5th Science AGILE Workshop

AGILE's First Year of Gamma-ray Astrophysics

ESRIN, Frascati, Roma,
12-13 June, 2008

An Example of Blazar Multiwavelength Activities as Prelude of the New Gamma-ray Era

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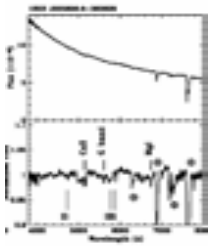
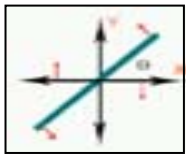
Summary

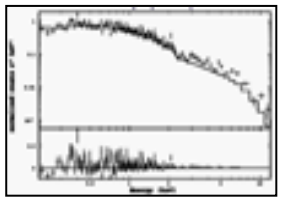
- Spectroscopy



- Polarization



- Multiwaveband campaigns



- Variability Flux Monitoring

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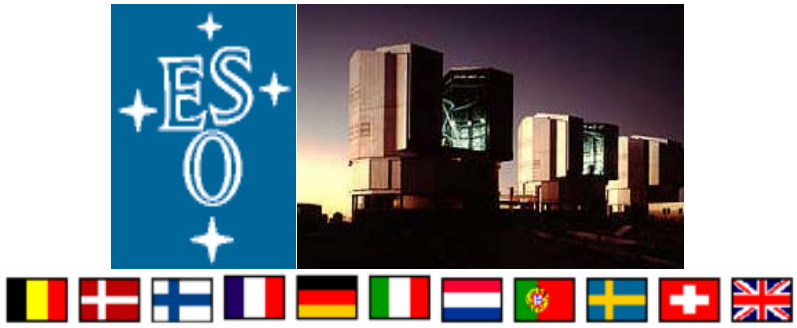
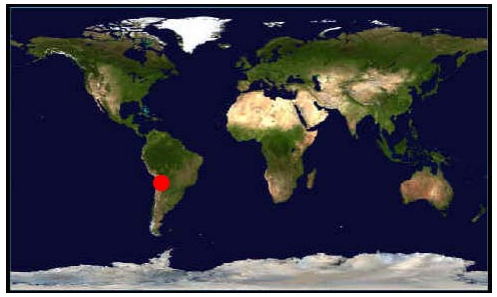
ESO Very Large Telescope high S/N spectroscopy of blazars

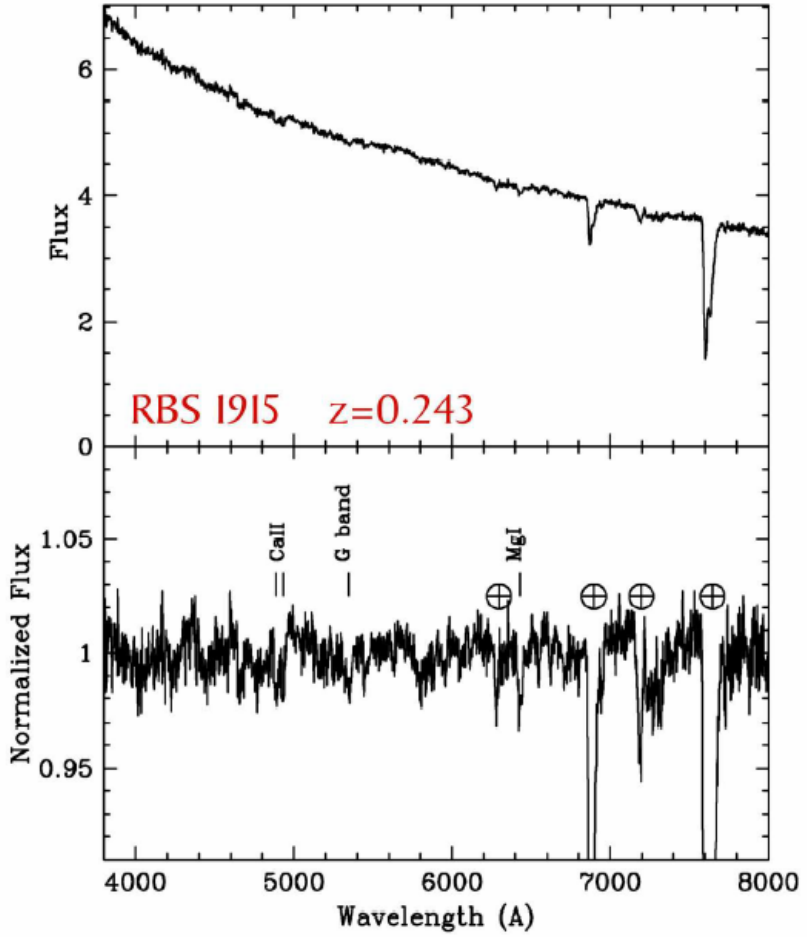
- Quasi-featureless spectra of BL Lac objects hinders the determination of their redshifts.
- Anyway knowledge of blazars' distance is important to constraint their physics, their intrinsic bolometric emission power, to select the best gamma-ray blazar-probes for the study of the cosmic EBL, to have a rather sure classification of an high-energy source, and sometimes to have a right blazar identification between close optical pair/multiple counterparts that can be put in the same slit and observation.
- In this view a program at the ESO 8m VLT for high S/N optical spectroscopy of BL Lac objects lacking a firm redshift estimate is ongoing:
  → 3 VLT runs accepted in 2003 and 2004 (ESO P71, P72, P73), all with PI A. Treves.
  → 3 VLT run accepted in 2006, 2008 and 2008-09 (ESO P77, P81, P82) all with PI: S. Ciprini.





ESO Very Large Telescope high S/N spectroscopy of blazars

- Why the VLT 8-meter (315 inch) "monster" telescopes ?
- The 4m-telescope class has achieved its limit regarding to BL Lac with quasi-featureless optical spectra → High S/N and spectral resolution needed in reasonable integration observing times.
- VLT run 2006 (P77) results: 15 observed objects, 12 confirmed as BL Lac objects, 1 a sub-DLA system, 1 reclassified as FSRQs, 1 misclassified, for 4 BL Lac objects a new determination. For the remaining 8 BL Lacs we give redshift lower limits based on the minimum detectable equivalent width of their featureless spectra (Sbarufatti et al. 2008, AJ, submitted).



Adapted by Sbarufatti et al. 2008, AJ, submitted.

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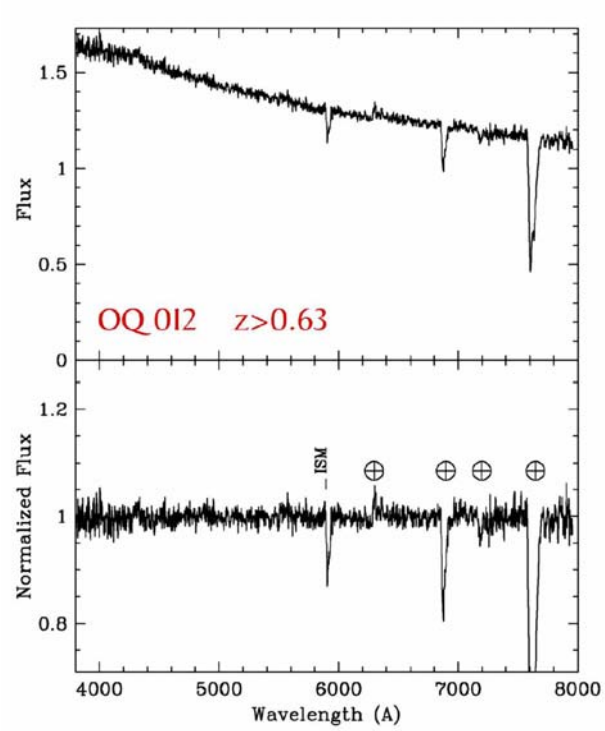
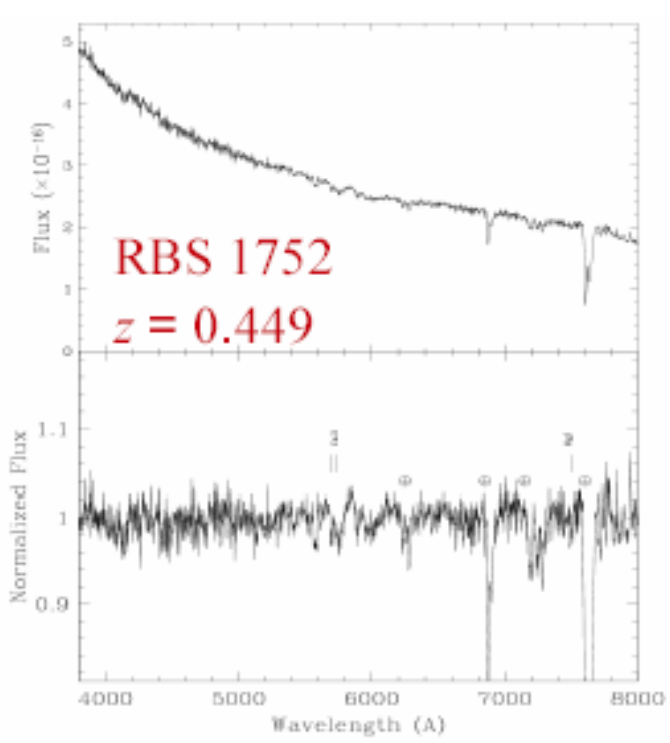
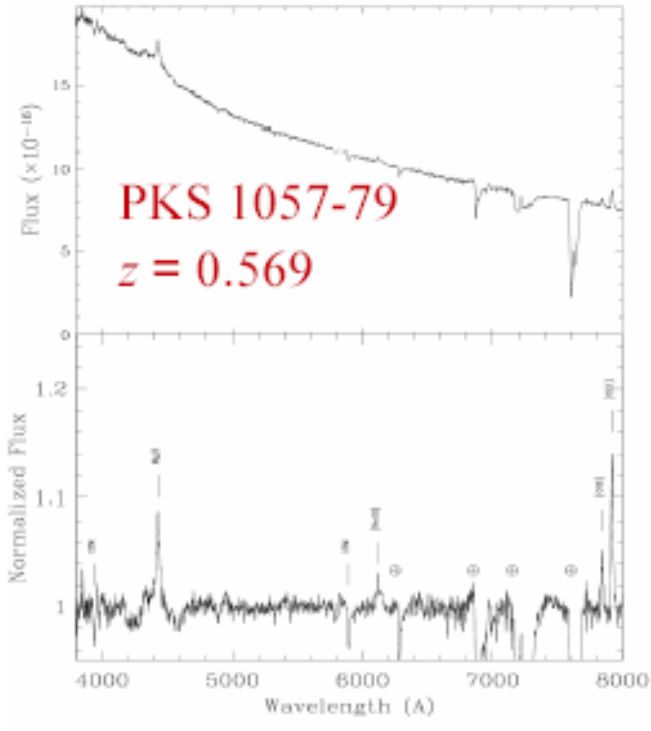
ESO Very Large Telescope high S/N spectroscopy of blazars

- Example of faint source-intrinsic lines detected: emission lines ([OIII], [NeIII], [MgII], [OII], H-beta, H-alpha, [NII], MgII); and absorption lines (CaII, MgI, G-band, and FeII, MgII in PKS 0823-223, a sub-damped Lyman-alpha absorber at z=0.91). Minimum Equivalent Width detected is between 0.09 and 1.84 A.







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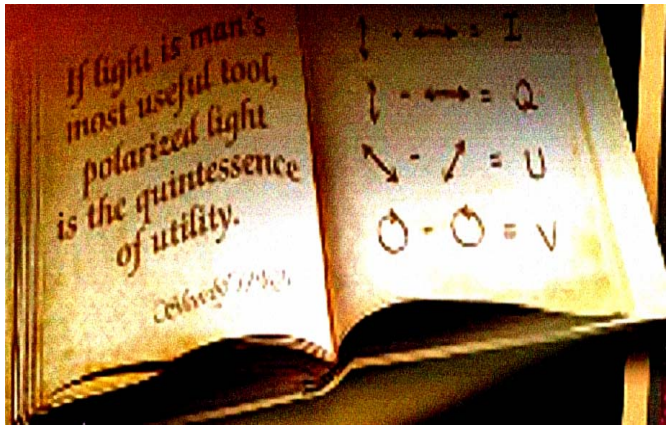
Optical polarization snapshots of new blazar candidates

- High degree (up to 3% to >30%) and variability of the optical polarization (OP) is one of the defining properties of blazars. OP observations are an important element in new blazar confirmation, when there is already a multiwaveband information about the candidates.
- High degree of OP is an evidence of strong non-thermal beamed radiation, the signature of a population of high-energy (HE) emitting particles (possibly producing also γ-rays), and provides information on source geometry and physics.
- Optical telescopes are biased to select optically bright blazars (i.e. possibly IBL, the best candidates to produce SSC GeV photons). The maximum level of information (polarization in particular) in the optical band is therefore desirable during AGILE/GLAST blazar observations.
- 1 run performed at the NOT (P31, PI S.Ciprini, but bad weather and only very few data obtained). More proposals planned for the INAF-TNG.



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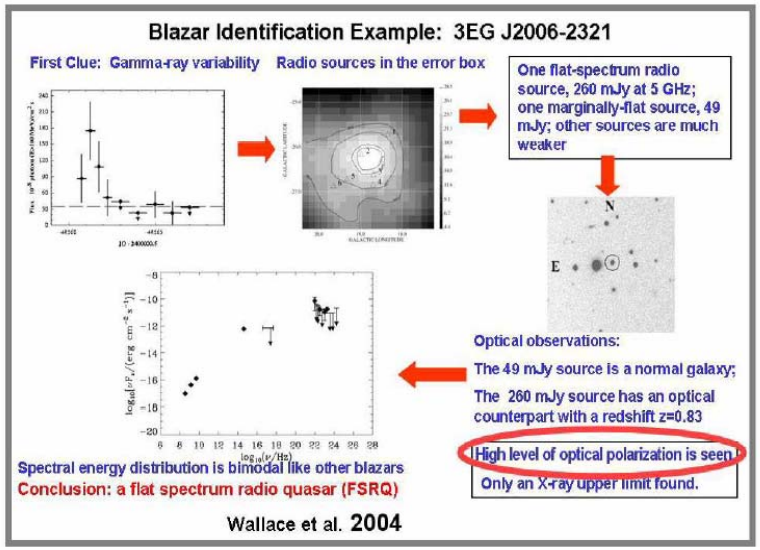
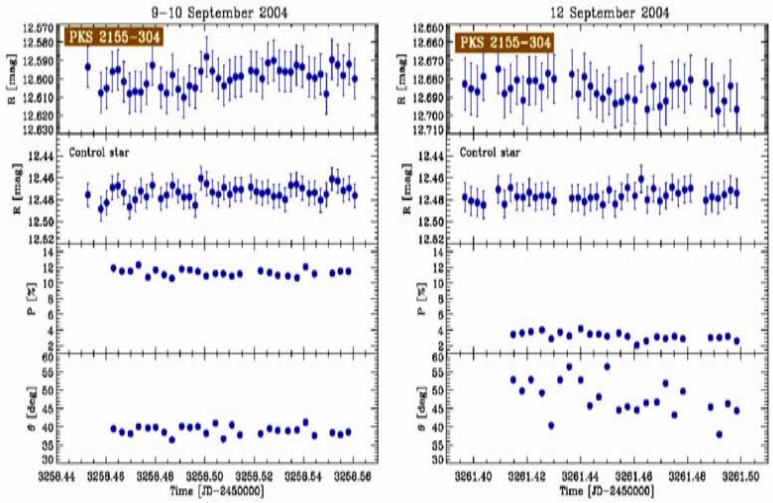
Optical polarization snapshots of new blazar candidates

- Aims: 1) to confirm or not their BL Lac or HPQ status, increasing the number of known blazars (useful for AGILE/GLAST source catalogs). 2) to have the first (or almost) measures of the optical polarization in such targets.
- Sample: possible, probable, new blazar candidates, and blazar with old/few/doubtful or no optical polarization measures. Mag(V) range between 17-20 for 4-m telescopes.
- NOT-run results: 65% of the granted time lost due to bad weather. 6 objects could be confirmed as blazars (opt. pol. degree > 5%), but frame reanalysis needed.
- Future: other applications are though for 4-m telescopes (polarization snapshot surveys & dedicated 1-source polarization monitoring during MW campaigns) .



An example of identification process for a EGRET gamma-ray source. Optical polarization snapshots are an important ingredient in such process (Wallace et al. 2004).



An example of intensive polarization monitoring of a bright blazar (PKS 2155-304) during the HESS campaign of 2004 (Ciprini et al. 2006)

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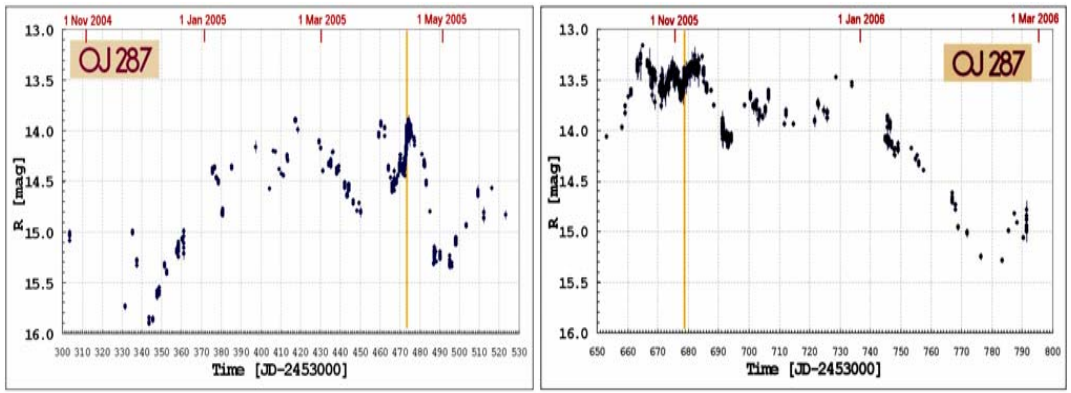
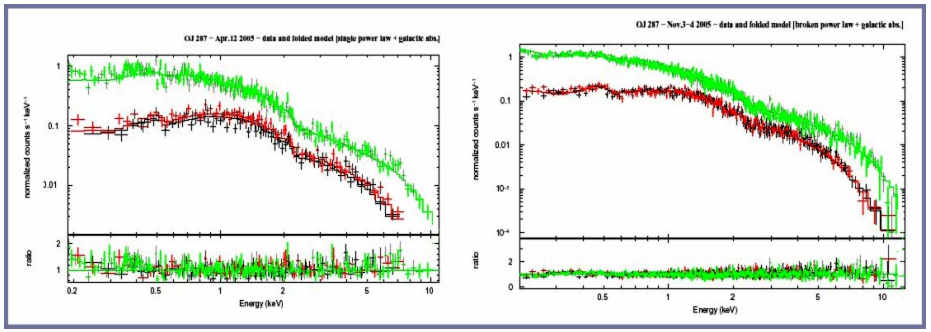
Example of multiwavelength campaign

→XMM-Newton observations (4 osb., from 2005 to 2008)
+ coordinated WEBT intensive campaign (PI S Ciprini)
→ And longer-term radio-optical monitoring + VLBA data.



The whole October 2004 - April 2006 optical light curve in R-band of OJ 287 obtained during our multiwavelength campaign. Data from more than 30
observatories. Intensive-observation data of about 1 week around the first satellite pointing date, and from about 20 days around the second satellite pointing belongs to the international consortium WEBT. In particular an enduring outburst phase was observed at the beginning of the second season.



XMM-Newton combined EPIC (pn, MOS1-MOS2) X-ray spectra of OJ 287, belonging to the 2 observations performed on Apr.12, and Nov.3-4, 2005. *Left panel:* the Apr.12 spectrum can be described by a simple power-law + galactic absorption (Γ =1.63 ± 0.02). *Right panel*: the Nov.3-4 spectrum can be described by a broken power-law + galactic absorption ($\Gamma 1$ = 2.65 -0.07/+0.12, and $\Gamma 2$ = 1.79 ± 0.02) with break at 0.7 keV. Such X-ray data indicates different flux intensity, spectral continuum slopes, and emission components (From Ciprini et al. 2007, Ciprini et al. in prep.).

Source	Other name	X-rays past observations	X-ray integral flux [erg cm^{-2} s^{-1}]
OJ 287 (z = 0.306)	PKS 0851+202 PG 0851+202 1ES 0851+203	Einstein,EXOSAT,ROSAT ASCA,BeppoSAX XMM (AO-4,AO-5,AO-6,S.Ciprini)	1.8, 2.5 ×10^{-12} (2-10 keV) (XMM, Apr., Nov. 2005)

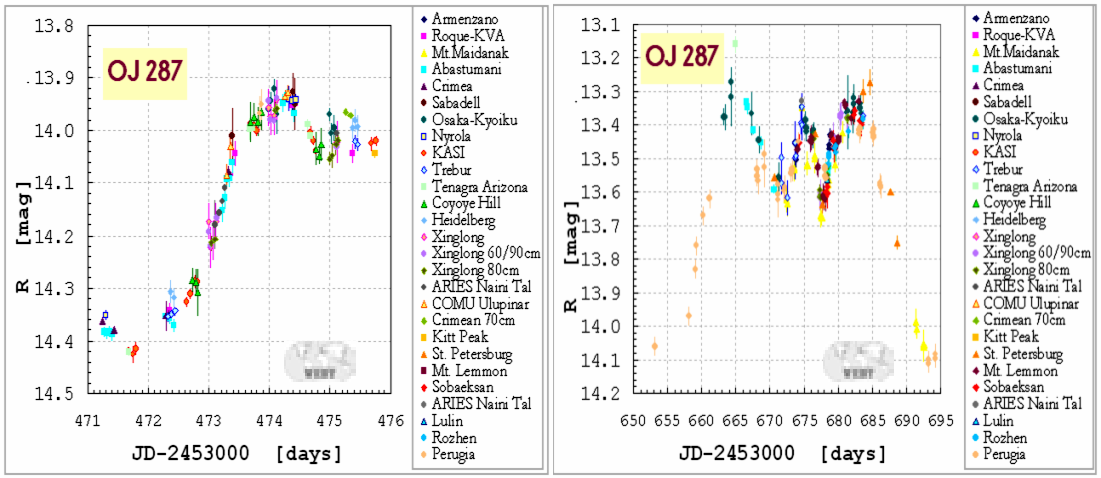
Example of multiwavelength campaign

Some of the ongoing MW programs on OJ 287 (list probably not complete, sorry):

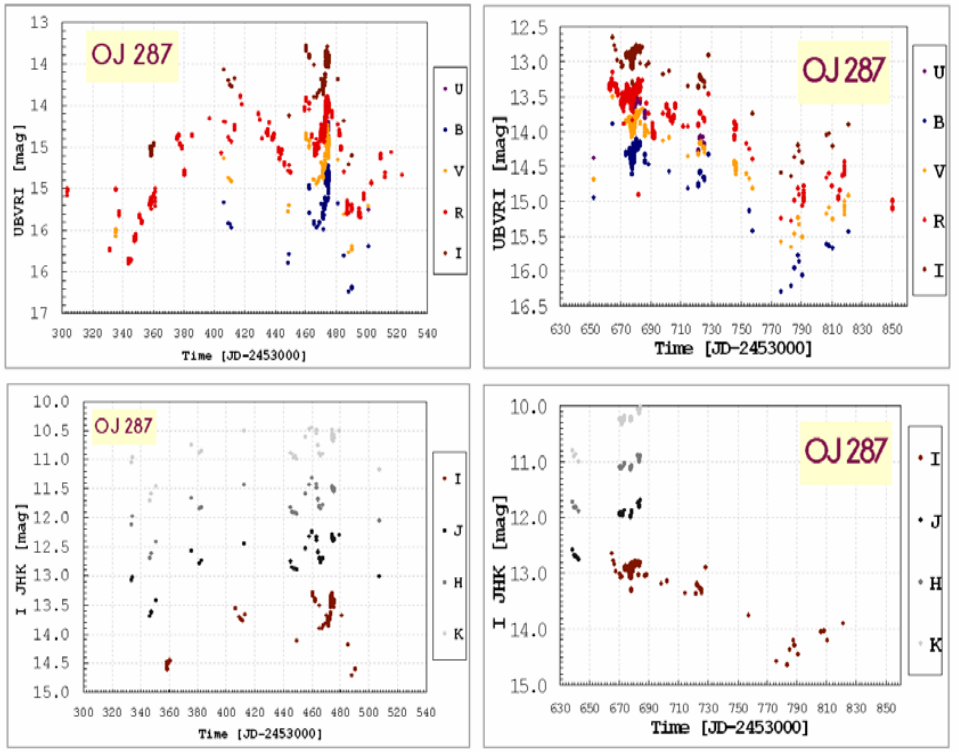
- ❑ **Long-term monitoring (OJ 287 2005-2008 Project and ENIGMA Campaign) begun in late 2004 (PM/CM: L. Takalo, A. Sillanpää).**
- ❑ **VLBA radio structure/polarization observations in 5 bands: 6 times, 8h for the period 2005-2006 (more obs. planned in 2007-08) (PI: T. Savolainen).**
- ❑ **VLBA and Global 3mm-VLBI radio-mm structure/polarization observations (as a calibrator, April 4 and 17, 2005, PI: I. Agudo).**
- ❑ **ESO VLT spectroscopic optical observations (4 epochs, PI: K. Nilsson).**
- ❑ **XMM-Newton X-ray observations: 2 pointings of about 40 ksec each in cycle AO-4 (April 12, and November 3-4, 2005, PI: S. Ciprini). A 3rd pointing performed in November 2006 (AO-5, PI: S. Ciprini). A 4th observation performed in April 2008 (AO-6, PI S. Ciprini).**
- ❑ **WEBT intensive ground-based MW campaign around the 2 XMM pointing epochs (CM: S. Ciprini) .**
- ❑ **ToO Effelsberg 100m radiotelescope flux/polarization observations on April 12 and Nov. 8-9-10 (ToO PI: L. Fuhrmann).**
- ❑ **4 sessions of Global 3mm-VLBI observations in period Oct.2005-Apr.2007 (PI: E. Rastorgueva, K. Wiik).**
- ❑ **MAGIC gamma-ray Cherenkov telescope observations in January (10h) and November 2005 (>5h, this last in ToO mode, PI: E .Lindfors).**
- ❑ **Optical polarization monitoring at NOT (PI: K.Nilsson) and CalarAlto (2006-2008, PI: J. Heidt).**

Example of multiwavelength campaign

The OJ 287 campaign: some examples of the obtained near-IR & optical data galore!



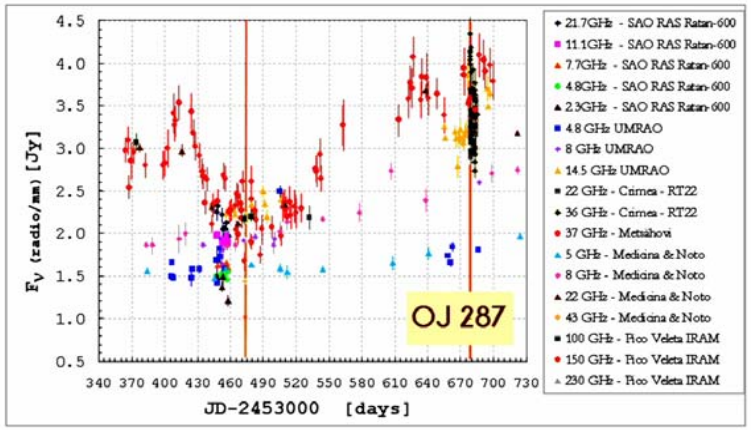
The detailed (and best sampled) R-band magnitude light curve corresponding to the intensive coordinated campaign performed by the WEBT consortium, around the two XMM-Newton pointing dates. In the right panel, in particular, an enduring (more than 20 days), symmetrical, and time-structured (we 3 major rather symmetric wiggles), optical outburst is evident and confirmed by many observatories in the period October-November 2005. The brighter R band magnitude detected here was R = 13.2. (From Ciprini et al. 2007, Ciprini et al. in prep.).



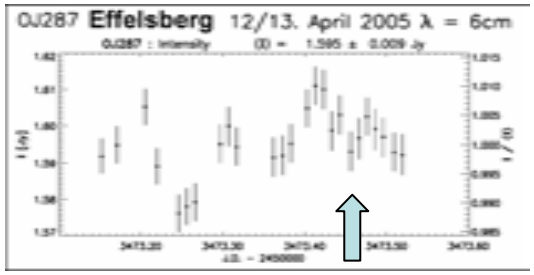
UBVRIJHK multi-band optical and near-IR light curves of OJ 287 acquired during our long-term 2004-2006 campaign

Example of multiwavelength campaign

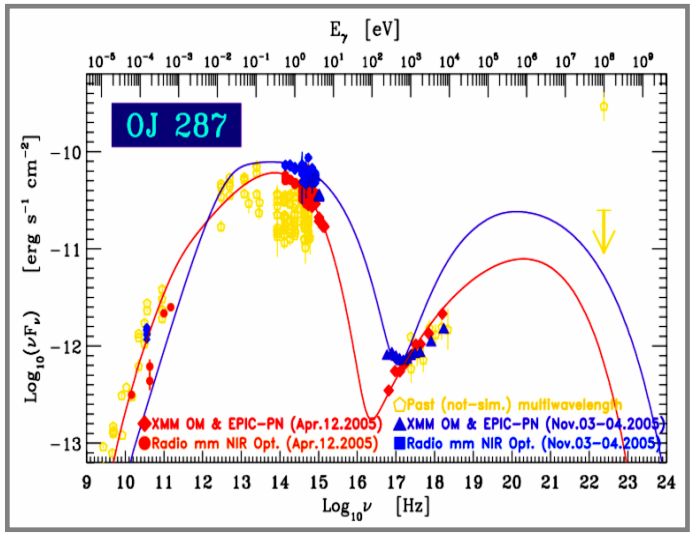
The OJ 287 campaign: some examples of radio data galore and multiwaveband SEDs.



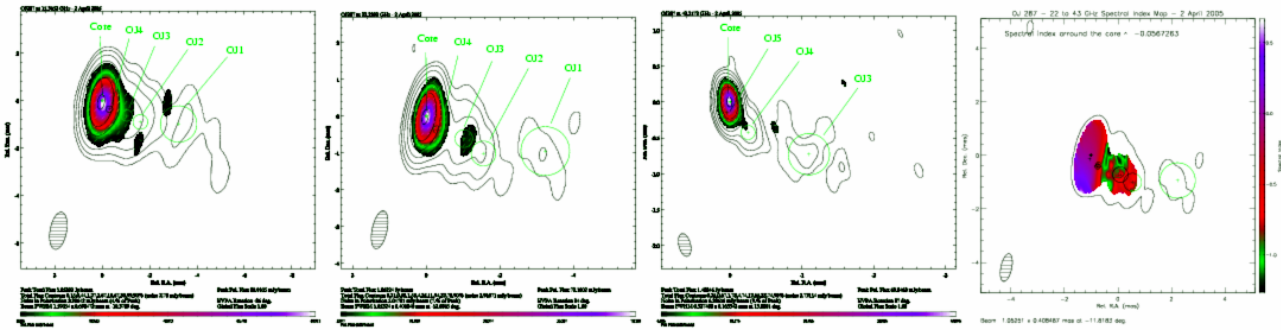
The radio-mm flux light curves of OJ 287 in different bands (frequencies span from 2.3 to 230 GHz), obtained during the extended monitoring campaign, and by independent observing programs. At a first inspection there is not a significant radio-optical correlation (From Ciprini et al. 2007, Ciprini et al., in prep.).



IDV ~ 3%



Radio-to-X-ray spectral energy distribution (SED) of OJ 287 simultaneous to the 2 XMM-Newton observations (OM and EPIC-pn data) of Apr.12, and Nov.3-4, 2005. A synchrotron self-Compton (SSC) model for these 2 epochs is reported (red and blue continuous lines). OJ 287 from the LBL family, arisen to the IBL category, as during flaring phases it can emit synchrotron photons even at the soft X-ray band. (From Ciprini et al., in prep.).



15GHz, 22GHz, 43GHz VLBA images and the map of the spectral index of the jet of OJ 287 obtained in April 2005.

GLAST pre-launch MW proposals

- 3 dedicated MW proposals were also submitted before the launch of GLAST, as support and service for the GLAST coll., and for tentative GLAST MW campaigns (all the proposals were made on behalf of the GLAST coll.).

- All the 3 following proposals made as PI were not accepted (motivation: *"GLAST is not flying"; "we would expect on-flight performances of GLAST"* .
…but *"try again it Sam"*, because now GLAST (and AGILE of course) are flying!

Spitzer Cycle-5 proposal: Investigating the far-mid infrared and gamma−ray connection in MeV (COMPTEL) blazars with Spitzer and GLAST. Observation of 7 MeV blazars. Comptonization of ambient infrared radiation from dust. Mid-far infrared investigation of the dusty−stuffed ambient of flat spectrum radio quasars, where dust is produced and survive. Its relation with gamma-ray emission.

XMM-Newton AO7 proposal: High-energy jet emission in intermediate blazars: the joined XMM-Newton and GLAST view. 3 bright intermediate-blazars (IBL), namely PKS 0735+178, GC 0109+224 (both IBL candidates with old X-rays analysis, and an interesting close environment) and W Com (the IBL prototype, with an observed twofold, synchrotron and inverse-Compton, X-ray spectrum).

NOT P36 proposal: Optical polarimetric survey of new gamma-ray blazar candidates for GLAST. Optical polarimetric snapshots of a sample of relatively bright new blazar candidates, selected by radio/optical X-rays surveys/catalogues.

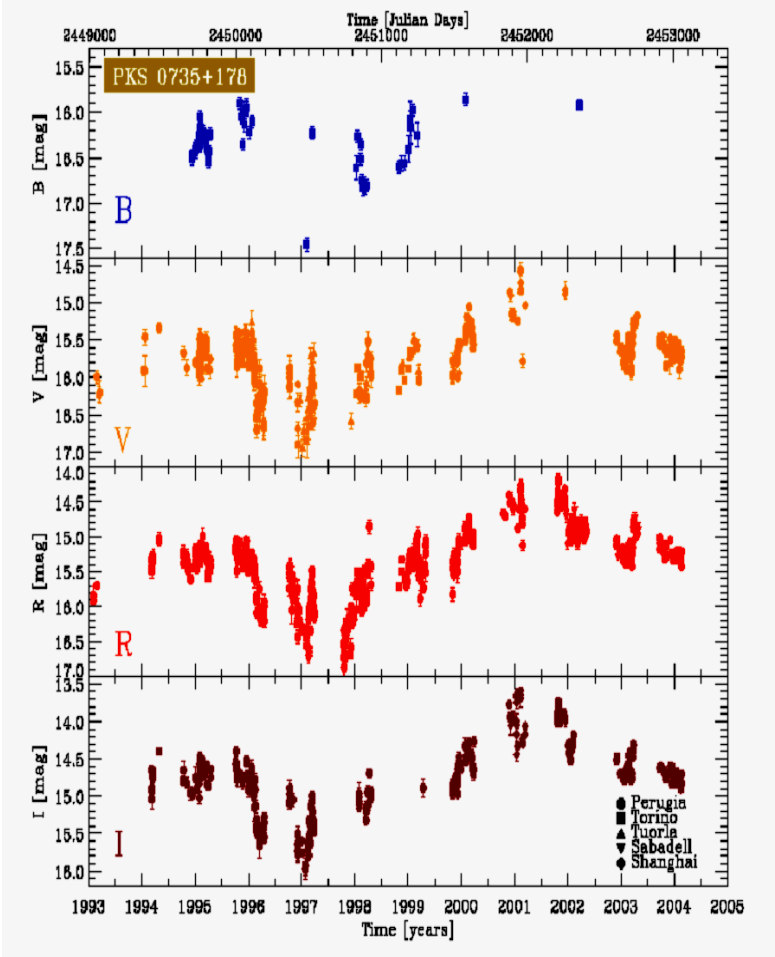
Example of long-term optical variability monitoring

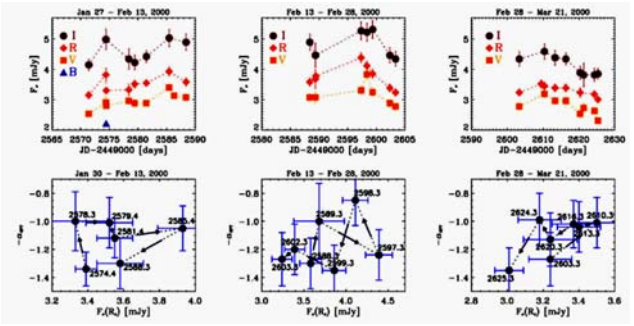
❑ 10 years (1994-2004) of optical monitoring data (*BVRI* bands) on PKS 0735+178 Data from Perugia Univ. Obs. (the bulk of data), Torino Obs., Tuorla Obs., Sabadell

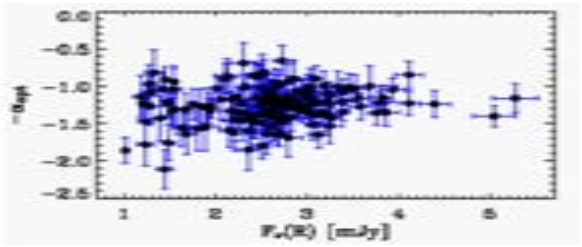
❑ **11 observing seasons, 10 years light curves, 1637 photometric data points, almost 500 nights of observations.**

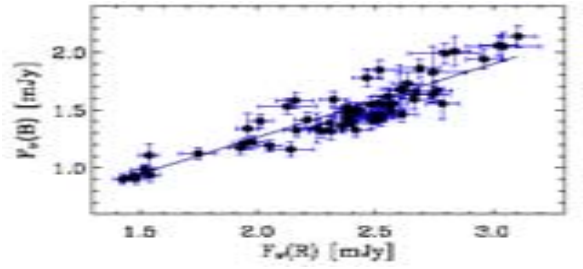
❑ **Rapid optical variations connected to slower variations. Intermediate or low level of activity.**

❑ **Long–term variability is essentially achromatic, whereas flares imply spectral changes. There is not clear hysteresis loops in the optical spectral index evolution during intermediate flares.**









Adapted from Ciprini et al. 2007

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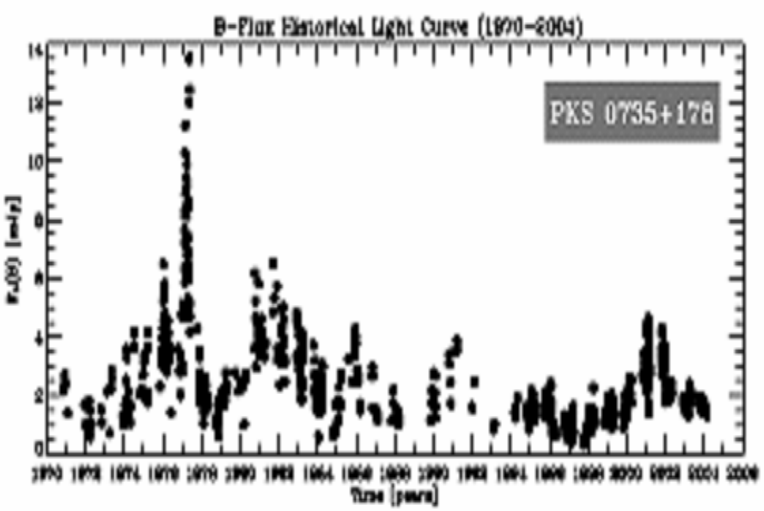
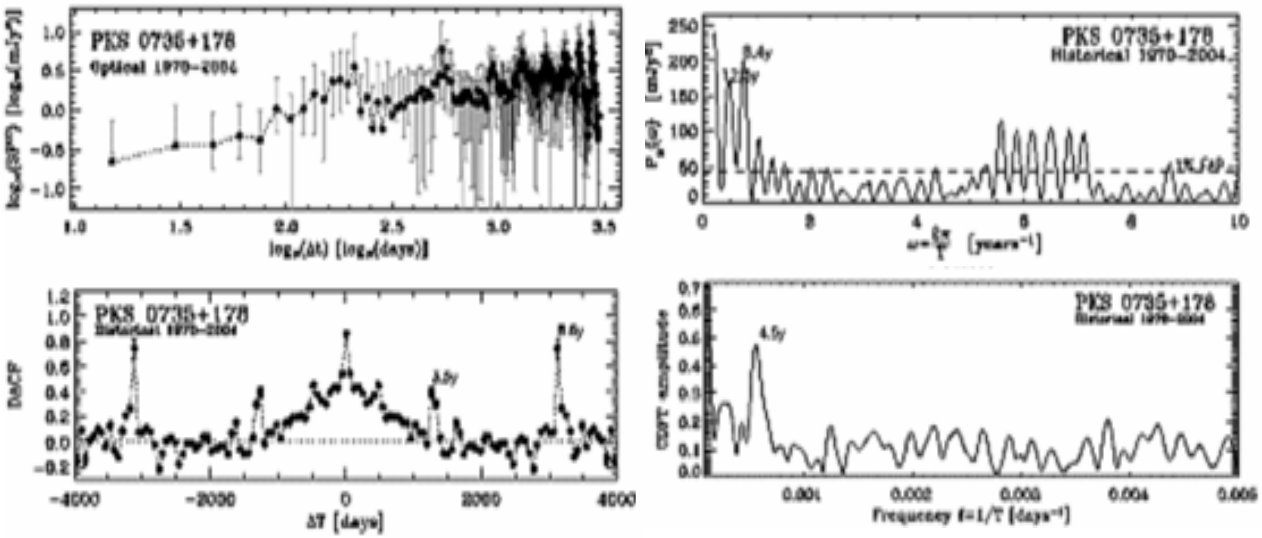
Example of long-term optical variability monitoring

❑ **Temporal behaviour: Temporal analysis of optical variability. To search for coherent time structures, characteristic timescales, and to identify duty-cycles and variability modes . This is important for GLAST twice:**
1) long-term and optical-gamma-rays correlation analysis;
2) standalone GLAST light curves analysis of bright gamma-ray blazars. GLAST will be able to observe variability on the same mid/long-term timescales monitored already in the optical band!
→ Long-term (months-weeks); mid-term (days) timescales investigated.





- Discrete Correlation Function.
- Structure Function SF.
- Lomb-Scargle Periodogram.
- Clean Discrete Fourier Transform.

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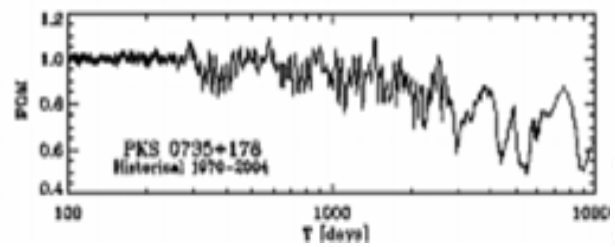
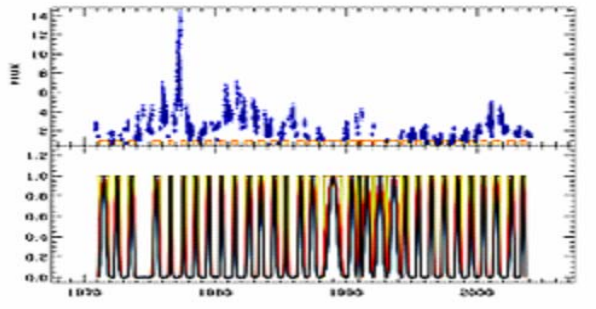
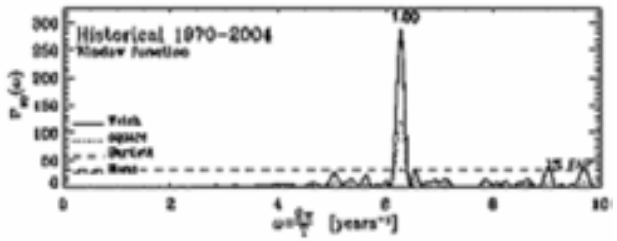
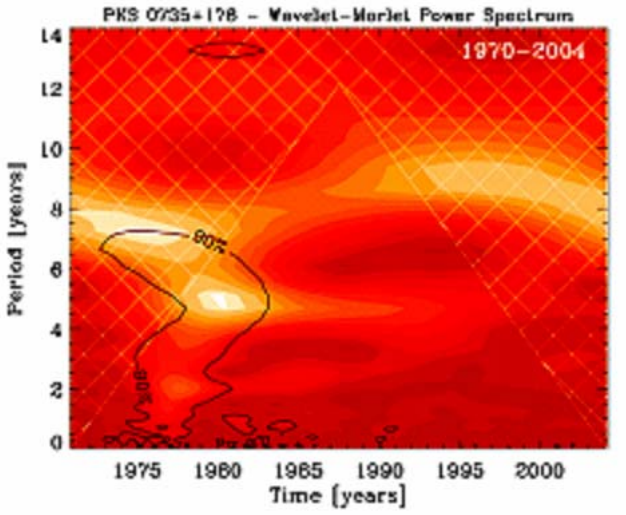
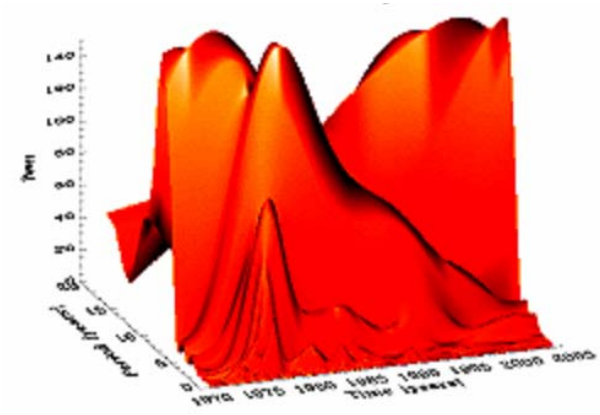
Example of long-term optical variability monitoring

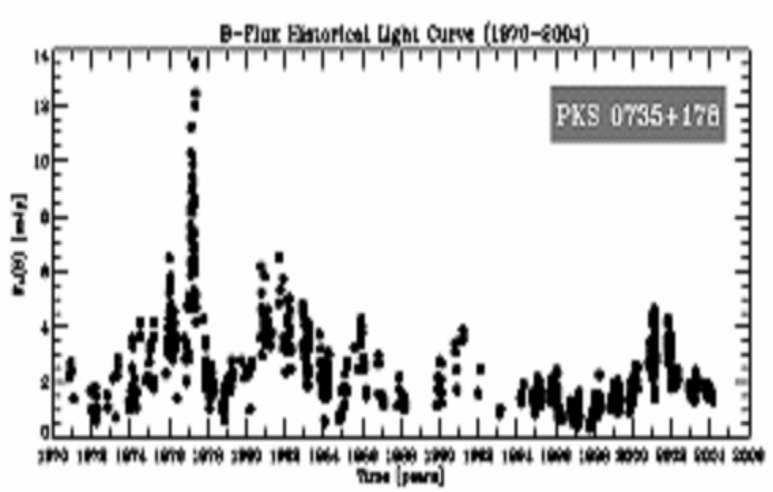












- Phase Dispersion Minimization.
- Gaps Window Function. periodogram GWFP.
- Discrete Wavelet Transform scalogram*.

Such methods can be applied to AGILE/GLAST long-term light curves of blazars.

The end

- Spectroscopy
- Polarization
- Multiwaveband campaigns
- Variability Flux Monitoring