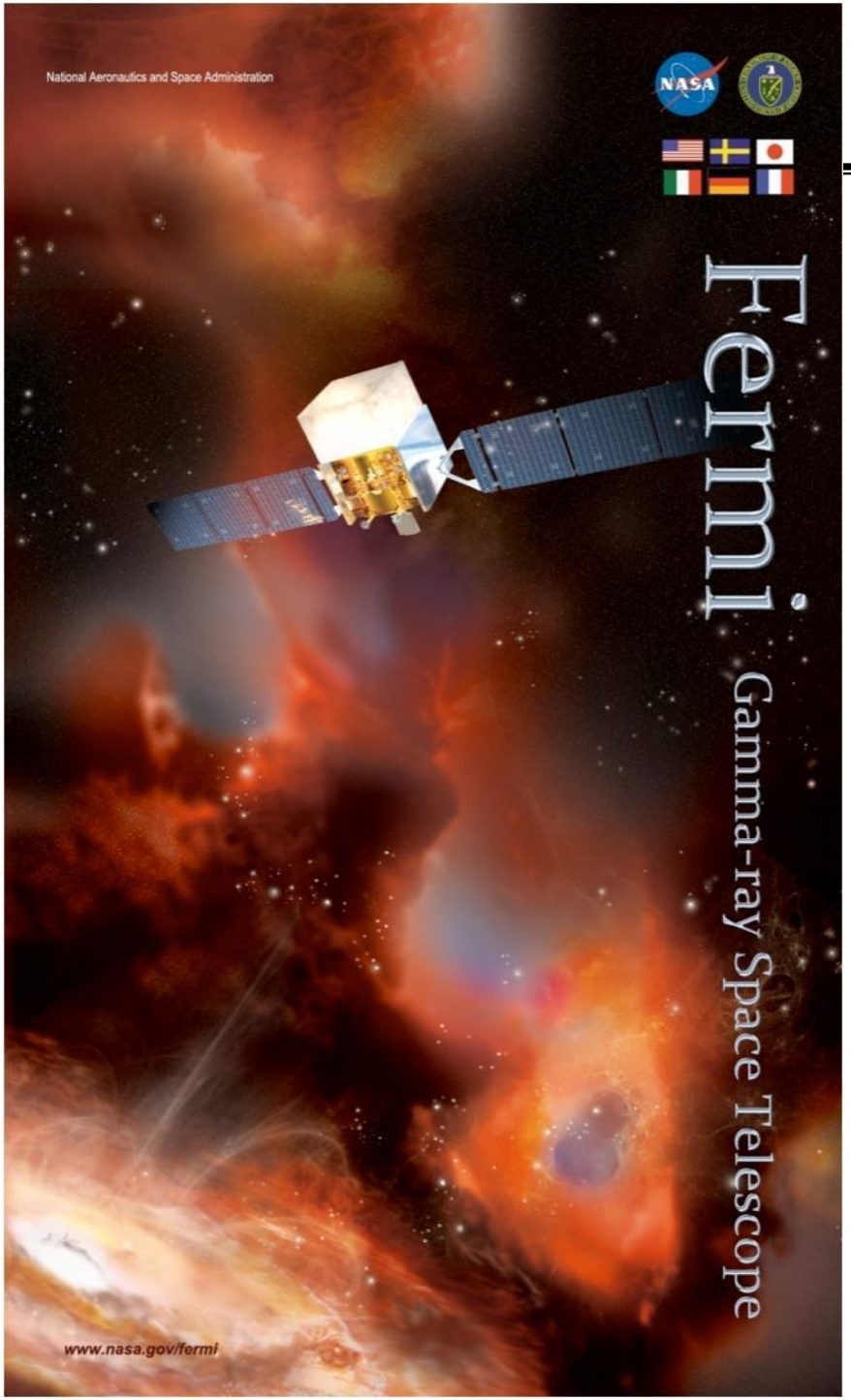
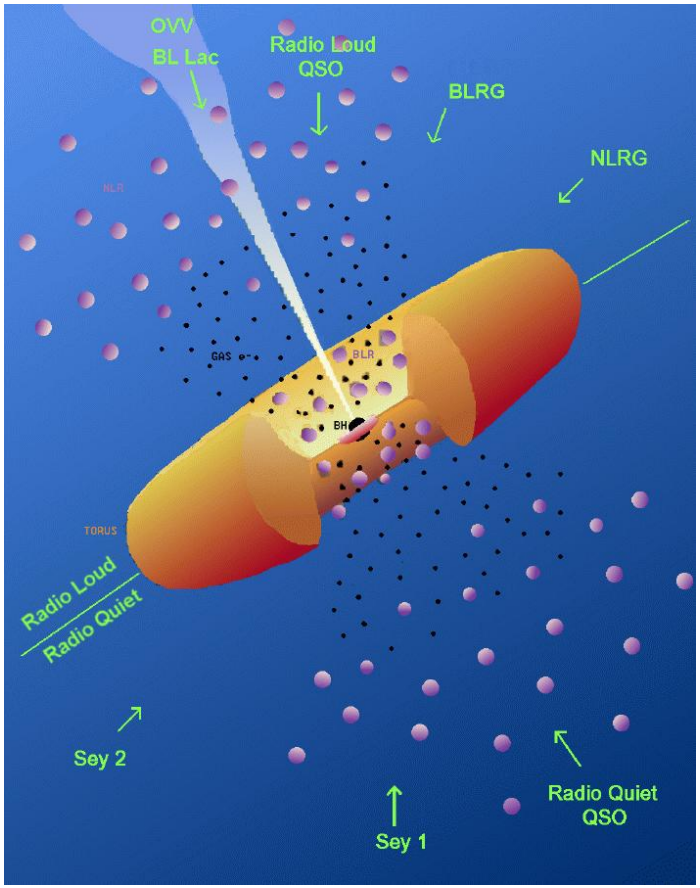


Fermi and Blazars

Elisabetta Cavazzuti
ASI Science Data Center
on behalf of the LAT collaboration

III Fermi Symposium
Roma, May 10, 2011

Synthetic introduction to blazars



- ✓ less than **5%** of the whole AGN class
- ✓ **beamed** (jet at ≤ 20-30°)
- ✓ broad band **non thermal continuum**,
  L up to 10^{49} erg s^{-1}
- ✓ **compact** radio morphology
  (core flux >> extended flux)
- ✓ **flat radio spectrum** (radio spectral index
  $\alpha_r \leq 0.5$, $S_\nu \sim \nu^{-\alpha}$)
- ✓ rapid **variability** (large $\Delta L / \Delta t$),
  superluminal motions
- ✓ high and variable **optical polarization**

Blazar research is much less developed than that of other AGN.
Still, blazars dominate the extragalactic sky in a number of *new* observational windows (μ-wave, hard x-ray, γ-ray, TeV)

As of today, about 3,054 blazars (BZCAT 3rd edition) are known and before the operations of Fermi, Planck and other facilities, only small good statistical samples existed.

Now this has changed.

Incomplete list of still open questions

- ✓ Emission models:
  - Homogeneous Synchrotron Self Compton, External Compton, Multiple SSC components, hadronic models ?
- ✓ Acceleration mechanisms
- ✓ The location of the gamma-ray emitting region in FSRQs and LSPs (inside or outside the BLR)
- ✓ Physical reasons for observational differences among FSRQ and BL Lac
- ✓ Variability
  - Duty cycle
- ✓ ....

multi-wavelength approach is fundamental to disentangle among different answers

LAT AGN Catalogs

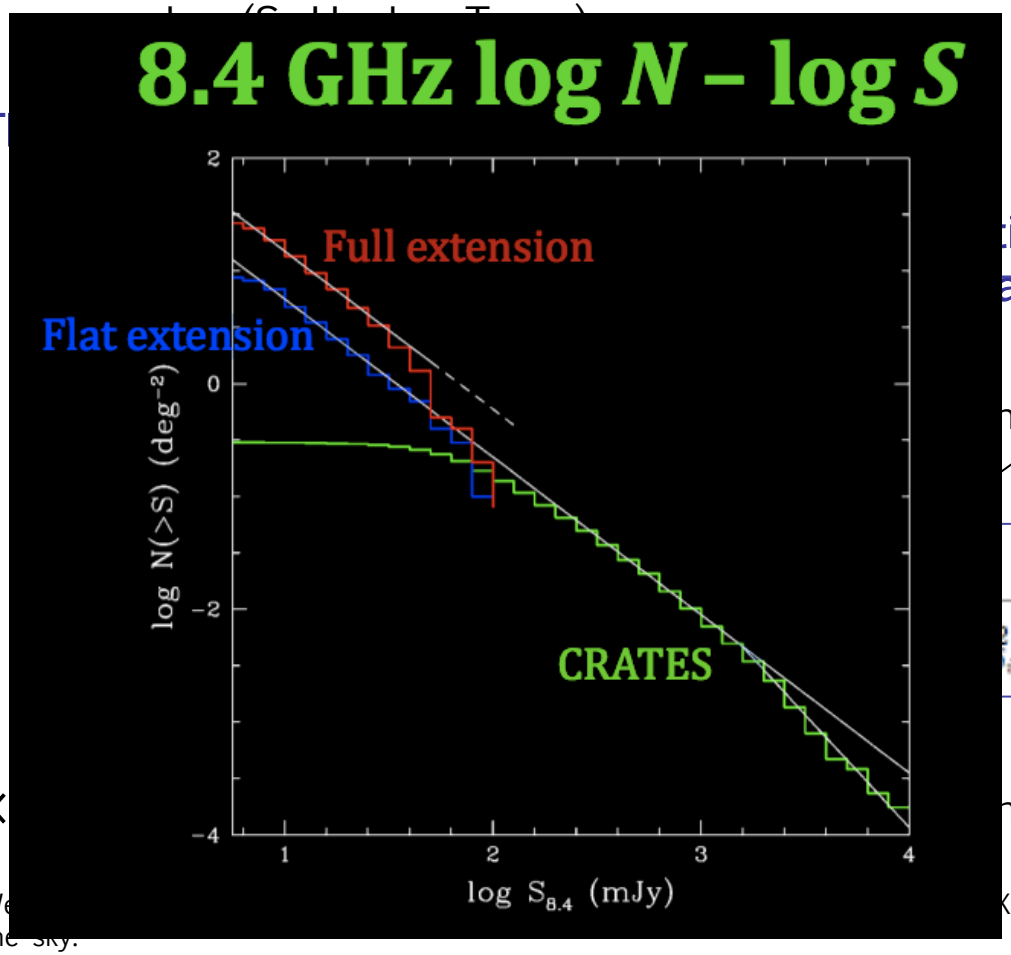
AGN Catalog papers:

LBAS (3 months of data) included 132 LAT counterparts at high latitude ($|b| > 10^{\circ}$) TS>100
1LAC (11 months of data) included 869 LAT counterparts at all latitudes TS>25
2LAC (24 months of data) includes ~ 1100 LAT counterparts at all latitudes above TS>25

Where does this improvement come from?

2LAC association methods

- ✓ Likelihood ratio method (ASDC Team)
- ✓ radio logN - logS association method for blazars with flat spectrum radio



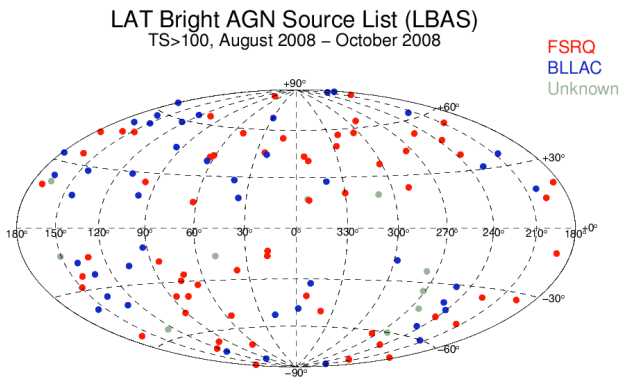
CRATES, CLASS and AT20GHz survey, PMN-CA, VCS, other radio flat spectrum samples

n candidate *i*.

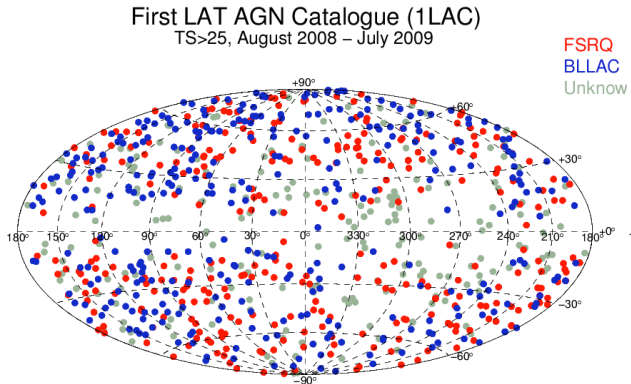
X-ray one: NVSS, SUMSS, PMN, RASS in order to cover all

(Posters: AGN S1.N14 Cavazzuti, E., Catalog S1.N3 Cutini, S.)

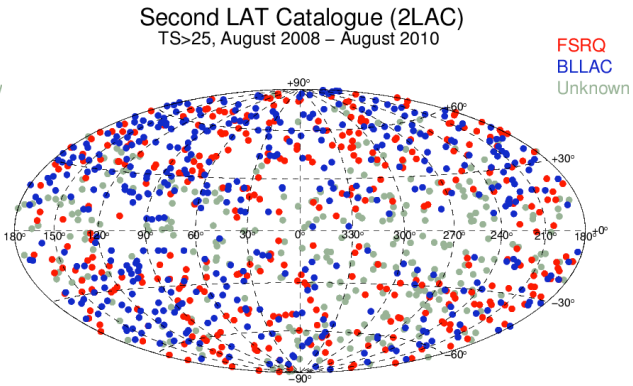
LAT AGN Catalogs - statistics



LBAS Abdo, et al. 2009, ApJ, 700, 597



1LAC Abdo, et al. 2010, ApJ, 715, 429



2LAC Abdo, et al. In preparation

BLAZARS	% |b|>10°	FSRQ	BL Lac	LSP (FSRQ + BL Lac)	ISP (only BL Lac)	HSP (only BL Lac)
LBAS	91.4%	58.5%	41.5%			
1LAC	87.3% 88.4%	47.4% 44.4%	52.6% 55.6%	59%	12%	29%
2LAC preliminary	77.2% 85%	45.4% 41.2%	54.6% 58.8%	50.5%	16.7%	32.8%

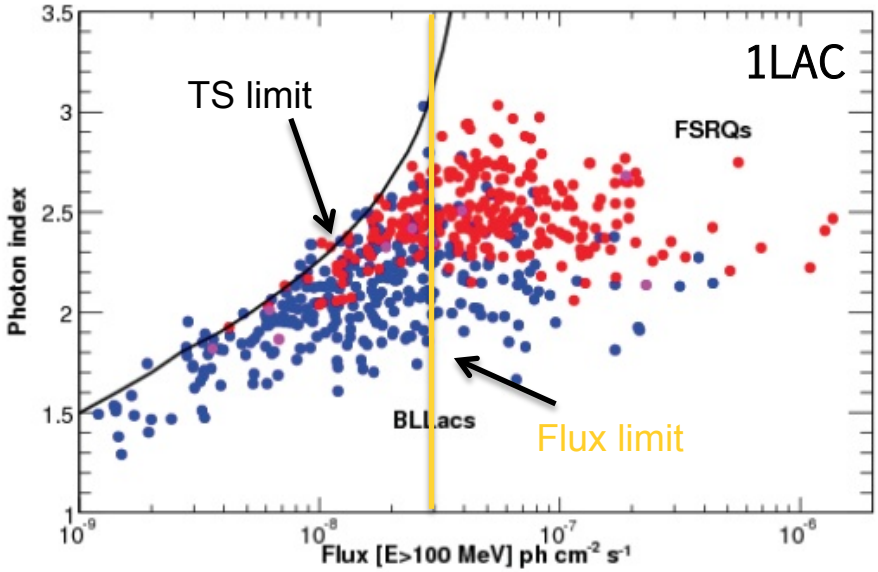
Caveats:

- LAT preference for hard sources -> HSP are favoured wrt LSP
- LAT selects radio sources fainter than those in radio catalogs of flat radio sources (eg. CRATES) -> many optically unclassified source (but blazar candidates) which will be targets for optical follow up.

Although deep optical follow up programs (R. Romani, M. Shaw, S. Piranomonte, ...), 60.8% of BL Lac are without redshift => probably they are far and bright.

(Posters: AGN S1.N14 Cavazzuti, E., Catalog S1.N3 Cutini, S.)

Significance limited samples vs flux limited samples



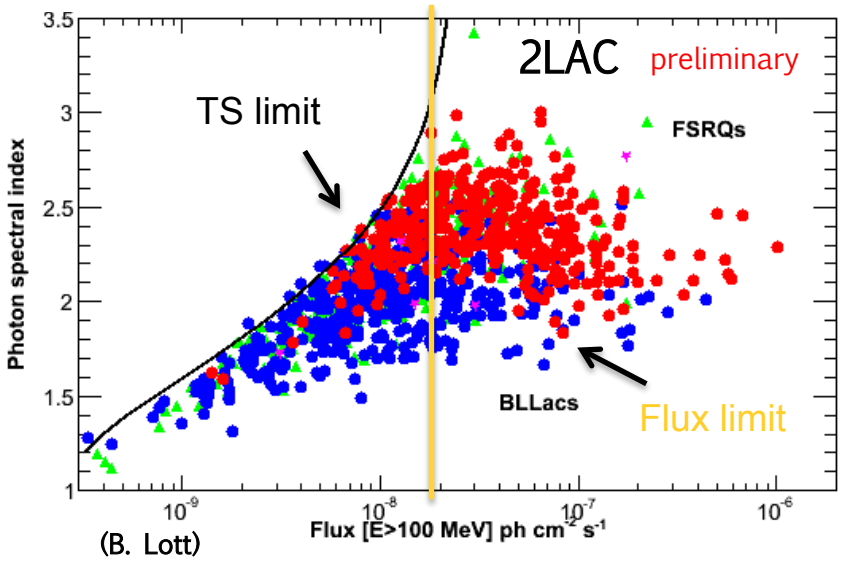
Abdo, et al. 2010, ApJ, 715, 429

In a significance limited sample we are able to include also faint sources, contrary to what we would have in a flux limited sample.
-> detection of lower-flux, hard-spectrum sources and non-detection of weak soft-spectrum sources.

FSRQ softer than BL Lac, boundary at Γ~2.2 (caveat: faint sources are visible only if they are hard (eg. HSP))

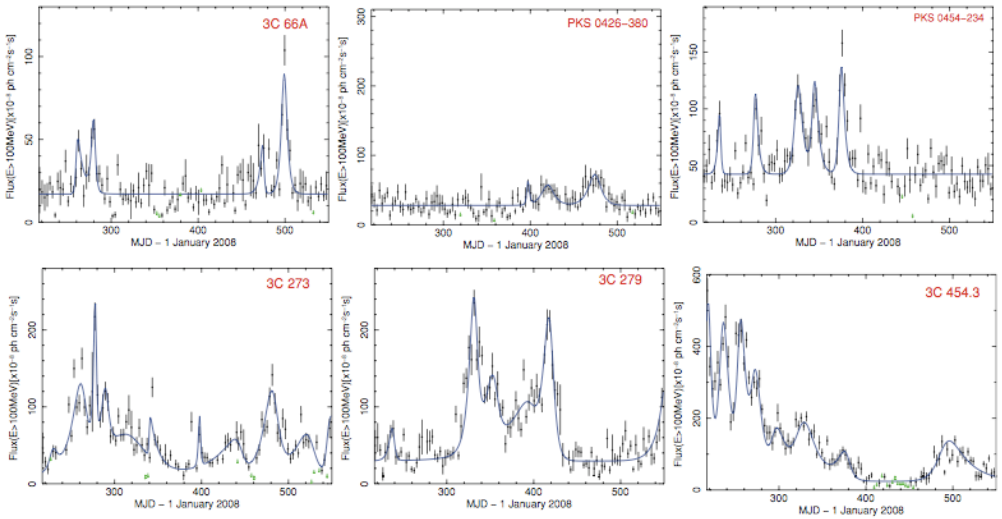
Spectral shape:
Log Parabola/BPL for all FSRQ, brightest BL Lac LSP and BL Lac ISP. Break at around 2 GeV.
PL for all HSP

Weak "harder when brighter" effect in LSP and ISP source while not in HSP.



AGN candidates:
50% in 1LAC sample have turned out to be BL Lac

γ-ray light curves



LAT capabilities: 3 days bins light curves

(Abdo, A. A. et al. 2010, ApJ, 722, 520)

Poster AGN S1.N18 Ciprini, S.

On average FSRQ and BL Lac LSP show higher variability amplitude than H P)

which shows an so

(F_{high}/F_{low})max in 2

they can!]

adjacent weekly

bins. Two flavours of v

rapidiliy varies a

source between 2

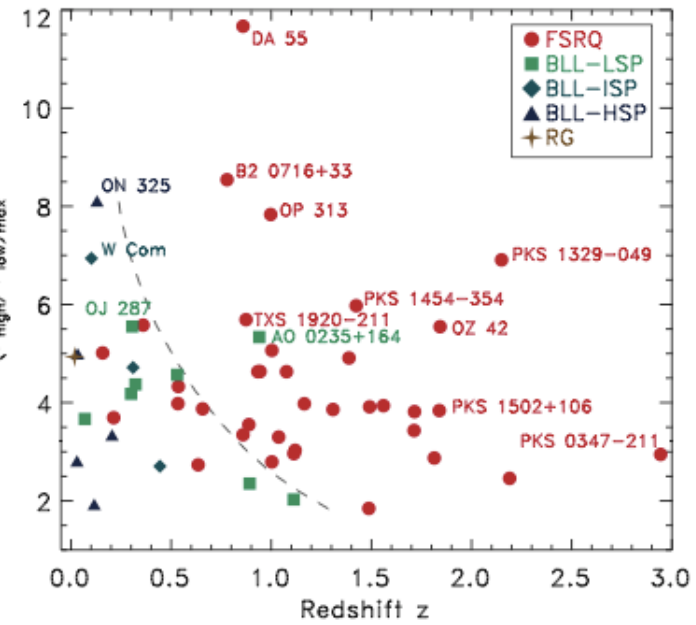
showing also inte

weeks

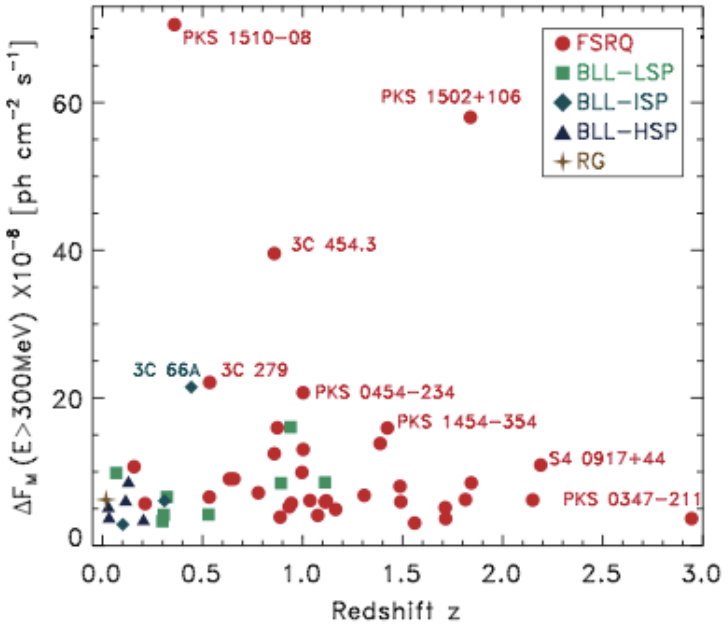
- ✓ A rather cons ty
- ✓ Few sources id structured time p

Correlated MW v

identifying a can ly



Largest Δflux in 2 adjacent weekly bins



GeV - TeV connection

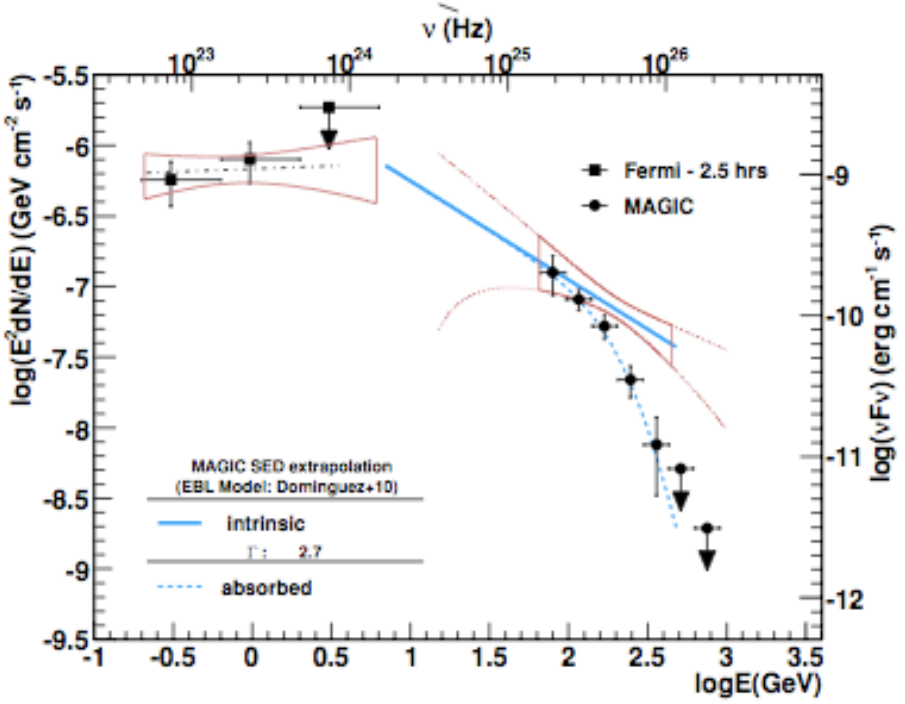
TeV blazars are the hardest GeV objects

From LBAS study: X-ray <---> TeV correlation => single population of relativistic particles responsible for both emissions.

PKS 1222+216 (4C+21.35): only 2 other FSRQ detected at TeV: PKS 1510-089 and 3C 279

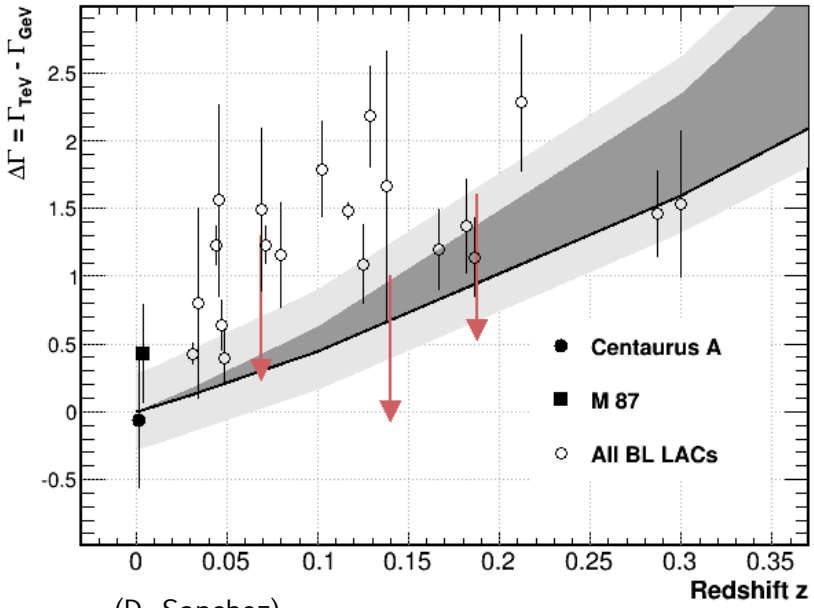
HE+VHE spectrum (corrected for EBL) with a unique PL ~ 2.72 from 3 to 400 GeV
⇒ emission belongs to a single component in the jet
and
⇒ γ-ray emission out of the BLR, which would absorb VHE γ-rays

VHE flux doubled in 10 minutes



(Aleksić et al. 2011, ApJL, 730, L8)

GeV - TeV synergy



(D. Sanchez)

Talk AGN Plenary today, Costamante, L.

Poster AGN S1.N38 Horan, D.

$\Gamma_{GeV}=\Gamma_{TeV}$

More distant sources show larger GeV-TeV break.

This is interpreted at least partly as an effect of the extragalactic background light (EBL): the gamma-ray photons pair produce with the photons of the EBL and thus get absorbed, softening the spectrum in the VHE band.

- Many of the BL Lac observed at TeV energy range are with redshift [except PG 1553+113 (HSP), PKS 1424+240 (ISP), 1ES 1440+122 (ISP), HESS 1943+213 (HSP), MAGIC J2001+435 (HSP)]
- 60.8% of 2LAC BL Lac are without redshift. About 24% are HSP.

Do the TeV telescopes have observed these objects? Long integration time is requested...

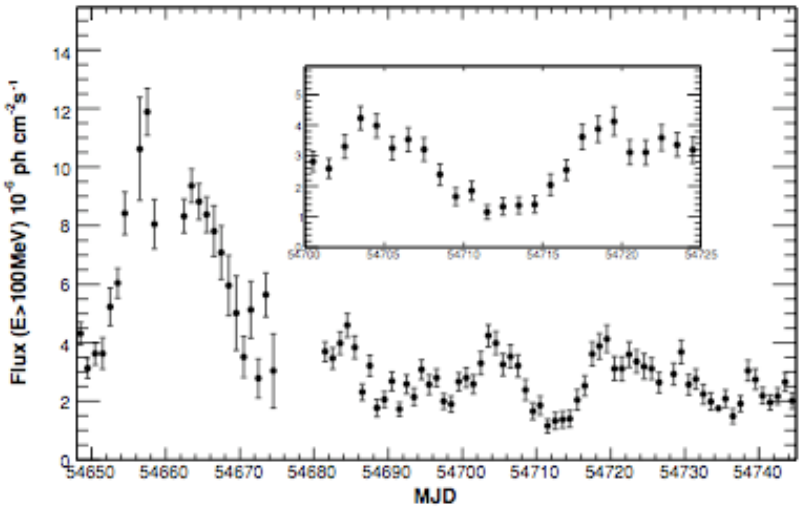
The observation of the GeV brightest BL Lac (in 100-200 GeV energy range the EBL absorption is low up to z~1) would contribute to their broad band study.

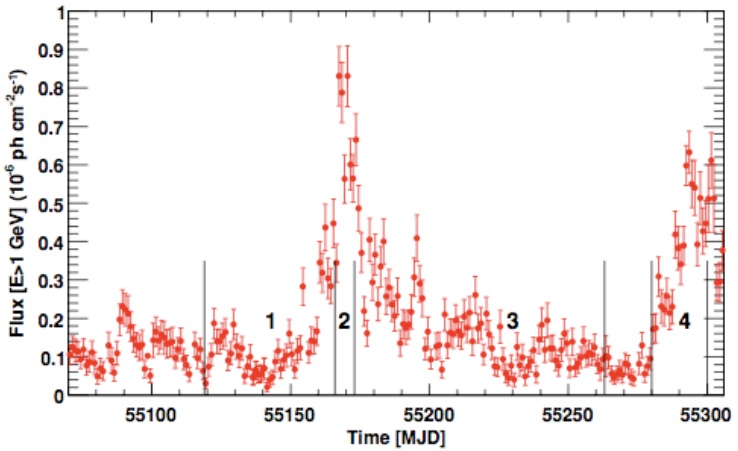
Flaring sources - 3C 454.3

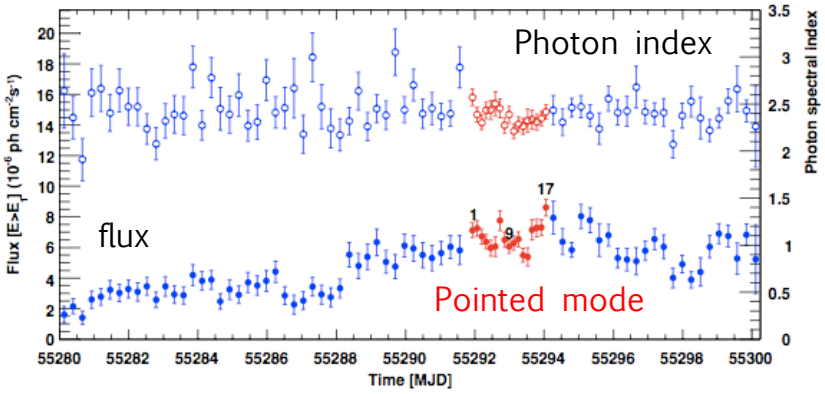
3 LAT papers on this source in less than 3 years, 92 abstracts (ADS) since 2008 among which 59 second Fermi data are public

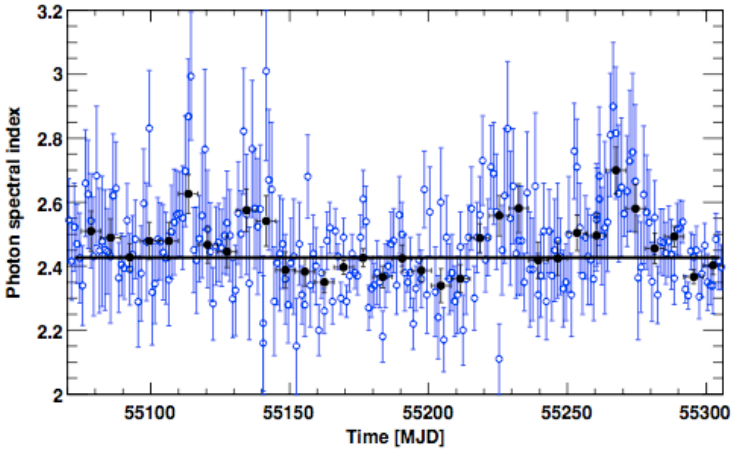
July 2008 flux ~ doubled in 2 days
Lγ ~ 2x10^{48} erg/s

Dec 2009 flux ~ doubled in 3 hrs
Lγ ~ 3.8x10^{49} erg/s





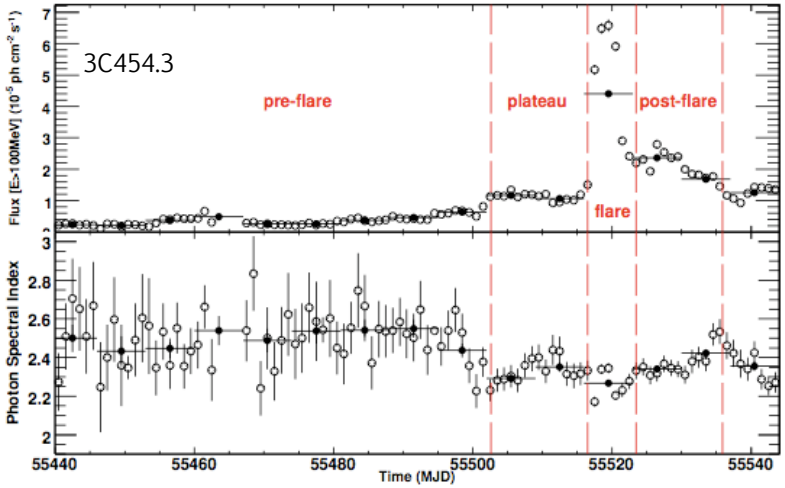




No spectral variations while flux varies

Posters AGN S1.N39 Isler, J.C., AGN S1.N98 Vercellone, S.

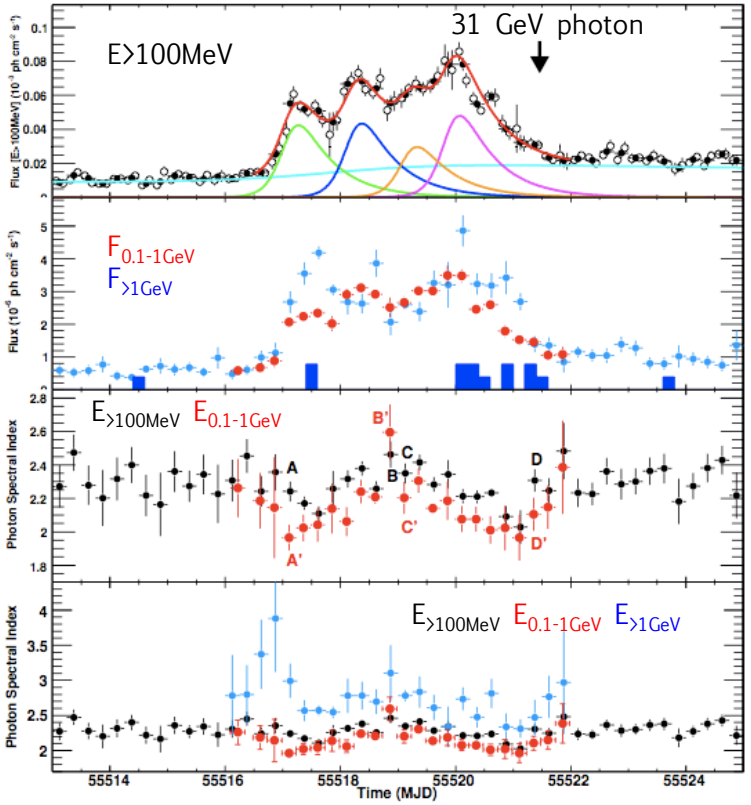
Flaring sources - 3C454.3 flare in Nov 2010

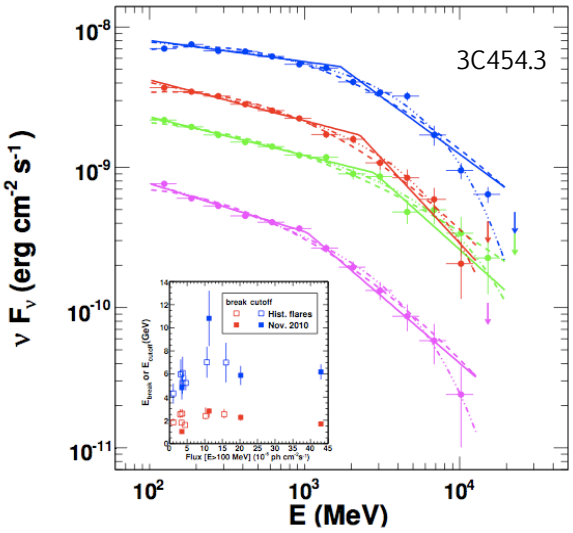


Daily light curve pre, during and after the flare
(common pattern to all its flares detected by LAT)

The highest ever recorded blazar Lγ ~ 2x10^{50} erg/s (>5 Vela)

Flare: longer in duration and higher in flux, shorter in doubling the flux (2xF in 6hrs) than the shortest detected by PKS 1502-106 and PKS 1510-089





Significant difference between light curves for $F_{0.1\text{-}1GeV}$ and $F_{>1GeV}$
⇒ clear spectral variability

E_{break} constant within a factor of ~2 while flux varies by a factor of ~40.

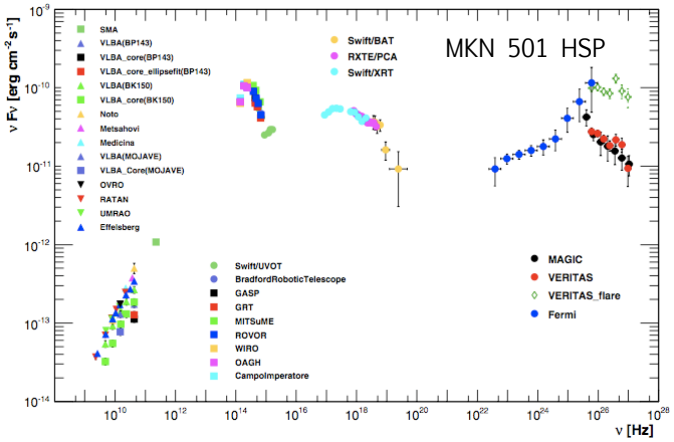
G. Madejski, Parallel Session 10A - AGN II,
Poster AGN S1.N27 Fuhrmann, L.

(Abdo, A. A. et al. 2011, ApJ, 733, L26)

Broad band MW studies

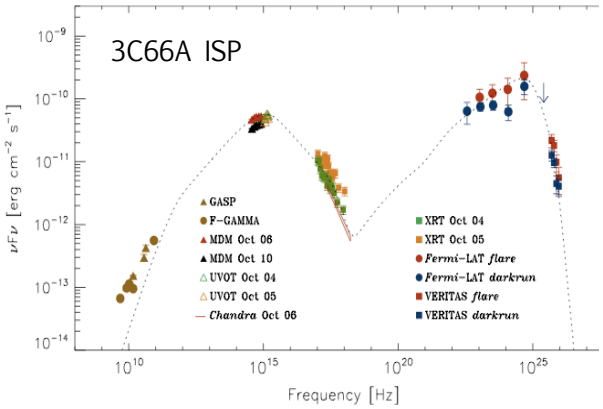
FSRQ IC peak frequency under 100 MeV
BL Lac IC peak frequency spans across the entire LAT energy range

Synchrotron peak frequency of FSRQ and BL Lac-LSP are different -> intrinsic difference in the mechanism of particle acceleration or selection effect (LSP BL Lac classified as FSRQ in the optical spectrum because low intensity lines would be visible?)

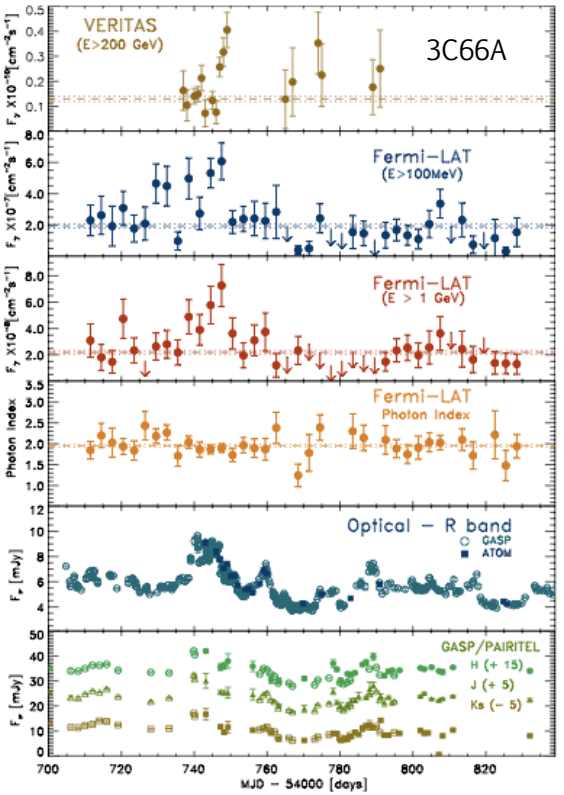


(Abdo, A. A. et al. 2011, ApJ, 727, 129)

Poster AGN S1.N77 Paneque, D.



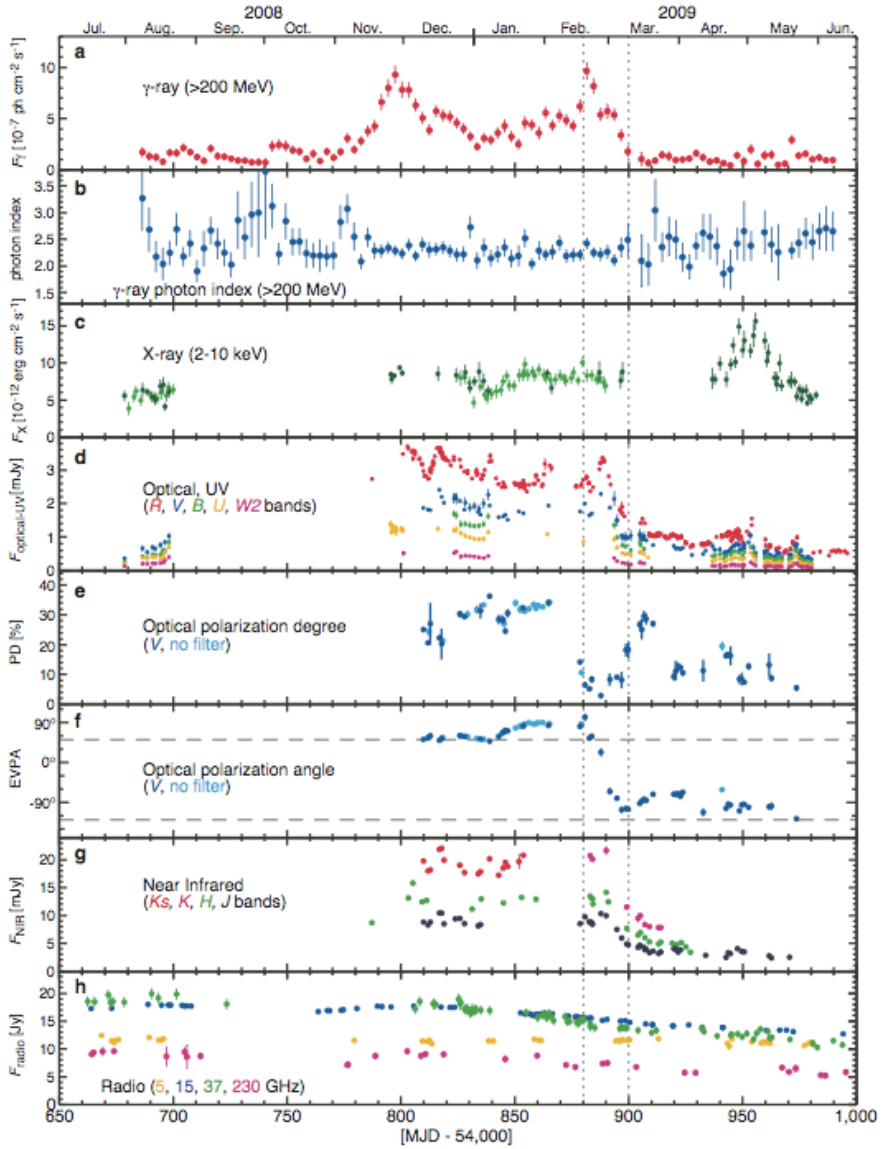
(Abdo, A. A. et al. 2011, ApJ, 726, 43)



A simple homogeneous one-zone SSC model is not able to reproduce all the variety of SEDs, especially of the LSP type
-> request for ERC or multiple SSC or... ?

This comes out both from MW population studies and single source studies.

Flaring sources - 3C 279



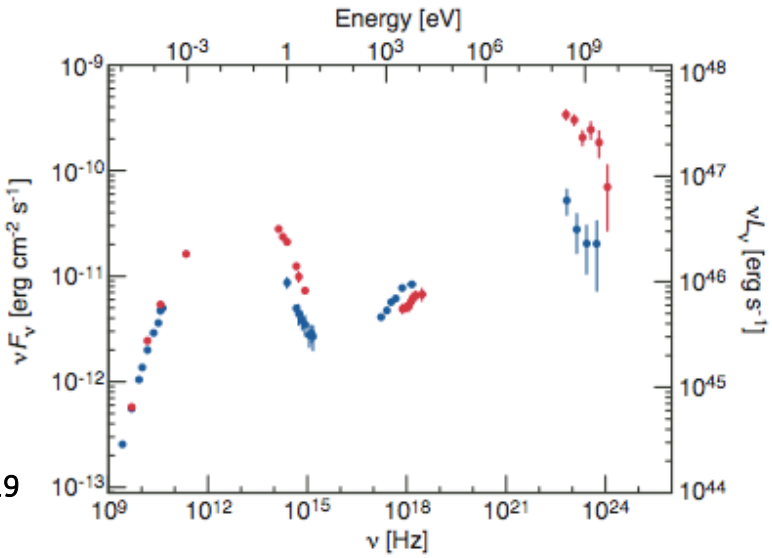
Abdo, A. A. et al. 2010, Nature, 463, 919

γ-ray flare coincident with a dramatic change in optical polarisation angle => co-spatiality of optical and γ-ray emitting regions

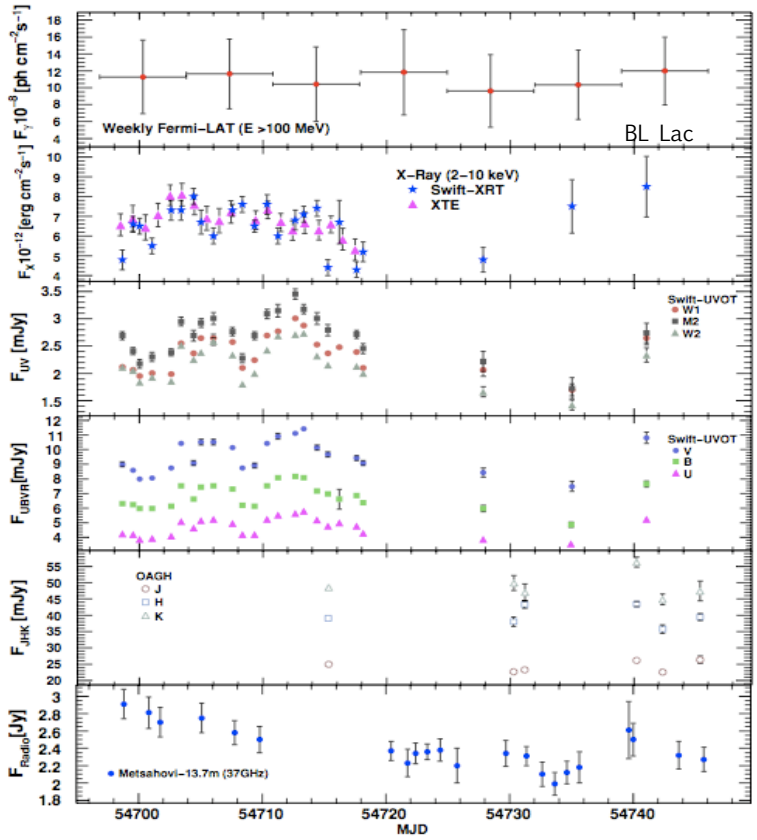
X-ray flare delayed wrt γ-ray one but same profiles => NO particle cooling BUT another mechanism involving primarily lower-energy electrons => SSC too simple!

Radio and mm fluxes are constant => blazar activity takes place where synchrotron radiation at this frequencies is not yet fully optically thin => constraints on blazar emission zone

Poster AGN S1.N36 Hayashida, M.



NON flaring sources - BL Lacertae

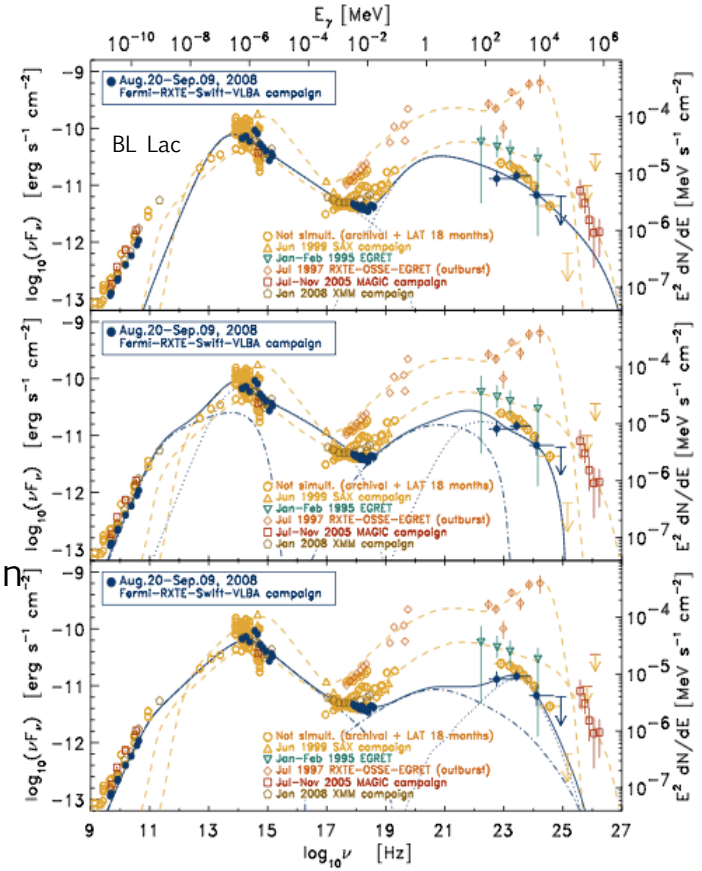


BL Lacertae (ISP)

Abdo, A. A. et al. 2011, ApJ, 730, 101

TeV detected (MAGIC) above 200 GeV
Uncorrelated variability UV <---> X-ray
No correlation optical <---> γ-ray

Concave X-ray spectrum as expected in ISP sources =>



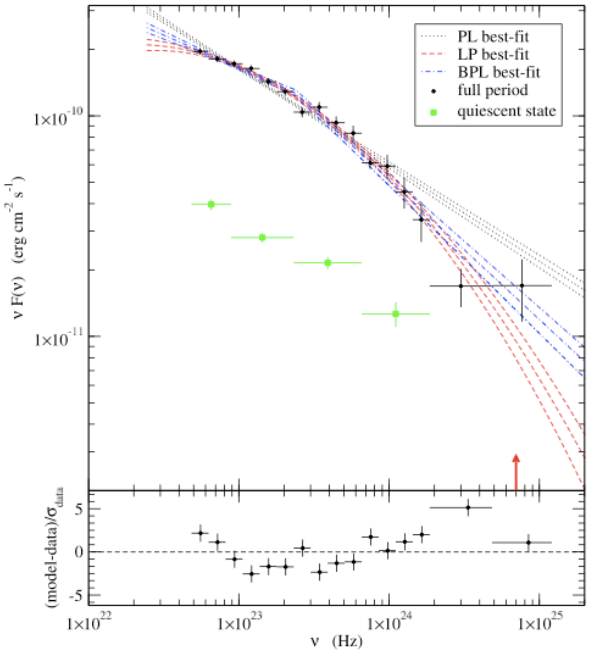
No correlation among Sync and IC peaks, as would be foreseen in one-zone SSC => SSC+ERC or 2 zone SSC

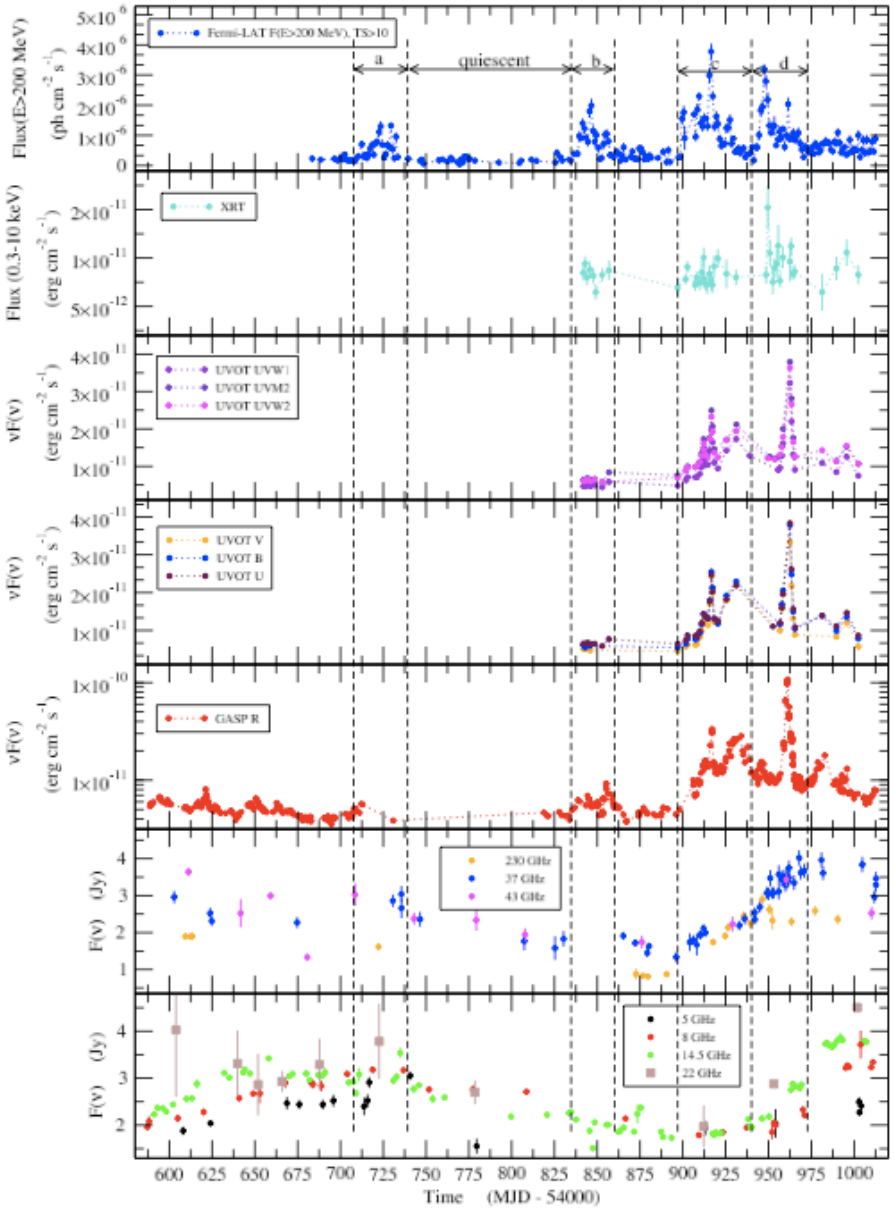
Another 2 zone SSC is S5 0716+71

NON flaring sources - PKS 1510-089

PKS 1510-089: Large Compton dominance, BBB.
νο Ξ <---> γ,
weak UV <---> γ,
significant optical <---> γ.
SSC + ERC

PKS 1502+106: no BBB during flare, similar curved spectrum,
yes X <---> γ and optical <---> γ fluxes,
strong UV <---> γ





Conclusions

After almost 3 years, Fermi has provided incredible new results contributing to improve the comprehension of the physics underlying blazars.

Of the previous knowledge, something has been confirmed but something else still remain unclear and with unexpected developments.

- 3C 454.3 : special source which cooperates a lot !
- Importance of GeV - TeV synergy for BL Lac studies
- Importance of MW studies

"We have understood that we still have to understand..." (Luigi C.)