

## The Second Catalog of AGNs Detected by the Fermi LAT (2LAC)

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on behalf of the *Fermi*-LAT collaboration

*The Second Catalog of Active Galactic Nuclei  
Detected by the Fermi LAT*

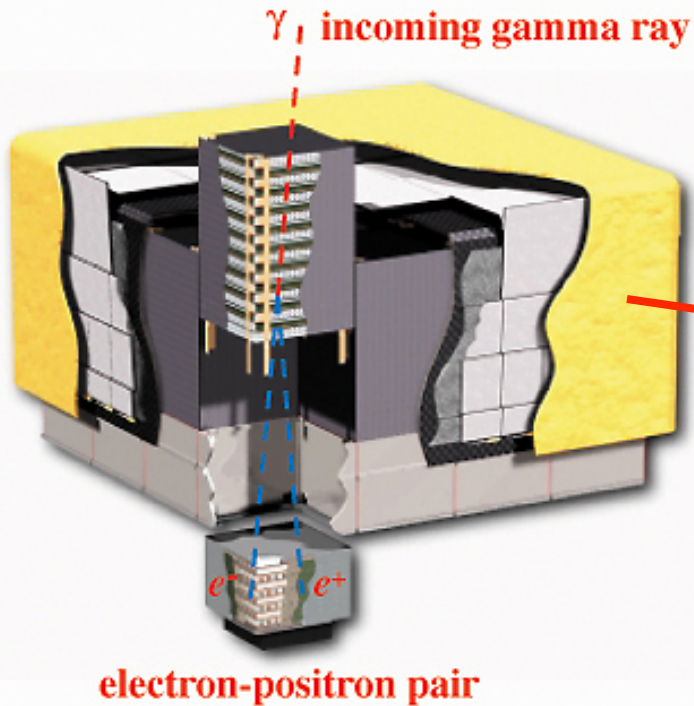
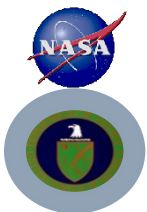
Ackermann, M. et al., *ApJ*, **743**: 171, 20 December, 2011  
arXiv:1108.1420

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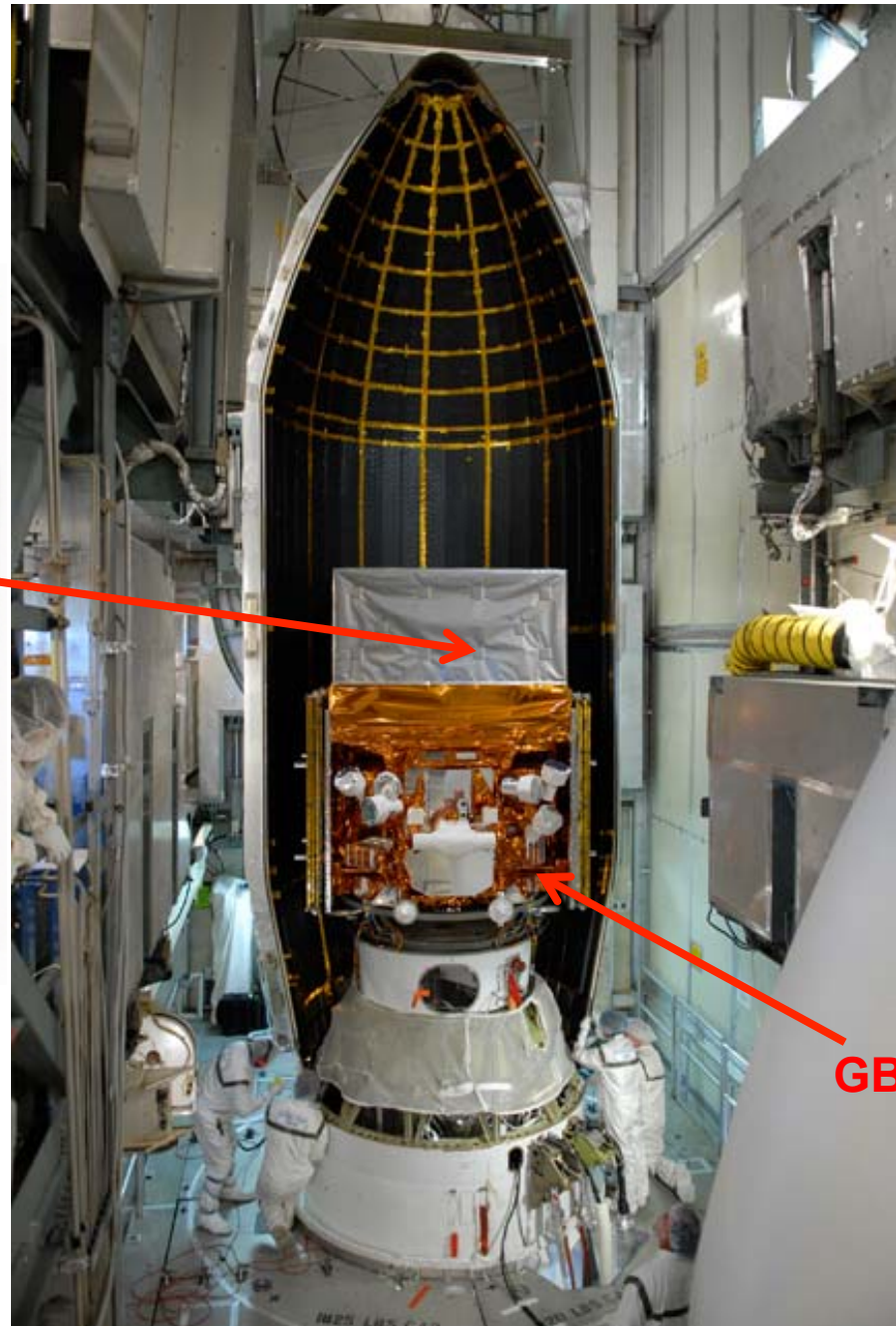
# GLAST: The Gamma Ray Large-Area Space Telescope

(launched June 11, 2008)



Large Area Telescope (LAT) images the sky one photon at a time:  $\gamma$ -ray converts in LAT to an electron and a positron; direction and energy of these particles tell us the direction and energy of the photon

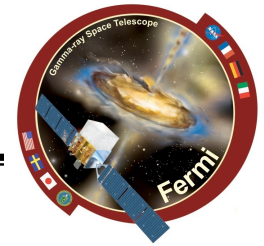
Austin AAS 2012



GBM

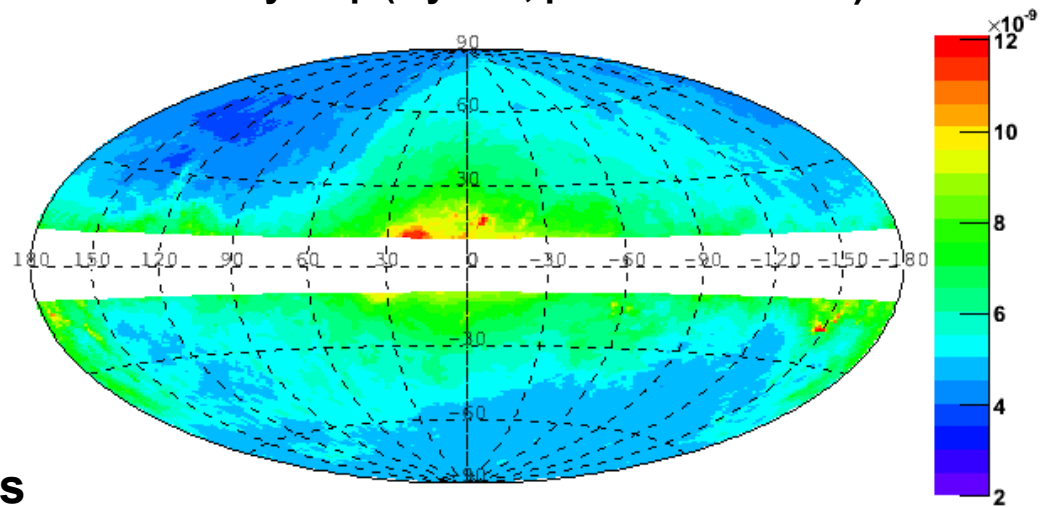
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# Assets for blazar science



- **unprecedented sensitivity**
- **sky scanned every 3 hours in survey mode**
- **fairly uniform at high galactic latitude**
- **alerts issued shortly after transient or new flaring sources are detected**

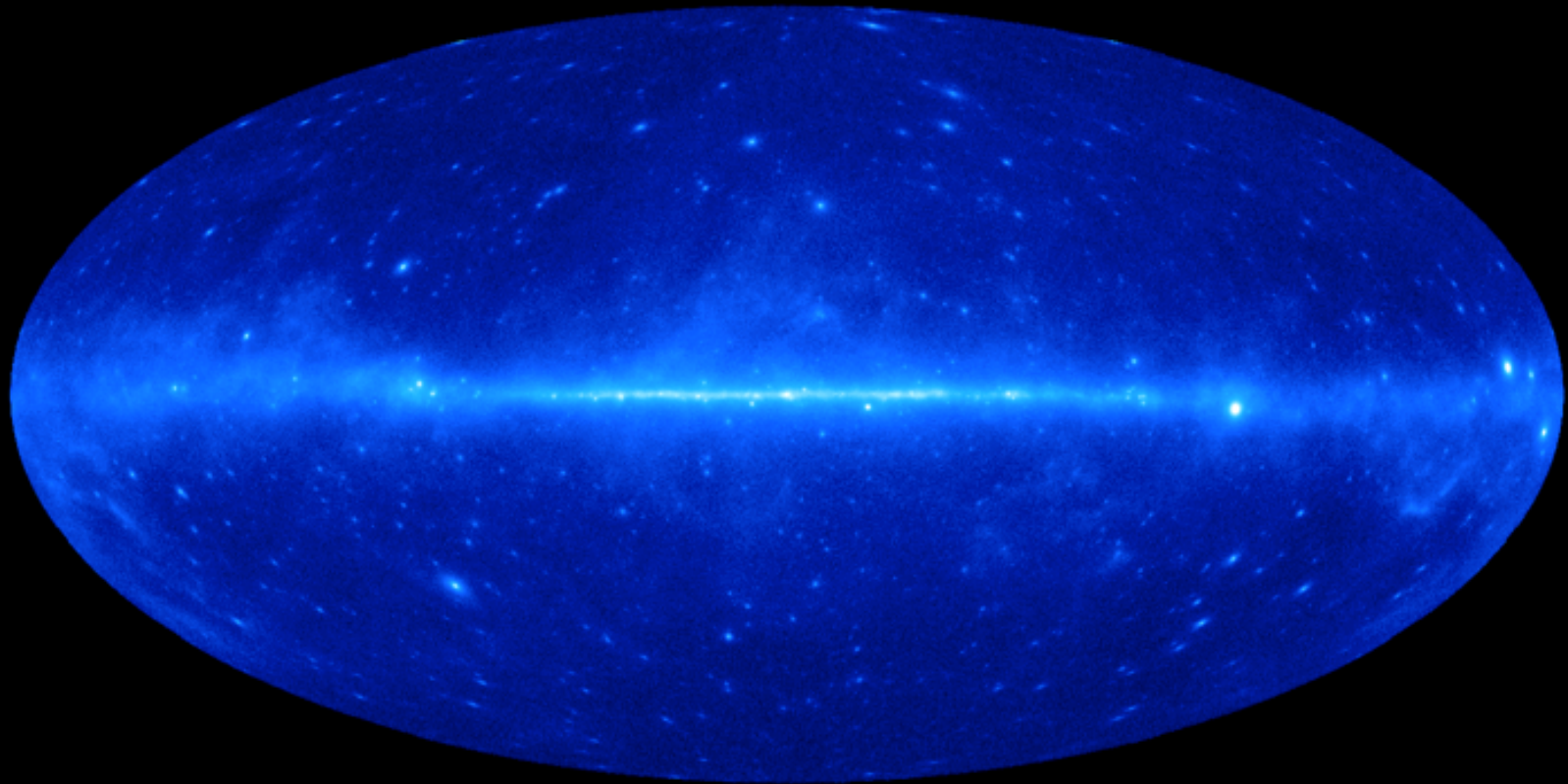
TS=25 sensitivity map (2 years, photon index=2.2)



Flux( $E > 100$  MeV)  $\text{ph cm}^{-2} \text{s}^{-1}$

- **continuous survey allows for source monitoring and variability studies on time scales ranging from months down to a few hours**
- **covers the little-explored 10-100 GeV domain**
  - **new spectral features at high energy discovered**
  - **identification of potential candidates of TeV sources (several discoveries)**

# Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration

# Fermi Large Area Telescope 2FGL catalog

○ AGN    ⊗ AGN-Blazar

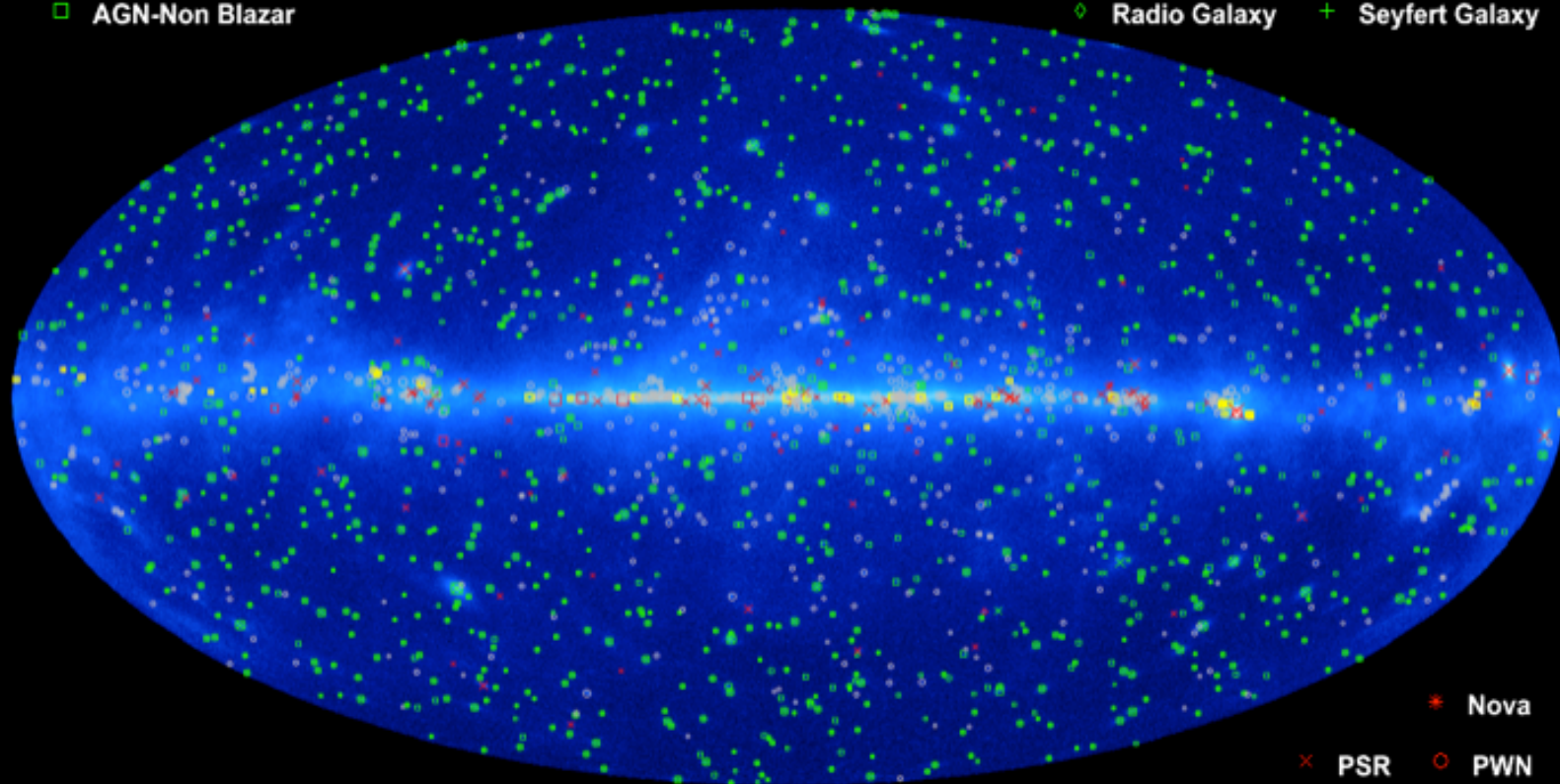
□ AGN-Non Blazar

× Galaxy

\* Starburst Galaxy

◇ Radio Galaxy

+ Seyfert Galaxy



○ Unassociated

□ Possible Association with SNR and PWN

\* Nova

× PSR

○ PWN

◇ PSR w/PWN

□ SNR

◇ Globular Cluster

+ HMB

**1873 sources with  $TS > 25$**

**The Fermi collaboration, submitted to ApJS, arXiv: 1108.1435**

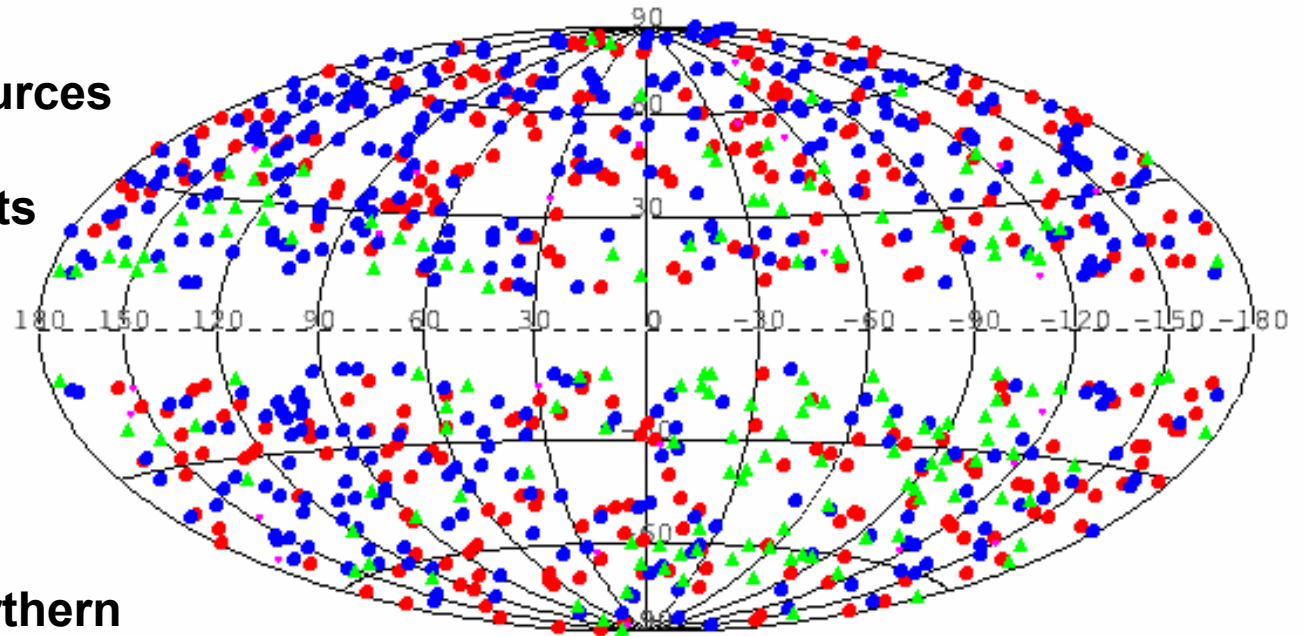
Credit: Fermi Large Area Telescope Collaboration

# The Second LAT AGN catalog (2LAC)



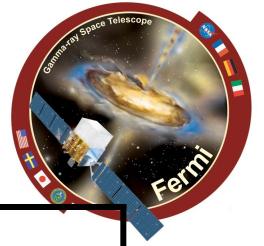
- 24 month data set
- 1319  $TS > 25$ ,  $|b| > 10^\circ$  sources
- 2LAC: 1017 counterparts  
991 sources
- 886 high-confidence ( $P_{\text{assoc}} > 80\%$ ) AGNs  
in *clean sample*

Differences between Northern  
and Southern Hemisphere  
(only 38% BL Lacs in South)



Ackermann, M. et al., *ApJ*, 743: 171

## Differences between 1LAC and 2LAC

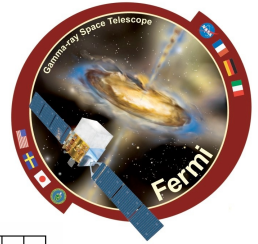


	1LAC/1FGL	2LAC/2FGL
<b>Period</b>	11 m	24 m
<b>Analysis</b>	unbinned	binned
<b>IRFs</b>	P6_V3_DIFFUSE	P7_V6_SOURCE
<b>Association methods</b>	Bayesian	Bayesian Likelihood-Ratio Log N- Log S
<b>Parent catalogs</b>	CRATES/BZCat	Many*
<b>Association**</b>	663/1079 (61%)	991/1319 (75%)
<b>Clean Sample</b>	599	886

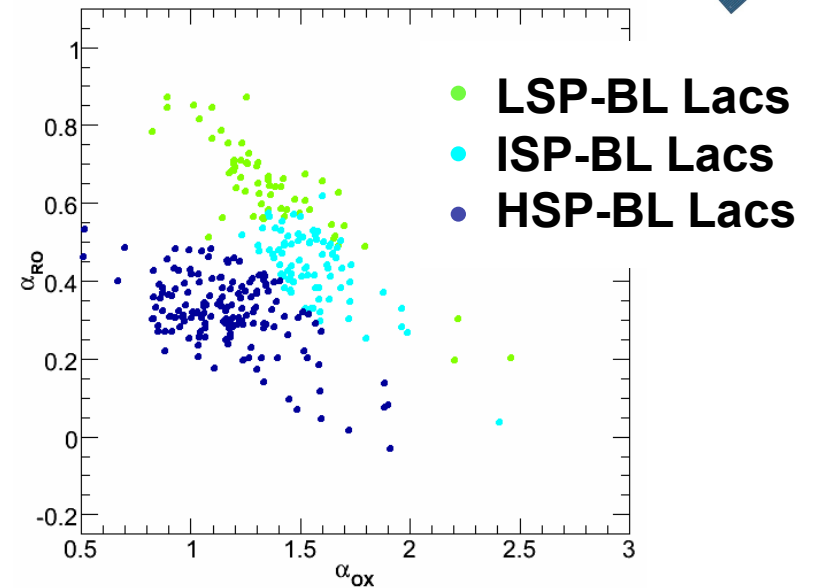
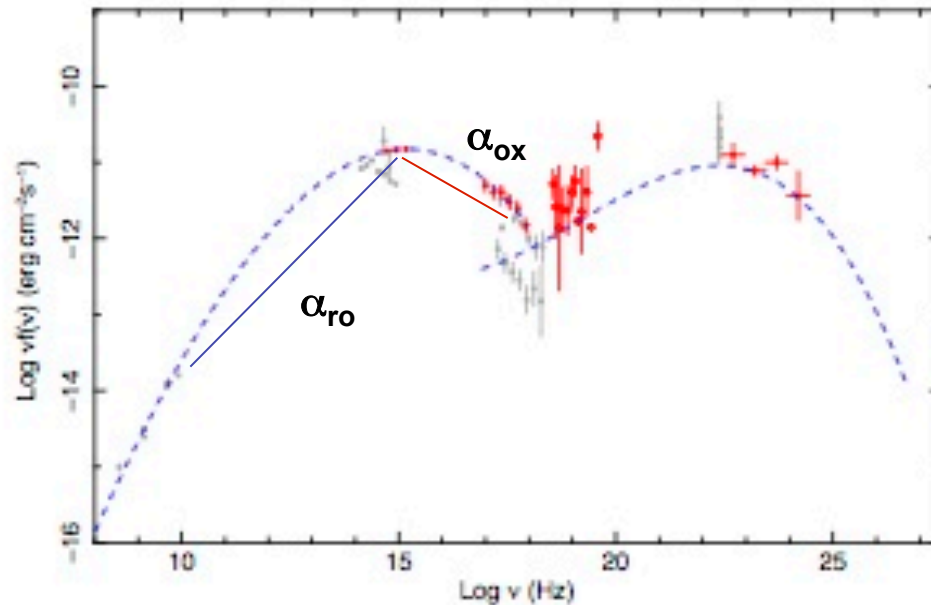
\* CRATES, BZCat, NVSS, SUMSS, PMN, ATCA 20 GHz, FRBA, GAPS, CLASS, VCS, RASS

\*\*  $\gamma$ -ray AGN source associations/total  $\gamma$ -ray sources at  $|b| > 10^\circ$

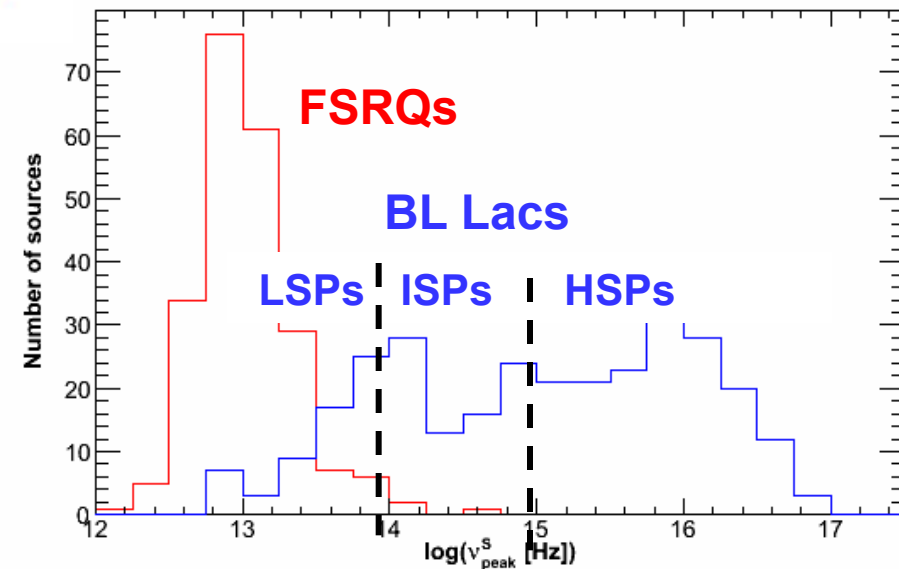
# SED-based classification



Abdo, A. A. et al. 2010, ApJ, 716, 30

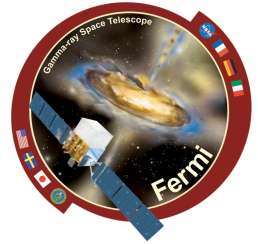


- relation with  $\nu_{\text{syn}}$  estimated from  $\alpha_{\text{ox}}, \alpha_{\text{ro}}$
- subclasses assigned from  $\nu_{\text{syn}}$   
LSP, ISP, HSP: Low-, Intermediate-, High-Synchrotron Peaked blazars
  - LSP:  $\log[\nu_{\text{syn}} \text{ (Hz)}] < 14$
  - ISP:  $14 < \log[\nu_{\text{syn}} \text{ (Hz)}] < 15$
  - HSP:  $\log[\nu_{\text{syn}} \text{ (Hz)}] > 15$





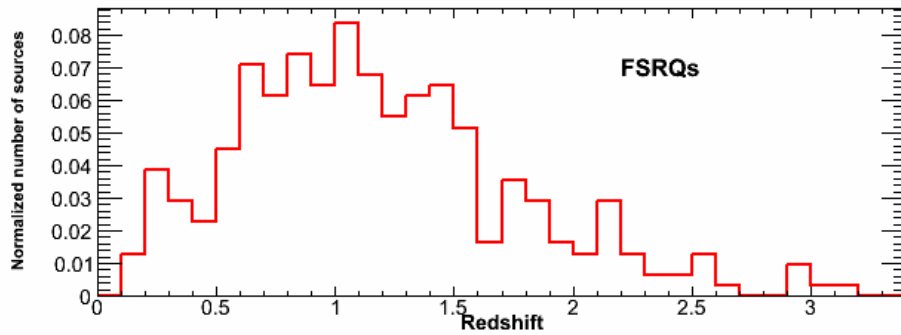
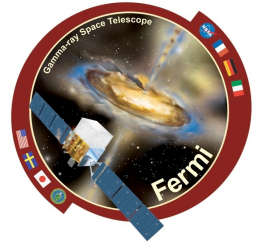
# Census



AGN type	Entire 2LAC	2LAC Clean Sample <sup>a</sup>	Low-lat sample
<b>All</b>	<b>1017</b>	<b>886</b>	<b>104</b>
<b>FSRQ</b>	<b>360</b>	<b>310</b>	<b>19</b>
...LSP	246	221	7
...ISP	4	3	2
...HSP	2	0	0
...no classification	108	86	10
<b>BL Lac</b>	<b>423</b>	<b>395</b>	<b>16</b>
...LSP	65	61	3
...ISP	82	81	3
...HSP	174	160	5
...no classification	102	93	5
<b>Blazar of Unknown type</b>	<b>204</b>	<b>157</b>	<b>67</b>
...LSP	24	19	10
...ISP	13	11	3
...HSP	65	53	13
...no classification	102	74	41
<b>Other AGN</b>	<b>30</b>	<b>24</b> *	<b>2</b>

\* 8 misaligned AGNs, 4 NLS1s, 10 AGNs of other types, 2 starburst galaxies  
 45 (out of 599) 1 LAC clean sample sources are missing in 2LAC  
 3C 78, 3C 111, 3C 120 out; Fornax A, Cen B in

# Redshift distributions

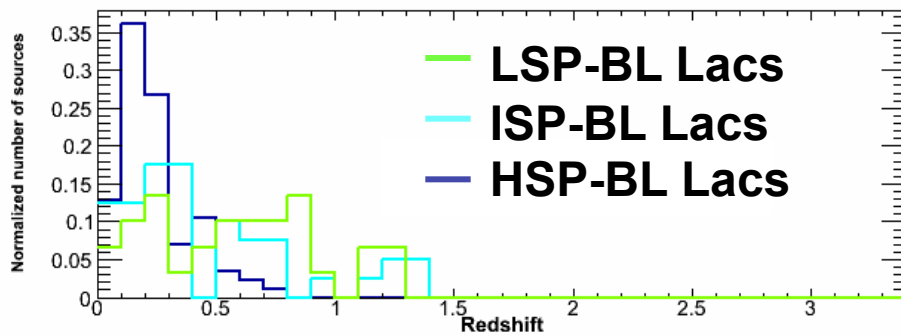
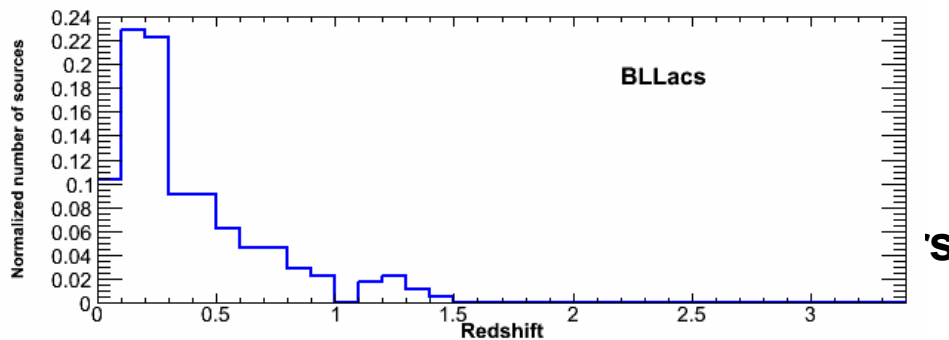


Distributions similar to 1LAC

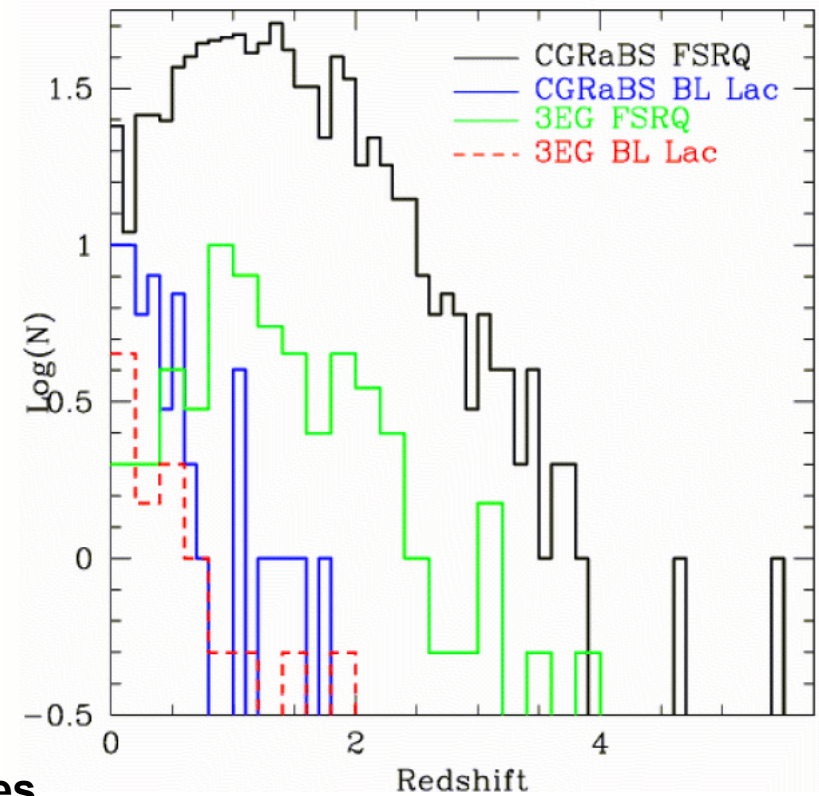
$z_{\text{max}}$  for FSRQs: 3.1

BAT: 40% of FSRQs with  $z > 2$

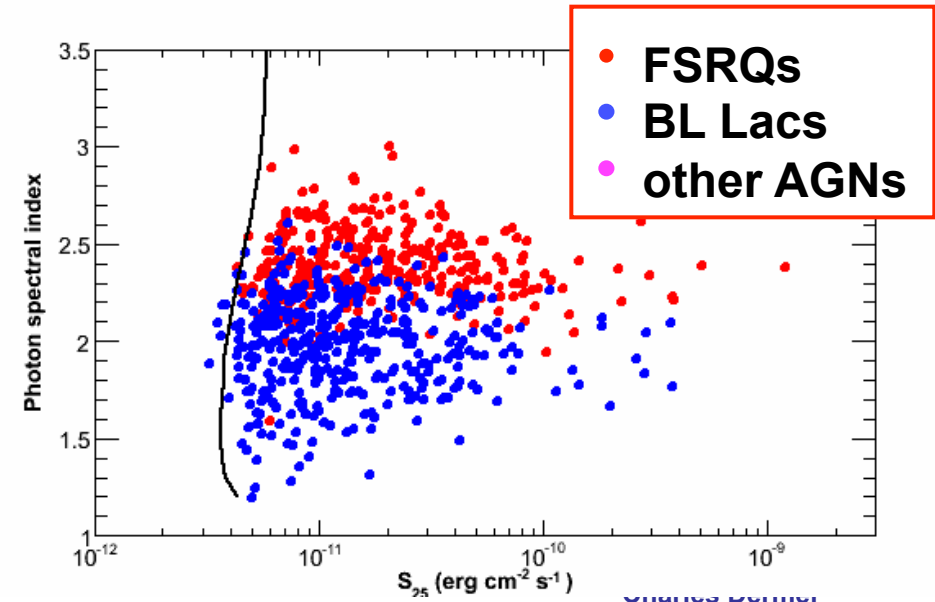
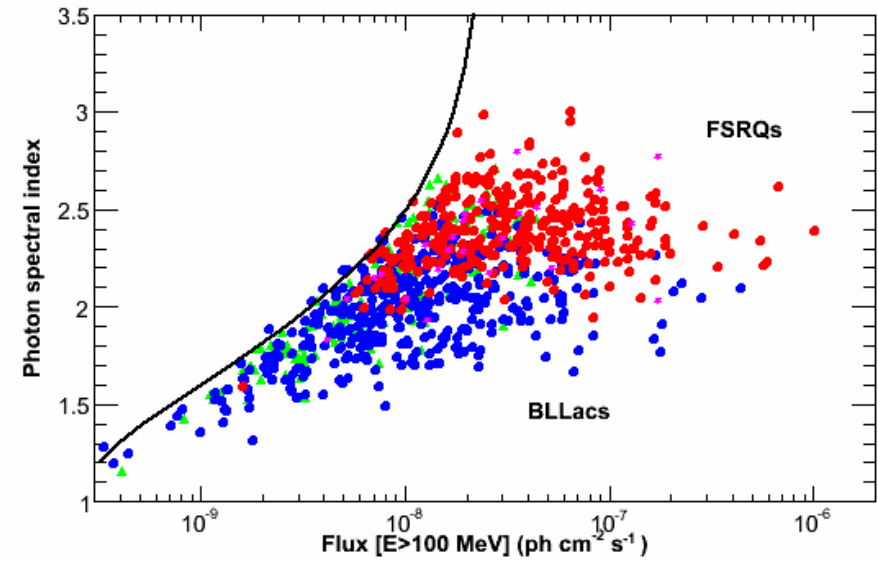
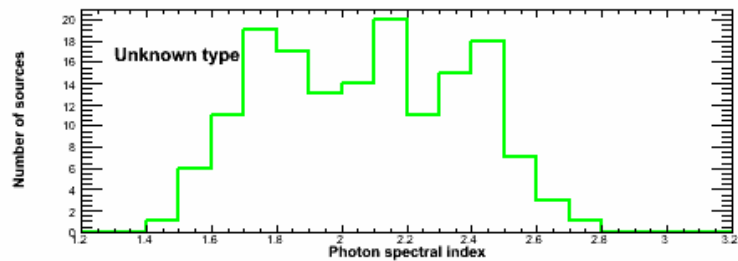
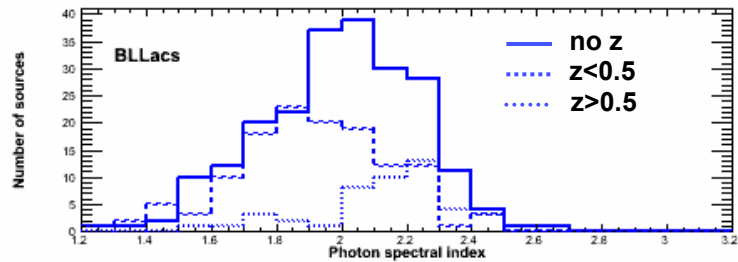
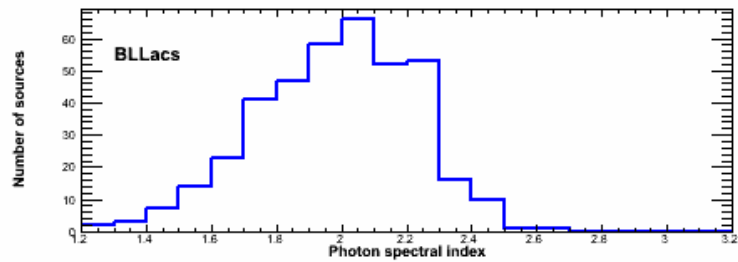
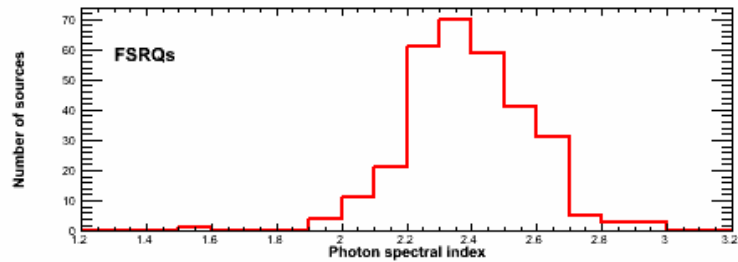
50 BZCat FSRQs with  $z > 2$



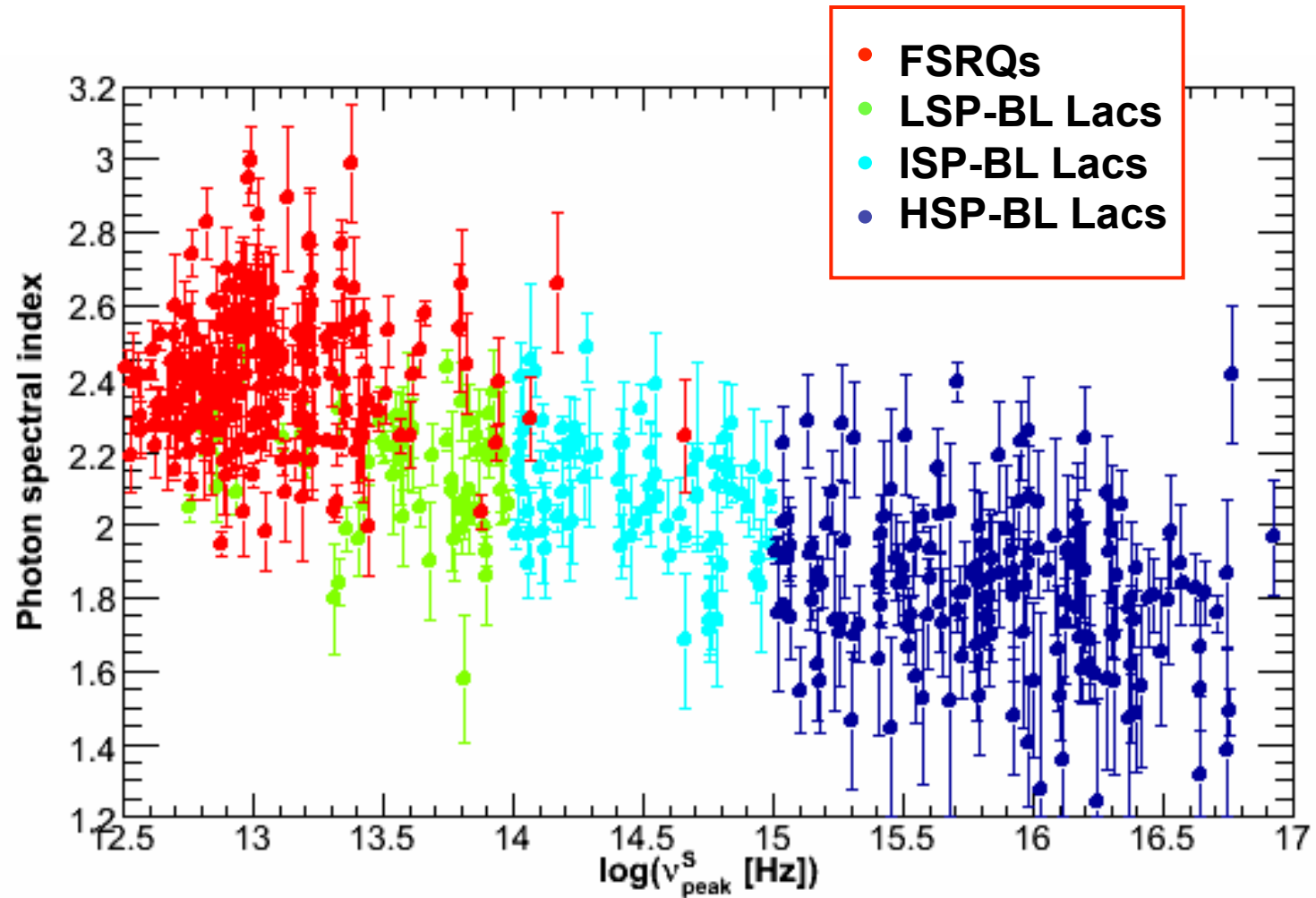
~50% of BL Lacs without redshift for all subclasses



# Photon index – Flux distributions



# Photon index vs. $\nu_{\text{peak}}$

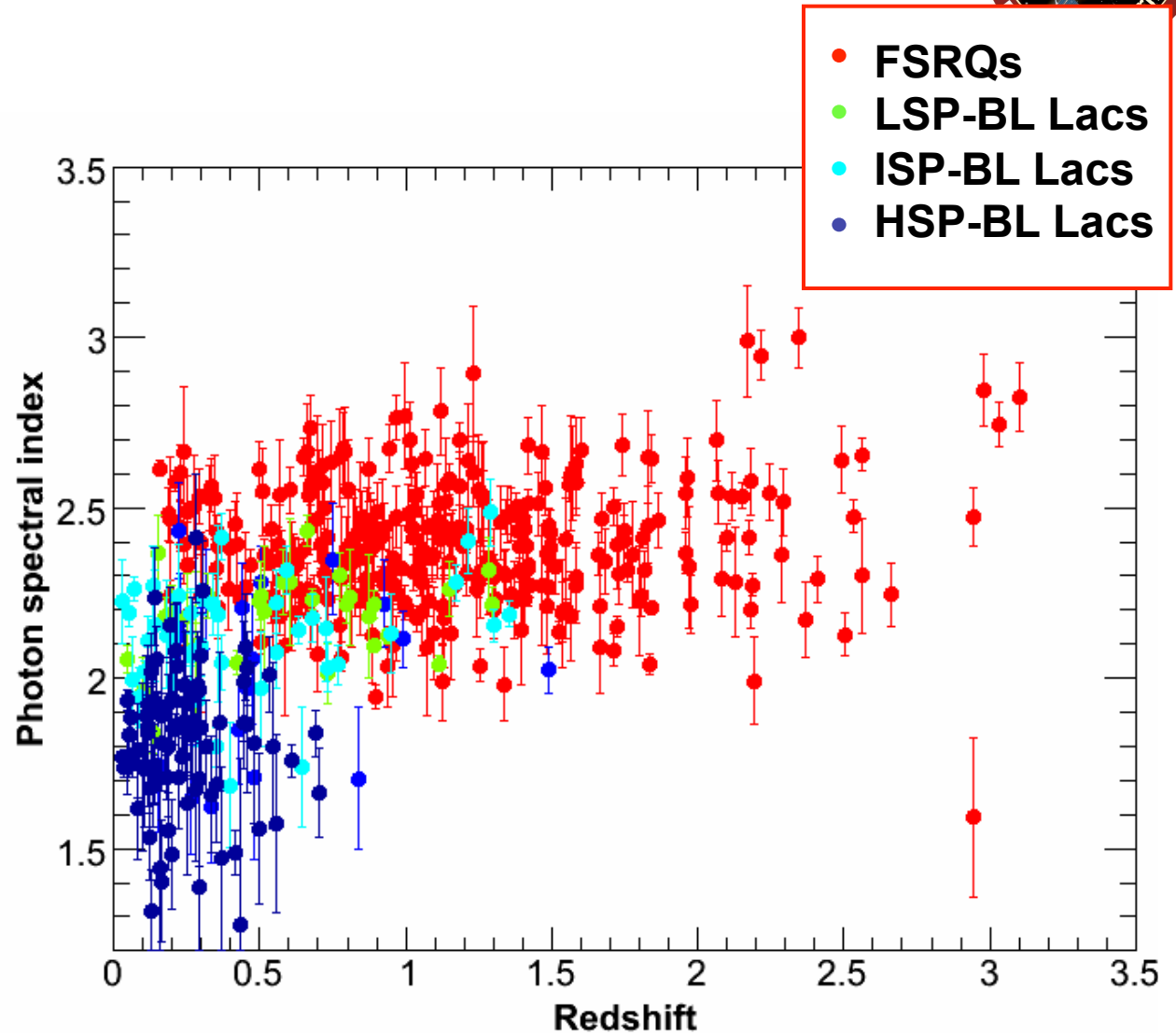


# Photon index vs. redshift



No evolution of photon index vs  $z$  for FSRQs

Strong evolution for BLLacs but just due to different subclasses (LSP, ISP, HSP) having different redshift distributions

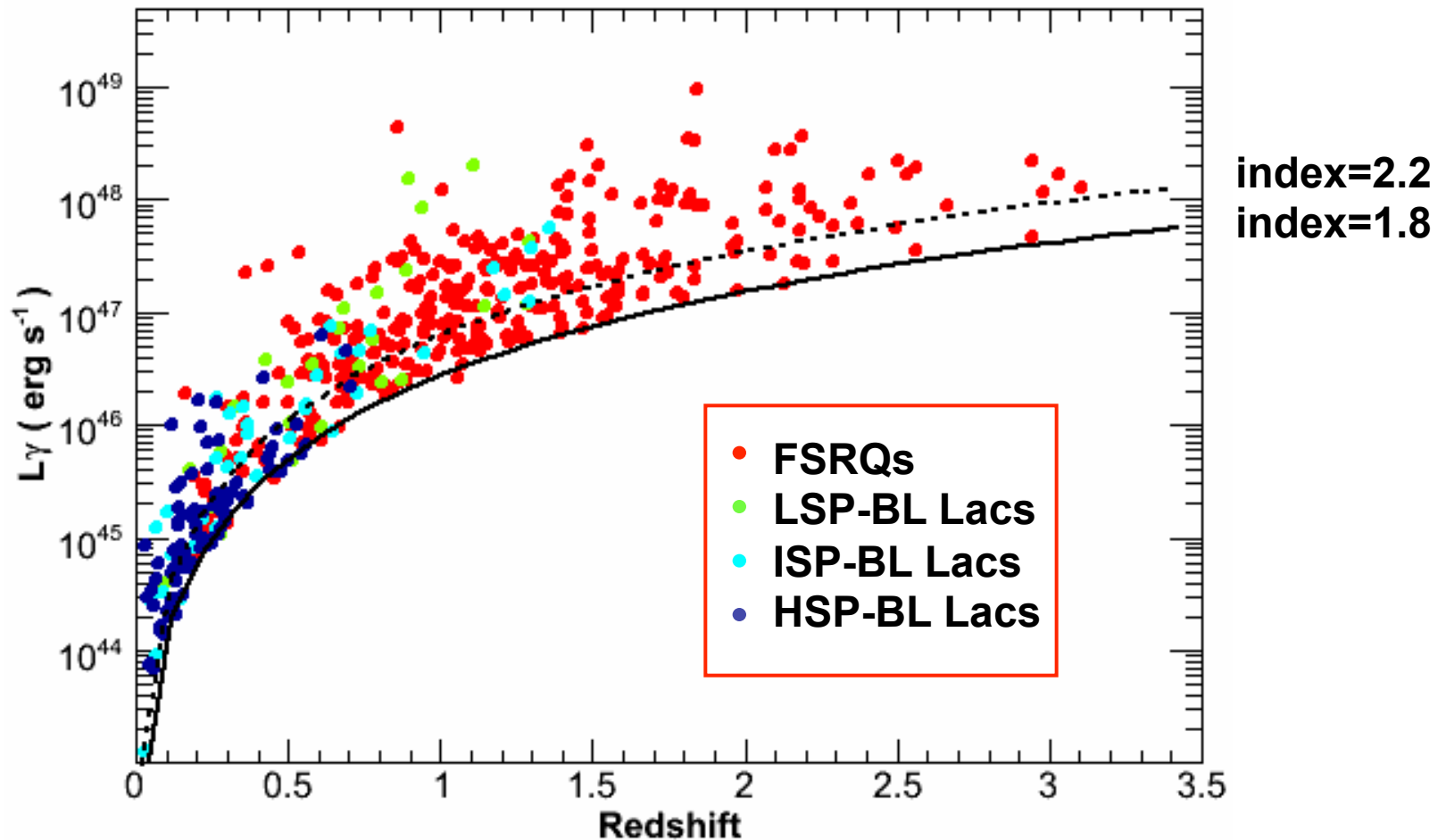


# Luminosity vs. redshift

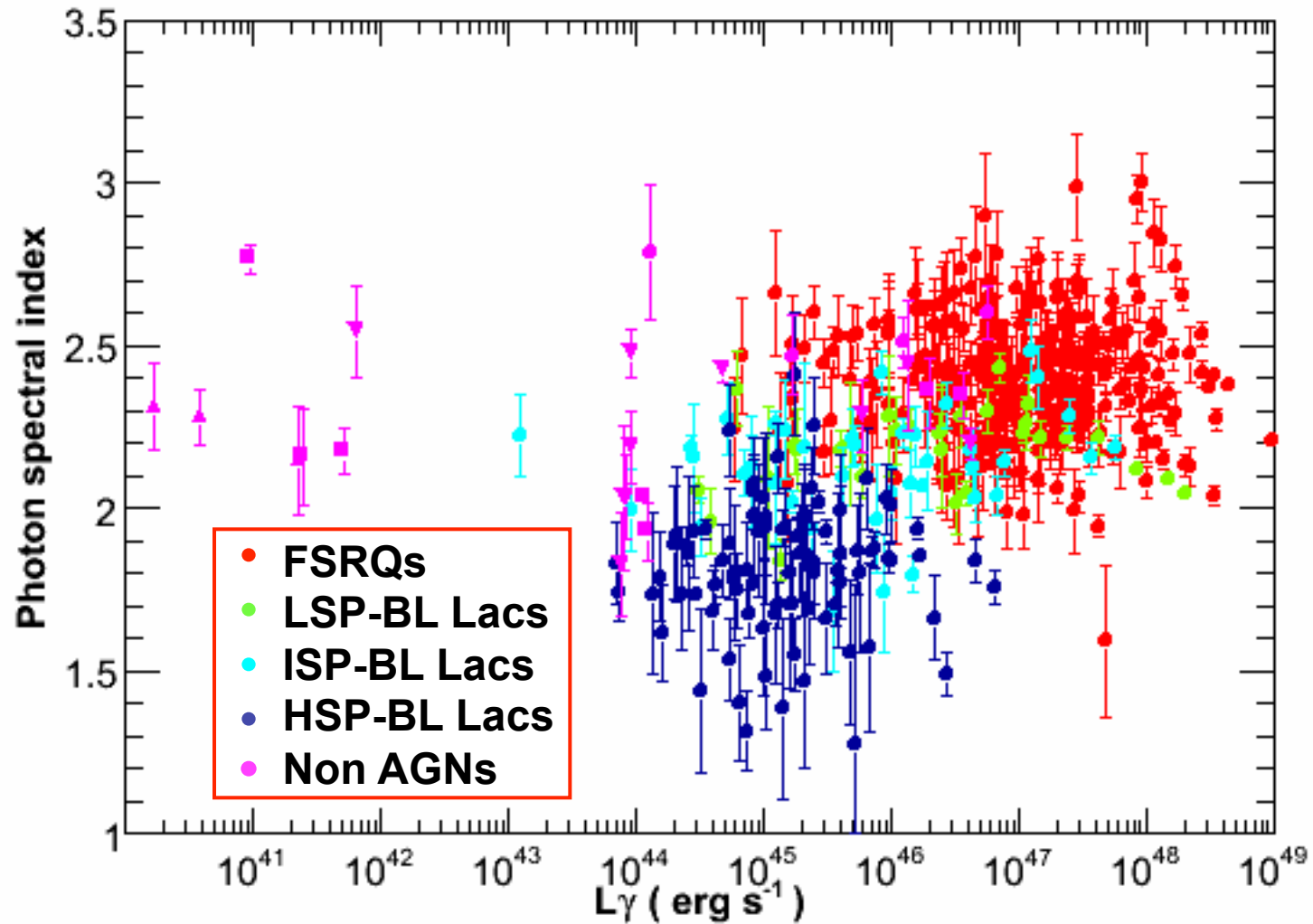
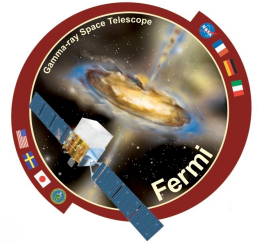


$$L_{\gamma} = 4\pi d_L^2 \frac{S(E_1, E_2)}{(1+z)^{2-\Gamma}}$$

$d_L$ : luminosity distance  
 $S(E_1, E_2)$ : energy flux between  
 $E_1$  (100 MeV) and  $E_2$  (100 GeV)



# Photon index vs. luminosity



## 2LAC summary

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- Number of associated sources has increased by 52% over 1LAC
- 75% of 2FGL sources at  $|b| > 10^\circ$  are in the 2LAC ; more than 97 % are blazars.
- 24 non-blazar sources in Clean Sample
  - 8 misaligned AGNs
  - 4 NLS1s
  - 10 AGNs of other types
  - 2 starburst galaxies
- BL Lacs outnumber FSRQs (395/310); 55% BL Lacs lack measured redshifts
- Among BL Lacs, HSPs dominate over ISPs and LSPs (53%, 27%, 20%)
- 39/45 TeV AGNs have now been detected
- Radio/ $\gamma$ -ray connection and Implications for blazar evolution and jet physics

Next catalog should be based on 5 years worth of data.