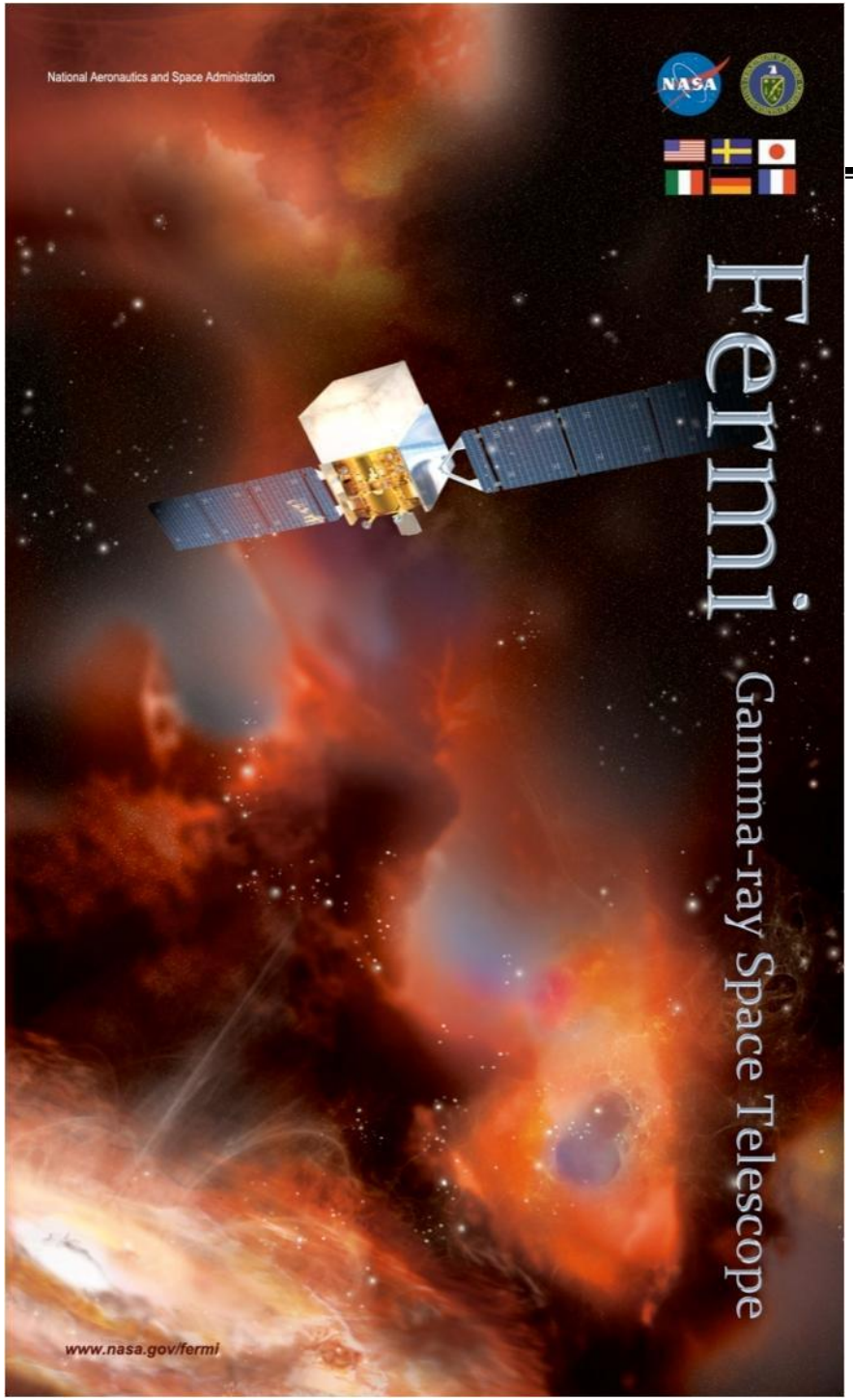

Fermi-LAT 2-years AGN catalog (2LAC)

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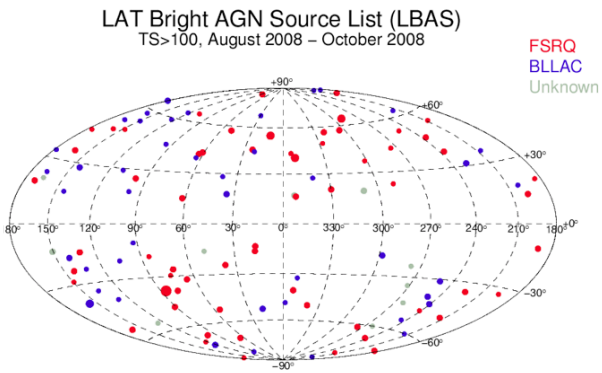
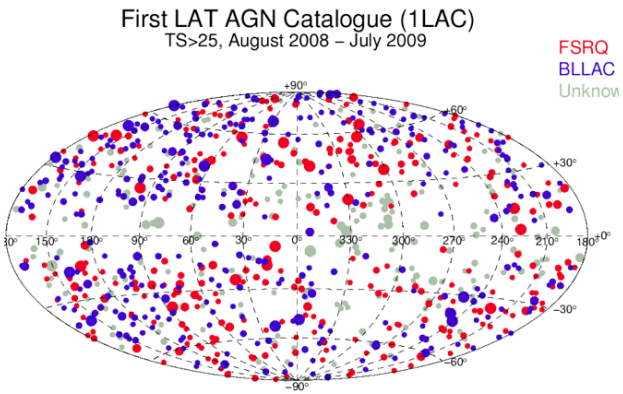
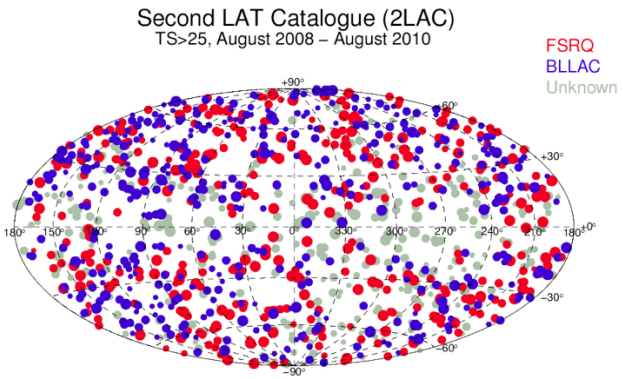
on behalf of the Fermi-LAT collaboration

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

Fermi AGN Catalogues







LBAS-high latitude:
58 FSRQs
42 BL Lacs
6 AGNs

1LAC-clean sample:
248 FSRQs
275 BL Lacs
50 Blazars with unknown type
26 AGNs

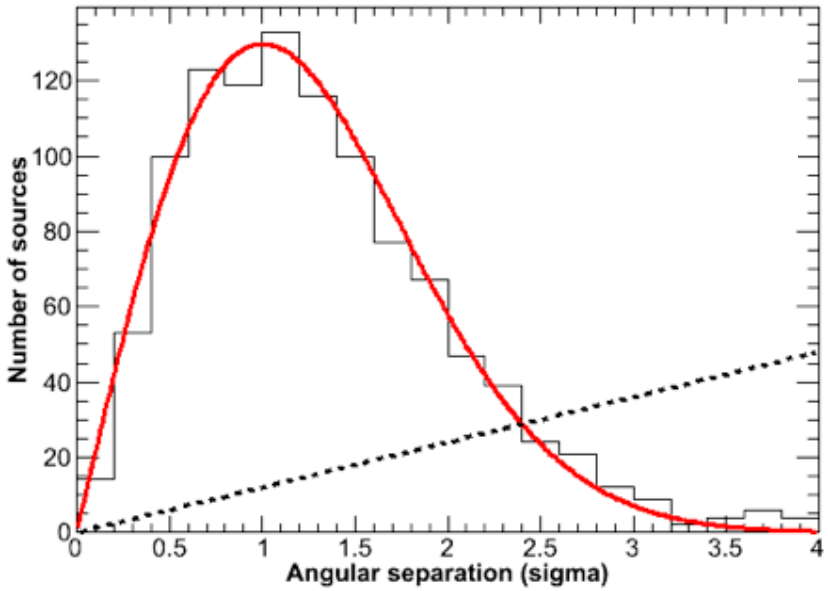
2LAC-clean sample:
310 FSRQs
395 BL Lacs
156 Blazars with unknown type
24 AGNs

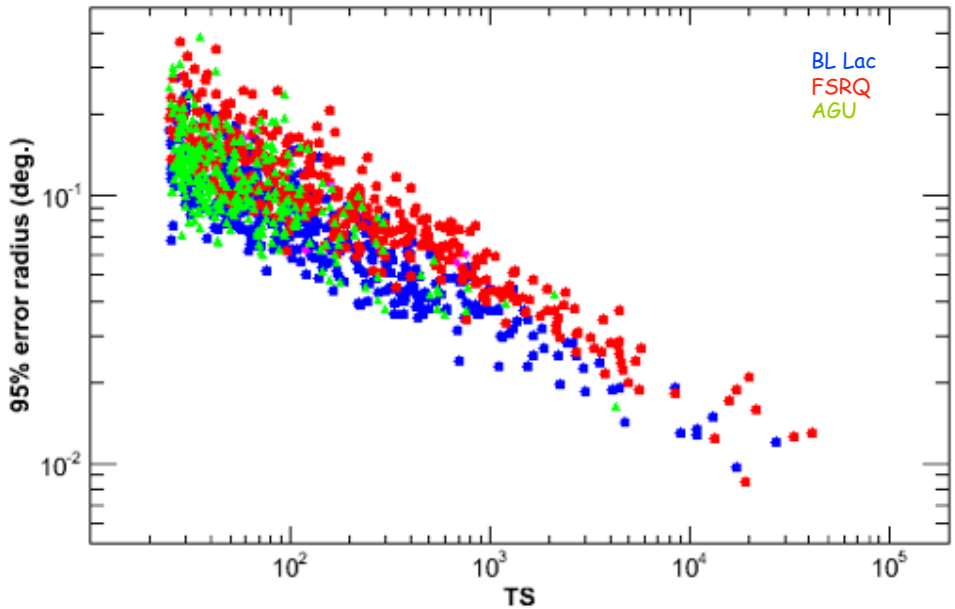
2LAC clean sample include 286 more sources than 1LAC clean sample, i.e. 48% increase
The fraction of FSRQ has dropped from 41% to 35% from 1LAC to 2LAC
The fraction of BL Lac has remained constant, roughly the 45% for 1LAC and 2LAC
The fraction of unknown type blazar candidates has increased dramatically --->due to improved association procedure

Association Methods

LAT localization accuracy is not precise enough to permit the determination of counterpart based only on positional coincidence
The procedure for building the 2LAC list makes use of three different methods (prob> 0.8):

- **Bayesian Method (used in 1FGL/1LAC)**
- **Likelihood Ratio Method -> Exploit the counterparts densities through the logN-logS**
- **logN-logS Method -> Based on Bayesian method but modified for blazars**

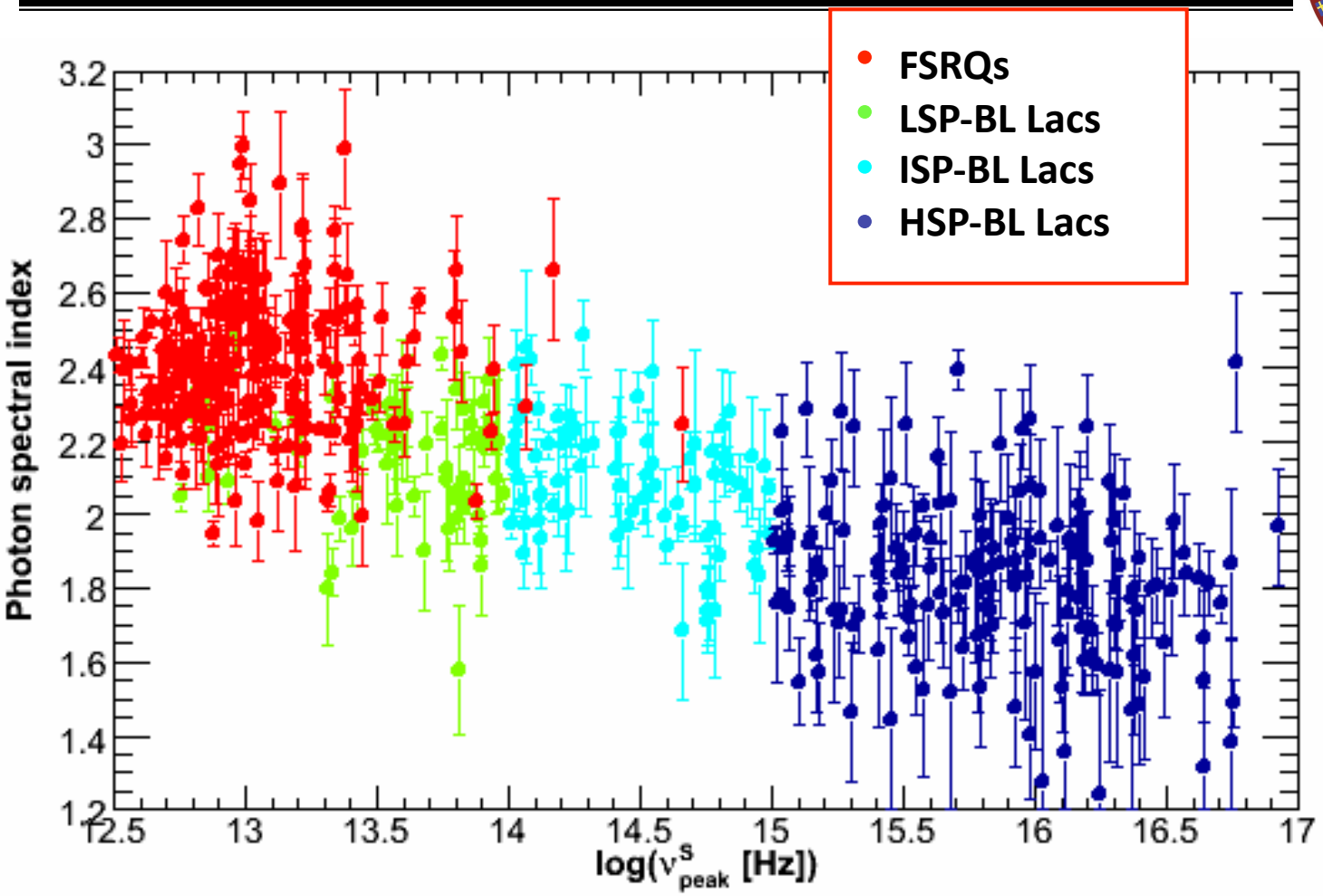




"Blazarness" search

- **The ingredients of the classification procedure are optical spectrum or other blazars characteristics:**
  - **Optical spectra from our intensive follow-up programs (Shaw et al 2012, Shaw et al. in prep. and Piranomonte et al. in prep.) BZCAT or literature**
  - **flat radio spectrum (at least between 1.4GHz and 5GHz)**
  - **broad band emission (spatially coincident faint radio source with bright X-ray source)**
- **We defined the following classes:**
  - **FSRQ, BL Lac, radio galaxy, SSRQ, Seyfert, Starburst: for sources with well-established classes in literature and/or with a good evaluation of the optical spectrum**
  - **AGU blazar-like sources without the optical spectra**
  - **AGN even more generic than AGU**

ν_{peak} vs photon index

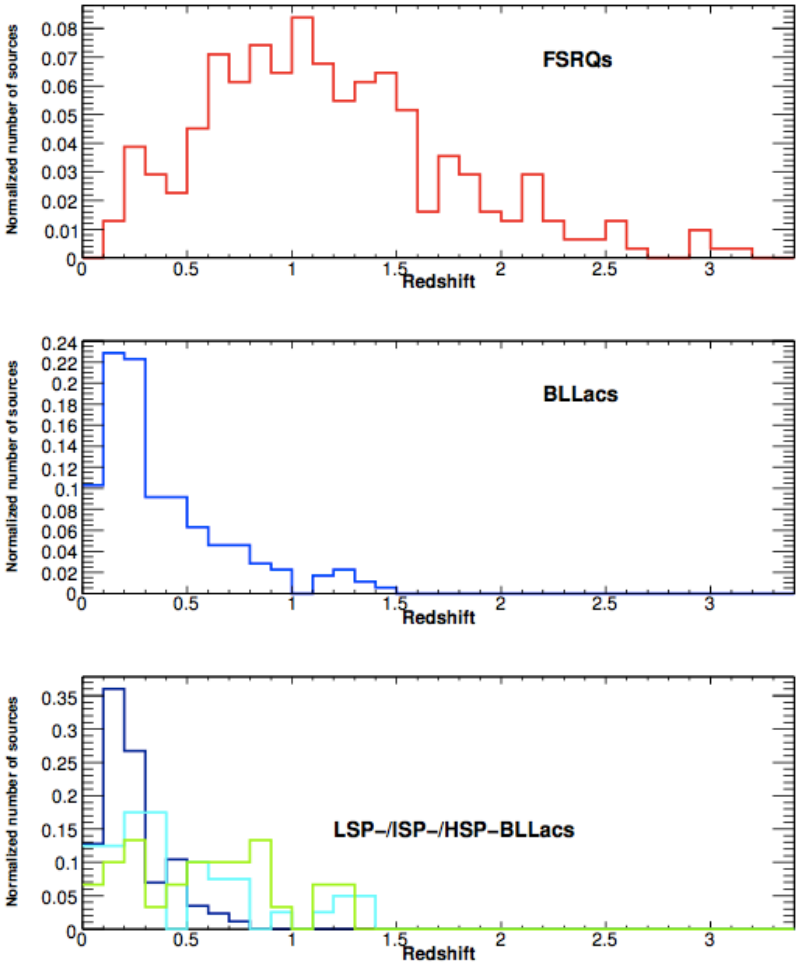


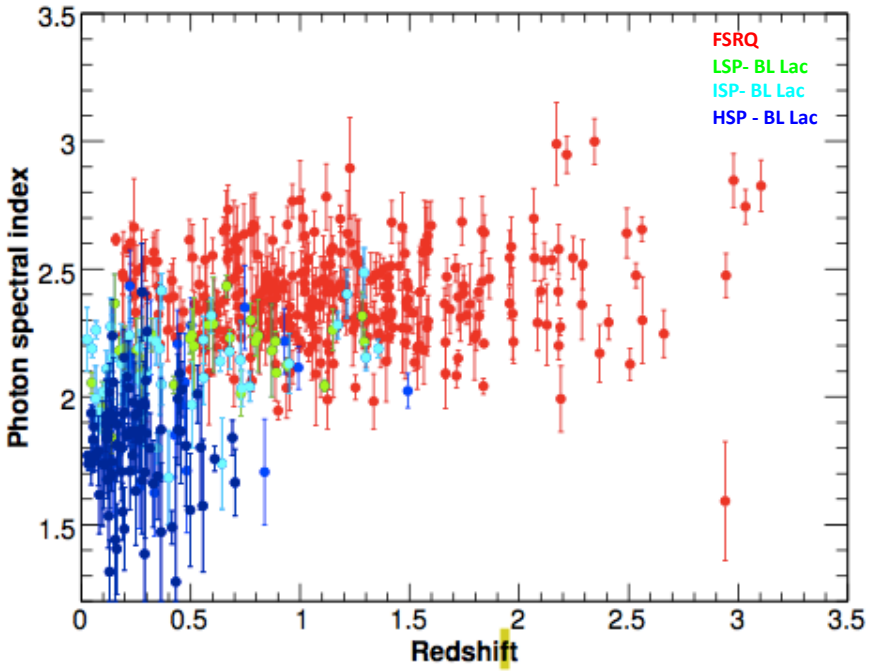
FSRQ: $\langle \log \nu^S_{peak} \rangle = 13.02 + 0.35$

BL Lac: spread the whole parameters space from LSP to HSP

Results consistent with Abdo et al. 2010 (ApJ 715, 429) and Giommi et al. 2012 (A&A 541, A160)

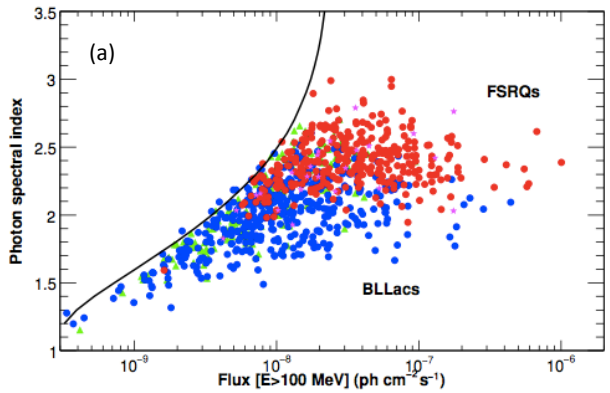
Redshift Distribution

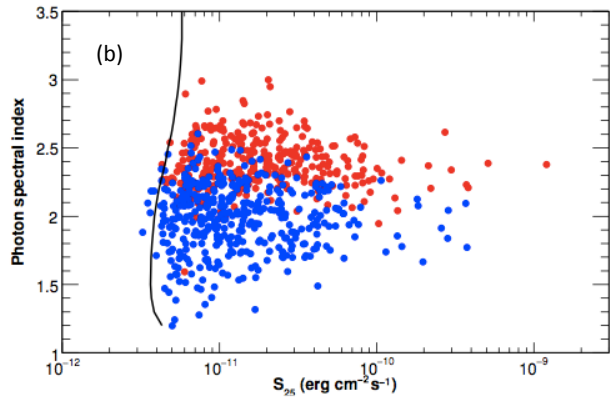




- FSRQ: <z> = 1.20+/-0.03
- BL Lac: <z> = 0.38+/-0.02
- 56% of BL Lac have no measured redshift
- Distribution of BL Lac redshift gradually extend to lower z as the location of the synchrotron peak shifts to higher frequency

Flux and Spectral Index





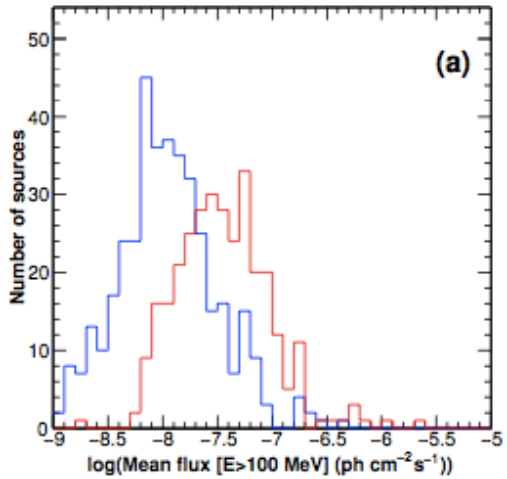
FSRQ: <ph_index> = 2.36+/-0.01
BL Lac: <ph_index>= 1.98+/-0.01

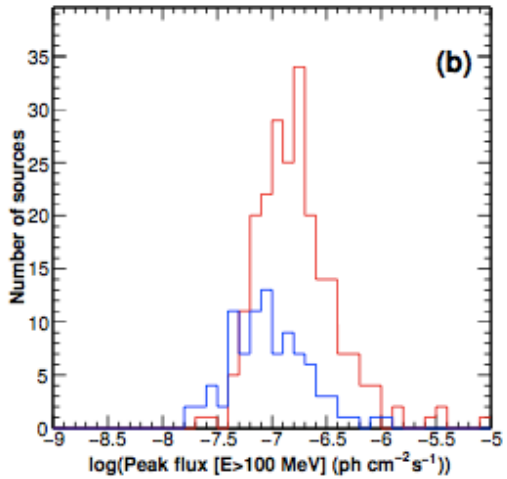
(a) Photon flux limit strongly depends on the photon index

(b) Energy flux limit is almost independent of the photon index

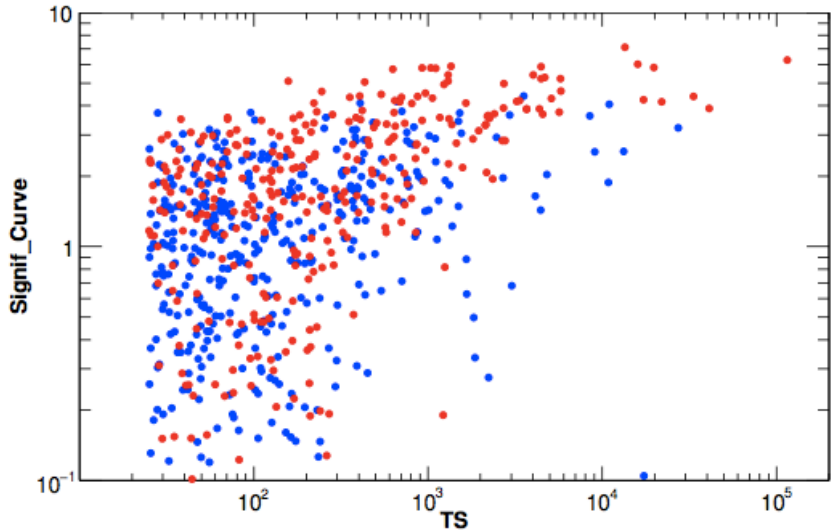
(a) Time average flux distribution:
FSRQs seem brighter than BL Lac ->higher detection limits

(b) Monthly peak-flux distribution:
Two distributions look similar, but FSRQ are still brighter.





Energy Spectra

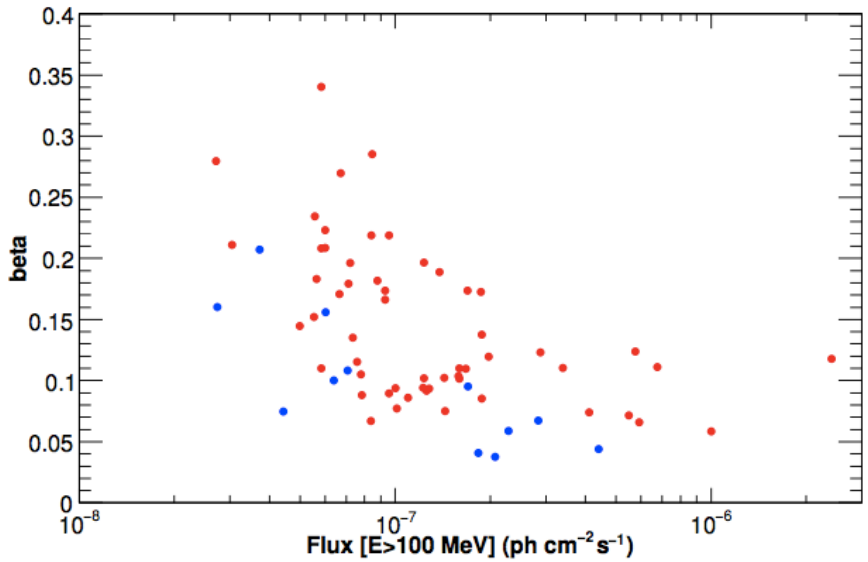


Significant curvature in the energy spectra of many FSRQ and some bright LSP/ISP BL Lac is now a well established feature (Abdo et al 2010 ApJ 710,1271).

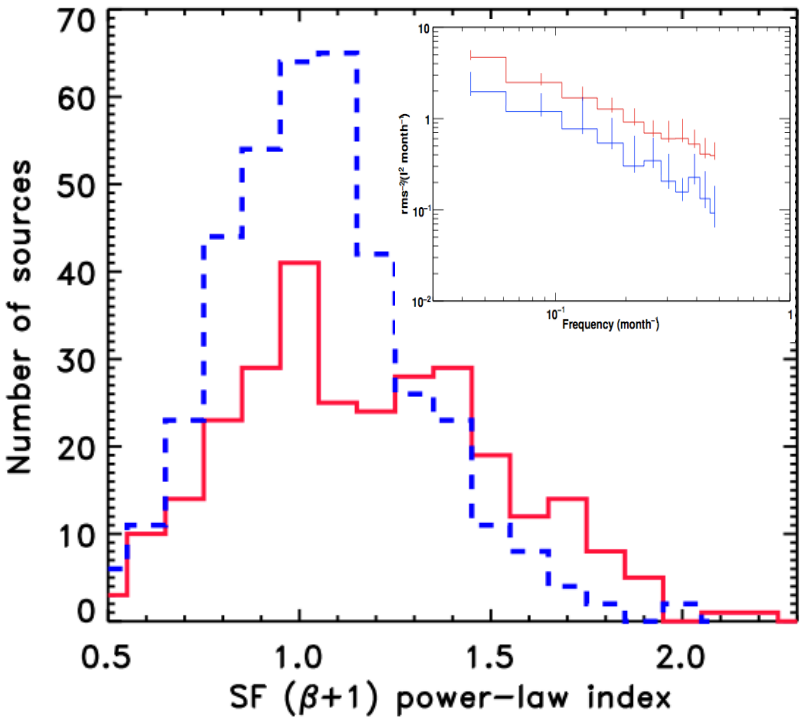
- $\gamma\ \gamma$ attenuation from He II line photons (Poutanen et al. 2010)
- intrinsic electron spectral breaks (Abdo et al 2009, ApJ 699, 817)

Different curvature between FSRQ and BL Lac

FSRQ: $<\beta>$ = 0.18+/-0.02
BL Lac: $<\beta>$ = 0.11+/-0.02



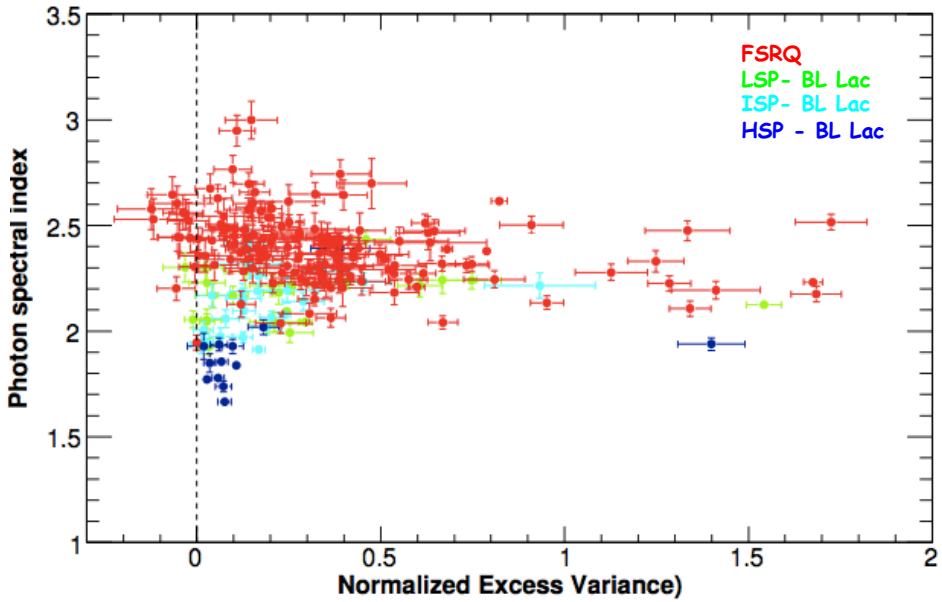
Variability



Average PDS of two the populations show the same slope for both ~1.15+/-0.10

The difference in height of the PDS means that the fractional variability of BL Lac is lower than the FSRQ

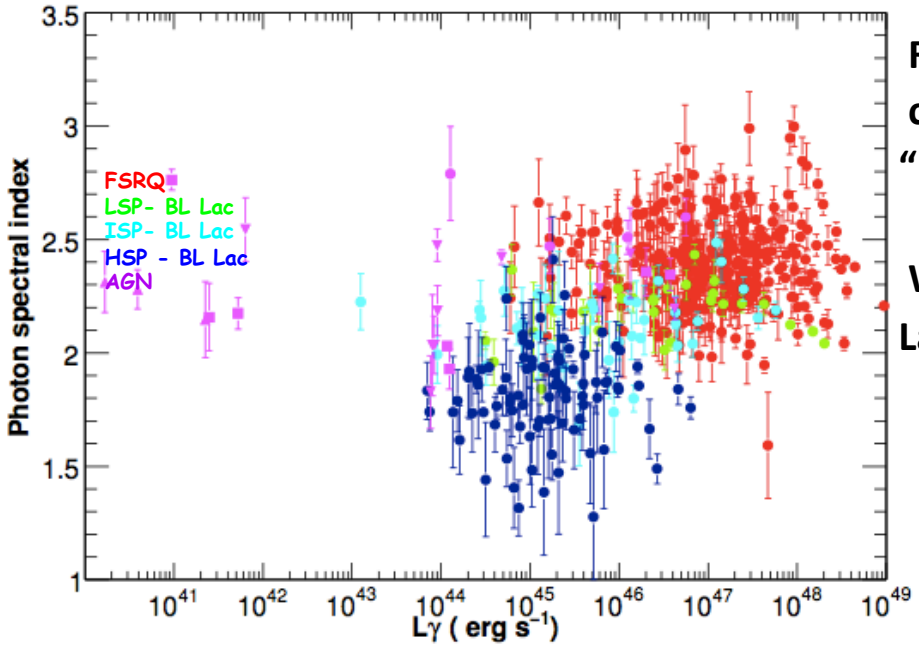
Distribution of single source PDS slopes evaluated with SF shows little differences between two populations



The most variable sources have a photon index greater than 2.2

HSP-BL Lac exhibit a variability lower than the other classes

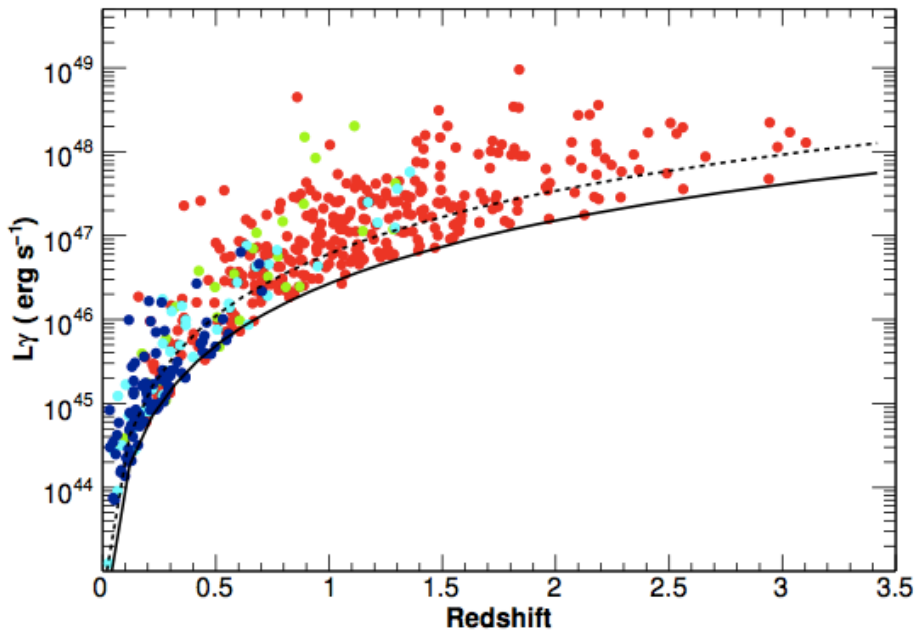
Luminosity



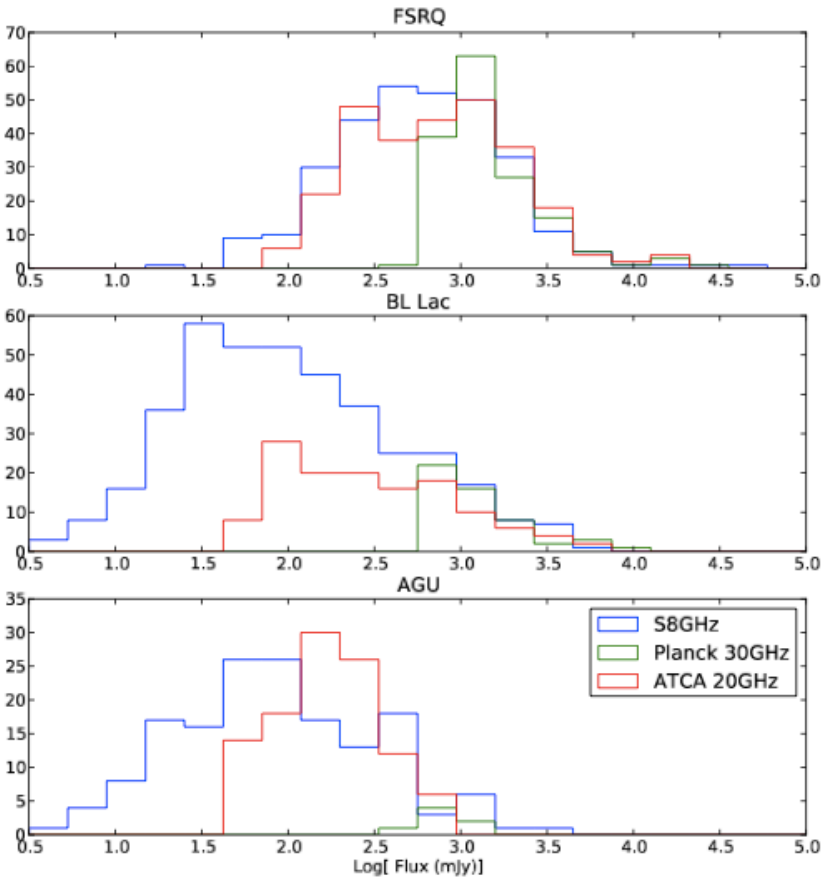
Redshift incompleteness influences any conclusions concerning properties based on knowledge of z -> "Blazars divide" (Ghisellini et al. 2009)

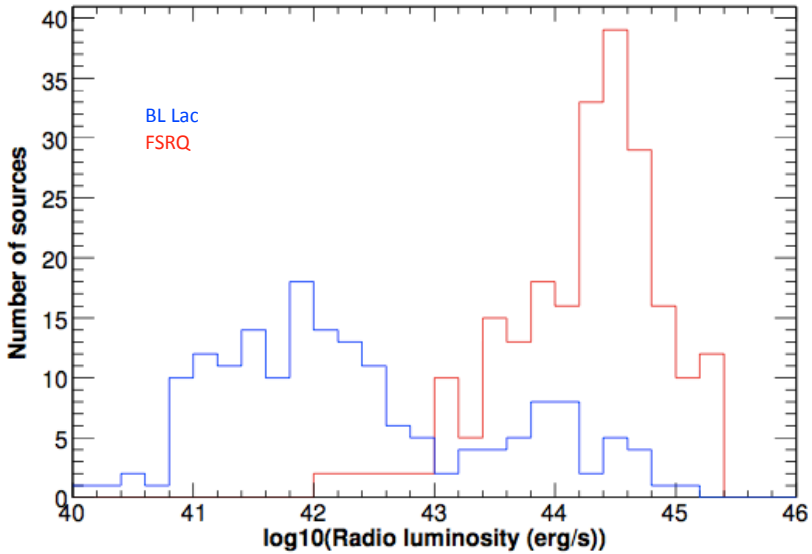
We found a very weak correlation separately for BL Lac and FSRQ

Malmquist bias is evident --> only high-luminosity (mostly FSRQ) sources are detected at large distances



Radio Distributions

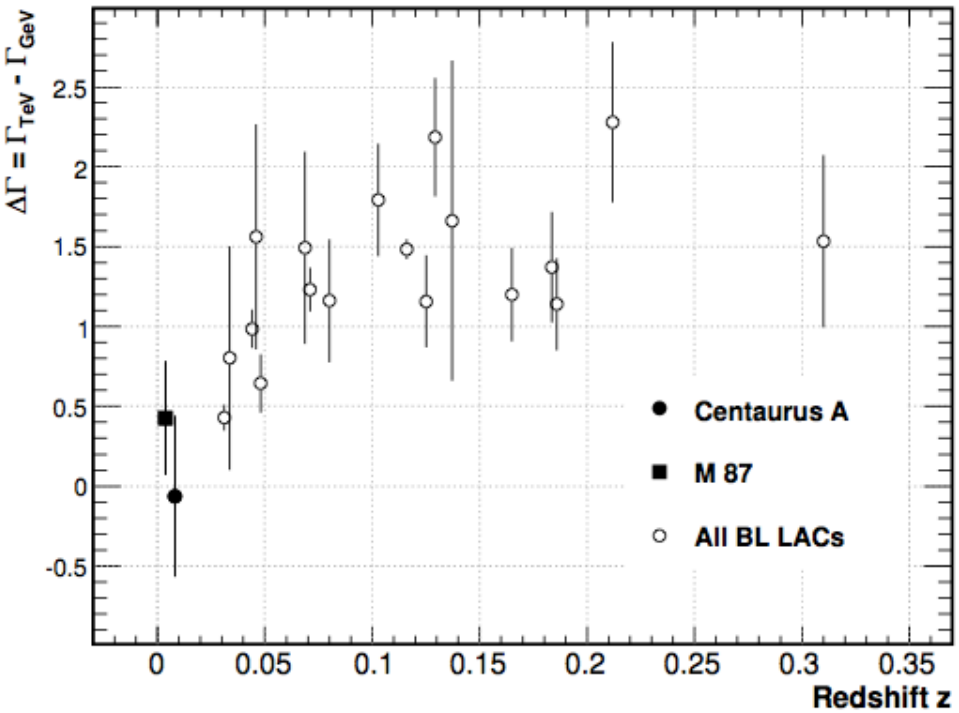




Ackermann et al 2011 (ApJ,741,30), Ghirlanda et al 2010, Lister et al. 2011 and Lindford et al. 2011 have shown a significant correlation between radio and gamma-ray activity

FSRQs are averagely brighter and "apparently" more luminous in radio than BL Lac-> z incompleteness

GeV-TeV Connection



34 TeV AGN are in the 2LAC clean sample

- 26 AGN are well fitted with simple power law in the LAT band pass
  - HSP: 17
  - ISP:2
  - LSP: 2
  - unknown SED Class: 5

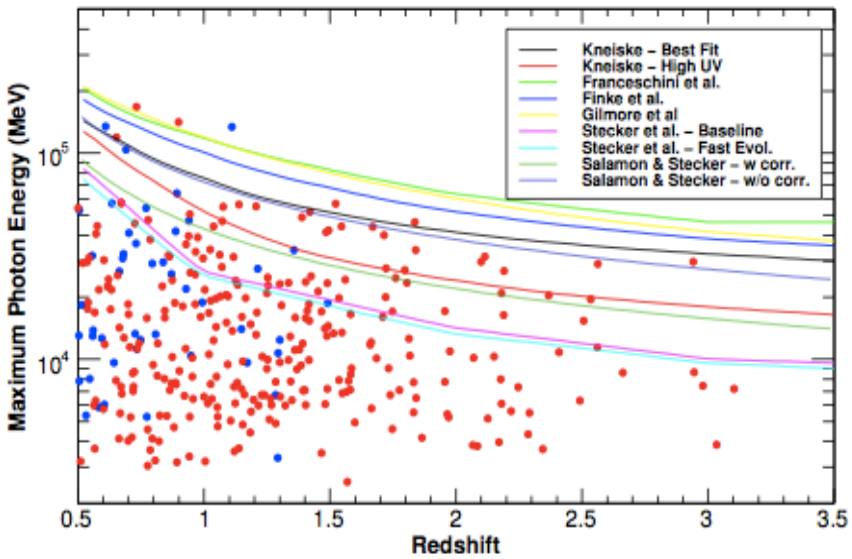
Deficit of distant sources with small values of $\Delta\Gamma$

- EBL: softening of the VHE spectrum dependent on z

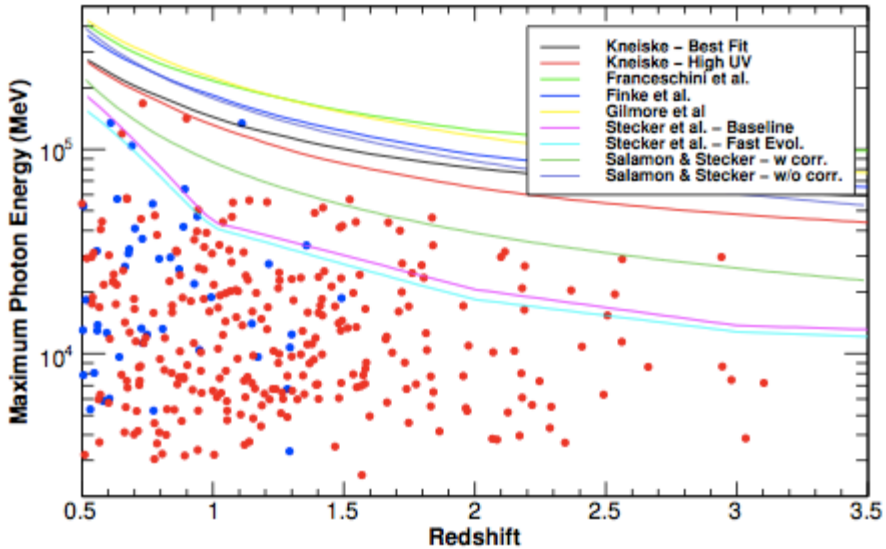
Highest energy photon

We find about a factor ~ 2 more candidate photon events coming from sufficiently high redshift (z > 0.5) to probe the models of the extragalactic background light (EBL) -> Thanks to better background rejection and increased exposure

τ =1



τ =3



Results

- 2FGL contains 1319 sources at high-latitude -> 1017 are high confidence AGNs (886 clean sample of 2LAC: 48% increase respect to 1LAC)
- Smaller error ellipse due to a longer integration results in a fewer multiple associations with respect to 1LAC (only 26 sources have more than one counterpart)
- BL Lacs outnumber FSRQs->Fermi-LAT detection limit
- BL Lac objects and FSRQs display slightly different variability flavors (more flicker or Brownian-like) and markedly different variability amplitudes
- The spectra of FSRQs are softer and more significantly curved than those of HSP/BL Lac
- The incompleteness of z estimation influences any conclusions concerning luminosity or other properties that depend on knowledge of redshift

Conclusions

- **The 2LAC represents a significant advance with respect to the 1LAC, including many more sources and reduced uncertainties thanks to the doubling of exposure and refinement of the analysis.**

- **2LAC should allow for a deeper understanding of the blazar phenomenon and the relations between blazar classes.**

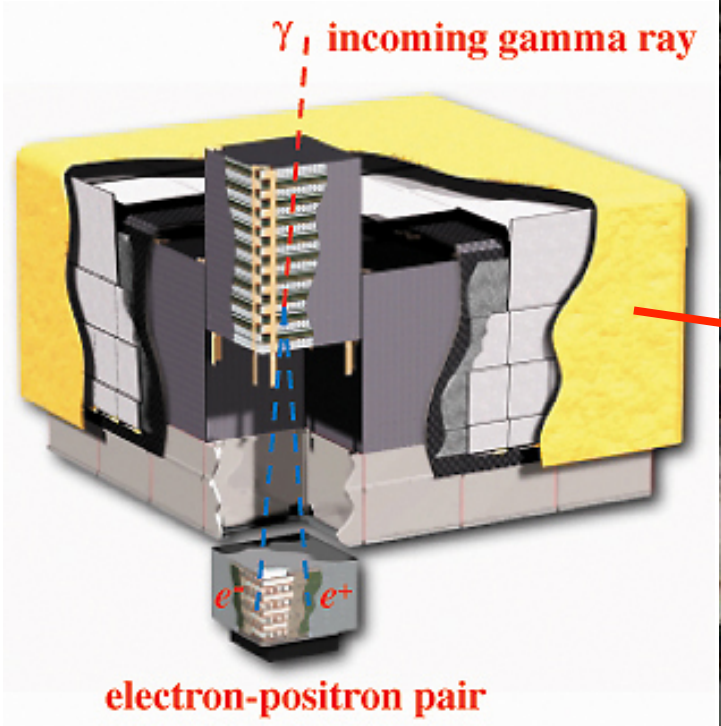
- **All the details and information are available in Ackermann, M. et al., ApJ, 743: 171, 20 December, 2011 arXiv:1108.1420**

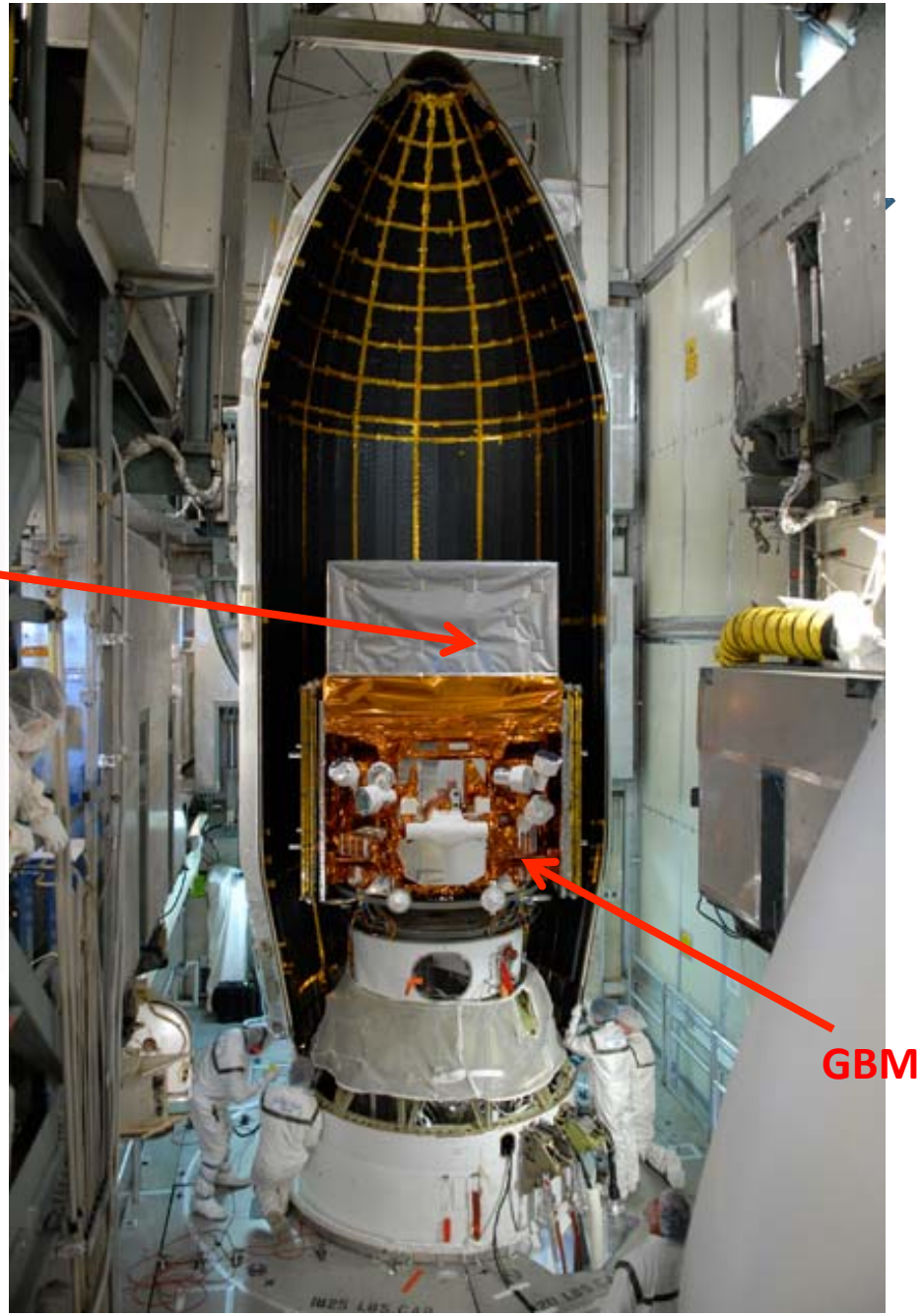
- **The table is available online here: www.asdc.asi.it/fermi2lac**

Thank you for attention

Backup slides

GLAST: The Gamma Ray Large-Area Space Telescope
(launched June 11, 2008)

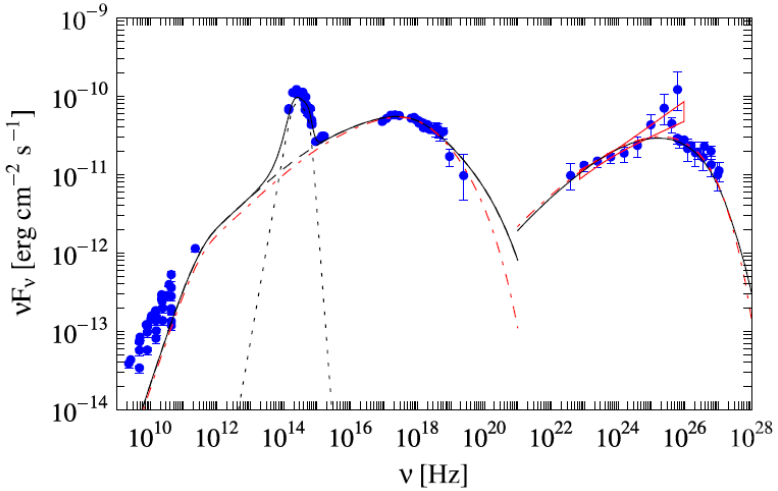


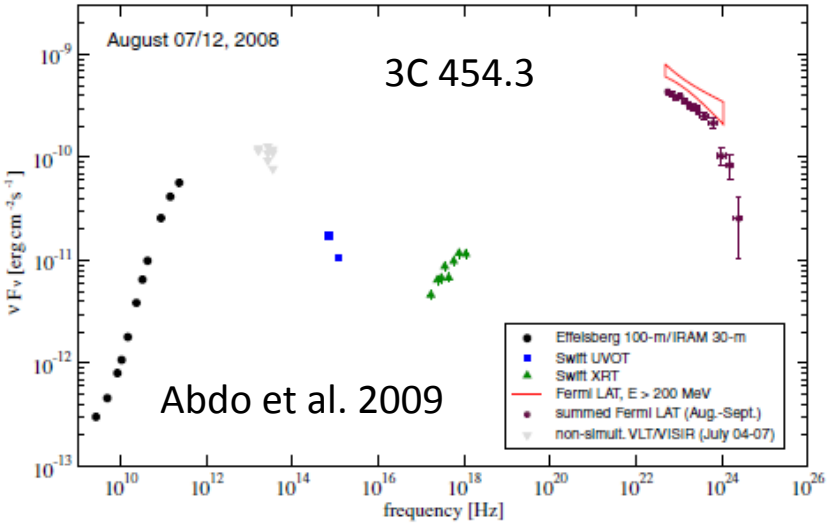


<u>Large Area Telescope (LAT) images the sky one photon at a time</u>: γ-ray converts in LAT to an electron and a positron; direction and energy of these particles tell us the direction and energy of the photon

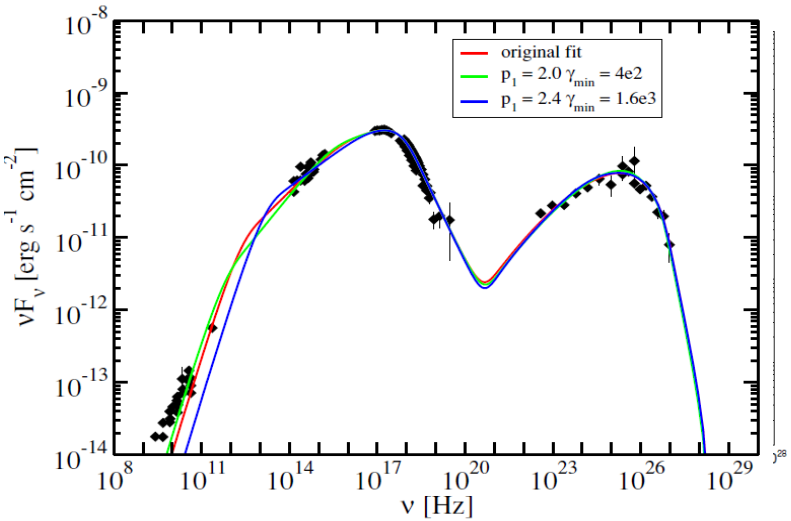
Advances in assembling simultaneous SED

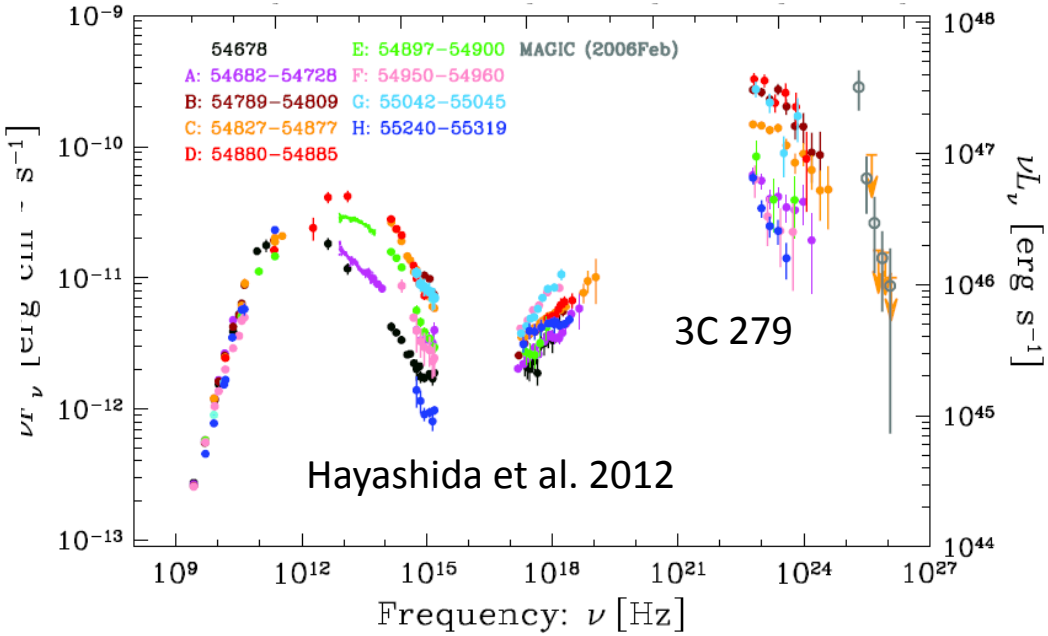
Abdo et al. 2011a





Abdo et al. 2011b



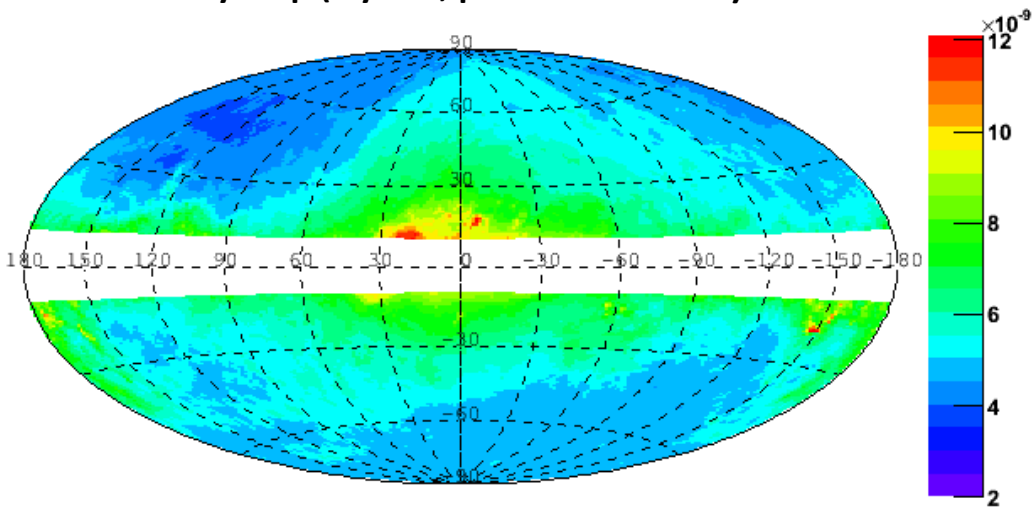


Dario Gasparrini

Assets for blazar science

- unprecedented sensitivity
- fairly uniform at high Galactic latitude
- sky scanned every 3 hours in survey mode
- 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) ph $cm^{-2}s^{-1}$

- 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)

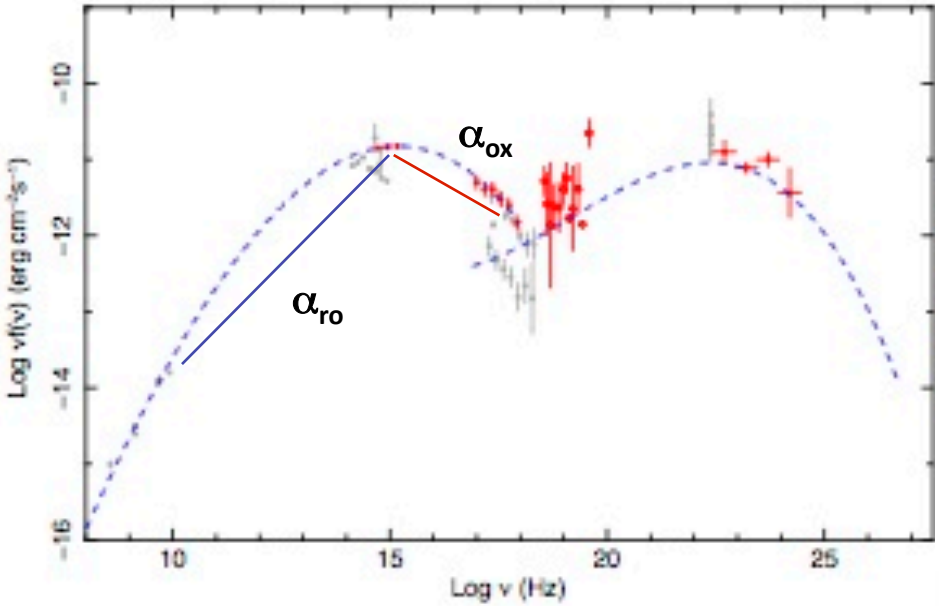
Differences between 1LAC and 2LAC

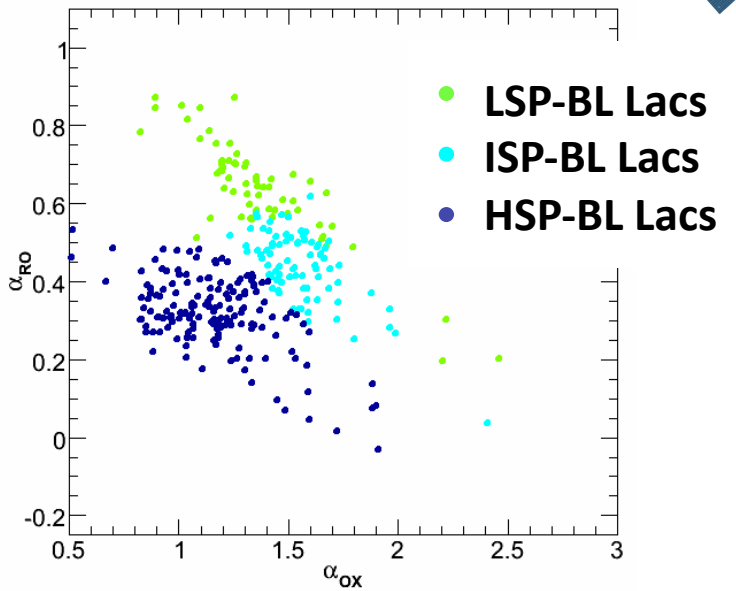
	1LAC/1FGL	2LAC/2FGL
Period	11 m	24m
Analysis	unbinned	binned
IRFs	P6_V3_DIFFUSE	P7_V6_SOURCE
Association methods	Bayesian	Bayesian Likelihood-Ratio Log N- Log S
Parent catalogs	CRATES/BZCat	Many
Total	671/709*	991/1017*
Clean Sample	599	886

* γ-ray sources/counterparts

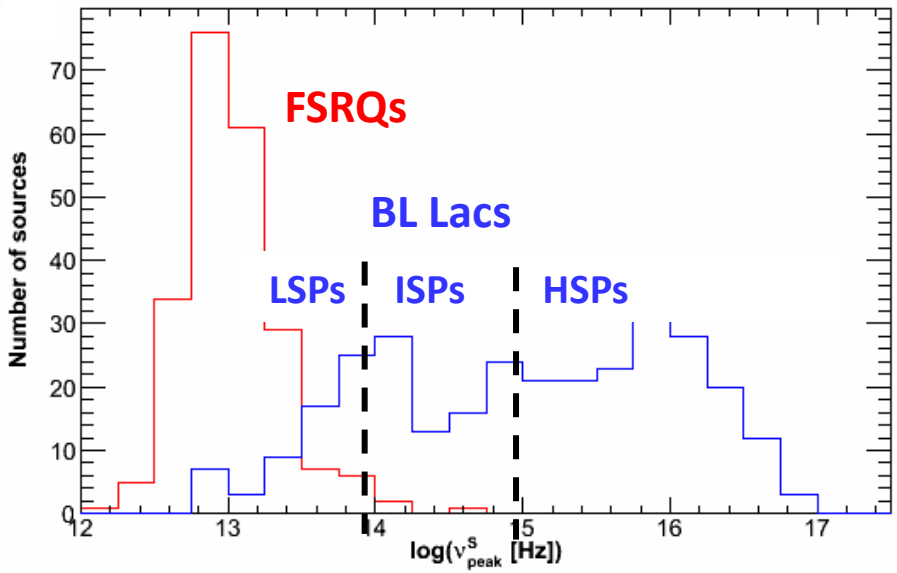
SED-based classification

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

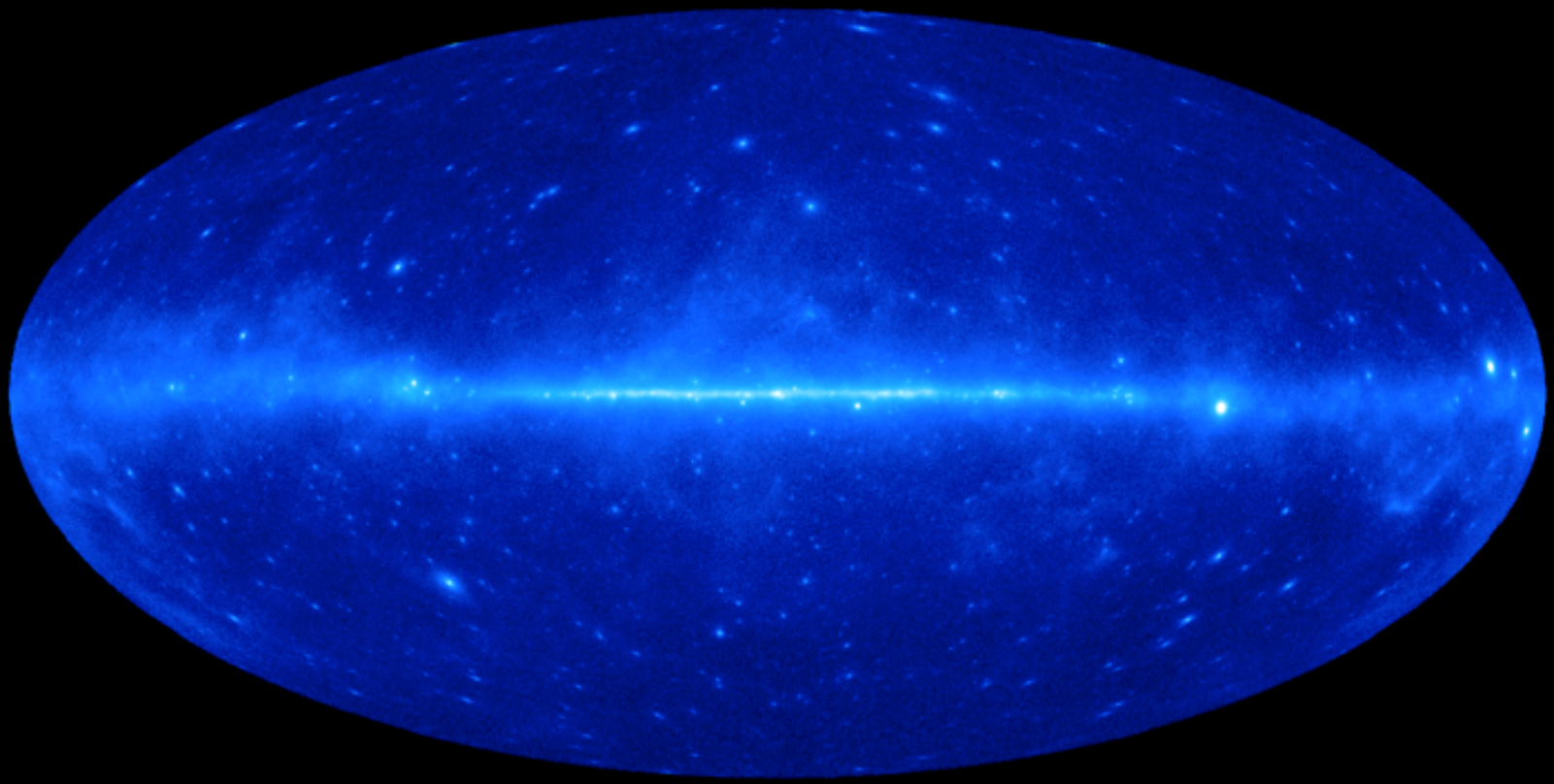




- relation with ν_{syn} estimated from α_{ox}, α_{ro}
- subclasses assigned from ν_{syn}
  LSP, ISP, HSP: Low-, Intermediate-, High-Synchrotron Peaked blazars
  - LSP: $\log[\nu_{syn}\,(Hz)] < 14$
  - ISP: $14 < \log[\nu_{syn}\,(Hz)] < 15$
  - HSP: $\log[\nu_{syn}\,(Hz)] > 15$

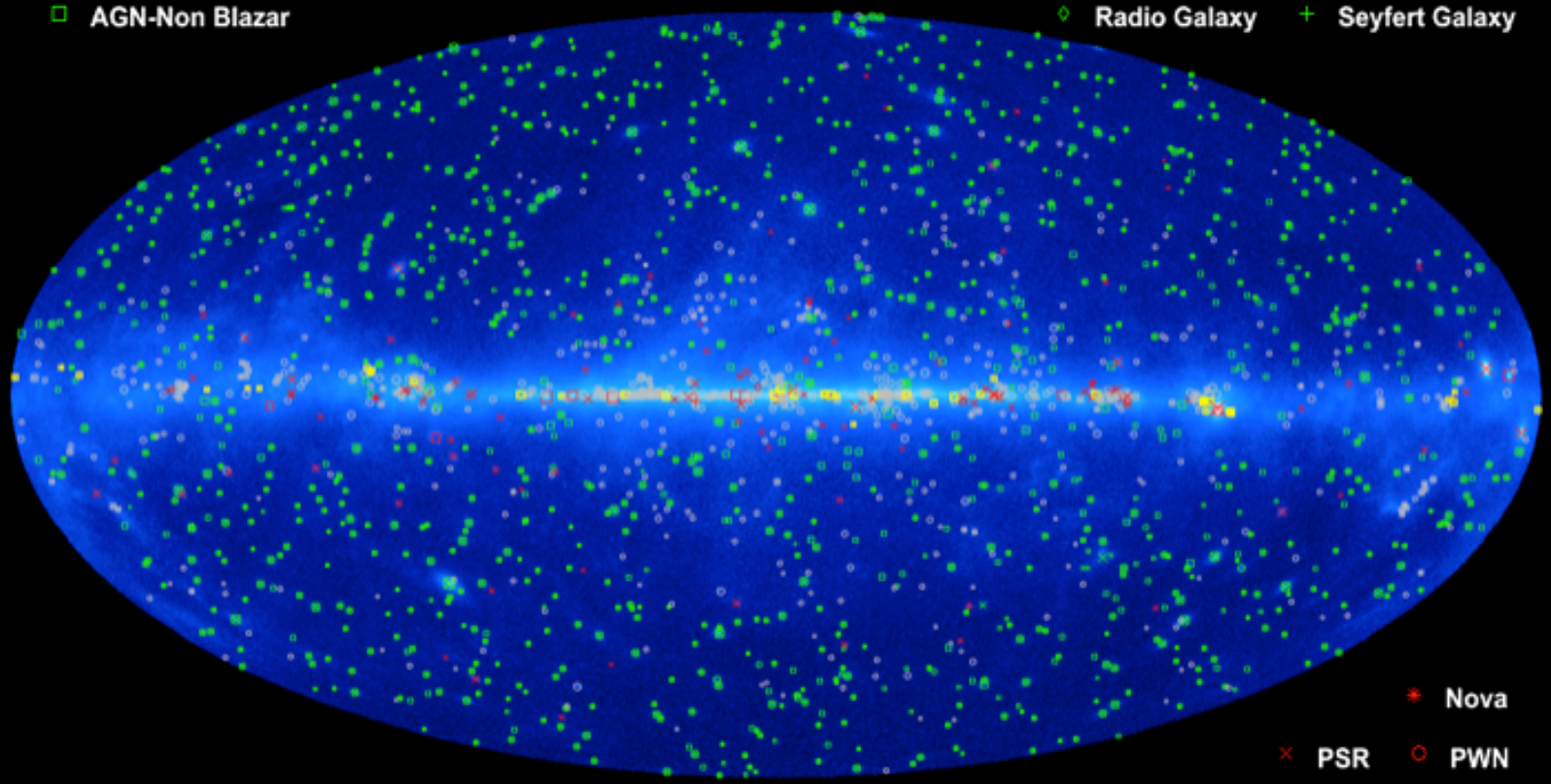


Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration

Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration

1873 sources with TS>25

The Fermi collaboration, submitted to ApJS, arXiv: 1108.1435