Reviewing AGILE results on blazars

I. Donnarumma
on behalf of the AGILE Team
INAF-IAPS

Outline

- ***AGILE results during 6-years in orbit:***

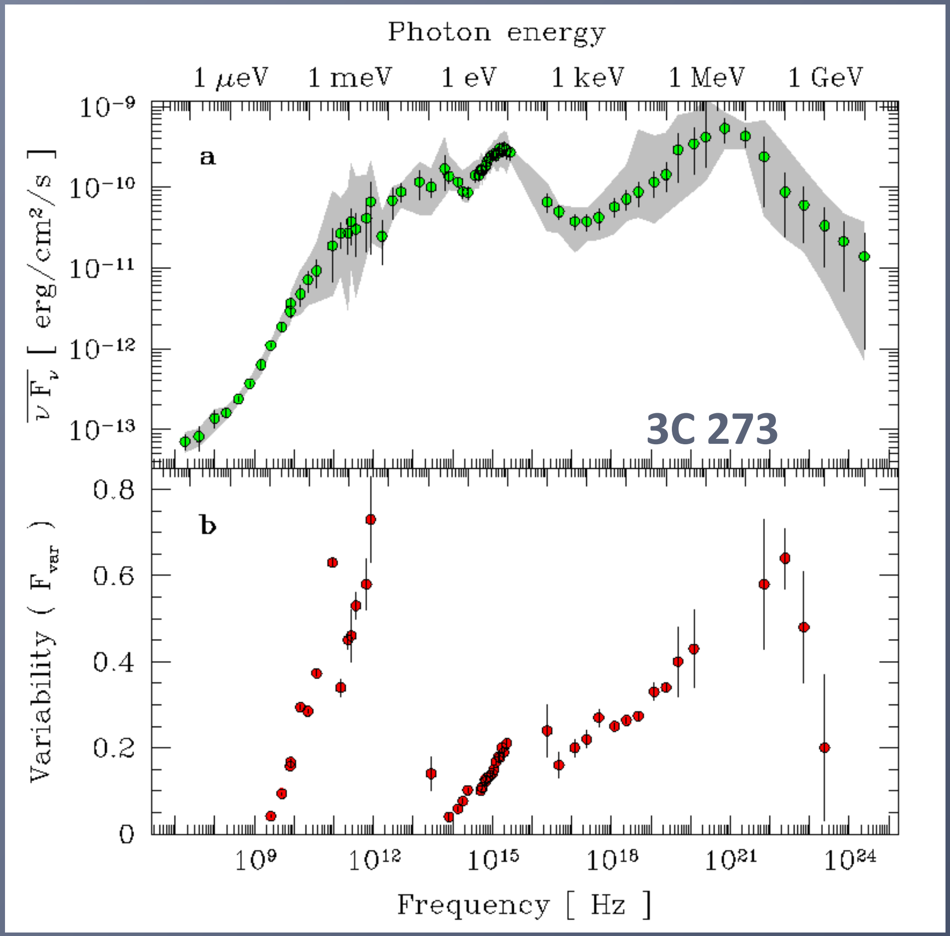
  - Optical-UV observations in different γ-ray states
  - Radio-Optical- γ-rays
  - Soft X and γ-rays
  - The GeV-TeV connection
  - Peculiar variability

- ***Perpesctives for future Gamma-ray instruments***

Blazar variability

The multi wavelength approach

Soldi et al., 2008, A&A, 486, 411



Observatory	Energy domain
VLBA/UMRAO	Radio
Spitzer	IR
REM	IR-Optical
WEBT-GASP	Radio-mm-Optical-IR
XMM-*Newton*	UV + soft X-ray
Swift	UV + soft X-ray + hard X-ray
Suzaku	Soft X-ray + hard X-ray
RXTE	Hard X-ray
INTEGRAL	Hard X-ray
Super-AGILE	Hard X-ray
AGILE/GRID	Gamma-ray
MAGIC	TeV
VERITAS	TeV
ARGO	TeV
H.E.S.S.	TeV

OPTICAL-UV OBSERVATIONS IN DIFFERENT GAMMA-RAY STATES

Optical-UV observations in different γ-ray states able to constrain:

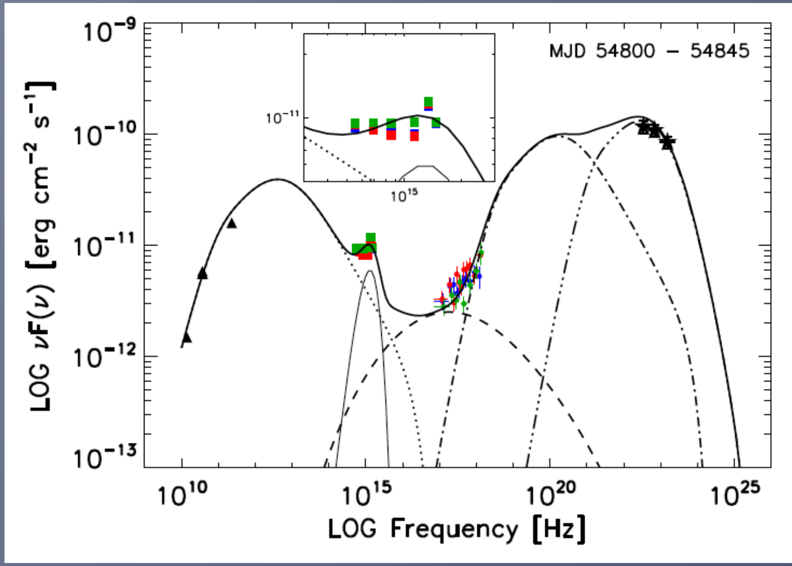
a) the acceleration efficiency given the evidence/lack of the thermal component in FSRQs

b) the external seed photon component responsible of the IC peak by estimating the accretion disk luminosity, with a better definition of the γ-ray dissipation region

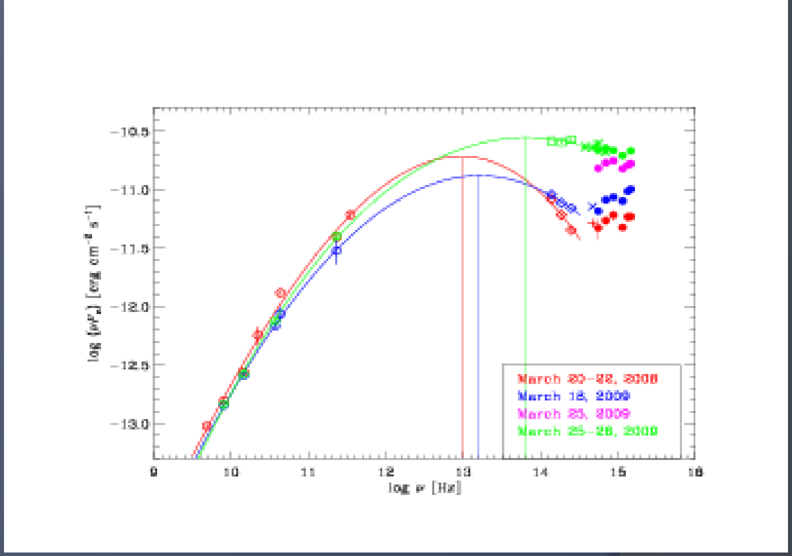
c) Possible time lags between synchrotron and IC emissions in low synchrotron peak sources.

Evidence/lack of optical/UV thermal components vs gamma-ray states

3C 454.3



PKS 1510-089



Vercellone et al., 2010, ApJ, 712, 405,

3C 454.3 – October 2008 campaign

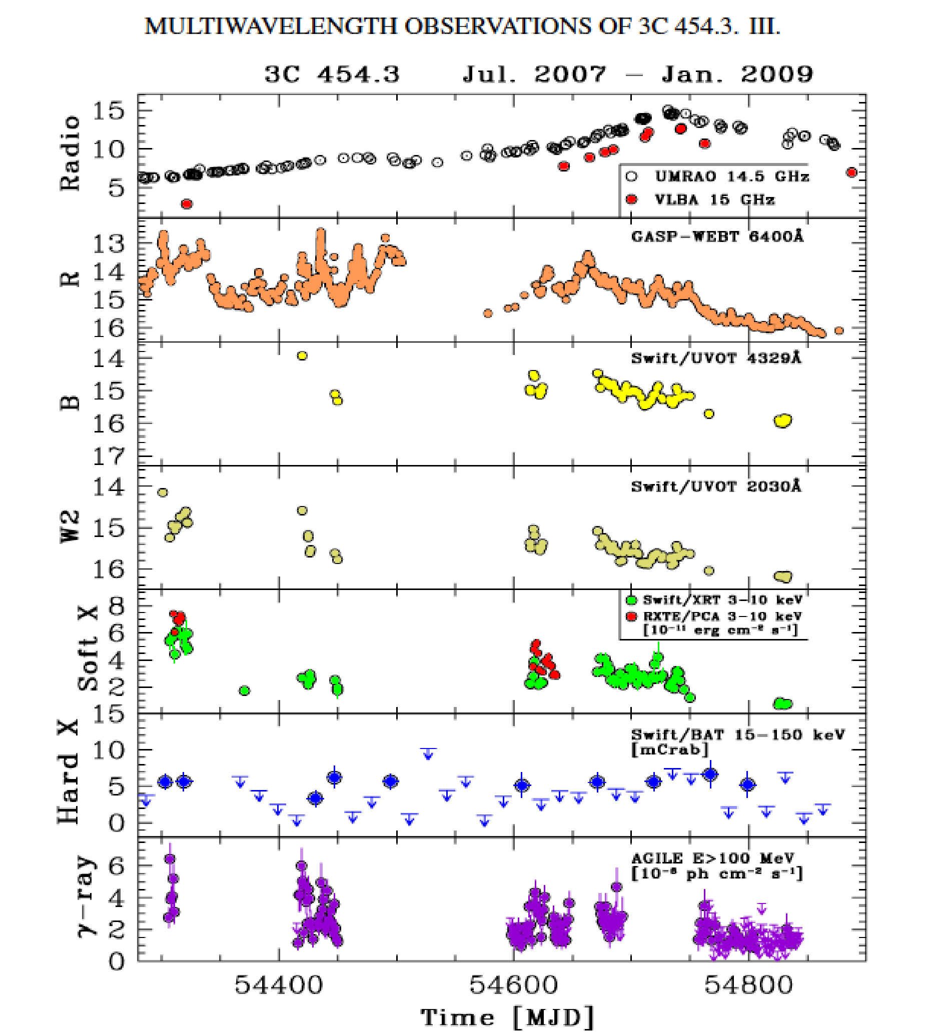
The thermal disc contribution is unveiled during the low gamma-ray state.

D'Ammando et al. 2011, A&A , 529, 145

PKS 1510-089 - March 2009 campaign

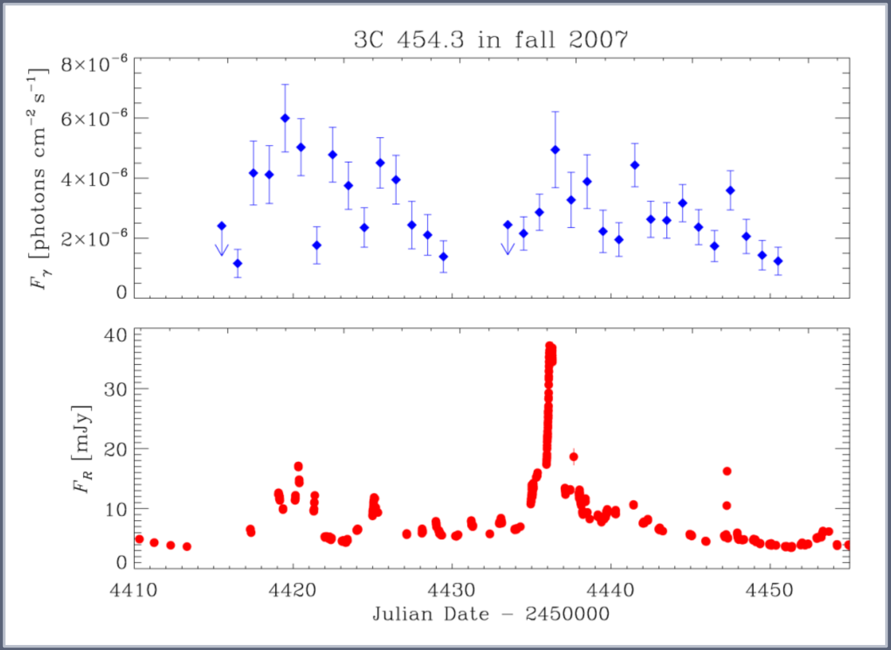
evidence of accretion disk variation in different states (red – blue points)

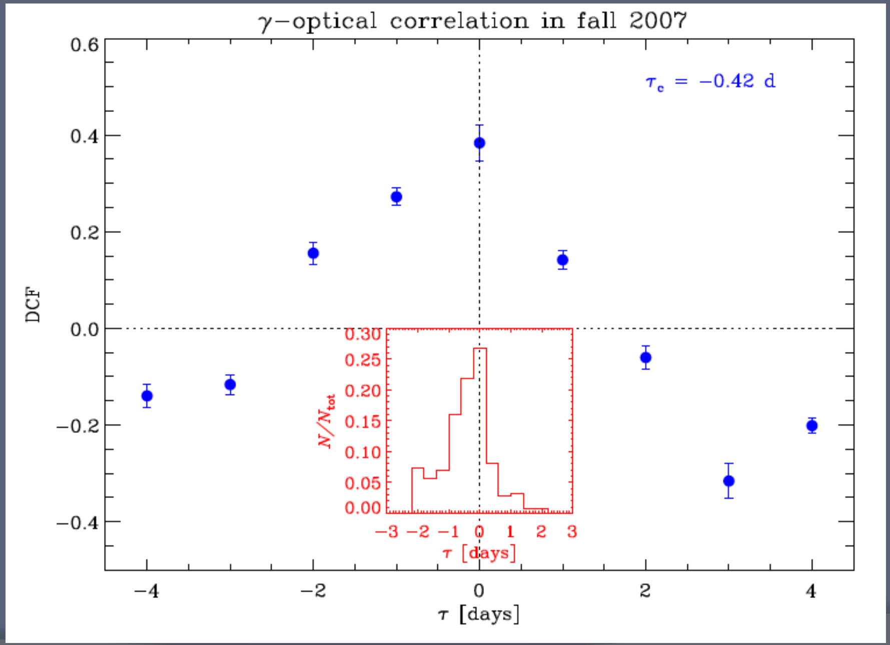
Long time-scale monitoring



Vercellone et al., 2010, ApJ, 712, 405
18 months campaign on 3C 454.3

Vercellone et al., 2010, ApJ, 712,405



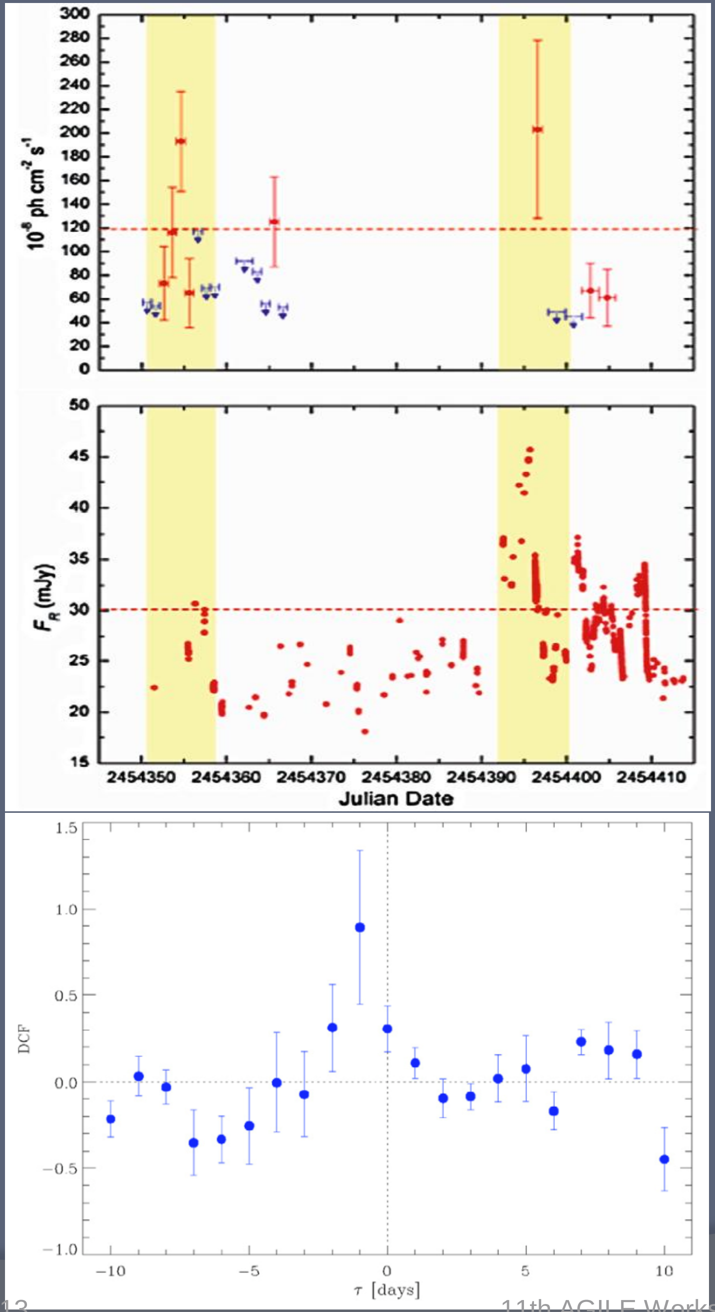


Time-lags: 3C 454.3

3C 454.3 – Nov.—Dec 2007 campaign

The shape of the DCF peak is asymmetric, and if we calculate the centroid distribution, we find that the time-lag is −0.42 days, i.e. the gamma-ray flux has a delay w.r.t the optical one of about half a day (see also Donnarumma et al. 2009).

Chen et al., 2008, A&A, 489, L37



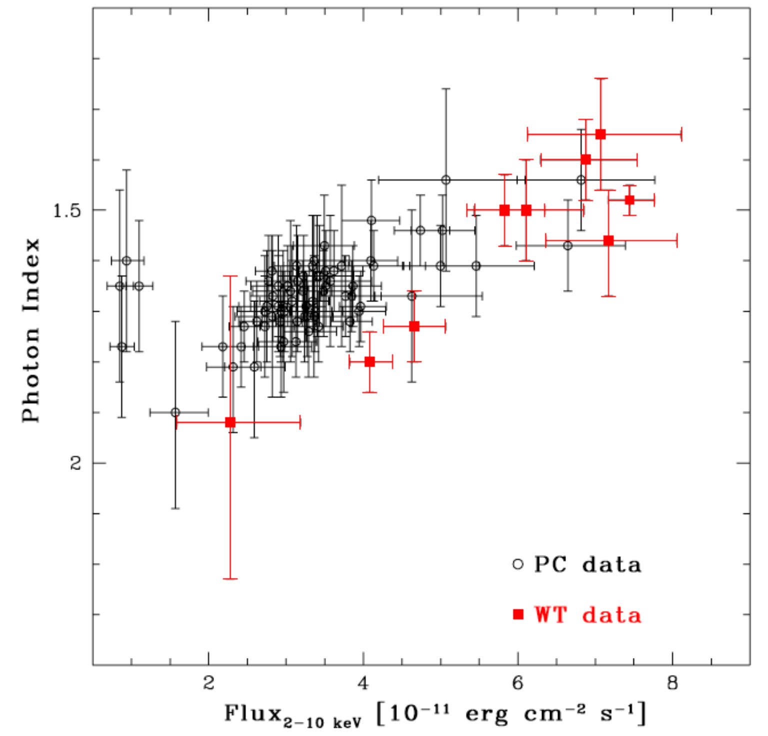
S5 0716+714: Sep.—Oct. 2007 campaign.

The DCF shows a significant peak for a time-lag of –1 day, suggesting a possible delay in the γ-ray flux variations with respect to optical ones.

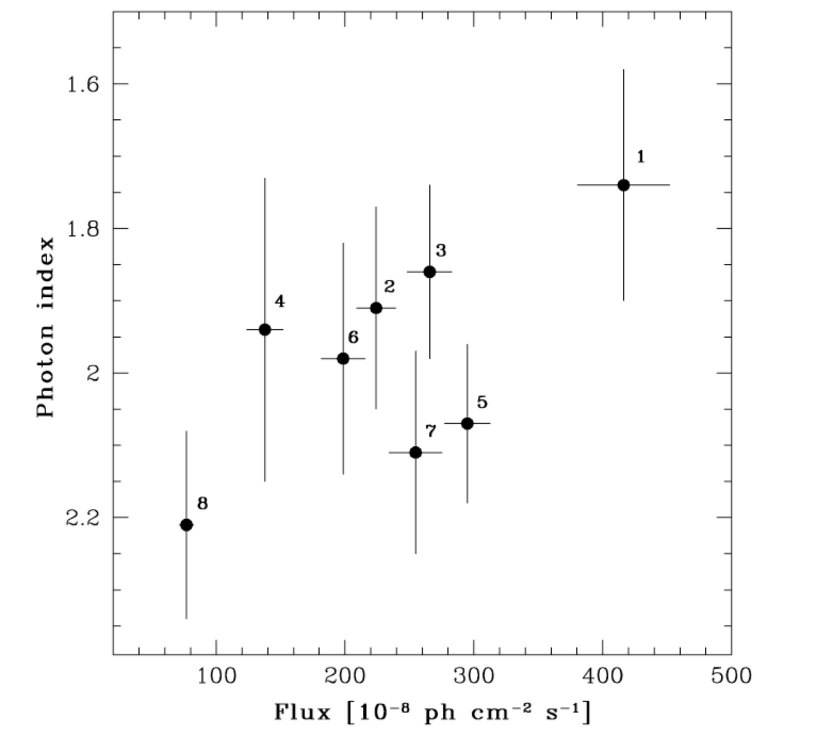
Long-term X-ray data seem to show an harder-when-brighter spectral trend; only hints found in the γ-ray data

3C 454.3: Vercellone et al., 2010, ApJ, 712, 405

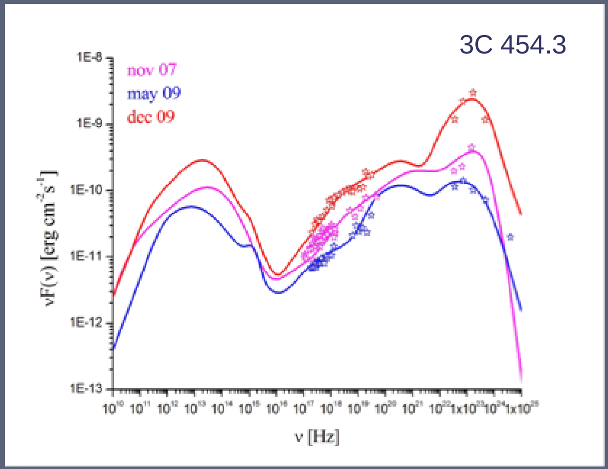
Swift/XRT

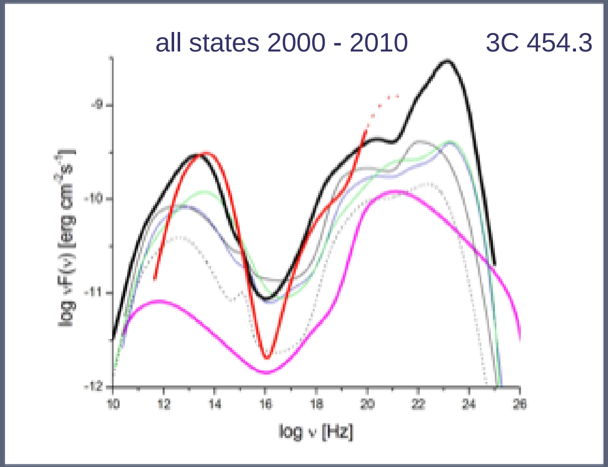


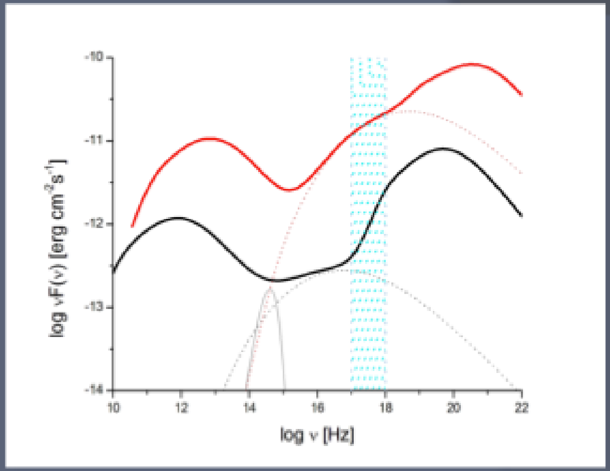
AGILE/GRID



"Detailed theoretical modeling of FSRQ SEDs"







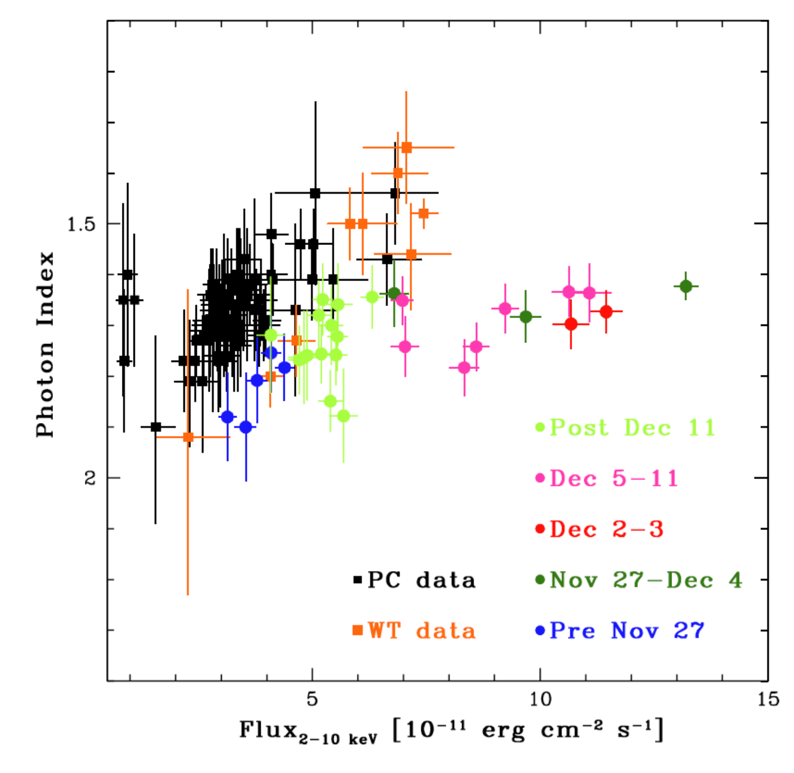
The X-ray slope variation appears to be moderate w.r.t. the other bands.

If e^- injection-acceleration was the only dominant mechanism ➔ we would obtain a remarkable softer-when-brighter trend.

The observed spectral trend could be interpreted by invoking an higher accretion rate or a larger value of the bulk Lorentz factor coupled with a slightly lower value of the magnetic field.

......but

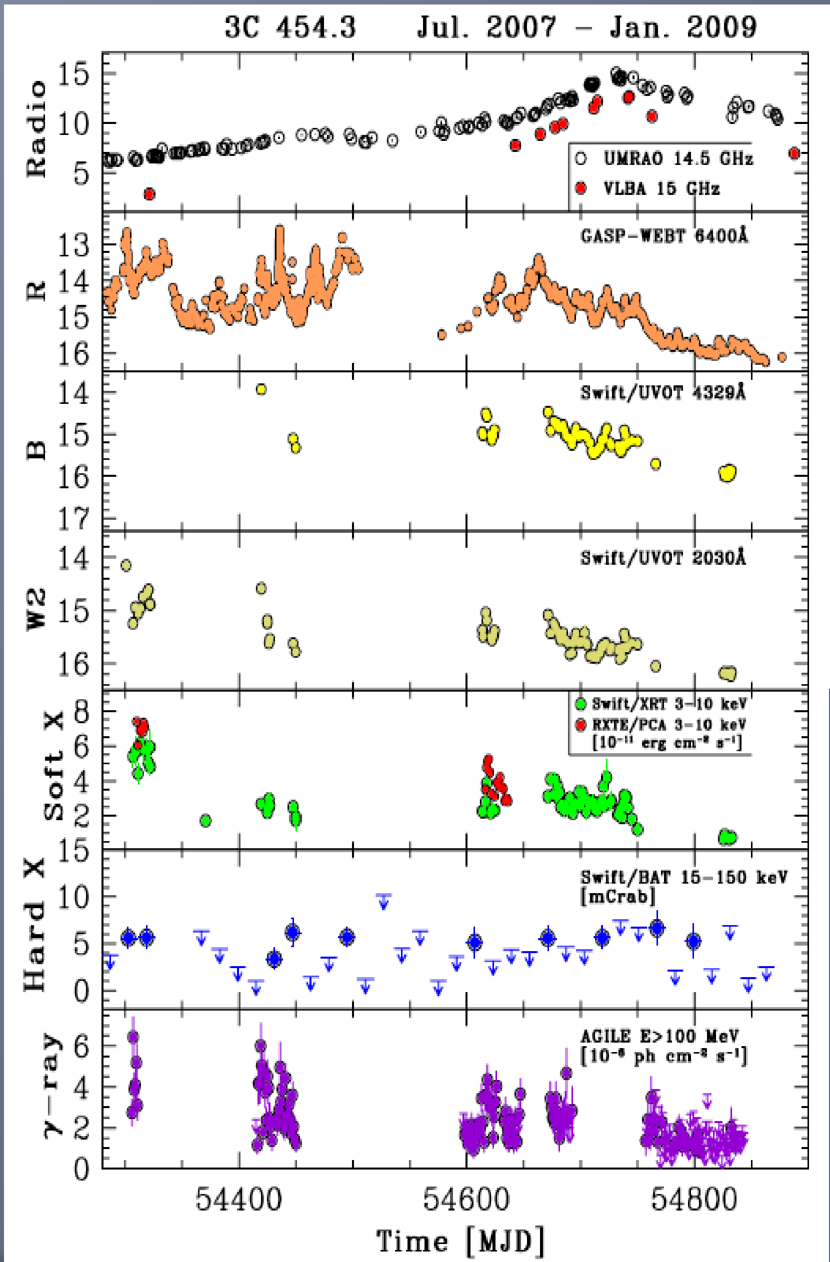
X-ray spectral trends in 3C 454.3

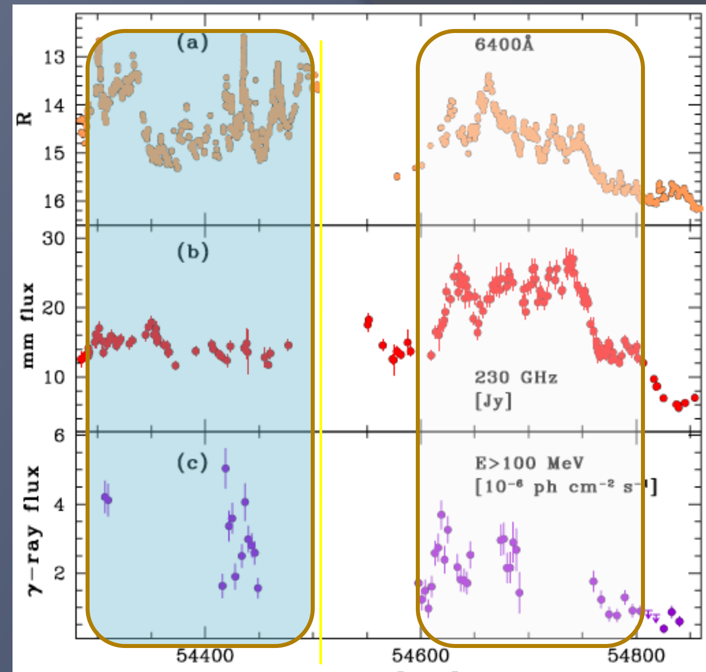


….a very complicated X-ray photon index vs flux dependency exists. A saturation in the photon index seems to be present (likely associated with the interplay between SSC and EC dominance in different X-ray states) (Vercellone et al. 2011, Donnarumma et al. 2012)

RADIO-OPTICAL-UV & GAMMA-RAYS OBSERVATIONS

Radio, optical & γ-rays: 3C 454.3



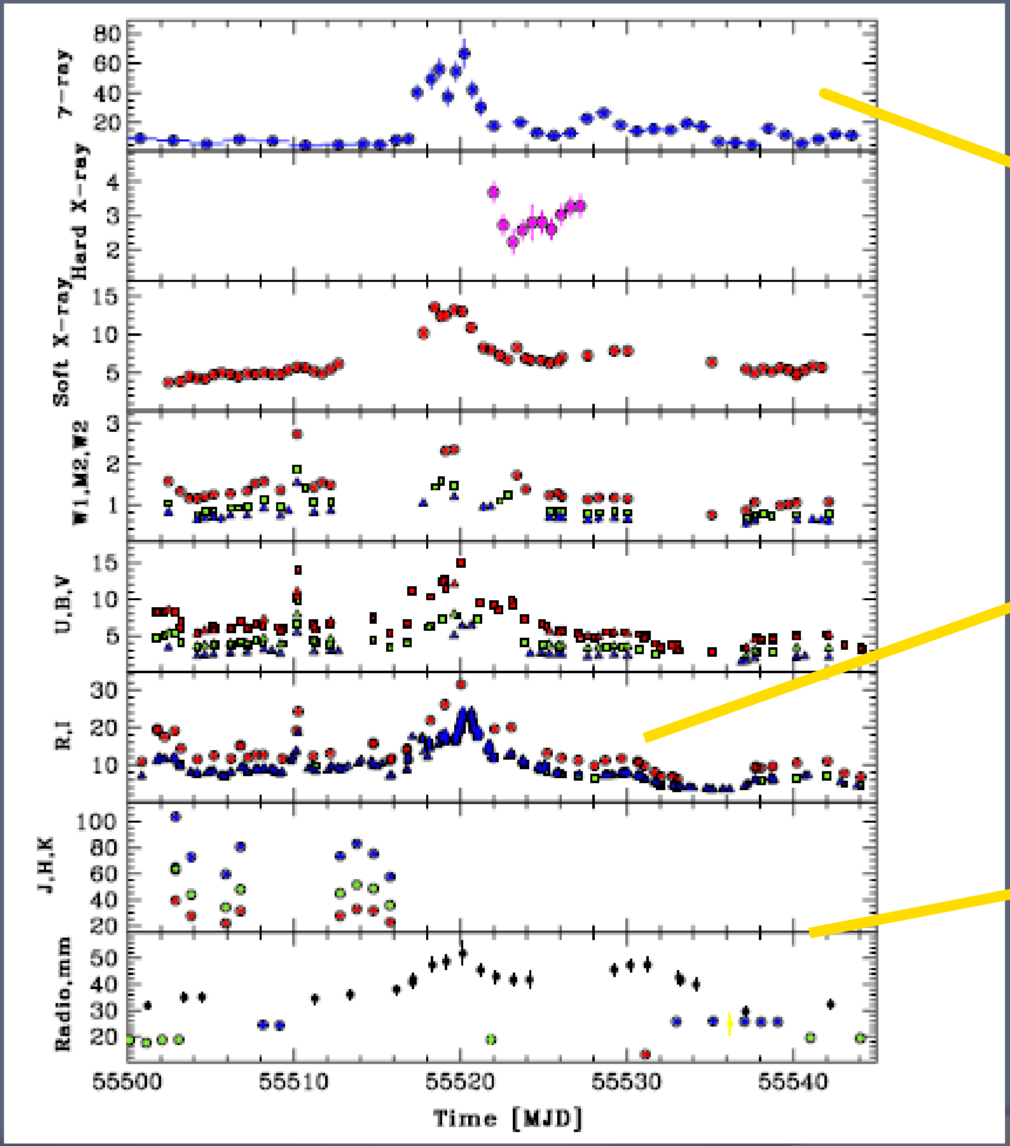


2007: the more pronounced fluxes and variability of the optical and γ-ray bands seem to favor the inner portion of the jet as the more beamed one.

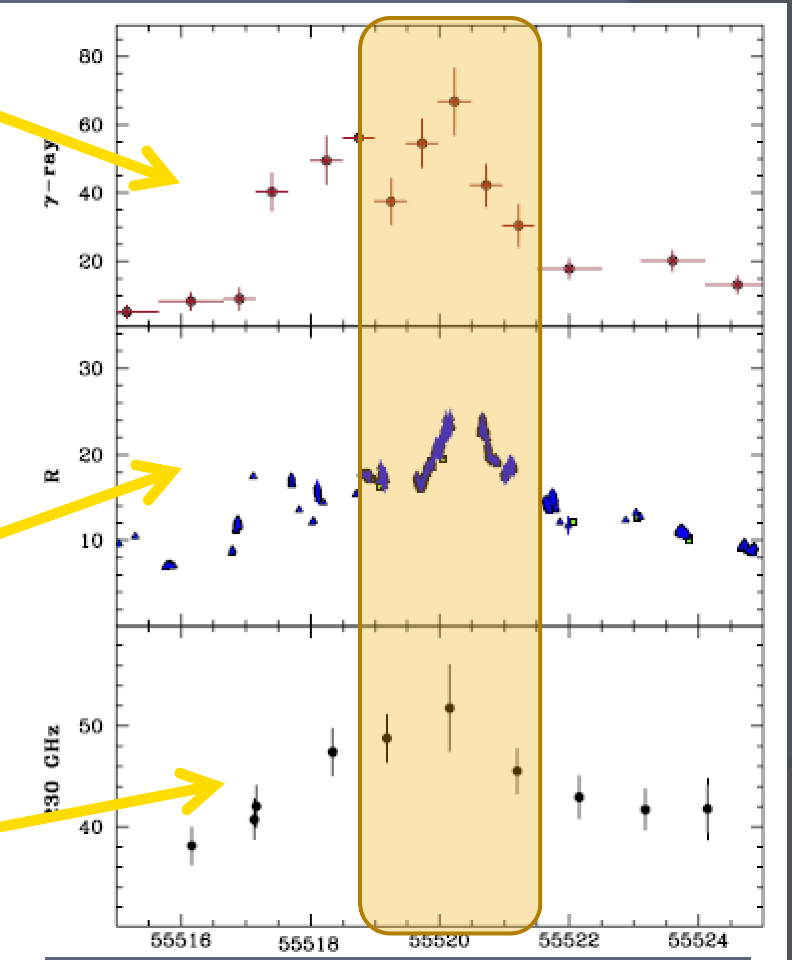
2008: the optical & γ -ray dimming trend, the higher mm flux emission and its enhanced variability seem to indicate that the more extended region of the jet became more aligned w.r.t. the observer line of sight (different alignmen configuration within the jet itself, Raiteri et al. 2011 by the inspection of the light curve between April 2008 and Marc 2010)

Vercellone et al. 2011

Radio, optical & γ-rays: 3C 454.3

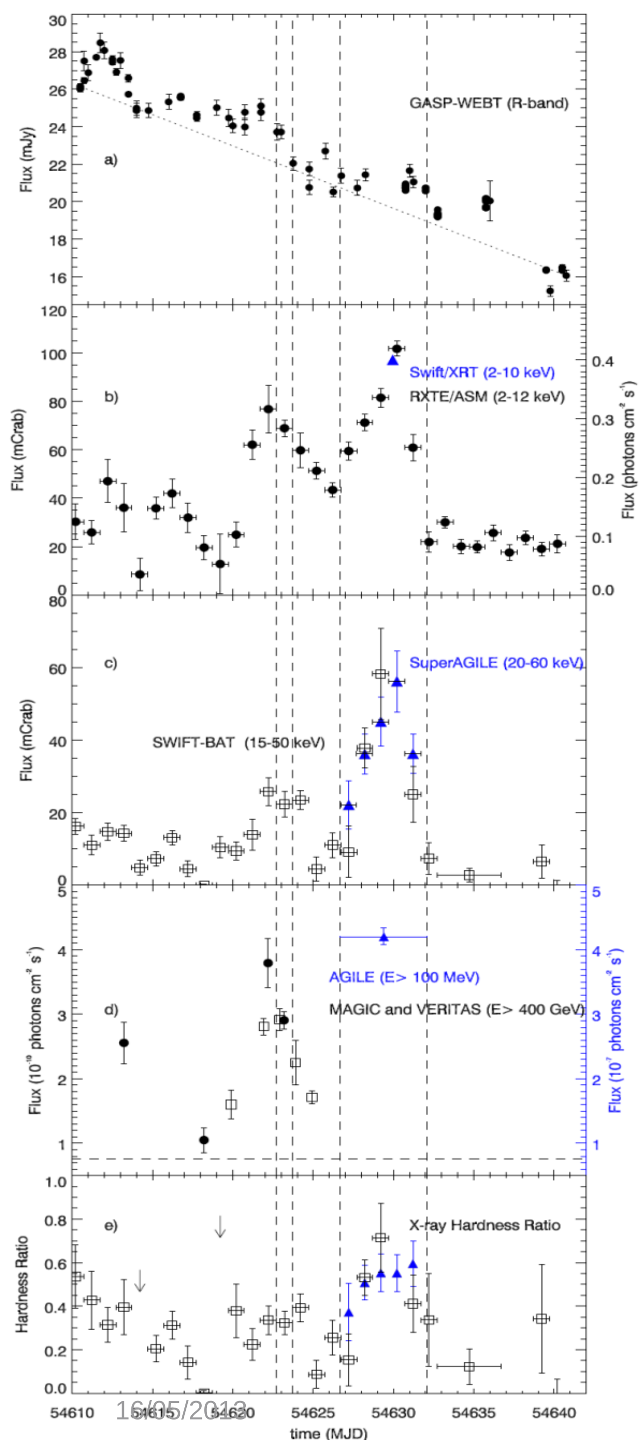


November 2010 flare



2010: SMA (230 GHz) data show that the radio emission was highly correlated with optical and γ-ray energy bands

GeV-TeV Connection



The GeV – TeV connection: MKN 421

Donnarumma et al., 2009, ApJL, 691, 13

The optical light curve shows variations of the order of 10% on a time scale of a few days, superimposed on a long decay during the entire period.

Soft, hard X-ray and TeV emissions seem to be correlated

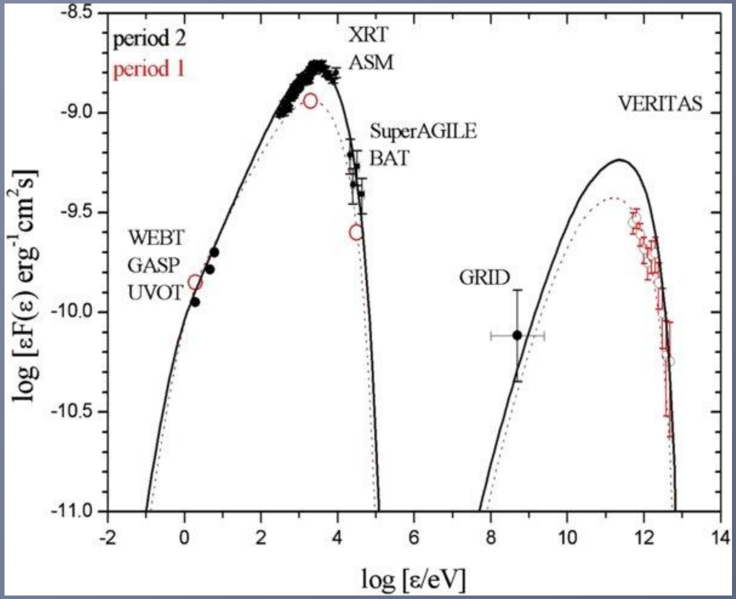
Individual soft and hard X-ray peaks show flux rising by a factor of ~ 2.5 and ~5, respectively, with growing peak-to-valley amplitudes on longer time scales.

Clear spectral hardening (X-ray) of the source during the flaring activity.

MAGIC and VERITAS data were missing during the AGILE γ-ray flare.

A similar flare was detected by NUSTAR in last April: Optical, X-ray (MAXI, NUSTAR, Swift) and gamma-ray behavior look similar to the one observed by AGILE in June 2008, while VHE gamma-ray reached an unprecedented value (x 20 its average state, about 10 Crab).

The GeV – TeV connection: MKN 421

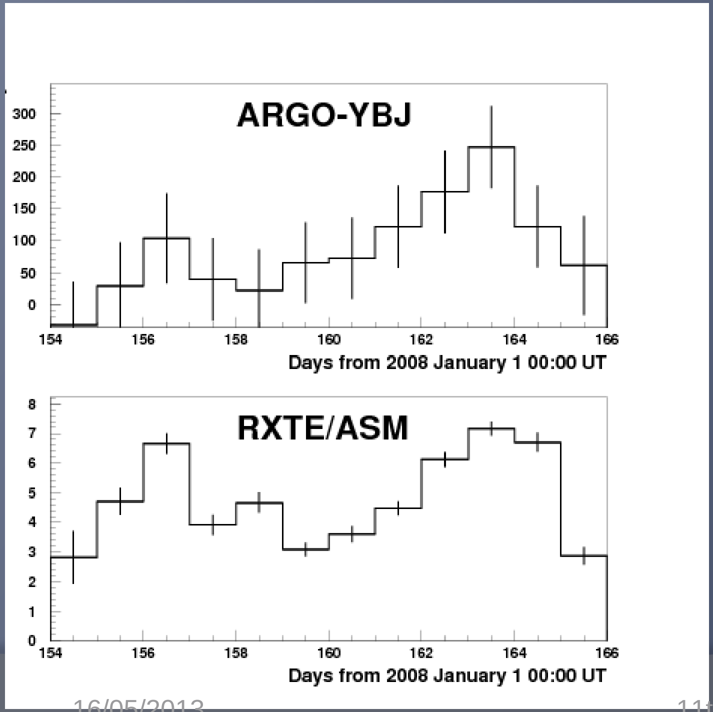


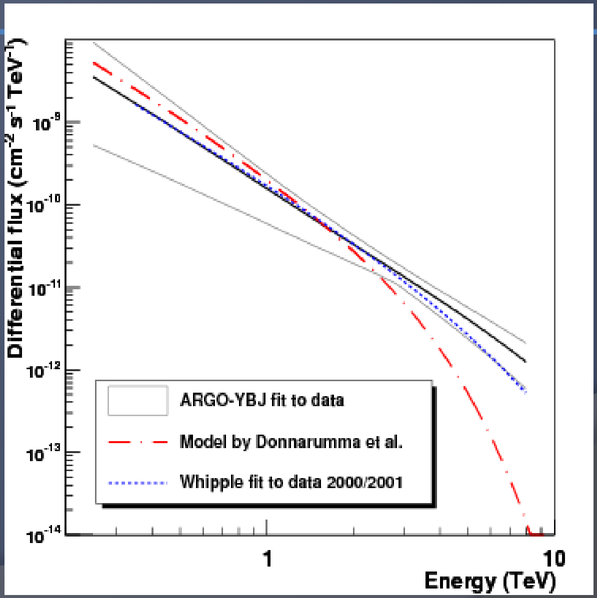
The SED is well described by a standard 1-zone SSC model; the SED variation interpreted as a rapid acceleration of electrons in the jet (Donnarumma et al. 2009)

Aielli et al., 2010, ApJL, 714, 208

ARGO/YBJ and RXTE/ASM correlate quite well

The second flare (June 11-13) seems to be higher than the one predicted by our theoretical modeling.above a few TeV.

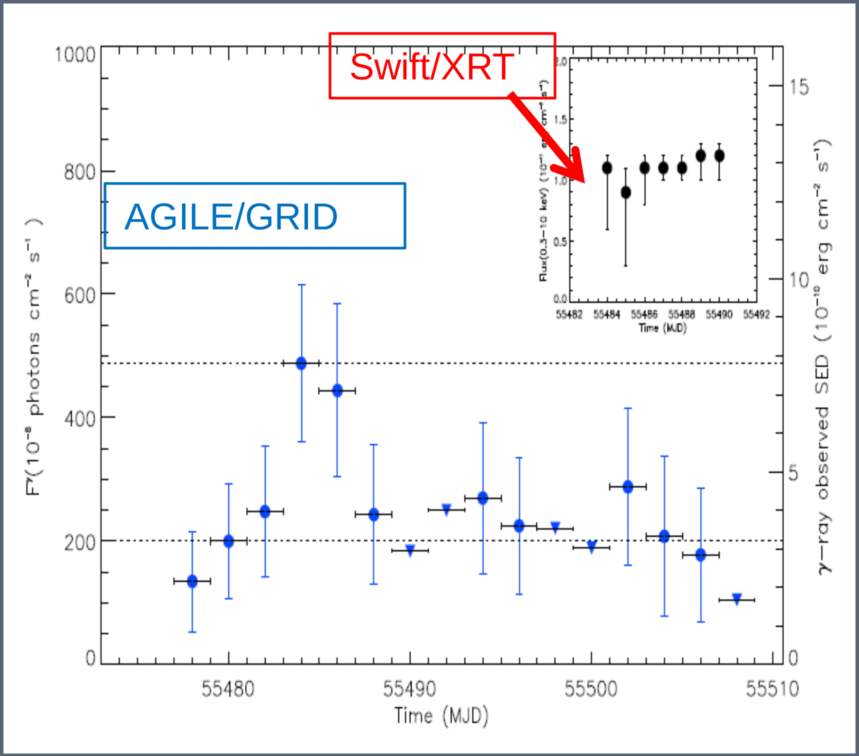




THE "GAMMA-RAY ONLY" FLARING BLAZAR

The remarkable gamma-ray flare of PKS 1830-211

Donnarumma et al. 2011



Gamma-rays: a 1-month enhancement by a factor of 4 (see bottom horizontal line in Fig. 1) with respect to the average flux (Abdo et al. 2010); the maximum exceeded the average flux by a factor of 12, which lasted about 4 days.

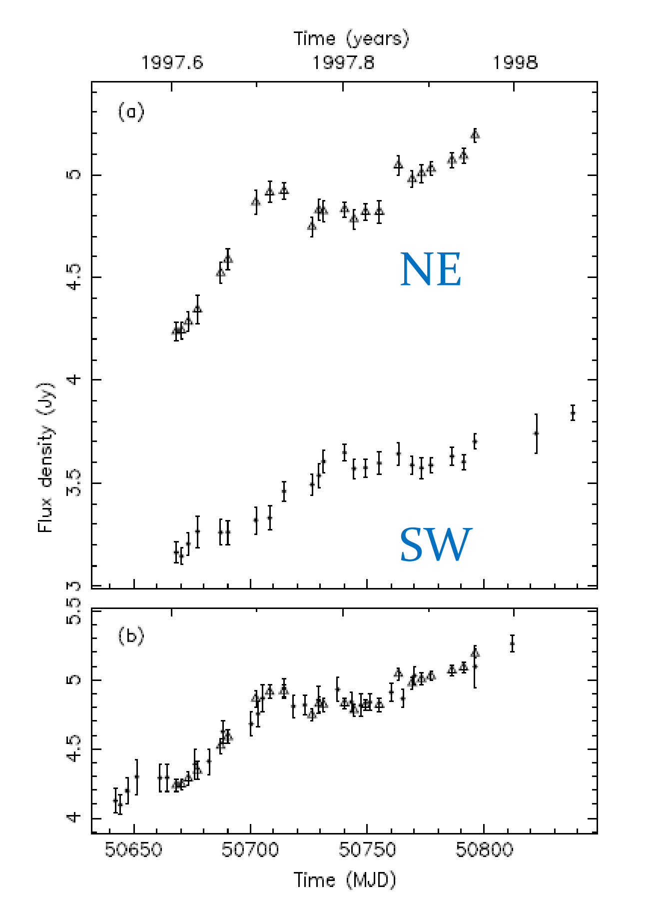
Hard X-rays: INTEGRAL monitoring of the Galactic bulge region (Kuulkers et al. (2007) across the γ-ray flare did not allow for a detection of PKS 1830-211, obtaining an UL of 1.95 10^{-11} erg cm^{-2} s^{-1} on 200 ksec integration time (October 14-18). It implied that variations greater than a factor of 1.5 in this energy band have to be excluded.

Soft X-rays The best fit values of the photon indexes as well as the flux in 0.3-10 keV are all consistent within 1-sigma given the large uncertainties. Our data analysis led to exclude variations greater than a factor of 1.6 with respect to the its average state (De Rosa et a. 2005).

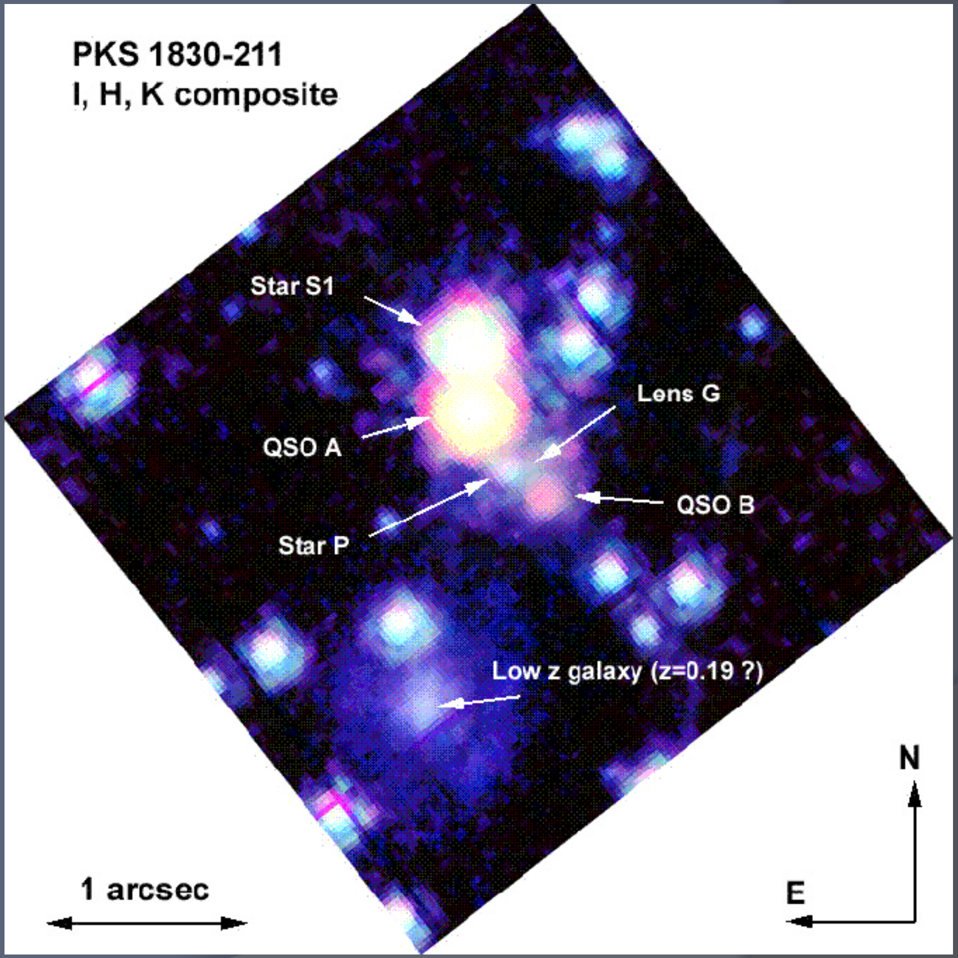
NIR/Optical: Optical and infrared data were obtained using the 1.3m telescope at the Cerro Tololo Inter-American Observatory (CTIO) under the SMARTS program. The source was not detected in single images nor in the summed image. Nevertheless, thanks to the NIR upper limit we can exclude variation greater than a factor of 2.5 in both synchrotron + non thermal emission of this source.

A time delay of 26^{+4}_{-5} days and a magnification ratio of 1.52±0.05 in the strong radio gravitational lens PKS 1830−211 (Lovell et al. 1999)

Time delay from IR, optical images hard to be determined (it strongly depends on the lensing environement)



Radio 8.6 GHz Lovell et al. 1999

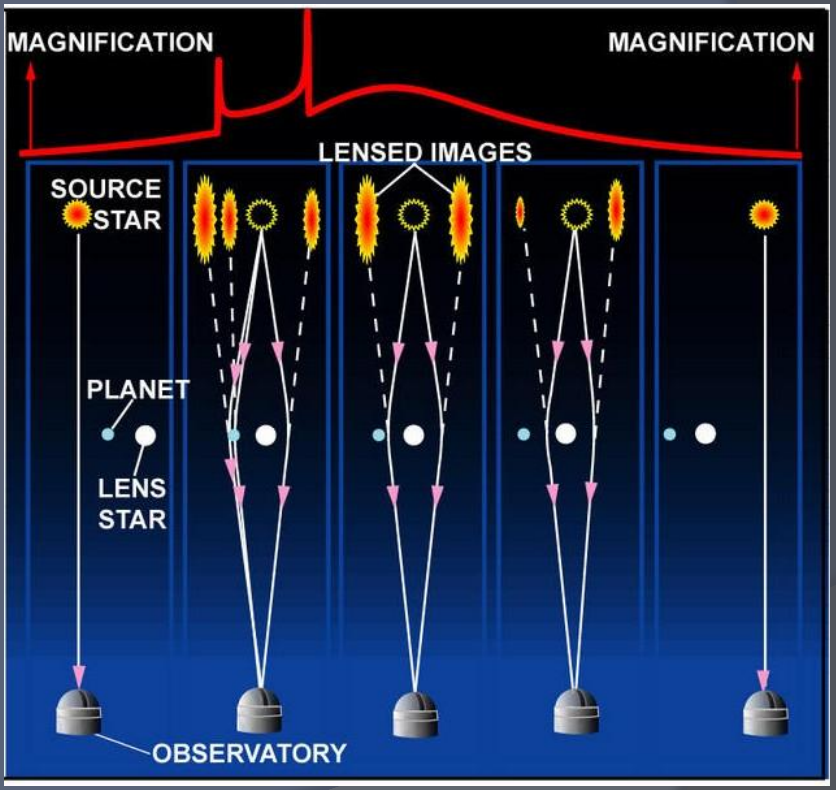


Composite image HST I (F814W), H (F160W), and K (F205W) band data.

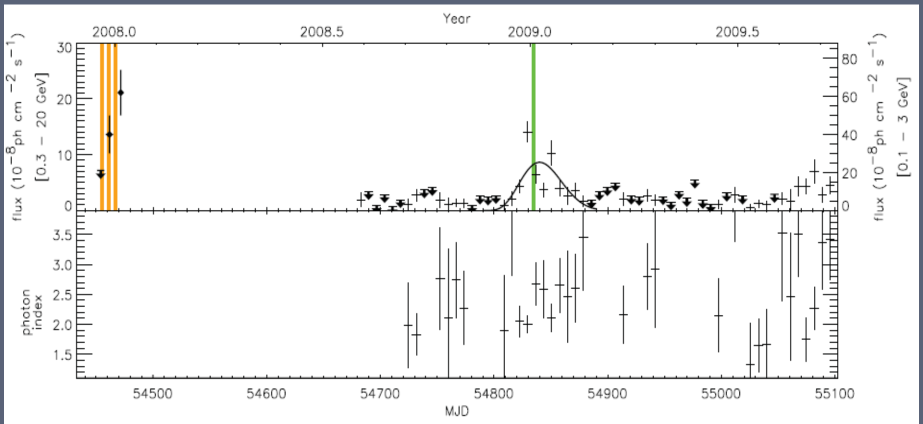
Is the γ-ray enhancement related to the lensing (macro-micro)?

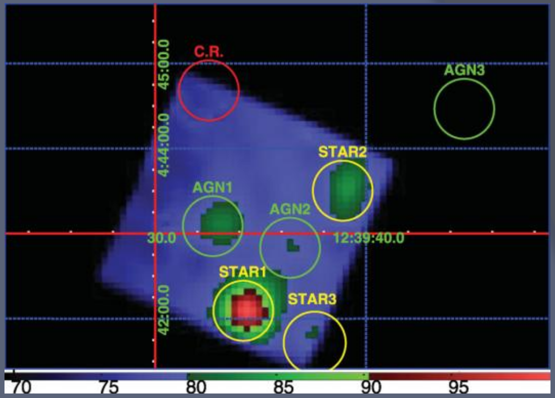
- NIR-optical, soft and hard X-ray emissions of this source did not follow the significant changes observed in γ-rays; the observed variations of the SED rule out the hypothesis that the γ-rays emission was connected to macrolensing, since its effects would be energy-independent.

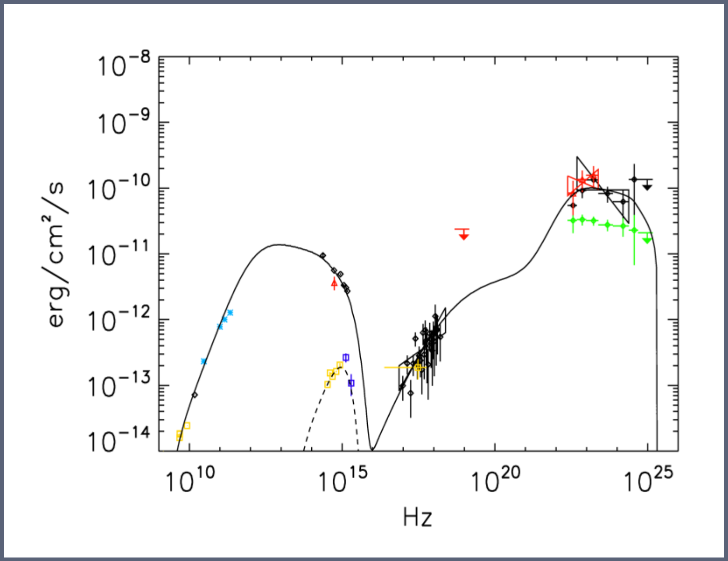
- the chromaticism of the SED variability could suggest that microlensing from stars in the lensing galaxy may cause the observed gamma-ray variability (Torres et al. 2003). This option seems to be disfavored due to the longer time scale (compared with the observed variability) required for microlensing to affect the gamma-ray emission of this source.



Pacciani, Donnarumma et al. 2012







Archival data: SDSS (photometry + spectrum), GALEX, MOJAVE, PLANCK

We confirm the association of SDSS J123932.75+0445.3 with the gamma-ray emitting source with a larger dataset (using INTEGRAL/OMC images), and looking for the other candidates in the Swift/UVOT images

We derived the disk luminosity and then the BH mass from the CIV line width [Vestergaard 2006], [ASSEF 2011]

The 30 days integrated gamma-ray spectrum lacks absorption features as predicted by [Poutanen & stern2010] and [Tavecchio & Mazin 2009] at 5 GeV/(1+z)

Very Hard Gamma-ray spectra favor dissipation beyond the BLRs;

Summary

Since its launch, AGILE is investigating the blazar properties by means of MW programs on specific sources.

The current spinning pointing mode allows us to cover a large fraction of the sky with a good sensitivity for transient events with a very fast QL alerts.

Optical-UV observations in different γ-ray states:

- constraint on possible time lags between synchrotron and IC emissions in LSPs
- Evidence/lack of thermal components → constraints on the acceleration mechanism efficiency and on the external seed photons responsible of the IC peak
- Constraints on the γ-ray dissipation region

X-ray observations:

- spectral trend investigation (interplay between SSC and EC in the soft X-ray band)

Radio-optical-GeV:

- deep investigation of γ-ray dissipation region with possible implications on the jet geometry

GeV-TeV connection:

- leptonic models at work (1-2 zone SSC, quest for EC component?)

Future plans:

- Exploration of the 50-200 MeV energy band. Possible investigations of "the gamma-ray only flaring" behavior

Gamma-400 Approved by ROSCOSMOS

originally devoted to the study of: gamma rays (0.03 – 3 TeV)
& high-energy electrons and positrons.

Availability for a revision of the project that does not alter the original objectives

- The characteristics of the satellite:
  - scientific payload 2600 kg,
  - power budget 2 kW,
  - expected lifetime >5 years

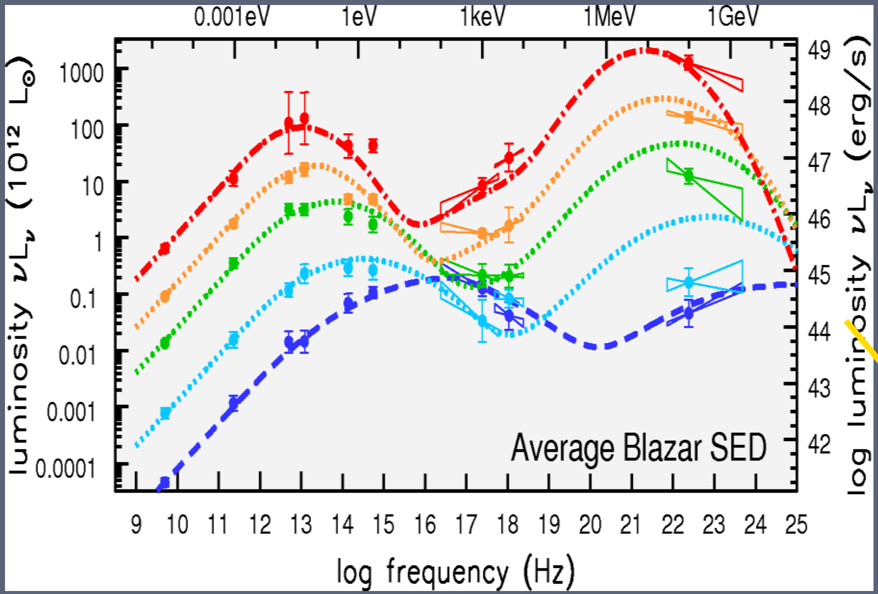
provide excellent opportunities to configure the apparatus for accomplishing extremely important physics tasks beyond the current generation of space missions. The Italian contribution to the project would concentrate on:

- Study of the p and He spectra up to the “knee” region (10^{14} – 10^{15} eV)
- Extension of the gamma capability in the 50 – 300 MeV region

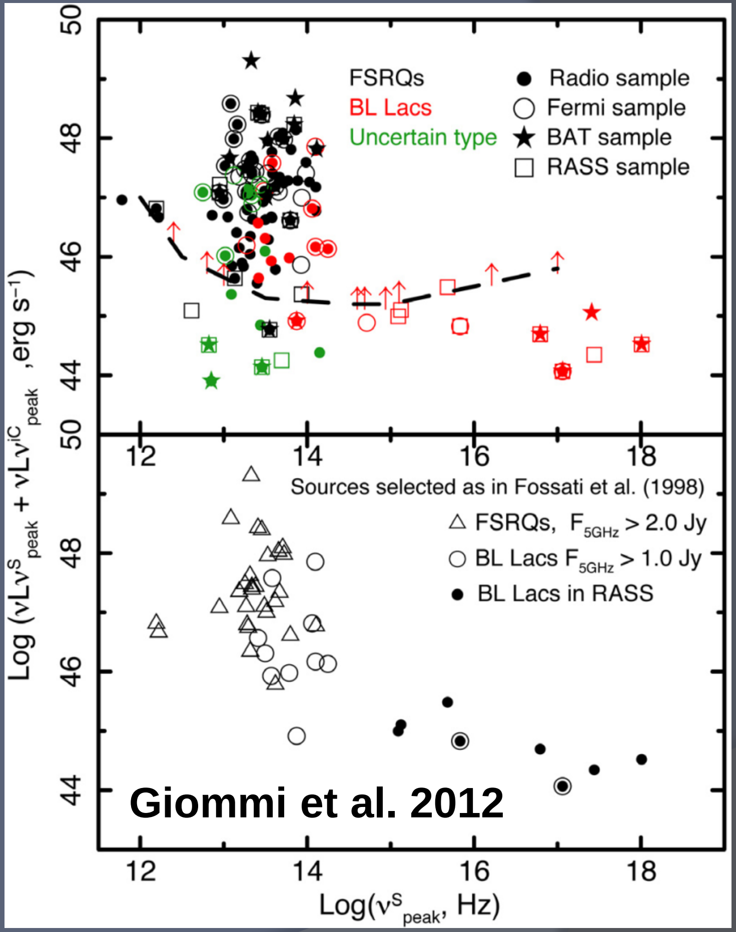
Among its scientific goals:

- **Acceleration processes at the highest energies, relativistic jets**
- **Transients gamma-ray sources**
- **AGNs and blazars resolved with much improved sensitivity and spatial resolution.**
- **Gamma-Ray Bursts**

The Blazar sequence paradigm?



Observational Bias in Blazar studies



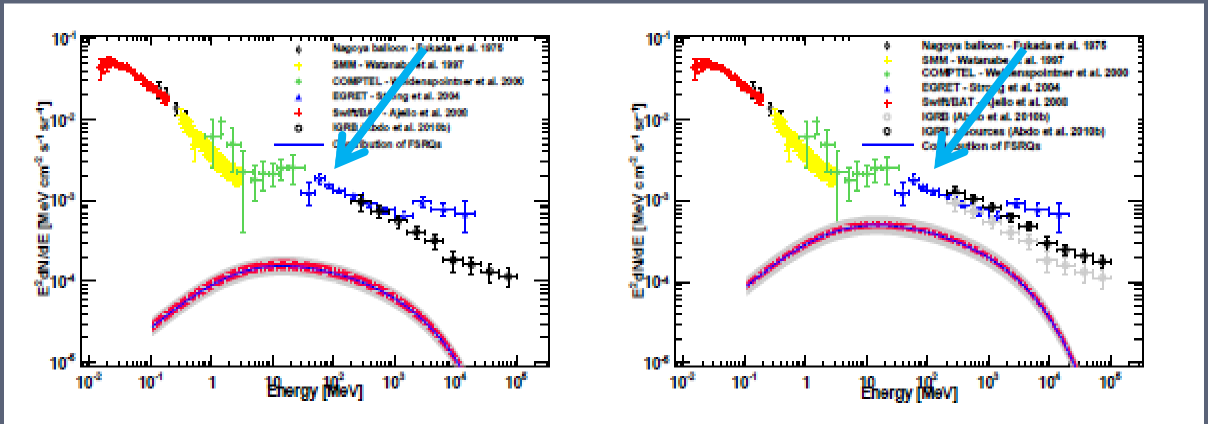
- Gamma-ray **flux-limited** samples favor bright gamma-ray objects and therefore highly Compton-dominated sources.
- Fermi-LAT **sensitivity-limited** samples favor sources with flat gamma-ray spectral slopes or high IC Peak sources.

This results in the overabundance of High Synchrotron Peak blazars (only BL Lacs) and of high Compton Dominated blazars (only FSRQs) in Fermi- LAT catalogs

The main concern is for the steeper FSRQs: in this case the gain in the source exposure (years) is limited by the imaging capability at low energies (confusion limits introduced by PSF).

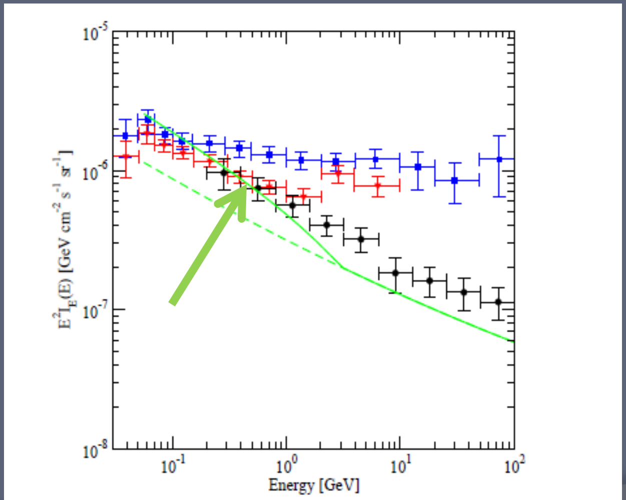
The contribution to the low energy EGB

Ajello et al. 2011



Contribution of *unresolved blazars 9.3%*
Contribution of all *blazars ~20% in 100 MeV-100 GeV*

Stecker et et al. 2011

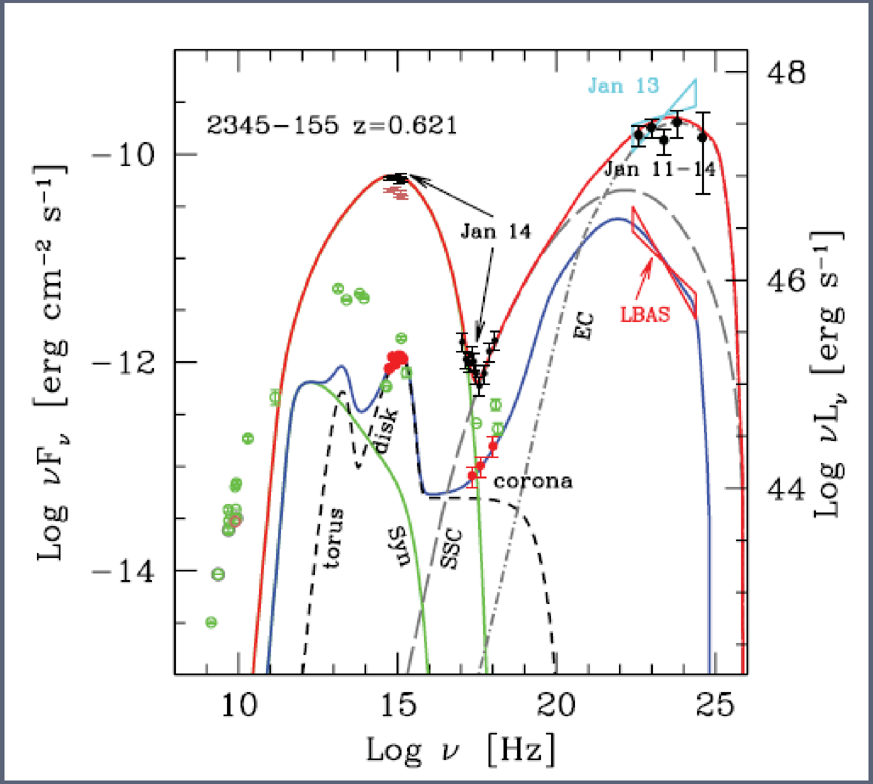


Contribution of *unresolved blazars if properly accounted for should significantly contribute to the low energy EGB*

The main concerns about possible claims are related to the gamma-ray variability and duty cycle of the FSRQs mostly contributing to the lower energies (those characterized by steeper spectra → MeV blazars)

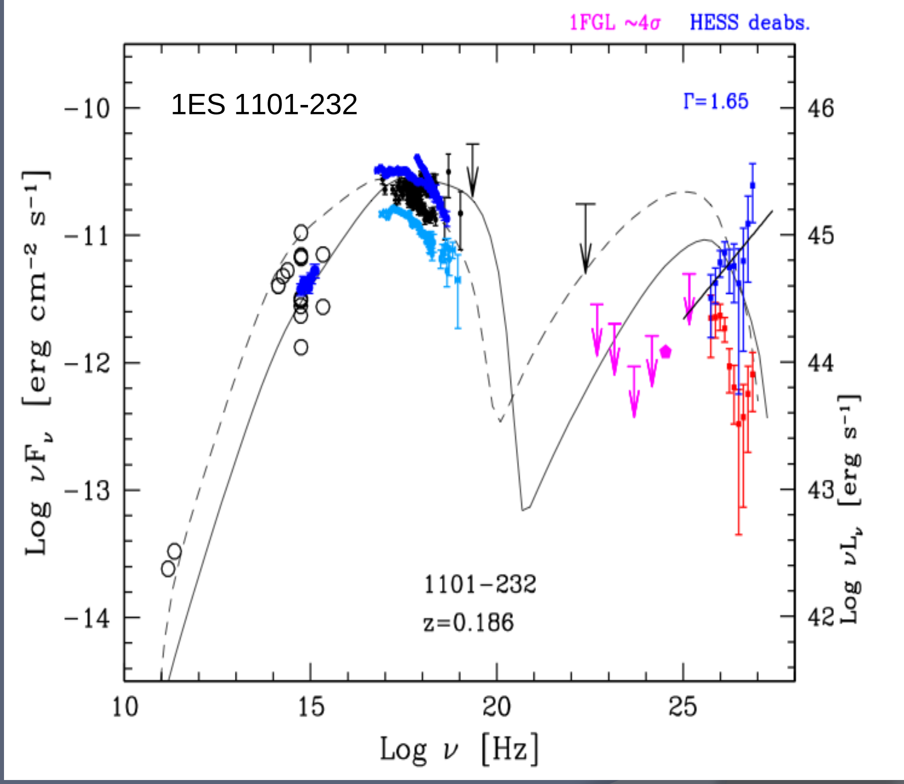
Looking forward to a future gamma-ray mission supporting CTA

Blue FSRQs



Ghisellini et al. 2013

TeV peaked BL Lacs



Costamante arXiV 1208.0808

Possible Advances in blazars studies achievable by

- Improving gamma-ray sensitivity at low energies and >1 GeV too (synergy with CTA)
- Applying magnetic reconnection to jet structure to reproduce both rapid variability at parsec scale and polarization swing.
- Exploring ultrafast variability in X-rays and TeV with LOFT and CTA
- Tracing the jet evolution on long timescale with SKA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