Measuring the Extragalactic Background Light with Fermi-LAT Gamma-Ray Bursts

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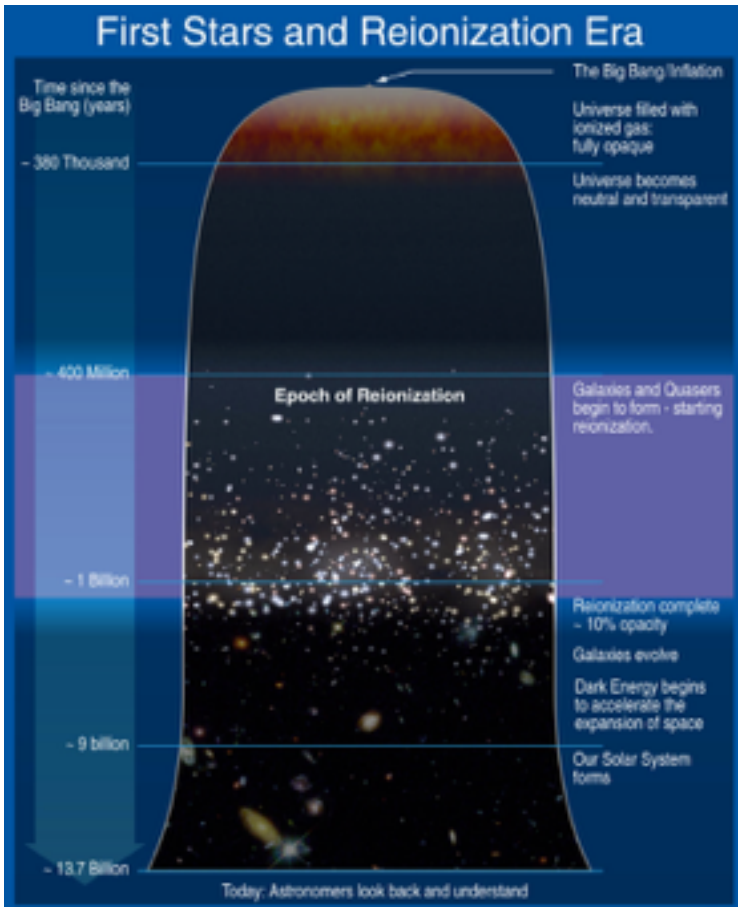
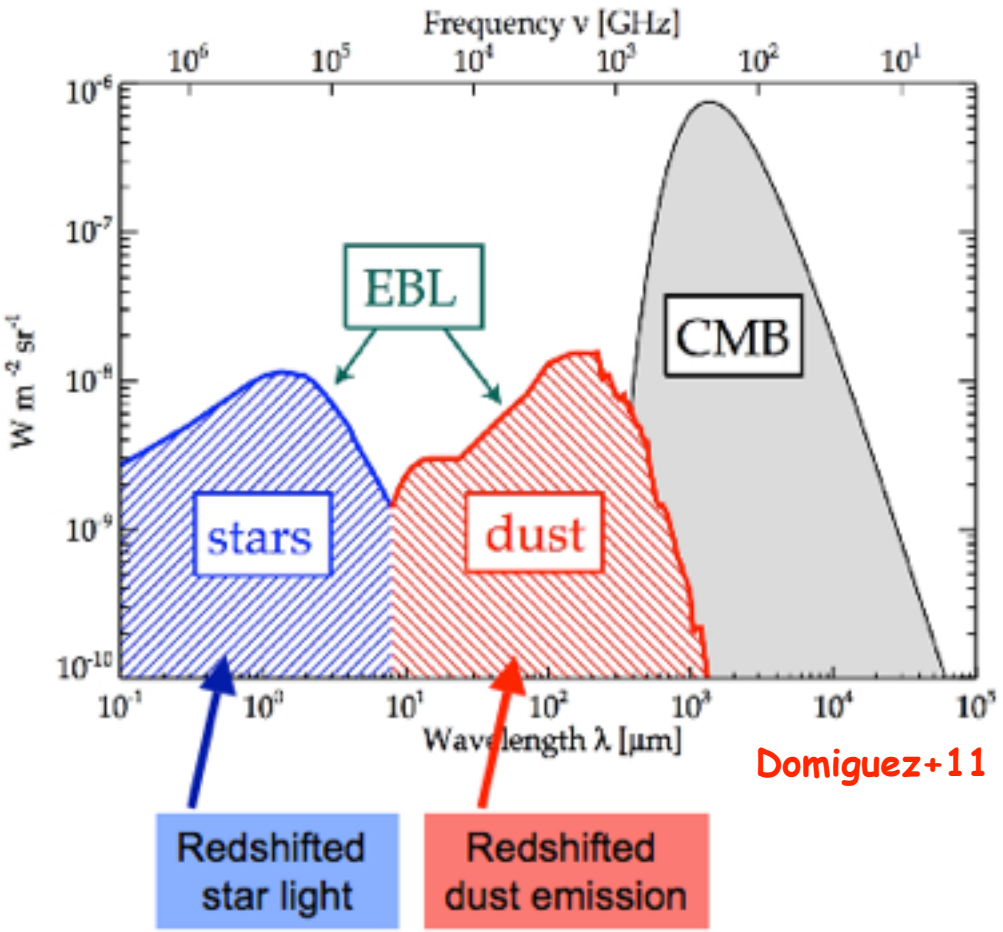
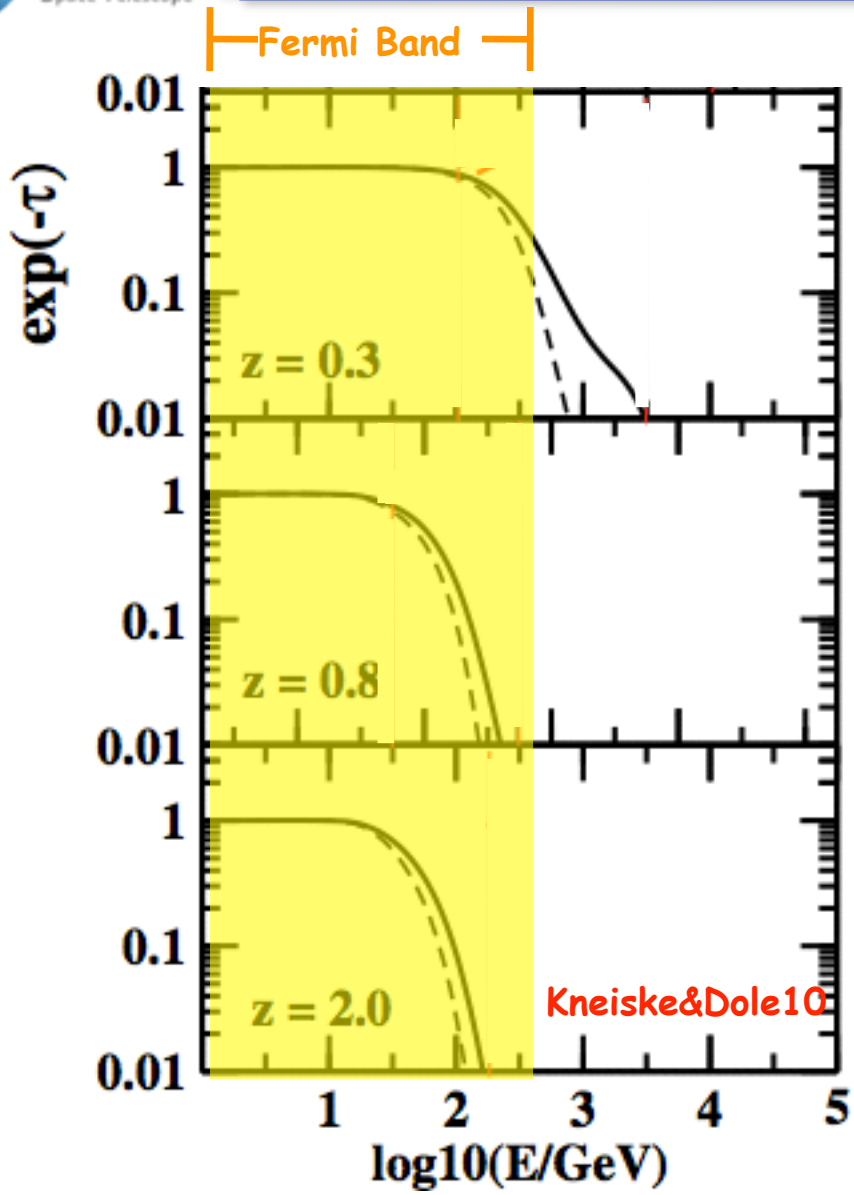
What is the Extragalactic Background Light ?





1) **Constraints on galaxy evolution, star formation activity, dust extinction processes**
2) **Understanding cosmic structure formation and evolution**

Attenuation due to the EBL



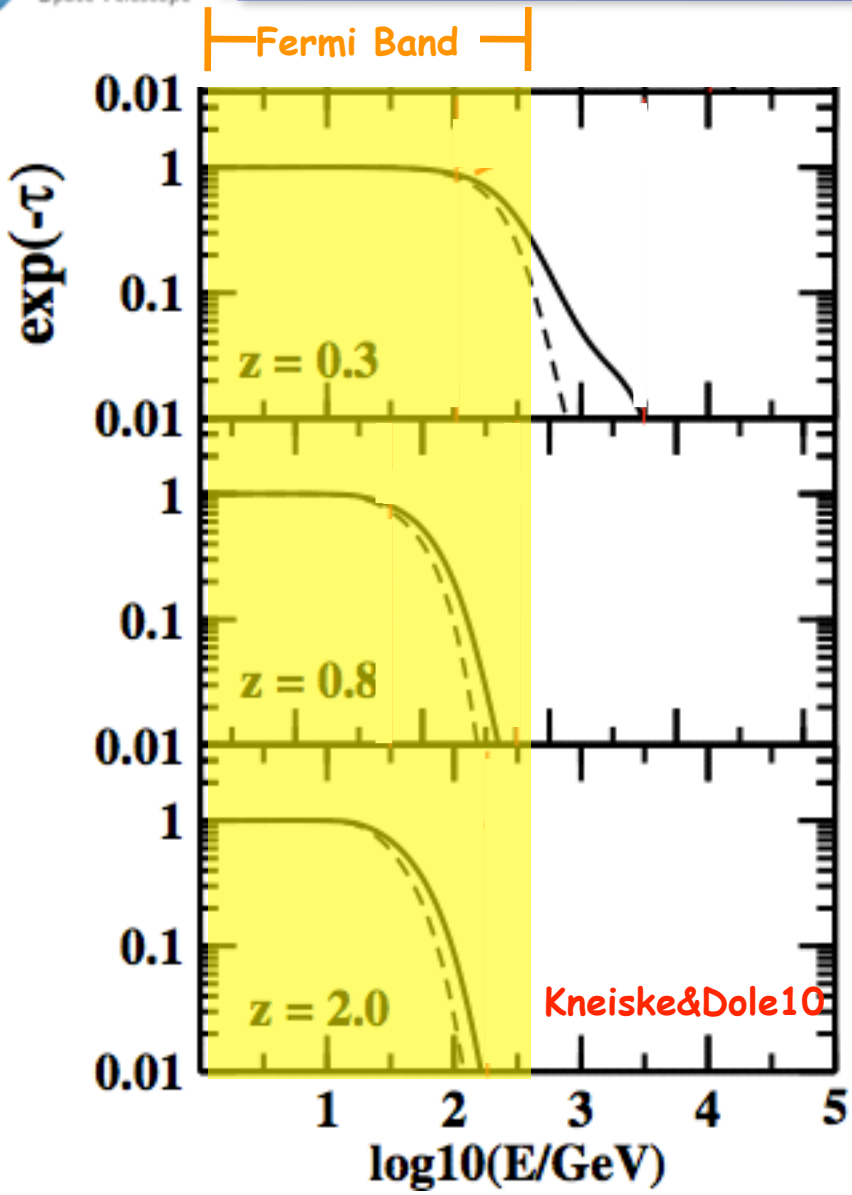
High energy radiation interacts with EBL:

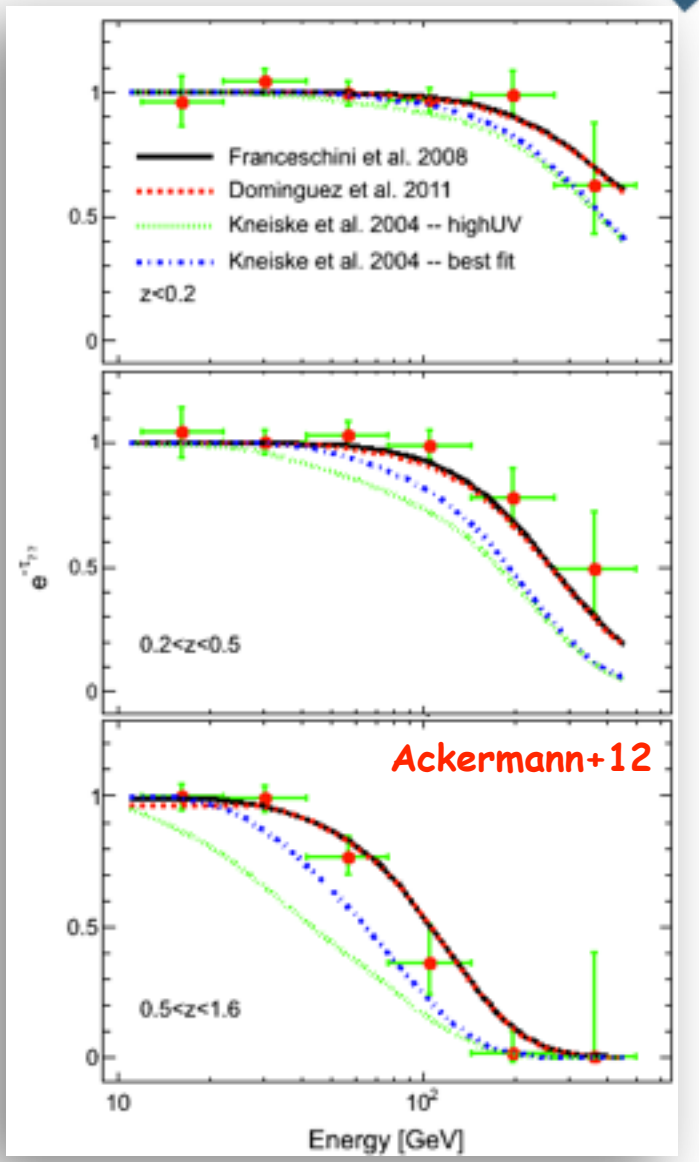
- **pair production**

At few hundreds GeV, most models predict an attenuation of >99% at z~1

The EBL leaves a unique redshift/energy dependent attenuation in the spectra of far gamma-ray sources (Blazars and GRBs)

Attenuation due to the EBL





Key Point

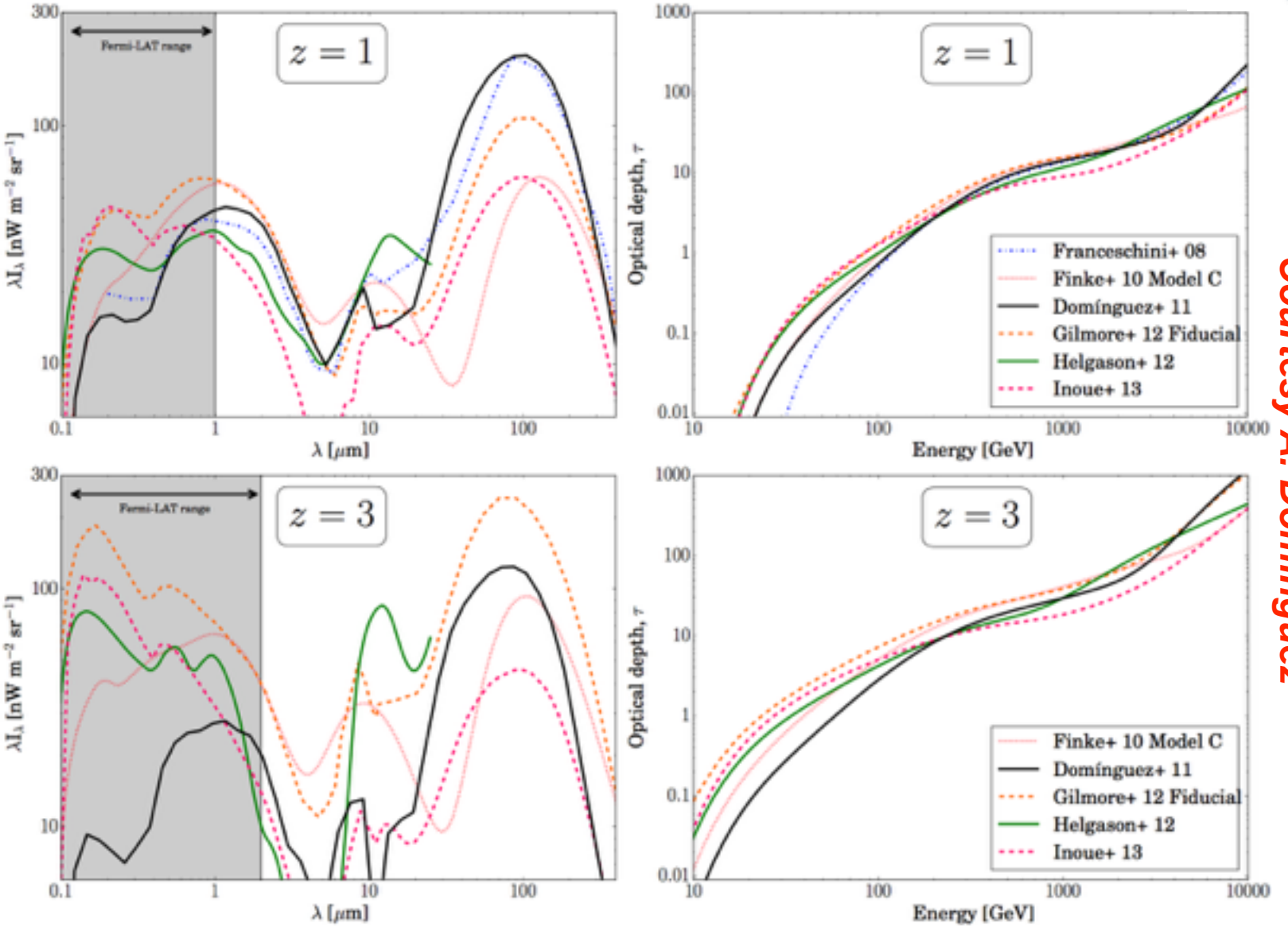
1) We are interested in how the EBL evolves with redshift

   - This can be studied by using sources at different redshifts
   - Direct measurements of the EBL can't do that !

Why GRBs

1) LAT has detected >1000 blazars, why bother with a few GRBs?
2) Main Complaint for BL Lacs
   - The gamma-ray emission might be produced by line of sight interaction of CRs with the CMB (e.g. it would be of secondary origin). As such it would travel a smaller distance and be less absorbed (Essey et al. 2011)
   - If TRUE, this means the optical depth measurements obtained so far are underestimated => Higher level of EBL
   - ***GRB short variability exclude this possibility***
3) Secondarily
   - LAT detected BL Lacs reached "only" z~1.6
   - LAT detected GRBs reach z=4.35

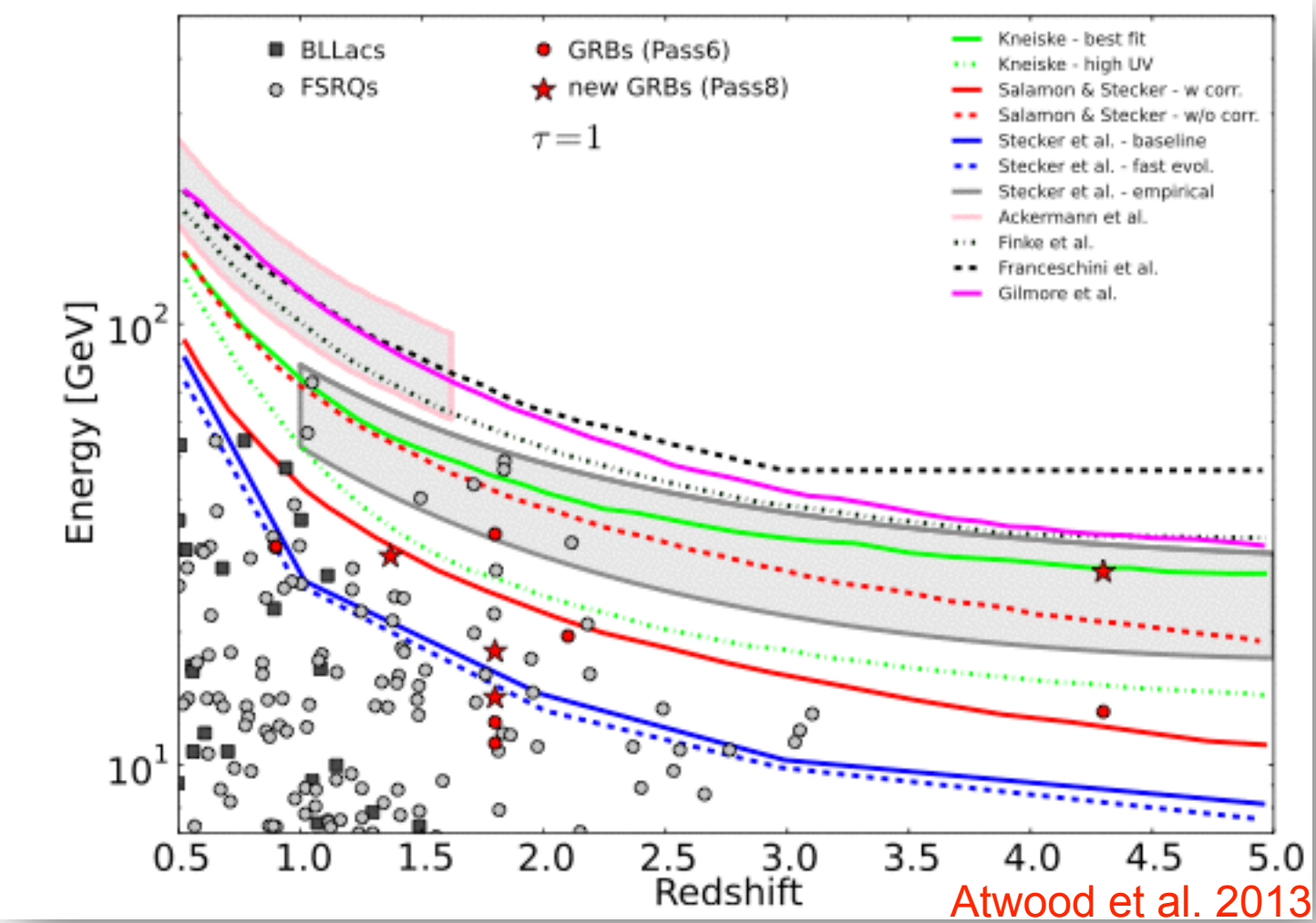
Model Predictions disagree at high z



Courtesy A. Dominguez

Pass 8 offers a new window

1) **Not the first time GRBs are used to constrain the opacity, but with P8 things can be much better**



Analysis Procedure

Unbinned likelihood with Pass 8 Transient R20 class

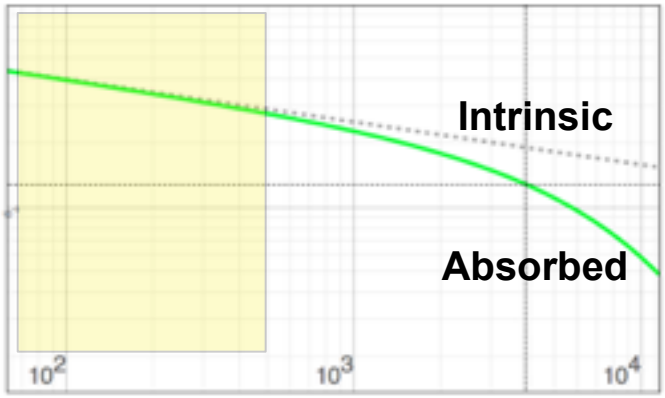
The power-law spectra of each GRB is attenuated by the EBL:

$$F(E)_{absorbed} = F(E)_{\text{int}\,rinsic} \cdot e^{-b\cdot\tau_{\text{mod}\,el}}$$

τ=τ(E,z) comes from one of the EBL models (Dominguez, Finke, etc)

b is a renormalization constant that allows to test several scenarios

1. **Each single GRB is analyzed independently and spectral parameters are optimized with Emax = 500 MeV and b=0;**
2. **All the GRBs are joined in a Composite Likelihood fit (Emax=100GeV) where all parameters are optimized independently except b that is a single parameters shared by all the objects**



Composite Likelihood Results

1) **Significance of the Detection:**
   - **Best-fit versus null hypothesis b=0: i.e. there is no EBL**

$$F(E)_{absorbed} = F(E)_{\text{int } rinsic} \cdot e^{-b \cdot \tau_{\text{mod } el}}$$

2) **Significance of `Rejection' of a given EBL model:**
   - **Best-fit versus null hypothesis b=1: i.e. the EBL model predictions are correct**

3) **We tested only a few of the EBL models (Finke10, Kneiske04, Kneiske&Dole10, Gilmore09)**
   - **Most models do not have predictions beyond z~2**

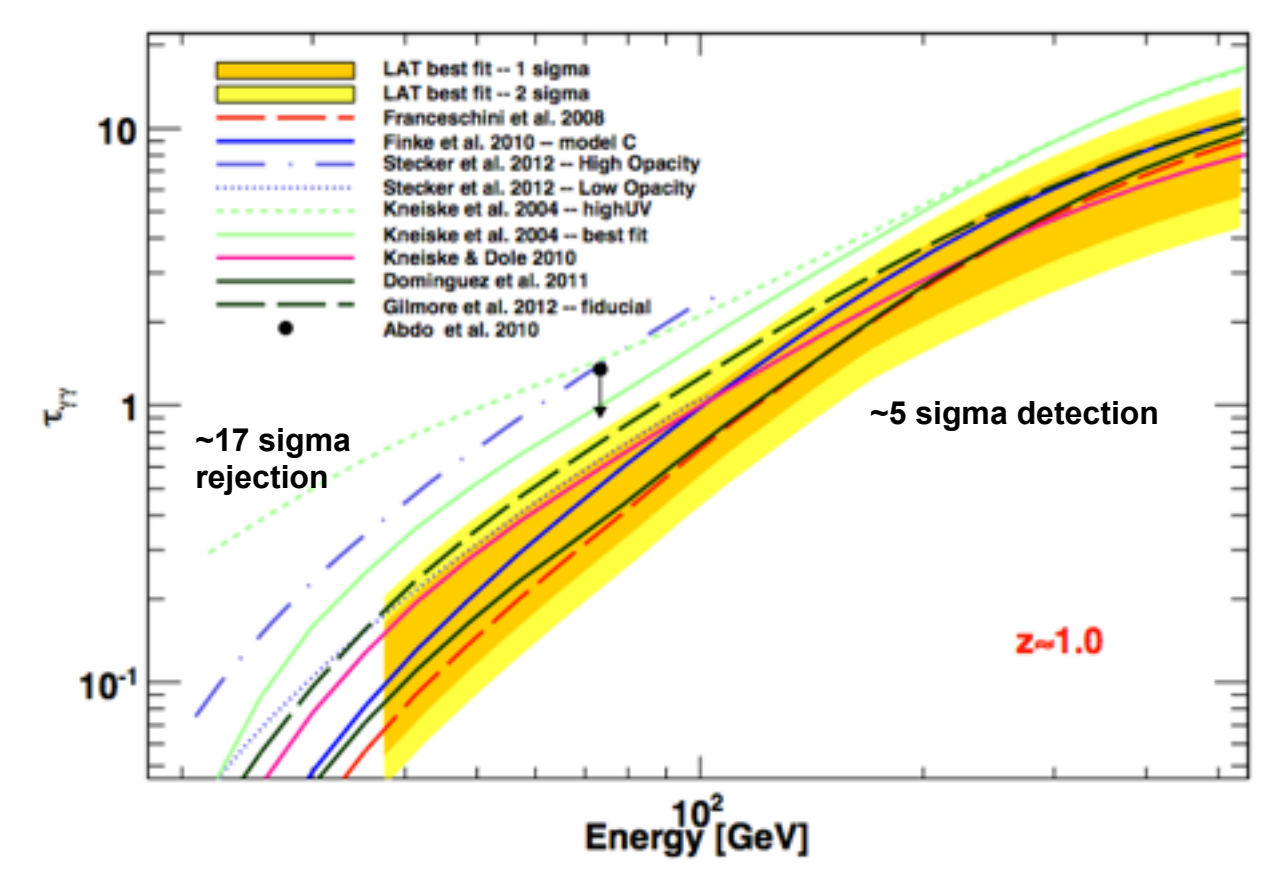
5) **Results (wrt to Finke+10 model):**

Redshift	TS	Scaling factor b
0.15<z<1.4	~2.1	0.80(±0.80)
1.4<z<4.35	~3.4	0.98(±0.80)
0.15 <z<4.35	~6	0.91(±0.60)

1. ***Marginal ~2σ detection of the EBL attenuation***
2. ***Value of b ~1 (model prediction are reasonably correct)***

BL Leac: where we stand

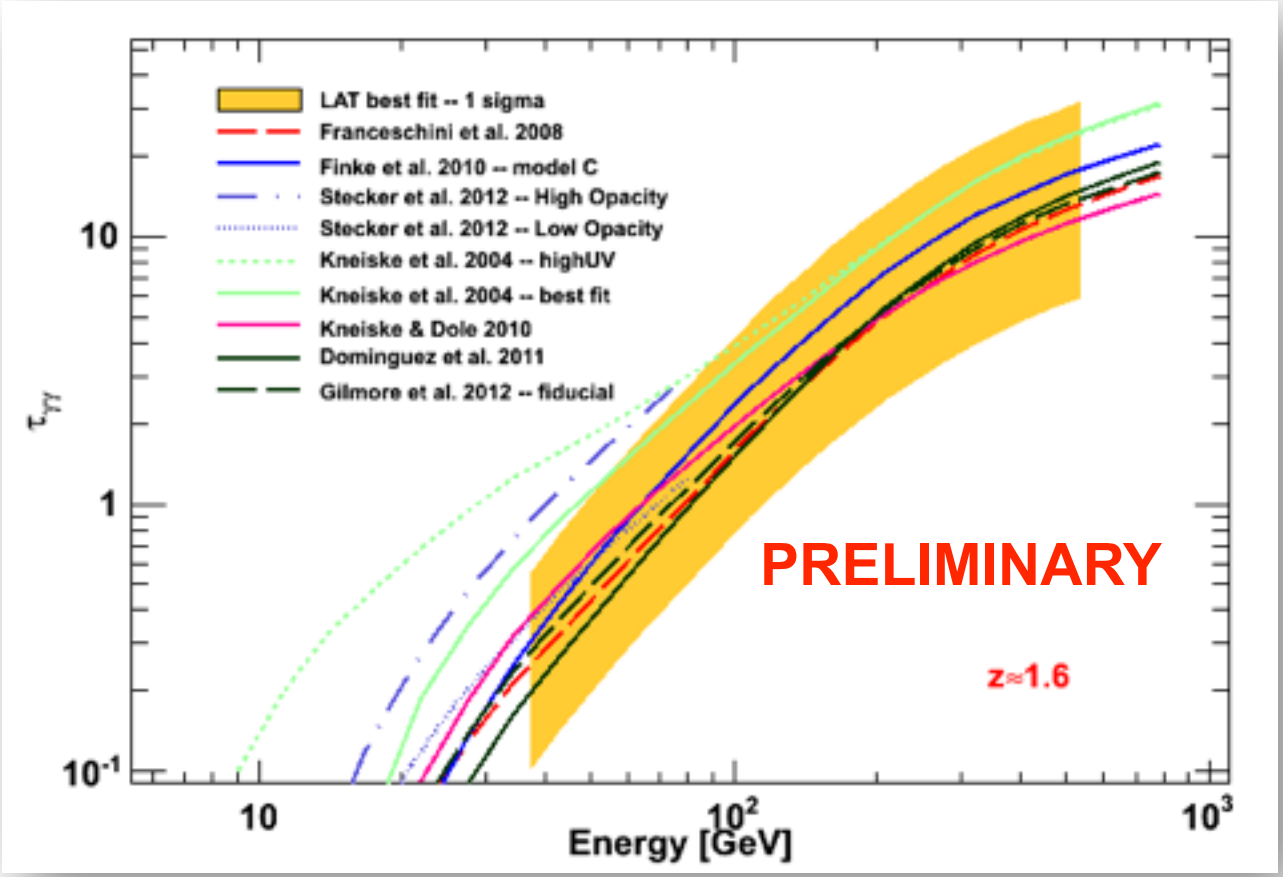
1) BL Lacs provided a measurement of the optical depth at z~1
   - The furthest BL Lac was at z~1.6



Data compatible with low-opacity models

With GRBs

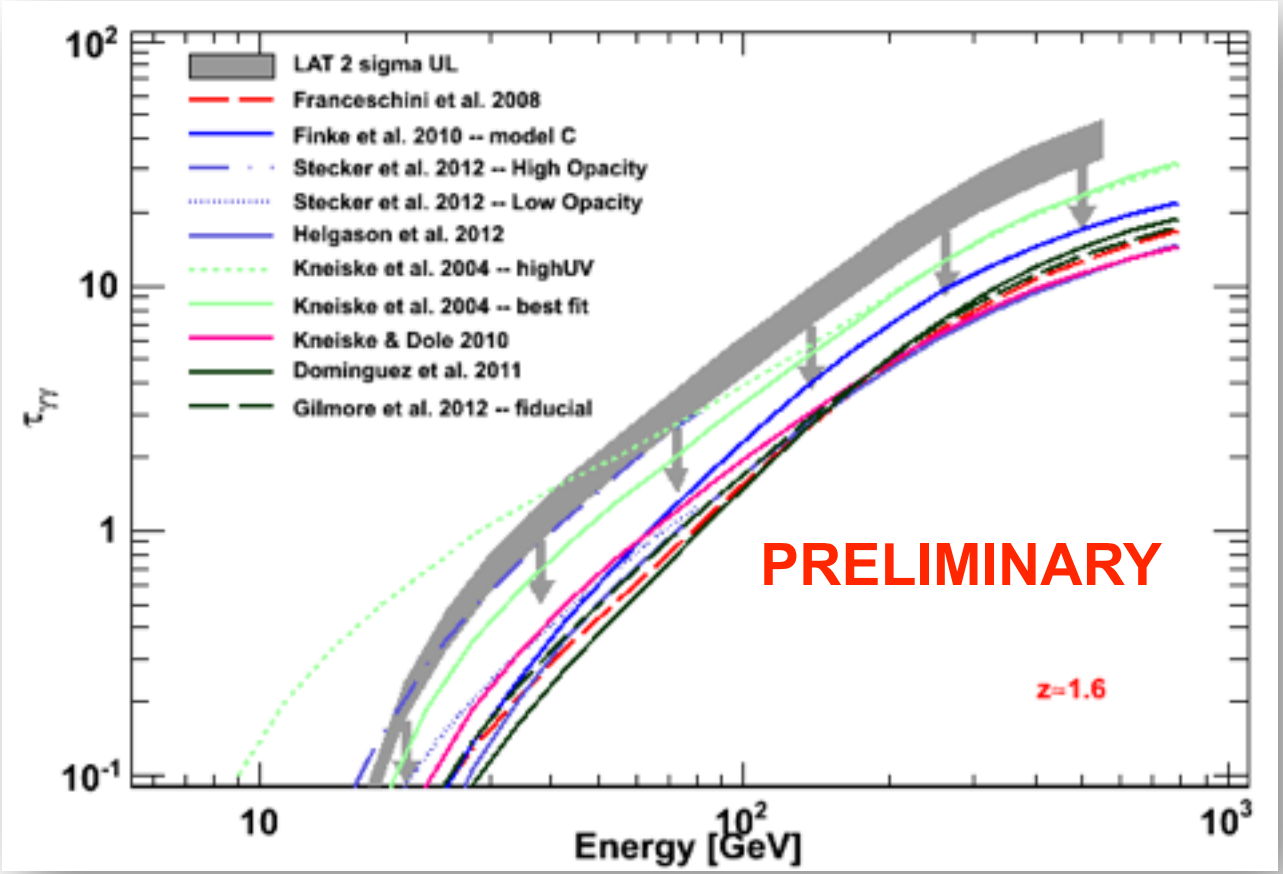
1) GRBs 'average' redshift is z=1.6
   - They take over almost exactly where BL Lacs left



GRB confirms with low-opacity models

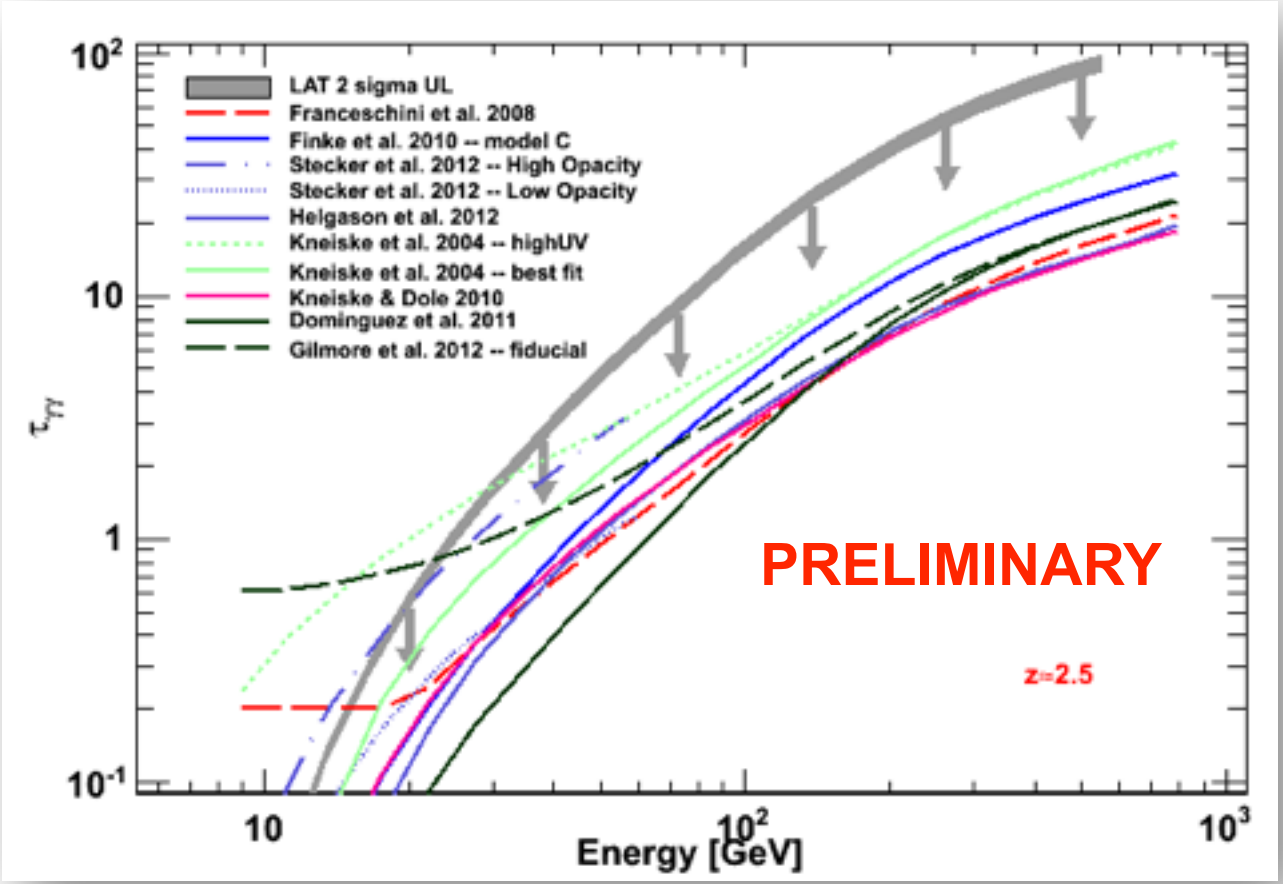
95% UL at z=1.6

1) **Average of the whole sample**



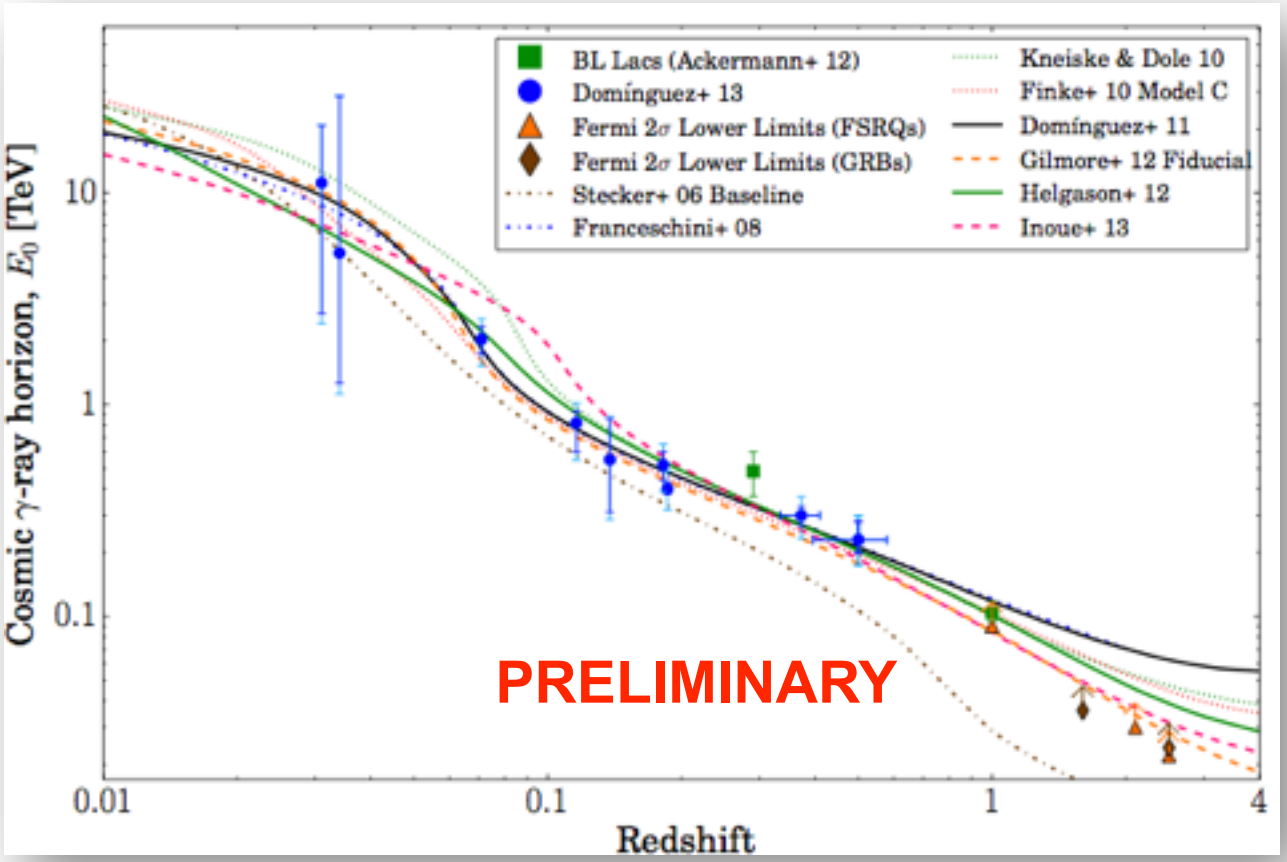
95% UL at z=2.5

1) Average of the highest redshift bin



All in a context

1) Even the UL probe a region that is otherwise inaccessible



Courtesy A. Dominguez

Summary

1) GRBs are excellent/ clean probes of the EBL
   - Reach high redshift -> probe of the UV background
   - Do not suffer from CR line-of-sight argument
2) P8 analysis of GRBs yields the following:
   - Marginal detection of the EBL at the level compatible with galaxy counts
   - Confirms EBL is low in agreement with the measurements using BL Lacs
     - Although not constrained, model with low absorption are favored: Good for HAWC & CTA!
   - Probes a region that is only accessible to the LAT and where model predictions widely disagree (fun!)
   - 95% UL are nicely constraining: Pass 8 improvement: Pass 8 Upper Limits are 2.6 times tighter than P7 (nice!)