SEARCHING FOR IMPRINT OF POPULATION 3 ERA IN SPECTRA OF HIGH-z GLAST GRB's

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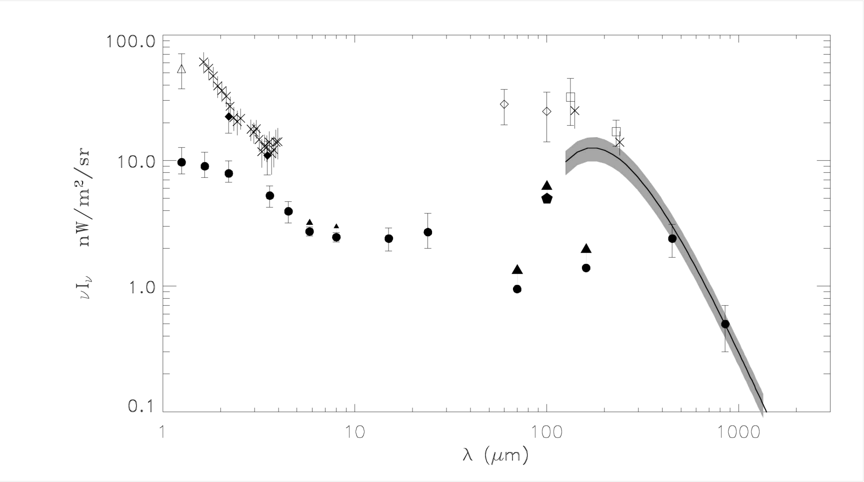
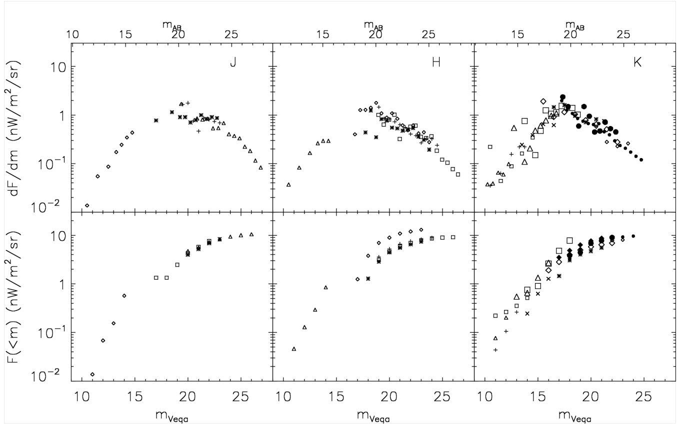
- There is now strong evidence of significant energy release during first stars (Pop 3) era
- This energy, released at z>10 or so, should leave a distinct imprint in spectra of high-z GLAST sources via 2-photon absorption
- Uncovering this with GLAST measurements will provide important direct evidence of Population III era emissions

Cosmic infrared background: measurements vs galaxies contribution

From Kashlinsky 2005, Physics Reports, 409, 361



CIB due to J, H, K galaxy counts



- Direct near –IR CIB measurements show excess emissions over known galaxy populations (NIRBE).
- CIB from observed galaxy counts saturates with fainter "ordinary galaxies," contributing very little extra flux
- Deep counts data (e.g. at 2.2 micron) show that <10% of the CIB flux is produced by ordinary galaxies at z>1
- The observed CIB excess can be reproduced w. only ~2-4 % of baryons having gone through Pop 3

(For reference galaxies at K=20 are at z~0.8-1.2, e.g. astro-ph/0609287)

- ***CIB data give:***

F_{NIRBE} = 29+/-13 nW/m^2/sr $\quad$ F(λ>:10μm) < 10 nW/m^2/sr

- ***Diffuse background from Pop 3*** ***(Kashlinsky et al 2004)***

$\int M\, n(M)\, dM = \Omega_{baryon}\, 3H_0^2/8\pi G\, f_*$ $\qquad$ f_* fraction in Pop 3

$$\frac{dF}{dt} = \frac{\int Ln(M)dM}{4\pi d_L^{\,2}}\frac{dV}{dt}(1+z)$$

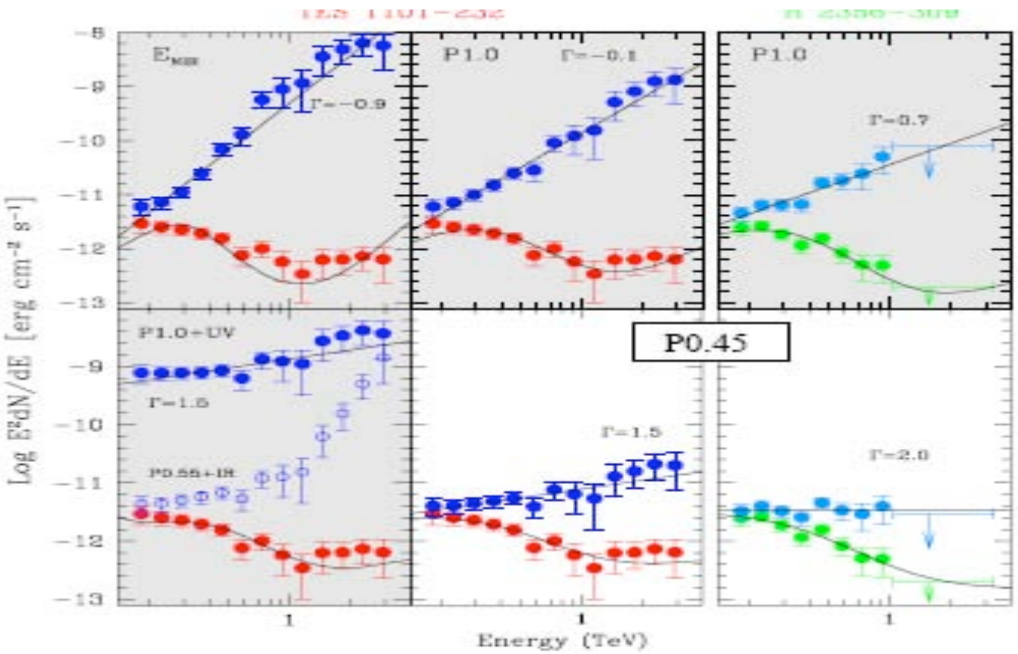
$dV = 4\,\pi\, c d_L^2(1+z)^{-1}\, dt$; $\quad L \approx L_{Edd} \propto M$; $\quad t_L = \epsilon\, Mc^2/L << t(z=20)$

$$\nu I_\nu = \frac{3}{8\pi}\frac{1}{4\pi R_H^{\,2}}\frac{c^5}{G}\varepsilon\Omega_{baryon} f_* \cong 1.2\times10^4\,\frac{\Omega_{baryon}}{0.044}\frac{\varepsilon}{0.007}h^2 f_*\,\frac{nW}{m^2 sr}$$

- ***The entire NIRBE can be reproduced with***

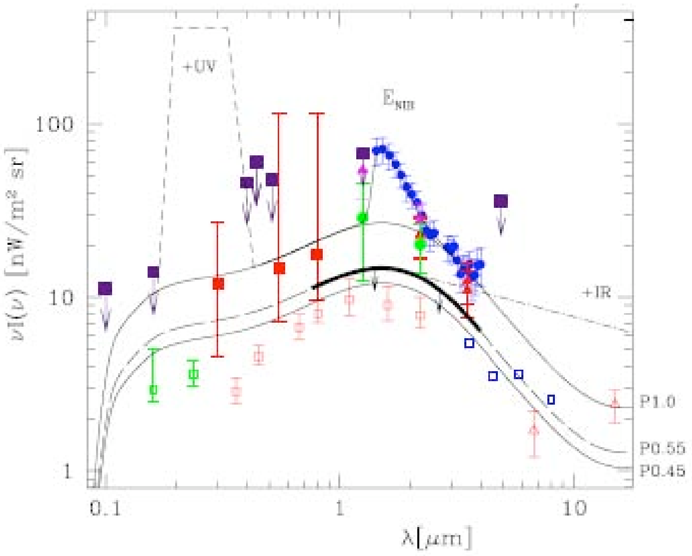
$f_* = 4$ +/- 2 % $\quad$ for ϵ=0.007

Near-IR CIB constraints from nearby blazars



Aharonian et al
(2006)

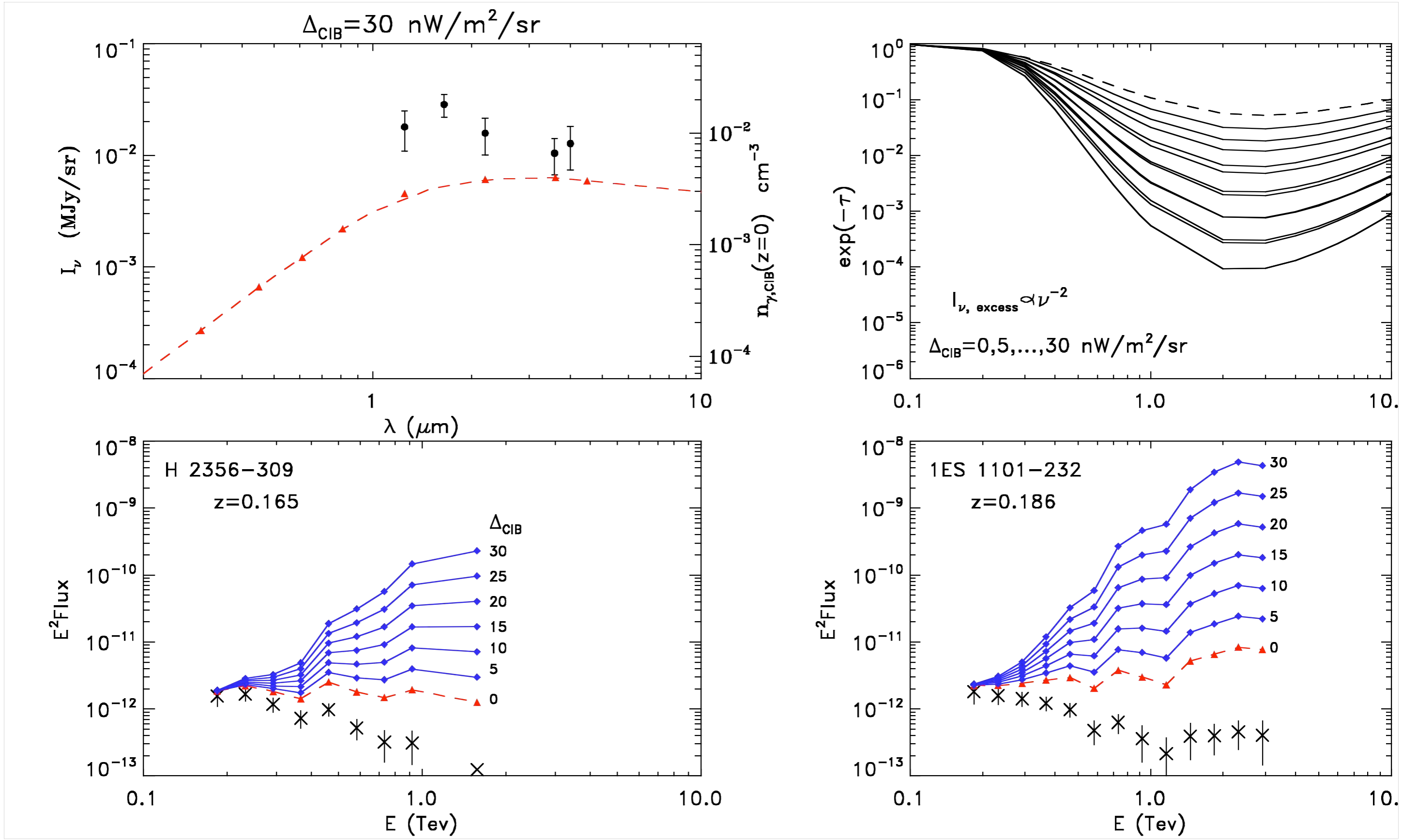
HESS observations of two blazars at $z \sim 0.18$



- HESS measurements suggest that for the assumed CIB template the levels of NIRBE are much smaller than claimed.

Population III contribution vs HESS data:

- *But substantial CIB levels from Pop 3 are still possible*



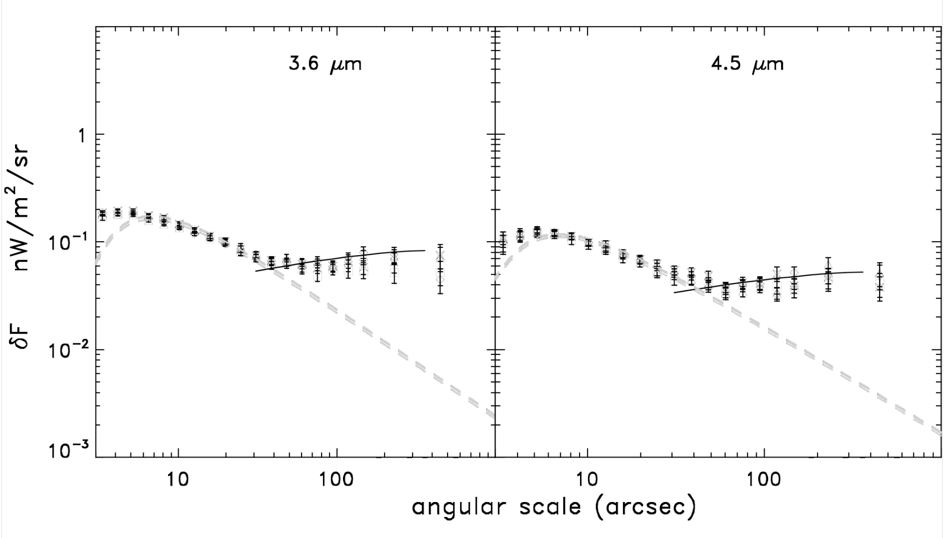
CIB: 1) ordinary galaxies contribution given by counts (red)

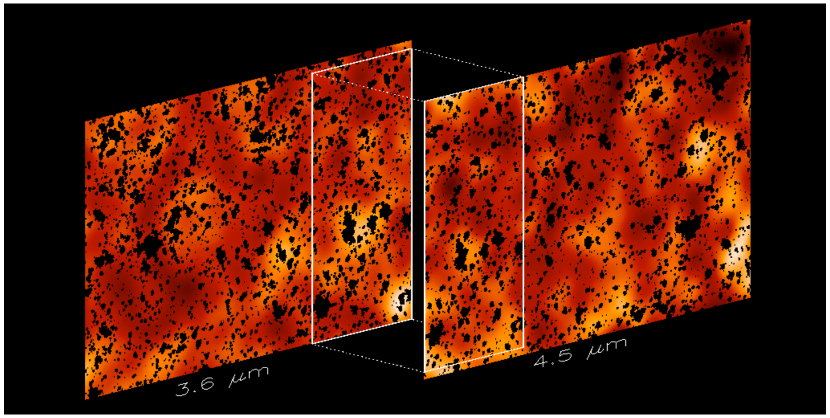
2) Pop 3 contribution: $I_\nu \infty \lambda^{-2}$ with z_3=10 normalized to Δ_{CIB}

Residual CIB fluctuations in Spitzer GOODS images

More direct evidence for significant emissions from early epochs is produced from studies of CIB fluctuations in deep Spitzer data (*Kashlinsky, Arendt, Mather & Moseley 2005, Nature, 438,45 and 2007, ApJL, 654, L1 and L5 – reviewed also in Nature's N&V on 3 Nov 2005 and 4 Jan 2007)*

Measured CIB fluctuations from remaining populations:



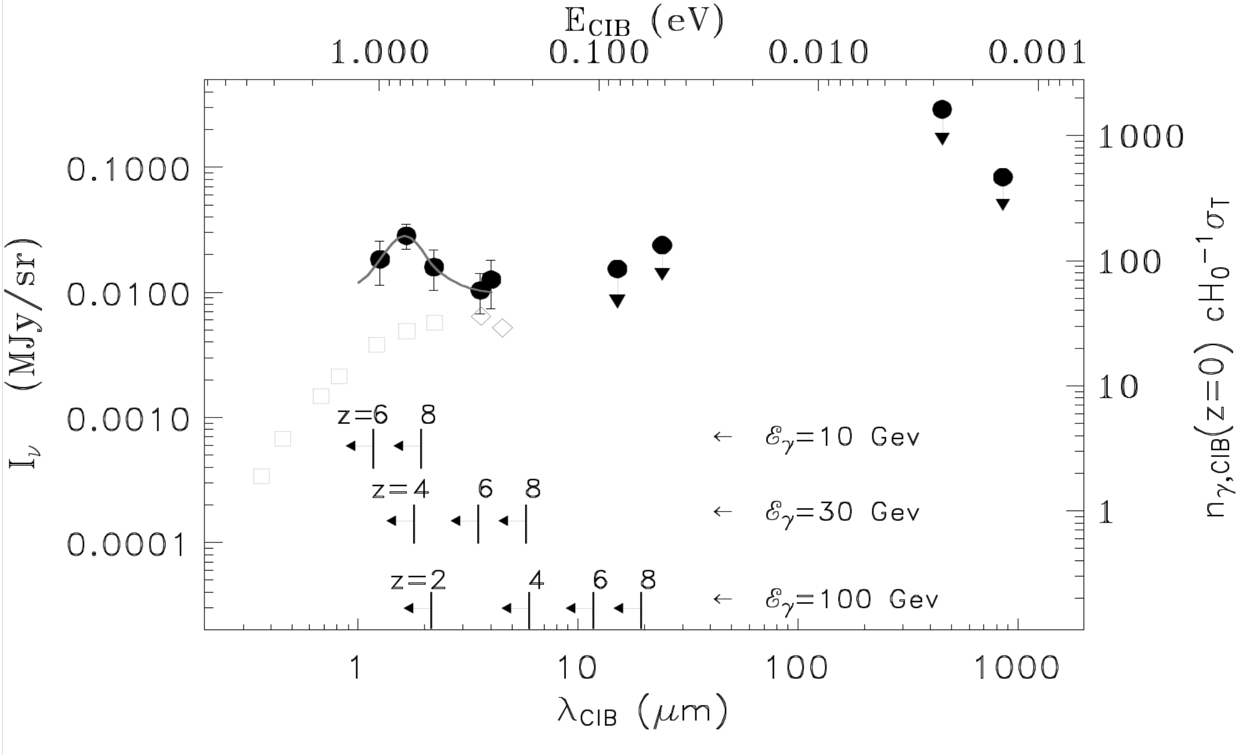


Measurements of CIB fluctuations indicate:

- *The amplitude of the fluctuations implies CIB levels at 3.6 mic produced by these populations of >1-2 nW/m*^{2}*/sr*
- These populations are such that they produce at most only low levels of the shot noise, but significant clustering component.
- *This in turn implies that the sources producing these fluctuations are individually faint with flux < 10-20 nJy*
- Such sources are very likely located at very early times of the Universe'e evolution.
- *At z=10 the Lyman cutoff for these emission is at* λ*~1 (z/10)* μ*m, so the GLAST/LAT limit of 300 GeV implies that these photons can be detected via 2-photon absorption*

Pop 3 live at z > 10; hence any photons from them were produced then so that $n_\gamma \infty (1+z)^3$ or

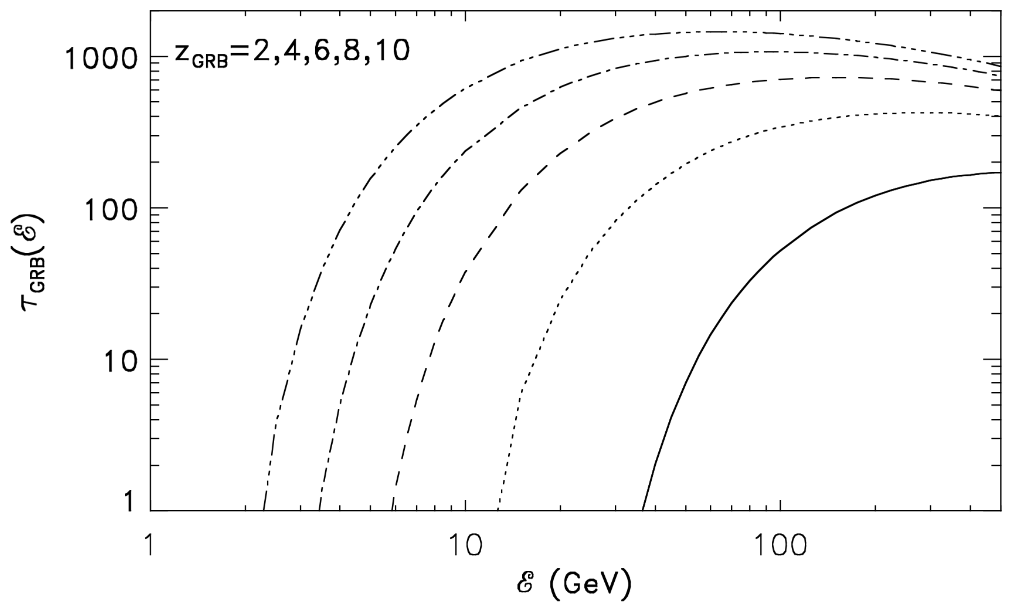
$$4\pi/c\, I_\nu/h_{\mathrm{Planck}}(1+z)^3 \text{ per } d\ln E = 0.6\, I_\nu(\mathrm{MJy/sr})\,(1+z)^3\mathrm{cm}^{-3}$$



(γ-ray absorption due to CIB photons peaks at ϵ_γ if source is at z)

Population III and high-z GLAST sources (GRBs/blazars)

- Two photon absorption due to these CIB photons would lead to a sharp cutoff at $\epsilon_{cut} = 260\,(1+z_{GRB})^{-2}$ GeV (for z_3=10) in the spectra of any high-energy GLAST sources such as GRBs.
- $\epsilon_{cut} \propto (1+z_3)$ where z_3 is the typical epoch of Pop 3 emissions
- Lower NIRBE levels shift the curves vertically.
- The complete absorption feature is insensitive to > than an order of magnitude changes in CIB levels from Pop 3.



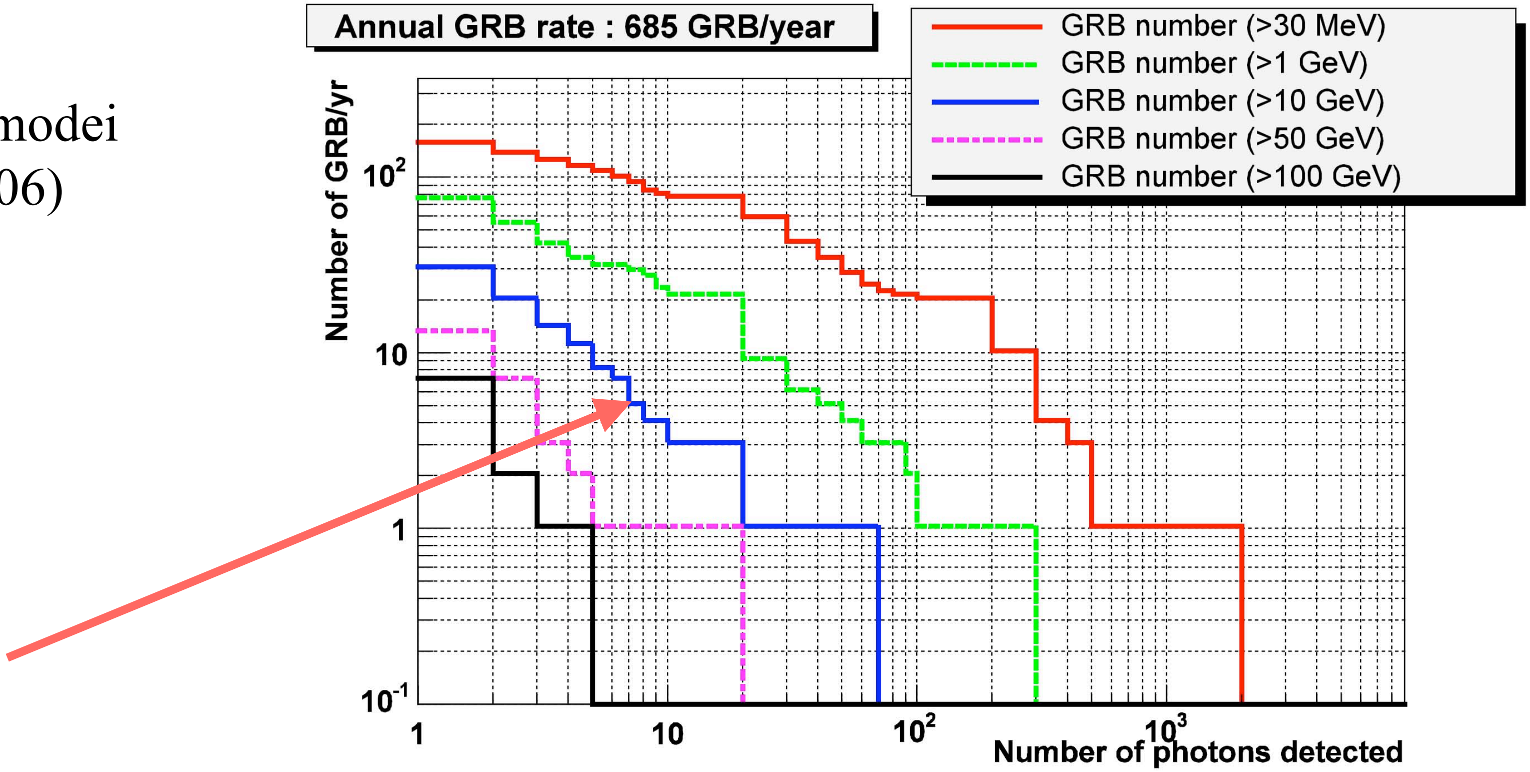
From Kashlinsky
(2005, ApJL,633,L5)

Observability of Cutoffs by GLAST

- $\epsilon_{cut} = 260\ (1+z_{source})^{-2}$ GeV is in LAT energy band
- Is the sample of GLAST-observed sources large enough to detect the emissions from Pop 3 sources at z>10?
- High-z (>3-5) blazars will provide a good data sample after ~ 1-2 yr
- We estimate that GLAST will detect ~7 GRBs/yr with observable Pop 3 cutoffs. Estimate depends on:
  - Detectability of cutoff in LAT spectra (⇔photon fluences)
  - Redshift distribution (⇔distribution of ϵ_{cut})

Detectability of Cutoffs in GLAST Bursts

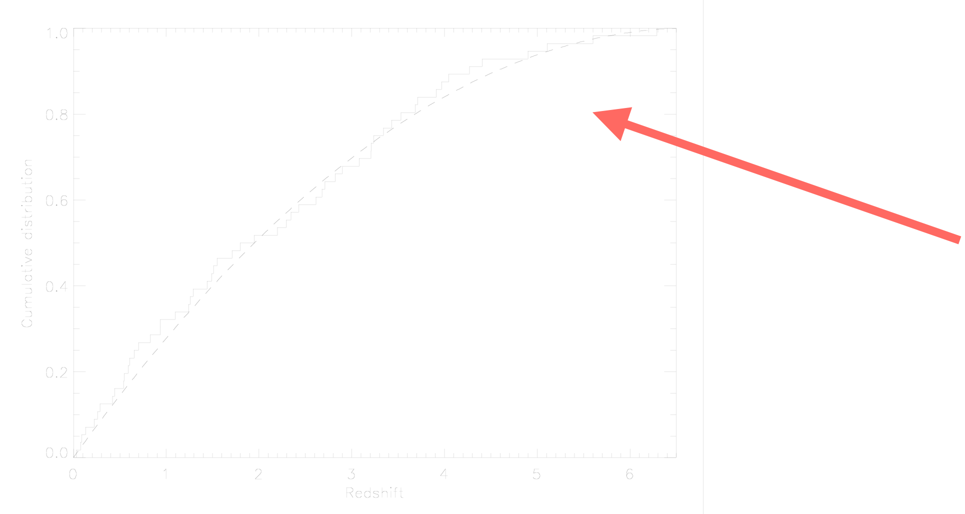
From Omodei et al (2006)



~7 bursts/yr should be detected with ϵ_{cut}<10 GeV

- Assume BATSE spectrum extrapolates to GLAST band (but there might be extra components). Use BATSE fluence distribution. Result: predicted distribution of bursts LAT will detect with more than a certain number of photons.
- Assume cutoff is detectable if intrinsic spectrum should produce more than 7 LAT photons above ϵ_{cut} ($P<10^{-3}$).
- Result is number of bursts LAT should detect with given ϵ_{cut}.

Redshift Distribution from Swift



Cumulative Swift
z-distribution
(from catalog)

Empirical
fit

- ϵ_{cut} corresponds to a redshift. What will be GLAST's redshift distribution?
- Use Swift's observed z distribution (many simplifying approximations)
- Convolve redshift distribution with LAT burst detectability
- GLAST may detect ϵ_{cut} in ~7 bursts/yr.
- But, will we know the redshifts of the GLAST bursts?
  - Swift will observe ~1/6 of GLAST bursts, ~40% of Swift bursts have redshifts
  - Ground followup observations based on GLAST positions
  - 'Pseudo'-redshifts from relations among burst parameters (e.g., luminosity)