
# H.E.S.S. Blazar Observations: Implications for EBL Models and GLAST

**Jim Chiang**
**GLAST SSC/ UMBC**

# Outline

- H.E.S.S. Observations
- Semi-Analytic Models – a handle on the astrophysics imprinted on the EBL (extragalactic background light)
  - $\Lambda$CDM and large scale structure
  - Galaxy formation
  - Star formation
- Measuring the EBL
  - Galaxy counts
  - Absolute photometry
  - $\gamma\gamma$ attenuation
- What can GLAST tell us?
- Conclusions

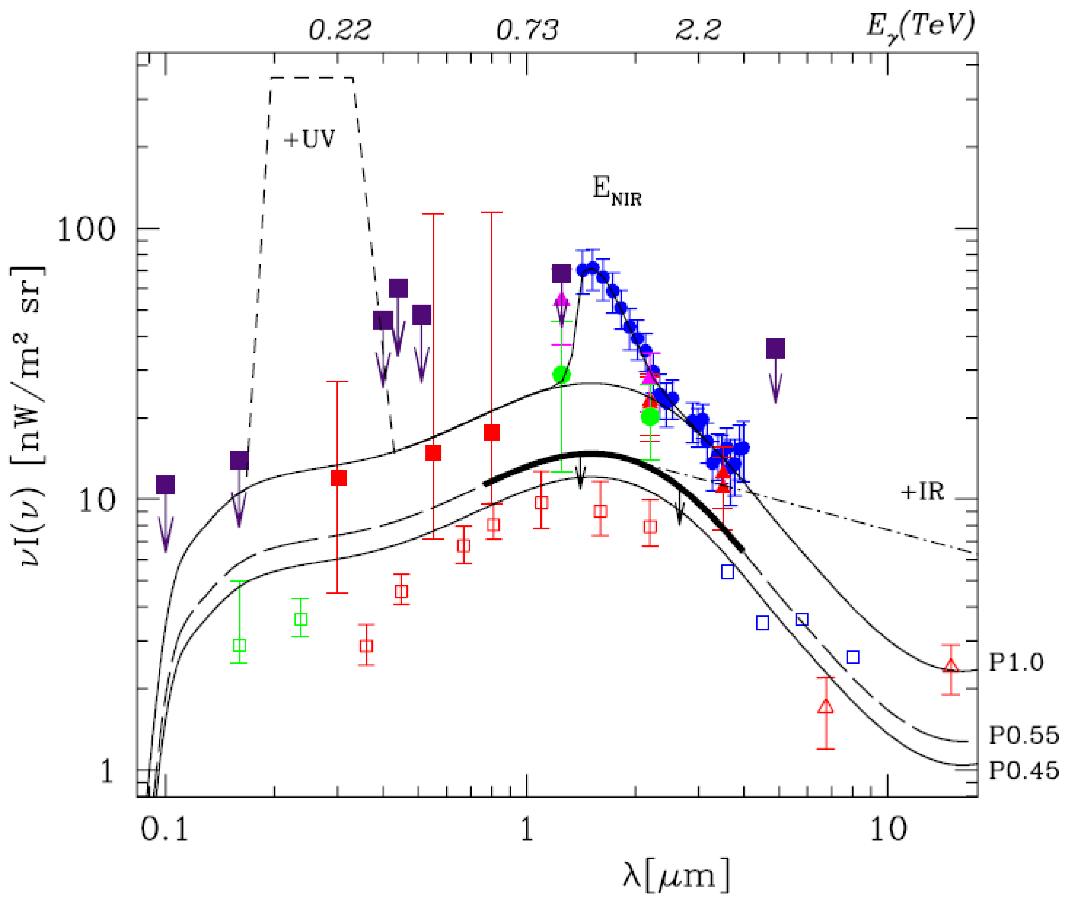
# H.E.S.S. Summary

- High Energy Stereoscopic System
  - Array of 4 Air Cherenkov Telescopes in Namibia
  - E $\geq$ 0.1 TeV
  - $\Delta E/E \sim 0.15$
  - Angular resolution: $\sim 0.1°$
  - Sensitivity: $\sim 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ (at 1 TeV, 100 hr)

- The Observations: 2 of 3 highest redshift BL Lac objects detected at TeV energies
  - H 2356–309, z = 0.165
    - June – Dec 2004
  - 1ES 1101–232, z = 0.186
    - March 04 – June 05

# H.E.S.S. EBL Models

- Open symbols: resolved sources (galaxy counts)
- Filled: absolute photometry

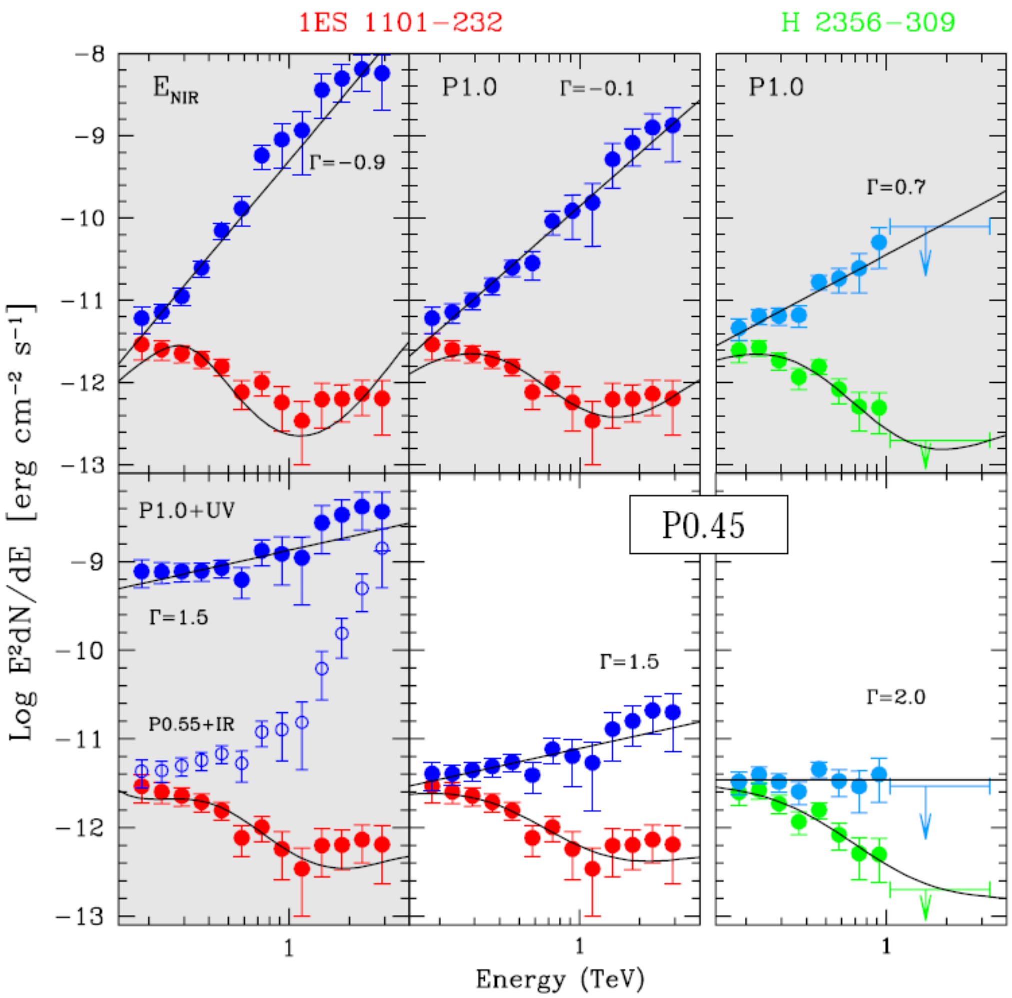


# Accounting for EBL Attenuation

- **Recall Paolo's caveat: We don't know the intrinsic spectrum of blazars, so dividing by the attenuation factor can be misleading.**
- **What do/can we know about blazar spectra?**
  - **Lower energy synchrotron emission suggest power-law particle distributions**
  - **Shock acceleration is typically invoked $\Rightarrow$ theoretical limits on particle distribution: $p \geq 1.5$, where $dN_e/d\Gamma \propto \Gamma^{-p}$**
- **Electron inverse Compton (and synchrotron) produce photon spectra with $\Gamma = (1 + p)/2$, where $dN/dE \propto E^{-\Gamma}$. Proton interactions will give $\Gamma \sim p$. So, expect $\Gamma \geq 1.25$.**
- **Anything harder requires processes unusual primary particle distribution – monoenergetic population, etc..**

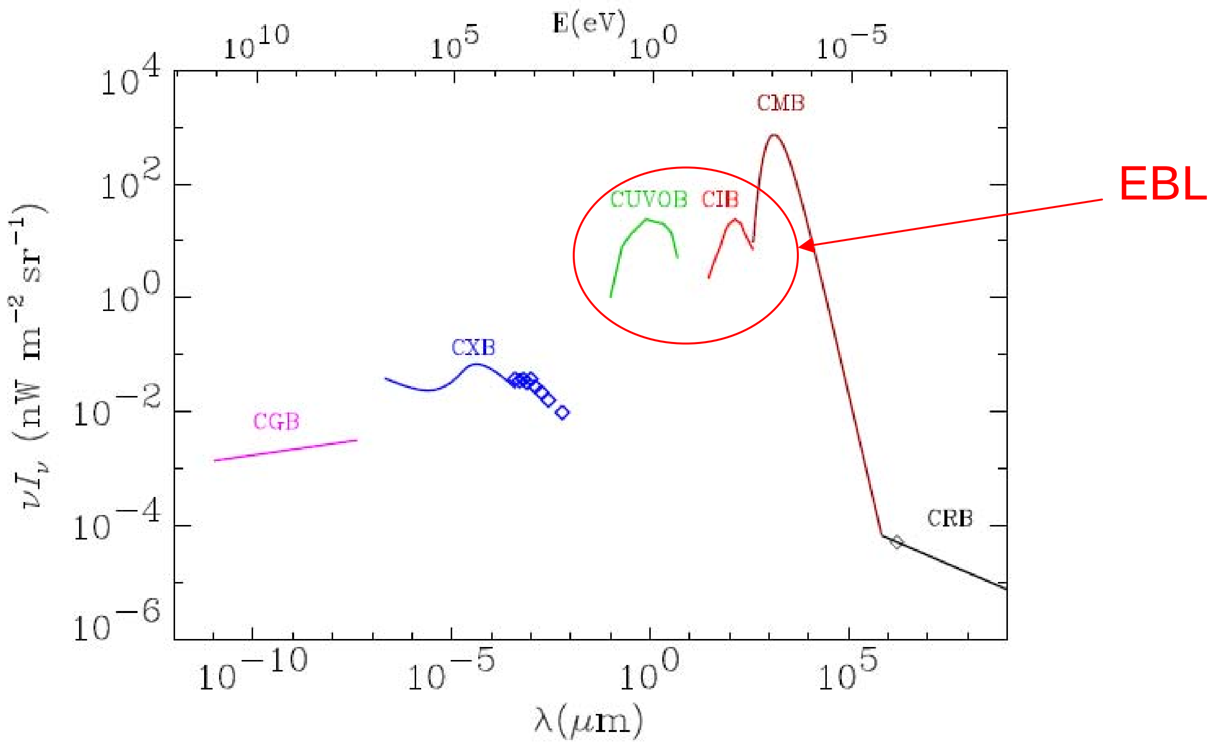
# HESS Spectra and Interpretation

- Intrinsic power-law recovered in almost all cases, except for models including IRST/NIRB measurements
- Most "natural" intrinsic spectra found for EBL just above lower limits implied by galaxy counts.



# Ingredients of the EBL

- Comprises almost all of the radiated energy of the Universe post-inflation
- Optical/UV from stars and AGNs
- Far IR (50-1000 microns) from reprocessing of OUV by dust

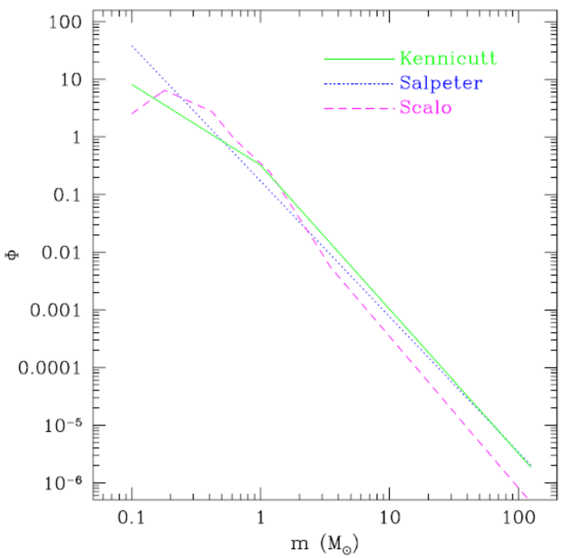


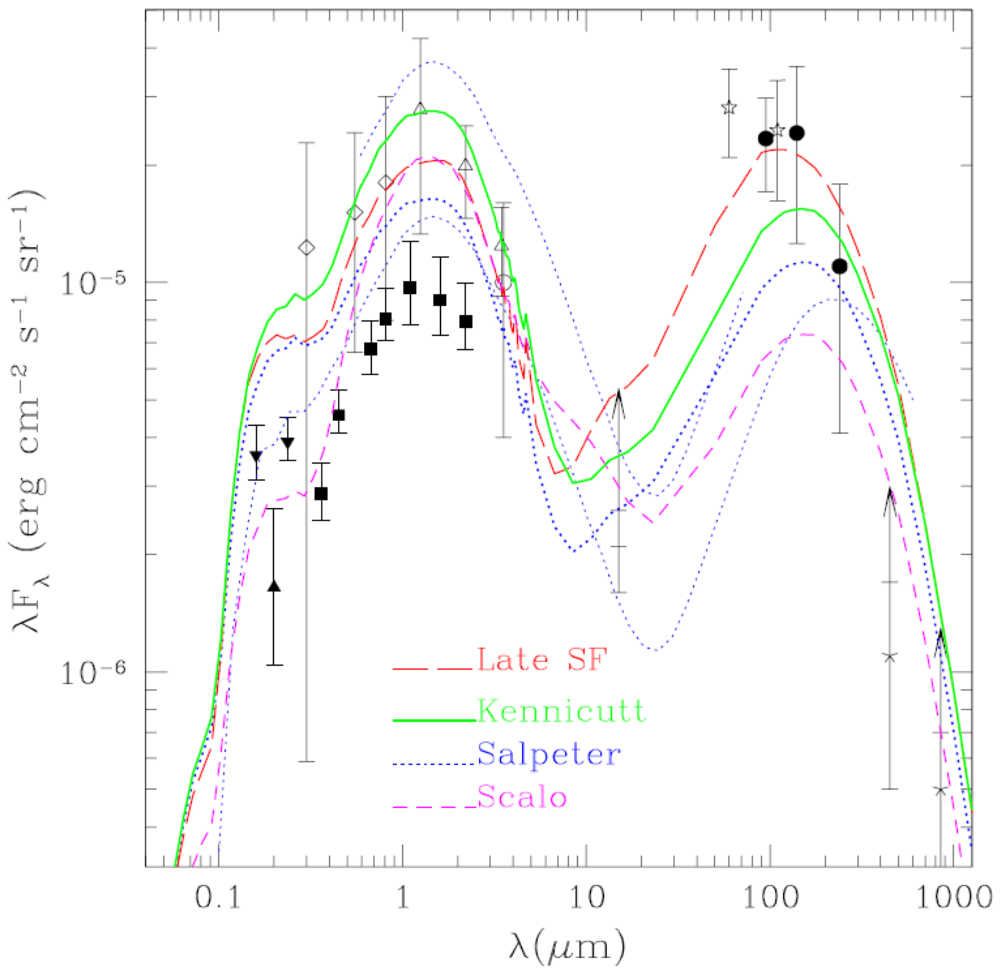
# Modeling the EBL

- Semi-Analytic ("forward" evolution) Models (SAMs; e.g., Primack, Sommerville, and collaborators):
  - Gaussian density fluctuations from Inflation
  - Large scale structure from ΛCDM ($\Omega_m$~0.3, $\Omega_\Lambda$~0.7, h~0.7)
  - Collapse and mergers of dark matter haloes
  - Cooling and shock heating of gas
  - Star formation and evolution (IMFs, supernova feedback, ISM enrichment)
  - Effects of dust (absorption and re-emission)
- "Backward" evolution models (e.g., Stecker, Malkan, & Scully 2005)
  - These models do not generally include galaxy SED evolution nor the effects of galaxy mergers, both of which likely contribute significantly to FIR.

# Impact of EBL Measurements

- Constrains intrinsic SEDs of sources and their redshift distribution
- e.g., Primack et al. 2000: IMFs (initial mass functions) differ in shape, primarily at M < $M_{Sun}$, and in metallicity.

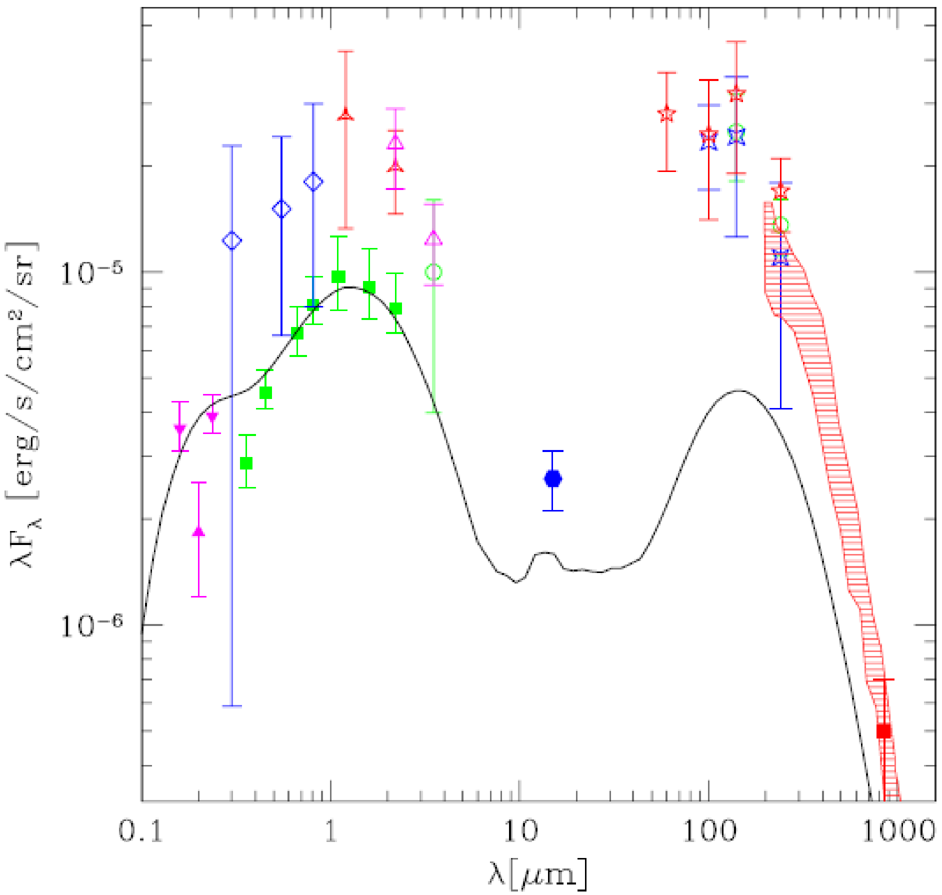


# More recent SAM calculation

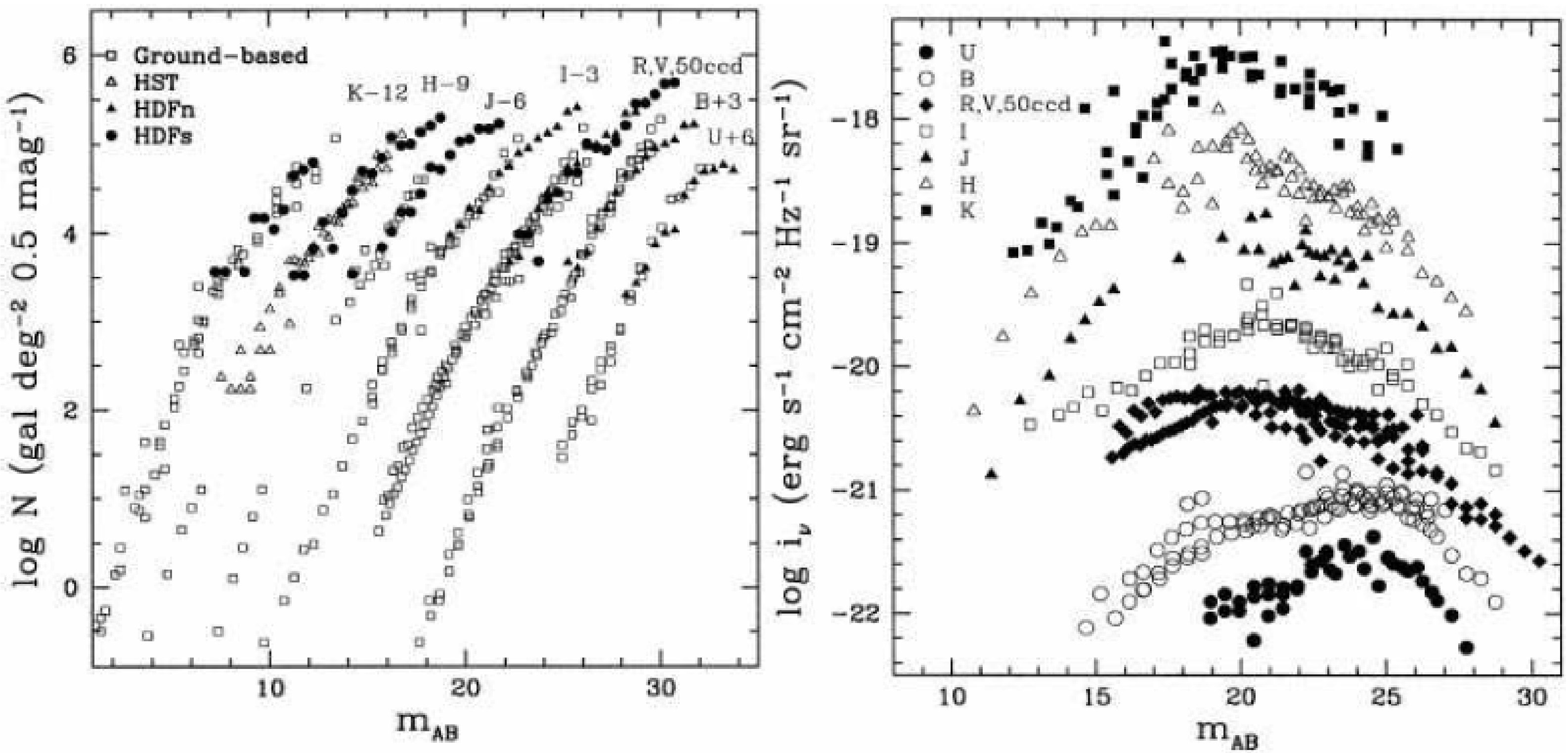
- Cosmology now constrained by WMAP
- OUV fitted at the galaxy count level (in agreement with HESS)
- Accounting for FIR is still a challenge.

- Primack et al. 2005:



# EBL contribution from galaxy counts

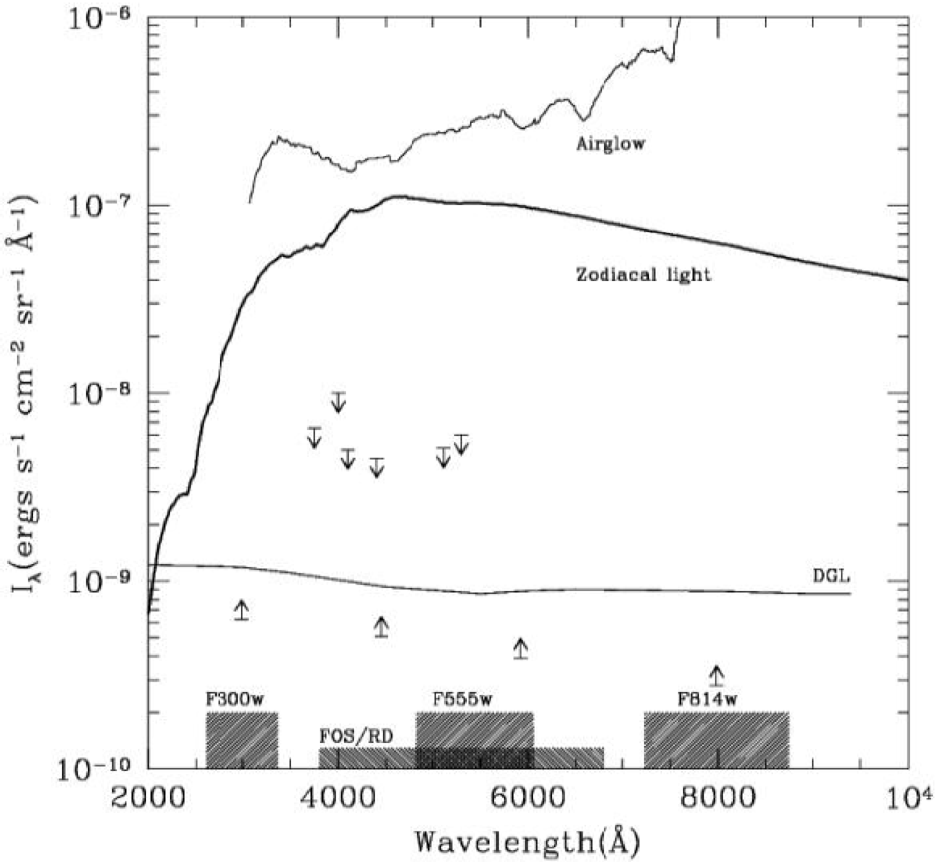
- **Madau & Pozzetti (2000) (HDF + ground-based):**




- **Caveat: “50% of flux from resolved galaxies with V>23 mag lie outside the standard apertures used by photometric packages.”**

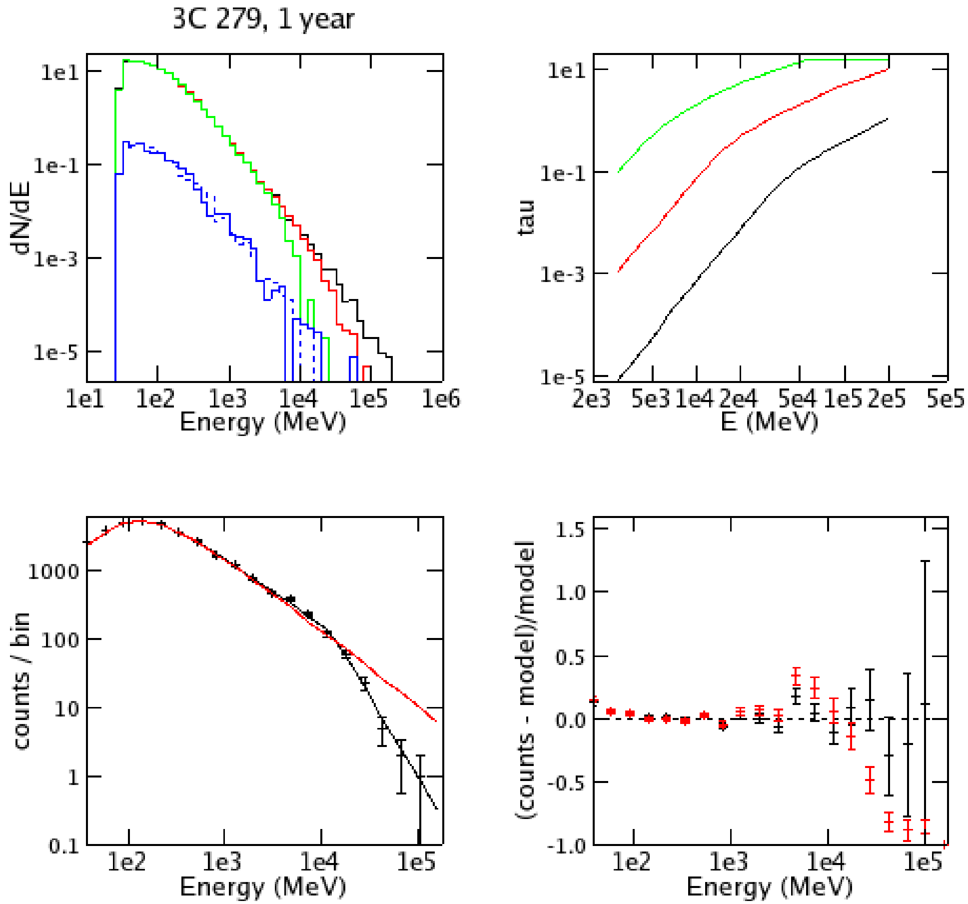
# Absolute Photometry

- Optical/UV: HST/ground-based (Bernstein, Freedman, & Madore 2002)
- NIR (1—4μm):
  - DIRBE (Wright & Reese 2000)
  - +2MASS (Cambresy et al. 2001)
  - IRST (Matsumoto et al. 2005)
- Foregrounds – diffuse Galactic light (DGL), stars, zodiacal, airglow – are a major hurdle. EBL is ~1% foreground level.



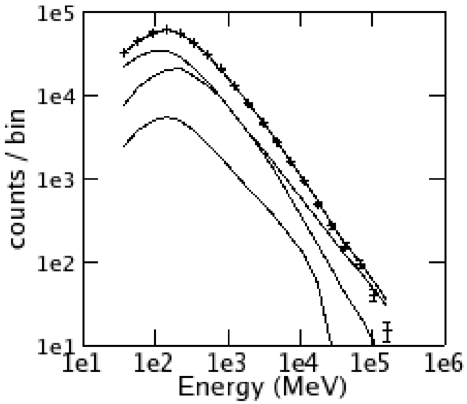
# GLAST Simulations

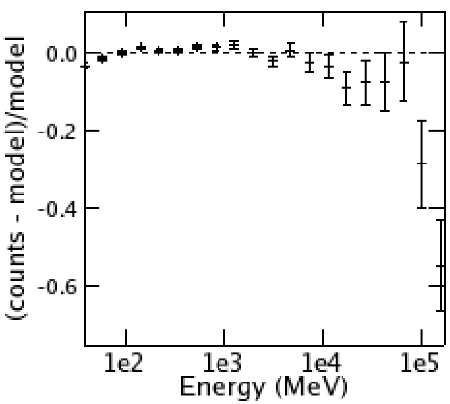
- **3C 279 for 1 year (Γ=1.96, ~33k events), no diffuse, DC1A**
- **EBL absorption (Primack05 model) with z = 0.538, 3, 6, and 3 (scaled by 70)**
- **Model fits: broken power-law, log-parabola (Massaro et al. 2005)**

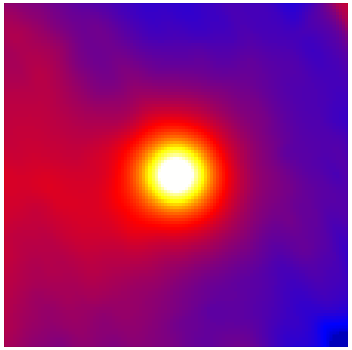


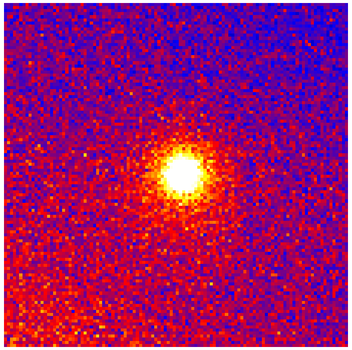
# GLAST Simulations w/ Diffuse

- **1 yr, 3C 279 (x70), z=3, w/ GALPROP and extragalactic diffuse**





# Conclusions

- H.E.S.S. observations imply near minimal EBL in OUV
  $\Rightarrow$ a more direct view of intrinsic spectra blazars
- But if true, galaxy formation models will struggle to account for FIR
- Possible "outs":
  - high UV component (ruled out for EBL…disk?)
  - very hard blazar spectra $\Rightarrow$ unusual particle acceleration
  - Lorentz invariance violation
- GLAST constraints on EBL will require bright, hard spectra blazars at $z > 2 - 3$, e.g., 3C 279-like, x10 - 100 more luminous (or like PKS0528+134, but with harder intrinsic spectrum)

# More on FIR difficulties

- **Star formation history and FIR galaxy counts:**