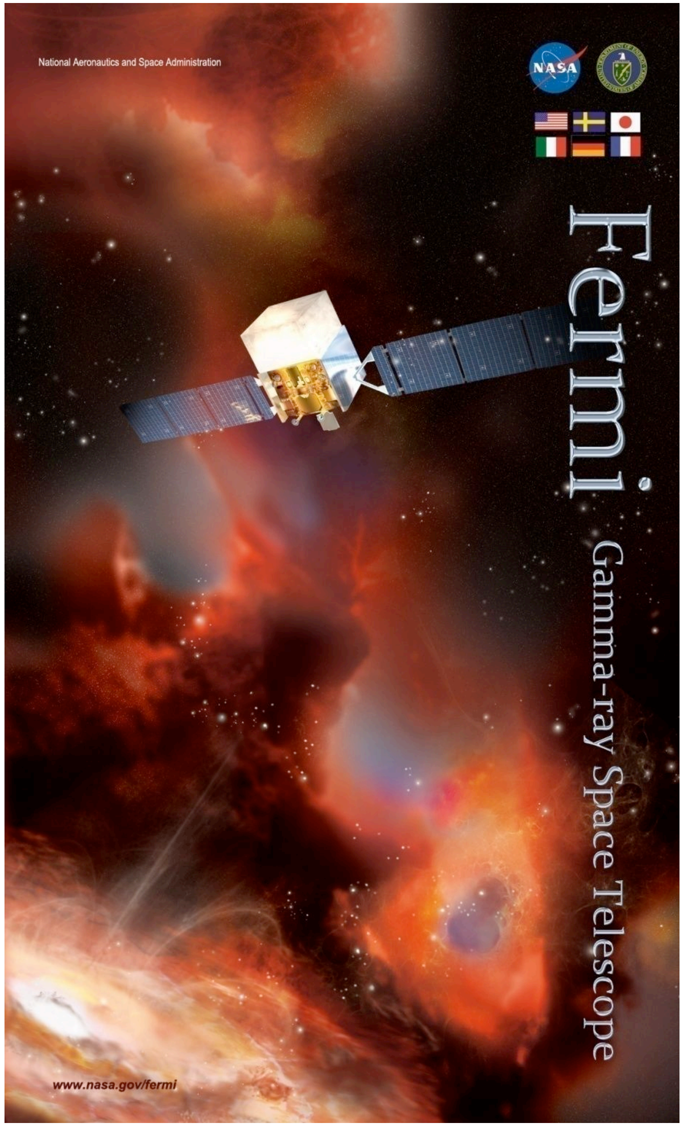


Fermi Hightlights on Active Galactic Nuclei

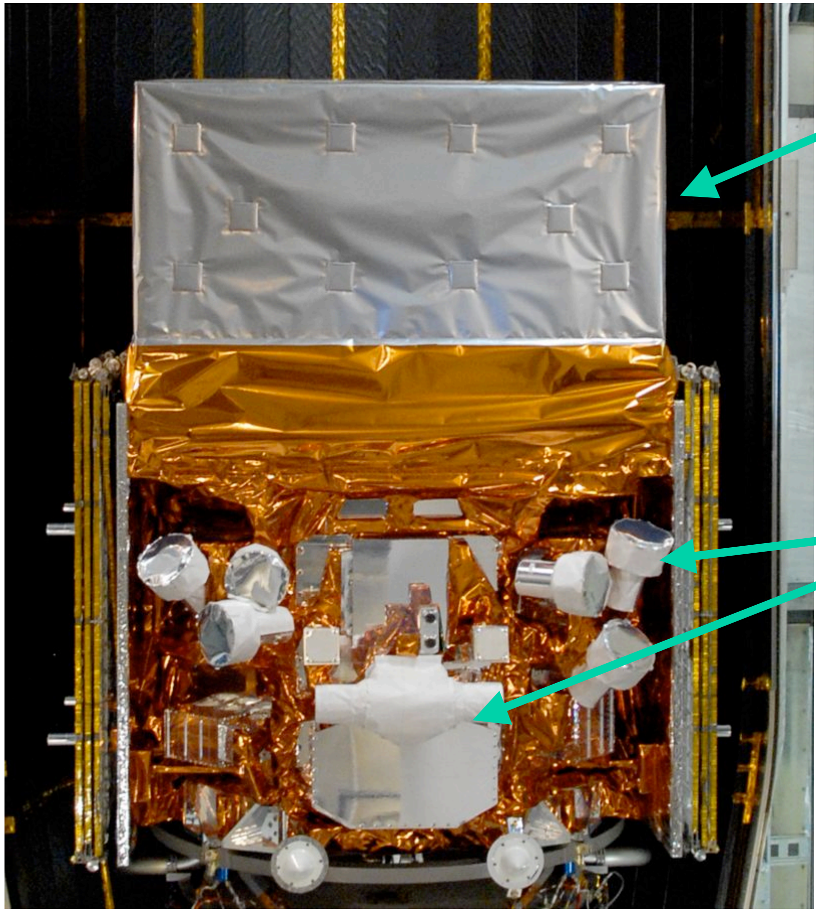
Gino Tosti

University & INFN Perugia

On behalf of the *Fermi*-LAT Collaboration

tosti@pg.infn.it

What is Fermi?



Large Area Telescope (LAT):

- 20 MeV - >300 GeV (including unexplored region 10-100 GeV)
- 2.4 sr FoV (scans entire sky every ~3hrs)

Gamma-ray Burst Monitor (GBM)

- 8 keV - 40 MeV
- views entire unocculted sky

Launch date: June 11th 2008

Fermi LAT Overview: Overall Design

Overall LAT Design:

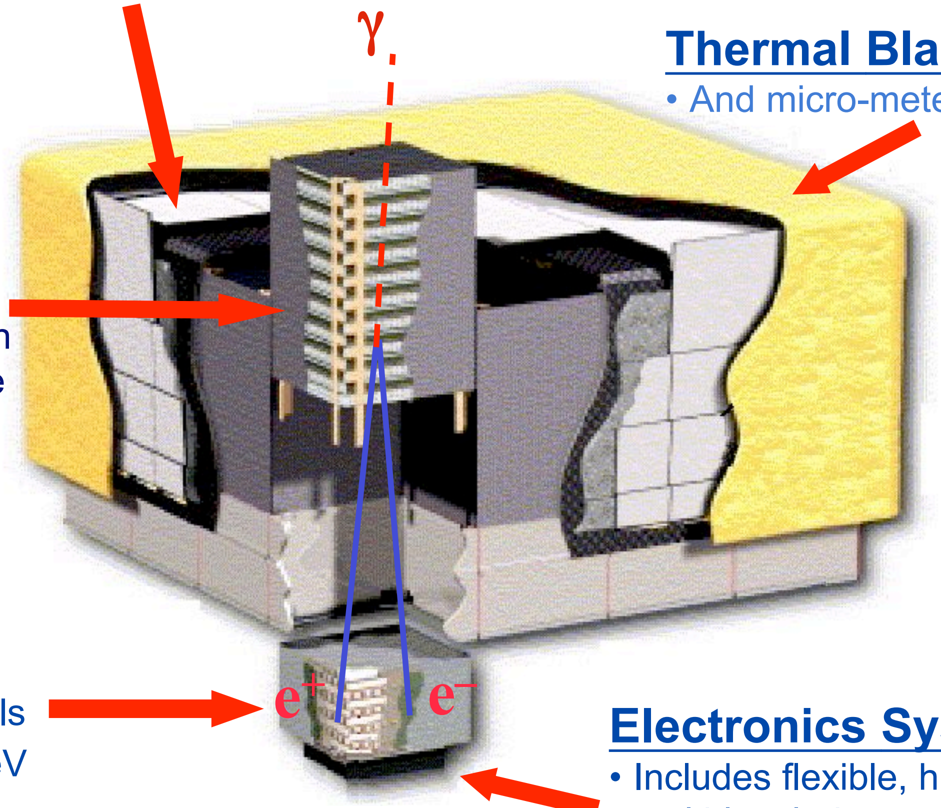
•4x4 array of identical towers
•3000 kg, 650 W (allocation)
•1.8 m × 1.8 m × 1.0 m
•**20 MeV – >300 GeV**

Anticoincidence Detector:

• 89 scintillator tiles
• **First step in reduction of large charged cosmic ray background**
• **Segmentation reduces self veto at high energy**

Thermal Blanket:

• And micro-meteorite shield



Precision Si-strip Tracker:

Measures incident gamma direction
18 XY tracking planes. 228 mm pitch.
High efficiency. Good position resolution
12 x 0.03 X0 front end => reduce multiple scattering.
4 x 0.18 X0 back-end => increase sensitivity >1GeV

Hodoscopic CsI Calorimeter:

• Segmented array of 1536 CsI(Tl) crystals
• 8.5 X0: shower max contained <100 GeV
• **Measures the incident gamma energy**
• **Rejects cosmic ray backgrounds**

Electronics System:

• Includes flexible, highly-efficient, multi-level trigger

The Fermi LAT collaboration

- France
  - IN2P3, CEA/Saclay
- Italy
  - INFN, ASI, INAF
- Japan
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- Sweden
  - Royal Institute of Technology (KTH)
  - Stockholm University
- United States
  - Stanford University (SLAC, KIPAC, and HEPL/Physics)
  - University of California at Santa Cruz - Santa Cruz Institute for Particle Physics
  - Goddard Space Flight Center
  - Naval Research Laboratory
  - Sonoma State University
  - Ohio State University
  - University of Washington

Sponsoring Agencies

Department of Energy
National Aeronautics and Space Administration

CEA/Saclay	ASI
IN2P3/CNRS	INFN
MEXT	K. A. Wallenberg Foundation
KEK	Swedish Research Council
JAXA	Swedish National Space Board

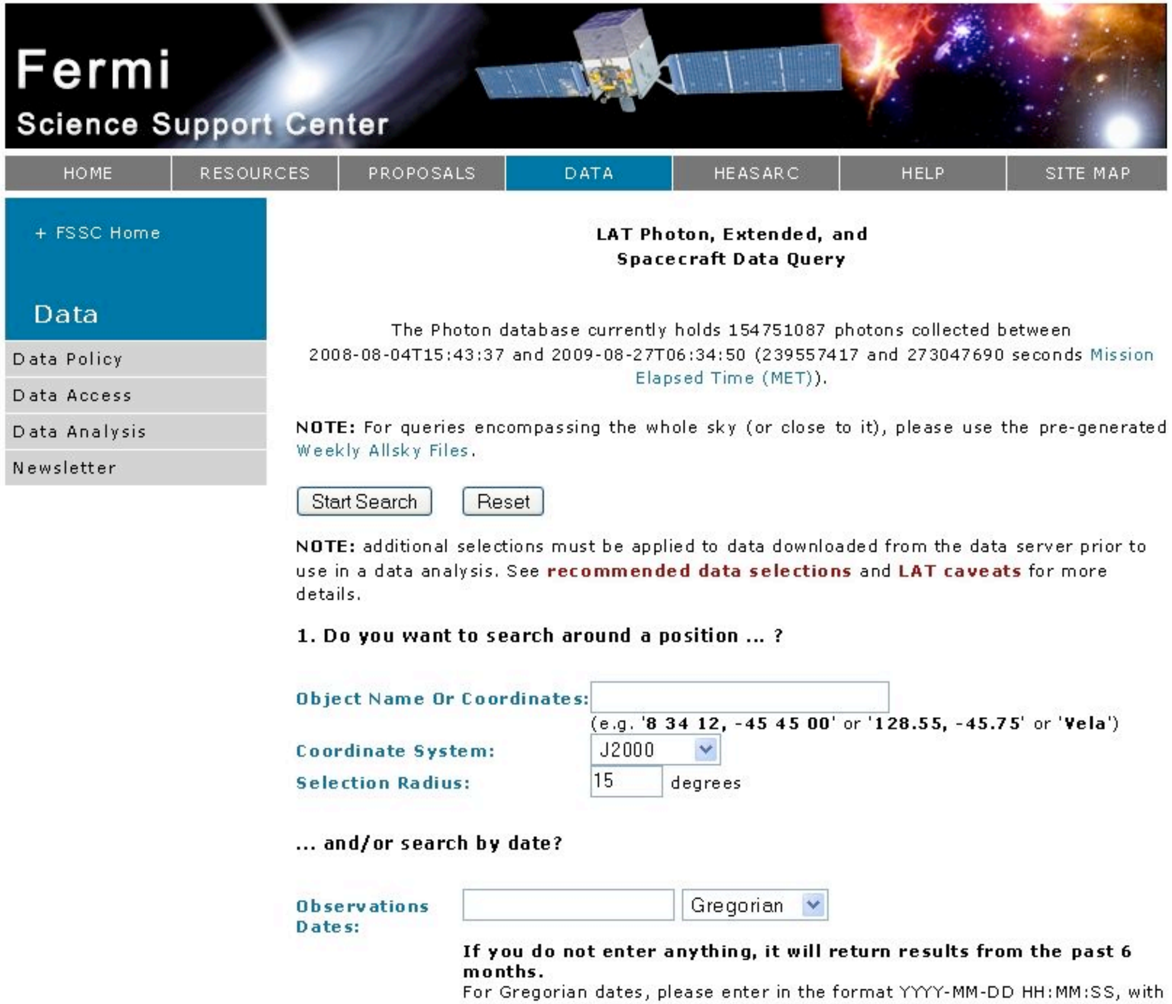
~390 Members
(~95 Affiliated Scientists, 68 Postdocs, and 105 Graduate Students)

construction managed by
SLAC National Accelerator Laboratory, Stanford University

also members from Australia, Germany, Great Britain, Spain

FSSC Data Server

LAT Level 1 data made available on Aug 25 2009.



LAT Photon, Extended, and Spacecraft Data Query

The Photon database currently holds 154751087 photons collected between 2008-08-04T15:43:37 and 2009-08-27T06:34:50 (239557417 and 273047690 seconds Mission Elapsed Time (MET)).

NOTE: For queries encompassing the whole sky (or close to it), please use the pre-generated Weekly Allsky Files.

Start Search | Reset

NOTE: additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See **recommended data selections** and **LAT caveats** for more details.

1. Do you want to search around a position ... ?

Object Name Or Coordinates:
(e.g. '**8 34 12, -45 45 00**' or '**128.55, -45.75**' or '**Vela**')

Coordinate System: J2000

Selection Radius: 15 degrees

... and/or search by date?

Observations Dates: Gregorian

If you do not enter anything, it will return results from the past 6 months.
For Gregorian dates, please enter in the format YYYY-MM-DD HH:MM:SS, with

1st Year Science Highlights

-pulsars

-globular clusters

-binaries

-active galaxies

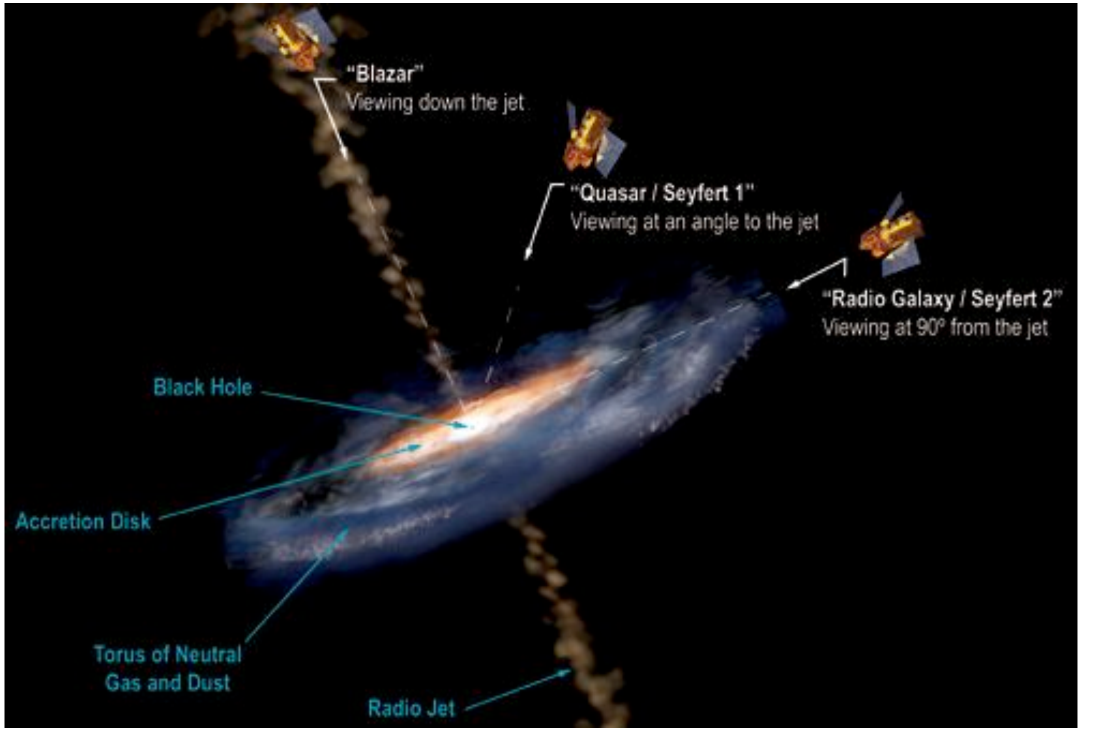
-gamma-ray bursts

-diffuse radiation

- e^+e^- spectrum

(14-08-2009)

Active Galactic Nuclei (AGN)



EGRET showed that AGN dominate the extragalactic MeV- GeV sky

- **~70 Blazars (3rd Catalog, Hartman et al 1999; >100 Sowards-Emmerd et al. 2003,2004); marginally detection of a couple of radio-galaxies**

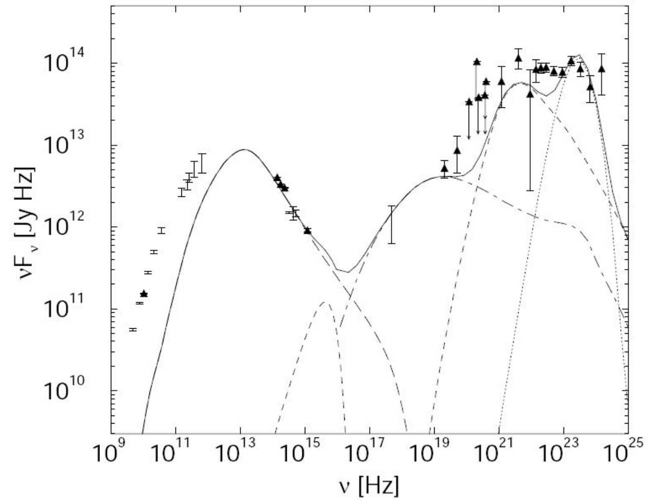
- **25 Blazars detected by ground based TeV telescopes**

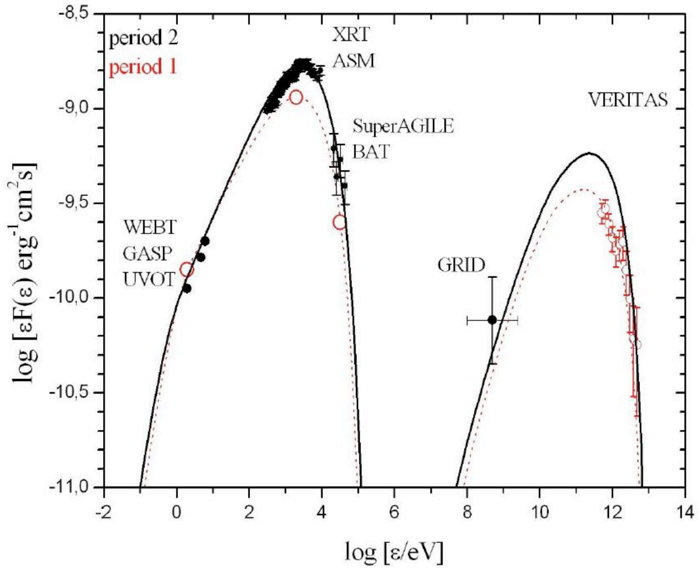
Blazar Spectral Energy Distributions

- Two main components:
  - Synchrotron at low energies
  - Inverse Compton and/or "hadronic" at higher energies

- Flat Spectrum Radio Quasars (FSRQs)
  - Multi-temperature disk emission and broad lines in OUV
  - Non-thermal components peak in IR & hard X-ray/MeV regime
  - Higher luminosity (L_{iso} ~10^{48} erg s^{-1}) and $z \geq 1$

- BL Lac objects
  - Little or no evidence of disk or emission lines in Opt-UV
  - Non-thermal peaks in UV/soft X-rays & GeV
  - Lower luminosity (L_{iso}~10^{45} erg s^{-1}) and $z < 0.5$



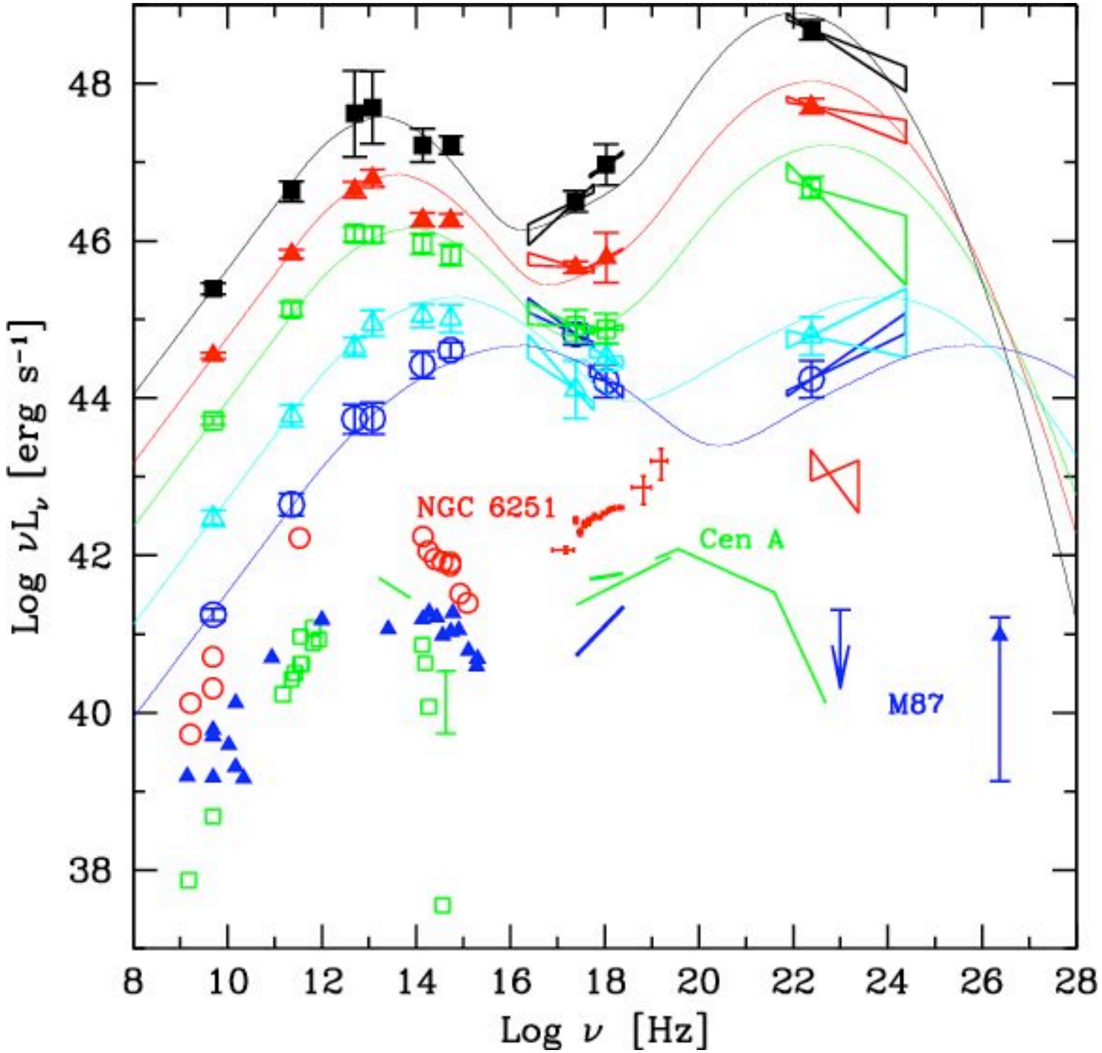


The Blazar Sequence

FSRQ

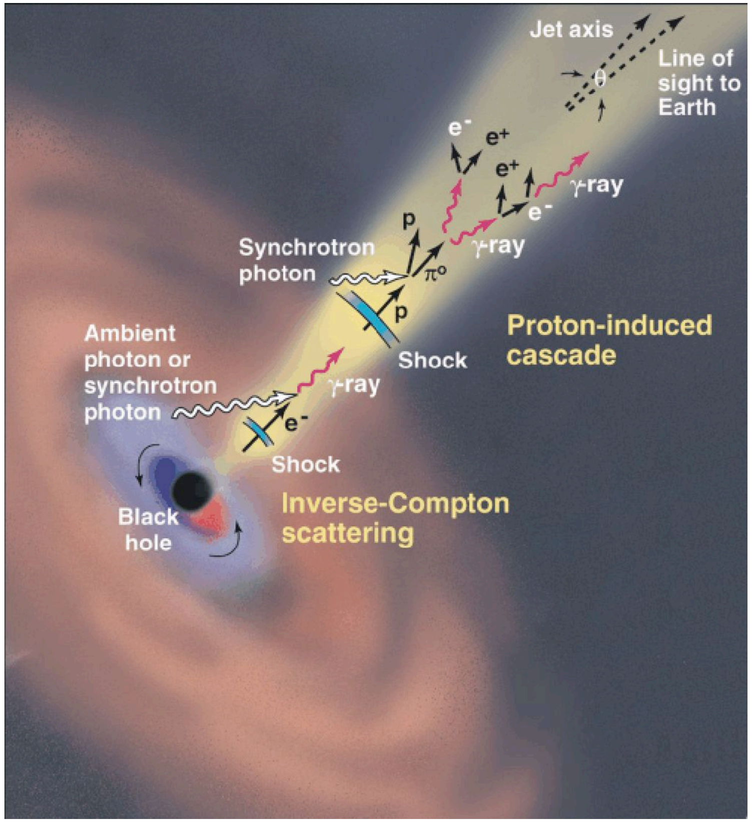
BL LAC

RG



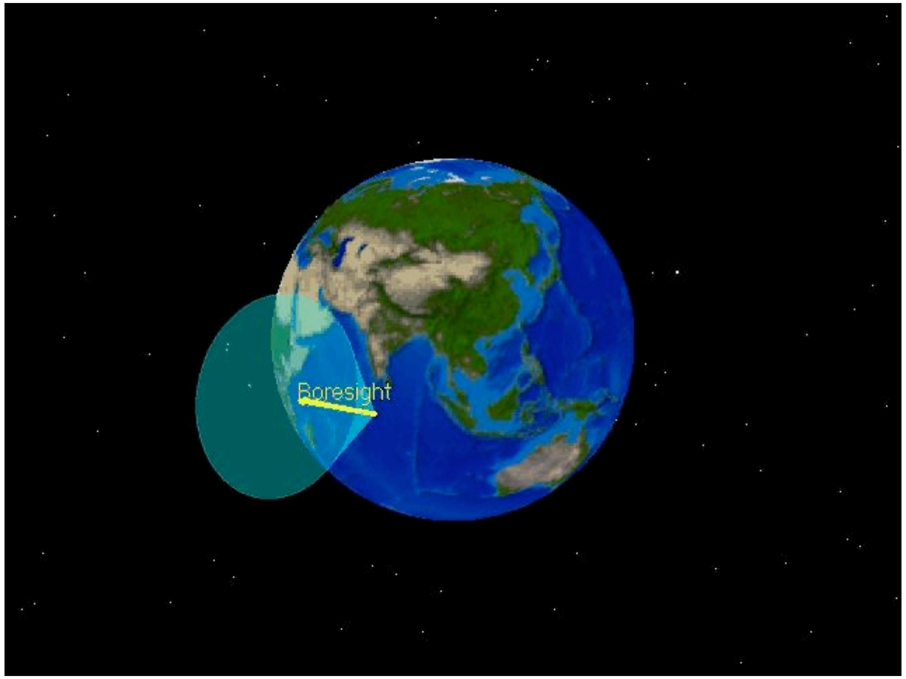
Key Questions for Blazars

- Emission mechanisms (especially for high energy component)
  - Leptonic (IC of synchrotron or external photons) vs hadronic ($\pi_0 \rightarrow \gamma\gamma$, proton synchrotron)
- Emission location
  - Single zone for all wavebands (completely constraining for simplest leptonic models)
  - Opacity effects and energy-dependent photospheres
- Particle acceleration mechanisms
  - Shocks, Blandford-Znajek
- Jet composition
  - Poynting flux, leptonic, ions
- Jet confinement
  - External pressure, magnetic stresses
- Accretion disk—black hole—jet connection
- Blazars as probes of the extragalactic background light (EBL)
- Effect of blazar emission on host galaxies and galaxy clusters



Gamma-ray Space Telescope

Monitoring the Sky

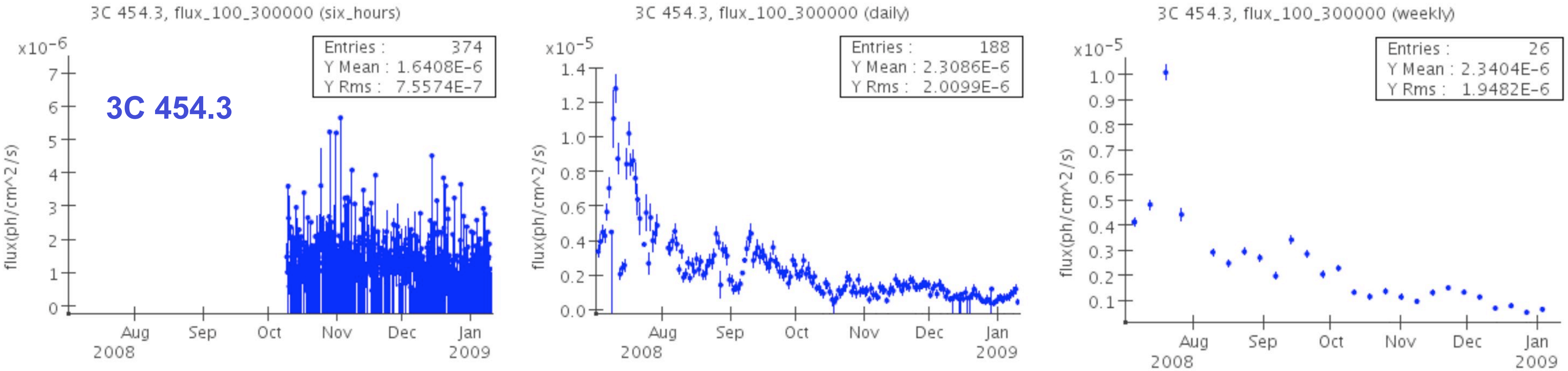


- In survey mode, the LAT observes the entire sky every two orbits (~3 hours), each point on the sky receives ~30 mins exposure during this time.
- Large effective area means that more gamma-rays are detected by LAT for a given source brightness.
- Long evenly sampled observations of all sources in the sky.
- Multiwavelength observations with the LAT source will be limited only by the ability to coordinate to observations in other wavebands.

Fermi Gamma-ray Space Telescope

Source Monitoring Activities

- **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**
  - **1×10^{-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 (43 Atels during the first year)**



http://fermisky.blogspot.com/

FERMI GAMMA-RAY SKY

WEDNESDAY, JUNE 3, 2009

Fermi LAT Weekly Report N. 52

Covered period: 2009.May.25 - 2009.May.31

- Candidate blazar **4C31.03** (see ATel #2054) seen in day timescales with flux levels reaching 0.8e-6 ph/cm^2/s.
- **PKS 1510-089** remains in the 1e-6 to 2e-6 daily flux range (>100MeV)
- **PKS 1502+106** shows a steady trend with daily fluxes (>100MeV) around 1e-6 ph/cm^2/s.
- **3C 454.3** showed consistent daily flux levels (>100MeV) just below 1e-6 ph/cm^2/s.

LAT DATA

LAT Monitored Source List Light Curves

LAT Bright Source List

Browse interface to monitored source data

BLOG ARCHIVE

▼ 2009 (8)

▼ June (1)

Fermi LAT Weekly Report N. 52

► May (4)

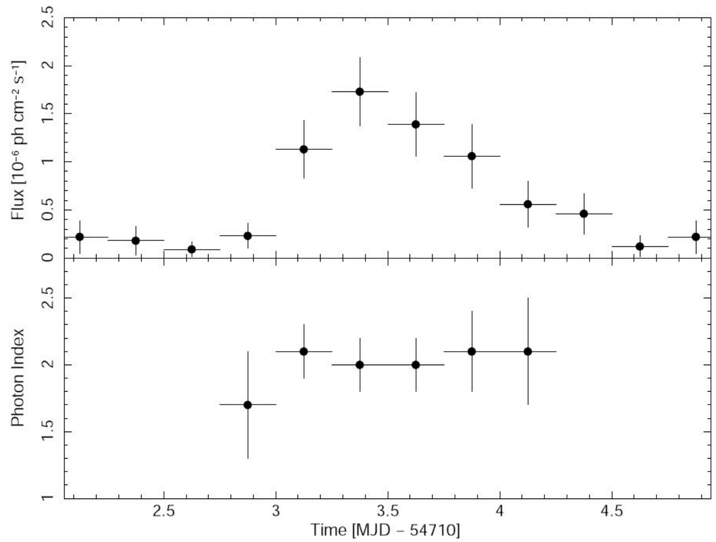
► April (3)

CONTRIBUTORS

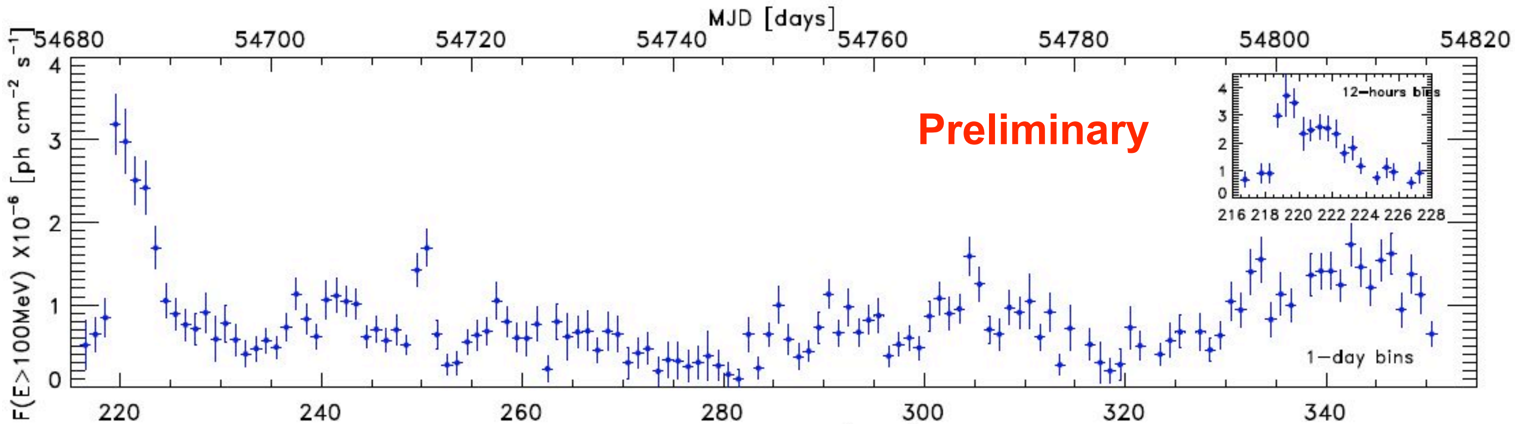
Flare Advocate

Flaring Blazars: Rapid flares

- **PKS 1454–354: factor ~5 increase of >100 MeV flux in 12 hours; achromatic flux variations**
- *(contact author L. Foschini)*

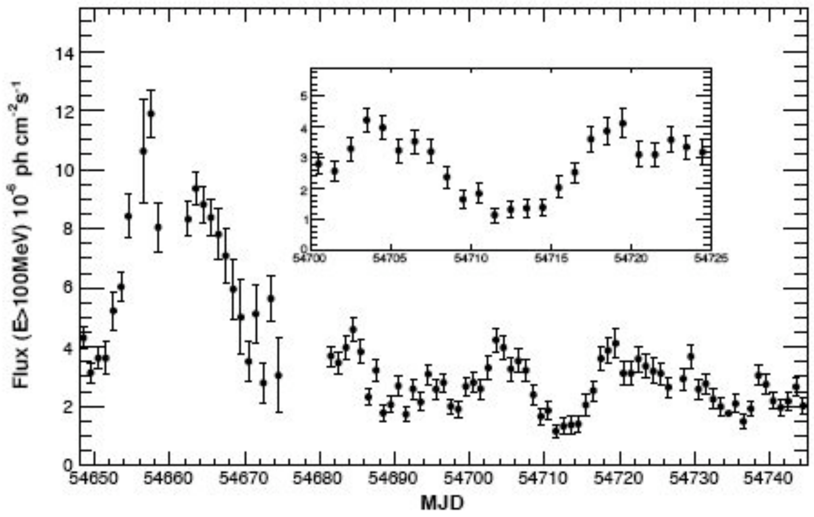


- **PKS 1502+106: z=1.84, factor 3 increase in <12 hrs, highest ΔL/Δt in GeV band** *(contact author S. Ciprini)*



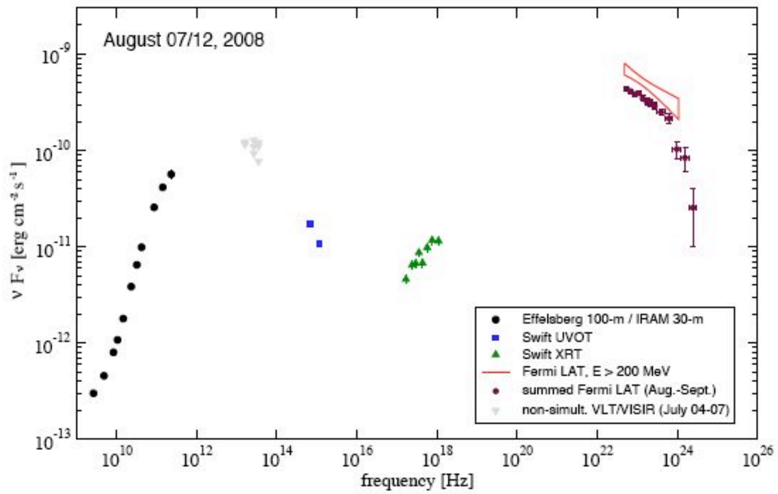
Flaring Blazars: 3C454.3
(Abdo et al. 2009)

• **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

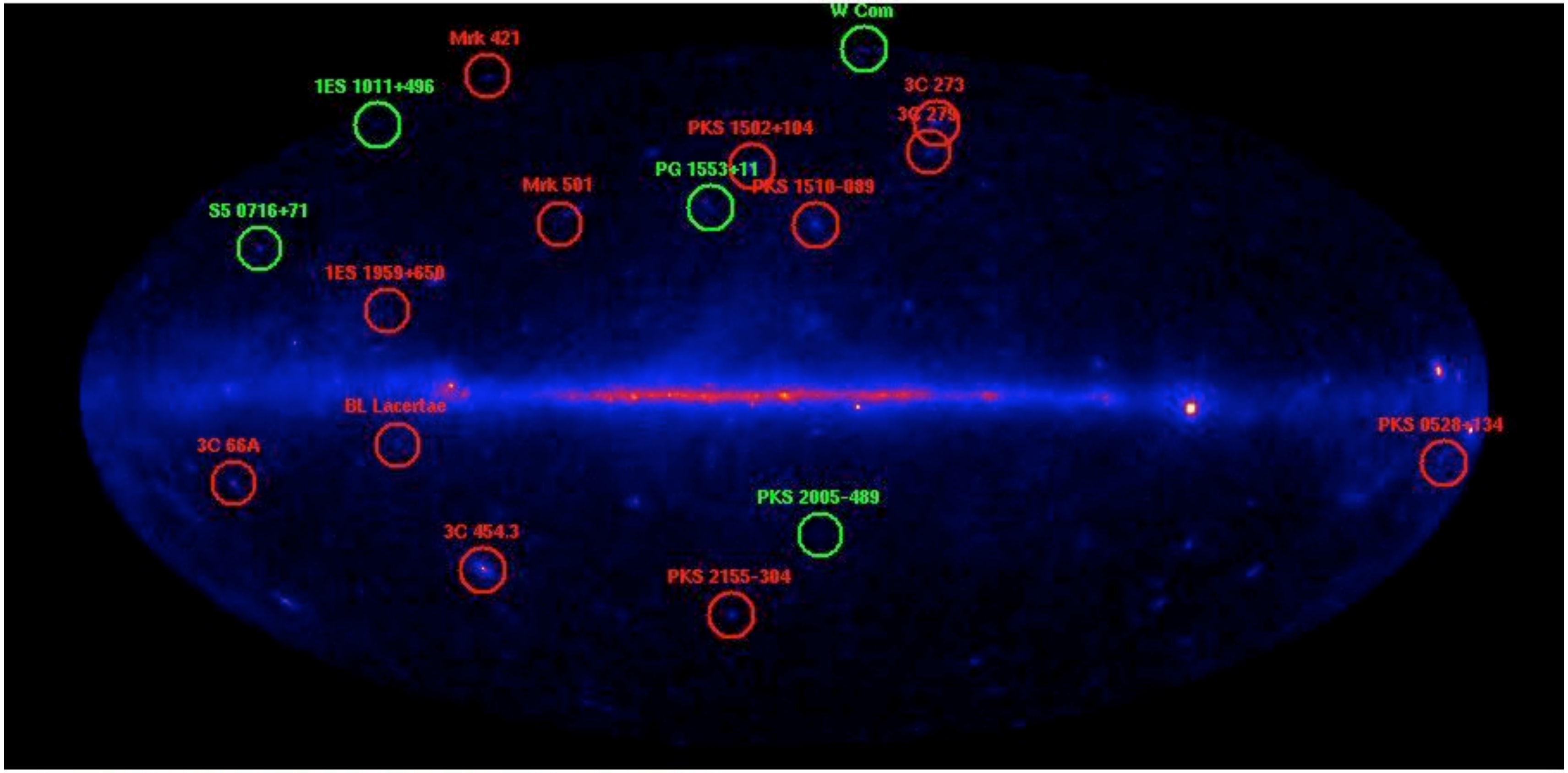
•First observation of a spectral break in the spectrum of a high luminosity blazar above 100MeV.



A possible interpretation 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)

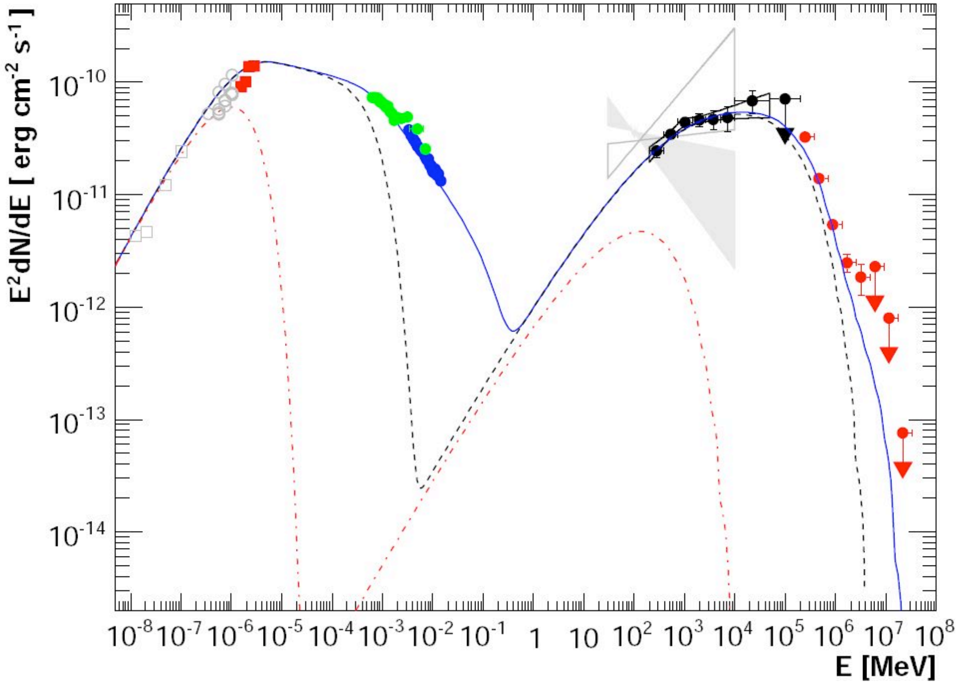
Multiwavelenght Campaigns



Planned MW Campaign:PKS 2155+304
(Abdo et al. 2009, 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.**

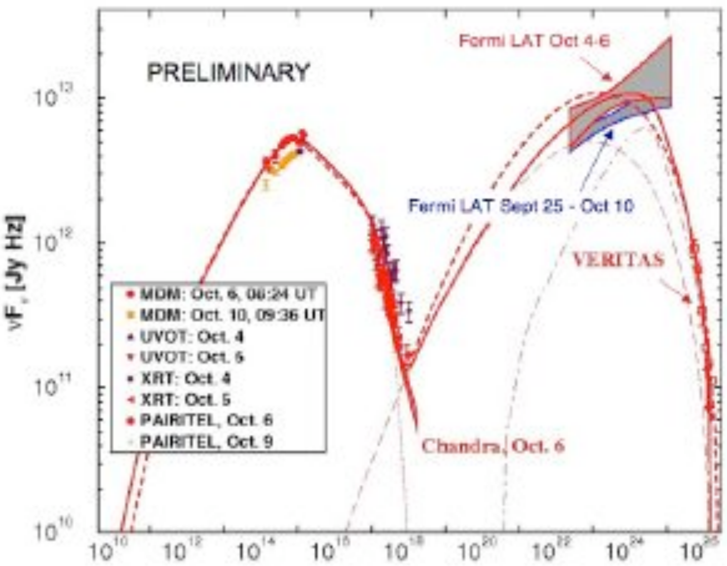
•Single zone SSC model fits the time-averaged SED, but variability patterns present some challenges.



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

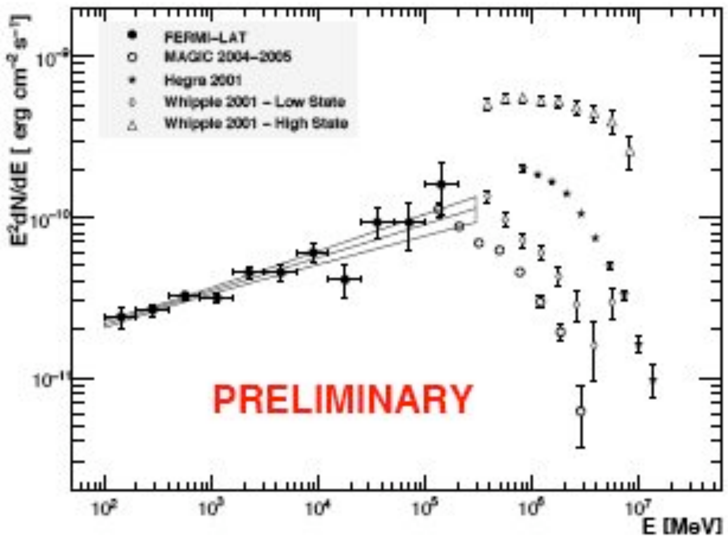
3C 66A & Mkn 421

3C 66A (IBL)



(Reyes et al. 2009,ICRC Proc)

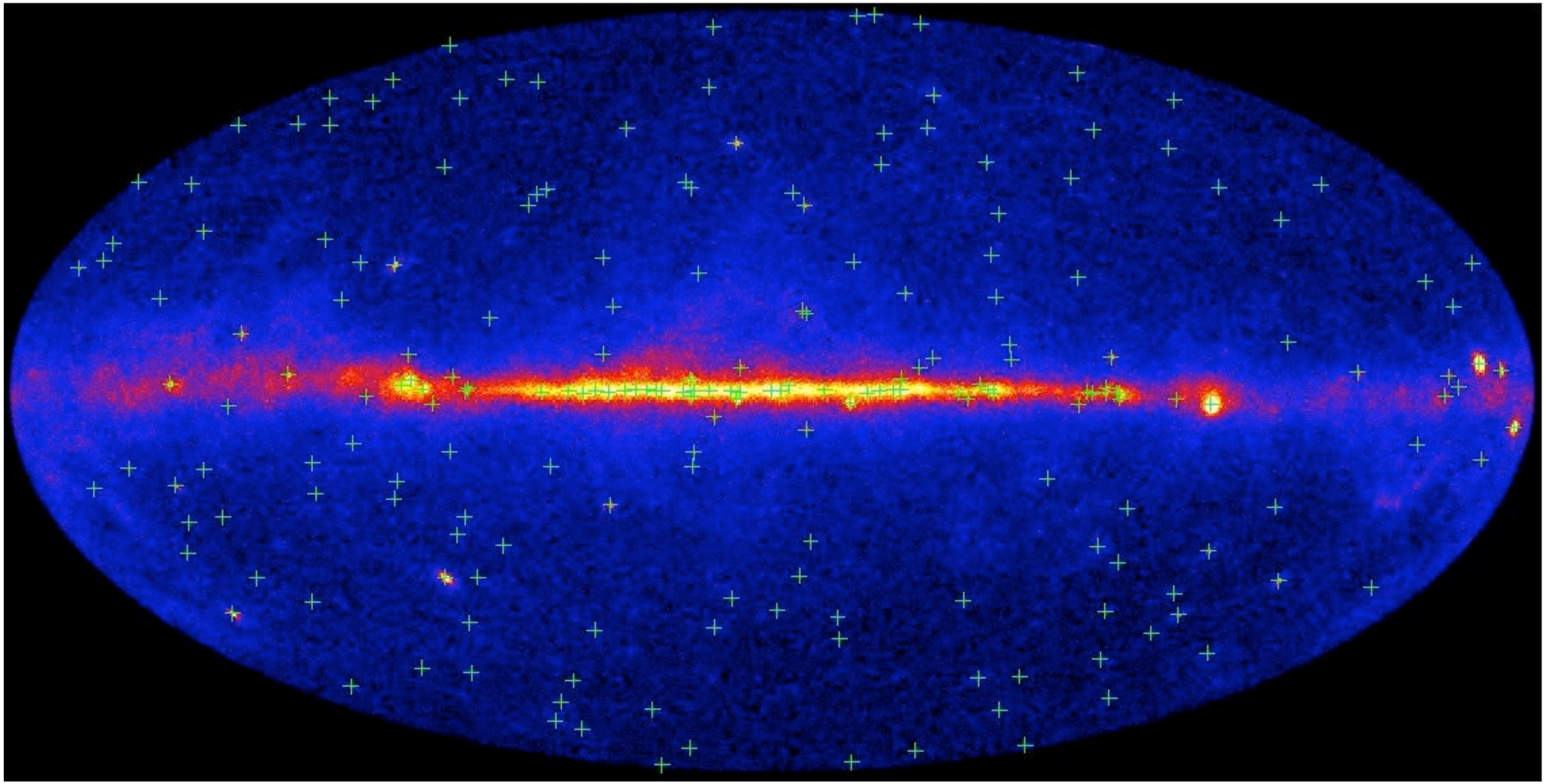
Mkn 421 (HBL)



(Paneque et al. 2009,ICRC Proc)

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

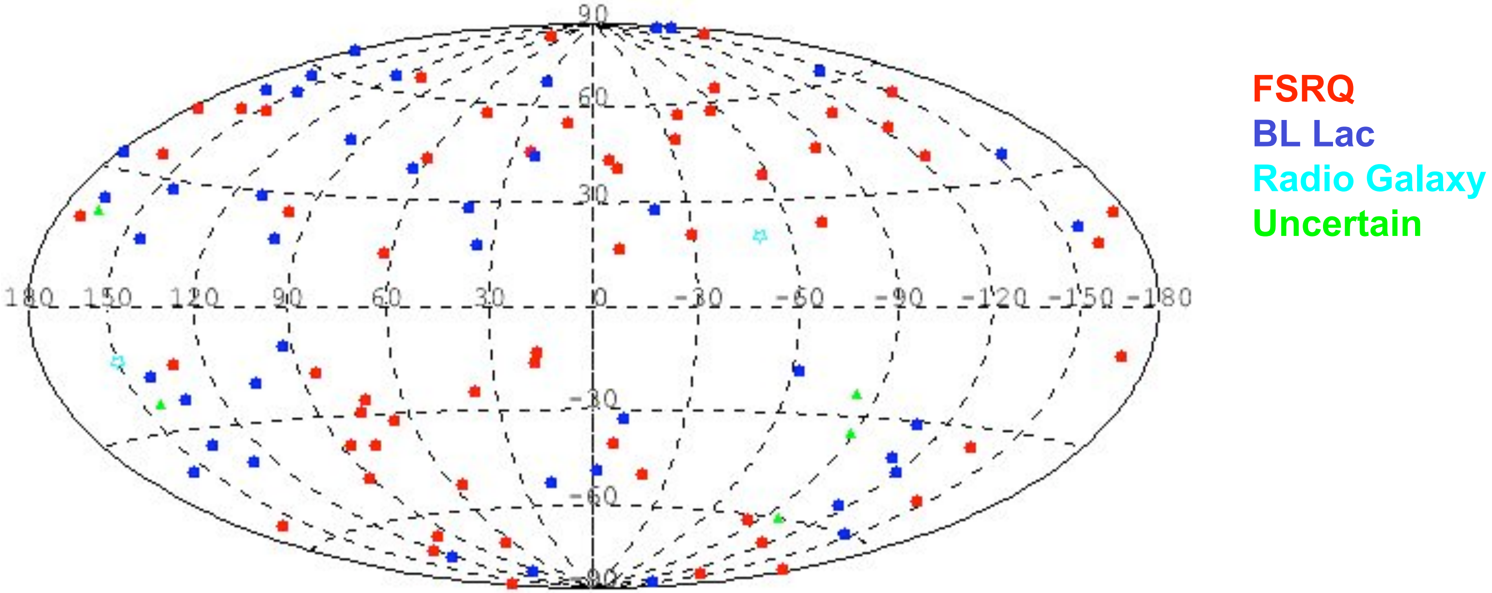
(Abdo et al. 2009, ApJ,700,597; arXiv:0902.1340)



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

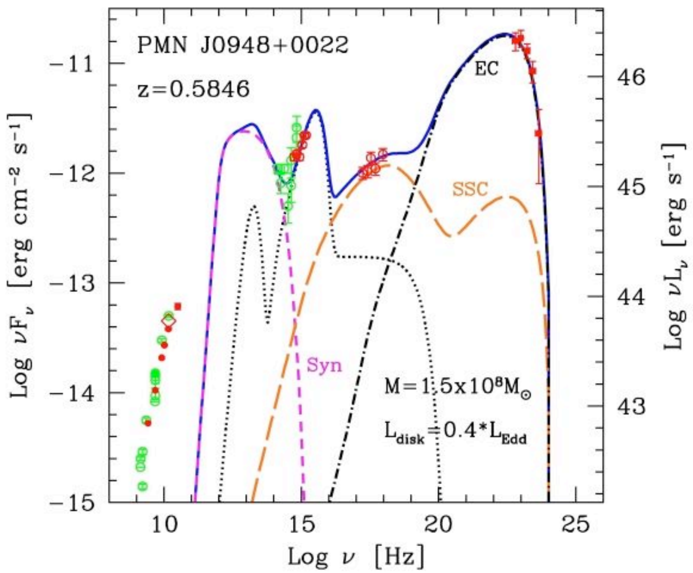
LAT Bright AGNs Sample (LBAS)

- 132/205 with |b| > 10° (7 pulsars, 14 unid)
  - 111/125 are bright, flat spectrum radio sources
  - 98/111 have optical classifications, 89/111 have redshifts
  - CRATES (all-sky radio catalog), CGRaBS (all-sky optical spectra), BZCAT
  - 34% BL Lac fraction (vs 19% for EGRET)



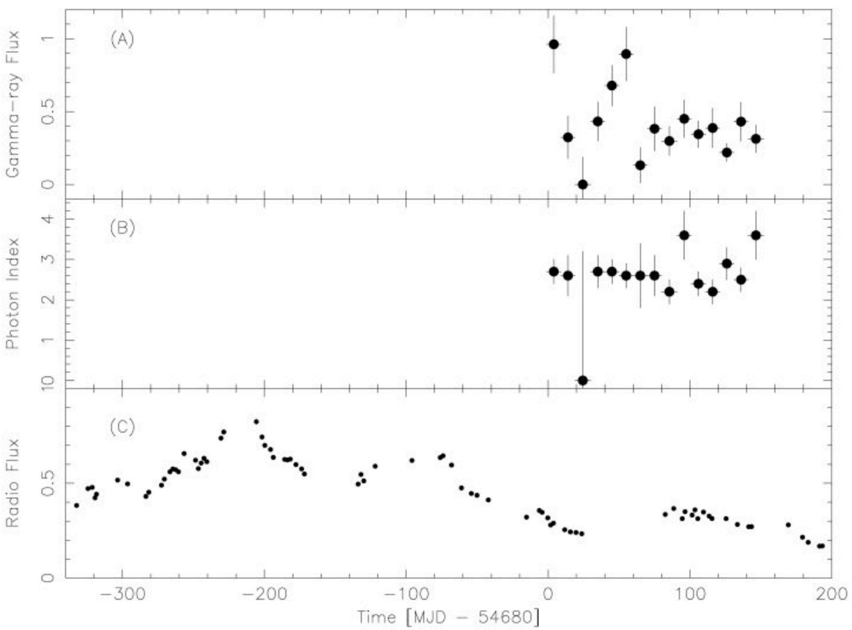
(Abdo et al. 2009, ApJ in press; arXiv:0902.1559)

Fermi/LAT discovery of gamma-ray emission from a RL-NLS1: PMN J0948+0022.



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.



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

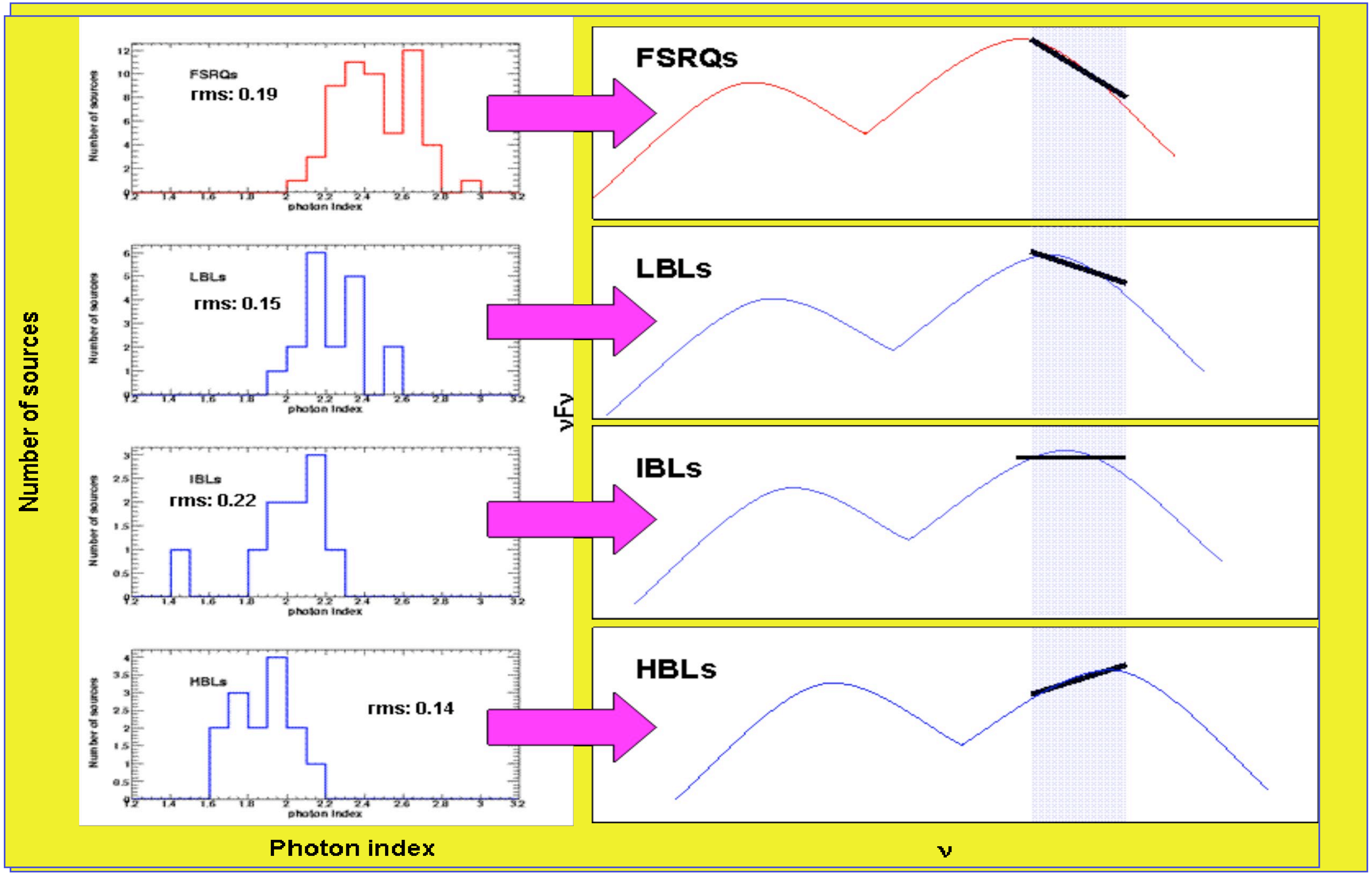
Many questions open:

•Is this a new type of γ-ray emitting AGN?

•Are there other sources of this type?

•What is the impact of narrow-lines?

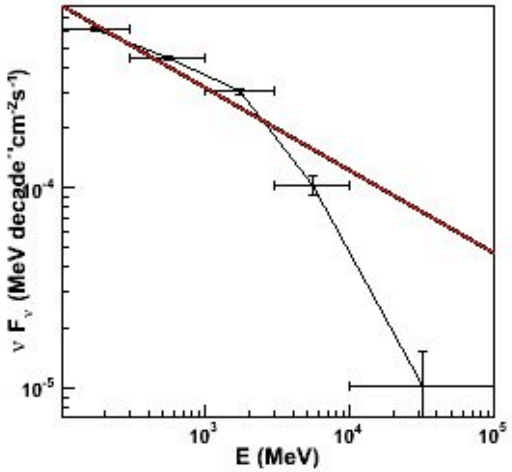
Key properties of the LBAS: Photon index



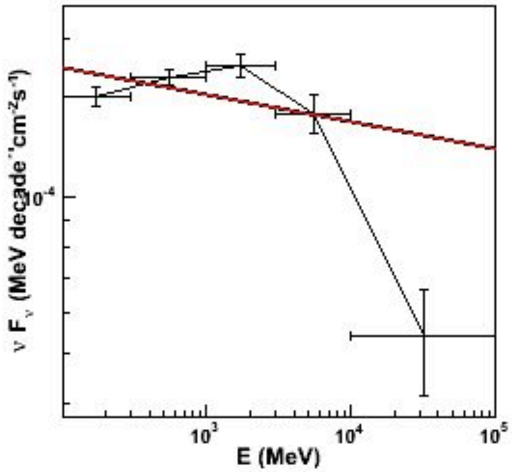
Key properties of the LBAS: Gamma-ray Spectra

Preliminary

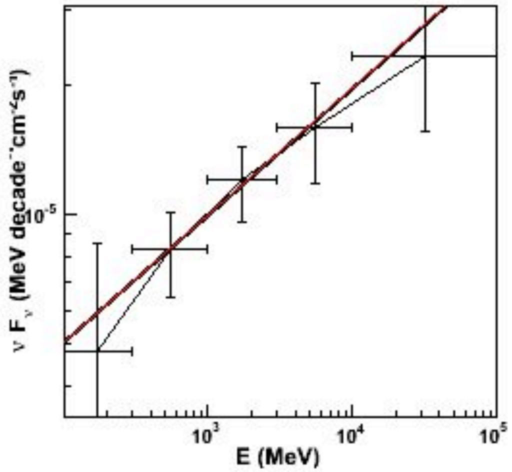
3C454.3 (FSRQ)



AO 0235+165 (IBL)



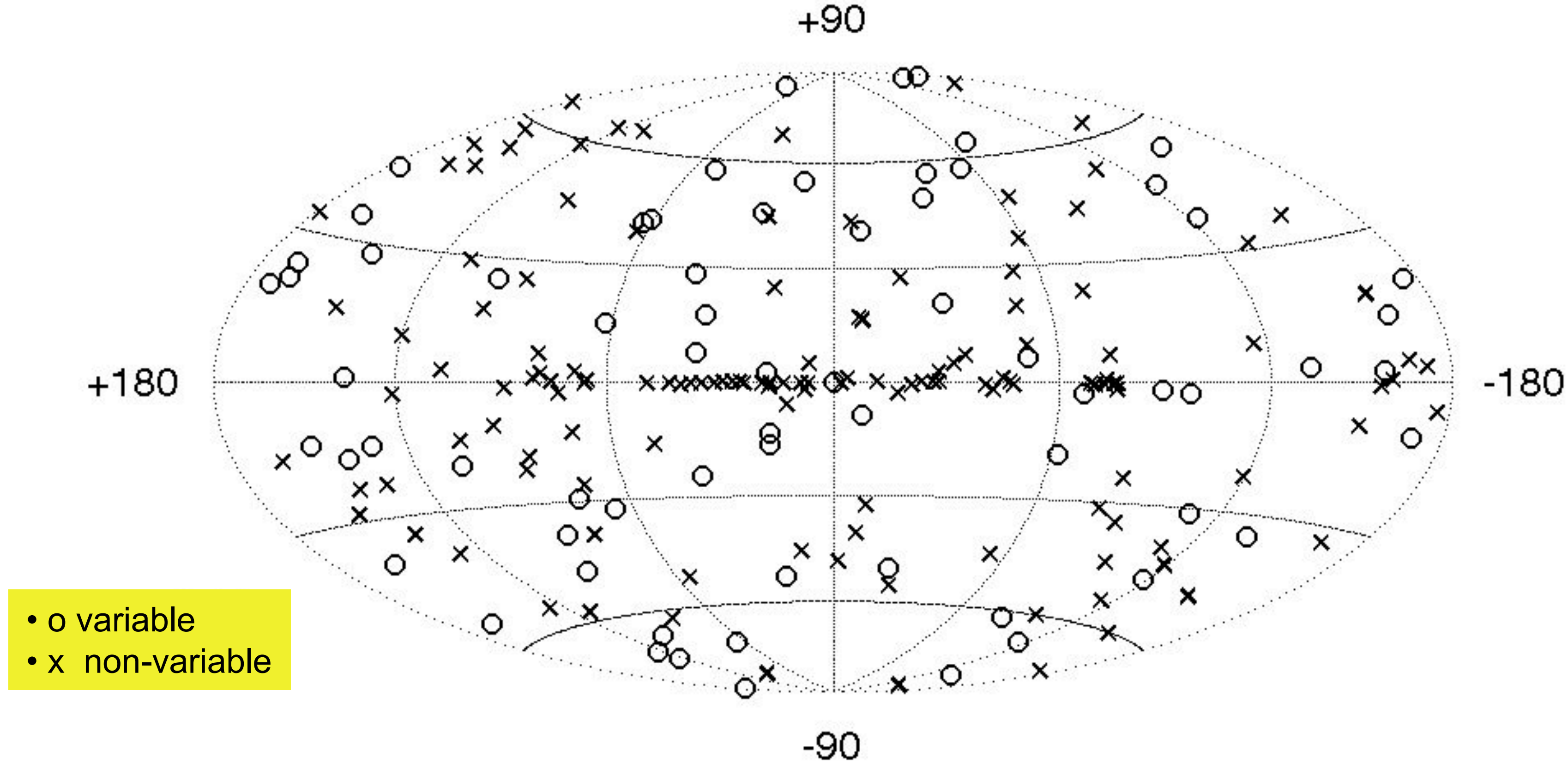
Mkn501 (HBL)



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.

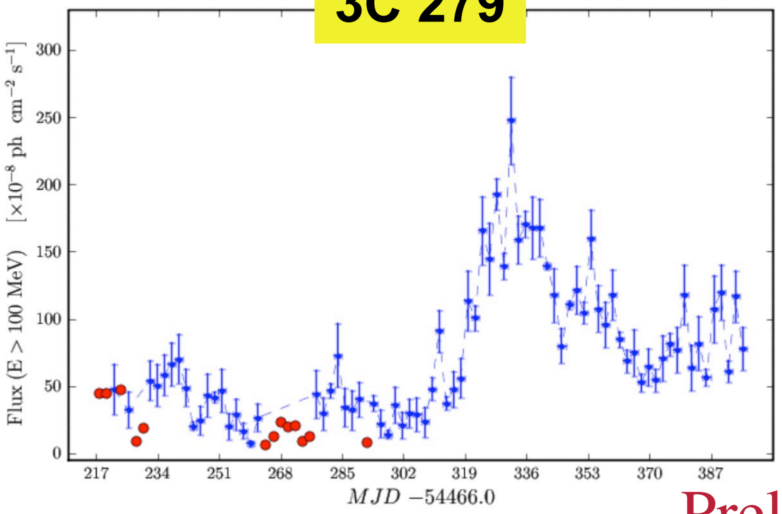
Variable sources in the LAT Bright Source List

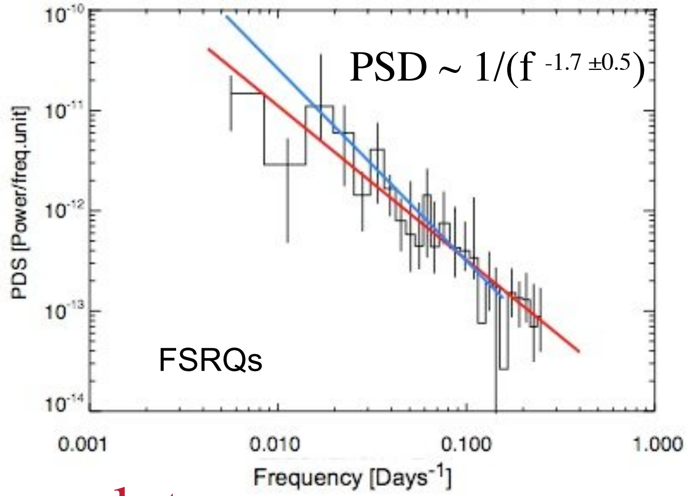


- **Based on 1 week time scales**
- **68 show variability with probability > 99% (Most Blazars)**
- **Isotropic distribution ⇒ blazars**

Key properties of the LBAS: Variability

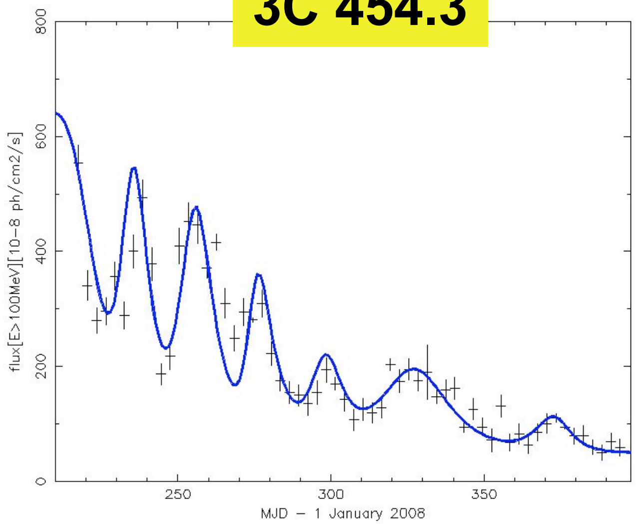
3C 279

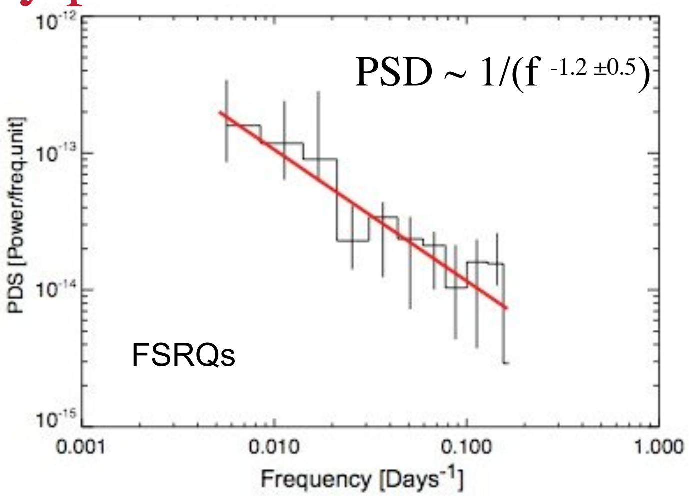




Preliminary plots

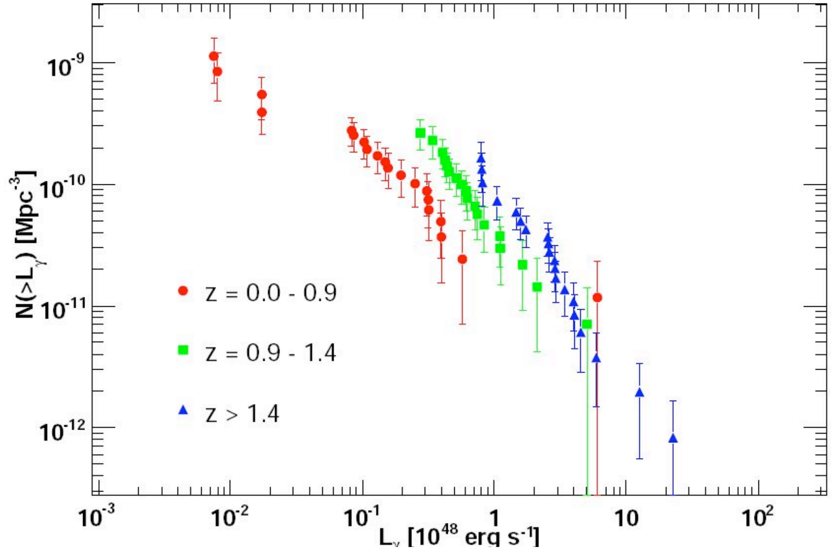
3C 454.3

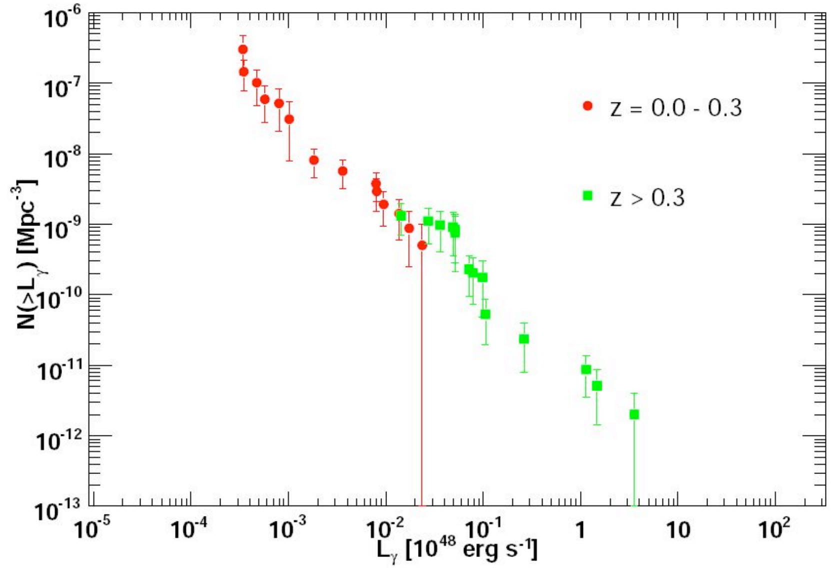




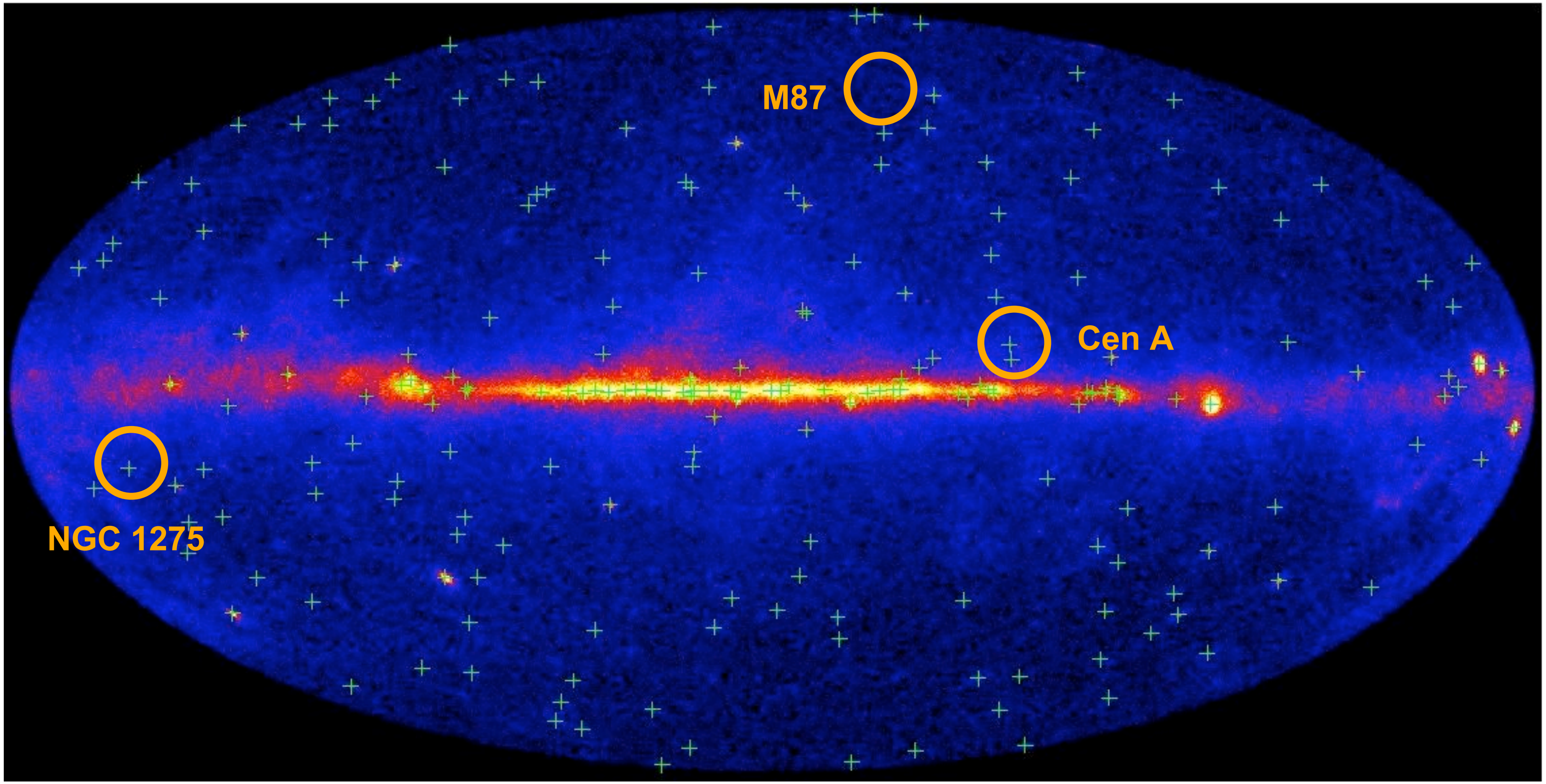
Key properties of the LBAS: Luminosity Functions

- **FSRQs**
  - **Strong evolution**
  - **The 3 month LAT AGN sample measures the bright end of the luminosity distribution.**
- **BL Lac objects**
  - **No evidence of evolution**
- **Combined emission from individual blazars in 3 month sample corresponds to 7% of EGRET extragalactic diffuse**

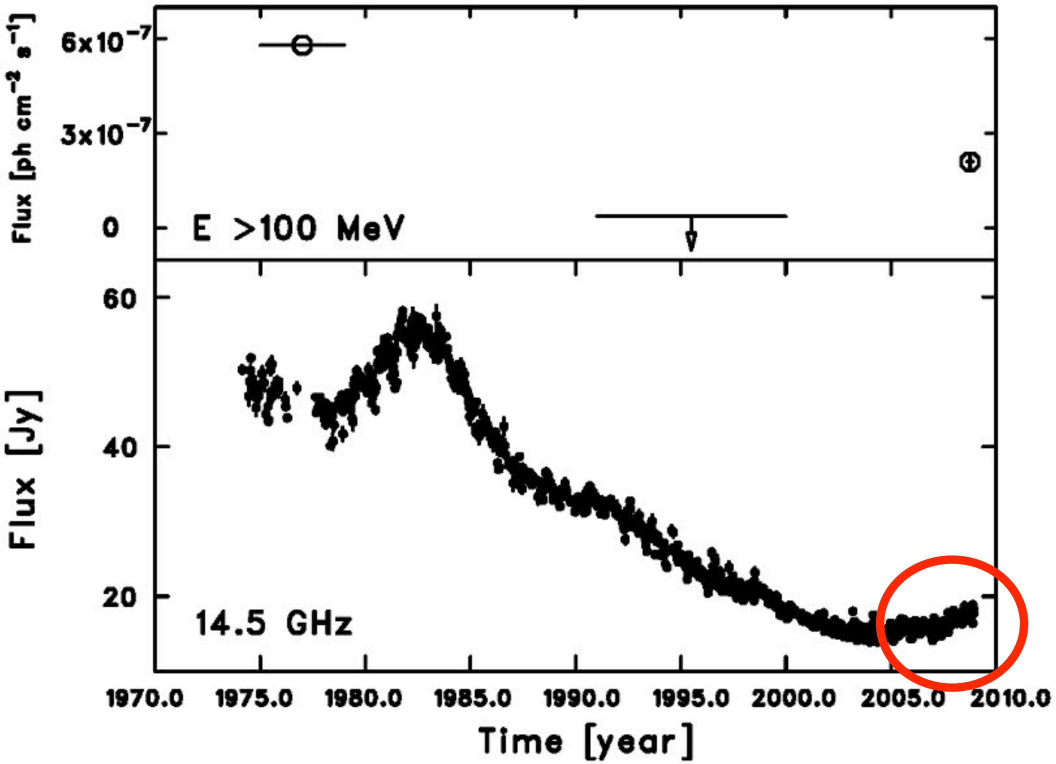




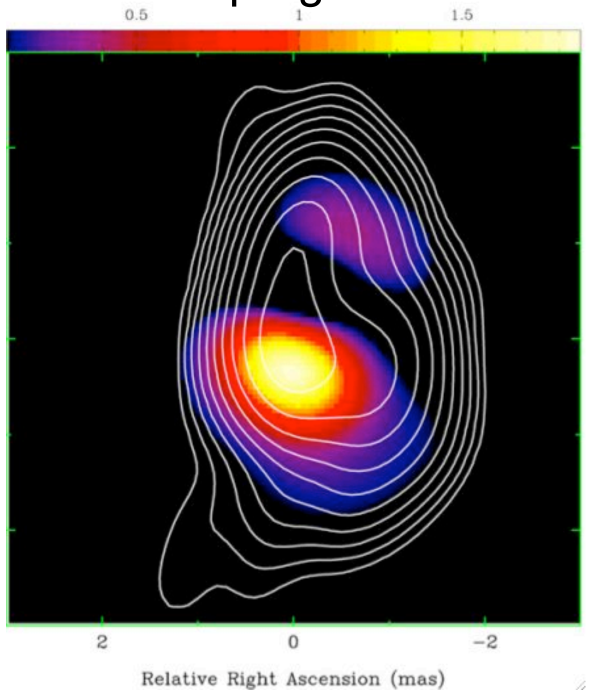
Radio Galaxies



NGC1275: Long Term γ-ray variability & Correlation with Radio?



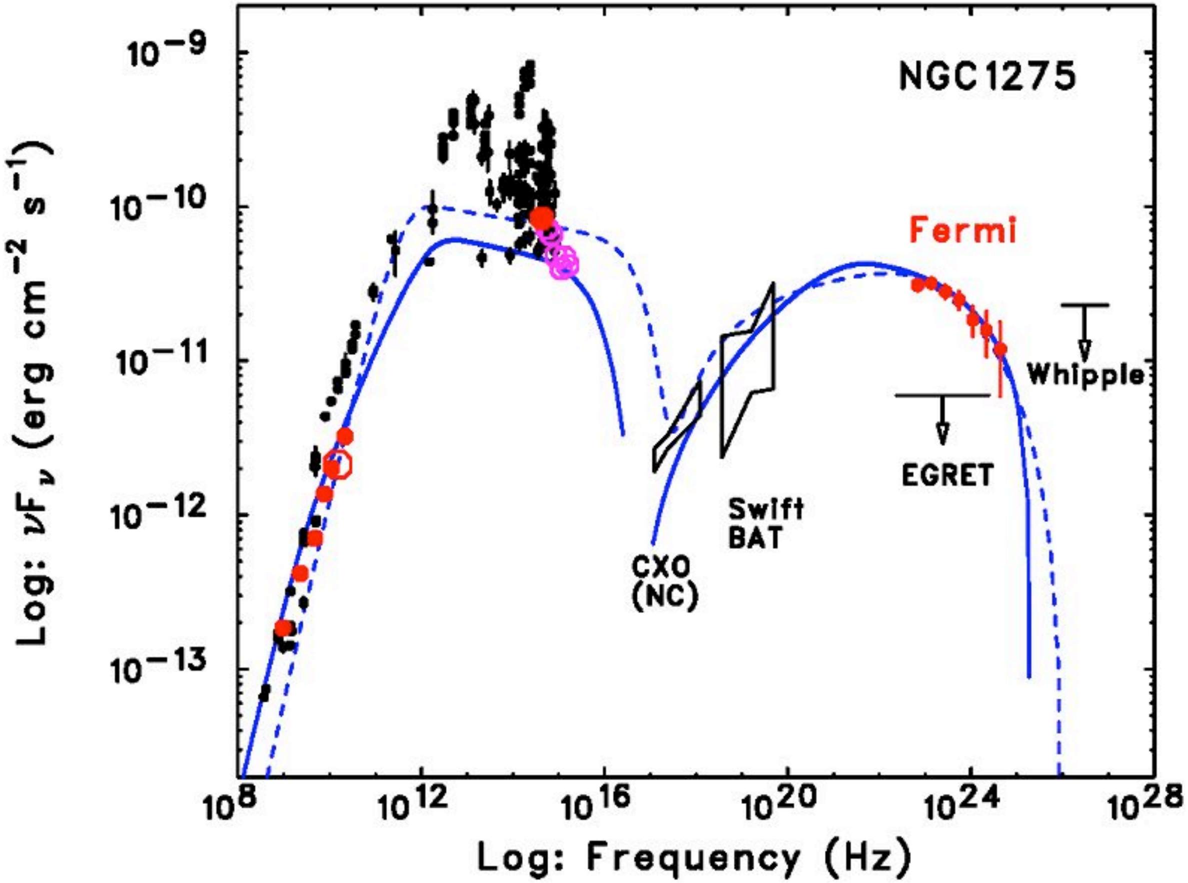
Contours: Aug '08 VLBA 15 GHz
Color: Sep '07 map subtracted
From MOJAVE program



- LAT flux 6x brighter than EGRET limit
- Historical COS-B detection while radio in high radio state
- Radio light curve rising during the Fermi observations with pc -scale outburst seen in MOJAVE maps

1 mas = 0.35 pc

NGC 1275: Spectral Energy Distribution



LAT spectrum:
Γ = 2.17 ± 0.05

(1) one-zone SSC
B= 0.05 G
R= 0.7 pc
δ= 2.3, Γ = 1.8
L_{jet} = 2.3e45 erg/s

(2) Decelerating flow
B = 0.2 G
D = 0.2 pc
R = 0.01 pc
Γ = 10 -> 2
L_{jet} = 6.0e43 erg/s

- SED LBL-like: possible unification of BL Lac and Radio Galaxies
- Jet power close to the power required to inflate the lobes of 3C 84 against the pressure of the hot cluster gas. (0.3-1.2)x 10^{44} erg/s: (Dunn & Fabian 2004)

Summary (I)

•As of today, several hundred blazars and several radio-galaxies (CenA, NGC1275, M87…) and 1 RL-NLS1 have been detected by the Fermi-LAT, confirming that AGNs still dominate the high-energy extragalactic sky.

•The LBAS sample comprises the 106 brightest sources (|b|>10°) confidently associated with AGNs, 2/3 of which were not previously known as gamma-ray emitters.

•BLLacs compose a larger fraction (~40%) of the detected blazars than in the EGRET sample (~25%). Many known HBLs detected.

•LogN-logS, luminosity functions have been obtained with the LBAS showing strong cosmological evolution for FSRQs and no evolutions for BLLacs. These conclusions are being refined using more sources.

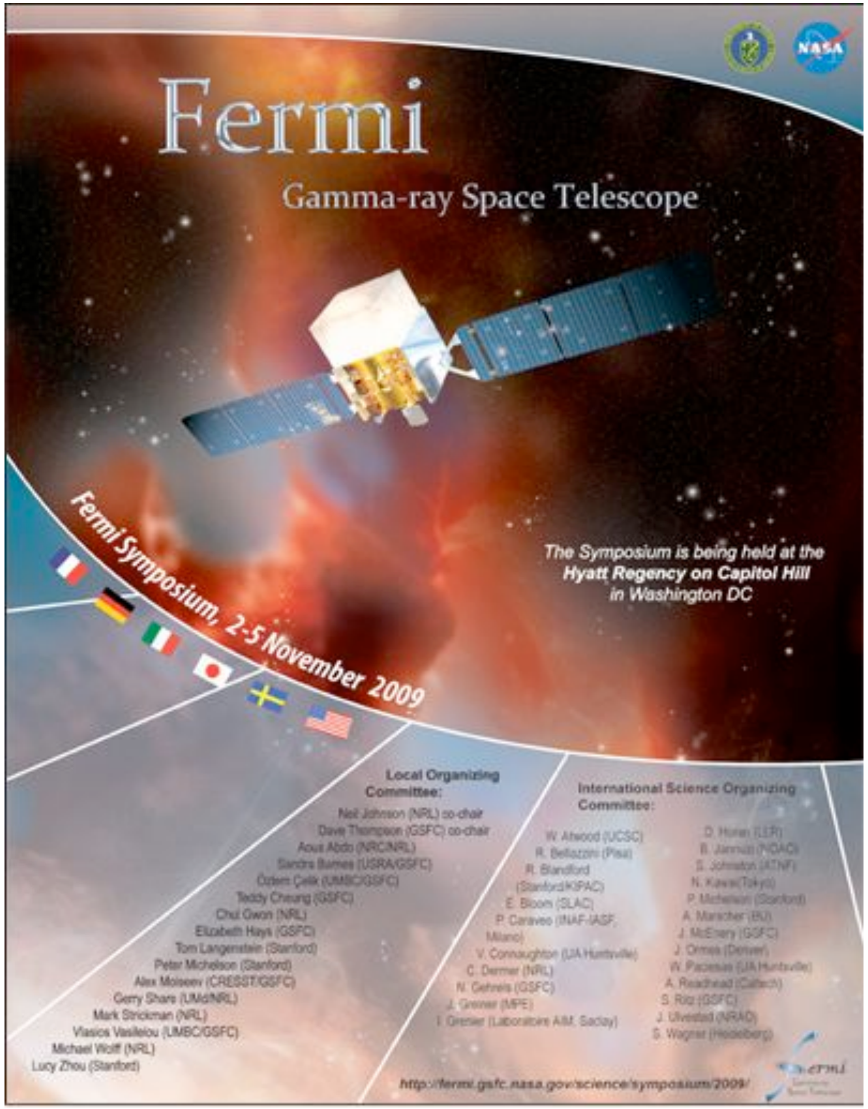
•A strong correlation between the blazar class (FSRQs, LBLs, IBLs, HBLs) and the photon index in the GeV range has been found.

Summary (II)

- The high-sensitivity and near-continuous sky coverage has enabled:
  - the issuance of many alerts on flaring blazars;
  - the production of light curves with unprecedented sampling, from which variability patterns are being derived;
- MW studies giving:
  - Time-resolved MW SEDs for several sources.
  - Interband timing correlation. Different types of correlations observed.
- Spectral breaks, most probably mirroring an equivalent feature in the energy distribution of the emitting electrons, are frequent in FSRQs, present in some LBLs and IBLs, absent in HBLs. This effect has implications for EBL studies and blazar contribution to extragalactic diffuse emission.

  New questions are rising about the current understanding of blazar emission mechanism

http://fermi.gsfc.nasa.gov/science/symposium/2009/



See You There!