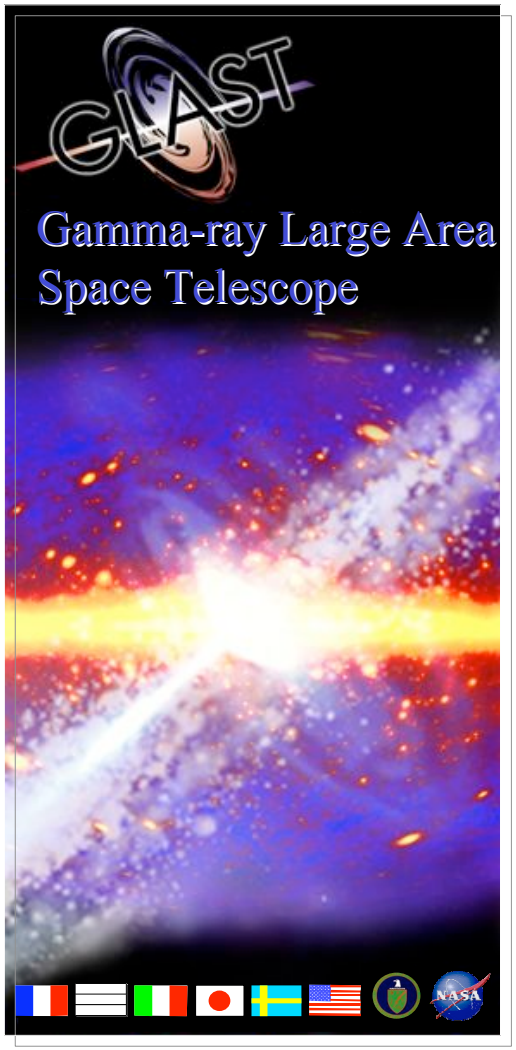


Multiwavelength collaborations of the LAT team

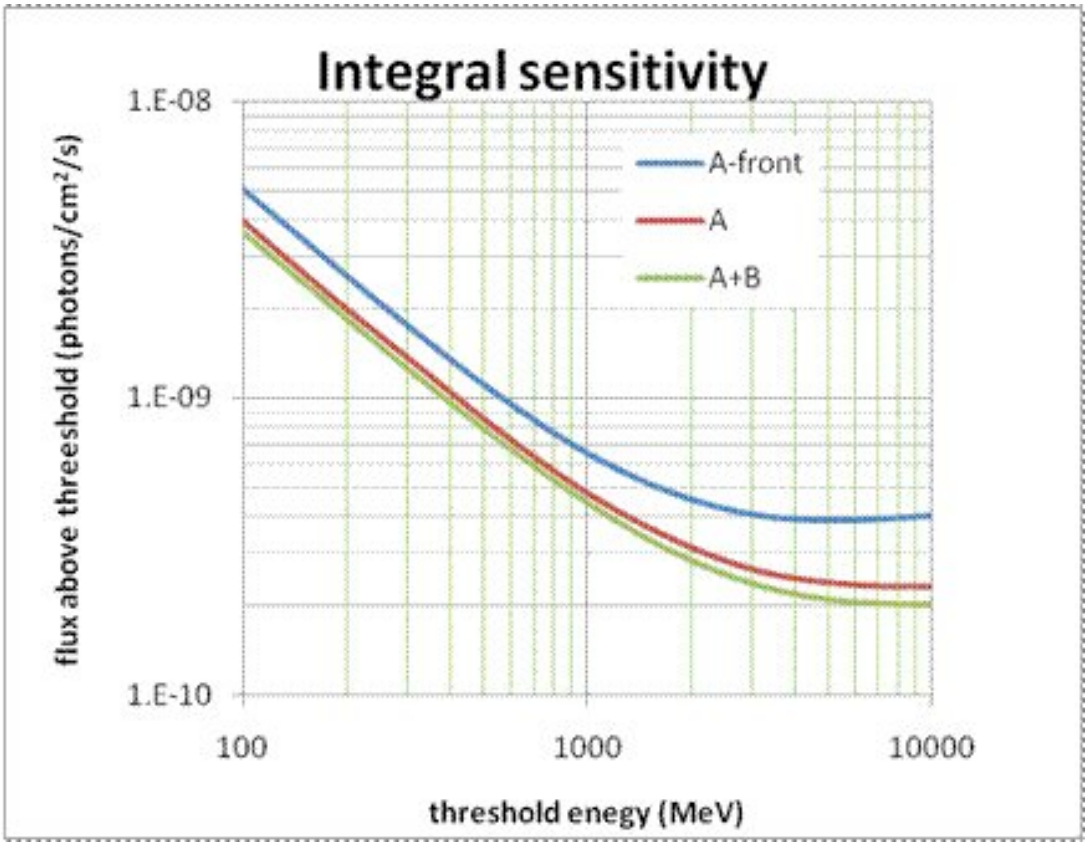
G. Tosti

Physics Dept. & INFN Perugia

GLAST LAT Blazars & other AGNs Science Group

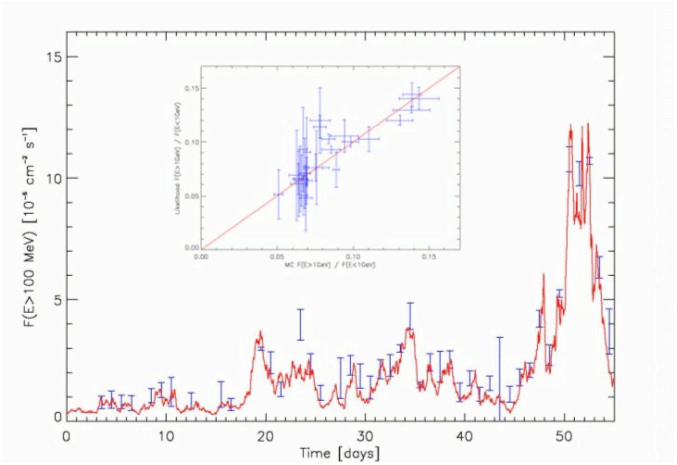
GLAST-LAT & Blazars: LAT Capabilities

- Coverage of about 20% of the sky at any istant with good sensitivity
- The entire sky will be observed every 3 hours
- Uniform exposure in survey mode
- Broad energy range (20 MeV – 300 GeV)



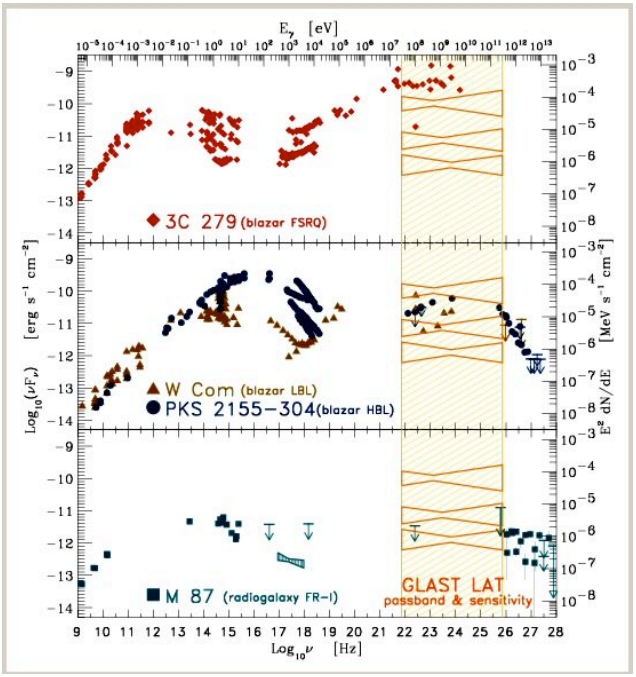
(see Benoit's talk)

GLAST-LAT & Blazars: LAT Capabilities



Simulation of a daily light curve as will be measured by the LAT for 3C279 . The inset displays the true F(E>1 GeV)/F(E<1 GeV) hardness ratios versus the measured ones.

- Daily sampled LC can be easily obtained for most of the bright blazars → Variability on timescales >= 1 day can be well investigated.
- Intra-day (hours) variations can be detected for the brightest gamma-ray blazars.
- Detailed spectral variation analysis and intrabands delays studies may be performed
- Multiepoch SEDs can be obtained.



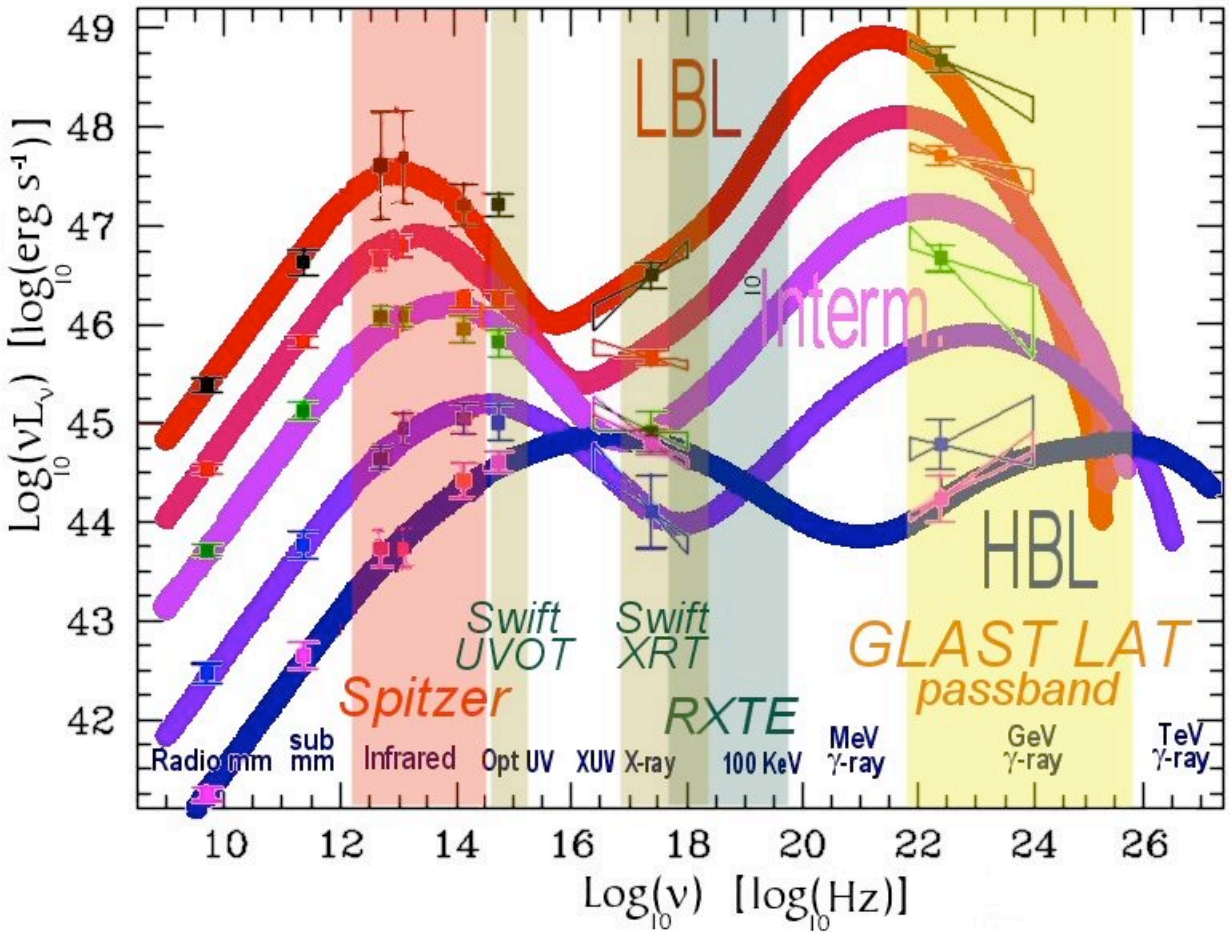
SEDs for four gamma-ray sources and the average expected LAT passband and sensitivity for 1 day, 1 month and 1 year of observations.

Science Goals: GLAST will help provide answers to key questions

- What is the jet beaming factor?
- What is the jet matter content (electron-proton vs. pair plasmas)?
- How are the relativistic electrons accelerated?
- What is/are the jet emission mechanism/s ?
- How and where jets emit gamma-rays ?
- What are the mechanisms producing blazar variability?
- What is the blazar duty-cycle?
- Etc…

GLAST can help to provide an answer to most of the open questions if a good coordination with other [ground/space based] observatories will be established → **Multiwavelength strategies** appear to be a key issue in understanding the blazar phenomenon during the GLAST Mission

The AGN Science Group MW Plan for 2008



Activities based on the AGN SG Science Goals Document (see Benoit's talk)
In coordination with the LAT MW Group (see Dave's Poster)

The AGN Science Group MW Plan for 2008

- **Target of Opportunity (MW-ToO)**
  - **When a source will be in a bright state in gamma ray**
- **Planned Intensive Campaign (MW- IPC, months)**
  - **On a few selected sources**
- **Planned Long-Term Campaign (MW- PLC , >=1 year)**
  - **On a sample of selected sources**

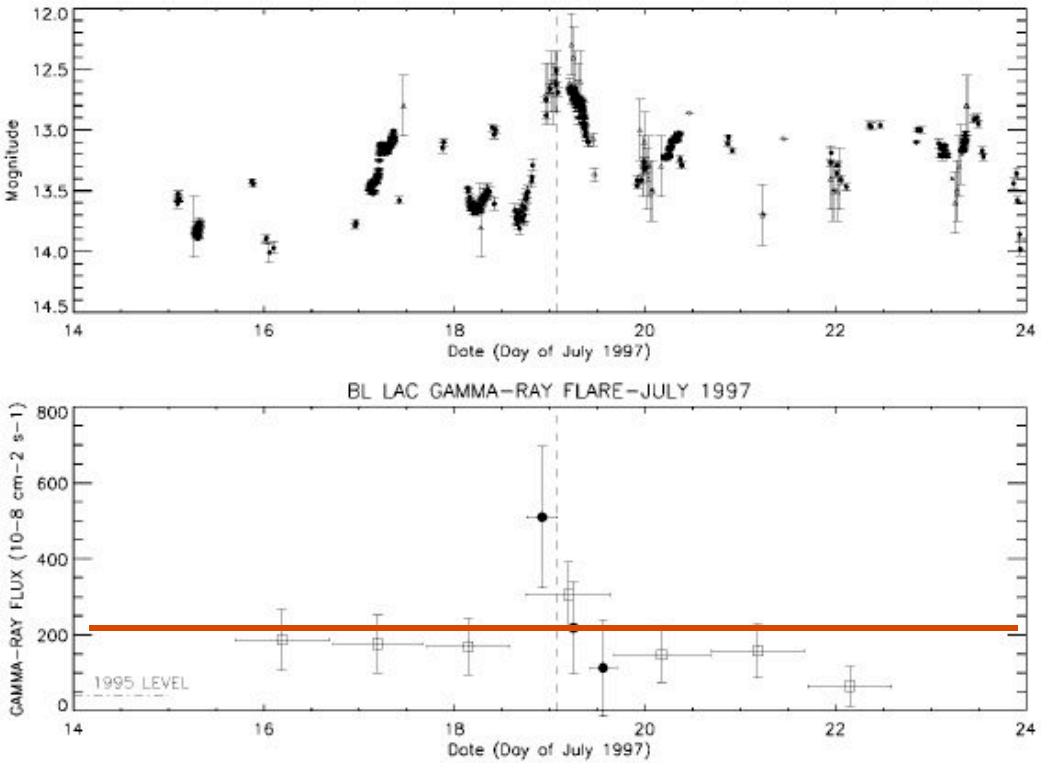
ToO Campaigns

0208-512	3EGJ0210-5055
PKS 0528+134	3EGJ0530+1323
0827+243	3EGJ0829+2413
Mrk 421	3EGJ1104+3809
W Com	3EGJ1222+2841
3C 273	3EGJ1229+0210
3C 279	3EGJ1255-0549
1406-076	3EGJ1409-0745
H 1426+428	
PKS 1622-297	3EGJ1625-2955
1633+383	3EGJ1635+3813
Mrk 501	
NRAO 530	3EGJ1733-1313
1ES 1959+650	
PKS 2155-304	3EG2158-3023
3C 454.3	3EGJ2254+1601
1ES 2344+514	

- **ISOC - Automatic Science Processing tool will monitor about 20 sources on daily and weekly time scales**
- **data will be made public**
- **Fast communication of a flaring event (e.g. GCN Notice-like system)**
- **For all other sources an alert will issue when a** flare over 2×10^{-6} ph cm^{-2} s^{-1} will be observed
- **In 1 yr of LAT, we expect ~24 sources flaring over 2×10^{-6} in the LAT field of view**
- **A LAT- AGN SG contact person ("friend" of a source) will be available to coordinate the MW efforts**

ToO Campaigns:EGRET

BL Lac (1997)



This campaign lead to the constitution of the WEBT (Mattox, 1999)

http://www.to.astro.it/blazars/webt/

ToO Campaigns: BeppoSAX

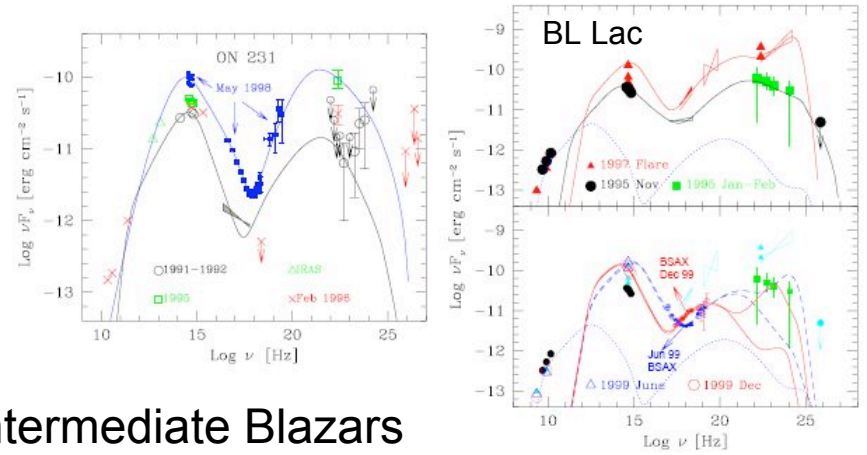
Journal of the *Beppo*SAX Blazars ToO observations

Source Name	Observ. Date	Exposure	Trigger
ON 231	11 May 1998	25 ks	optical
	11 Jun 1998	32 ks	
PKS 2005-489	01 Nov 1998	52 ks	X-ray
BL Lac	05 Jun 1999	54 ks	optical+X-ray
	05 Dec 1999	54 ks	
OQ 530	03 Mar 2000	26 ks	optical
	26 Mar 2000	23 ks	
S5 0716+714	30 Oct 2000	43 ks	optical
MS 14588+2249	19 Feb 2001	48 ks	optical
1ES 1959+65	23 Sep 2001	7 ks	optical
	28 Sep 2001	48 ks	
Mkn 421	22 Jun 1998	32 ks	X-ray
OJ 287	20 Nov 2001	40 ks	Optical

(BeppoSax, 1-200KeV)

Blazars ToO program has been dominated by optical triggers → bias towards LBL

(Tagliaferri 2003)



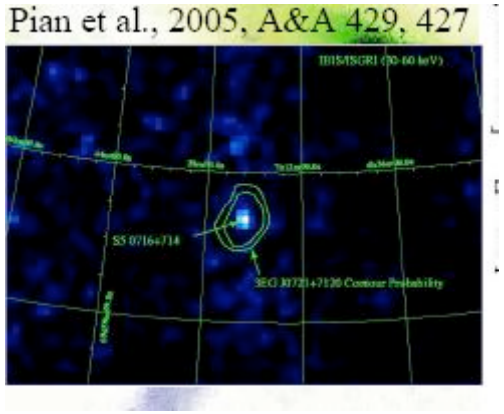
Discovery of several Intermediate Blazars

ToO Campaigns: INTEGRAL

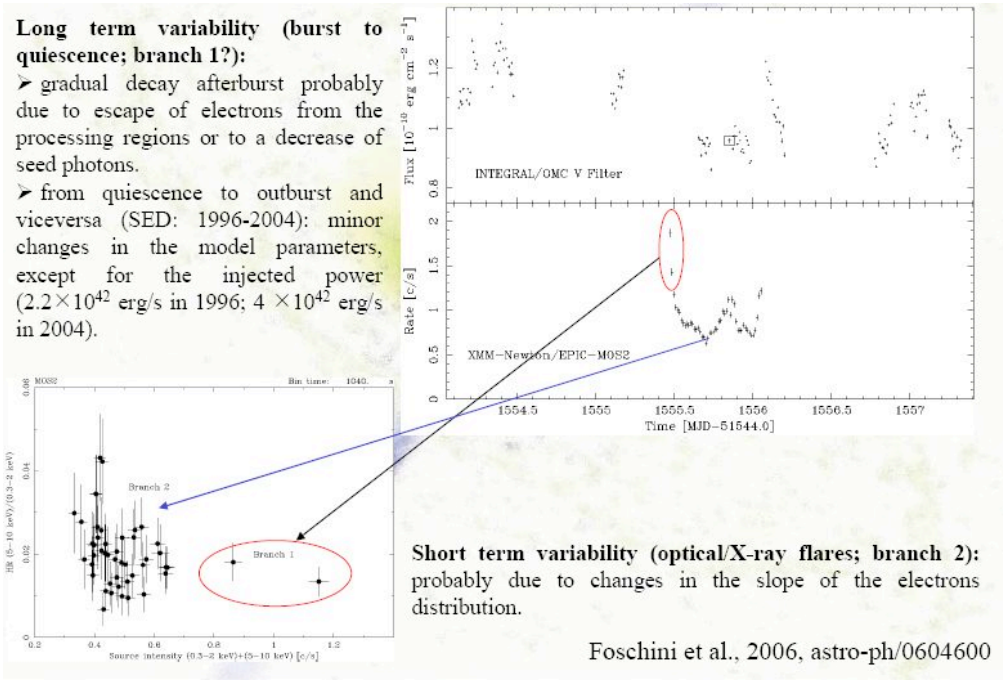
These ToO observations (optical triggered) were so successful that they were continued with other more recent satellite missions

S5 0716+714 0ptical outburst at the end of March 2004: **historical peak** recorded on 27 March 2004 with **R=12.1**!

TOO with *INTEGRAL* (PI E. Pian; 2-7 April 2004; 280 ks) and *XMM-Newton* (PI G. Tagliaferri; 4-5 April 2004; 50 ks):



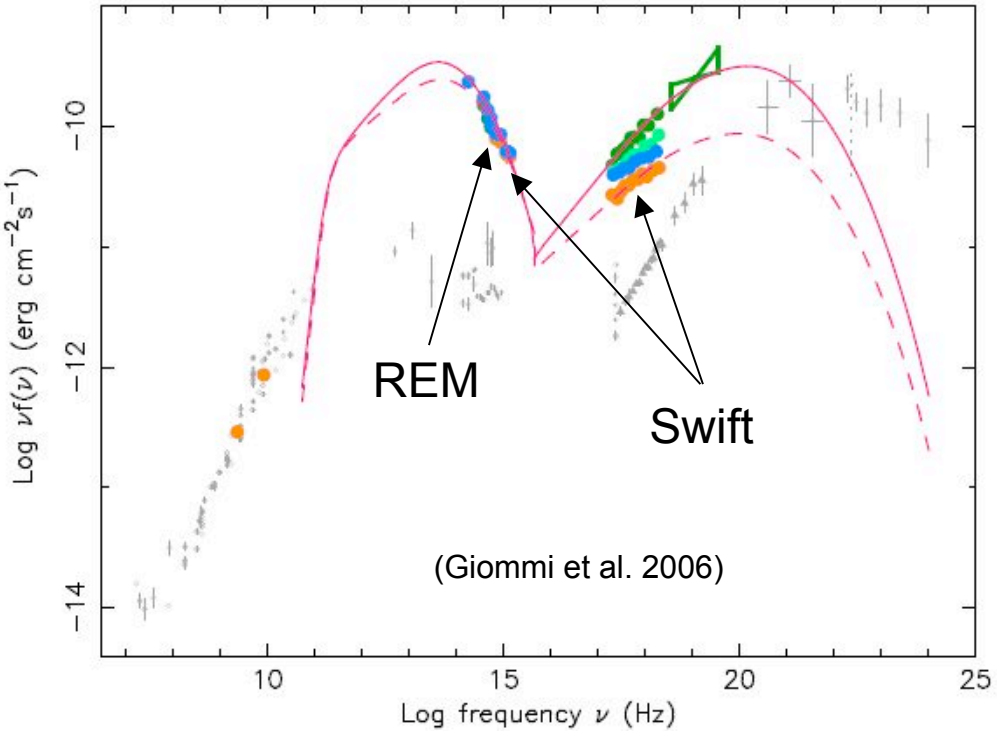
The target has been detected with IBIS/ISGRI up to 60 keV,



Unfortunately the ToOs were approved "too" late… the source was declining…

ToO Campaigns: SWIFT

3C 454.3 blazar of the year 2005



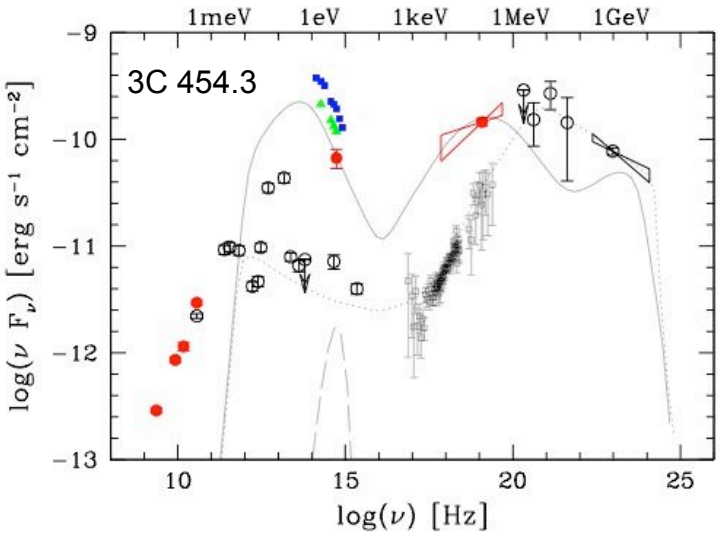
•The observed SED implies that at the time of the Swift pointings **3C 454.3 was one of the brightest objects in the extragalactic sky**.

Time variability in the optical-UV flux is very different from that in the X-ray data:

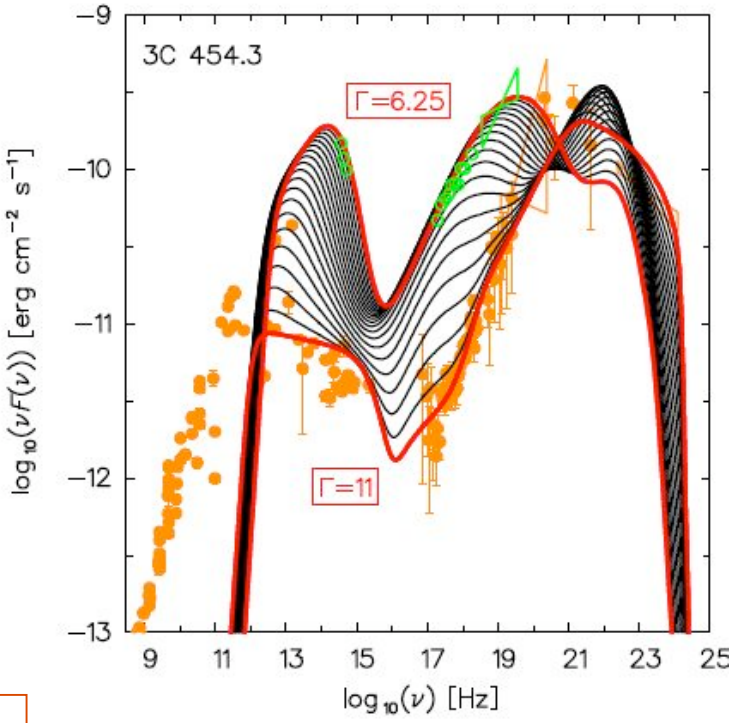
- optical-UV component varied by a factor 2 within a single exposure (constant between different observations)
- Inverse Compton component did not vary on short time-scales but changed by more than a factor of 3 between observations separated by a few days.

We need to collect simultaneous multi- frequency data over a wide range of time-scales to fully constrain physical parameters in blazars.

ToO Campaigns: INTEGRAL



(Pian et al. 2006)



(Katarzinski & Ghisellini, 2007)

Are there sources flaring in the optical and X–ray bands, but not in gamma–rays?

Unfortunately GeV data were not available

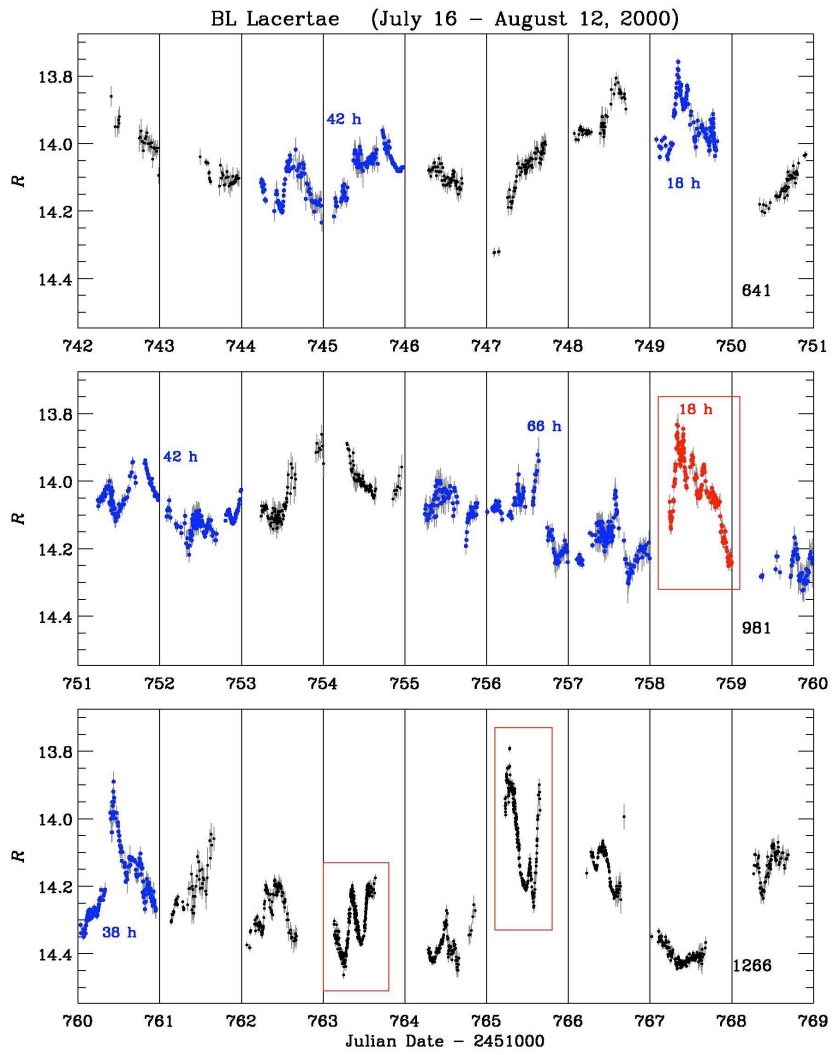
ToO Campaigns: The AGN Science Group List

Proper Name	EGRET name	class	z	F	LAT Proposals Submitted
				10-8ph/cm2/s	
3C 66A	3EG J0222+4253	LBL	0.444	18.7 +/- 2.9	Spitzer, RXTE
AO 0235+16	3EG J0237+1635	LBL	0.940	65.1 +/- 8.8	Spitzer, RXTE, Chandra
PKS 0528+134	3EG J0530+1323	FSRQ(LP)	2.060	93.5 +/- 3.6	Spitzer, RXTE, Chandra
PKS 0537-441	3EG J0540-4402	LBL	0.894	25.3 +/- 3.1	Spitzer, RXTE
S5 0716+71	3EG J0721+7120	LBL	0.300	17.8 +/- 2	Spitzer, RXTE
PKS 0735+17	3EG J0737+1721	LBL	>0.424	16.4 +/- 3.3	Spitzer, RXTE
OJ 248	3EG J0829+2413	FSRQ	0.940	24.9 +/- 3.9	Spitzer, RXTE
OJ 287	3EG J0853+1941	LBL	0.306	10.6 +/- 3	Spitzer, RXTE
S4 0954+65	3EG J0958+6533	LBL	0.368	15.4 +/- 3	Spitzer, RXTE
W Com	3EG J1222+2841	IBL	0.102	11.5 +/- 1.8	Spitzer, RXTE
3C 273	3EG J1229+0210	FSRQ(LP)	0.158	15.4 +/- 1.8	Spitzer, RXTE
3C 279	3EG J1255-0549	FSRQ(HP)	0.536	179.7 +/- 6.7	Spitzer, RXTE
PKS 1406-076	3EG J1409-0745	FSRQ(LP)	1.494	97.6 +/- 9.1	Spitzer, RXTE
PKS 1510-08	3EG J1512-0849	FSRQ	0.320	18 +/- 3.8	Spitzer, RXTE
PKS 1622-29	3EG J1625-2955	FSRQ(LP)	0.815	258.9 +/- 15.3	Spitzer, RXTE
BL Lac	3EG J2202+4217	LBL	0.069	39.9 +/- 11.6	Spitzer, RXTE, Chandra
CTA 102	3EG J2232+1147	FSRQ(HP)	1.037	19.2 +/- 2.8	Spitzer, RXTE
3C 454.3	3EG J2254+1601	FSRQ(HP)	0.859	53.7 +/- 4	Spitzer, RXTE

These sources are also included in the ToO sources list of non-LAT (but coordinated with LAT) proposals:

- XMM (PI. G. Tagliaferri) accepted
- INTEGRAL (PI. E. Pian) submitted

WEBT Coordinated Campaigns:BL Lac



(July 16 - August 12, 2000)

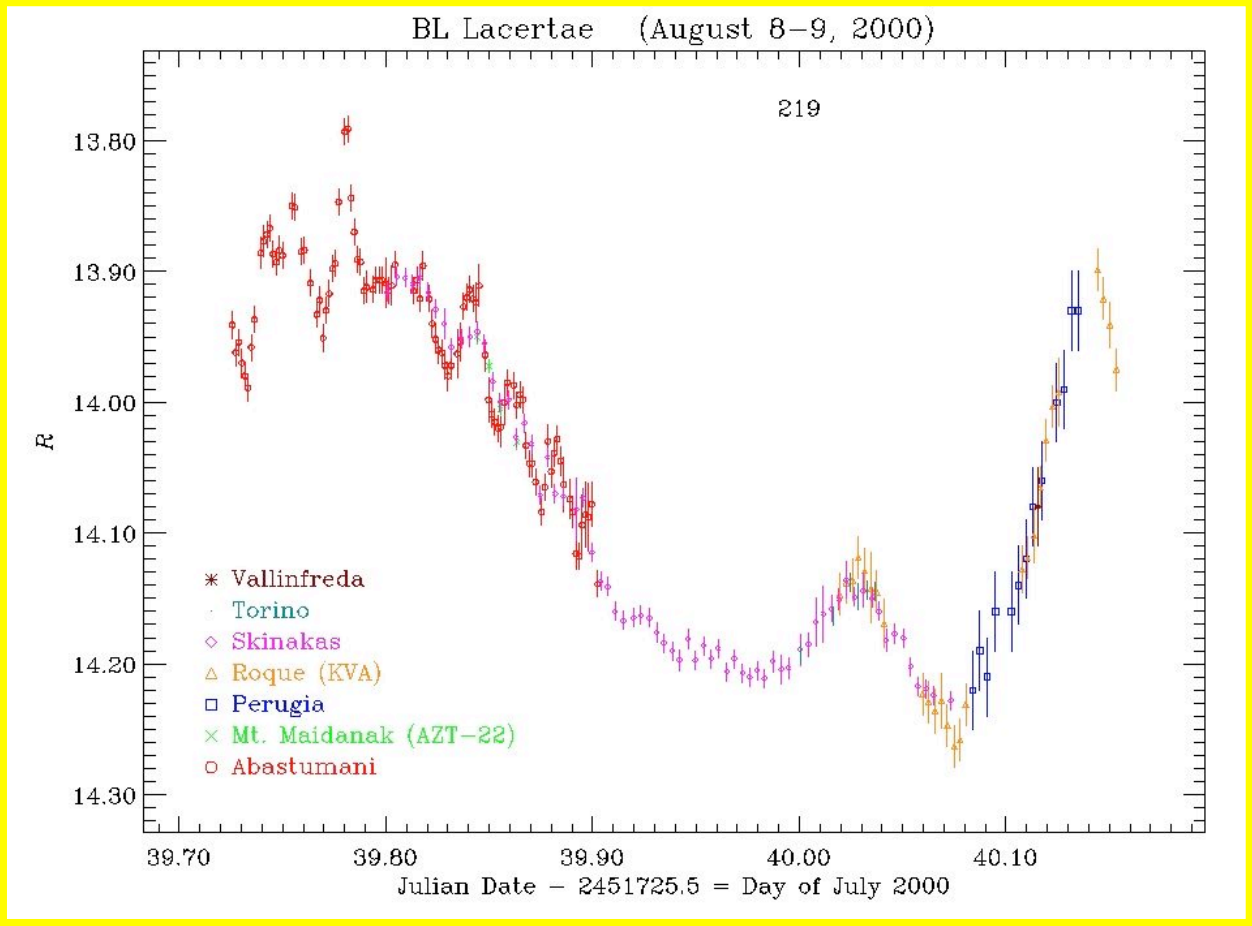
19 telescopes from Japan to Western Canada

Blue/red segments indicate the best covered periods (gaps < 4 hours)

2888 *R* final data in 27 days
107 data/day
$\Delta t(R) \sim 13$ min

Problem: paucity of observers in the Pacific area

WEBT Campaign:BL Lac 2000

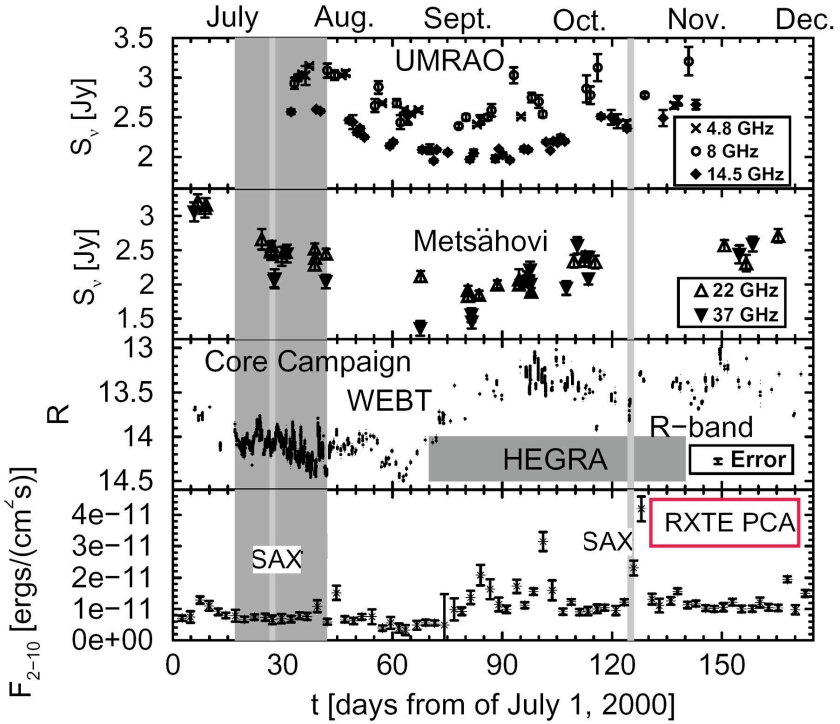


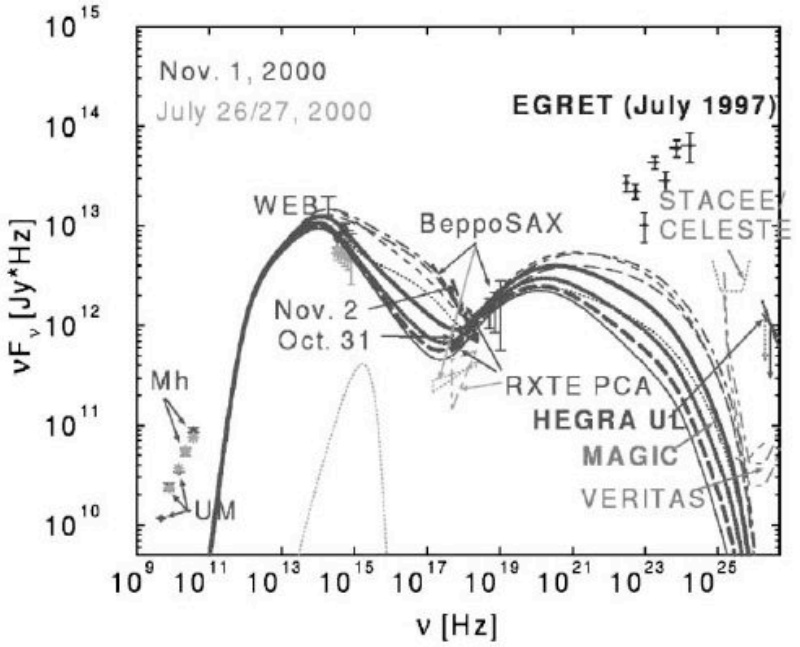
7 telescopes from Uzbekistan to La Palma

219 *R* final data in 10.3 hours $\Delta t(R) \sim 2.8$ min

0.5 mag brightness fall in ~7 h, followed by ~ 0.4 mag brightening in 1.7 h

WEBT Coordinated Campaign:BL Lac





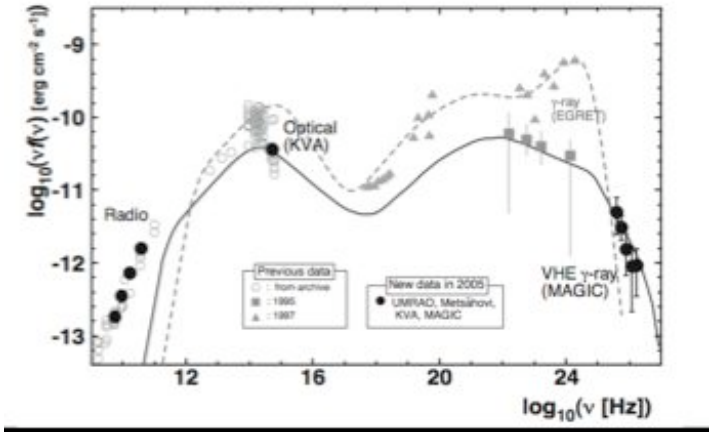
"..Model revealed that the observed optical and X-ray spectral variability in BL Lacertae in 2000 can be reproduced hrough short-term fluctuations of only the electron injection spectral index, with all other parametersremaining unchanged.."

(Bottcher et al. 2004)

MW – Planned Intensive Campaings (1-3 months)

Source Name	Epoch (mm,yyyy)	Campaign Manager
PKS 0528+134	02/11,2008	B. Lott
3C 279	01,2009	G. Madejski
Mrk 501	04-07,2008	D. Paneque
1ES 1959+650	05-10,2008	
Mrk 421	03-05,2008	
PKS 2155-304	07- 08,2008	B. Giebels
BL Lacertae	08-09,2008	G. Tosti

BL Lacertae detected by MAGIC (astro-ph/0703084)

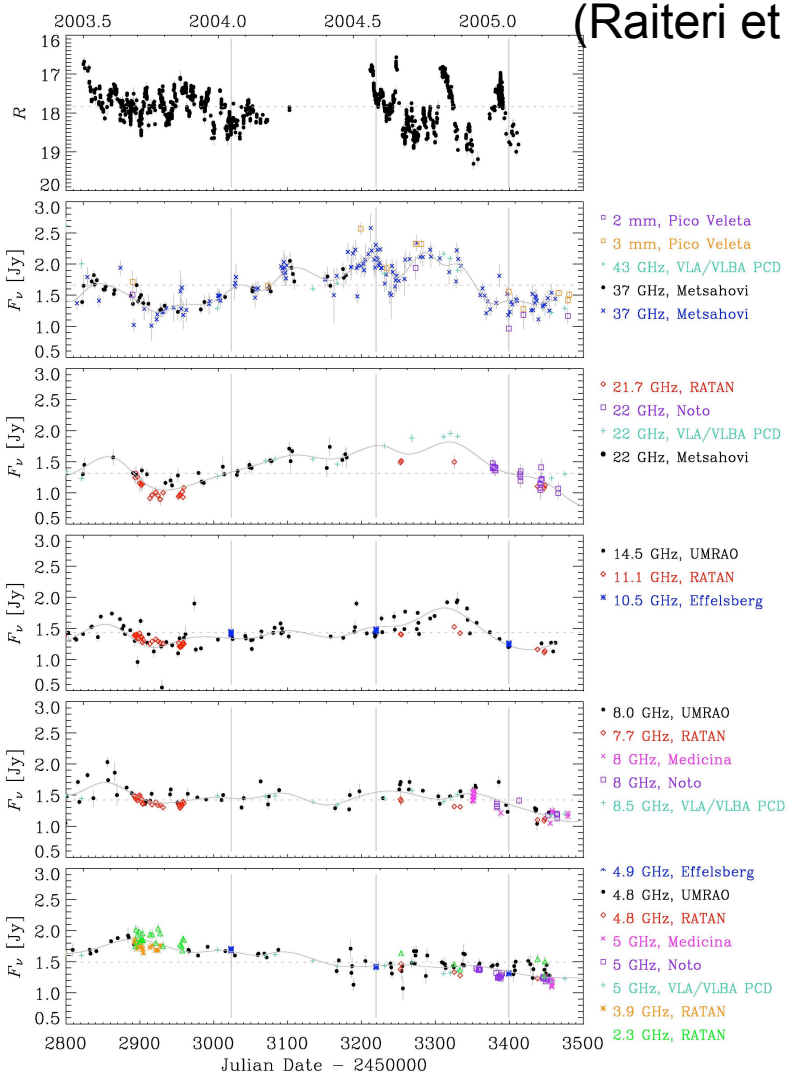


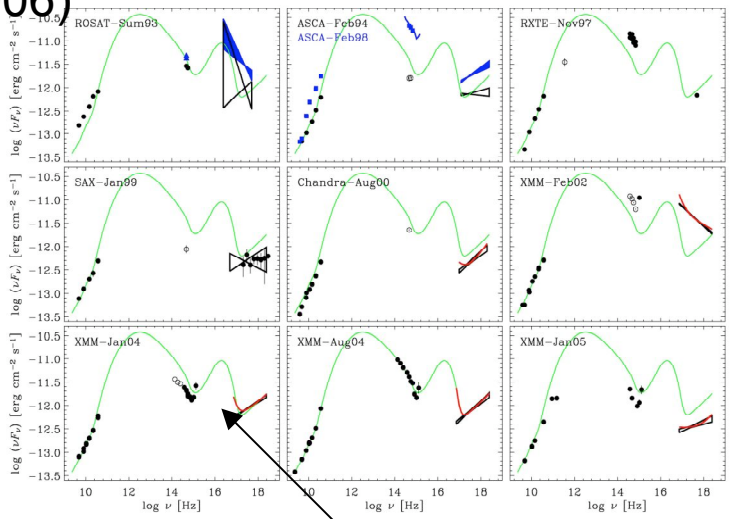
Other Sources of interest for MW-PIC

PKS 0735+178 , PKS 0537- 441, AO 0235+164, OJ 287, PKS 1510-08
S5 0716+714, W Com (ON 231), 3C 66A, 3C 454.3

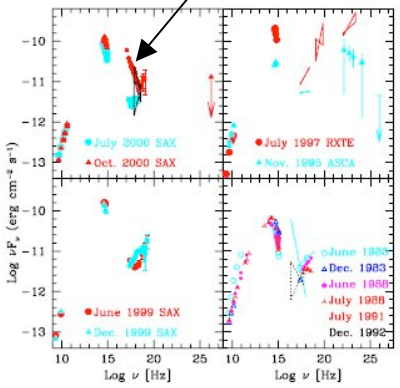
WEBT Long term Campaign: AO 0235+16

(Raiteri et al. 2006)





Extra Component ?



BL Lac

(Ravasio et al. 2003)

MW observations: Long Term Monitoring

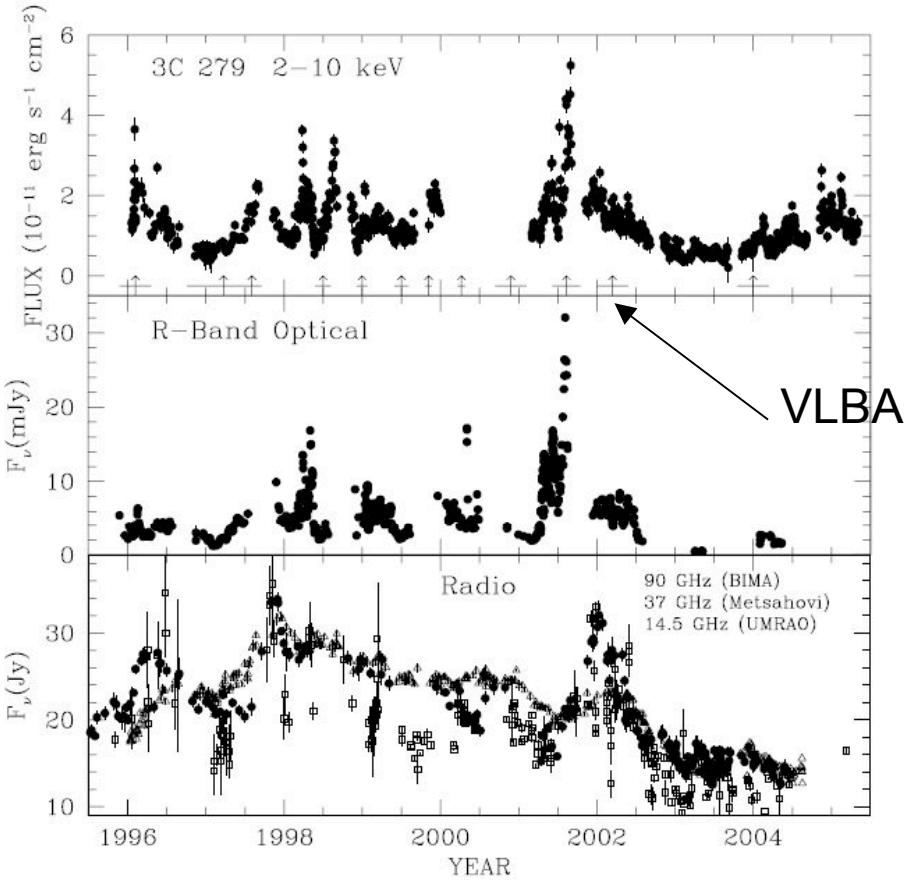


Figure 4. X-ray, optical, and radio/mm-wave light curves of 3C 279. Arrows give times of known ejections of superluminal radio knots up to 2004.3. Ejections in mid-1996 may have been missed because of gaps in the time coverage of VLBA observations. Data are from Marscher et al. (2004) and Marscher et al. (2006).

(Marscher 2006)

"..The great problem in interpreting multiwaveband light curves: **How can we associate high and low flux states at one frequency with those at another?"**

Can polarisation studies help?

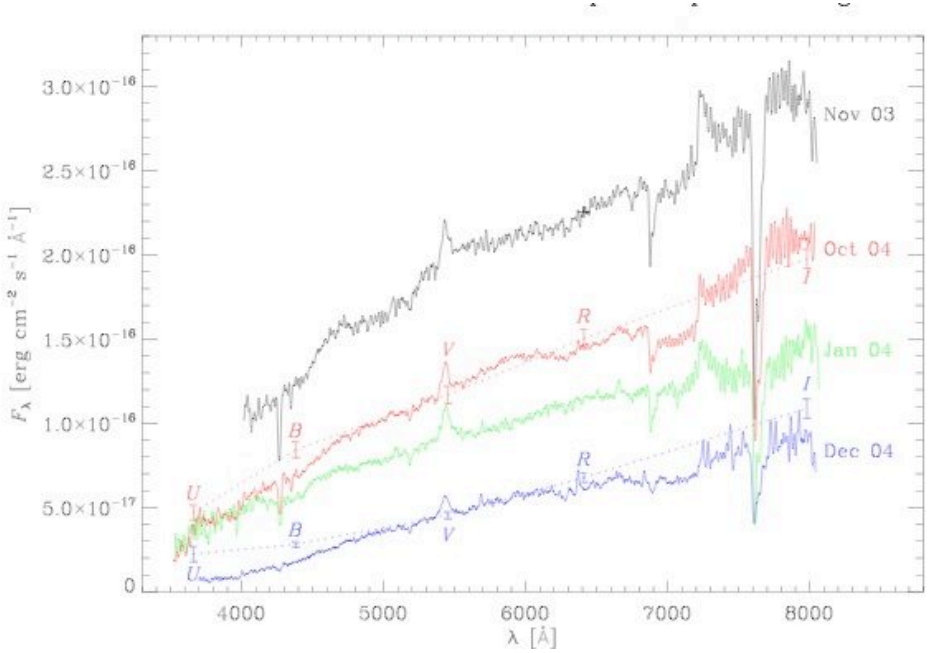
Marscher & Jorstad (2005) show an example of similarities in the **polarization electric-vector position angles** of some blazars at 7 mm, 1.3/0.85 mm and optical wavelengths.

See D'arcangelo et al. 2007 for some recent results on PKS 0420-014

but….. only a few polarimetric facilities are available in the optical

Spectroscopic Monitoring: AO 0235+16

Provide Important information on the different components of an AGN



The source was in a faint state, and a broad Mg II emission line was clearly detected in all spectra. The flux of the line showed an overall variation by a factor 1.9, while the continuum flux density changed by a factor 4.3.

The line Flux is independent of the optical continuum (as in BL Lac).

Aug. 2003 - Aug. 2004: VLT+TNG (Raiteri 2007)

It will be important to have a spectroscopic monitoring of a few sources

Known/Candidate Blazars Catalogs

GLAST always observes all blazars in the sky…..waiting for MW all Sky Monitor

On-line ASDC tables

- Multi-wavelength catalog of (known) Blazars. Massaro et al. 2005 http://www.asdc.asi.it/bzcat
- The Sedentary survey of extreme HBL BL Lacs. Giommi et al. 2005 http://www.asdc.asi.it/sedentary
- ASDC Rosat-NVSS-SDSS Blazar Sample. Turriziani et al., http://www.asdc.asi.it/blsloan
- Blazars observed by BeppoSAX. Giommi et al. 2002 http://www.asdc.asi.it/blazars
- WMAP catalog of Bright foreground sources (Bennett et al., Giommi et al.) http://www.asdc.asi.it/wmap

VIPS

- http://www.phys.unm.edu/~gbtaylor/VIPS/

Candidate Gamma Ray Blazar Sample (CGRaBs) (Romani et al.)

Like most of the Blazars detected by EGRET, also most of the new candidates are faint in optical(R>23):

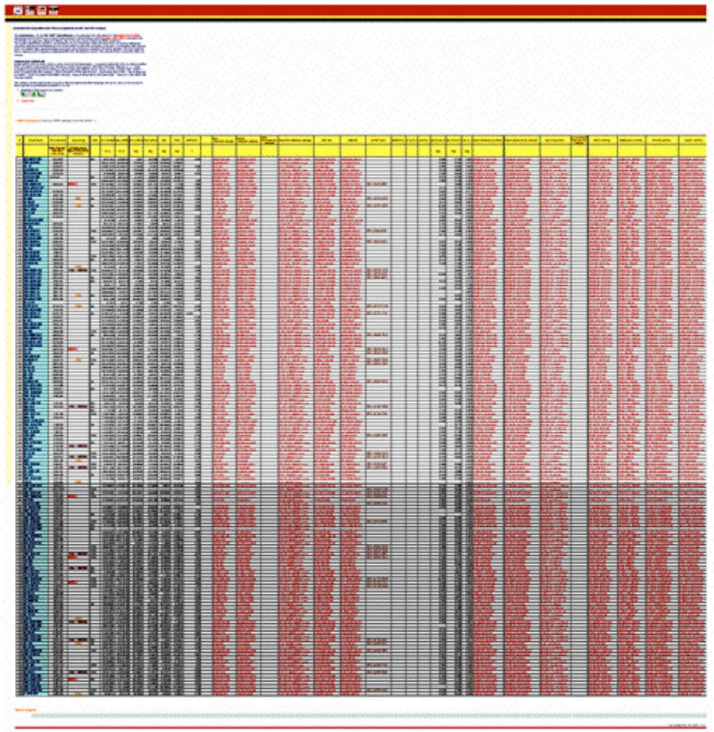
---> Large telescopes to follow-up GLAST detections

Bright Sources

GLAST always observes all blazars in the sky: …..waiting for MW all Sky Monitors

A public web-page with a table of 150 "VIP" AGN/blazar targets for GLAST and MW analysis:
`http://glastweb.pg.infn.it/blazar/`

- Bright AGN/blazars assembled trying to collect basic data with direct links to existing databases (avoiding duplication/obsolescence).
- This web-table can be useful to **plan long term MW campaign**, to select input sources for science **Proposals to MW facilities** (other satellites, ground-based obs.), to perform simultaneous MW analysis joint with the GLAST data, spectral-temporal analysis/comparison based on long-term historical datasets, etc.
- **It might be also a starting point to develop a dedicated MW blazars database for GLAST**.



of course it will be revised when GLAST will be is in orbit

Please check the list an send us your comment, suggestions, sources

LAT AGN MW Collaborations:Radio

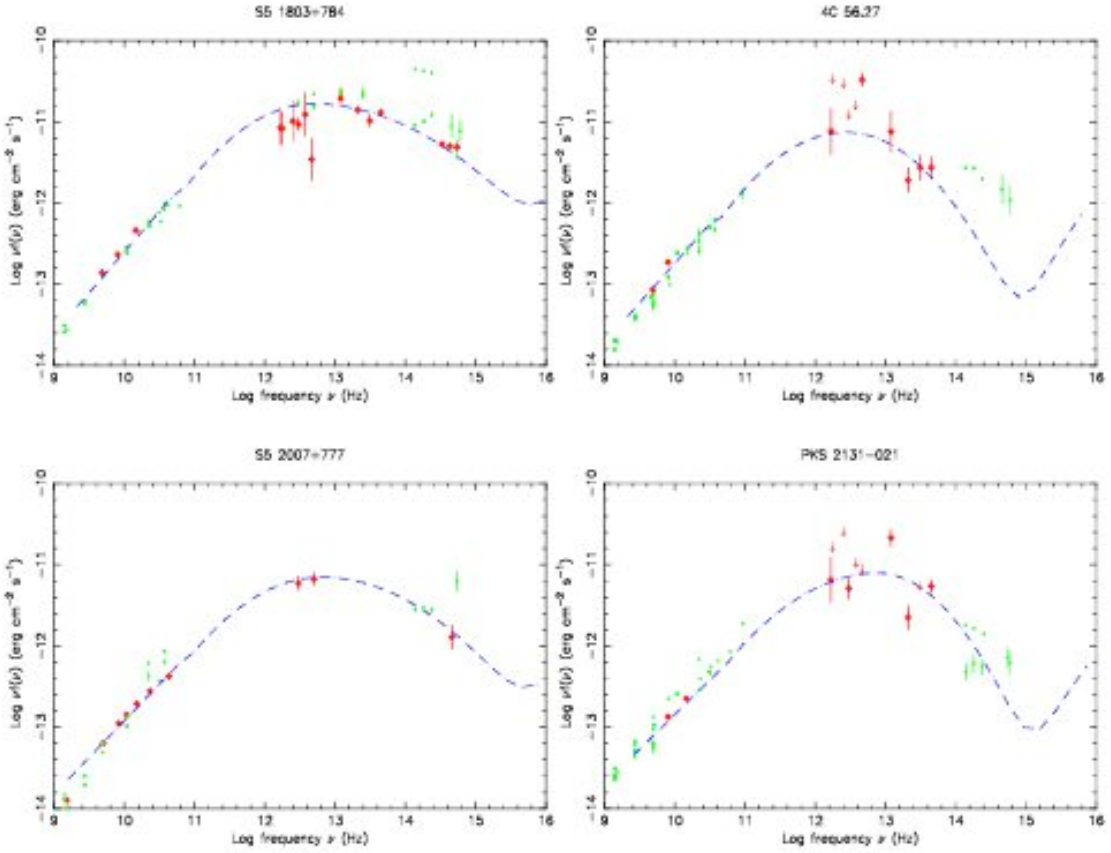
- VLBI
  - MOJAVE
  - VIPS
  - Marscher
  - European VLBI Net

- Single Dish
  - RATAN-600
  - Michigan
  - Metsähovi
  - Torun,
  - Eastern Kentucky,
  - Owens Valley,
  - LMT,
  - Effelsberg
  - others?

NRAO-GLAST MOU
Southern Hemisphere coverage is weak?

LAT AGN MW Collaborations:Infrared

ISO Observations of 1Jy BL Lac Objects



Synchrotron peak centered At 30 μm

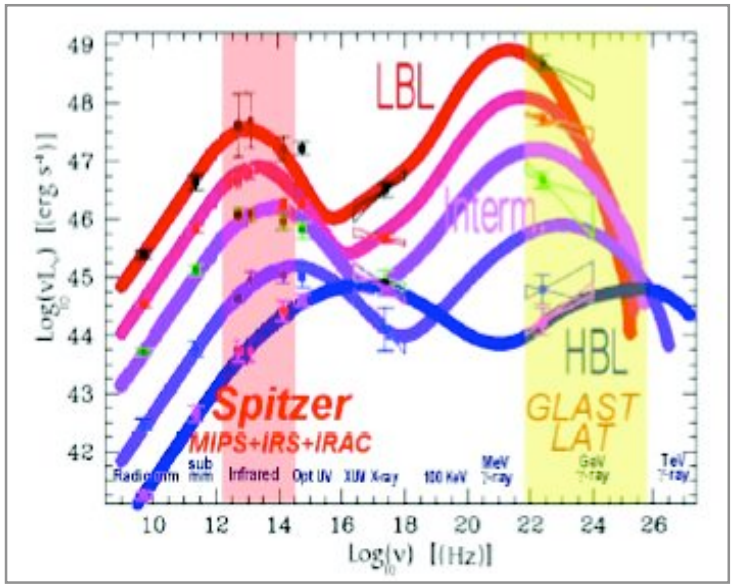
(Padovani et al. 2006)

LAT AGN MW Collaborations: Infrared

Spitzer-GLAST Blazars (PI A. Wehrle)

❑Population Study. A broad IR survey of **100 blazars** in a flux-limited sample from the all-sky WMAP catalog, twice with the IRS instrument on board of Spitzer.

❑ **Detailed Studies of 5 Archetypal Blazars**. Disentangling the emission processes at work. Intensive observations of 5 blazars daily during intense month-long global multiwavelength GLAST campaigns. Time resolved SEDs, light curves and interband variability.



–Far IR –
–Herschel (to be launched)
–Mid-IR -
–VISIR, IRAIT
–Near IR
– Magdalena Ridge,REM, others?

However, overall coverage seems limited

LAT AGN MW Collaborations: Optical-UV

- Optical:
  - Groups
    - –WEBT
    - –GTN
    - –U.S. observers (Miller, Webb, Carini, Balonek,others)
  - Telescopes
    - –REM
    - –NOT
    - –Liverpool
    - –Hiroshima
    - –Swift UVOT
  - Surveys
    - –PanStarrs, SkyMapper

– UV:
  - GALEX?
  - FUSE?

-Southern Hemisphere coverage is weak
-Robotic-telescopes involved in GRBs follow-up
Should be involved

LAT AGN MW Collaborations: WEBT

The WEBT support to the GLAST observations will consist of both:

long-term monitoring

about 15 observatories 30 blazars

shorter-term campaigns

all the WEBT collaborators (typically 30–50 observatories).

GLAST-AGILE Support Program (GASP) Source List

IAU Name	Object Name	Priority	RA (J2000.0) [h m s]	DEC (J2000.0) [d m s]	Redshift z	Finding Chart
0219+428	3C 66A	1	02 22 39.6	+43 02 08	0.444	
0235+164	AO 0235+16	1	02 38 38.9	+16 36 59	0.94	
0420-014	PKS 0420-01	2	04 23 15.8	-01 20 33	0.914	
0528+134	PKS 0528+134	2	05 30 56.4	+13 31 55	2.06	
0716+714	S5 0716+71	1	07 21 53.4	+71 20 36	0.3	
0735+178	PKS 0735+17	1	07 38 07.4	+17 42 19	0.424	
0827+243	OJ 248	2	08 30 52.1	+24 11 00	0.939	
0829+046	OJ 49	2	08 31 48.9	+04 29 39	0.173683	
0836+710	4C 71.07	2	08 41 24.3	+70 53 42	2.172	
0851+202	OJ 287	1	08 54 48.9	+20 06 31	0.306	
0954+658	S4 0954+65	1	09 58 47.2	+65 33 55	0.368	
1101+384	Mkn 421	1	11 04 27.3	+38 12 32	0.030021	
1156+295	4C 29.45	1	11 59 31.8	+29 14 44	0.729	
1219+285	ON 231	1	12 21 31.7	+28 13 59	0.102	
1226+023	3C 273	2	12 29 06.7	+02 03 09	0.158339	
1253-055	3C 279	1	12 56 11.1	-05 47 22	0.5362	
1510-089	PKS 1510-08	2	15 12 50.5	-09 06 00	0.36	
1611+343	DA 406	2	16 13 41.0	+34 12 48	1.401	

X-ray Proposals Accepted/Submitted

	Facility	Lead	Sources		Period
1.	**Suzaku Cycle 2**	**G. Madejski**	**PKS0528+134**	**(accepted)**	**Jan.-Apr. 2008**
2.	RXTE cycle 12	G. Tagliaferri	ToO (18 EGRET blazars)		launch-03/2009
3.	RXTE cycle 12	J. Carson	ToO on 3C273		launch-03/2009
4.	RXTE cycle 12	B. Giebels	PKS 2155-304		launch-03/2009
5.	RXTE cycle 12	G. Tosti	BL Lac		launch-03/2009
6.	RXTE cycle 12	D. Paneque	Mrk 421, Mrk 501, 1ES 1959+650		launch-03/2009
7.	RXTE cycle 12	G. Madejski	3C279		launch-03/2009
8.	RXTE cycle 12	B. Lott	PKS 0528+134		launch-03/2009
9.	Chandra Cycle 9	G. Madejski	ToO on flaring blazar		12/2007-12/2008
10.	INTEGRAL AO-5	V. Lonjou	KP Cygnus region (including BL Lac)		08/2007-08/2008
11.	INTEGRAL AO-5	W.Collmar	KP Program NE region		08/2007-08/2008
12.	INTEGRAL AO-5	L. Foschini	KP Galactic Center		08/2007-08/2008

- Insufficient number of observed sources
- Probably Swift will be the most important single MW resource we can have for the LAT (GLAST-SWIFT teams are discussing to obtain coordinated observations)

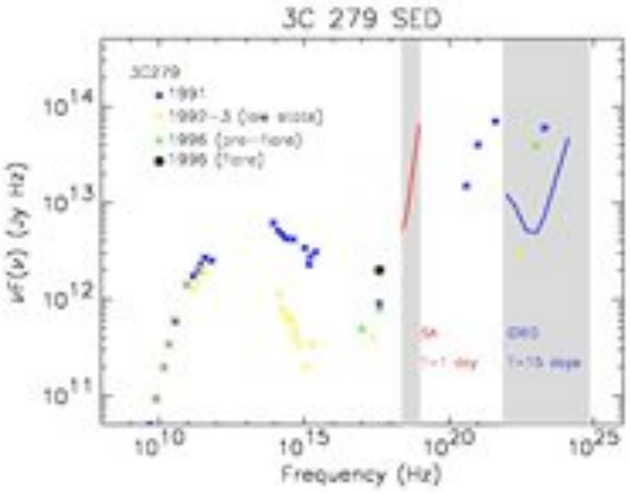
LAT AGN MW Collaborations : GeV-TeV

GeV:

- AGILE (launched April 23, 2007)

- **GRID in the gamma-ray energy range (30 MeV-30 GeV)**

- **Super-AGILE in the hard X-ray range (15-60 keV).**



The AGILE satellite integrated on the fourth stage of the PSLV rocket (April 15, 2007)

http://agile.rm.iasf.cnr.it/

LAT AGN MW Collaborations : GeV-TeV

TeV:

- **Joint RXTE proposal with H.E.S.S. for 2155-304**
- **Agreements with MAGIC and VERITAS for possible cooperation on RXTE TOOs**

(Ong, ICRC 2005)

We have a draft MOU with the H.E.S.S. group (in review by them) and informal agreements with CANGAROO, MAGIC, and VERITAS.

Conclusions

- *We invite all of you to join the LAT team MW campaigns on blazars*

- More information about the LAT MW activities, can be found at **http://glast.gsfc.nasa.gov/science/multi/**.
- People interested to collaborate with the LAT team in MW activities on blazars can contact:
- the LAT MW coordinator: D. Thompson (**djt@egret.gsfc.nasa.gov**)
- the LAT AGNs science group coordinators (**lott@cenbg.in2p3.fr** and **tosti@pg.infn.it**)
- the MW-PIC Campaign Managers:
- **lott@cenbg.in2p3.fr** for PKS 0528+134
- **tosti@pg.infn.it** for BL Lacertae
- **madejski@slac.stanford.edu** for 3C 279
- **carson@slac.stanford.edu** for 3C273
- **dpaneque@slac.stanford.edu** for 1ES 1959+654, Mkn 421 and Mkn 501;
- **berrie@poly.in2p3.fr** for PKS 2155-304

....your comments, suggestions, observations are welcome