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The Absorption Feature of the Collective Spectrum of Unresolved Blazars

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Workshop on Contributions of High-energy Astrophysics Experiments to Cosmology

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Attenuation at the Highest Energies of the EGRB

- Gamma rays of energies >20 GeV suffer attenuation due to interactions with the EBL (IR/Opt./UV - dust; starlight in ordinary galaxies)
- Cascades - Primary interactions
  - e^+e^- pair production
  - inverse Compton scattering of cascade electrons
- For a cosmological population - spectrum should exhibit a suppression at the high energy part of the EGRB and an enhancement at the lower energy part

  - How sensitive is the shape of this feature to the inputs (i.e. model of the EBL; spectral index distribution; gamma-ray luminosity functions)?

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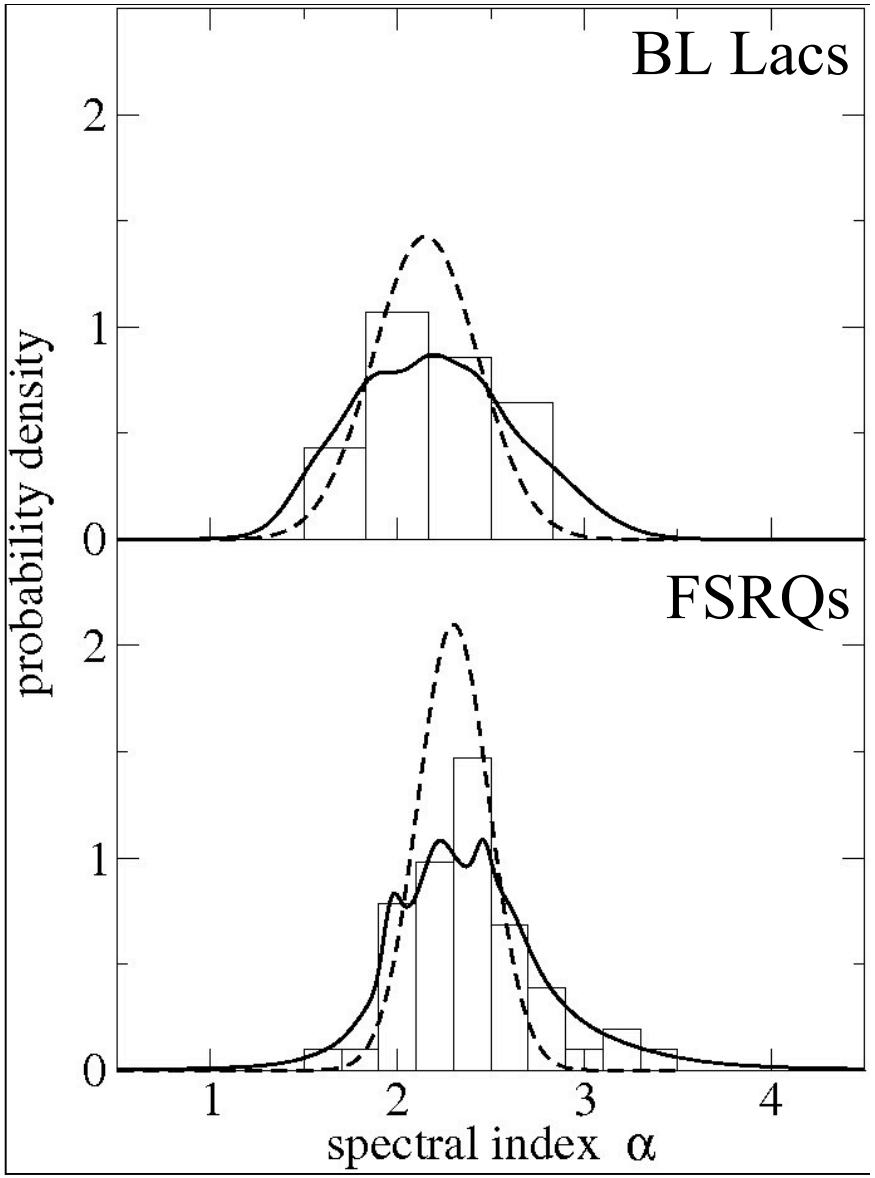
Past Work

Blazar spectral indices form a distribution (SID - spectral index distribution) with some spread (Stecker & Salamon 1996)

Affects the blazar contribution to the EGRB → concavity of the spectrum



$$p(\alpha) = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{\sigma_i\sqrt{2\pi}}e^{-\frac{(\alpha-\alpha_i)^2}{2\sigma_i^2}}$$

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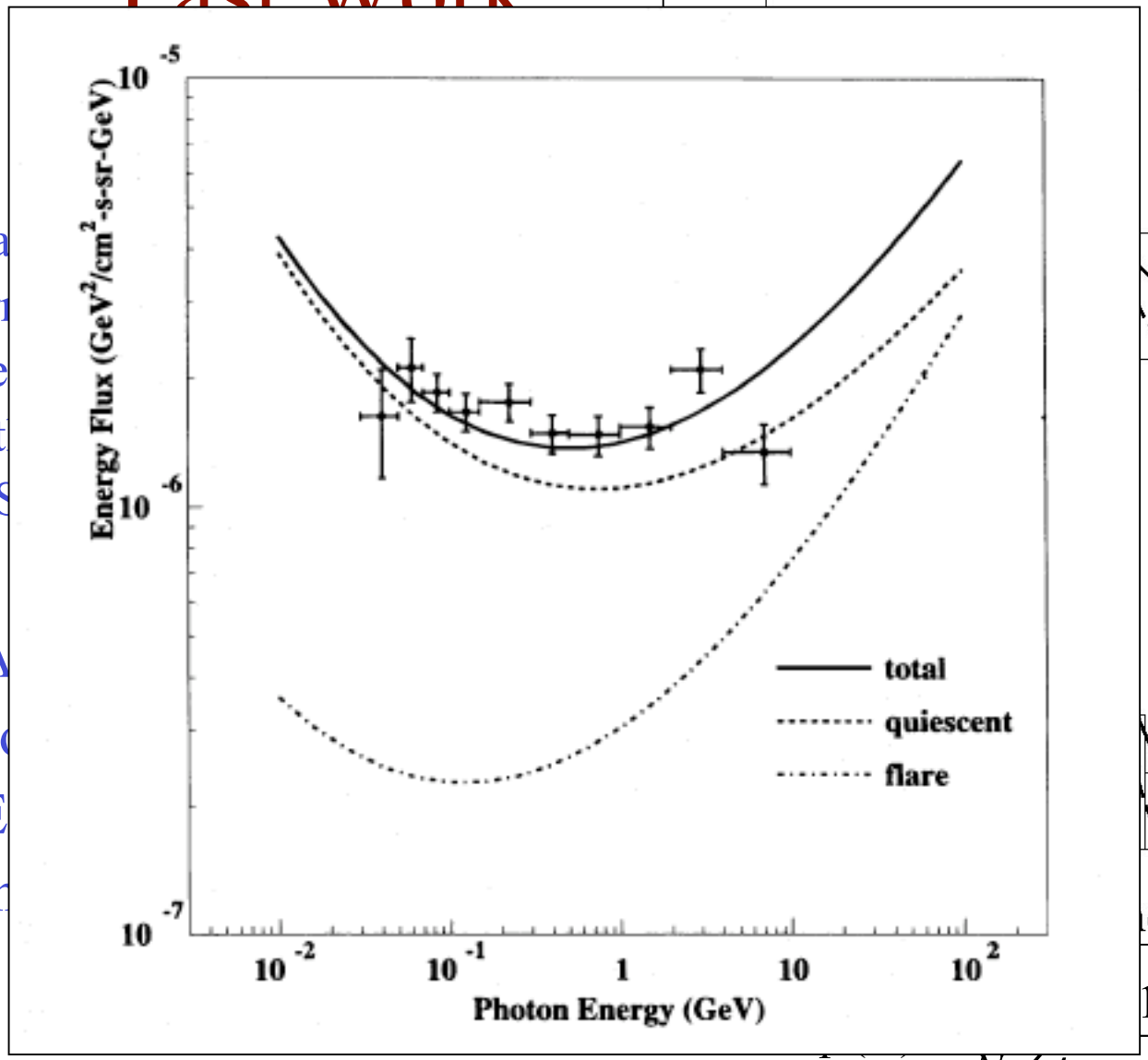
Past Work



$$N \sum_{i=1} \frac{1}{\sigma_i \sqrt{2\pi}} e^{-\frac{(\alpha-\alpha_i)^2}{2\sigma_i^2}}$$

Must carefully treat spectral index measurement errors!!!

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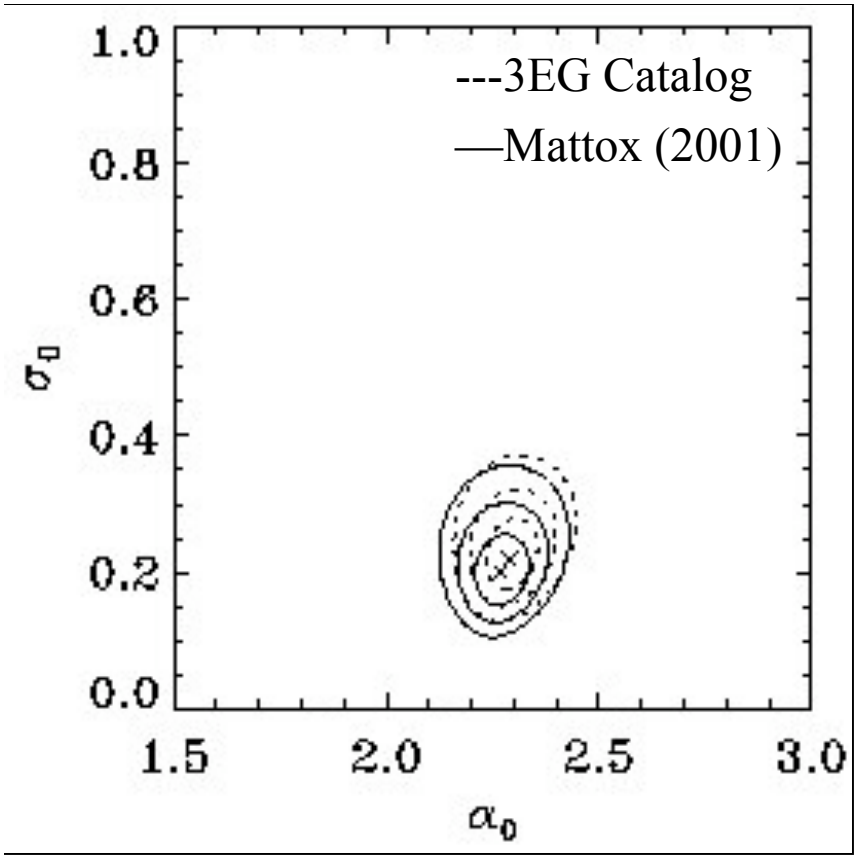

Spectral Index Distribution - The Maximum Likelihood Approach

$$P(x_i \mid y_j) \propto P(x_i) \times \mathcal{L}(y_j \mid x_i)$$

$$\mathcal{L} = \prod_{j=1}^{N} l_j$$

$$l_j = \int d\alpha \frac{\exp[-(\alpha - \alpha_j)^2 / (2\sigma_j{}^2)]}{\sqrt{2\pi}\sigma_j} \frac{\exp[-(\alpha - \alpha_0)^2 / (2\sigma_0{}^2)]}{\sqrt{2\pi}\sigma_0}$$

$$\mathcal{L} = \left(\prod_{j=1}^{N} \frac{1}{\sqrt{\sigma_0{}^2 + \sigma_j{}^2}} \right) \exp\left[-\frac{1}{2} \sum_{j=1}^{N} \frac{(\alpha_j - \alpha_0)^2}{\sigma_0{}^2 + \sigma_j{}^2} \right]$$

TMV & Pavlidou 2007

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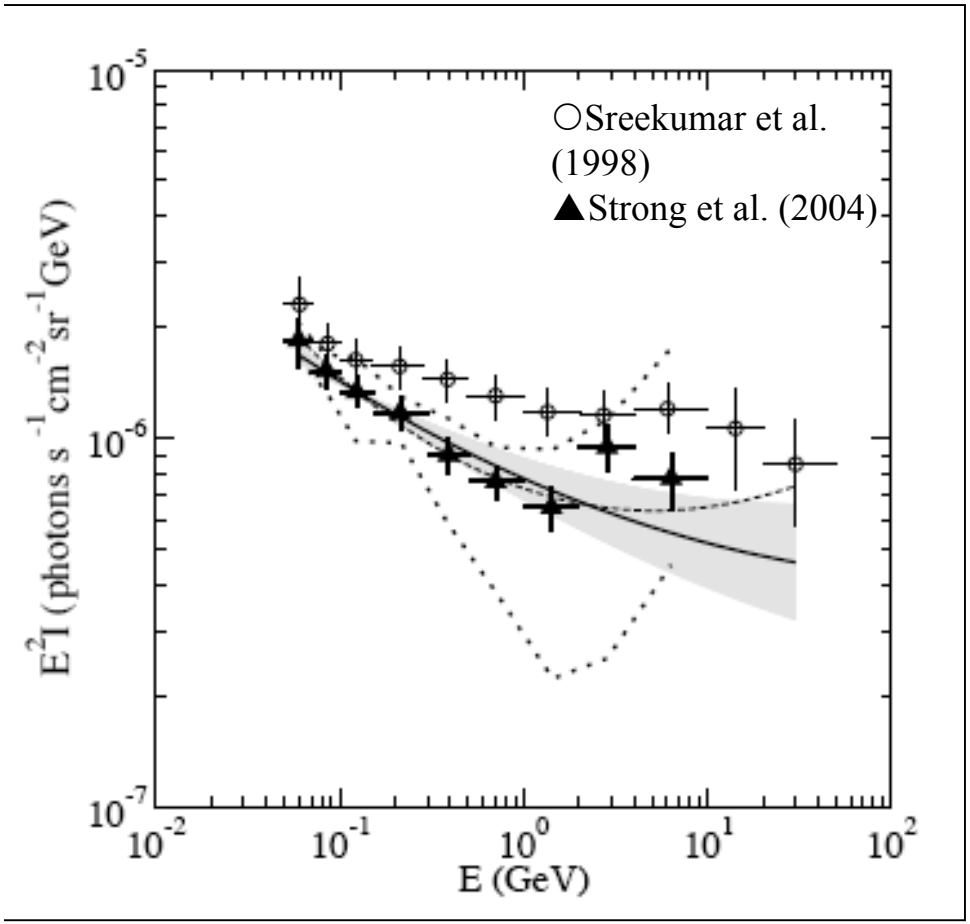
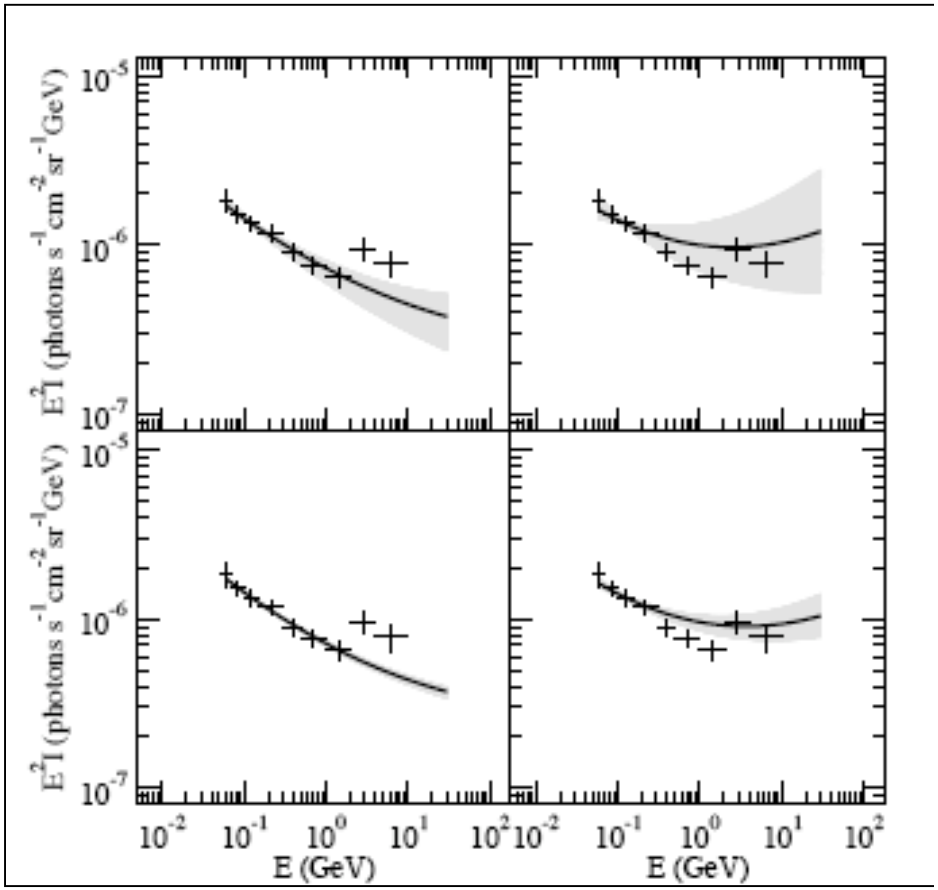
The Spectral Shape of Blazars





Shape only!!!

Pavlidou & TMV 2008

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Not the Whole Story…

- Include cascade effects
  - Absorption at higher energies
  - Enhancement at lower energies
- Systematic Effect - Flux-limited sample - biased towards harder spectral indices
  - Easier to see low-luminosity, high-redshift objects if the spectra are hard (more photons in the energy range of telescope)
  - Correction depends on GLF

TMV, Reyes, & Pavlidou 2008
TMV & Pavlidou 2008

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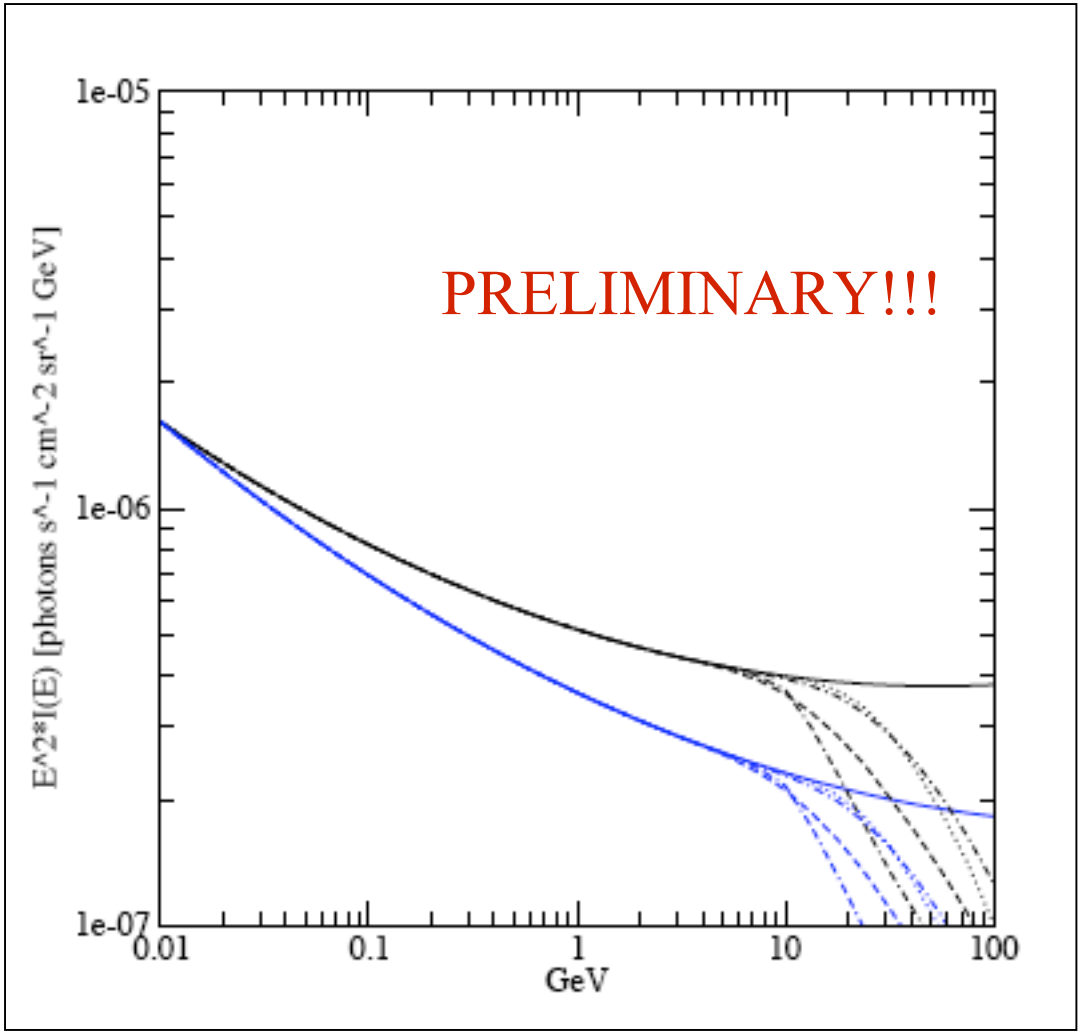
Shape + Absorption



TMV, Reyes, & Pavlidou 2008

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Conclusions

- Spectral indices of blazar form a distribution - dictates shape of the blazar contribution to the EGRB
- Absorption at the highest energies due to pair production - downturn in the spectrum (*this work*); cascades - pile-up at lower energies (*work in progress*)
- Resulting shape - depends on EBL model, blazar spectral indices, & blazar gamma-ray luminosity function (*work in progress*)

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