The Detection of the Cosmic γ-ray Horizon

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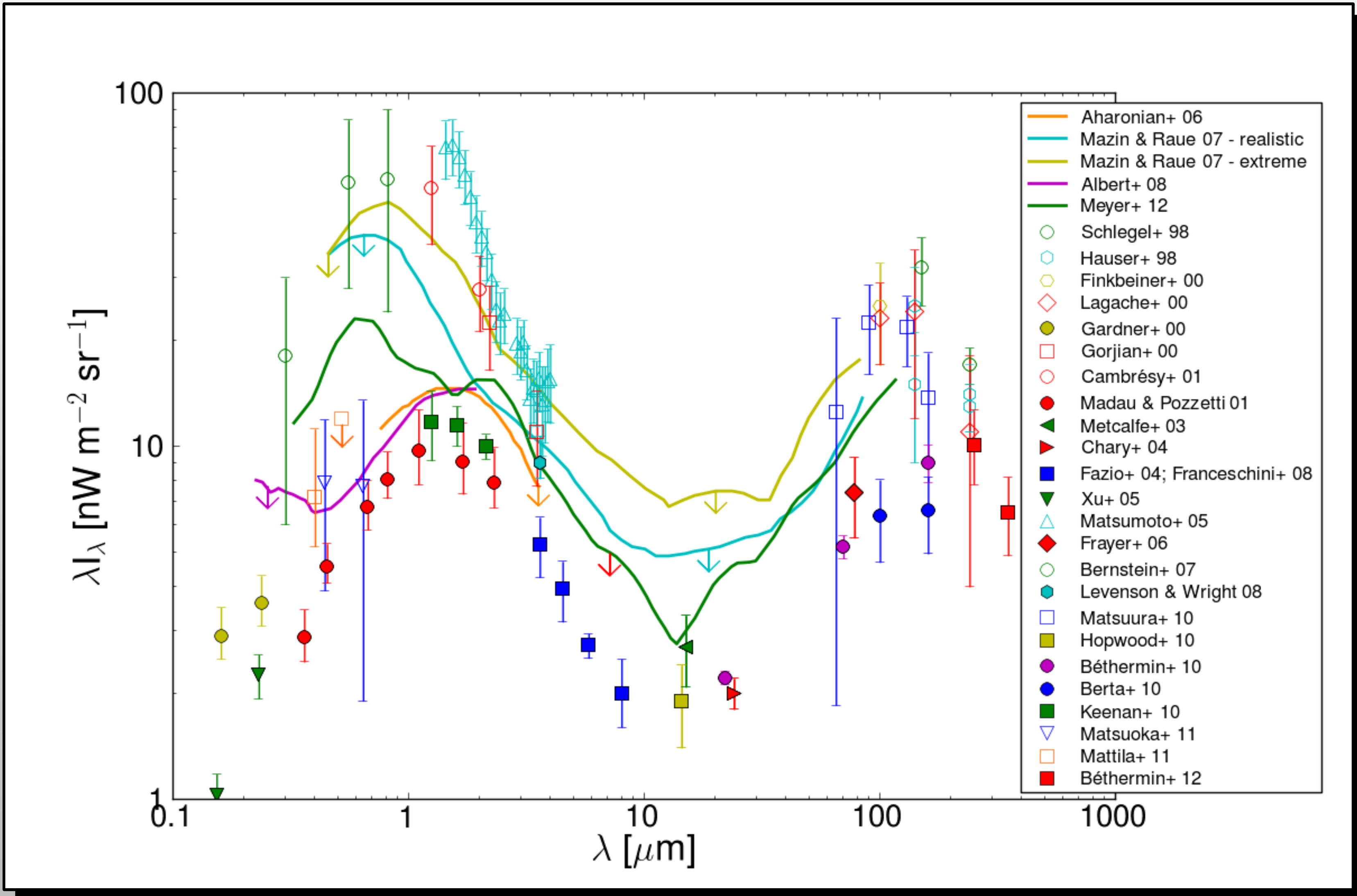
Outline

1.- Extragalactic Background Light: data, γ-ray limits, and models.
Domínguez, Primack, Rosario, Prada, et al., 2011, MNRAS

2.- The detection of the Cosmic γ-ray Horizon
Domínguez, Finke, Prada, Primack, et al., 2012, submitted
(on behalf of the Fermi-LAT collaboration)

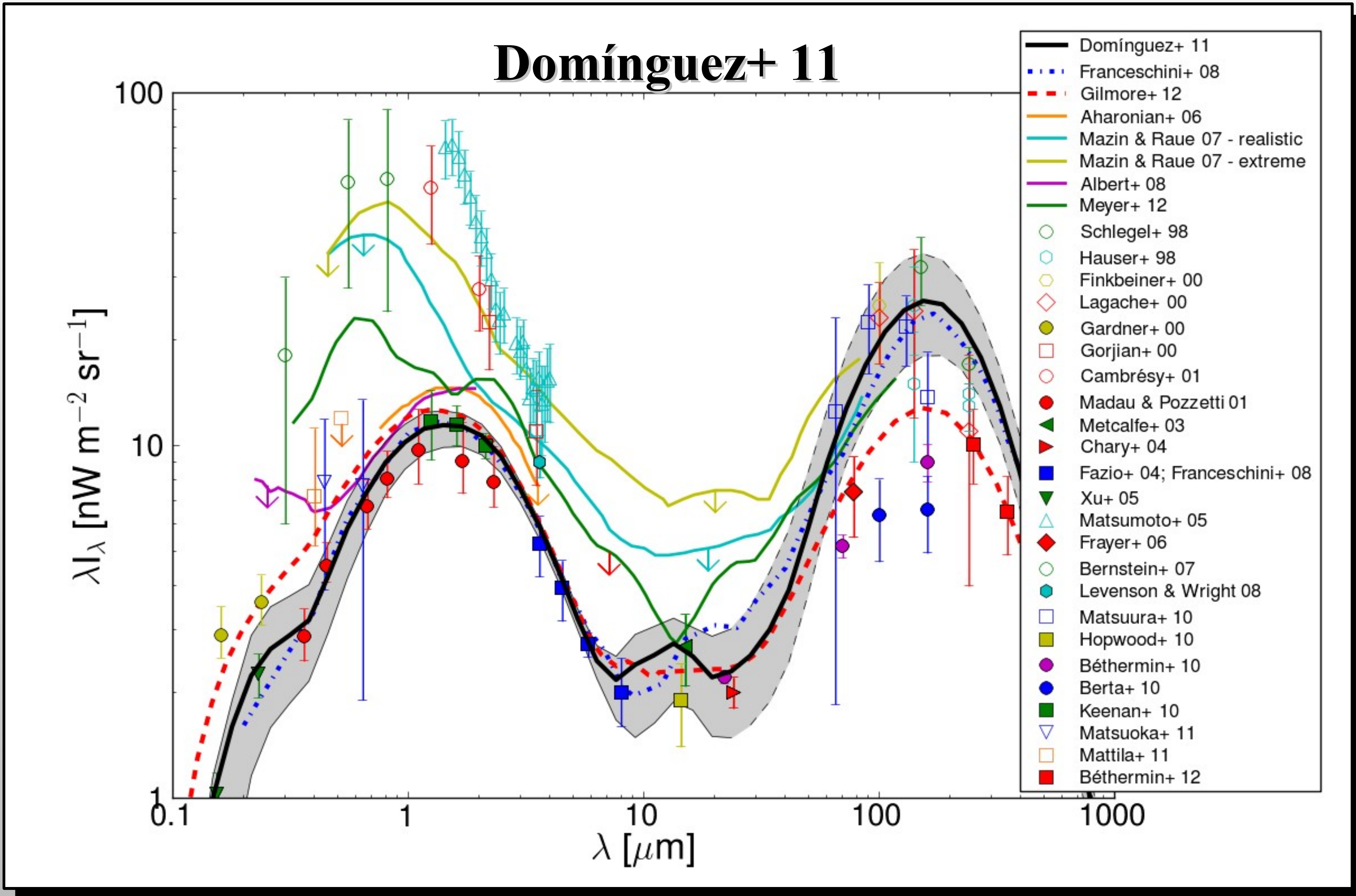
Local EBL data and γ-ray limits



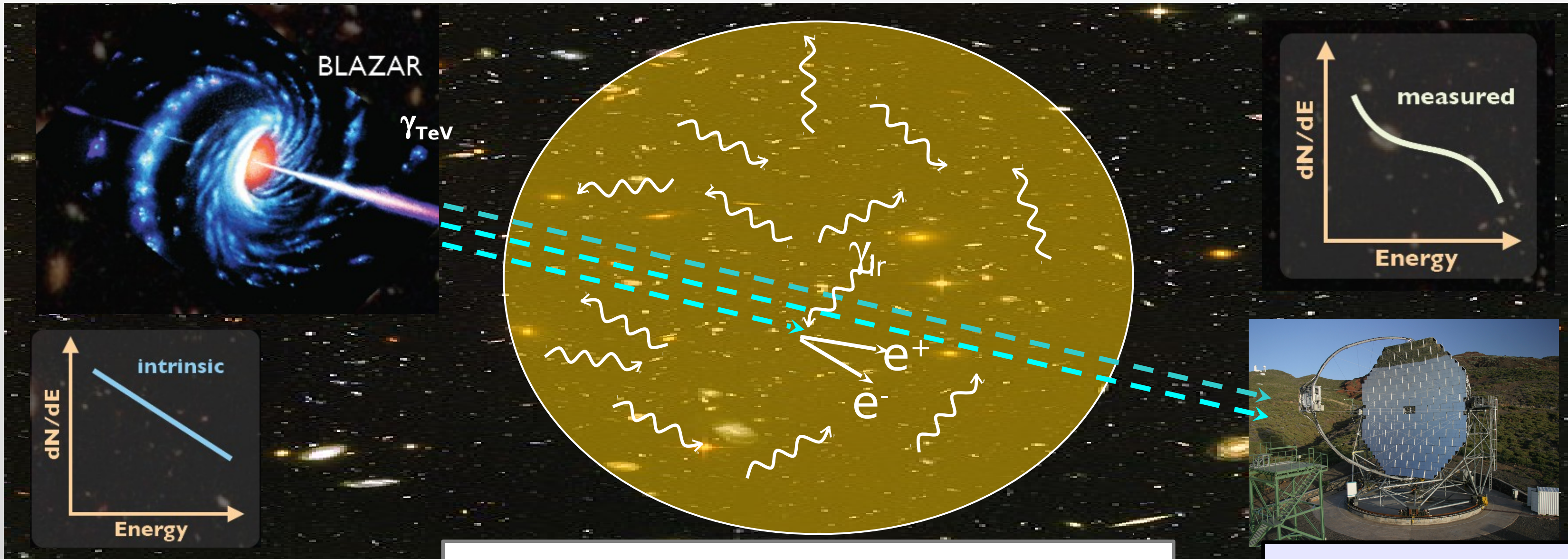
EBL models

Type of modeling and refs.	Galaxy number evolution	Galaxy emission
Type i, Forward evolution (Somerville+ 12; Gilmore+ 12)	**Semi-analytical models**.	**Modeled**. Stars: Bruzual & Charlot 03 (BC03); Dust Absorption: Charlot & Fall, 00; Dust Re-emission: Rieke+ 09.
Type ii, Backward evolution (Franceschini+ 08)	**Observed** local-optical galaxy luminosity functions (starburst population) and near-IR galaxy luminosity functions up to z=1.4 (elliptical and spiral populations)	**Modeled**. Consider only a few galaxy types based on optical images.
Type iii, Inferred evolution (Finke+ 10; Kneiske & Dole 10)	**Parameterization** of the history of the star formation density of the universe. By construction, they do not include quiescent and AGN galaxies.	**Modeled**. Stars: Single bursts of solar metallicity from BC99 (Kneiske+)/BC03 (Finke+); Dust Absorption: General extinction law; Dust Re-emission: Modified black bodies.
Type iv, Observed evolution (Domínguez+ 11)	**Observed** near-IR galaxy luminosity functions up to z=4.	**Observed**. Multiwavelength photometry from the UV up to MIPS 24 for ~6000 galaxies up to z=1. Consider 25 different galaxy types.

Local EBL: data, γ-ray limits, and models



Gamma-ray attenuation



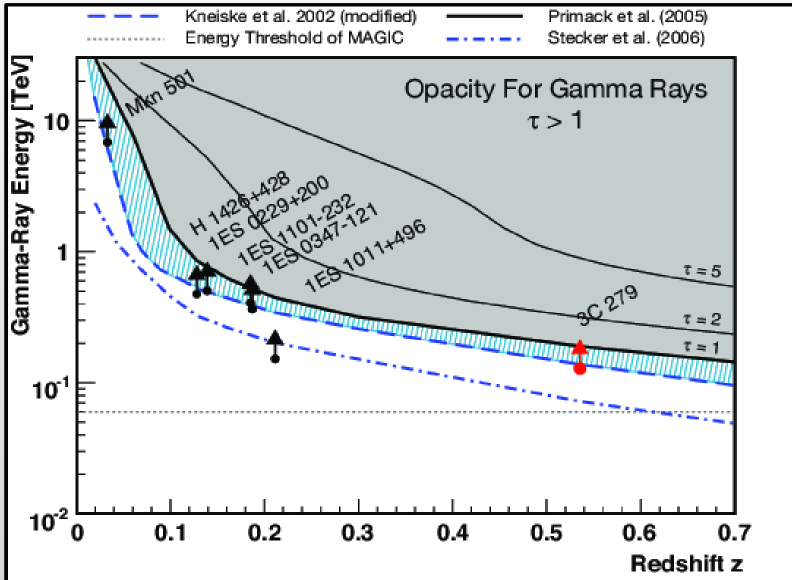
Ilustration: D. Mazin & M. Raue

$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$

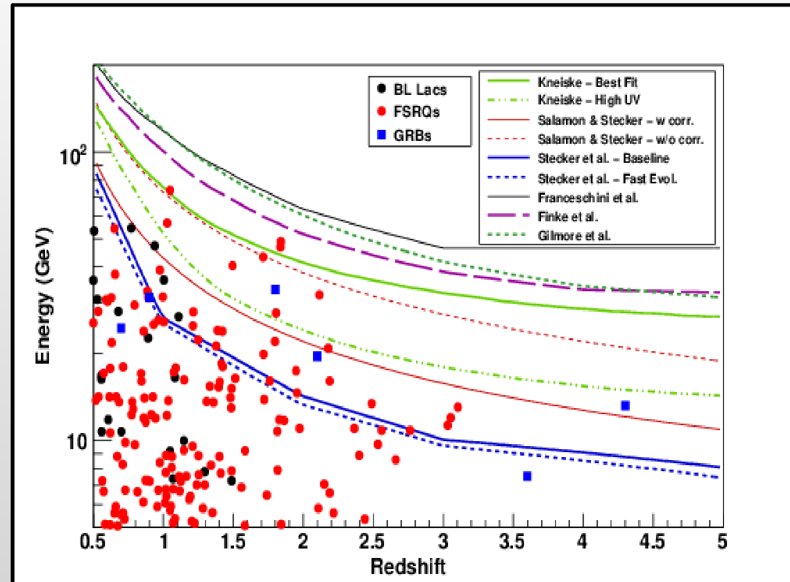
The cosmic gamma-ray horizon (CGRH) is by definition the energy as a function of redshift at which the optical depth due to EBL is the unity.

The measurement of the CGRH is a primary scientific goal of the Fermi Gamma-Ray Telescope (Hartmann 07; Stecker 07; Kashlinsky & Band 07)

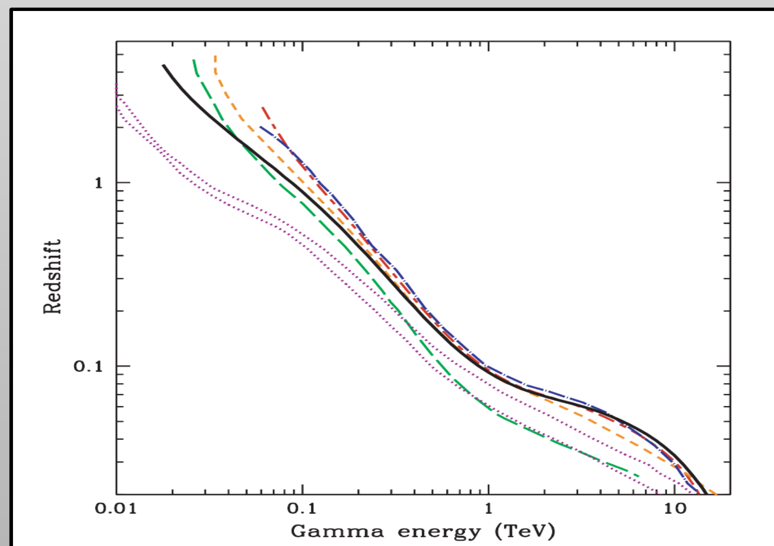
Cosmic γ-ray Horizon: previous estimations



Albert+ 08



Abdo+ 10



Gilmore+ 12

Cosmic γ-ray Horizon: methodology

Source	Redshift
Mkn 421	0.031
Mkn 501	0.034
1ES 2344+514	0.044
1ES 1959+650	0.048
PKS 2005-489	0.071
W Comae	0.102
PKS 2155-304	0.116
H 1426+428	0.129
1ES 0806+524	0.138
H 2356-309	0.165
1ES 1218+304	0.182
1ES 1101-232	0.186
1ES 1011+496	0.212
3C 66A	0.444
PG 1553+113	$0.500^{+0.080}_{-0.105}$

Quasi-simultaneous multiwavelength catalog of 15 BL Lacs (based on the compilation by Zhang et al. 2012).

Synchrotron self-Compton models

Blazars: AGNs emitting at all wavelength with energetic jets pointing towards us.

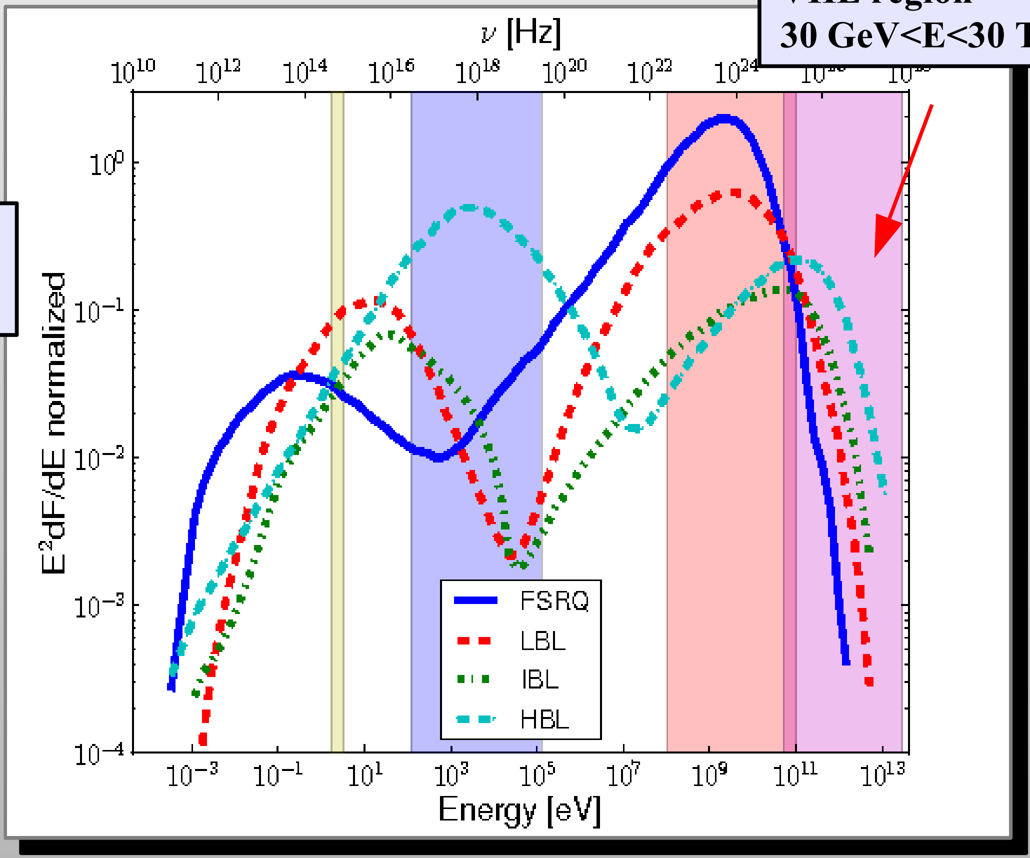
Emission described by synchrotron/synchrotron-self Compton model.

$$\left.\frac{dF}{dE}\right|_{int} = F_0 E^{-\Gamma_{int}}$$

$$\Gamma_{int} \geqslant 1.5$$

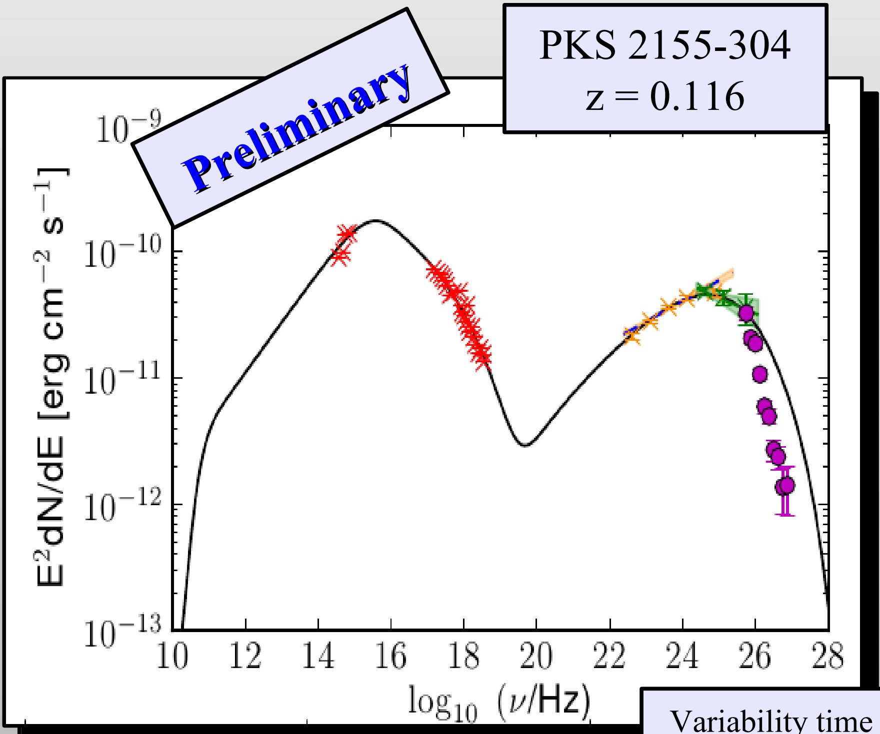
Observations and theoretical arguments in the VHE

VHE region
30 GeV<E<30 TeV

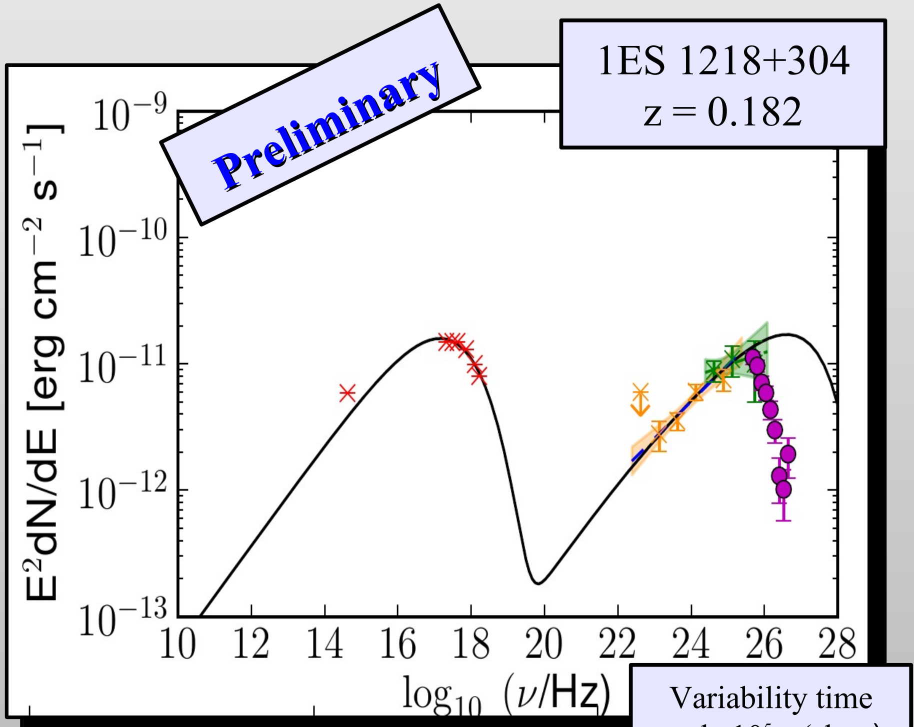


SED multiwavelength fits

A one-zone synchrotron/SSC model is fit to the multiwavelength data excluding the Cherenkov data, which are EBL attenuated. Then, this fit is extrapolated to the VHE regime representing the intrinsic VHE spectrum. Technique similar to Mankuzhiyil et al. 2010.



Variability time scale 10^4 s (fast)



Variability time scale 10^5 s (slow)

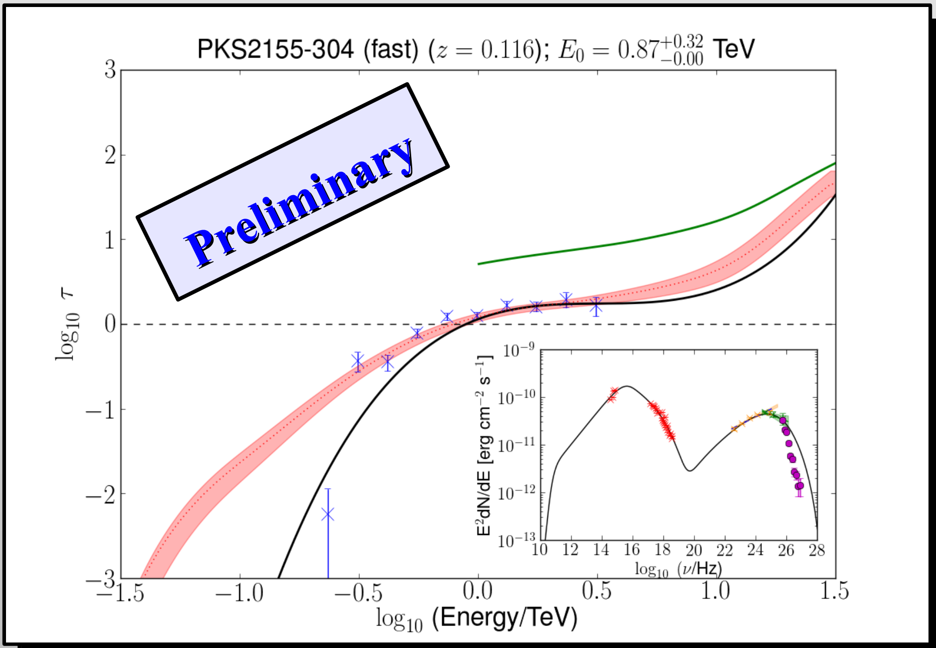
Optical depth estimation and determination of the CGRH

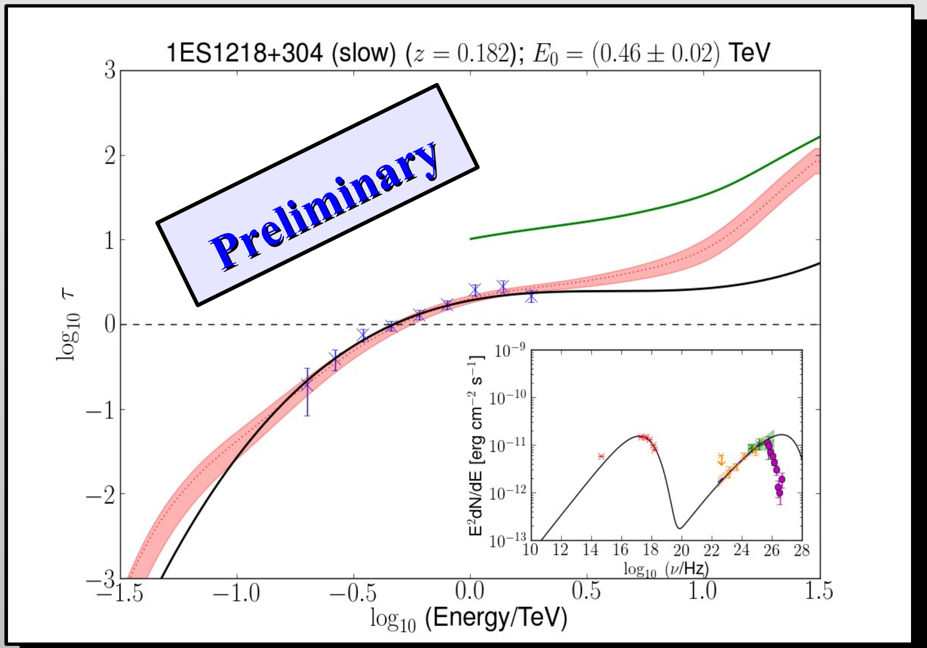
Maximum likelihood technique with three EBL-model independent conditions:

1.- The optical depth is lower than 1 at E = 0.03 TeV.

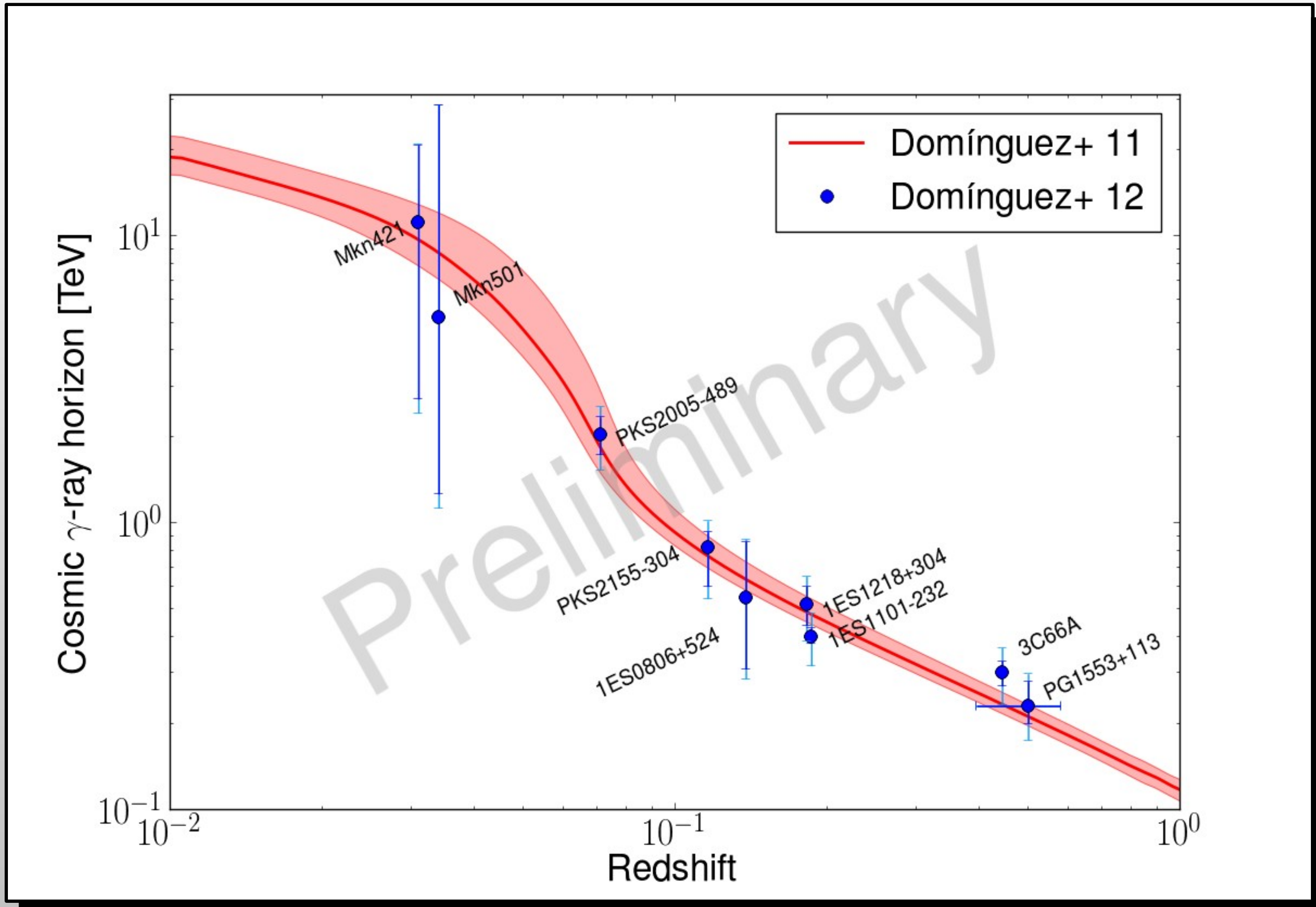
2.- The optical depth is lower than the optical depth calculated from the upper limits from Mazin & Raue, 07; especially 1 < τ < UL(z) at E = 30 TeV.

3.- The polynomial is monotonically increasing with the energy.





Cosmic γ-ray Horizon: results



There are 4 out of 15 cases where our maximum likelihood methodology could not be applied since the prediction from the synchrotron/SSC model was lower than the detected flux by the Cherenkov telescopes.

Two other cases where the statistical uncertainties were too high to set any constraint on E0.

Summary

1.- The local EBL seems well constrained in the optical/near-IR
since direct detection data, galaxy counts, γ-ray limits, and EBL models converge.

2.- The first statistically significant detection of the CGRH
that is independent of any EBL model has been presented.

3.- Our CGRH results implies that γ-ray attenuation is in agreement
with the current EBL knowledge contrary to other claims by Orr et al. 11.

4.- Our CGRH detection is sensitive to the total EBL
and implies that most of the EBL has been detected by other techniques.