Image credits: https://blenderartist.org

γ-ray Blazars above 100 MeV

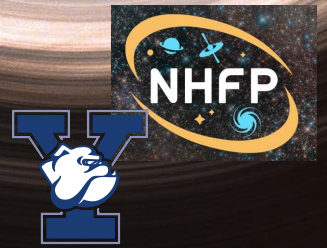
γ-2022, Jul 5 2022

Density, evolution and origin of the Extragalactic Gamma-ray Background

Presented by: Lea Marcotulli

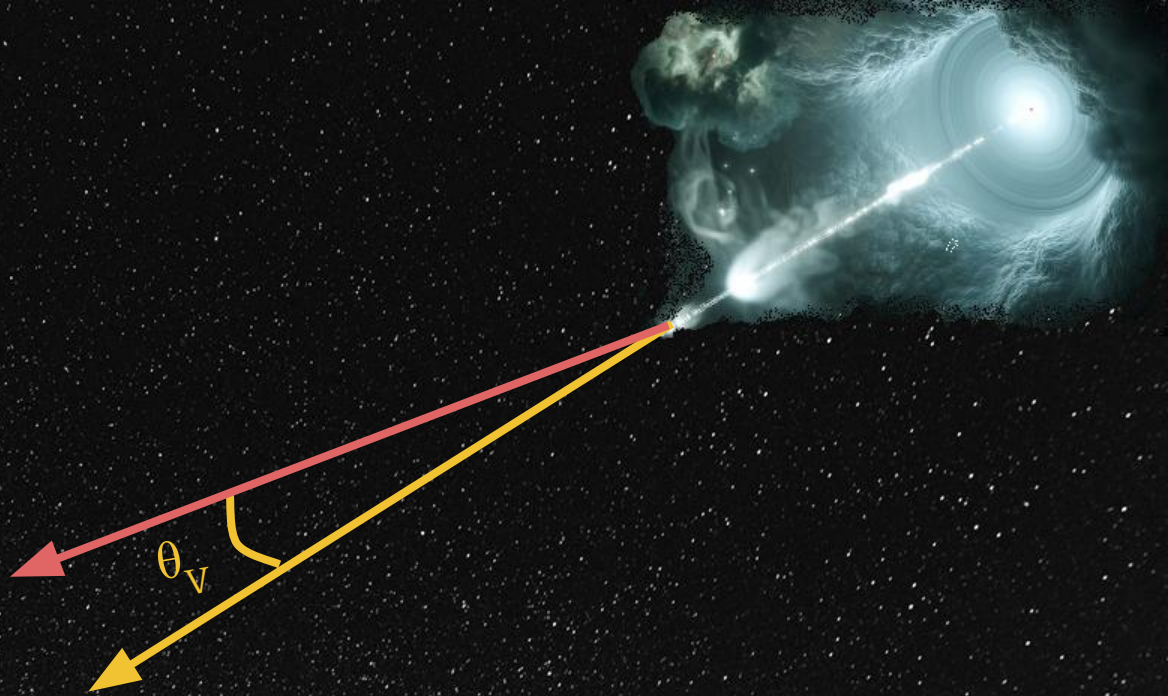
lea.marcotulli@yale.edu

On behalf of: Marco Ajello, Mattia di Mauro



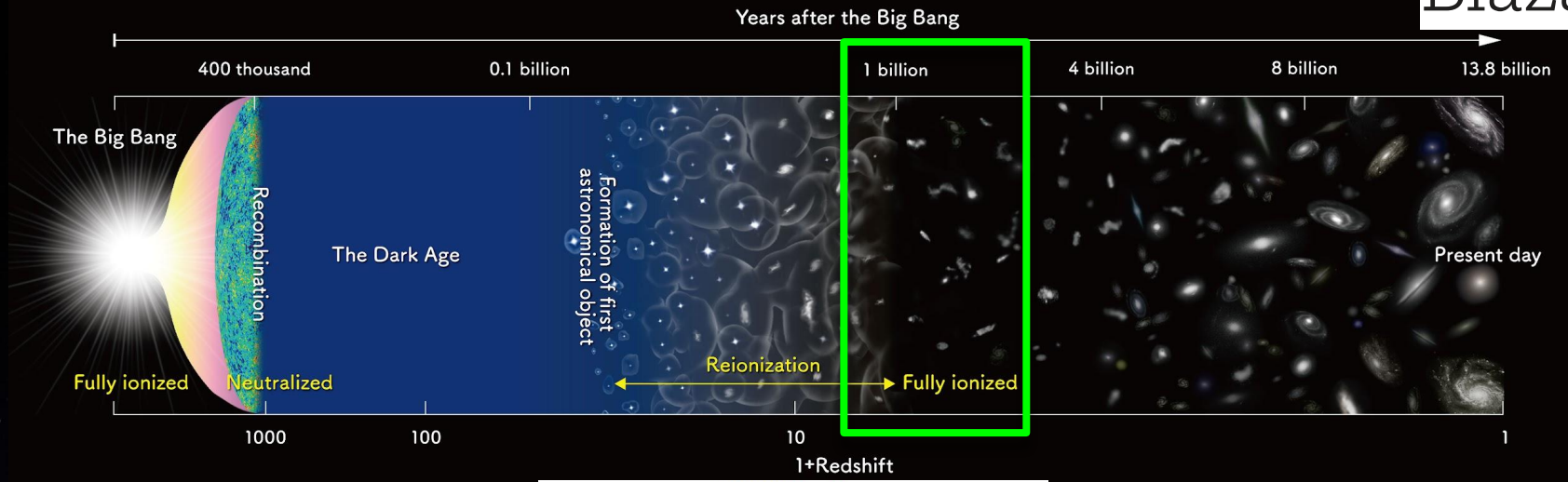
Lea Marcotulli | lea.marcotulli@yale.edu

$$\theta_V \leq 5^\circ - 10^\circ$$

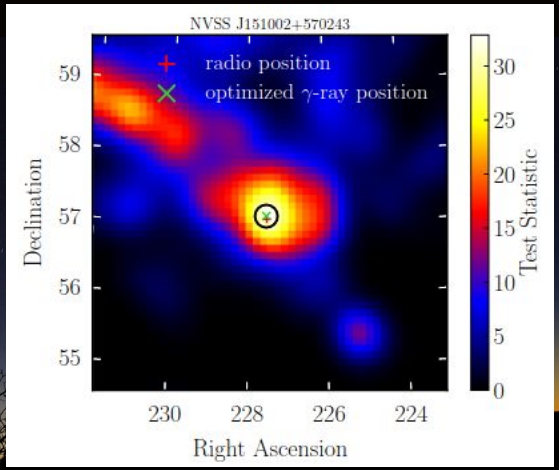


Lea Marcotulli | lea.marcotulli@yale.edu

Blazars



E.g. Sbarrato et al. 2015; An & Romani 2018; Marcotulli et al. 2020

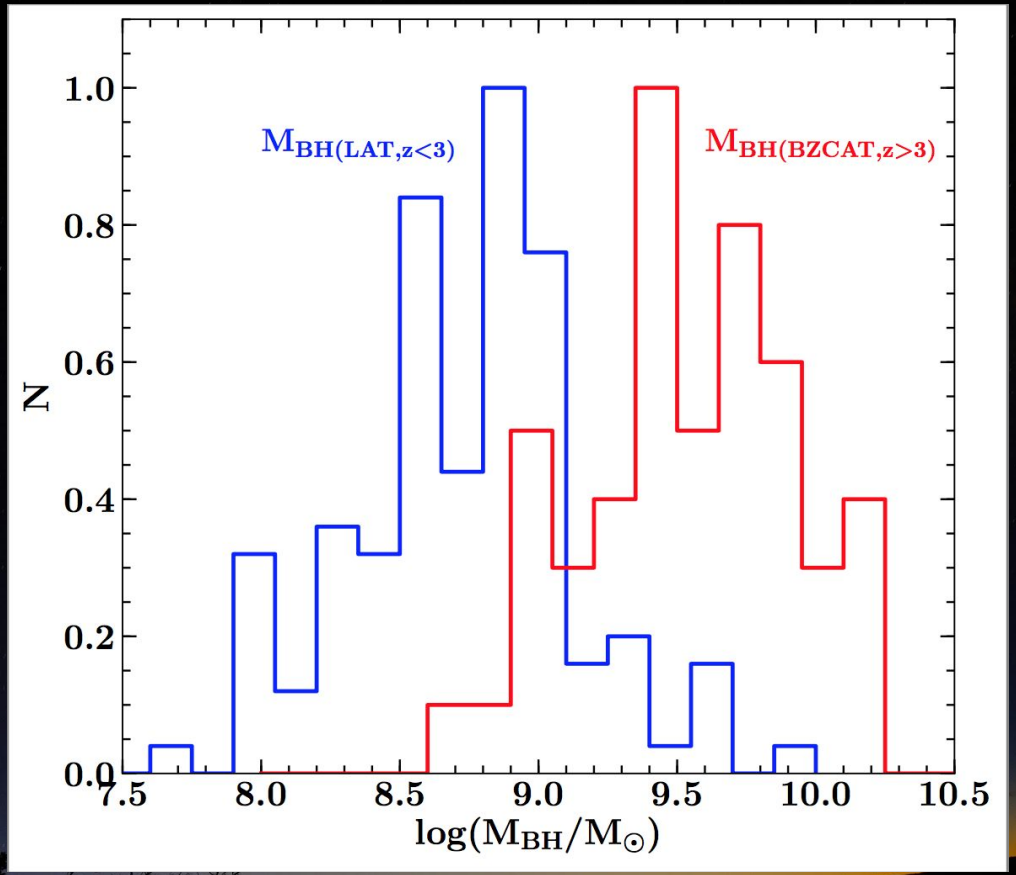


Ackermann et al. 2017

z = 4.3

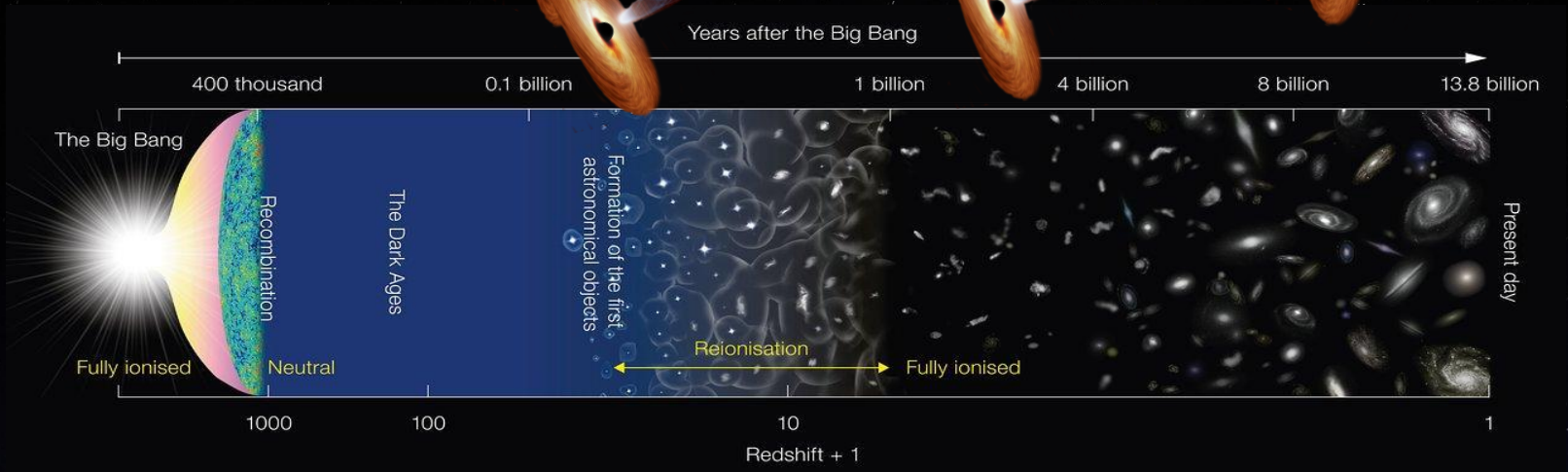
Lea Marcotulli | lea.marcotulli@yale.edu

Blazars



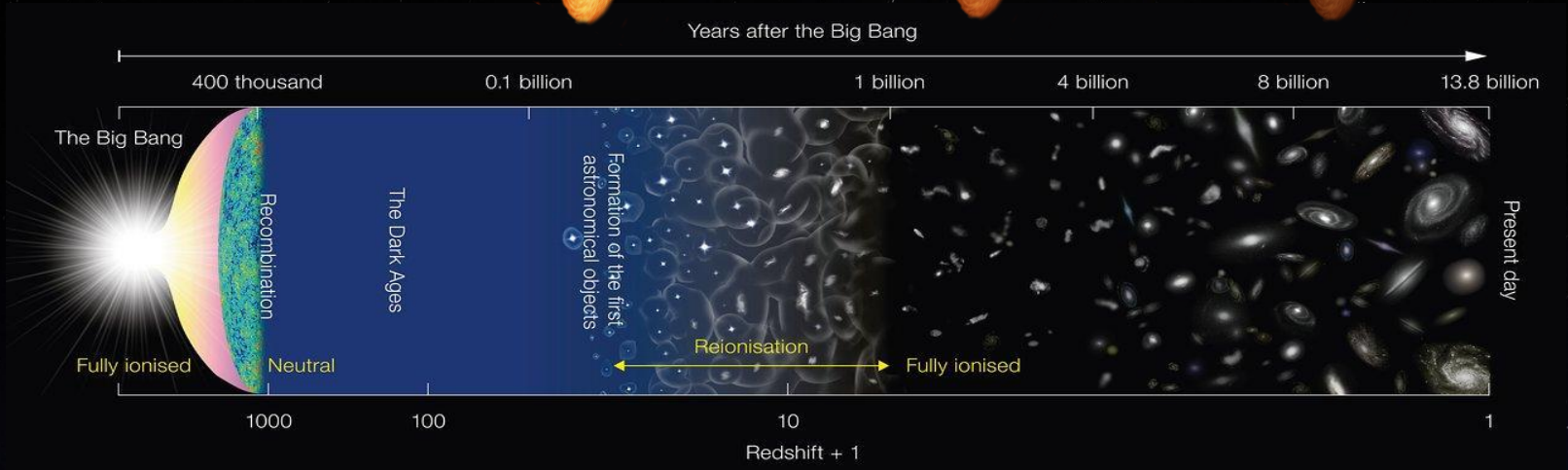
Paliya, Marcotulli et al. 2017

Blazars Evolution



→ Pure Density Evolution (**PDE**)

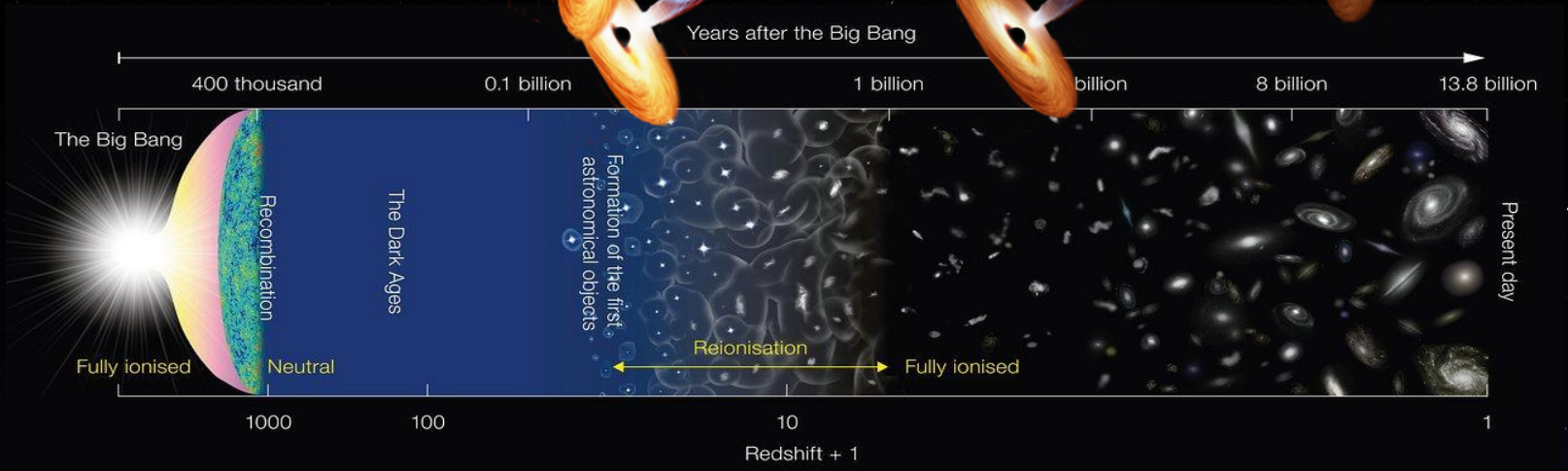
Blazars Evolution



→ Pure Density Evolution (PDE)

→ Pure Luminosity Evolution (**PLE**)

Blazars Evolution

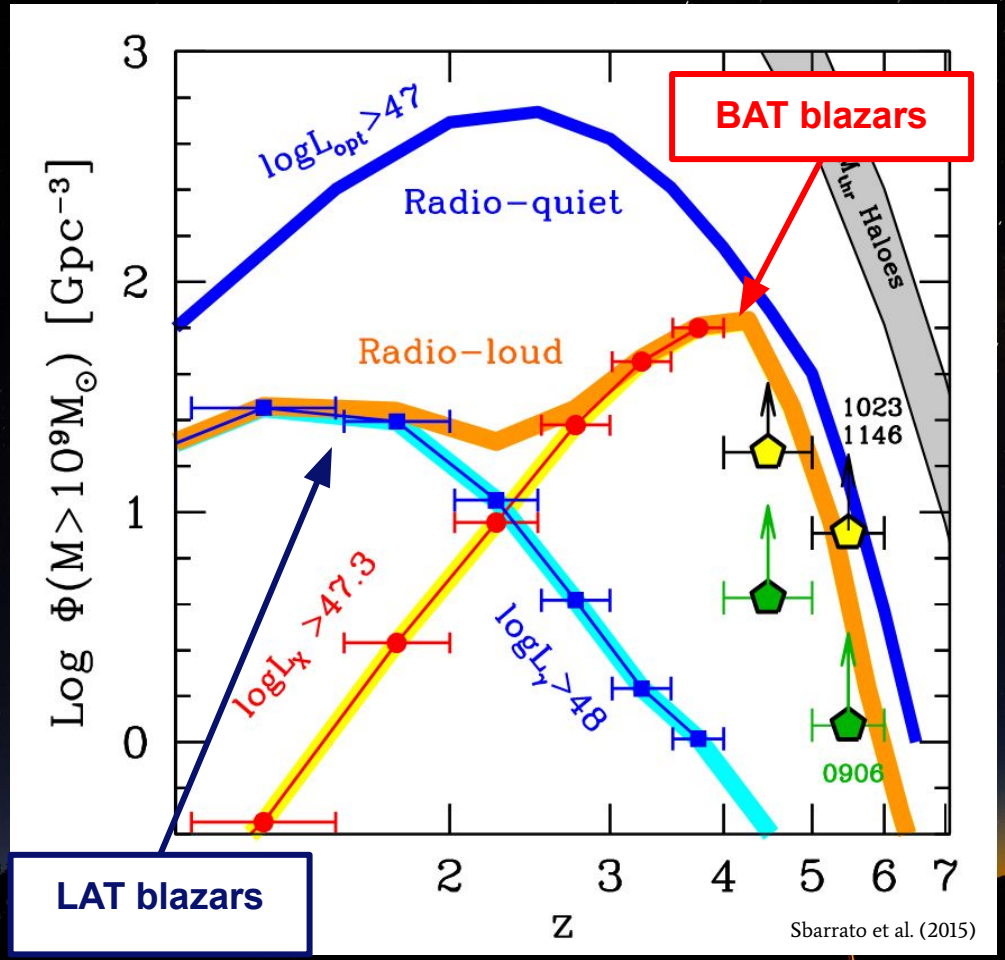


→ Pure Density Evolution (PDE)

→ Pure Luminosity Evolution (PLE)

→ Luminosity-Density Dependent Evolution (**LDDE**)

Blazars and SMBH Evolution



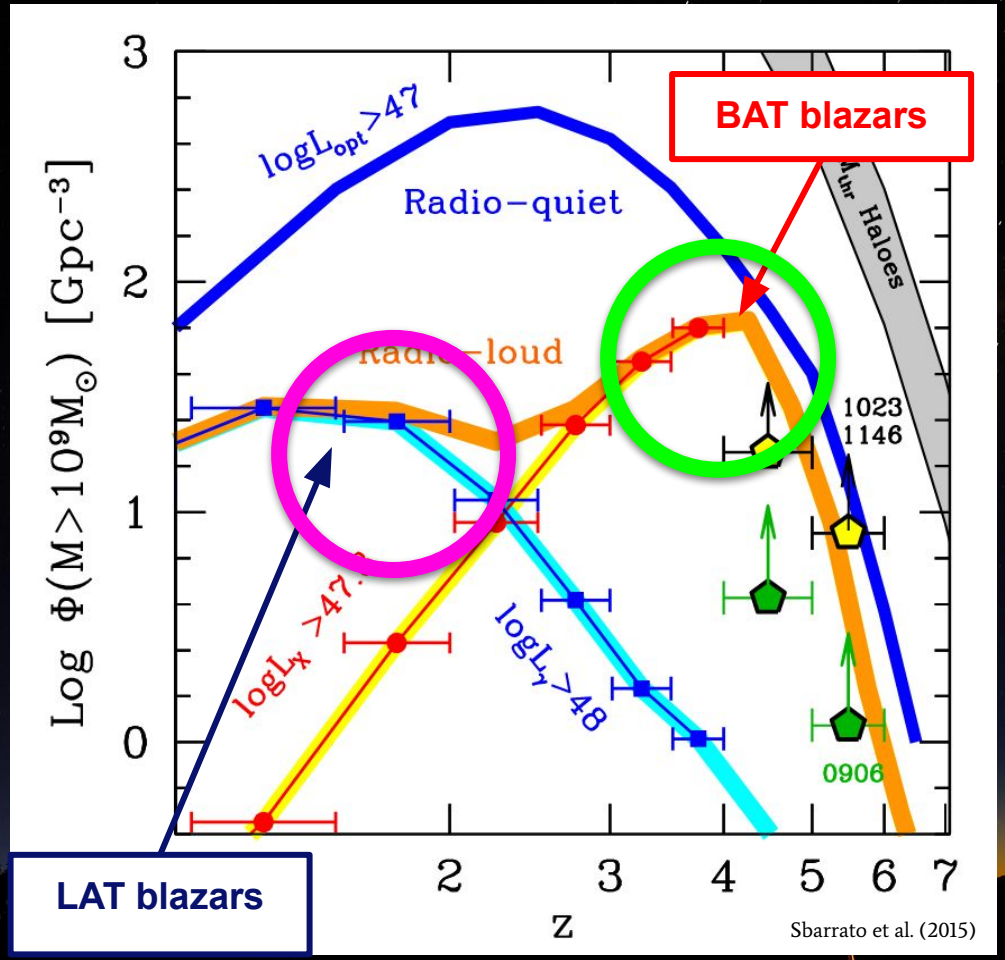
Sbarrato et al. (2015)

JETS

↕

SMBH GROWTH

Blazars and SMBH Evolution

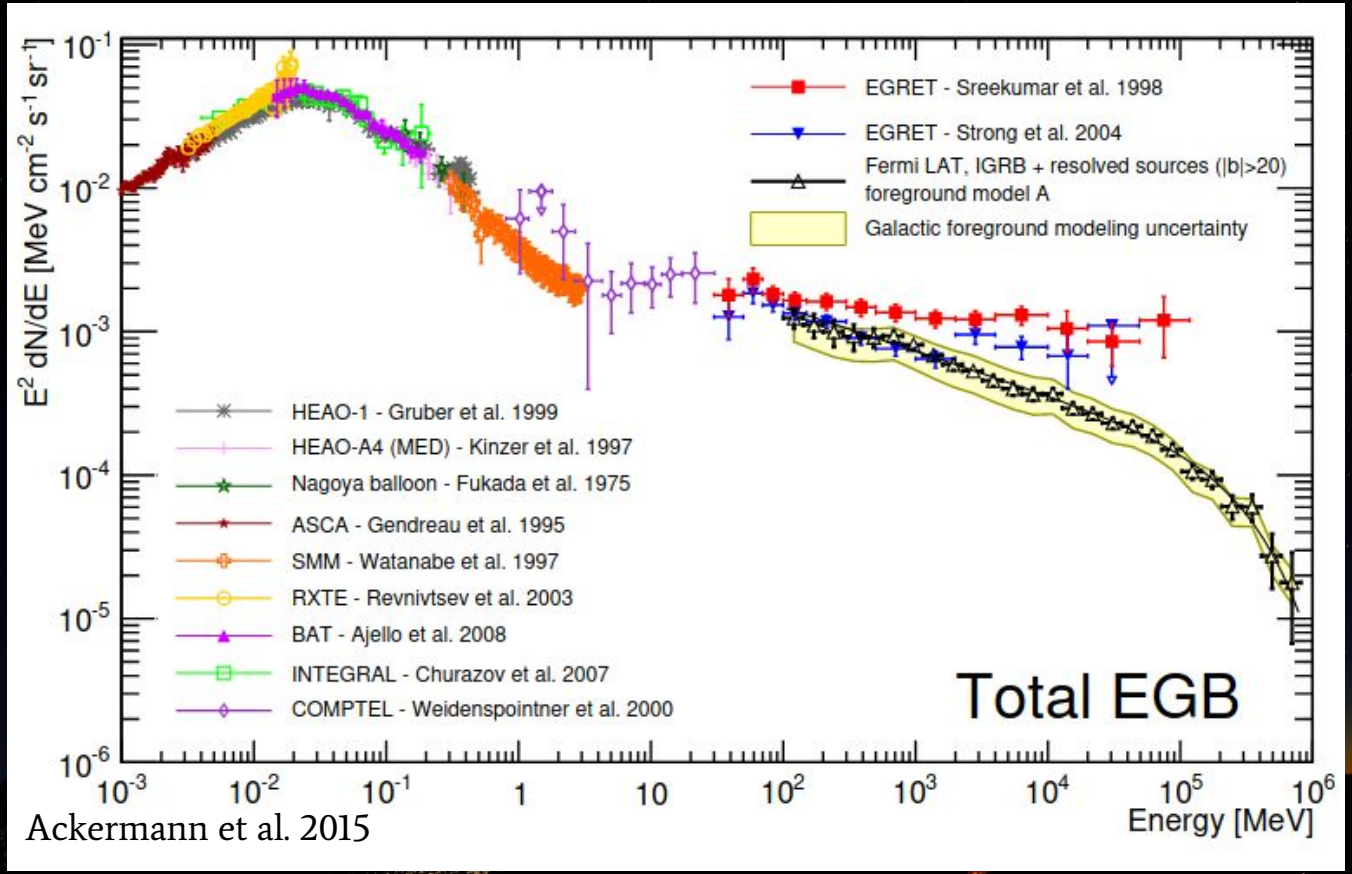


Sbarrato et al. (2015)

JETS

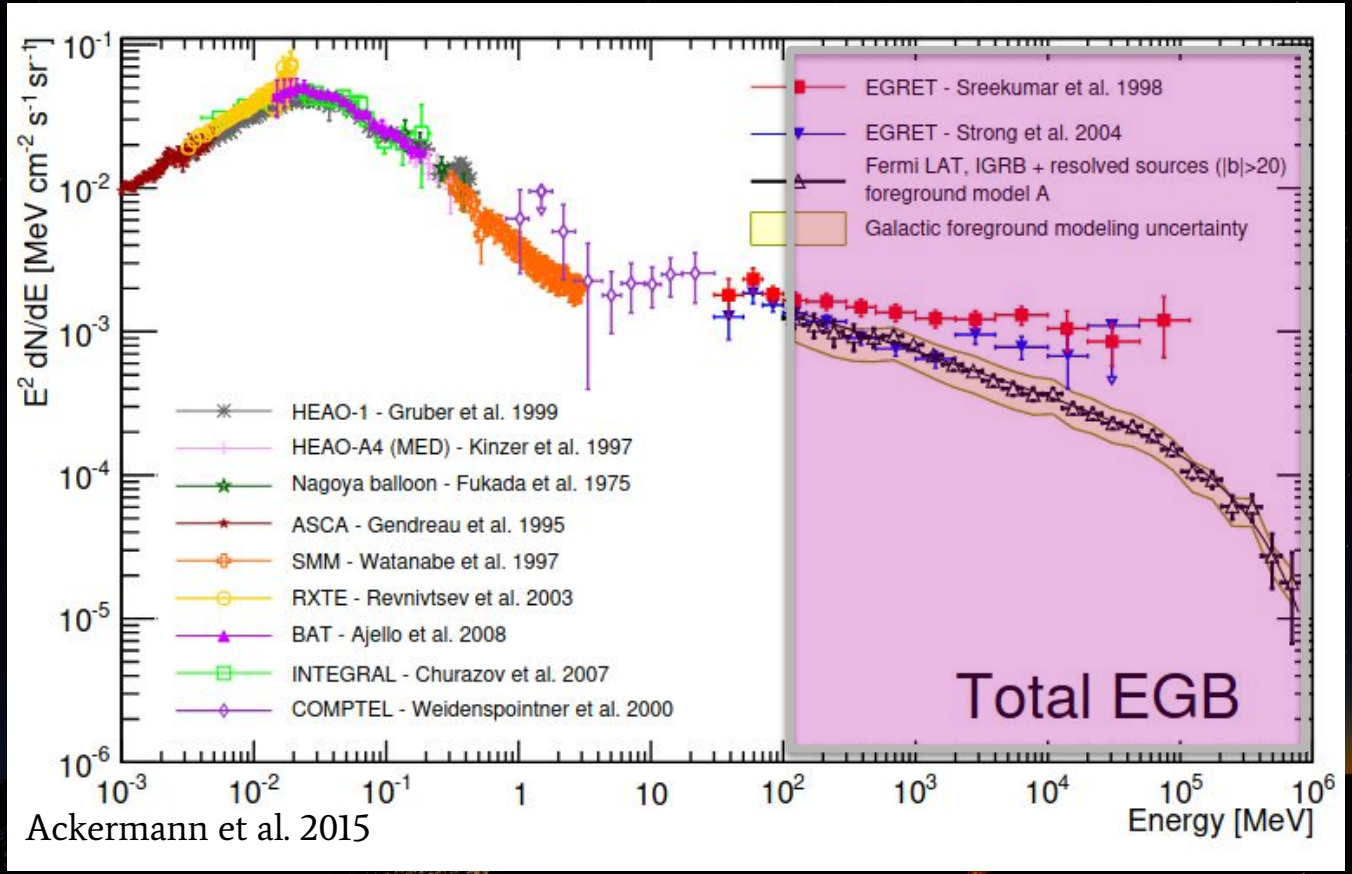
SMBH GROWTH

The Cosmic High-Energy Background



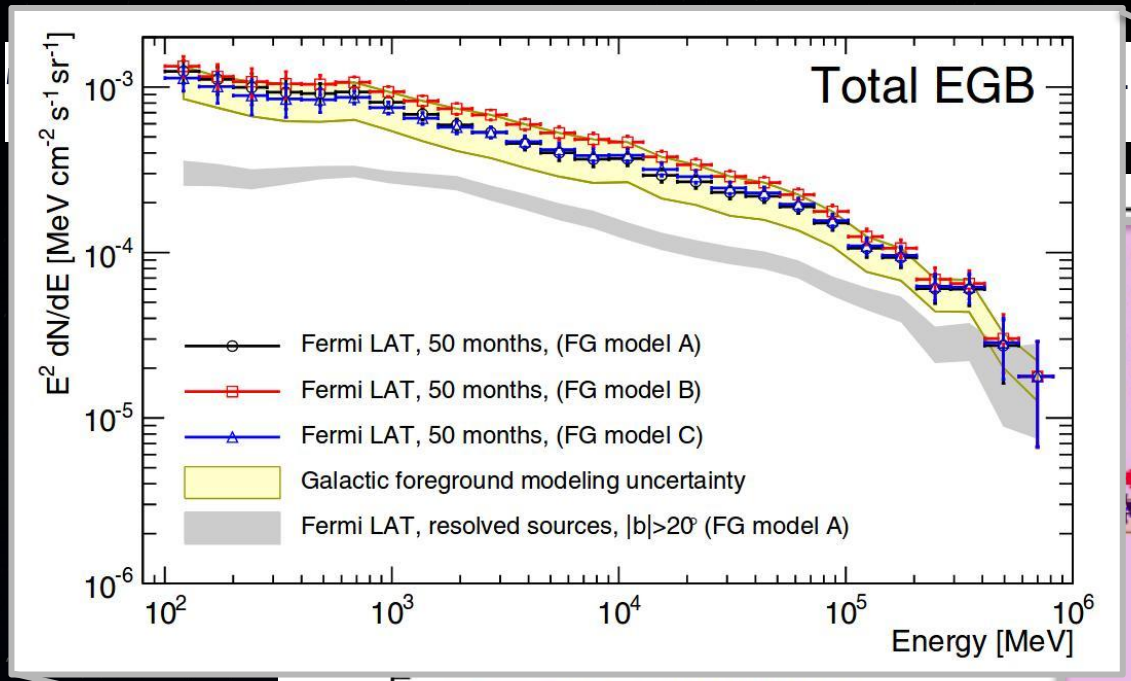
Ackermann et al. 2015

The Cosmic High-Energy Background



Ackermann et al. 2015

round

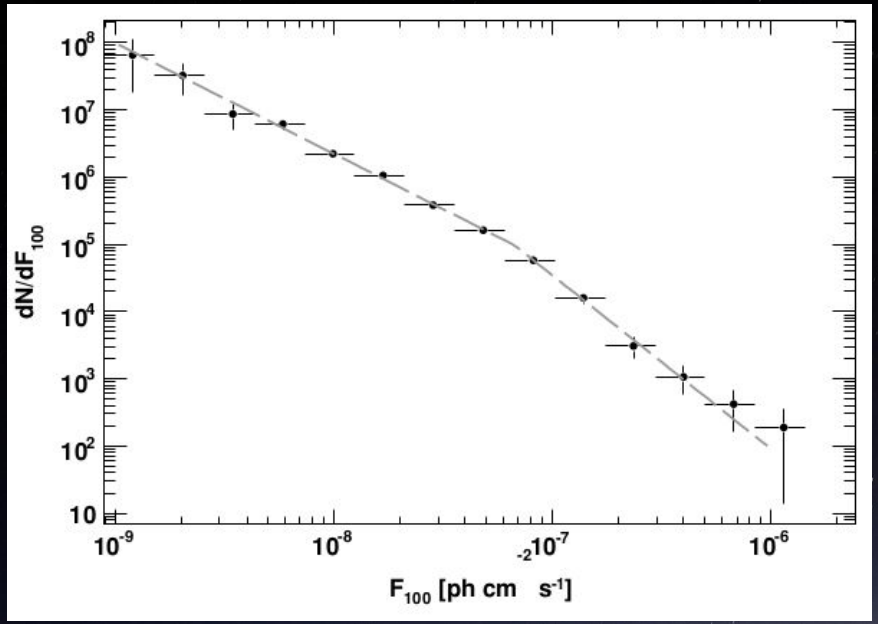


Ackermann et al. 2015

Blazars account for ~30% of the EGB below 100 GeV and for more than 50% above 100 GeV

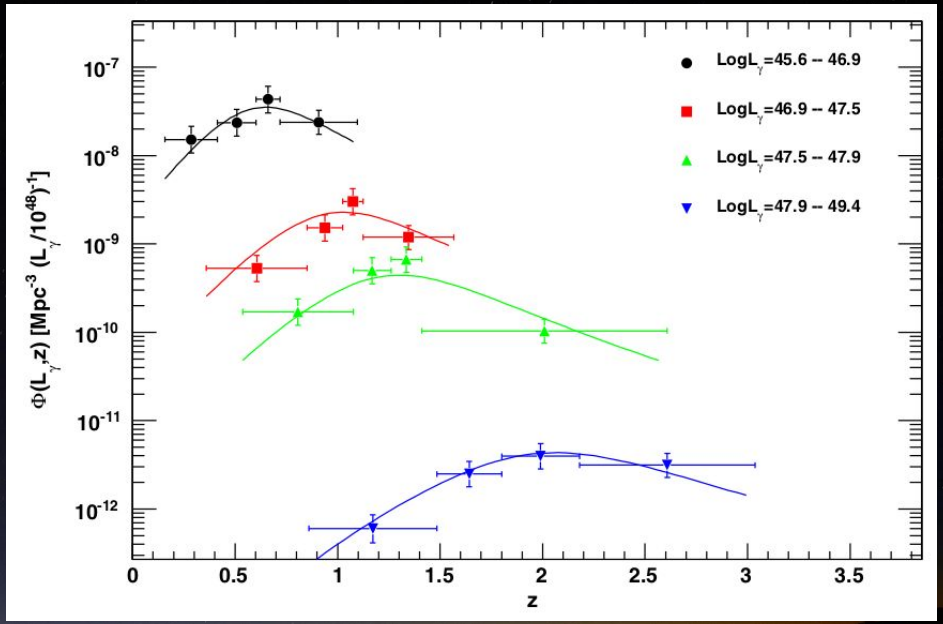
The strategy

Source count distribution



Adbo et al. 2010

Luminosity function

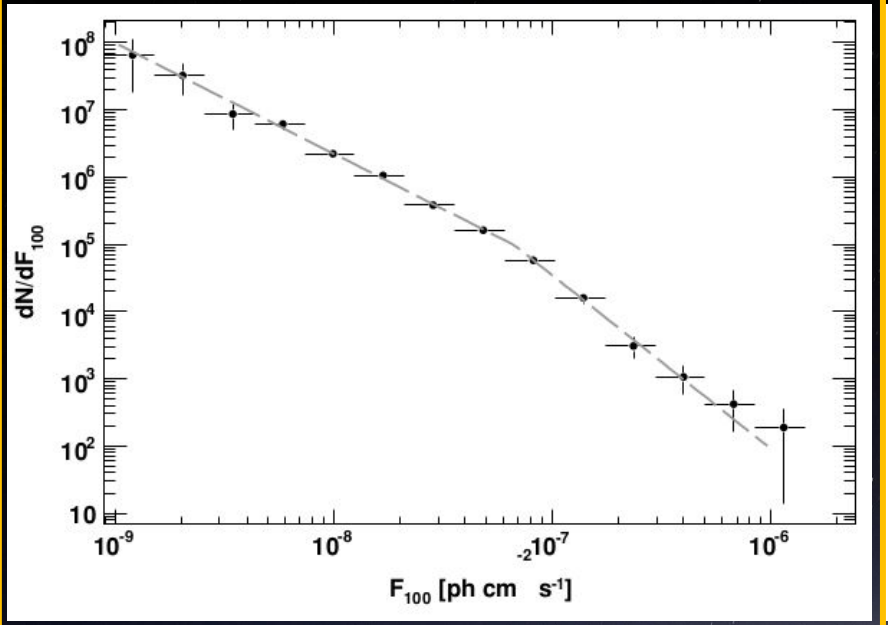


Ajello et al. 2012

The strategy

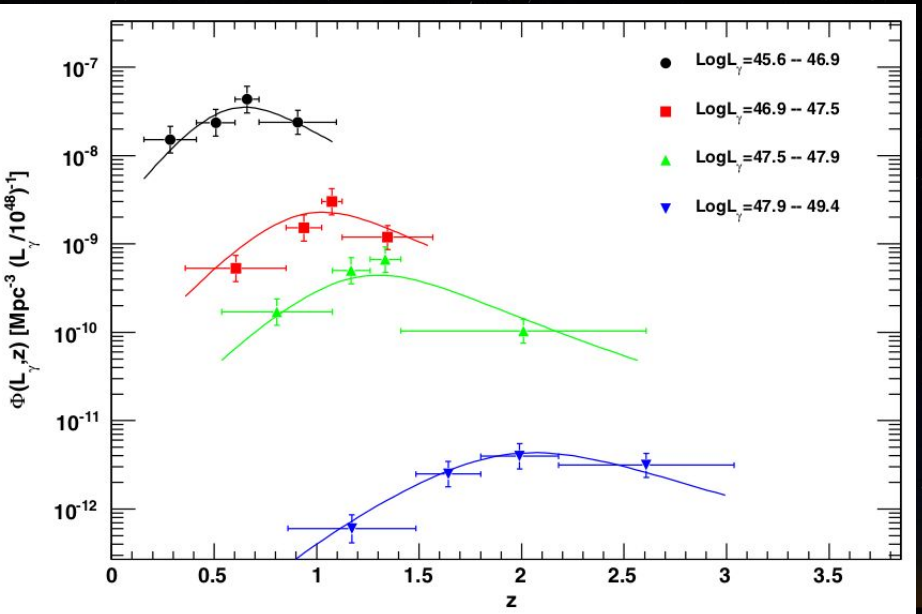
Lea Marcotulli | lea.marcotulli@yale.edu

Source count distribution



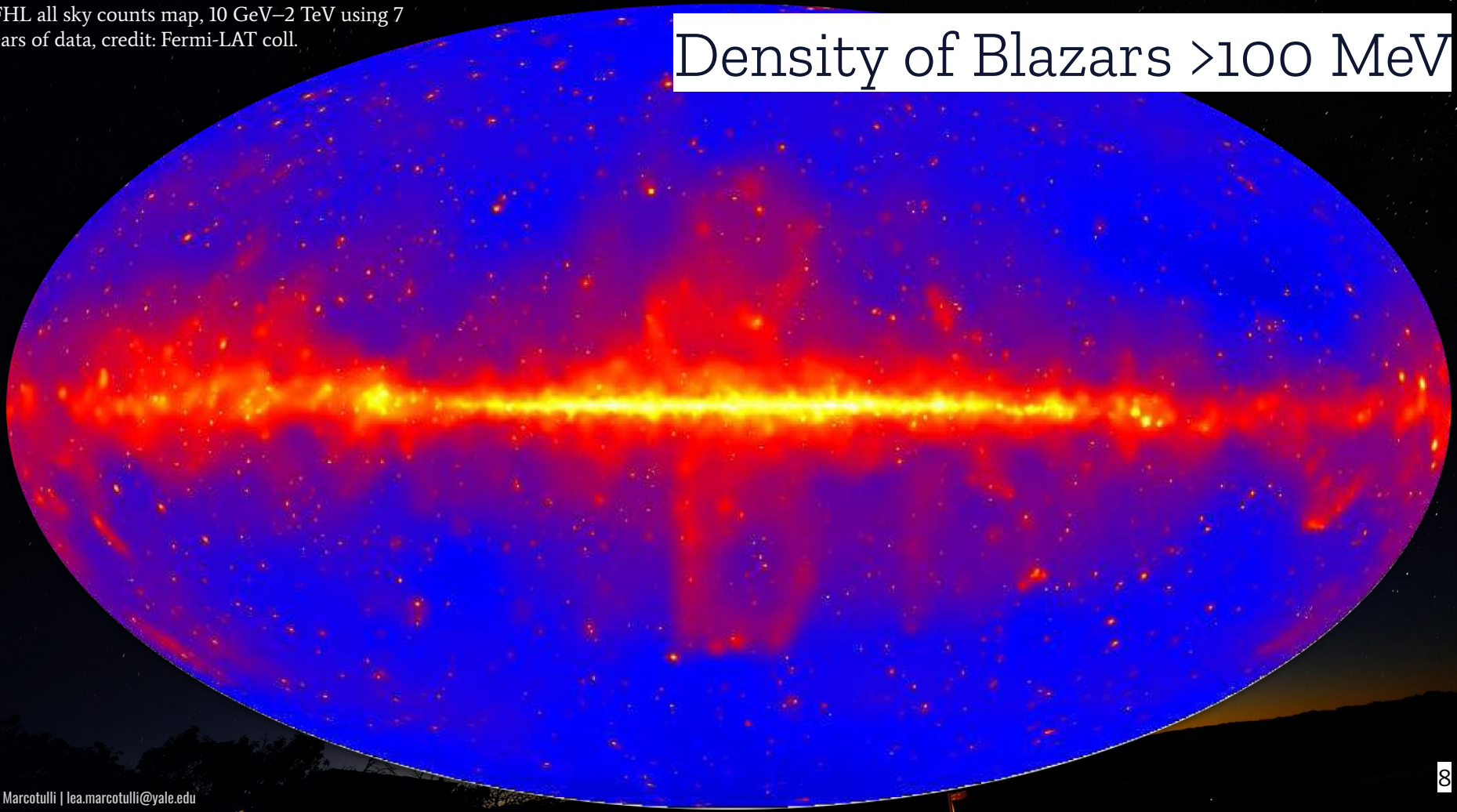
Adbo et al. 2010

Luminosity function



Ajello et al. 2012

Density of Blazars >100 MeV



3FHL all sky counts map, 10 GeV–2 TeV using 7 years of data, credit: Fermi-LAT coll.

Efficiency correction method - The recipe

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Detect real sources above Galactic latitudes (|b|>20°) using 8 years of Pass 8 data

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Perform detailed Monte Carlo simulations to derive survey biases

Efficiency correction method - The recipe

Detect real sources above Galactic latitudes (|b|>20°) using 8 years of Pass 8 data

Derive the efficiency of the LAT to account for these biases

Perform detailed Monte Carlo simulations to derive survey biases

Efficiency correction method - The recipe

Detect real sou

Galactic latitu

using 8 years

data

he efficiency of

to account for

ases

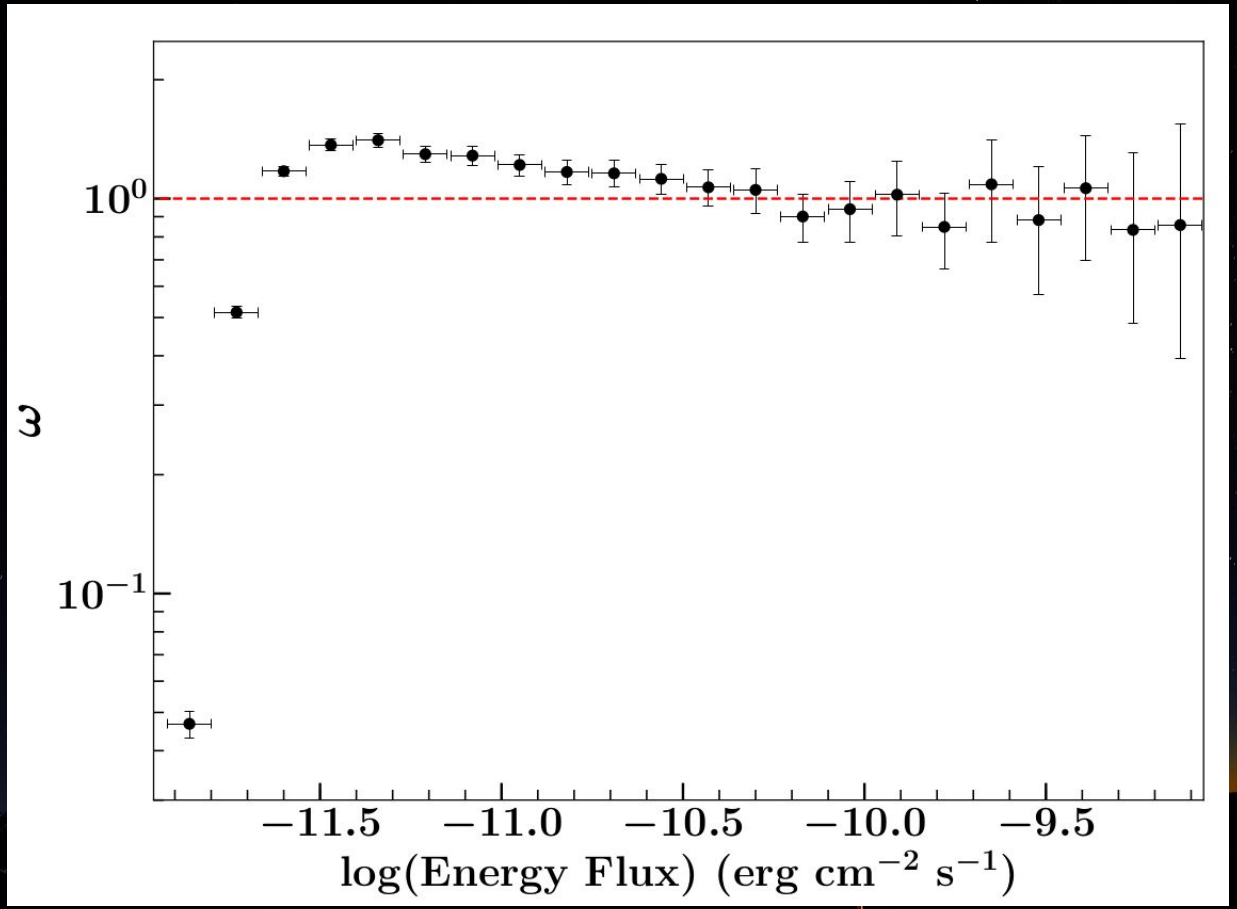
Perform detail

Carlo simulati

survey biases

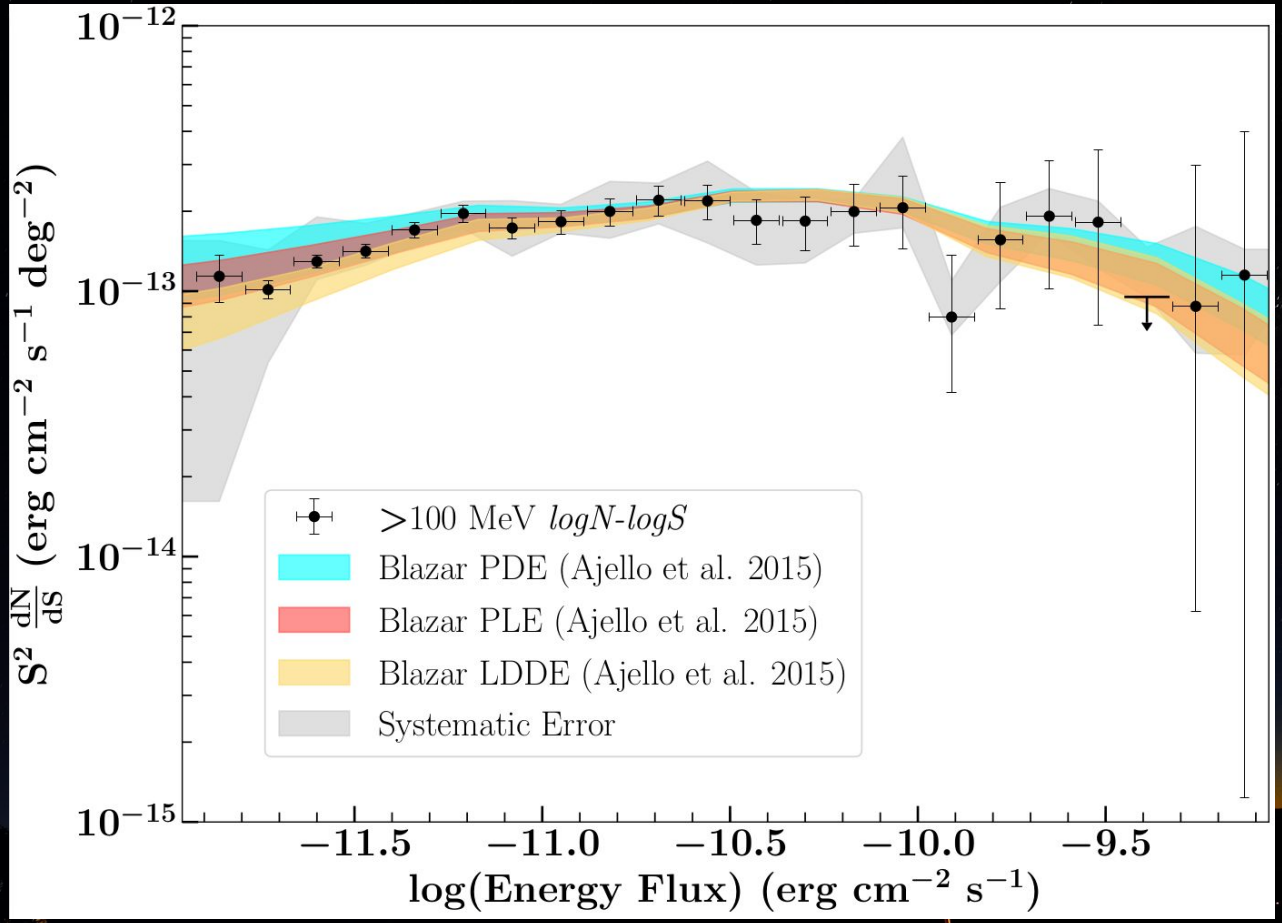
Derive the intrinsic source count distribution of the blazar population

Efficiency (ω)



Marcotulli et al. , 2020

Intrinsic source count distribution

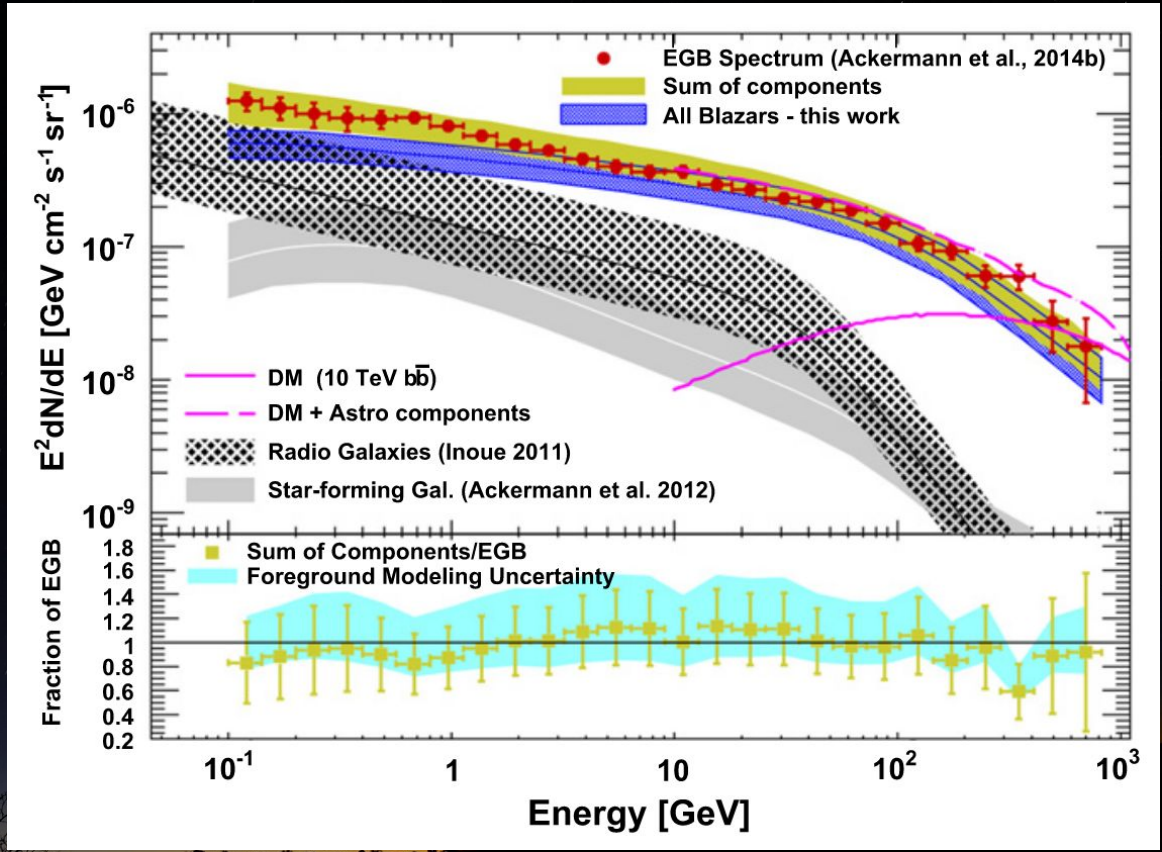


Marcotulli et al. , 2020

Origin of the EGB

$$I_{EGB} = 5.6^{+0.9}_{-0.4} \times 10^{-6} (\mathrm{cm^{-2} s^{-1} sr^{-1}})$$

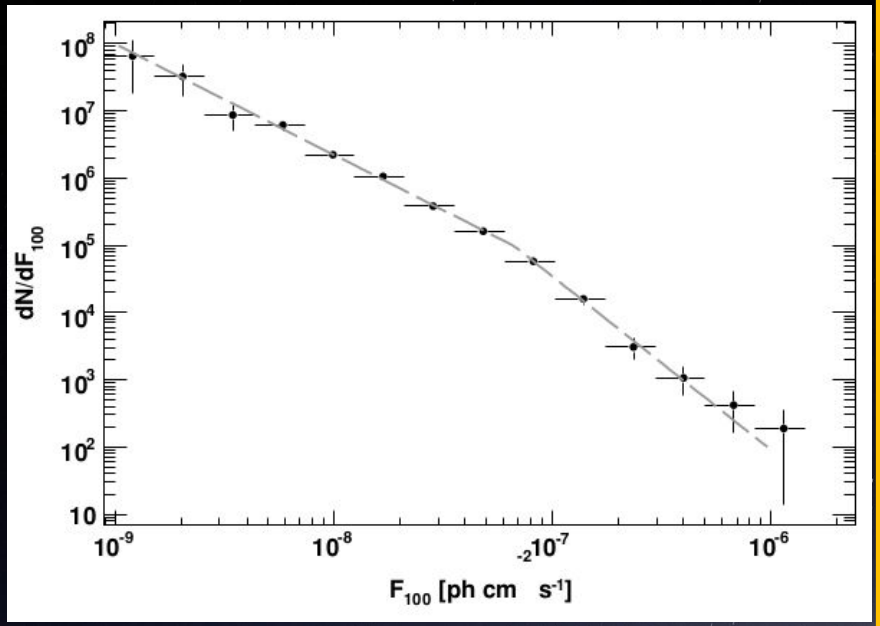
➔ **Point-sources (i.e. blazars) account for $\sim 50^{+10}_{-5}\%$ of the total EGB**



Ajello et al. 2015; Di Mauro et al. 2015

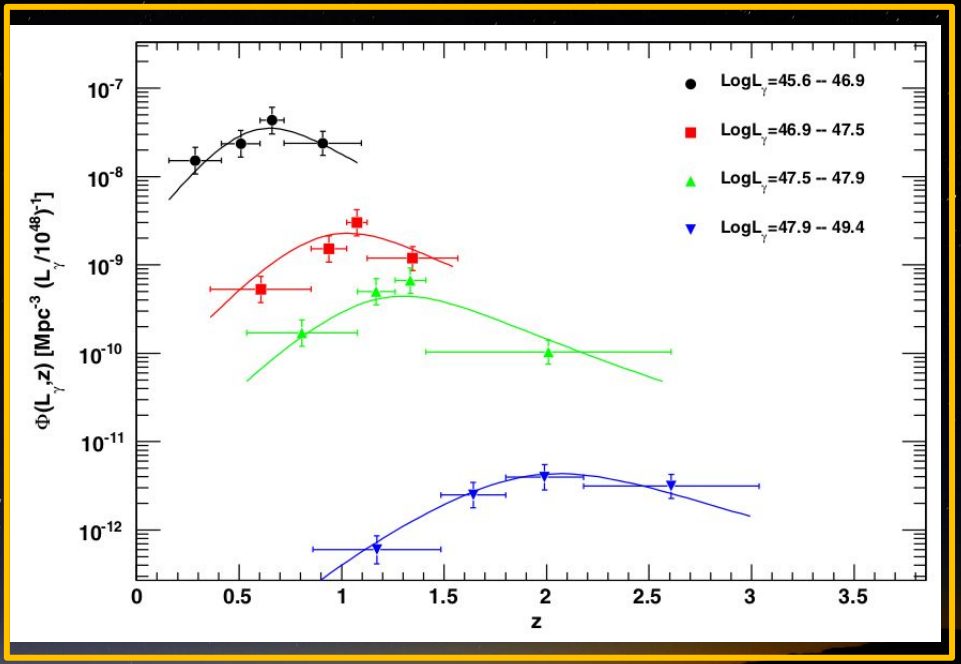
The strategy

Source count distribution



Adbo et al. 2010

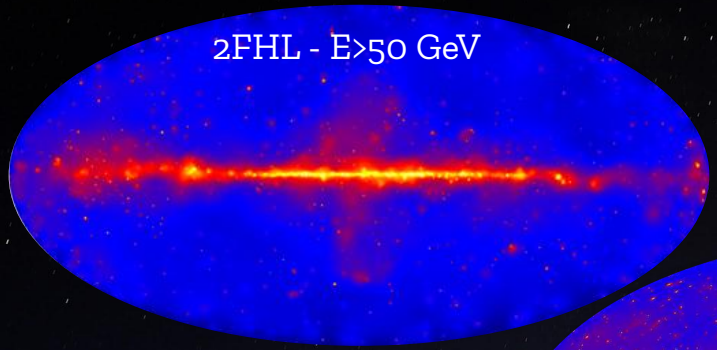
Luminosity function

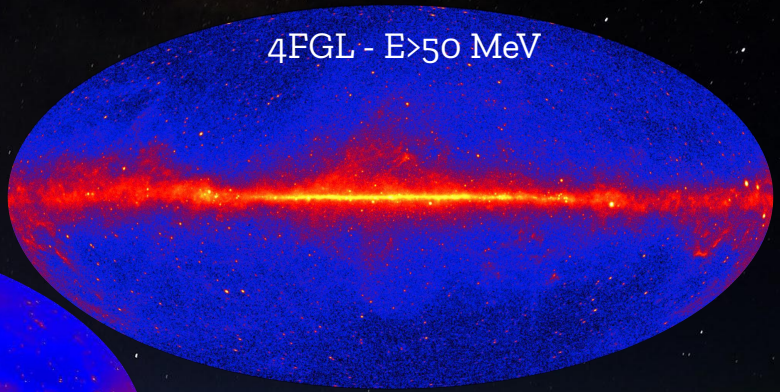


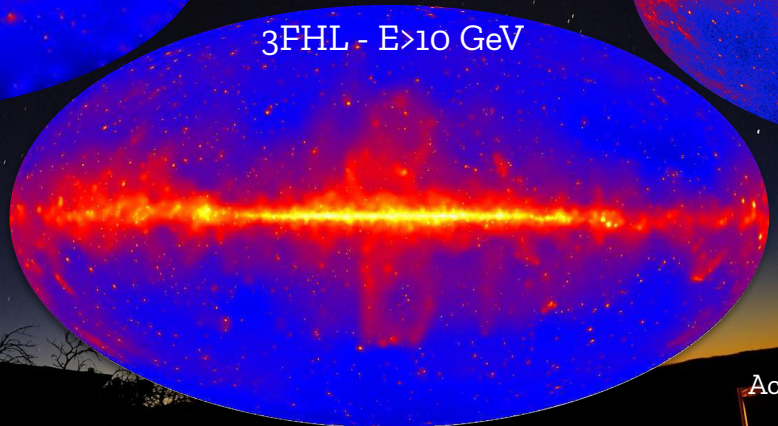
Ajello et al. 2012

What's next

1. Clean samples (i.e. blazars with measured redshift and flux)







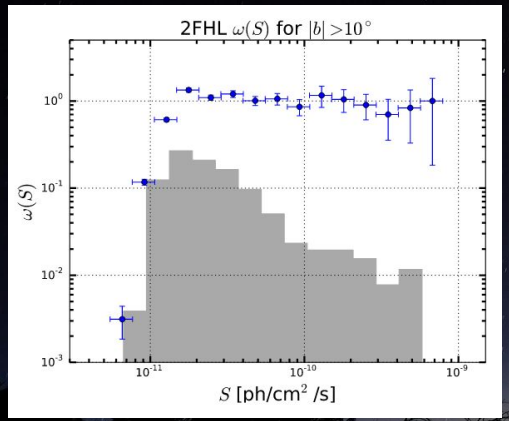
Ackermann+2016; LAT-collaboration 2017;2022

What's next

1. Clean samples (i.e. blazars with measured redshift and flux)
2. **Set of cuts to minimize uncertainties (e.g. |b|; TS)**

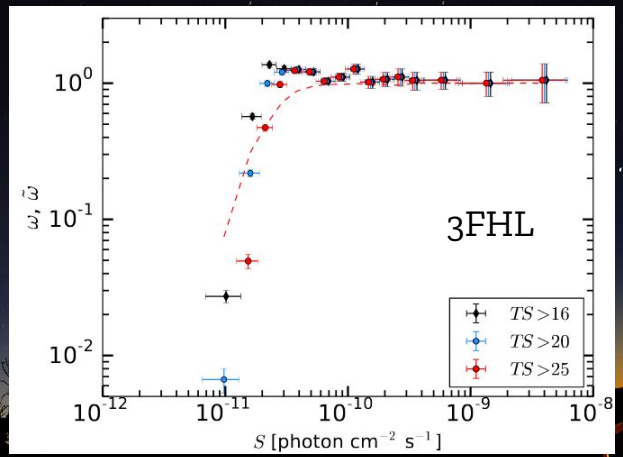
What's next

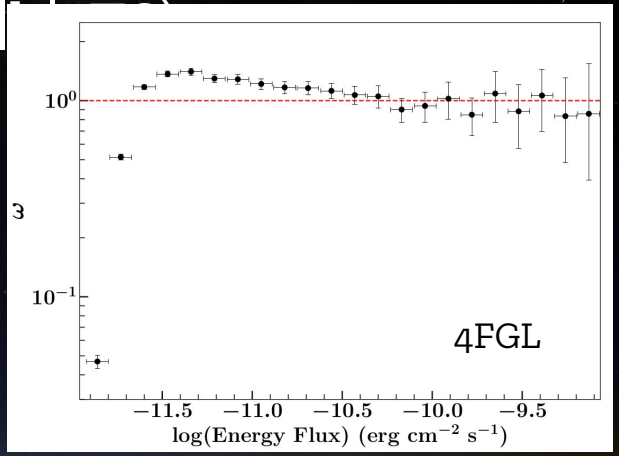
1. Clean samples (i.e. blazars with measured redshift and flux)
2. Set of cuts to minimize uncertainties (e.g. [illegible])
3. **Efficiency**



LAT collaboration 2016

Di Mauro et al. 2021

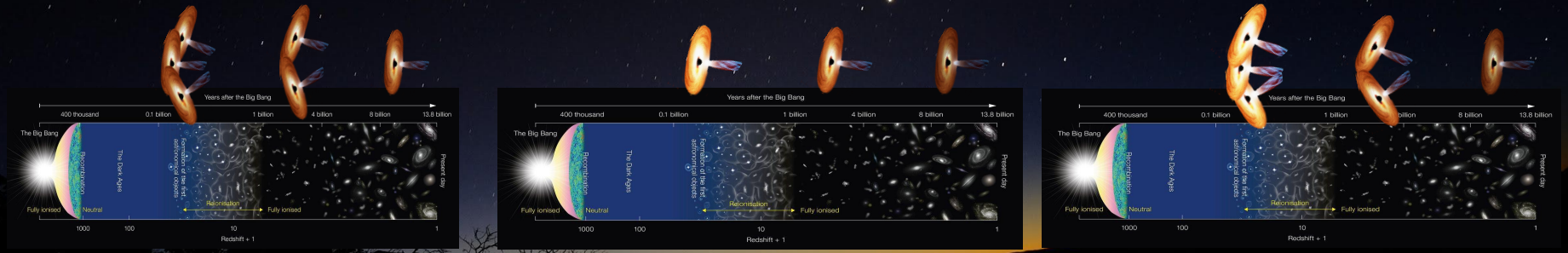




Marcotulli et al. 2020

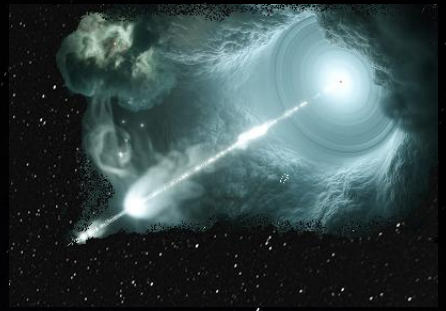
What's next

1. Clean samples (i.e. blazars with measured redshift and flux)
2. Set of cuts to minimize uncertainties (e.g. |b|; TS)
3. Efficiency
4. **Luminosity function models (Ajello et al. 2009/2012/2014)**



Lea Marcotulli | lea.marcotulli@yale.edu

TAKE HOME MESSAGE



- ★ New analysis characterizes the logN-logS to a **factor of 10 lower fluxes** !
- ★ The Pure Density Evolution model is the preferred evolution model.
- ★ This implies that point-sources (i.e. blazars) account up to 60% of the total EGB (Marcotulli et al. 2020).

What's next

- ★ Derive γ-ray luminosity function of blazars (Bl Lacs and FSRQs) using all available datasets and constraints (i.e. 3 or more LAT catalogs, γ-ray anisotropies, BAT sample etc.)

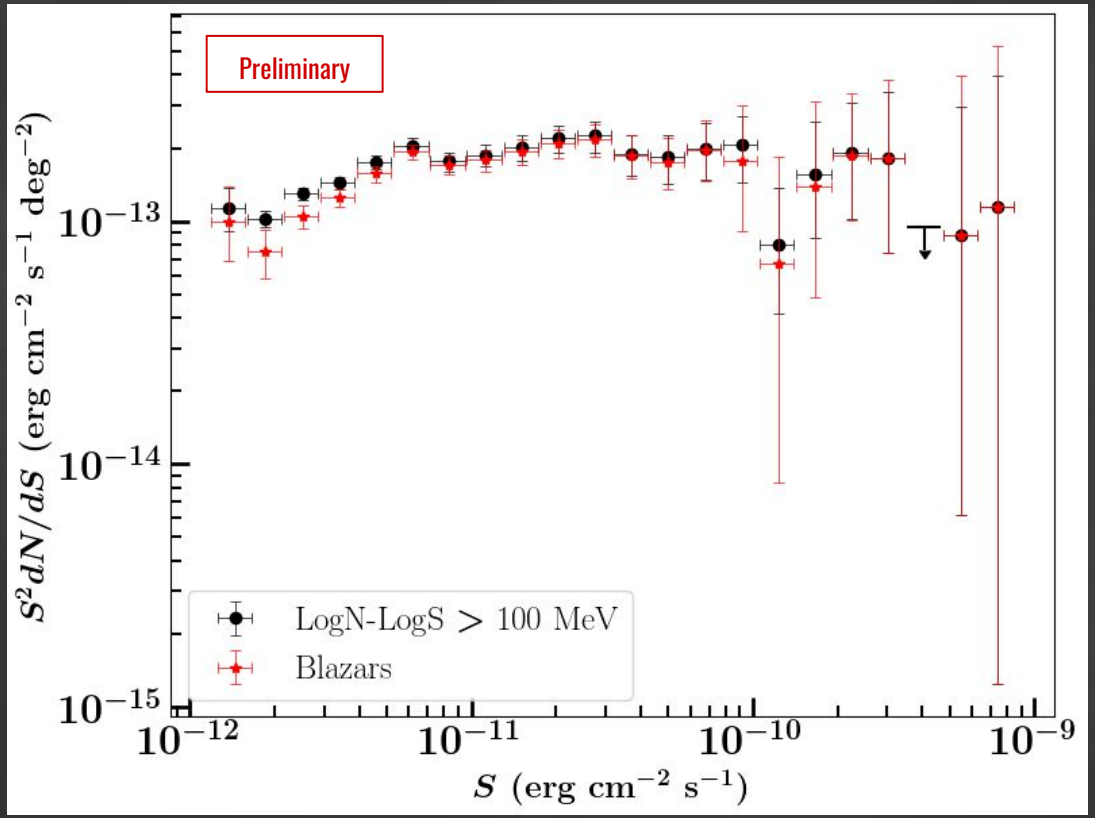
EXTRA SLIDES

LAT data analysis

Data Set	Pass 8 (P305)
Event Class	SOURCE
Energy Range	100 MeV - 1 TeV
Time interval	2008 August 4 U.T. 15:43:36.00 to 2016 August 2 U.T. 05:44:11.99
ROI size	15°
IRF	P8R3 SOURCE V2
Diffuse Emission	Galdiff = 'gll_iem_v06_extended.fits' Isodiff = 'iso_P8R2_SOURCE_V6_v06_ext.txt'
Catalog/s	NONE

- PSF and zenith angle selection following FL8Y recommendations
- Iterative detection procedure: from the brightest to the faintest
- **Test for curvature**: bright sources fitted with both Power Law and Log Parabola spectra and, if significantly curved (TS_{CURV}>16), kept as Log Parabola

Blazars contribution



Marcotulli et al. , 2020

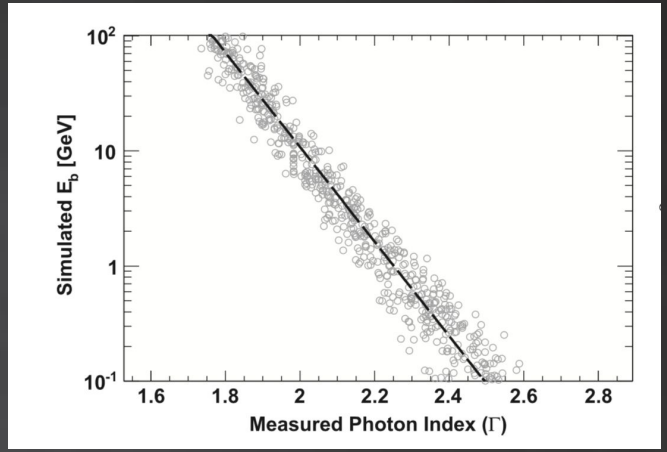
SIMULATIONS

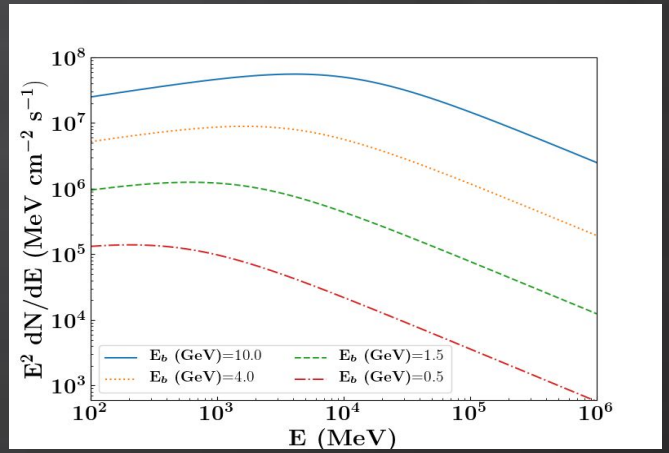
- Number of simulations: 6
- LogN-logS input shape very similar to the final one (iterative process)
- Flux Range: [10^{-11}, 10^{-6}] ph cm^{-2} s^{-1}
- Photon indices drawn from a Gaussian distribution <x>=2.45, σ=0.40
- Double power-law SED for simulated sources (following Ajello et al., 2015)

$$\frac{dN}{dE} = K\left[\left(\frac{E}{E_b}\right)^{\gamma_1} + \left(\frac{E}{E_b}\right)^{\gamma_2}\right]^{-1}$$

- γ_1=1.7 if E_b<100 GeV, otherwise drawn from a Gaussian distribution <x>=2.45, σ=0.40
- γ_2=2.8 (optimized already to reproduce 3FHL LogN-LogS)

Ajello et al. 2015





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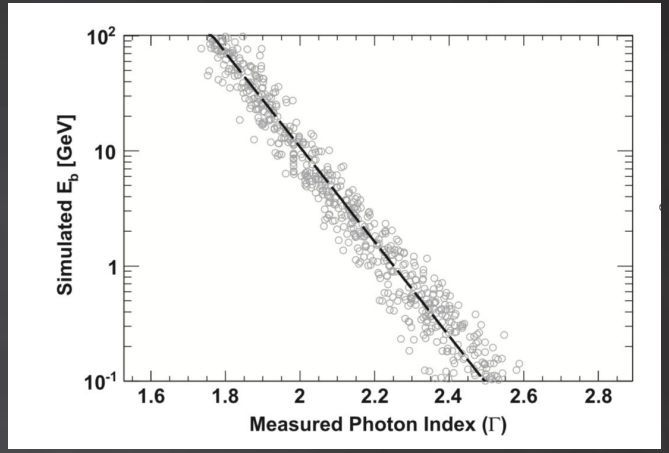
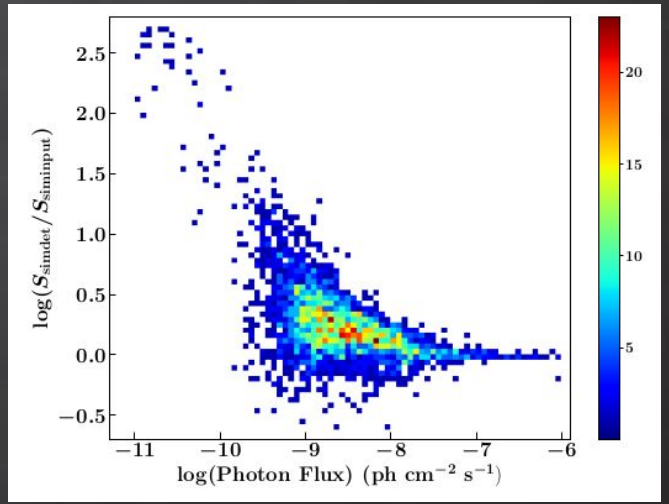


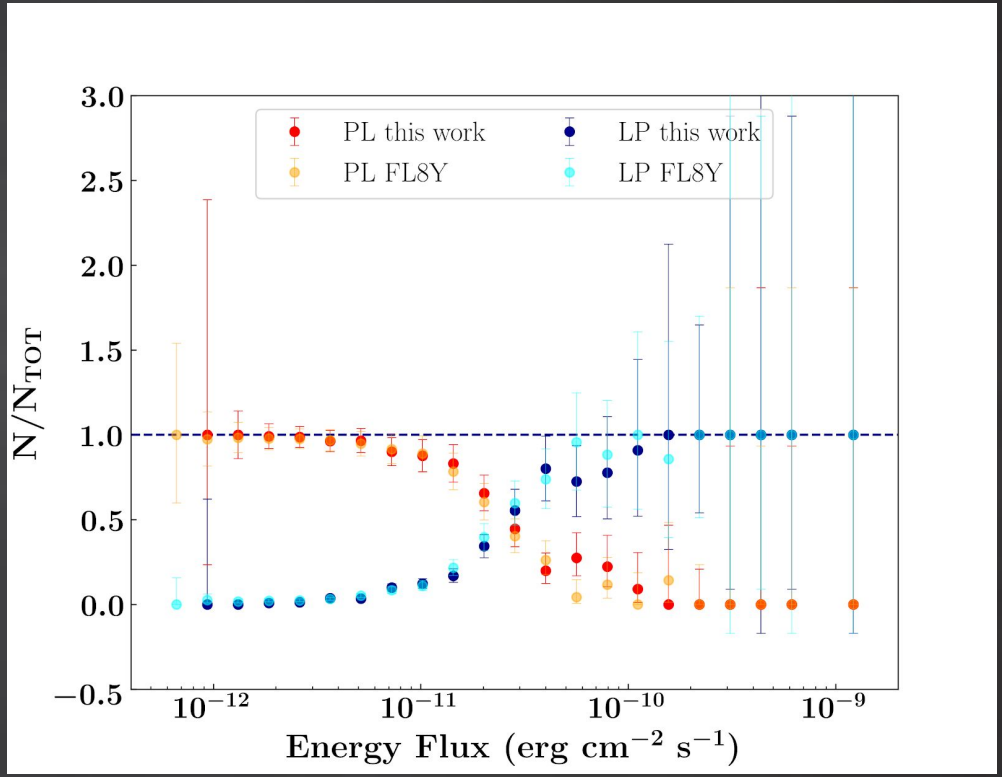


Marcotulli et al. , 2020

The real sky vs. FL8Y (fraction of PL and LP sources)

	This work	FL8Y
Total # sources |b|>20	2680	2930
Power Law	2410	2638
Log Parabola	270	248

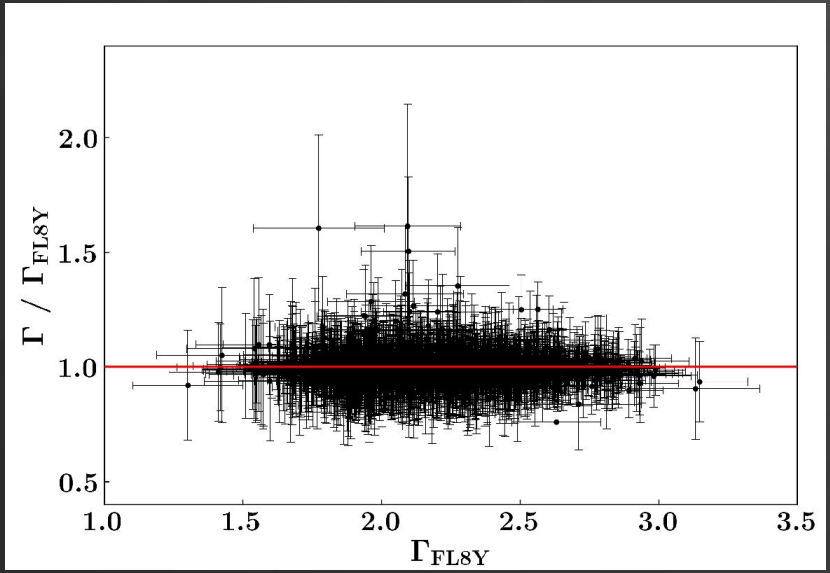
- Positional matches with 95% positional error: 2443



Marcotulli et al. , 2020

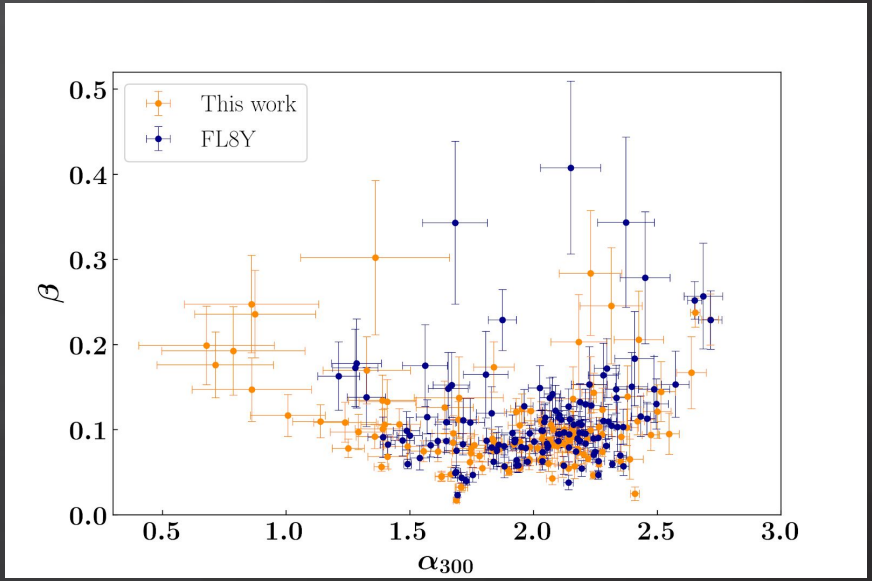
The real sky vs. FL8Y

Index comparison of matching Power Law sources, listed as blazars in FL8Y



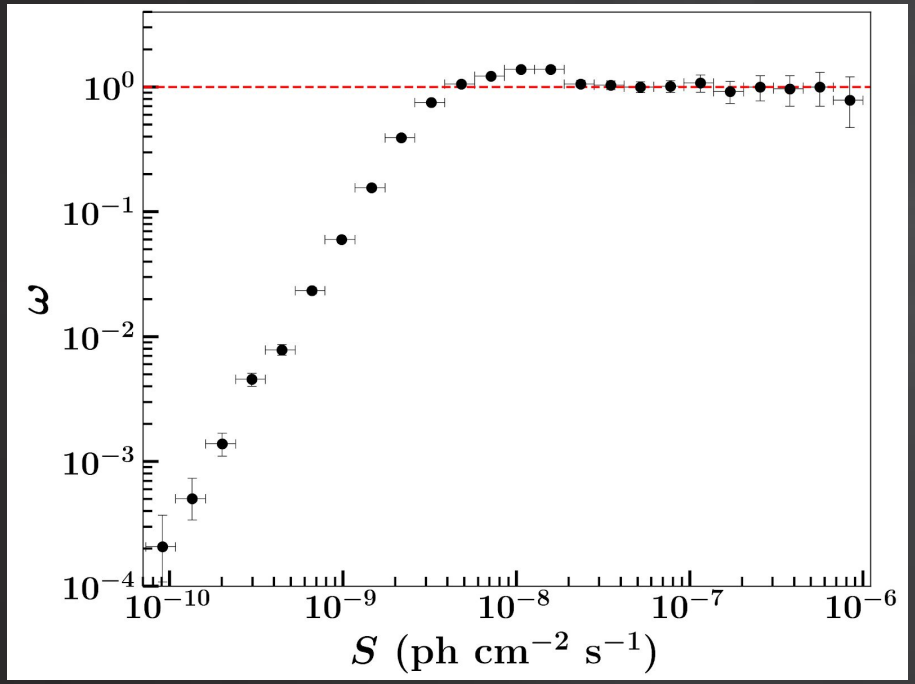
Index and beta comparison of matching Log Parabola sources, listed as blazars in FL8Y

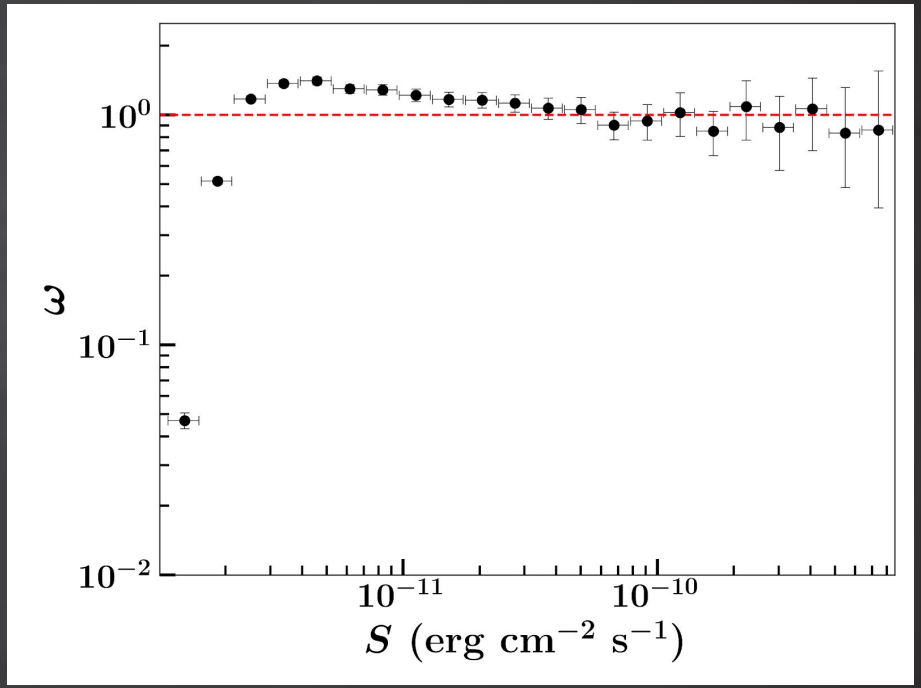
Marcotulli et al. , 2020



EFFICIENCY

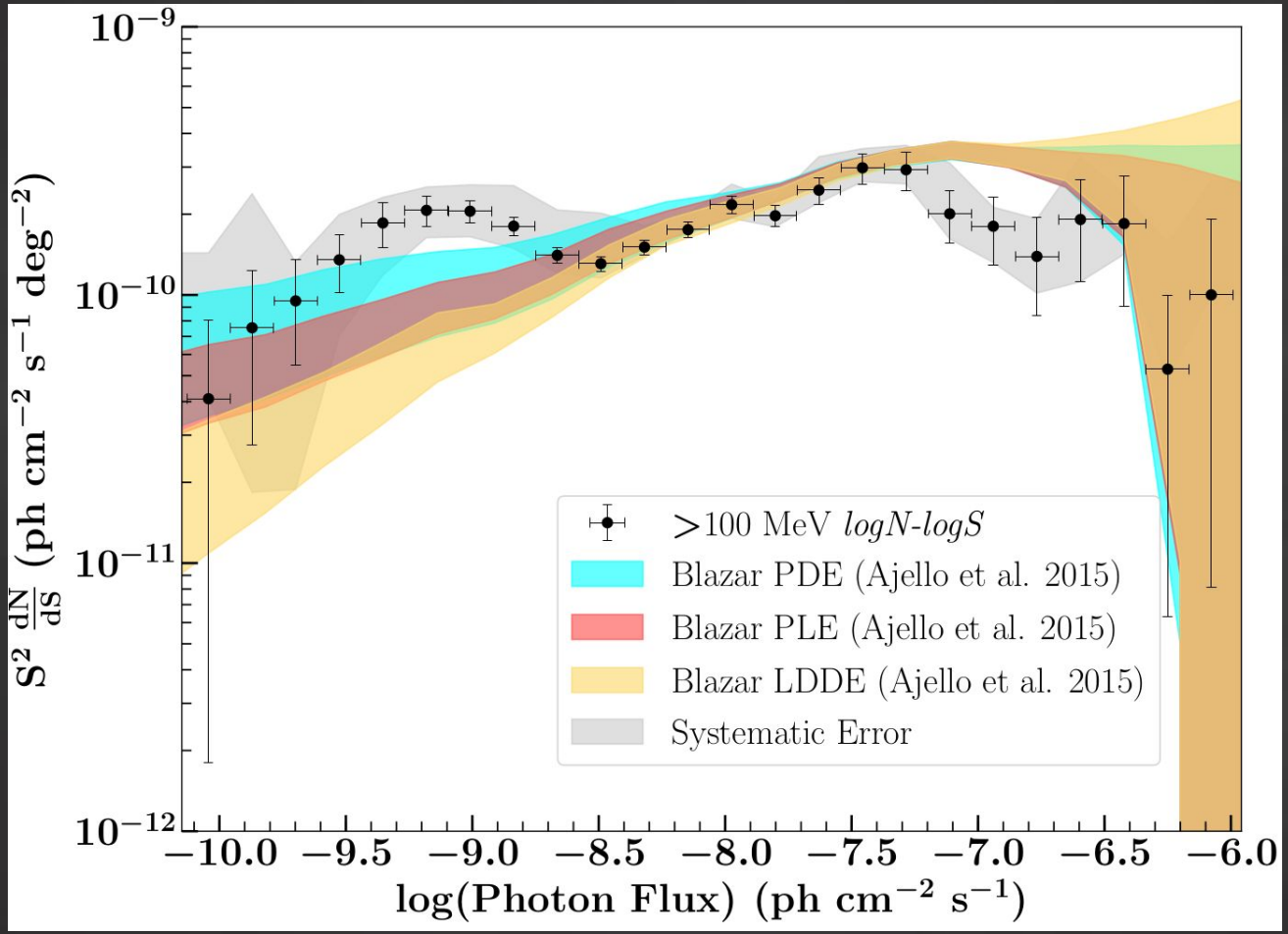
$$\omega = \frac{N_{SIM\ DET}}{N_{SIMULATED}}$$





Marcotulli et al. , 2020

INTRINSIC SOURCE COUNT DISTRIBUTION



Marcotulli et al. , 2020

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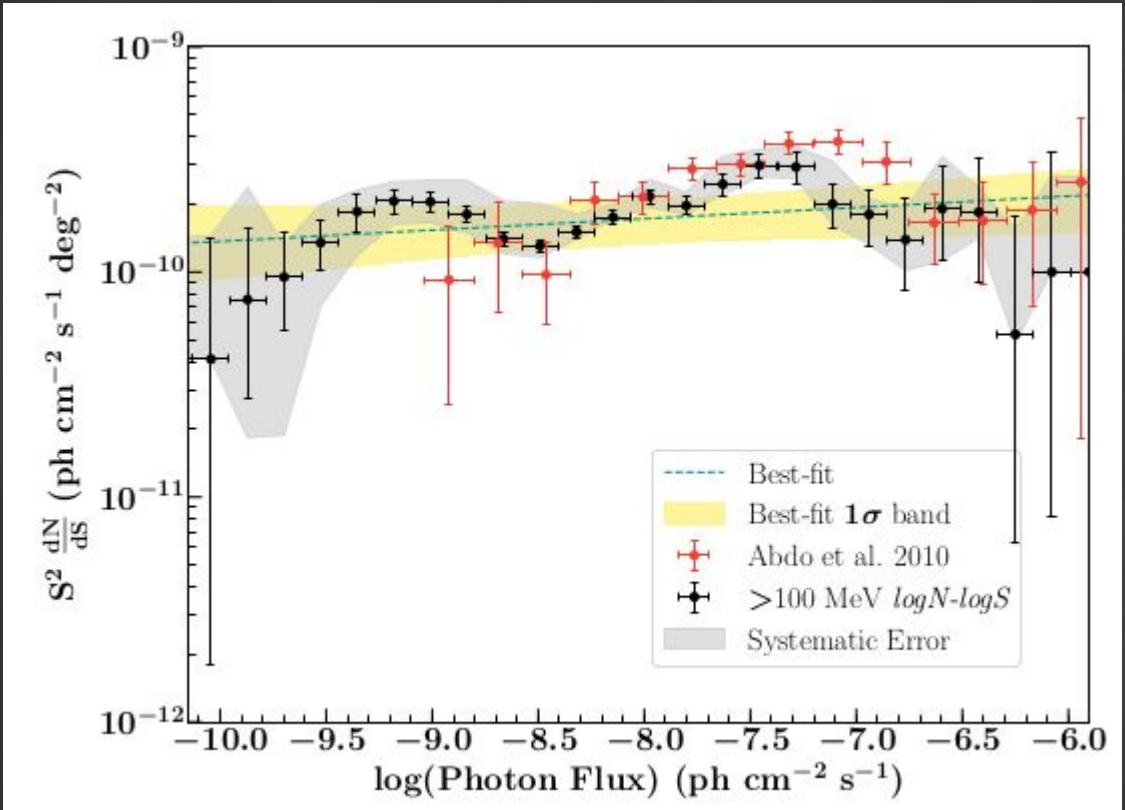
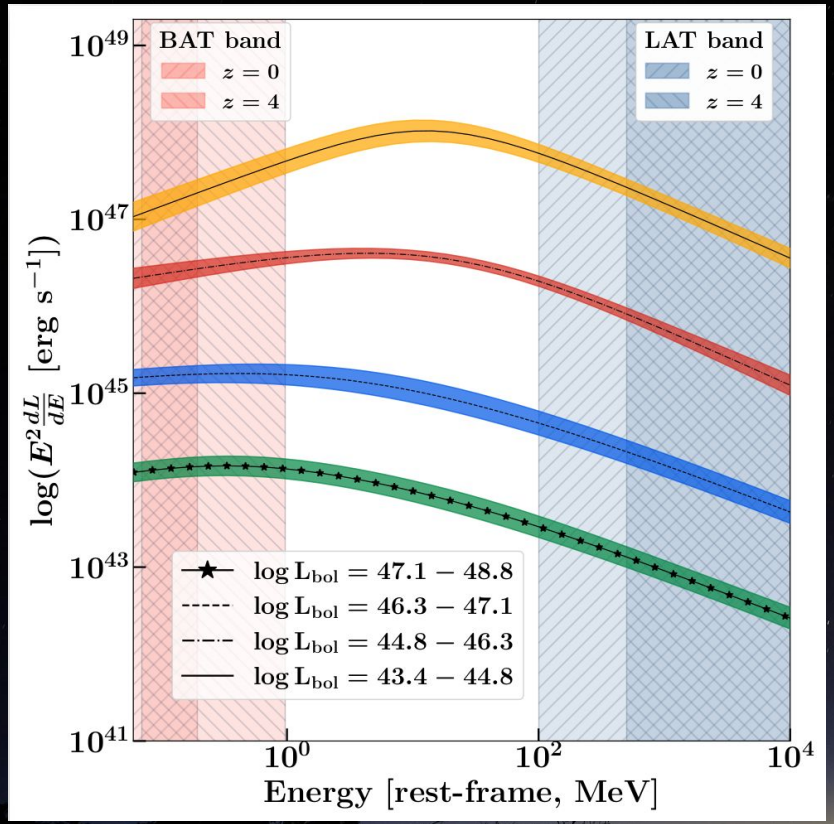
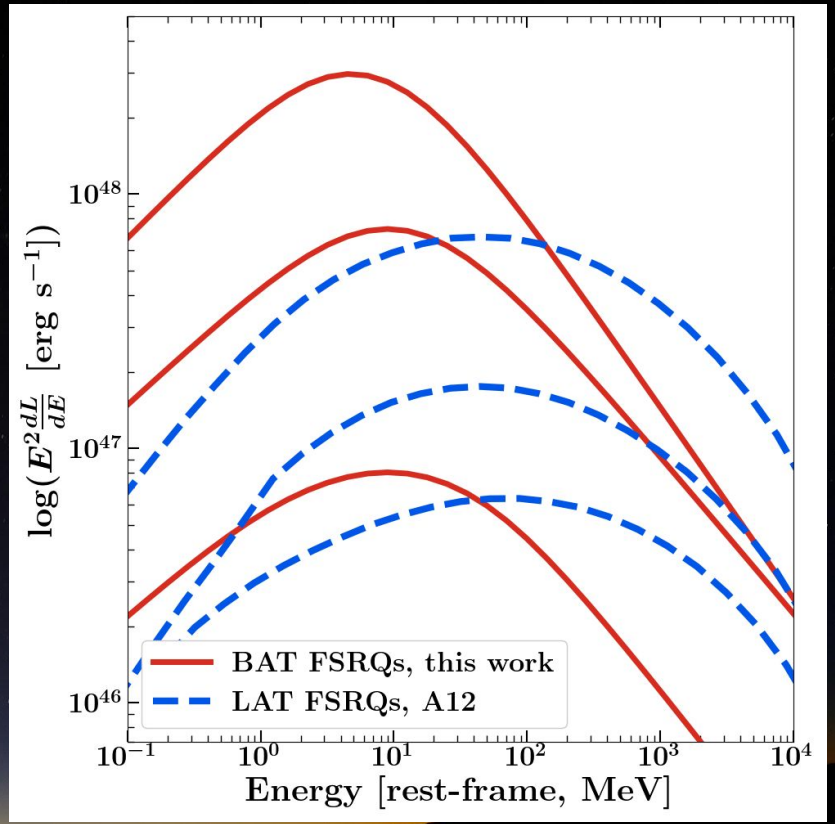


Marcotulli et al. , 2020

Average SED

Lea Marcotulli | lea.marcotulli@yale.edu





Marcotulli et al., submitted to ApJ