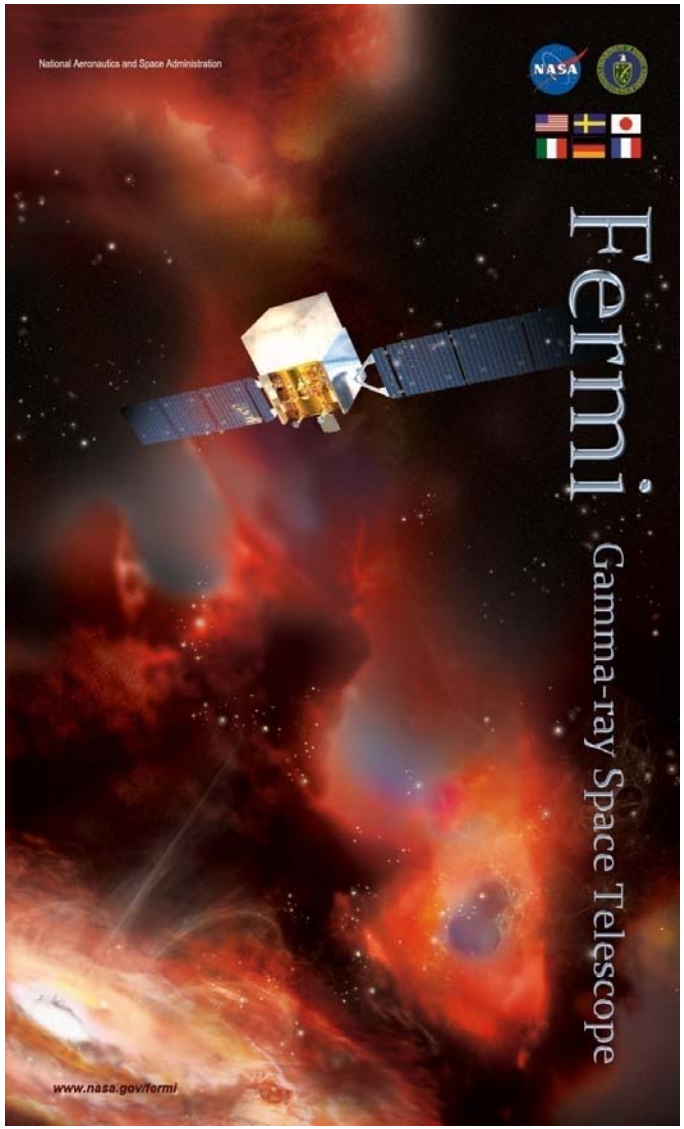
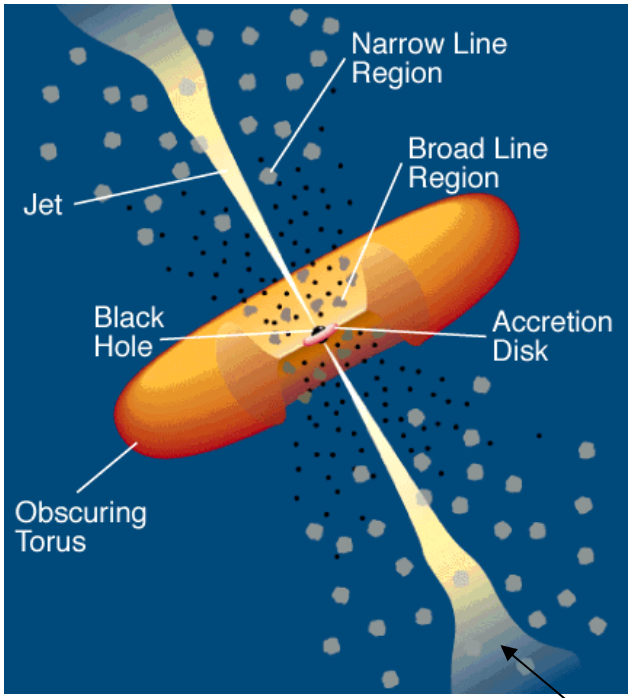


First *Fermi*-LAT results on AGNs

Gino Tosti
University & INFN Perugia
On behalf of
Fermi LAT Collaboration

to Paolo Maffei

Blazars



Almost all galaxies contain a massive black hole
-99% of them are (almost) silent (e.g. our Galaxy)

-1% is active (mostly radio-quiet AGNs): BH+disk: most of the emission in the UV-X-ray band

0.1% is radio loud: jets mostly visible in the radio

Blazar characteristics

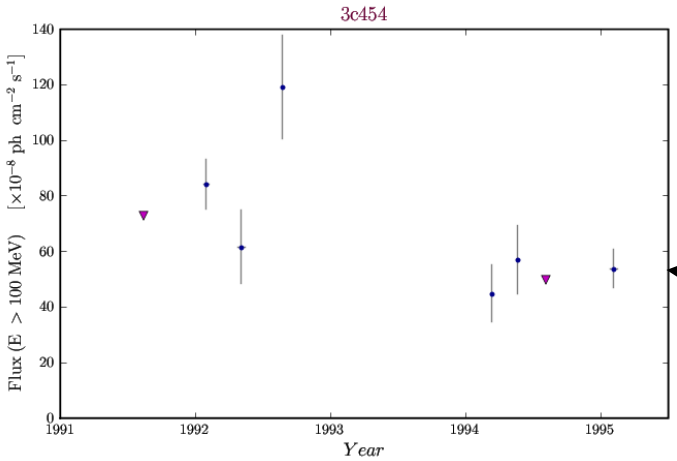
- Compact radio core, flat or inverted spectrum
- Extreme variability at all frequencies
- High optical and radio polarization

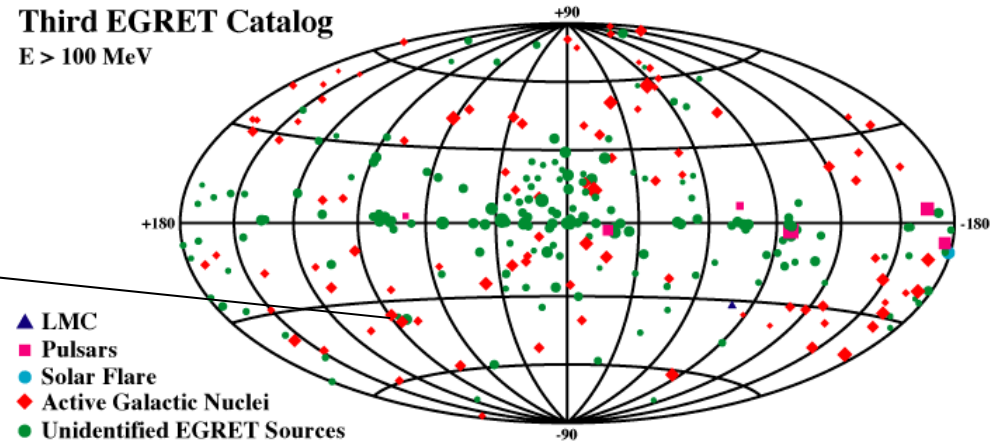
FSRQs: bright broad (>2000 km/s) emission lines often evidences for the "blue bump" (acc. disc)

BL Lac: weak (EW<5 Å) emission lines no signatures of accretion

Gamma-ray loud Blazars

Although blazars comprise only a few per cent of the overall AGN population, they dominate the extragalactic high-energy sky

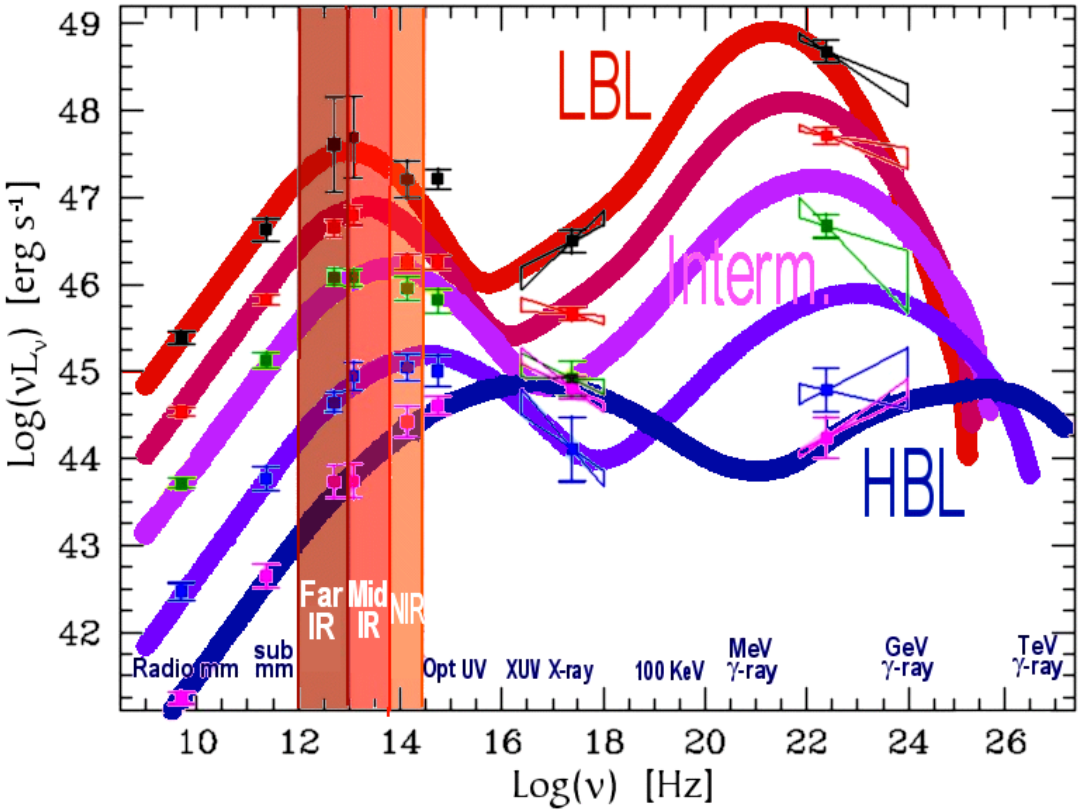




- **The Energetic Gamma Ray Experiment Telescope (EGRET) discovered about 70 (3rd Catalog, Hartman et al 1999; >100 Sowards-Emmerd et al. 2003,2004) blazars emitting gamma-rays**
- **About 20 sources were detected at E>200 GeV by the ACTs**

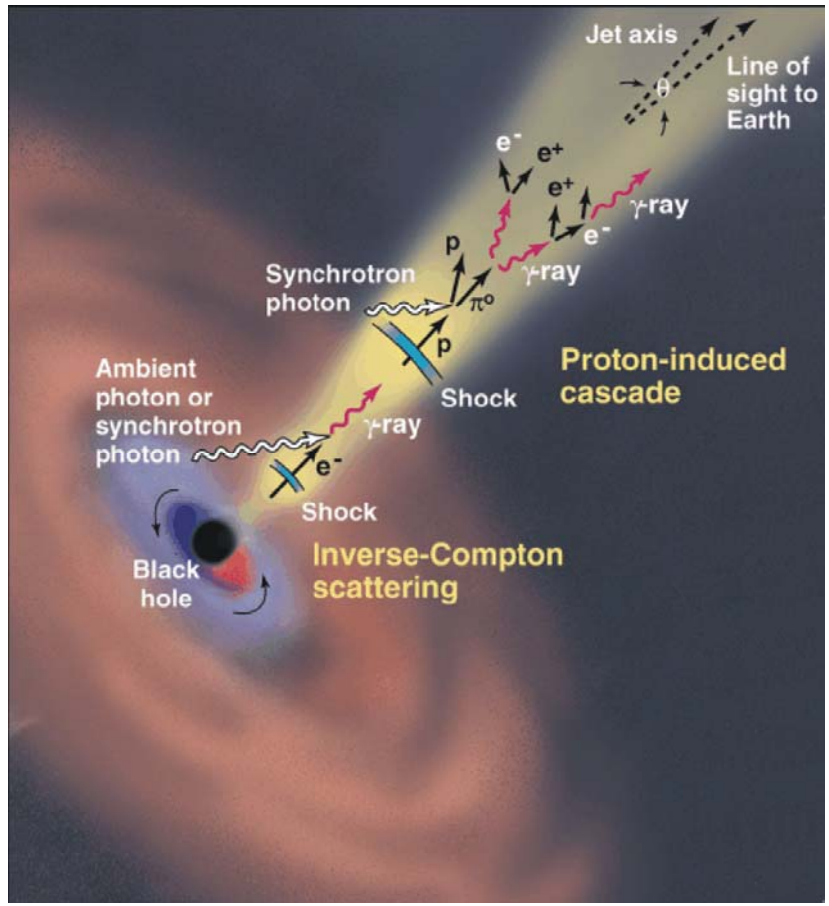
Blazar Spectral Energy Distribution (SED)

The broadband continuum spectra of blazars are dominated by non-thermal emission and consist of two distinct, broad components.



Open questions about Blazar Physics

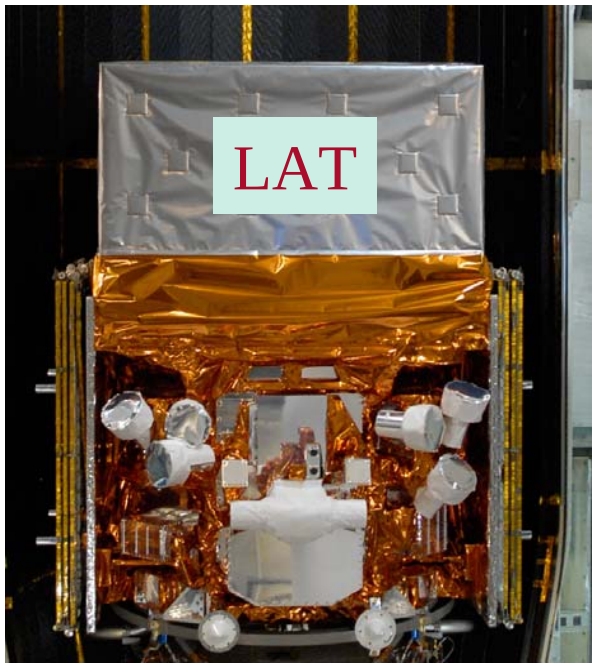
- How are jets made by accreting black holes?
- How and where are jets accelerated (why they have high Lorentz factors)?
- How are jets focused to opening angles less than a few degrees?
- How do shocks, turbulence, instabilities, jet bending and precession arise?
- What is the jet matter content (electron-proton vs. pair plasmas)?
- How are the relativistic electrons accelerated?
- Which is the jet emission mechanism ?
- How and where jets emit gamma-ray ?
- What are the mechanisms producing blazar variability?
- Which is the blazar duty-cycle?
- Etc…

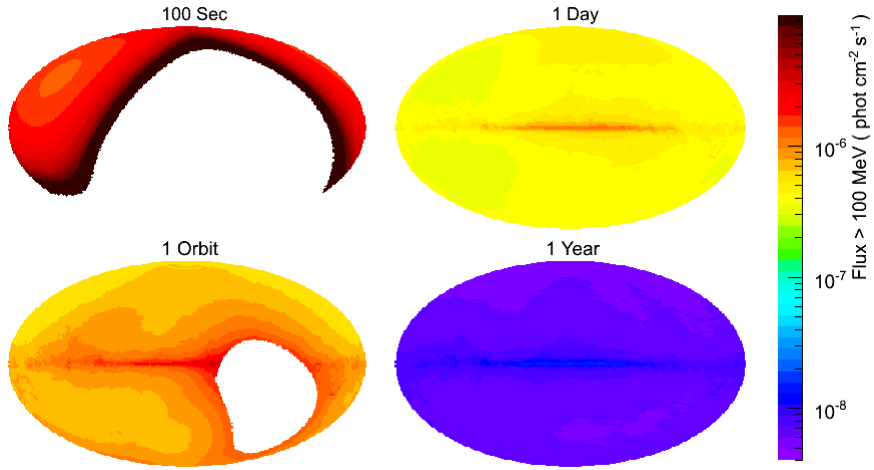


Fermi-LAT is starting to give an answer to most of these questions

Fermi LAT & Blazars

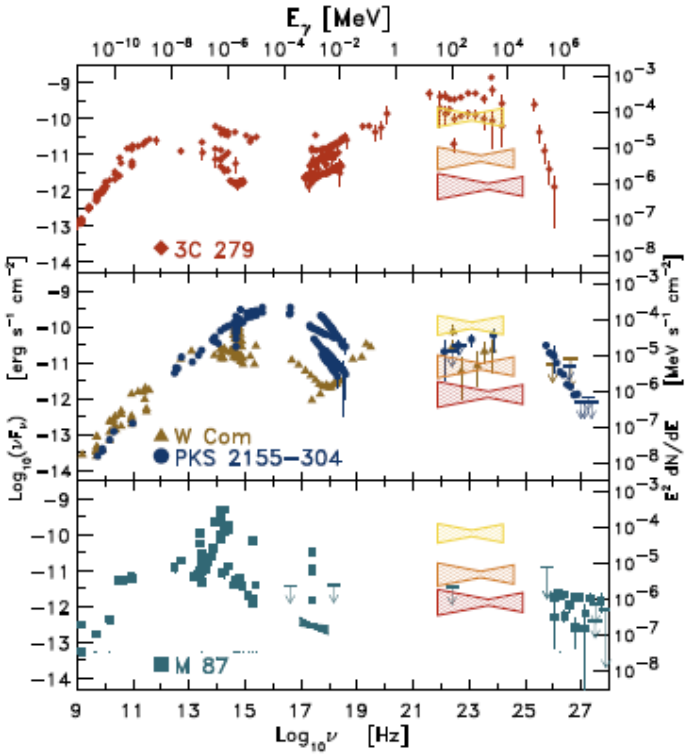
- **Sky Survey as primary operating mode**
  - **Full sky observed every 2 orbits (3 hours)**
  - **Uniform exposure, with each region of the sky viewed for ~30 minutes every 2 orbits (20% of the sky in the LAT FOV at any time)**
  - **EGRET sensitivity reached in days**
- **Huge energy range, including largely unexplored band 10 GeV - 100 GeV.**





Fermi LAT & Blazars

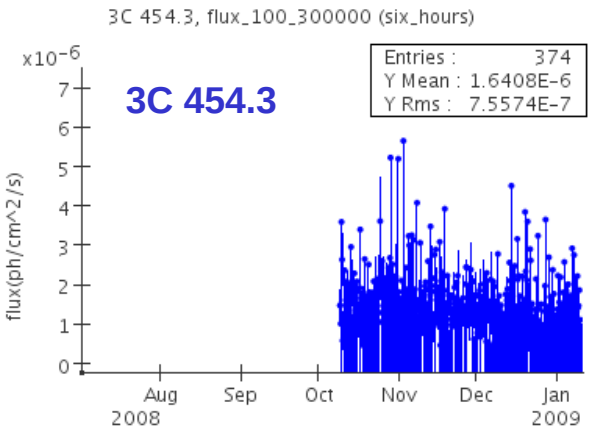
- Prompt detection of flaring Blazars
- Daily sampled LC can be easily obtained for most of the brightest blazars → Variability on timescales >= 1 day can be well investigated.
- Intra-day (hours) variations can be detected for the very bright gamma-ray blazars.
- Detailed spectral variation analysis and intra-bands delays studies may be performed
- Multiepoch Spectral Energy Distributions (SEDs) can be obtained
- Population Studies

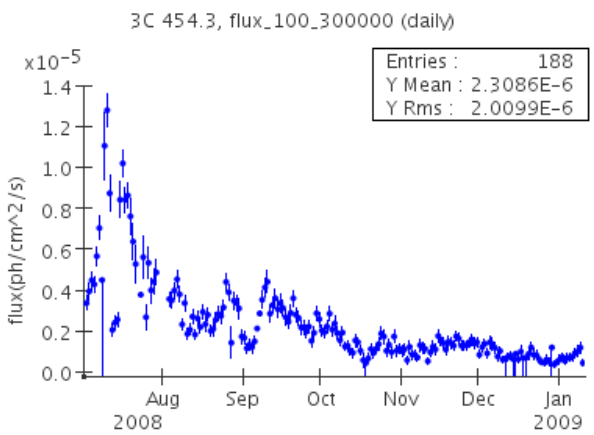


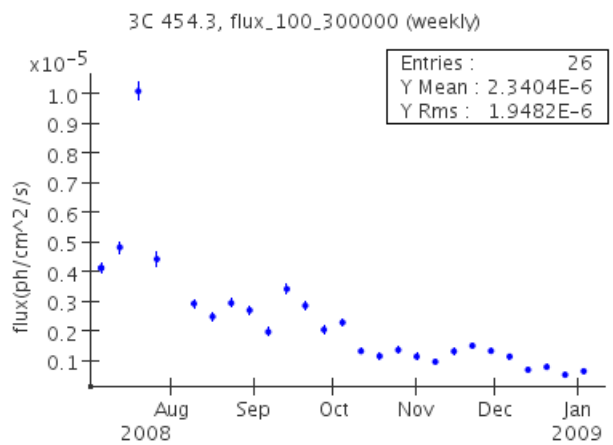
(Atwood at al. 2009, arXiv:0902.1089)

Flaring Sources detection and Source Monitoring

- **Automated Science Processing (ASP)**
  - **Transient detection: Uses source detection (pgwave) to find all point sources in data from each epoch (6hr, day, week)**
  - **Follow-up monitoring: Runs full likelihood analysis on list from source detection step + "Data Release Plan" (DRP) sources**
  - **2×10^{-6} ph cm^{-2} s^{-1} threshold (daily) for public release of non-DRP**
- **Flare Advocates:**
  - **LAT scientists from Galactic and Extragalactic groups examine output from ASP pipeline and perform follow-up analyses, produce ATels, and propose ToOs**







ATels on Flaring Sources

DATE	ATel#	Title
2009-02-19	1933	Fermi LAT detection of Increased Flux from new gamma-ray blazar **PKS 0250-225**
2009-02-18	1932	Fermi LAT detection of a GeV flare from new gamma-ray blazar **PKS 1118-056**
2009-01-29	1919	Fermi-LAT detection of increased gamma-ray activity from the blazar PKS 0727-115
2009-01-22	1905	Fermi-LAT detection of renewed activity from the blazar PKS 1502+106
2009-01-19	1902	Fermi LAT detection of a high gamma-ray state from high-redshift blazar 0917+449
2009-01-12	1898	Fermi LAT detection of increasing gamma-ray activity of blazar PKS 0454-234
2009-01-09	1897	Fermi-LAT detection of another rapid GeV flare from the blazar PKS 1510-089
2009-01-08	1894	Fermi-LAT detection of a GeV flare from a source positionally consistent with PKS 1244-255
2009-01-04	1888	Fermi-LAT and Swift detection of a large GeV and optical flare from J123939+044409
2008-12-17	1877	Fermi LAT detection of a gamma-ray source positionally consistent with QSO B0133+47
2008-12-06	1864	Fermi LAT detections of increasing gamma ray activity of blazar 3C 279
2008-11-21	1850	Fermi LAT Observations of the Cygnus Region
2008-10-17	1788	Fermi LAT Detection of a New Gamma-ray Transient in the Galactic Plane: J0910-5041
2008-10-15	1784	Fermi/LAT detection of strong activity on short timescales of the blazar AO 0235+164
2008-10-08	1771	Fermi LAT Detection of Brightening of the Galactic Plane Source 3EG J0903-3531
2008-10-03	1759	Fermi LAT detections of gamma ray activity in three blazars: 3C 66A, PKS 0208-512, PKS 0537-441
2008-09-26	1744	Fermi LAT strong detection of blazar AO 0235+164 during outburst at Optical-to-Radio Wavelengths
2008-09-26	1743	Fermi LAT observations of the PKS 1510-089 outburst
2008-09-08	1707	Fermi LAT detection of 3C 273 in flaring state
2008-09-05	1701	Fermi LAT detection of a possible new gamma-ray flaring blazar: PKS 1454-354
2008-08-08	1650	GLAST LAT detection of a possible new gamma-ray flaring blazar: PKS 1502+106
2008-07-24	1628	GLAST-LAT detection of extraordinary gamma-ray activity in 3C 454.3

Public light curves for most of the detected flaring sources are available at: http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/

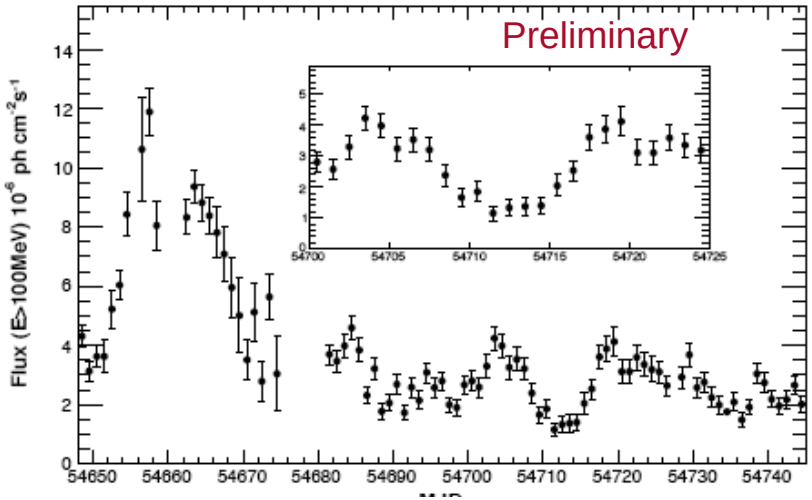
Flaring Blazars: 3C454.3
(Abdo et al. 2009, ApJ, submitted)

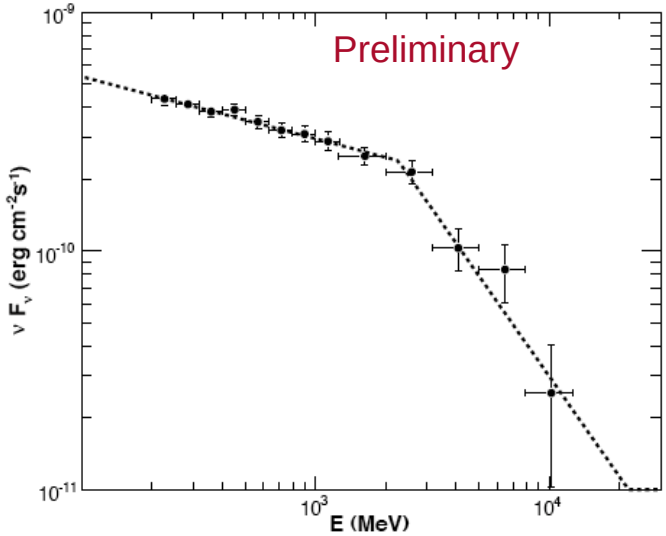
• **Well-known blazar, at z = 0.859. Detected by EGRET, AGILE. Very active (bright, rapidly variable) since 2000**

•Fermi-LAT data show rapid, quasi-symmetric, flares on a time scale of ~3 days

•First observation of a spectral break in the spectrum of a high luminosity blazar above 100MeV.

A possible interpretattion of the break is that it is the direct signature of an intrinsic break in the energy distribution of the radiating particles.



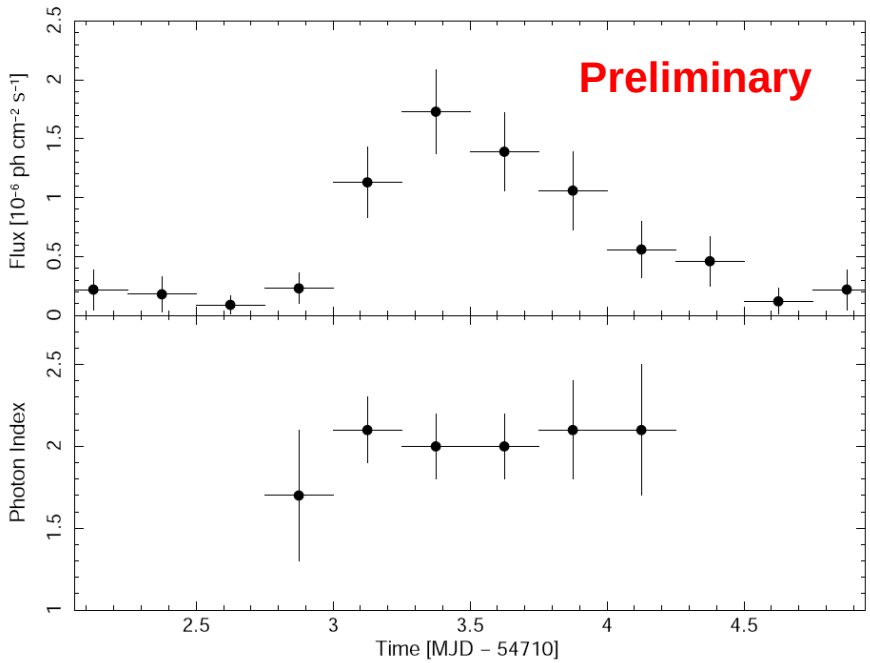


(Contact authors:G. Madejski & B. Lott)

Flaring Blazars: PKS 1454–354
(Abdo et al. 2009, ApJ submitted)

- **Fermi -LAT data demonstate that PSK 1454-354 (z=1.424) is the most probable counterpart of the unidentified EGRET source 3EG J1500-3509**

- **The source showed a factor ~5 increase of >100 MeV flux in 12 hours; achromatic flux variations**

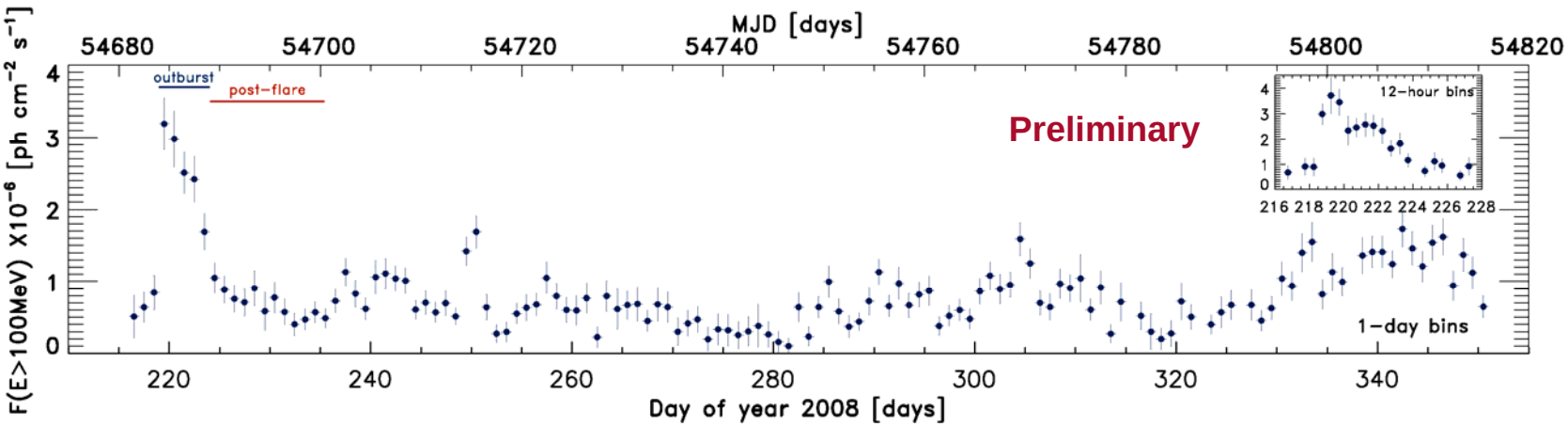


(Contact authors:L. Foschini)

Flaring Blazars: PKS 1502+106
(Abdo et al. 2009, in preparation)

•PKS 1502+106 (z=1.839) was not detected by EGRET

•Extremely rapid flare, possibly the highest $\Delta L/\Delta t$ detected to date at E>100 MeV.



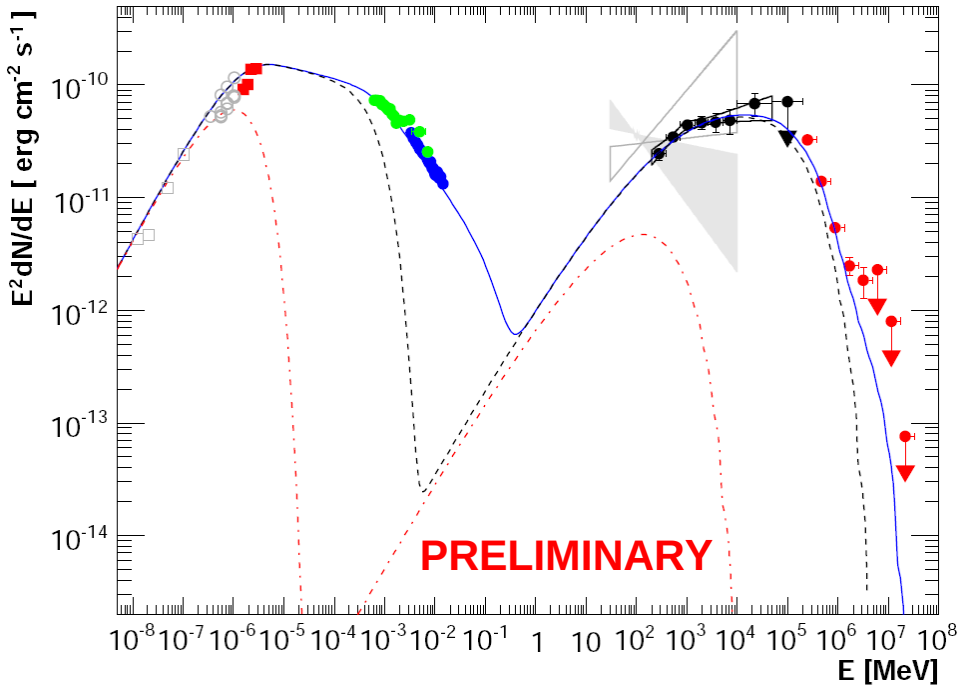
•A MW Campaign started soon after its detection: Swift, INTEGRAL, VLBA(MOJAVE),OVRO, Effelsberg, RATAN and Kanata observatories

(Contact author:S. Ciprini)

Planned MW Campaign: PKS 2155+304
(Abdo et al. 2009, submitted to ApJ)

- **PKS 2155-304: HBL, z=0.116**
  - **11 nightly obs. using HESS, ATOM, RXTE (+ Swift)**
  - **First multiwaveband observations of a blazar SED using Fermi and an ACT**
  - **Study correlated variability between various bands.**

•Single zone SSC model fits the time-averaged SED, but variability patterns present some challenges.



(Contact authors: J. Chiang & B. Giebels)

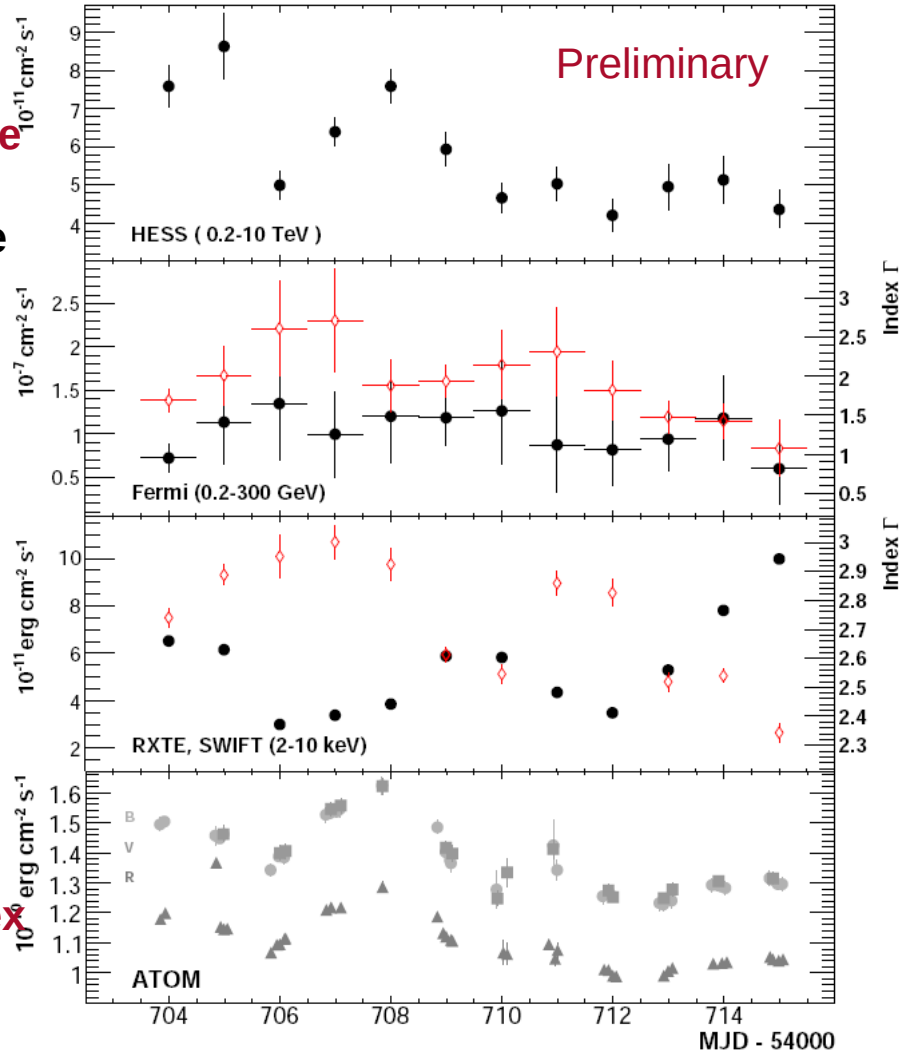
Planned MW Campaign: PKS 2155+304

- **X-rays show large spectral variations, consistent with strong radiative cooling, while > 0.2 TeV emission shows no evidence of spectral variation despite factor ~2 changes in flux ⇒ Electrons producing the X-rays are at higher energies than those producing the 0.2-10 TeV emission.**

- **Optical-TeV correlation and $\Delta\Gamma_{VHE} < 0.2$ strongly suggest optical is driving the TeV variability.**

- **Lack of HE flux variability implies optical photons are produced by a distinct population of electrons (multizone SSC)**

- **X-ray flux correlation with HE spectral index (along with other correlations) defies easy explanation in any model.**



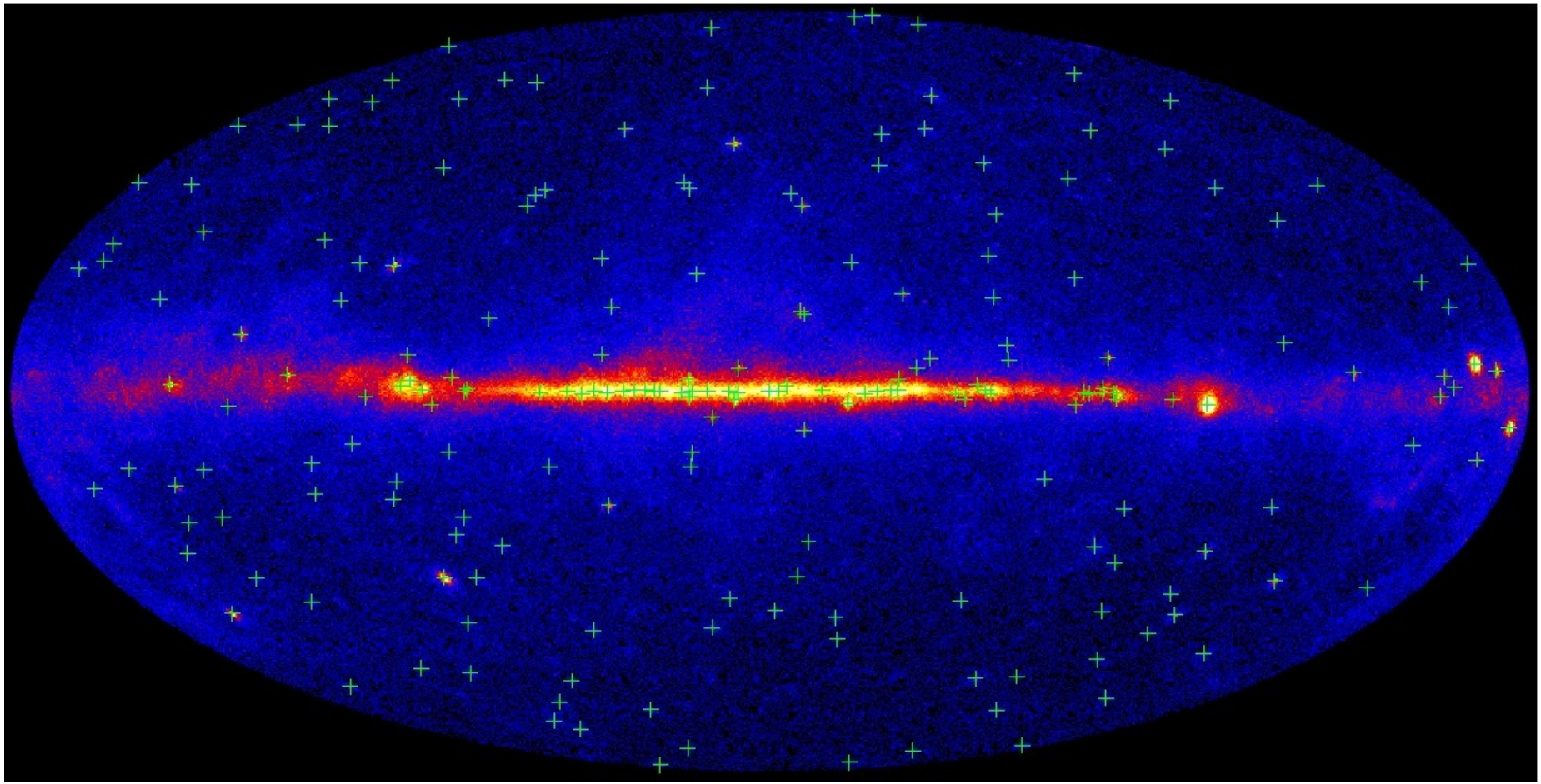
Other Multiwavelength Campaigns

- **3C 454.3: radio, opt, UV, Swift**
- **BL Lac: opt, UV, X-ray**
- **PKS 0528+134: radio, IR, opt, UV, X-ray**
- **3C 273: radio, opt, X-ray**
- **3C279: radio, opt, X-ray**
- **Mrk 421, Mrk 501, 1ES 1959+654: radio, opt, X-ray, TeV (VERITAS, MAGIC)**
- **3C66A, AO0235+16: radio, opt, X-ray**

Fermi-LAT synergies with other All-Sky monitor instruments like MAXI will be of great importance for the MW study of Blazars

3-month Survey: 205 LAT Bright Sources (LBS)

(Abdo et al. 2009, arXiv:0902.1340)



- **205 sources with significance > 10σ (EGRET found fewer than 30).**
- **Typical 95% CL error radius is <10 arcmin. ~1/3 show variability.**

LAT Bright AGN Sample (LBAS)

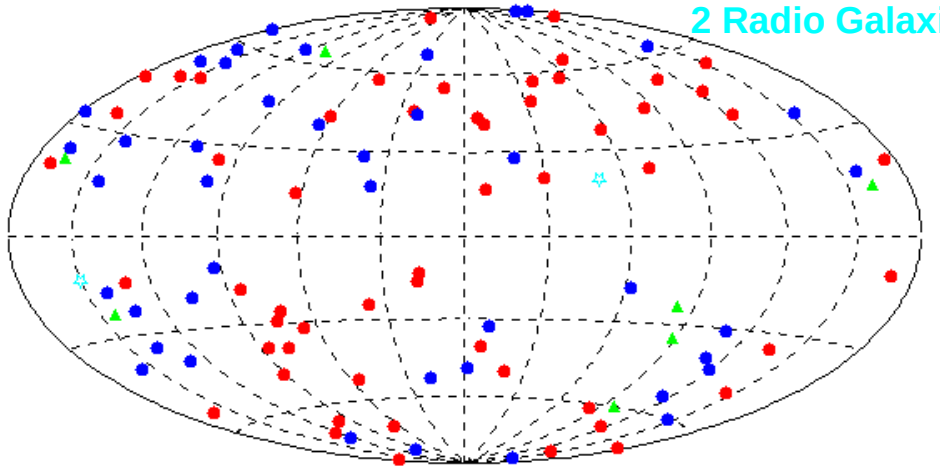
(Abdo et al. 2009, arXiv:0902.1559)

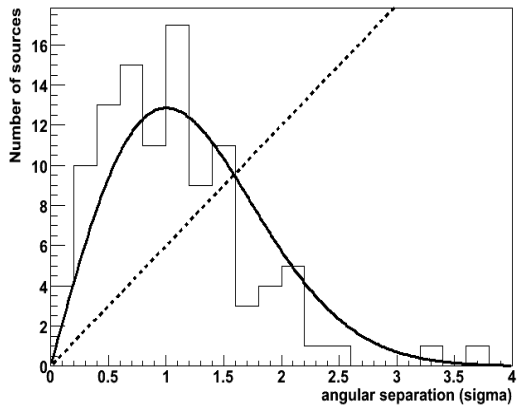
- 125 non-pulsar sources at |b|>10°
- 106 high-confidence (P>90%) associations with AGNs: (LBAS)
- 10 lower-confidence associations
- FSRQs: 57
- BLLacs: 42
- Uncertain class: 5
- Radiogalaxies: Cen A, NGC1275
- 40% BLLacs (23% for EGRET)
- 7 HBLs (3+1 for EGRET)
- 9 unidentified (3EG: 96/181 at |b|>10°)

(Contact authors: LAT AGN Science Group)

Preliminary

57 FSRQ
42 BLLac
5 of Uncertain class
2 Radio Galaxies





$\Theta_{95\%}$ ~0.14° (EGRET sample ~0.62°)

Radio-Galaxies: NGC 1275
(Abdo et al. 2009, sub. to ApJ)

- **NGC 1275, a.k.a. 3C84 or Perseus A, is a nearby radio galaxy containing a flat-spectrum, compact (VLBI-scale) blazar-like, variable radio source**

- **It has been detected in the Fermi LAT data, at a much higher level than the upper limit from EGRET. ⇒ variable, i.e., not cluster emission.**

QuickTime™ e un
decompressore TIFF (Non compresso)
sono necessari per visualizzare quest'immagine.

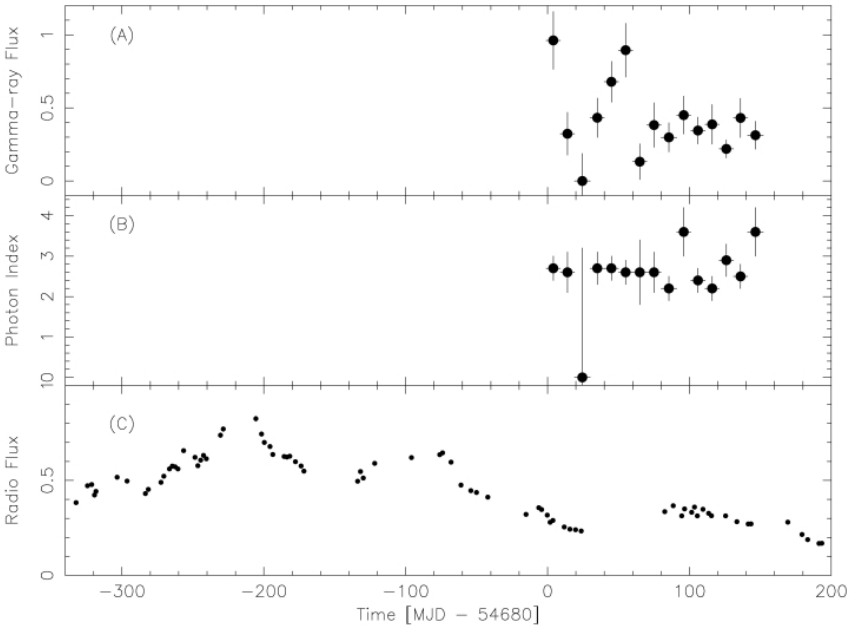
(Contact Author: J. Kataoka)

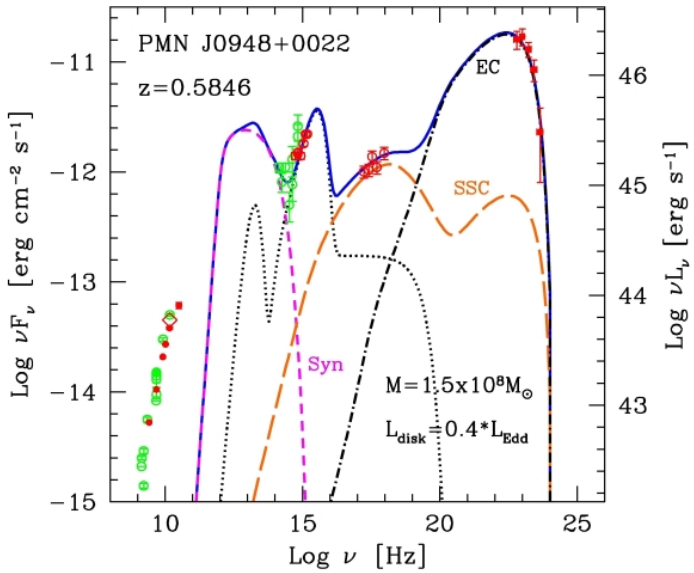
Narrow-Line Quasar PMN J0948+0022

(Abdo et al., 2009, Submitted to ApJ)

Optical spectrum of narrow-line Seyfert 1 type (usually radio quiet). It shows only narrow permitted lines:
FWHM(Hβ) ~ 1500 km/s,
while all FSRQ have FWHM(Hβ) > 2000 km/s.

Radio emission is strongly variable
and with flat spectrum -> suggests Doppler boosting, now confirmed by LAT.





First γ-ray detection of such an object

SED modeling shows this is a typical FSRQ, although with a relatively low power.

Many questions open:

- Is this a new type of γ-ray emitting AGN?
- Are there other sources of this type?
- What is the impact of narrow-lines?

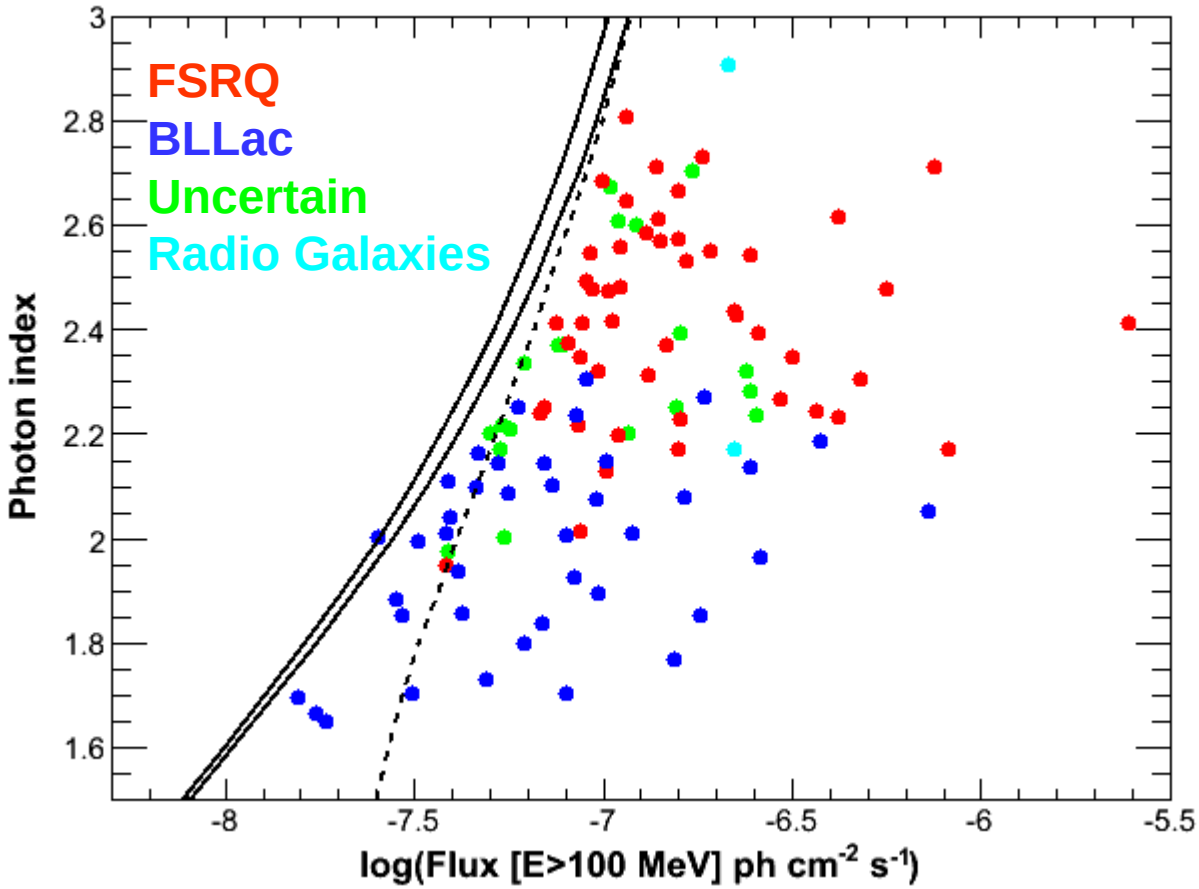
(Contact authors:L. Foschini)

Key properties of the LBAS: Flux vs index

Preliminary

TS=100
b=20, 80 deg.

TS=100
b= 20 deg.
E< 3 GeV



Dim hard-spectrum sources are favored to be detected with the Fermi-LAT compared to EGRET

Key properties of the LBAS: Flux distributions

Preliminary

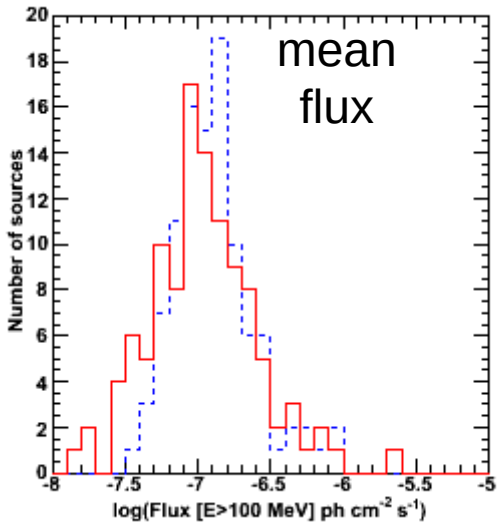
Fermi
EGRET

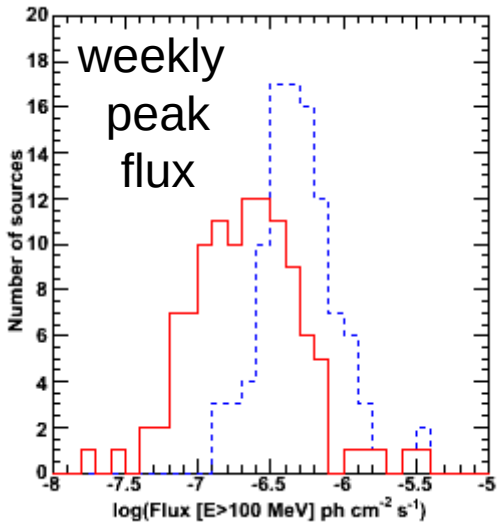
EGRET mean flux
« 1234 VP»

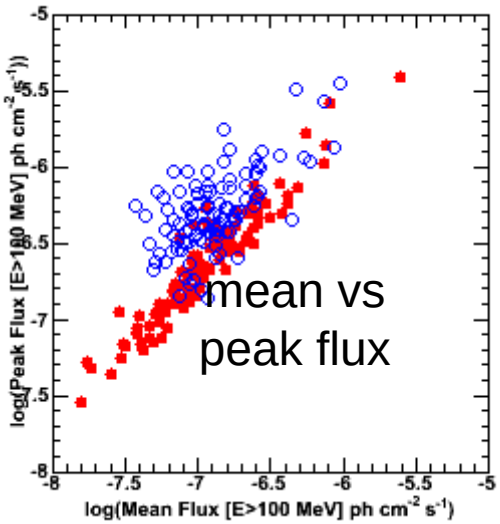
EGRET peak flux:
maximum in 2-w VPs

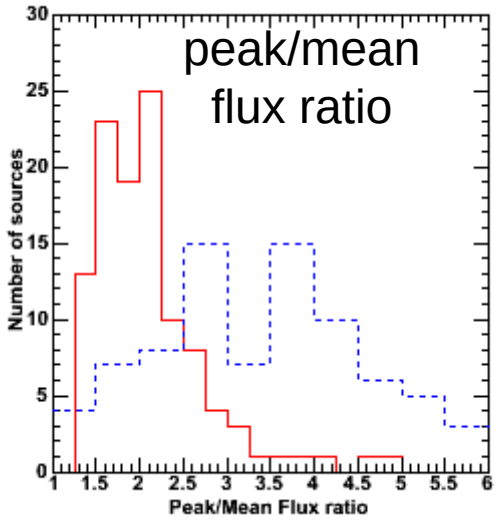
Fermi mean flux:
3-m averaged

Fermi peak flux:
maximum in 1-w periods





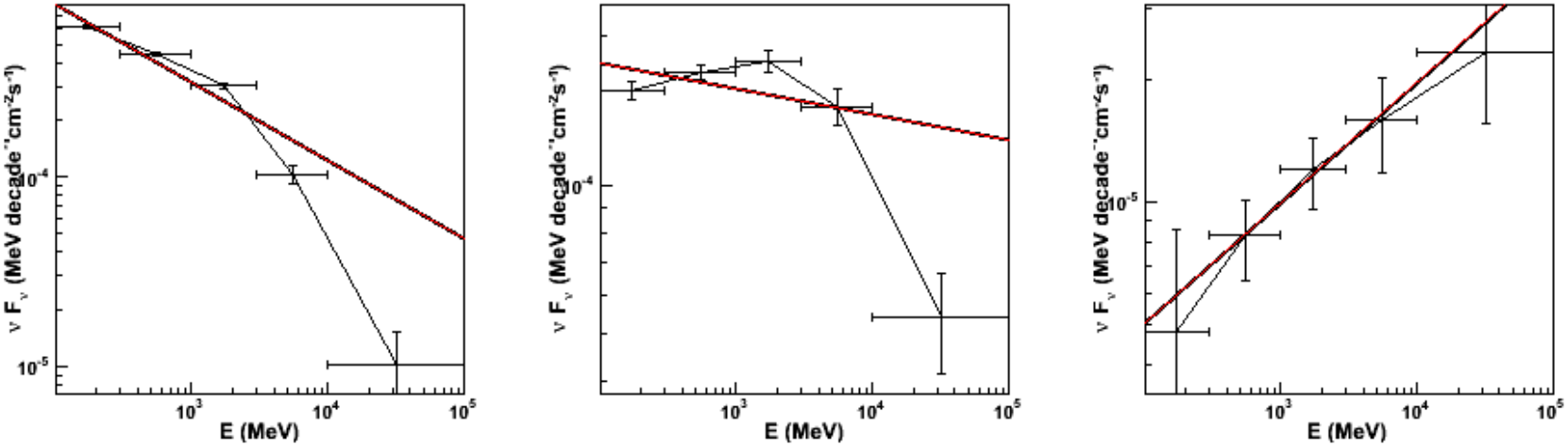




Key properties of the LBAS: Gamma-ray Spectra

Preliminary

3C454.3 (FSRQ) **AO 0235+165 (IBL)** **Mkn501 (HBL)**

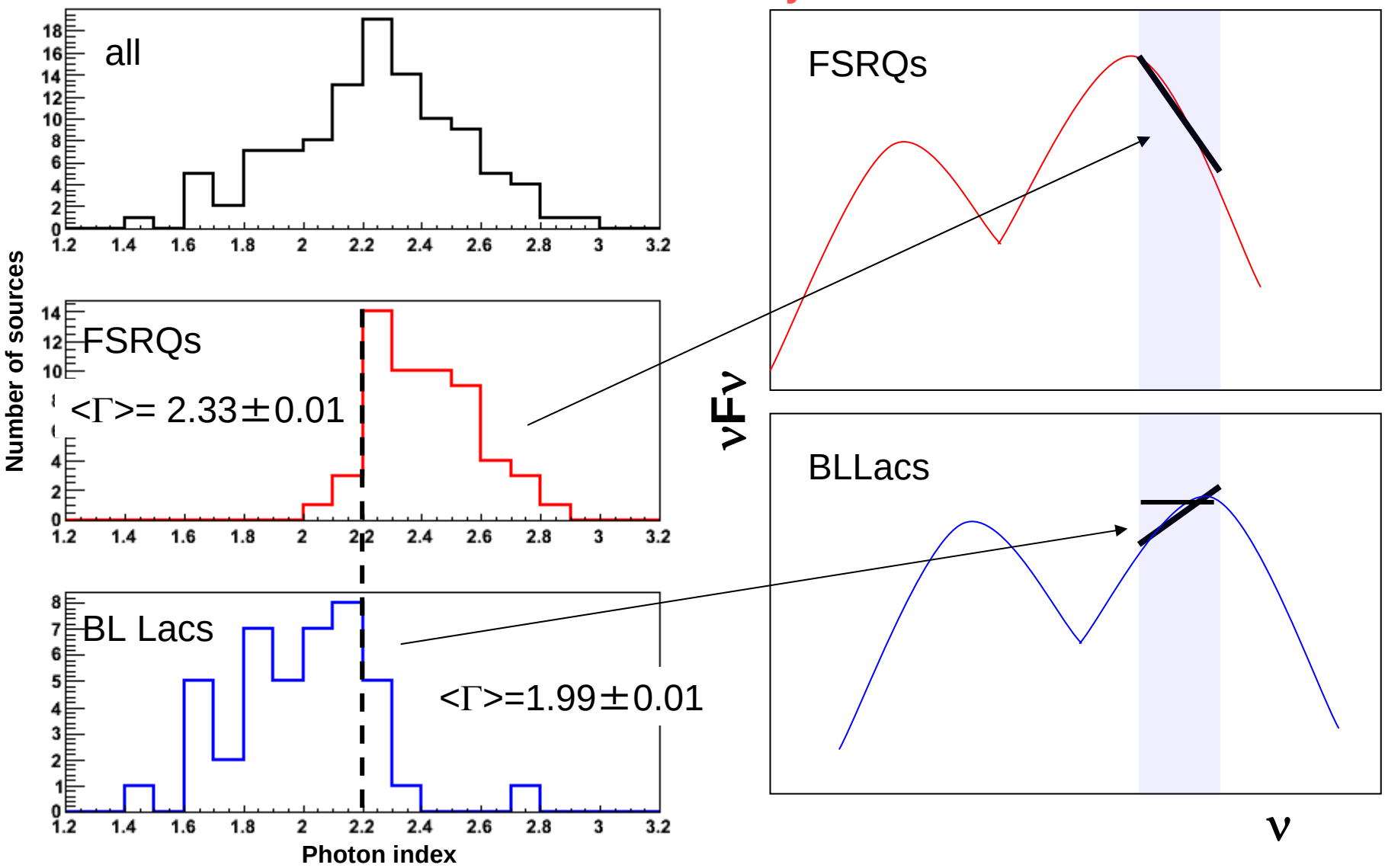


Significant departures from pure power-law distributions for bright blazars!

If the spectral softening observed around fews GeV in flaring FSRQs will be confirmed also for weaker sources, the fraction of BL Lac objects detected by Fermi-LAT will be even greater than now over longer times.

Key properties of the LBAS: Photon index

Preliminary



Key properties of the LBAS: LBAS Sources in 3EG

33 AGNs/116 LAT-sources (30%) in 3EG catalog with a comparable

Others are found at lower fluxes

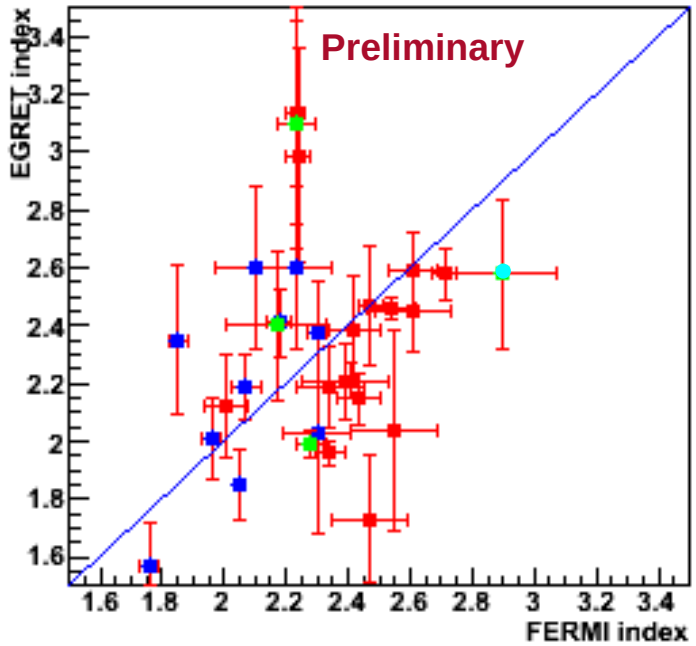
FSRQs: 20

BLLacs: 11

Uncertain: 3

Radio galaxy:1

EGRET vs FERMI photon index



FSRQ

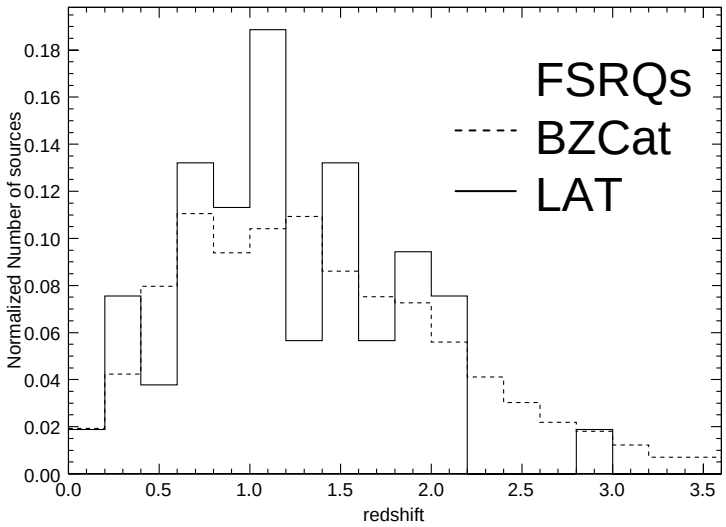
BLLac

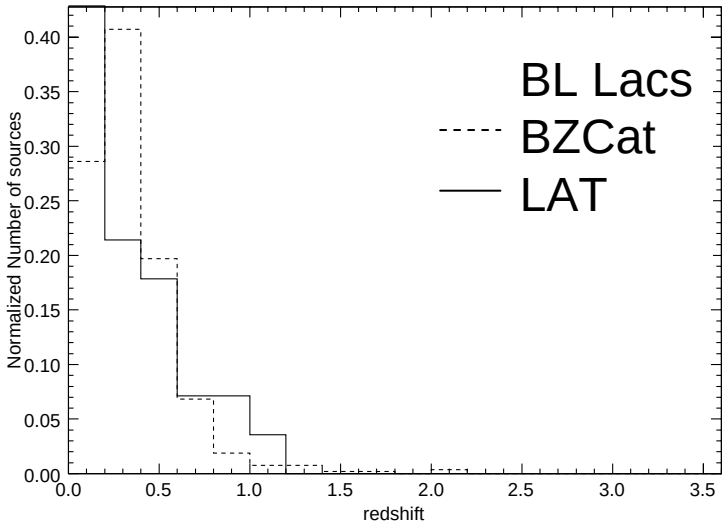
Uncertain

Radio galaxies

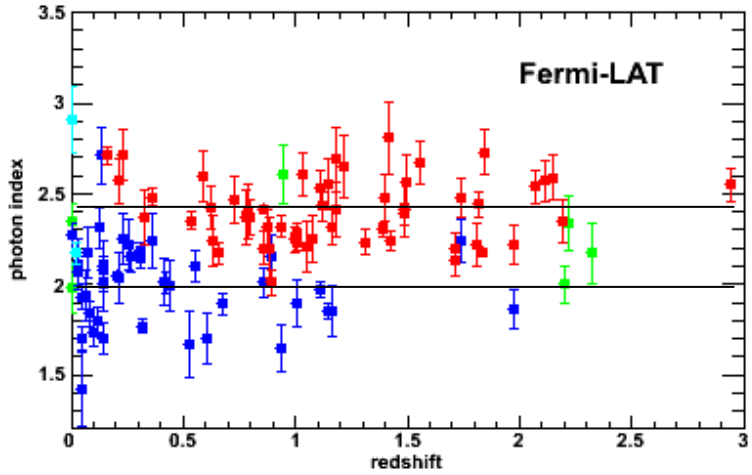
Key properties of the LBAS: Redishift distributions

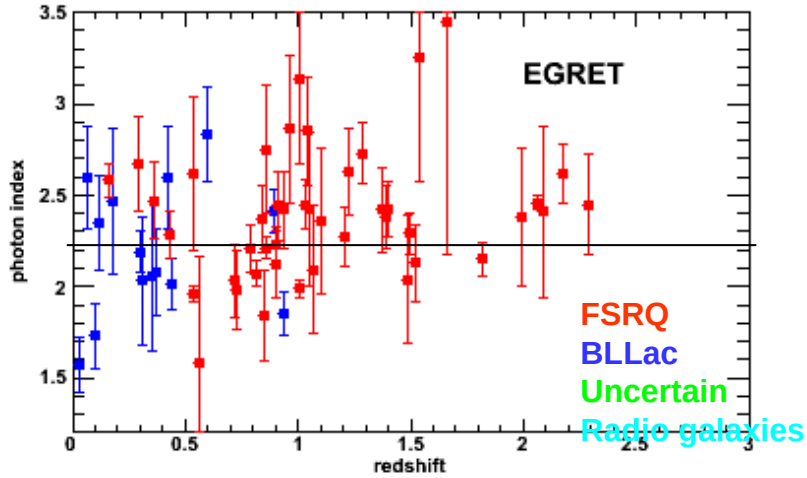
Preliminary



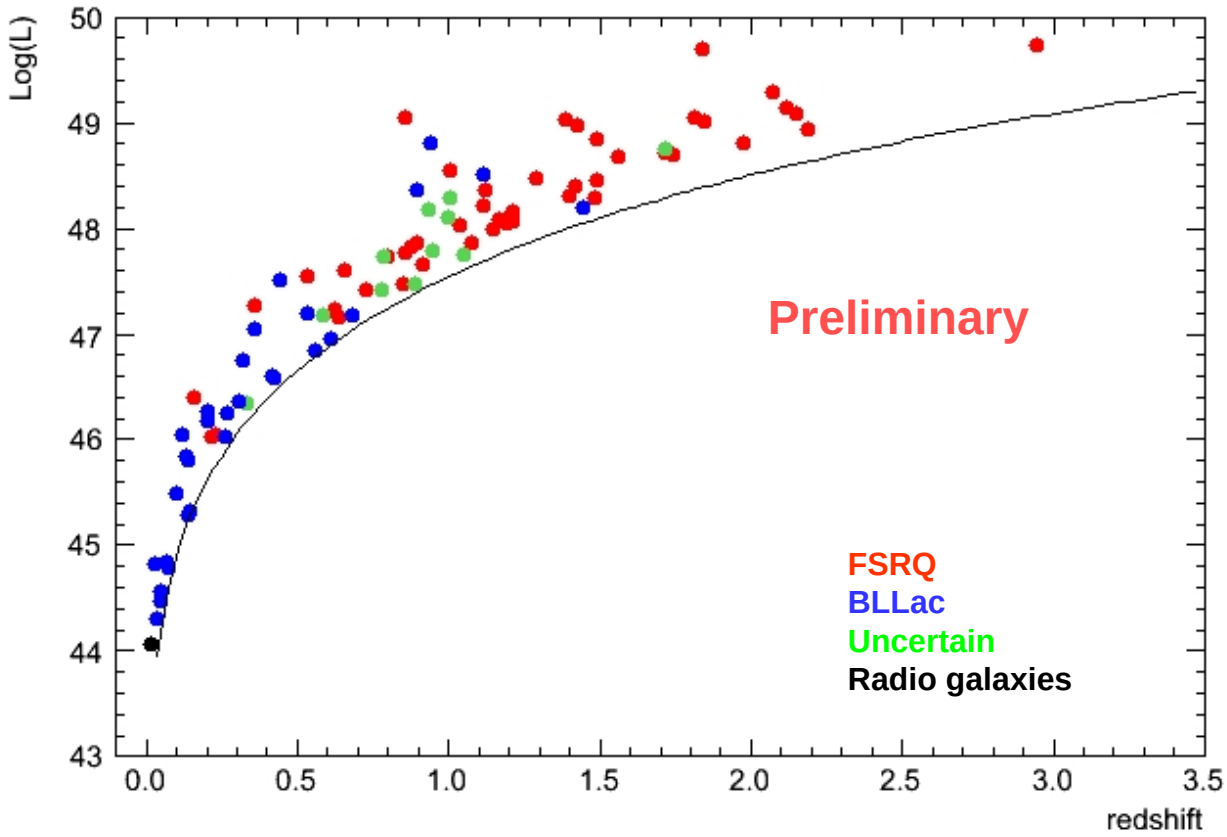


Preliminary





Key properties of the LBAS: Luminosity vs redshift



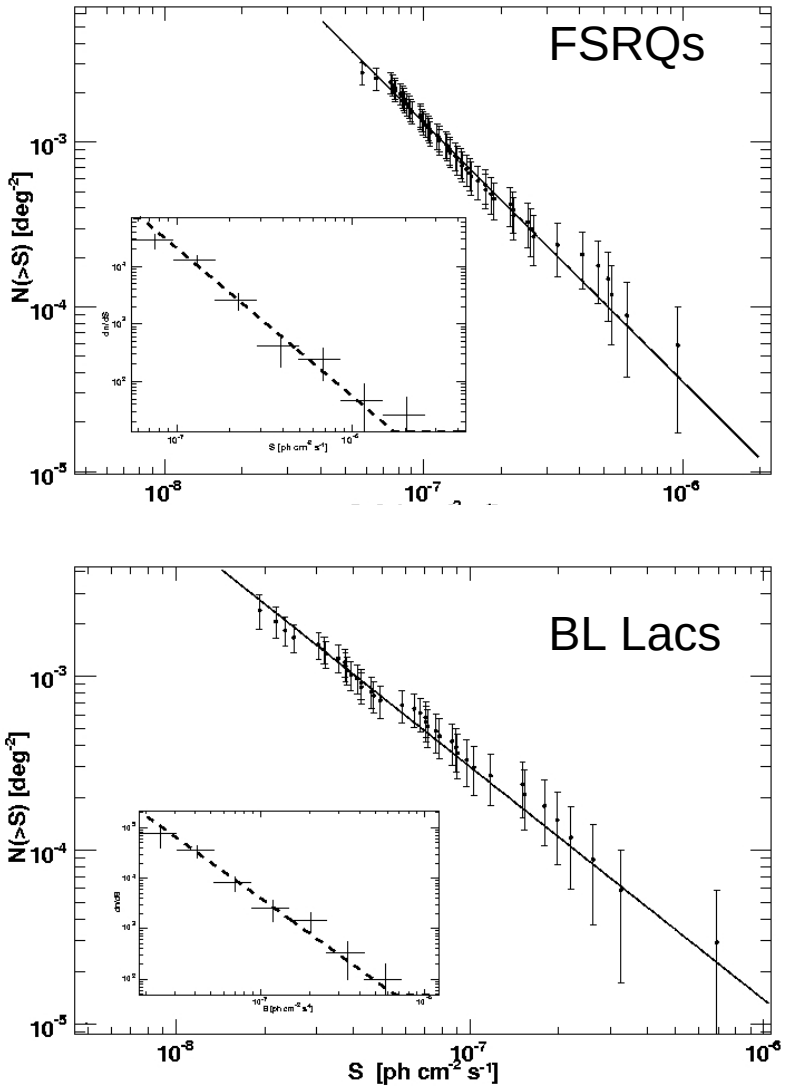
This distribution is similar to the EGRET one, but we are now see more low-redshift BL Lac objects.

Key properties of the LBAS: Log N - Log S

Preliminary

- « sky coverage » enables the log N-LogS to be computed
- Euclidian space: slope=2.5

Blazar class	slope
All	2.50±0.12
FSRQs	2.55 ±0.12
BLLacs	2.32 ±0.15



Key properties of the LBAS: Evolution of Blazars

$\langle V/V_{max} \rangle$: ratio between the comoving volume within which the source was detected and the maximum volume available for its detection

Population uniformly distributed in Euclidian space, non evolving: $\langle V/V_{max} \rangle \sim 0.5$

Preliminary

Sample	#objects	$\langle V/V_{max} \rangle$
FSRQs	57	0.645 ± 0.043
BLLacs	42	0.473 ± 0.046
All with z>0	92	0.512 ± 0.031

Positive evolution for FSRQs (more FSRQs in the past)
Compatible with no evolution for BLLacs

Conclusions

- **These early results from the first months of the science mission of the Fermi- LAT demonstrate its exceptional capabilities to provide important new knowledge about gamma-ray emission from active galactic nuclei and blazars.**

- **Current set of results are just the tip of the iceberg. As the Fermi-LAT data accumulate:**
  - **many more AGNs at lower flux levels will be detected**
  - **many more flaring AGNs will be detected**

All this will help to improve our understanding of supermassive black holes.

Thank you for your attention