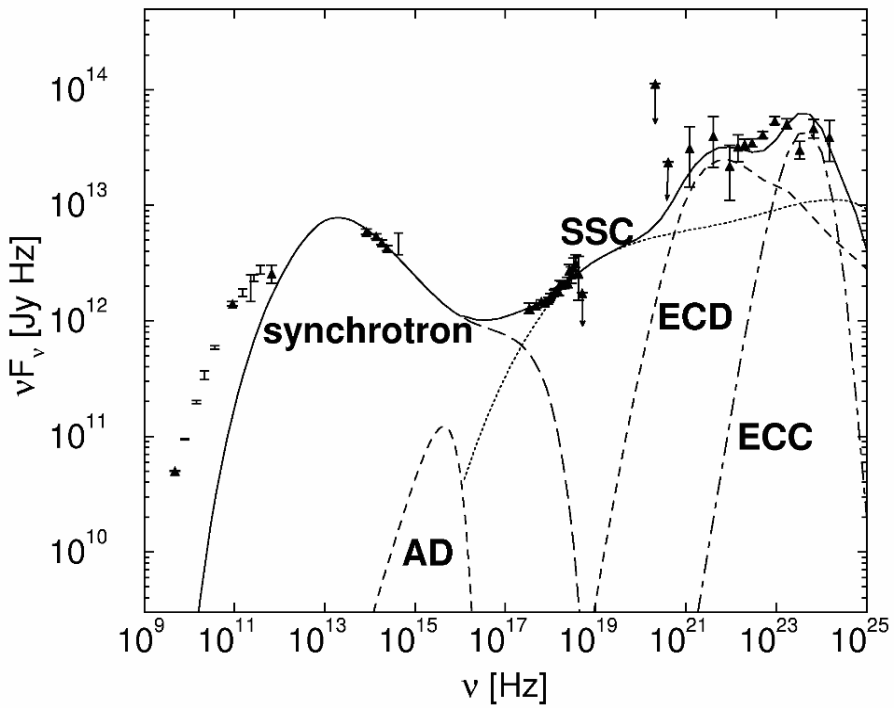
$$\mathrm{Exp}[\,-(E - E_b)/P_1]; \quad \text{if } E > Eb$$

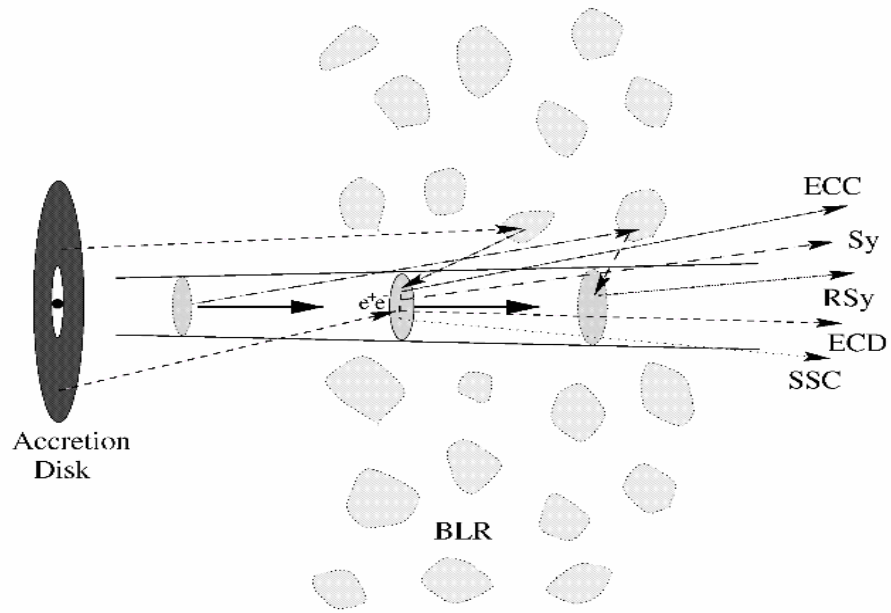
- It is simple and sensitive to steepening in the spectra of bright to moderately bright blazars



EBL studies with multiwavelength observations

Boettcher et al 2001





- Complete knowledge of the intrinsic spectrum of just one blazar is enough to measure the EBL attenuation.
- Contemporaneous multiwavelength observations combined with blazar emission models can be used to calculate the intrinsic spectrum. How much can the models be trusted?

Caveats

- Sources of bias:
  - Selection effects:

    - Source misidentification (or lack of identification)

    - Internal absorption could be more common in high luminosity sources:

    high luminosity $\stackrel{?}{=}$ *high accretion rate -> strong radiation fields* $\stackrel{?}{\rightarrow}$ *intrinsic absorption*

  - Blazar variability:

    spectral variability could lead to a bias in the energy cutoff determination

    different flaring states of the same blazar -> same cutoff energy? (cross check)

  - Blazar evolution could mimic EBL attenuation:

    Did blazars in the early universe suffer more internal absorption?

- Redshift determination:

  - Measuring the redshift of thousands of blazars is a formidable task

Detecting the EBL attenuation of blazars with GLAST: Conclusions

- Under reasonable assumptions, GLAST will measure the EBL attenuation of blazars and thus, probe the optical-UV EBL

- The large number of GLAST-detected blazars would allow a new approach to EBL studies: systematic attenuation as a function of redshift

- If enough sources are observationally available at high redshifts ($z>3$), EBL attenuation of distant gamma-ray sources could become a cosmological probe of the early processes of star formation

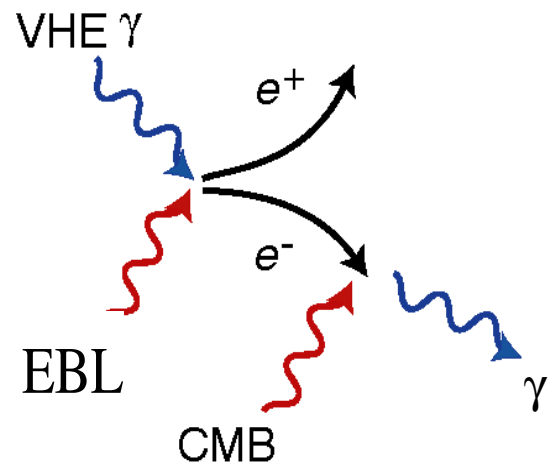
- Blazar evolution could mimic the effect of EBL attenuation and thus, needs to be considered. GLAST observations in any case will provide an important constraint

Related EBL Phenomena

- EBL attenuation of gamma-ray bursts (GRBs)
  (same EBL, but different sources and systematics)

- Effects of the EBL attenuation on the gamma-ray extragalactic diffuse (spectral steepening of the diffuse is expected... how much will tell us about its origin)

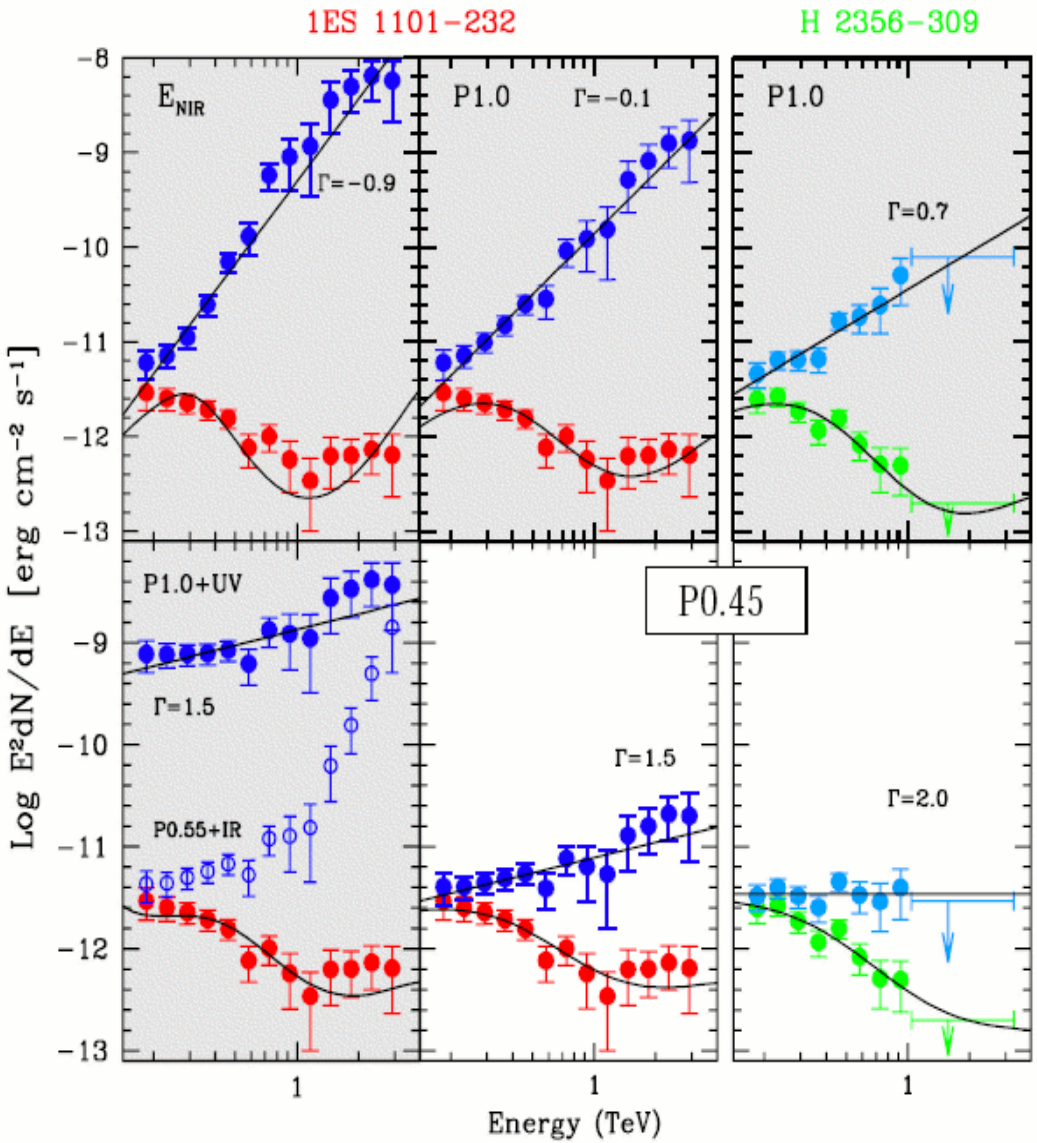
- Gamma-ray cascades:
  (Dai et al 2002, Aharonian, Coppi, Volk 1994)
  - could become a probe of the intergalactic magnetic field and UHE gamma-ray universe
  - All of these at the end is dumped into the extragalactic diffuse

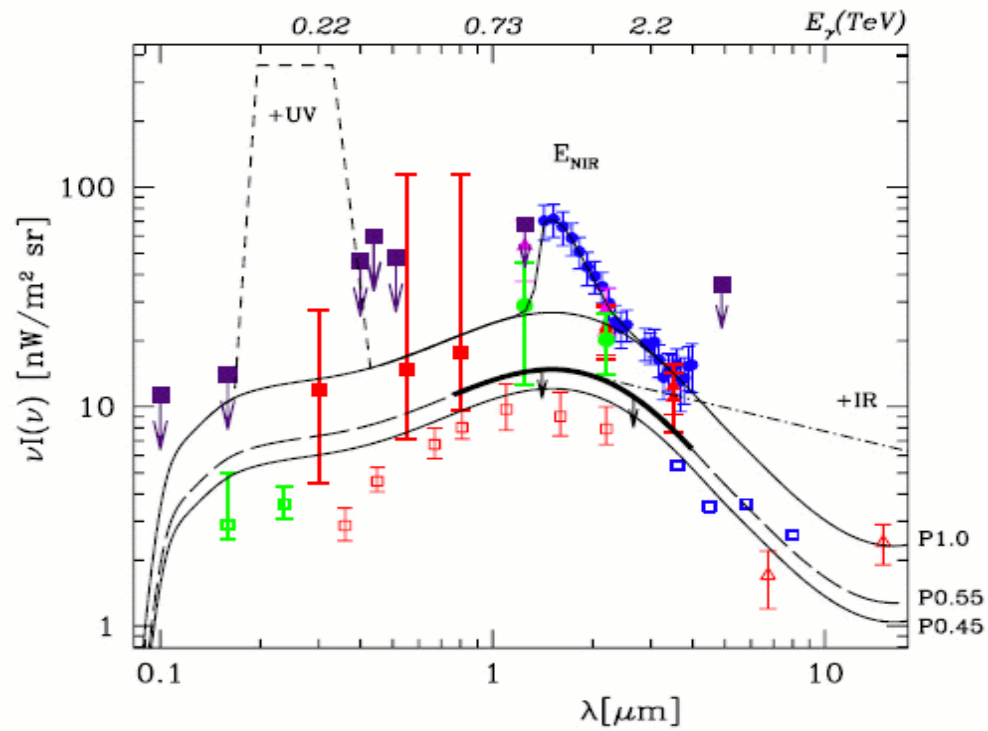


BACKUP SLIDES

HESS' measurement of EBL density

Aharonian et al (astroph 050873)





- HESS' premises:
  - Blazar spectrum with $\Gamma \geq 1.5$
  - EBL peaks around 1-2 μm
- Results:

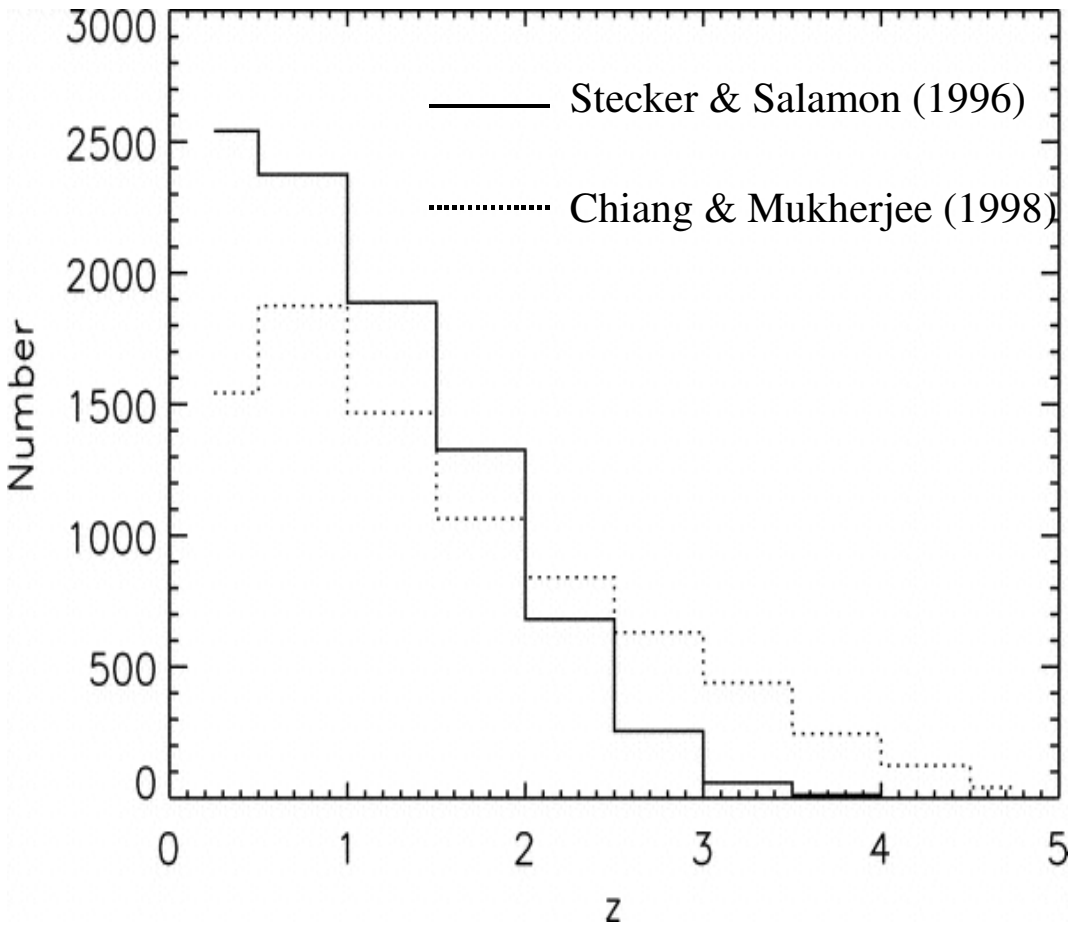
$$\text{EBL} < (0.45 + 0.1 \pm 0.1 \pm 0.05) \times \text{P1.0}$$

EBL evolution (Primack's model)

Stat and Sys Errors

15% Energy Res.

Expected number of GLAST-detected blazars

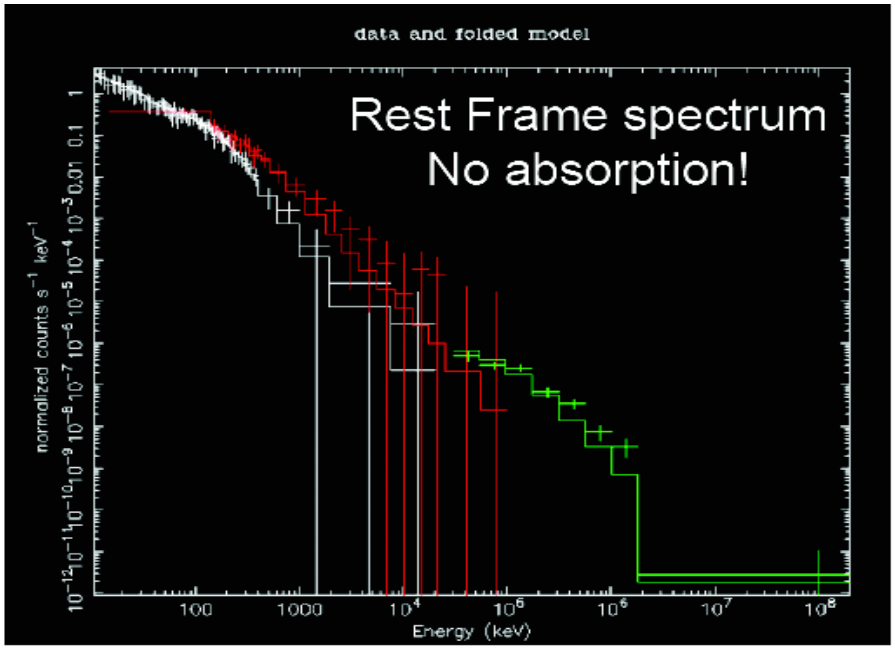


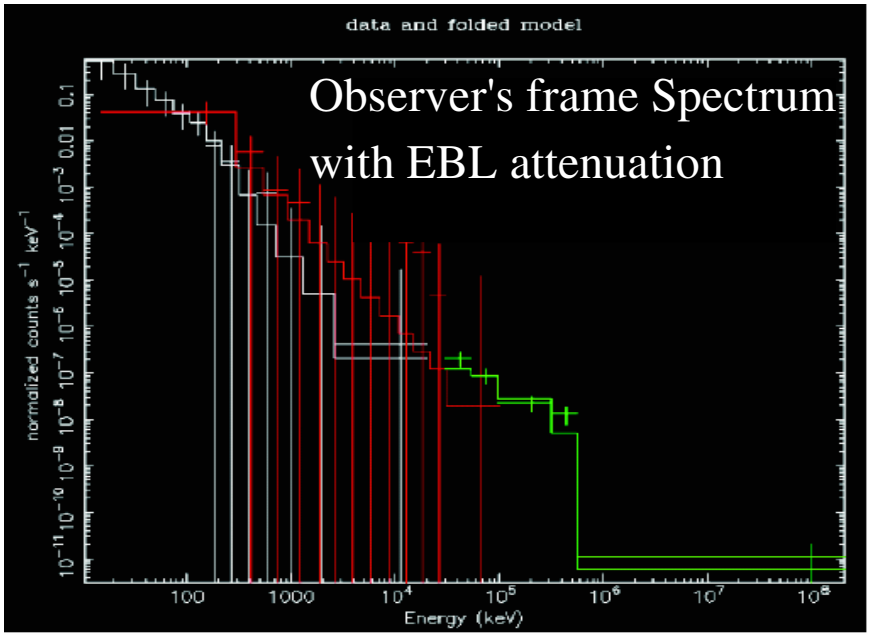
- A luminosity function describes the distribution of astrophysical objects as a function of redshift and luminosity.
- Blazar luminosity function is "known" at the very high luminosity end from EGRET observations (about ~100 blazars)
- Reasonable extrapolations predict that GLAST will detect thousands of blazars.
- Predictions from the literature are used here, however this is something that GLAST will measure (extremely important measurement by itself)

EBL and GRBs

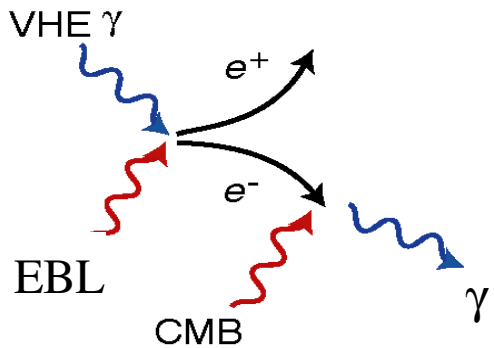
- GRBs and blazars experience the same EBL attenuation!
- GRBs at very high redshift z > 6 are expected to be quite common. Quite cool since that extends the redshifts that GLAST might be able to probe
- To use GRBs to probe the EBL one requires a significant number of photons with energy > 10 GeV. How is the high energy part of the spectrum like for GRBs?
- How many GLAST detected GRBs are going to have measured redshift?

GRB 050904 (z=6.3) simulated by Nicola Omodei: (Bottom line, not enough photons with E > 10 GeV)





Cascades from EBL interactions



Relevant physical quantities:

- gamma-ray spectrum of the source
- Intergalactic Magnetic Field
- EBL spectra

Possible scenarios:

- VHE γ rays are absorbed quickly by the EBL and the direction of the resulting pair is randomized by the magnetic field (if strong enough ~10^{-9} G). Compton-upscatter photons are emitted isotropically (Aharonian, Coppi & Volk, 1994)
  - EM halo is formed around the sources
  - Off-axis radio-loud galaxies become candidates for faint γ-ray emission
  - Many halos overlapping will contribute to the ExtraGalactic Diffuse γ emission.

- If the original γ rays are absorbed over cosmological distances (E < 100 GeV) then the observer might be inside the halo, therefore contributing to the ExGal Diffuse)

- γ rays are absorbed by the EBL but the magnetic field is not strong enough (~10^{-17} G) to randomize the direction of the e-pair. Secondary GeV emission will follow the original TeV emission with some delay due to angular spreading time (Dai et al, 2002)