Monitoring of gamma-ray blazars with AGILE

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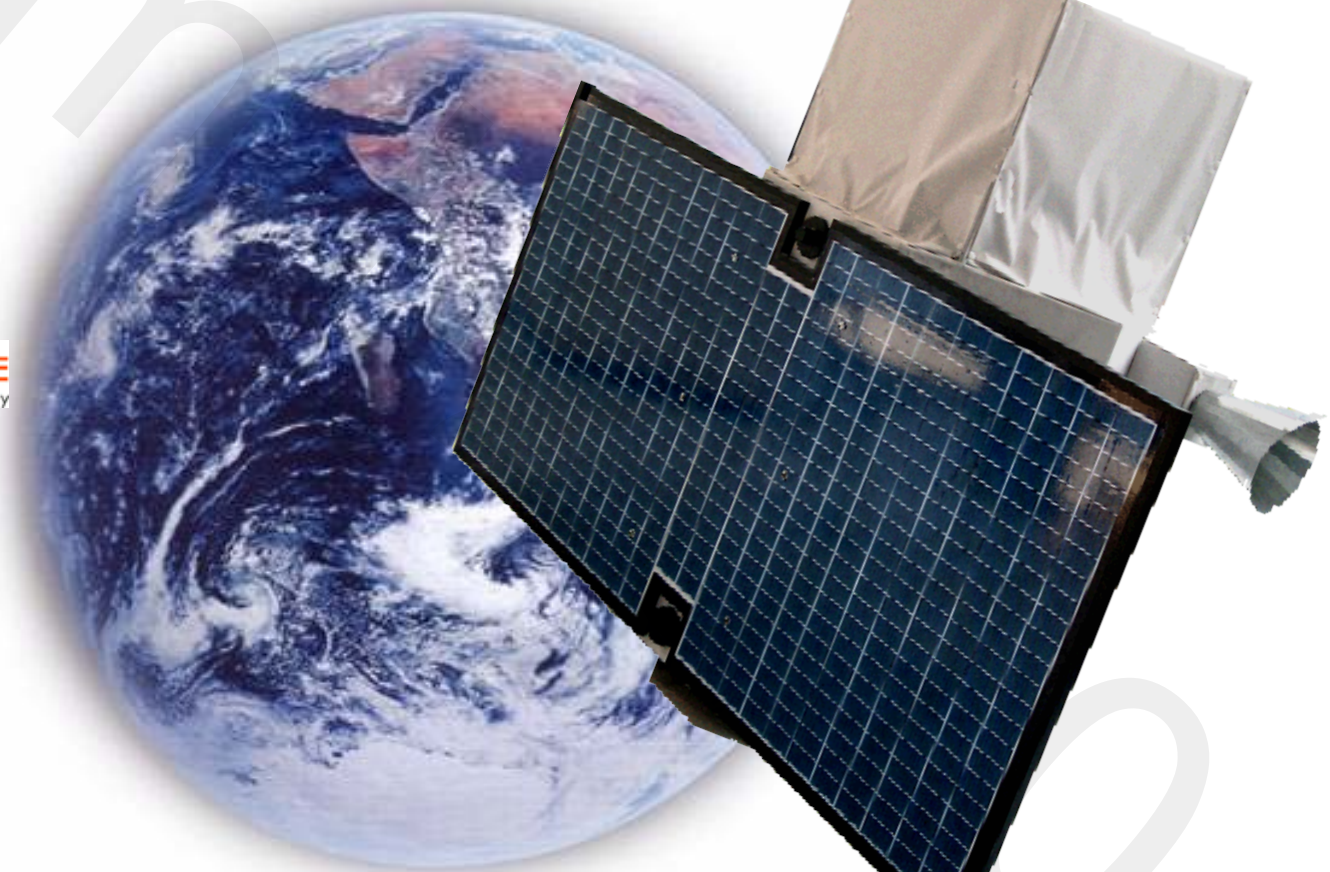
On behalf of the AGILE WG AGN

with the collaboration of many MW colleagues (C. M. Raiteri, M. Villata, P. Romano, S. Covino, D. Fugazza, H. Krimm, E. Pian, G. Giovannini, A. Tiengo, M. Aller, H. Aller, M. Gurwell....)

AGILE: an Italian Mission



AGILE in orbit

AGILE is the first gamma-ray satellite more than ten years after the EGRET *era*

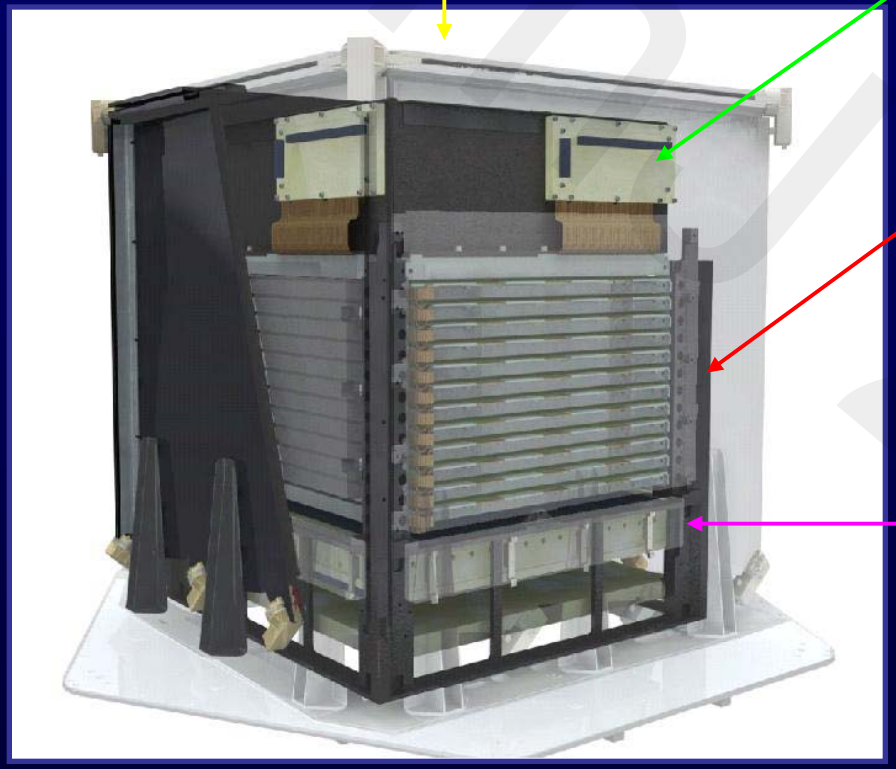
AGILE was successfully launched on April 23 2007 by the Indian PSLV – C8 rocket from the Satish Dhawan Space Center SHAR, Sriharikota (Chennai-Madras)

The satellite orbit was almost equatorial (altitude: 540 km, inclination: 2.5°)

The AGILE Payload

Anticoincidence Shield (AC)
Plastic scintillator + photomultipliers

SuperAGILE (SA)
Silicon strips detector + coded-mask
Energy range: 18 - 60 keV



Silicon Tracker (ST)
12 trays of tungsten / silicon strips
Energy range: 30 MeV – 30 GeV

MiniCALorimeter (MCAL)
CsI(Tl) bars with photodiodes
Energy range: 0.3 - 100 MeV

Volume : ~ 0.25 m^3 Power Consumption : ~ 60 W Mass : ~ 120 Kg

The most compact instrument for high-energy astrophysics

AGILE main scientific topics

- *Active Galactic Nuclei*
- Gamma-Ray Bursts
- Pulsars and Pulsar Wind Nebulae
- SNR and origin of cosmic rays
- Diffuse Galactic gamma-ray background
- Unidentified gamma-ray sources
- Microquasars
- Galactic Neutron Stars and Black Holes
- Terrestrial Gamma-Ray flashes

The AGILE AGN Working Group

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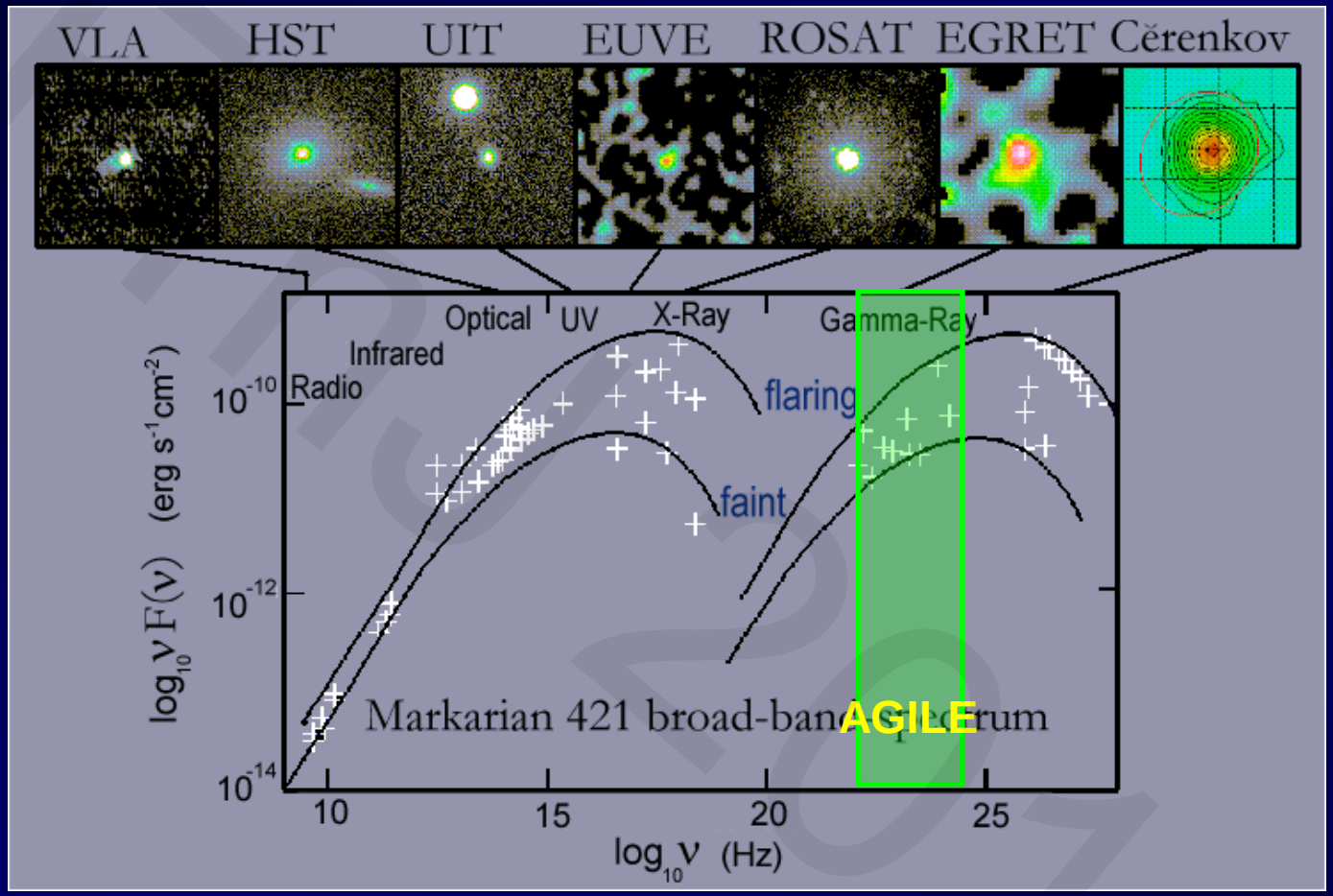


Blazars emit across several decades of energy from radio to TeV energy bands and are the perfect candidates for multifrequency studies

The multiwavelength coverage

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

To a more possible complete knowledge of the mechanism at works it is important to have information in all the colors of the electromagnetic spectrum

W. Kandinsky

Bright blazars studied in detail by AGILE

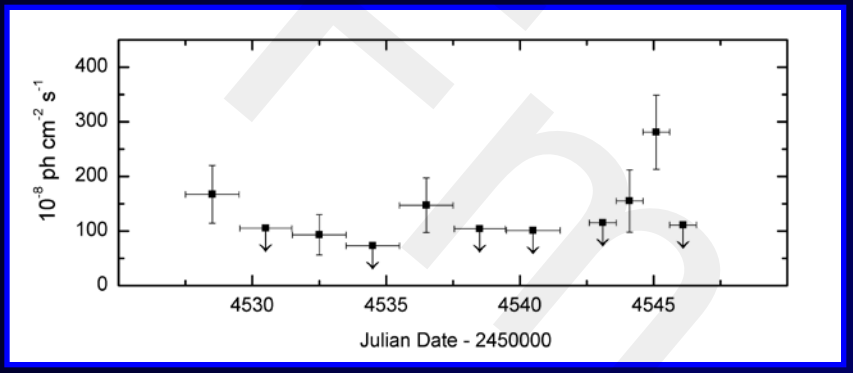
- BL Lac objects:

  S5 0716+714
  W Comae
  PKS 0537-441
  Mrk 421
  PG 1553+113

- Flat Spectrum Radio Quasars:

  PKS 1510-089
  3C 454.3
  3C 273
  3C 279

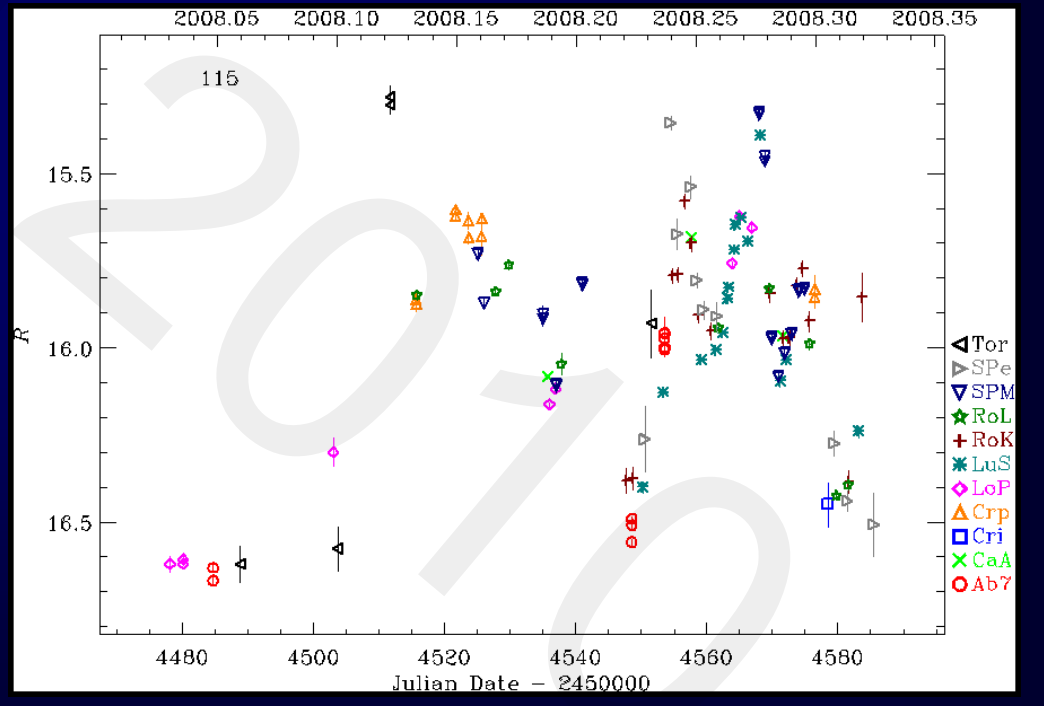
PKS 1510-089: a rapid gamma-ray flare in March 2008



After 2 episodes of medium intensity the source was not detected for some days in gamma-ray band and suddenly a rapid flare was observed by AGILE on 18-19 March 2008

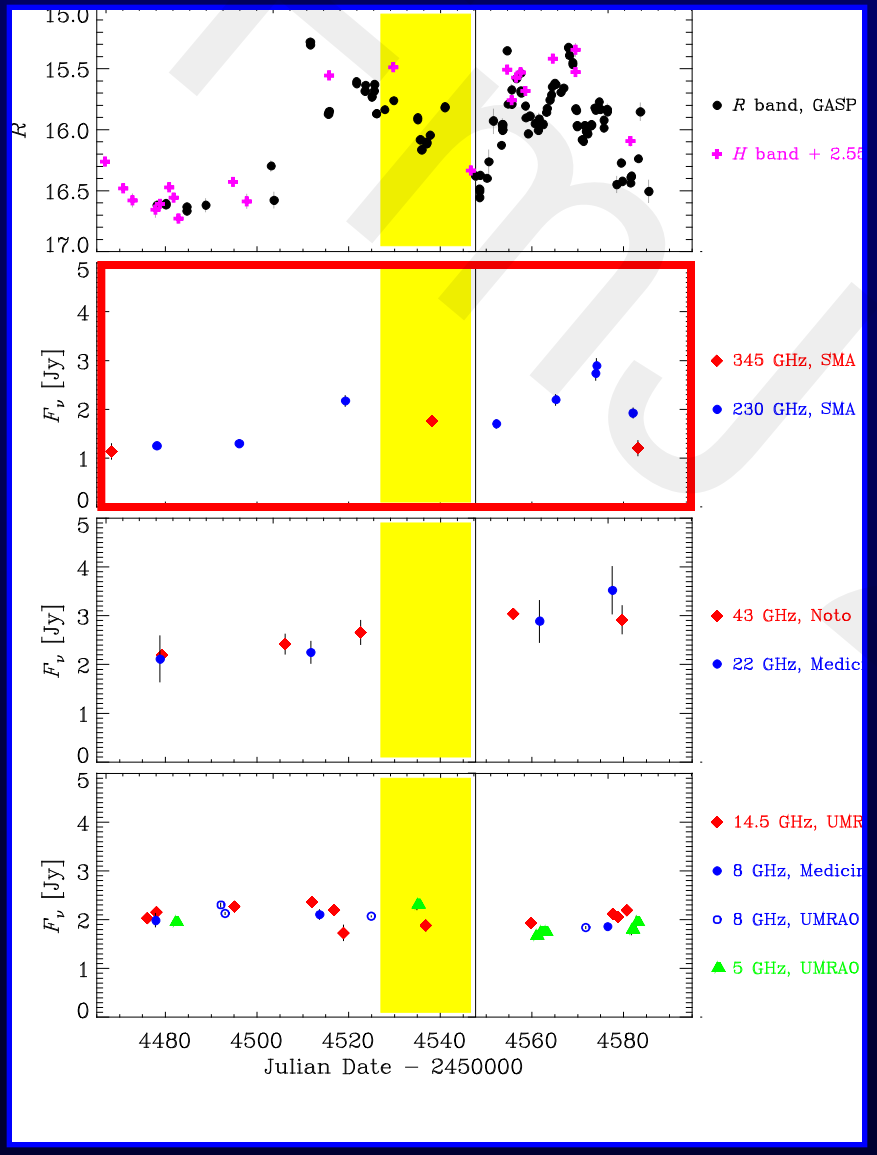
Between January and April 2008 PKS 1510-089 showed intense optical activity, with several episodes of fast variability detected by GASP - WEBT.

3 Swift/XRT ToO observation between 20 and 22 March 2008: the spectrum becomes harder when the source is brighter.



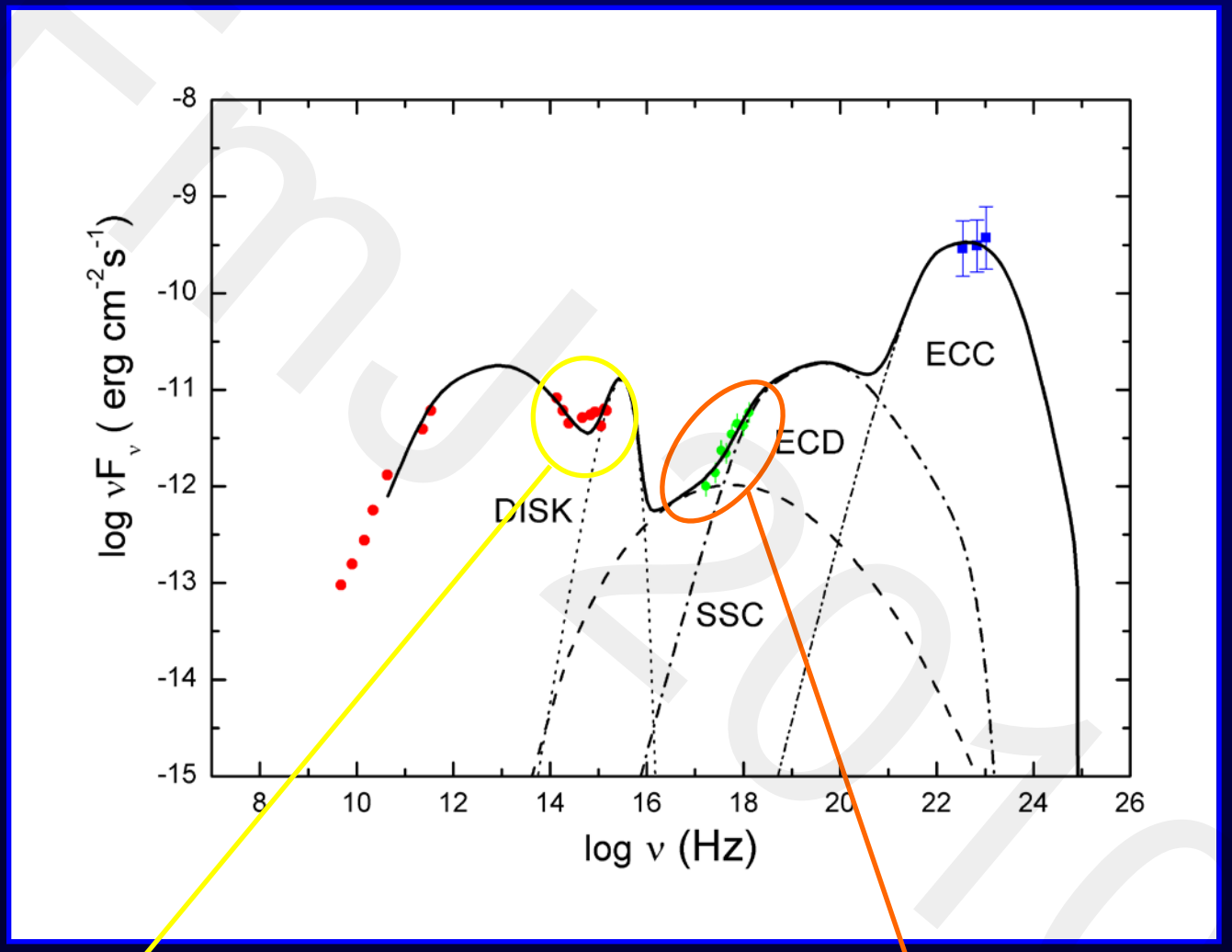
D'Ammando, et al. 2009, A&A, 508, 181

Radio-to-optical behaviour



The light curve at 230-345 GHz suggest that the mechanism producing the flaring activity observed in optical in March-April 2008 and in gamma-ray in mid-March 2008 also interested the millimetric emitting zone, with some delay

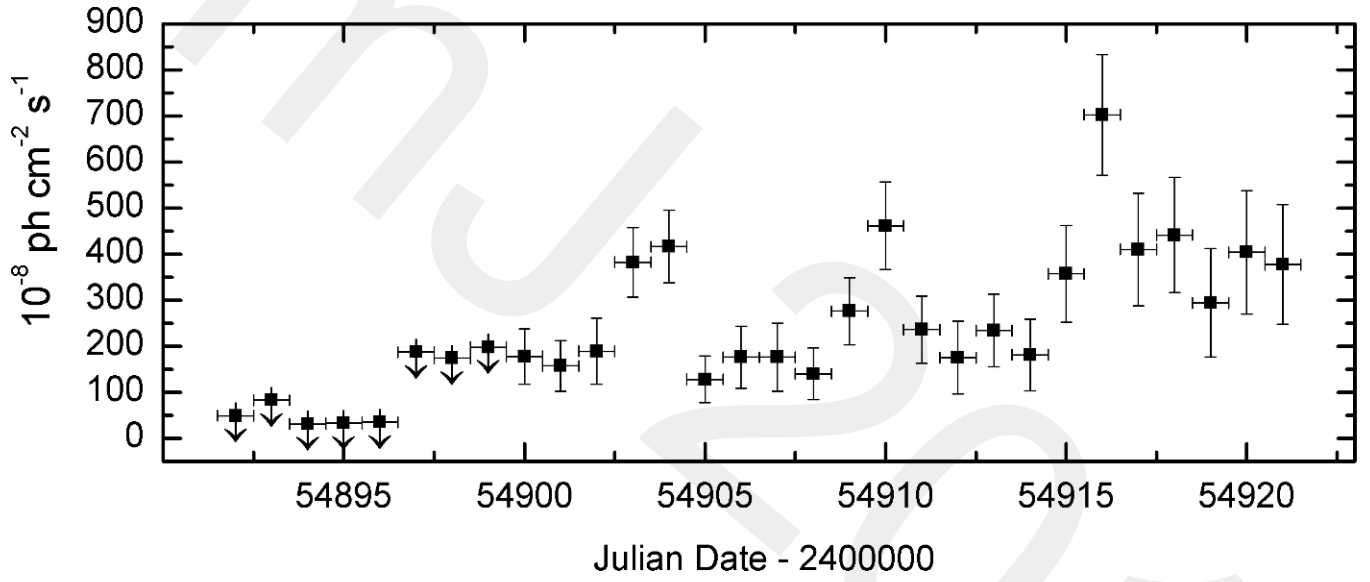
SED of PKS 1510-089 during March 2008



Signatures of the little and big blue bumps

Very hard X-ray photon index ($\Gamma = 1.16 \pm 0.16$)

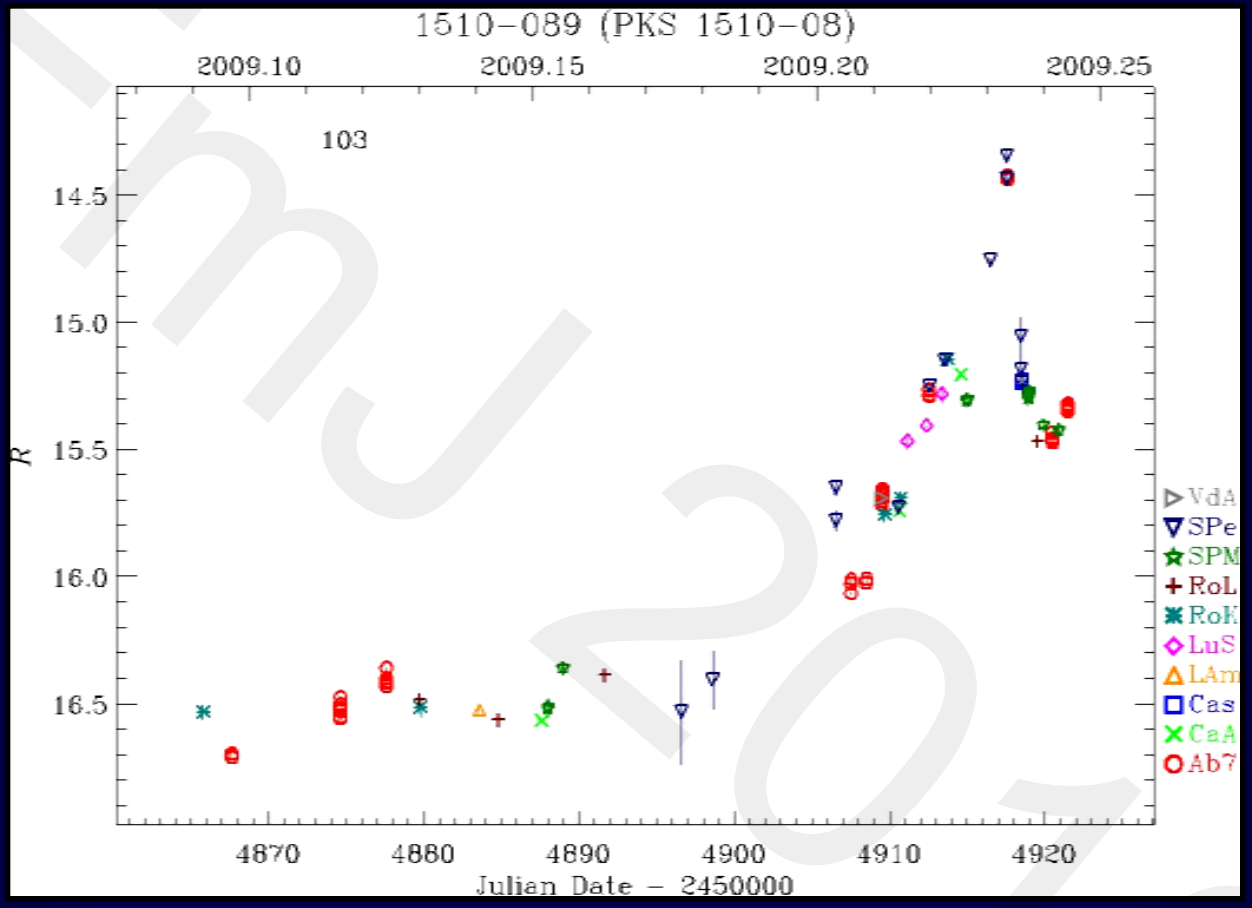
Amazing gamma-ray activity of PKS 1510-089 during March 2009...



D'Ammando et al., in preparation

AGILE detected an extraordinary γ-ray activity by PKS 1510-089 during March 2009, with several flaring episodes of increasing entity that could be an overlapping of different episodes

...and an optical flare observed by GASP-WEBT

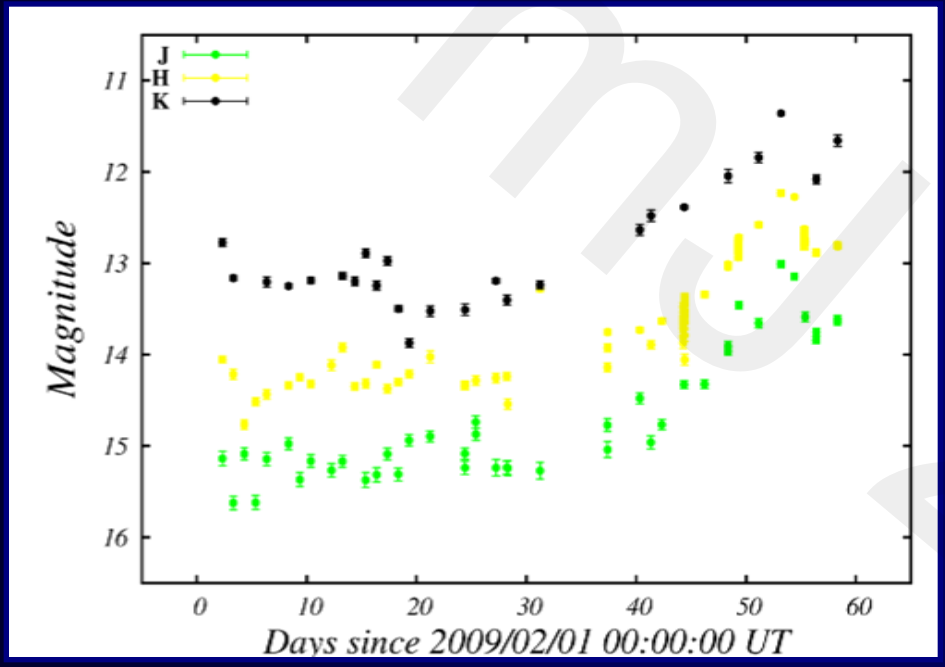


D'Ammando et al., in preparation

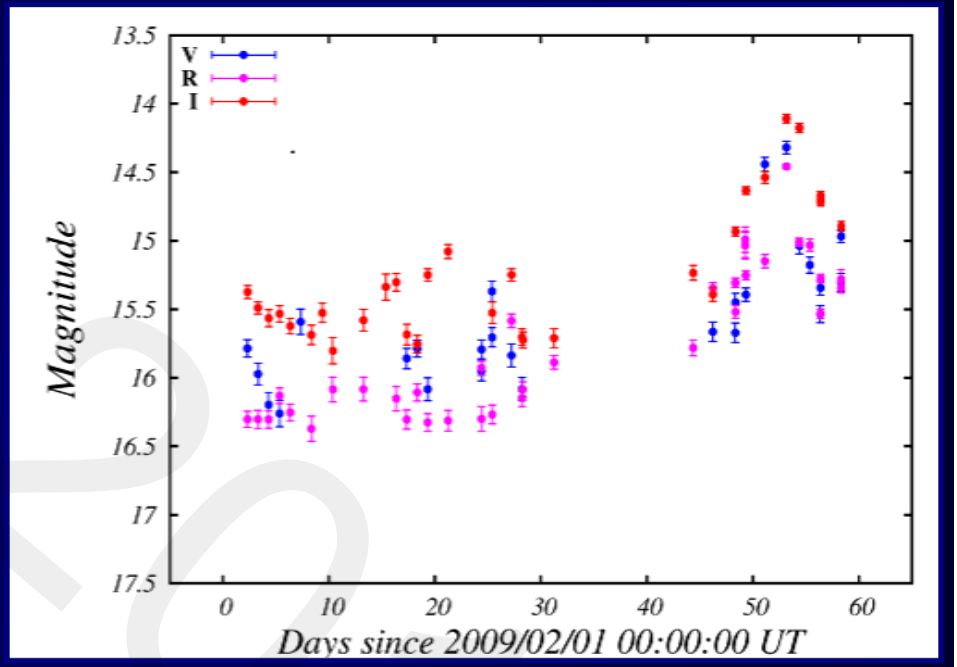
After a low intensity period in February 2009, the optical activity of PKS 1510-089 is greatly increased in March with an intense flare on 27 March 2009

REM observations of PKS 1510-089 in NIR/optical

Near Infrared



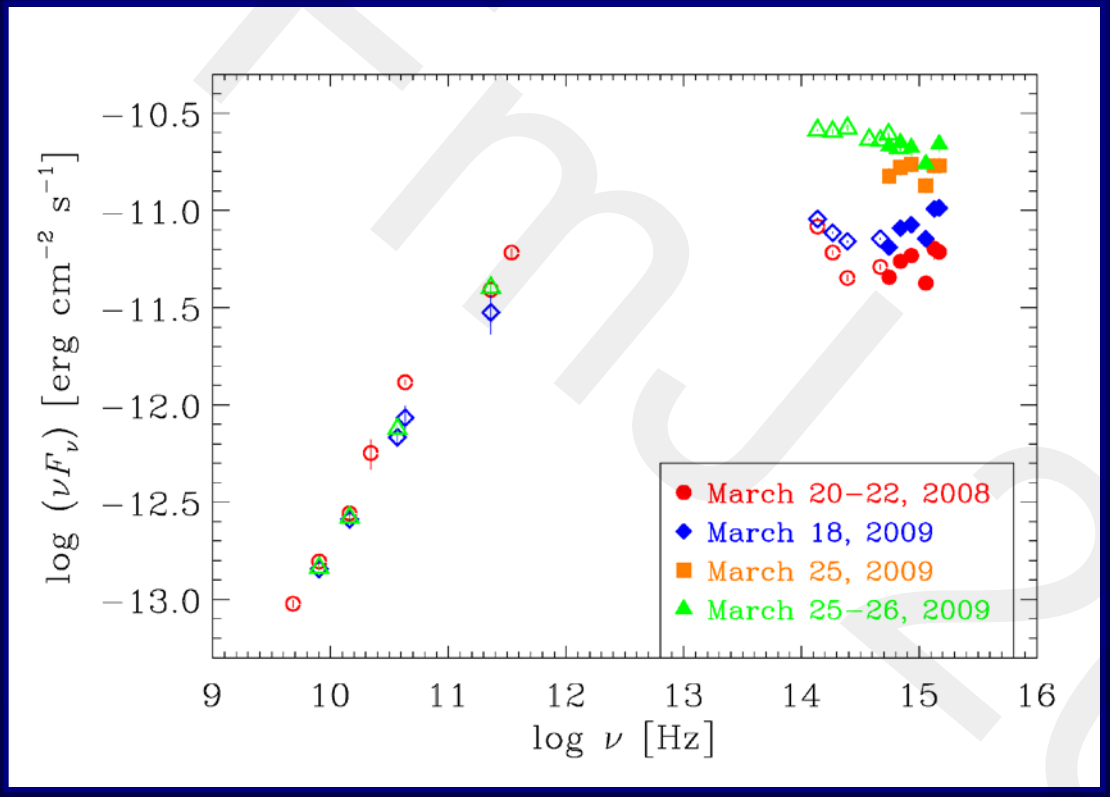
Optical



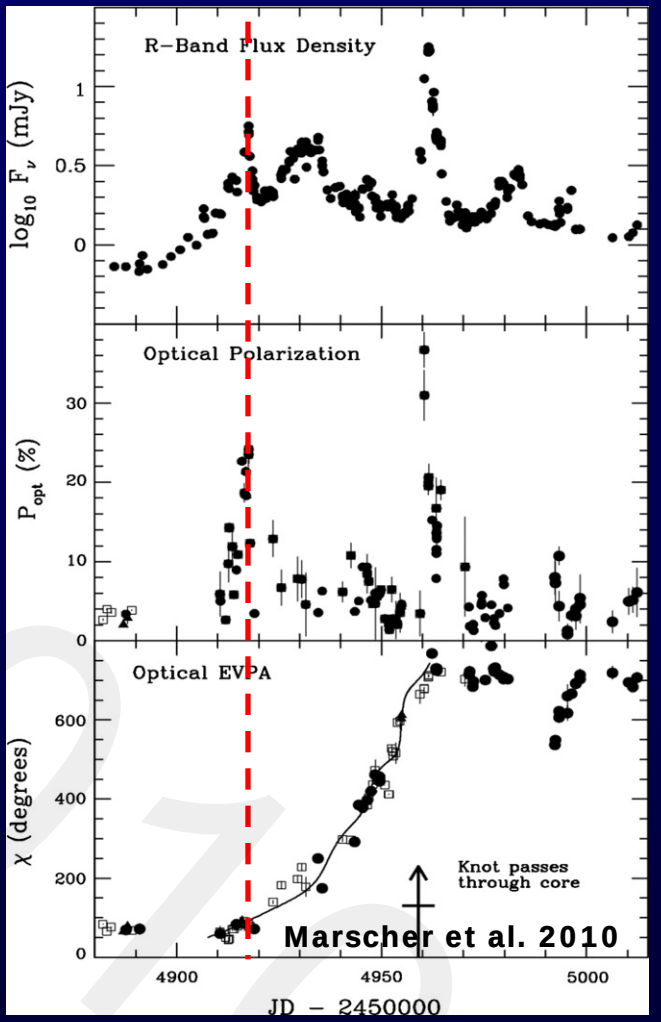
D'Ammando et al., in preparation

A progressive increase of the source activity, similar to the behaviour of the optical light curve, was observed also by REM in NIR/optical bands, suggesting that *an unique mechanism* is responsible to the flux enhancement observed from NIR to optical band

SED radio-to-UV of PKS 1510 in 2008-2009

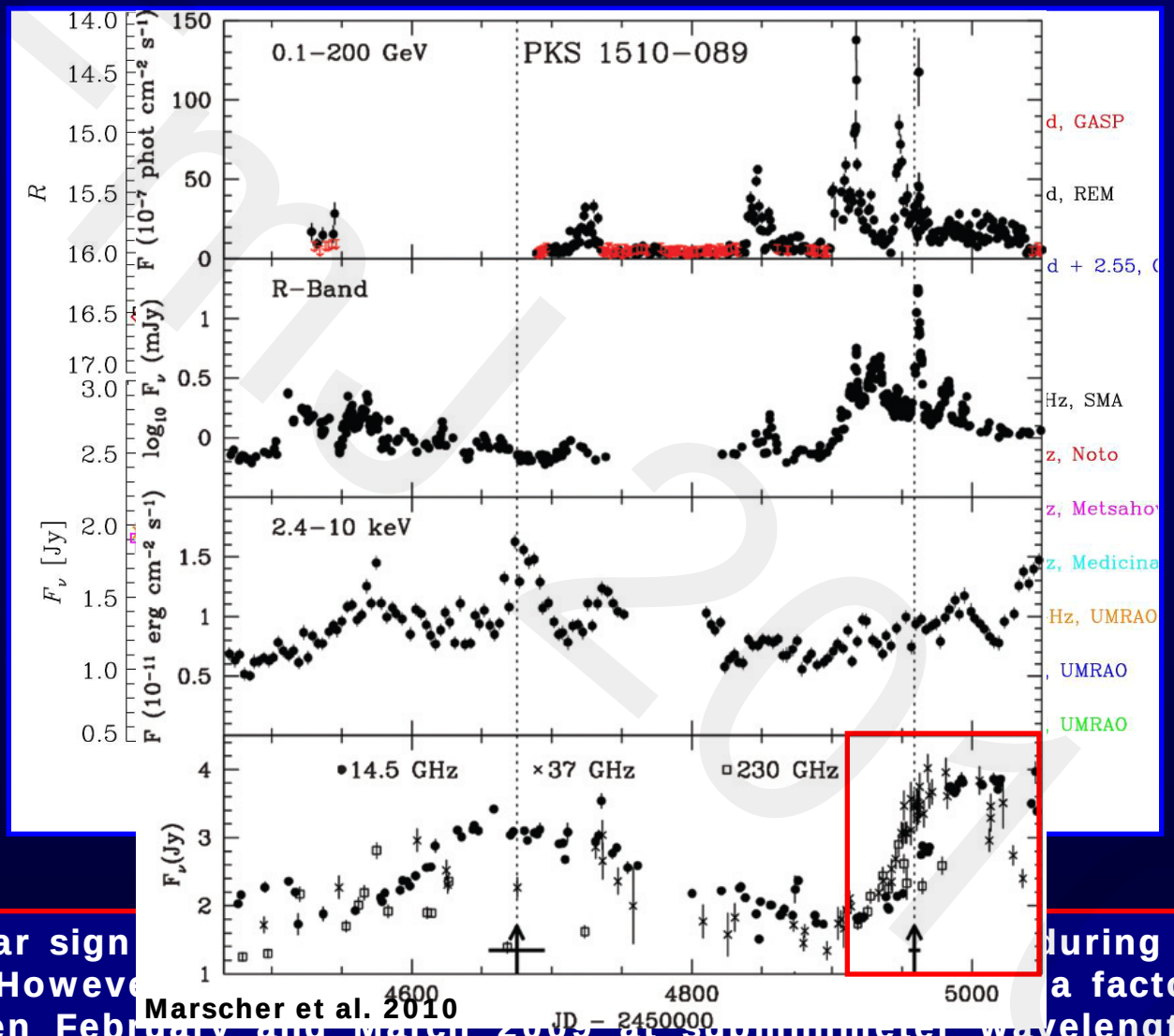


D'Ammando et al., in preparation



Considering that the synchrotron peak usually is observed in the infrared band in PKS 1510-089, this is an indication of a significative shift of the synchrotron peak during very high activity of the source

Radio-to-optical behaviour in March 2009

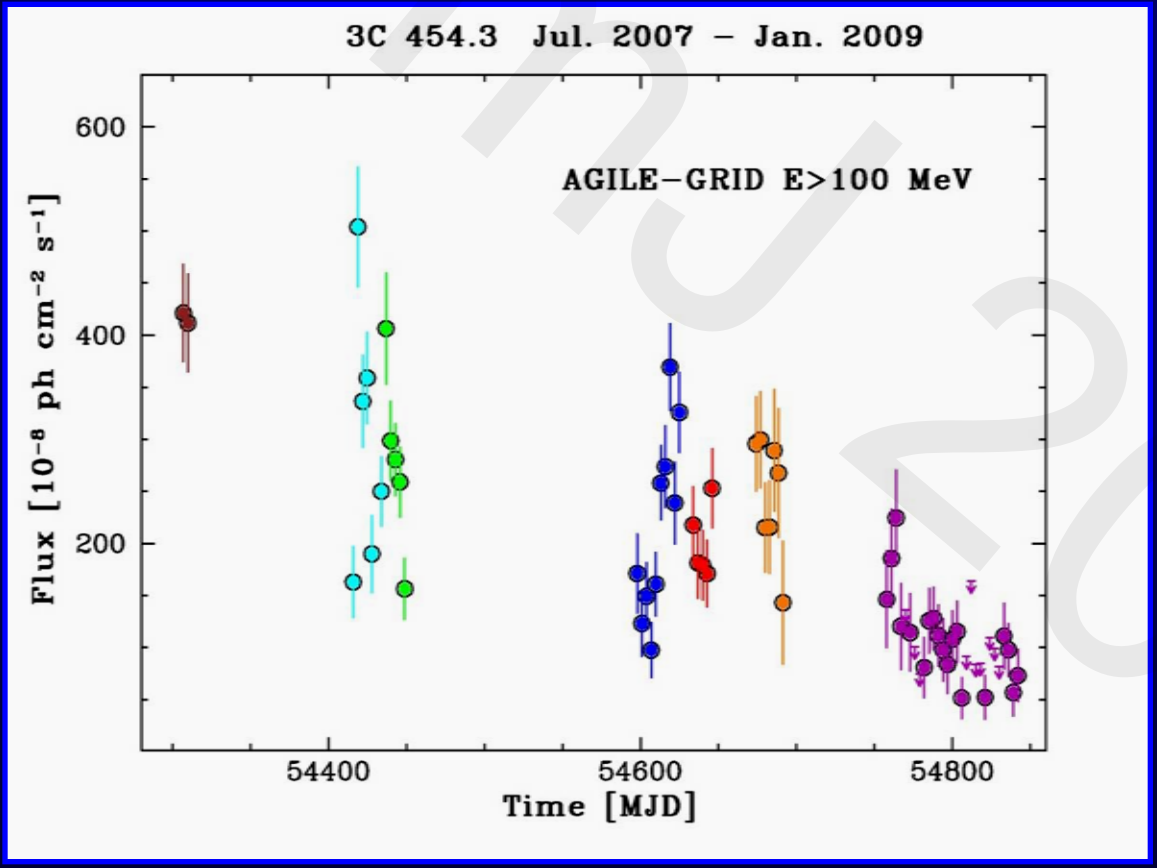


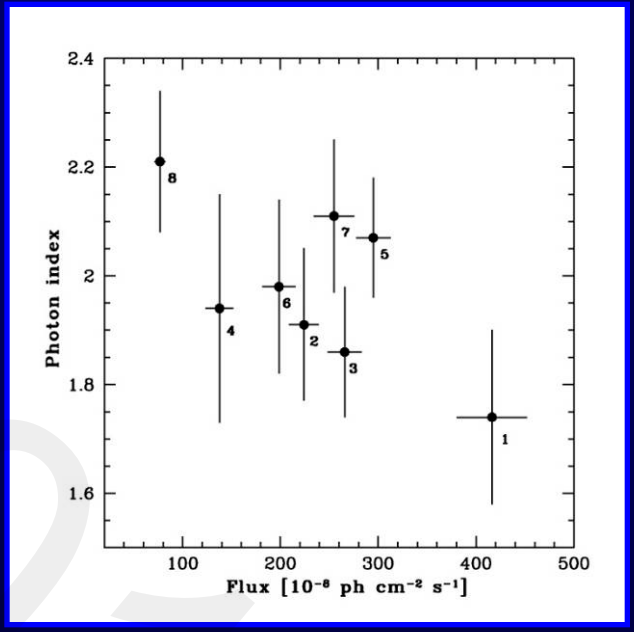
Marscher et al. 2010

No clear sign … during March 2009. Howeve… a factor two between Febr… wavelengths, in agreement with the optical behaviour.

3C 454.3: 18 months of gamma-ray and multiwavelength monitoring

See Vercellone's poster





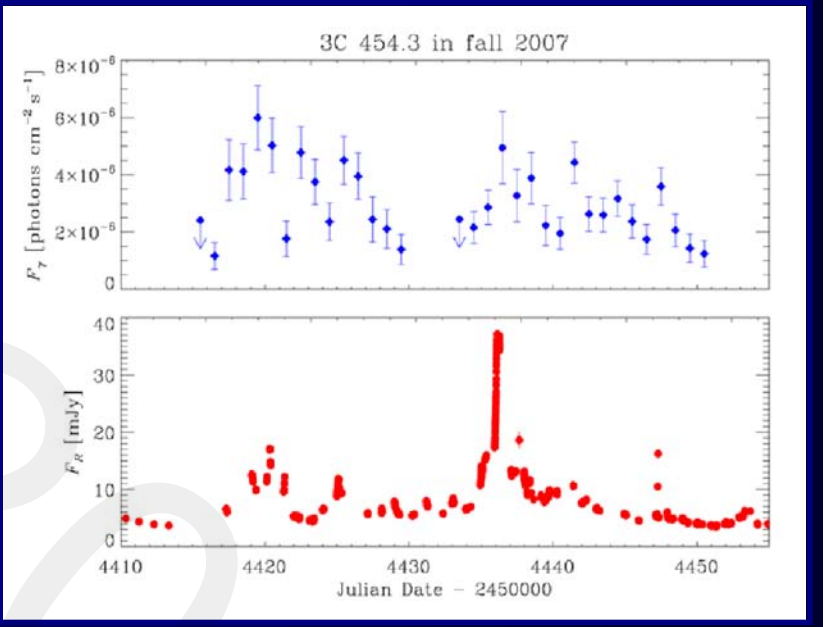
A possible spectral trend in gamma-rays: harder-when-brighter behaviour

Gamma-ray emission highly variable: a factor of about 5 in dynamic range in about 1.5 yr

Vercellone, D'Ammando, et al. 2010, ApJ, 712, 405

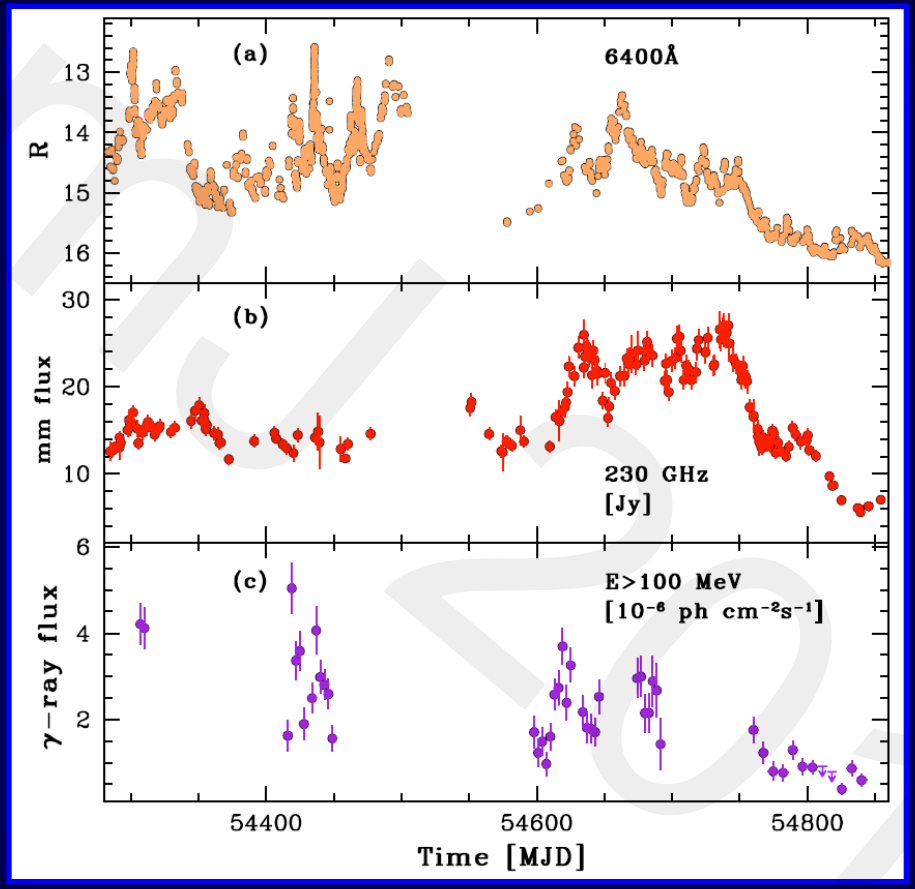
See Vercellone's poster

radio emission



Emission in optical appears to be correlated with that at gamma-ray energies, with a lag (if present) of the gamma flux with respect to the optical one less than 1 day...at least for the bright states

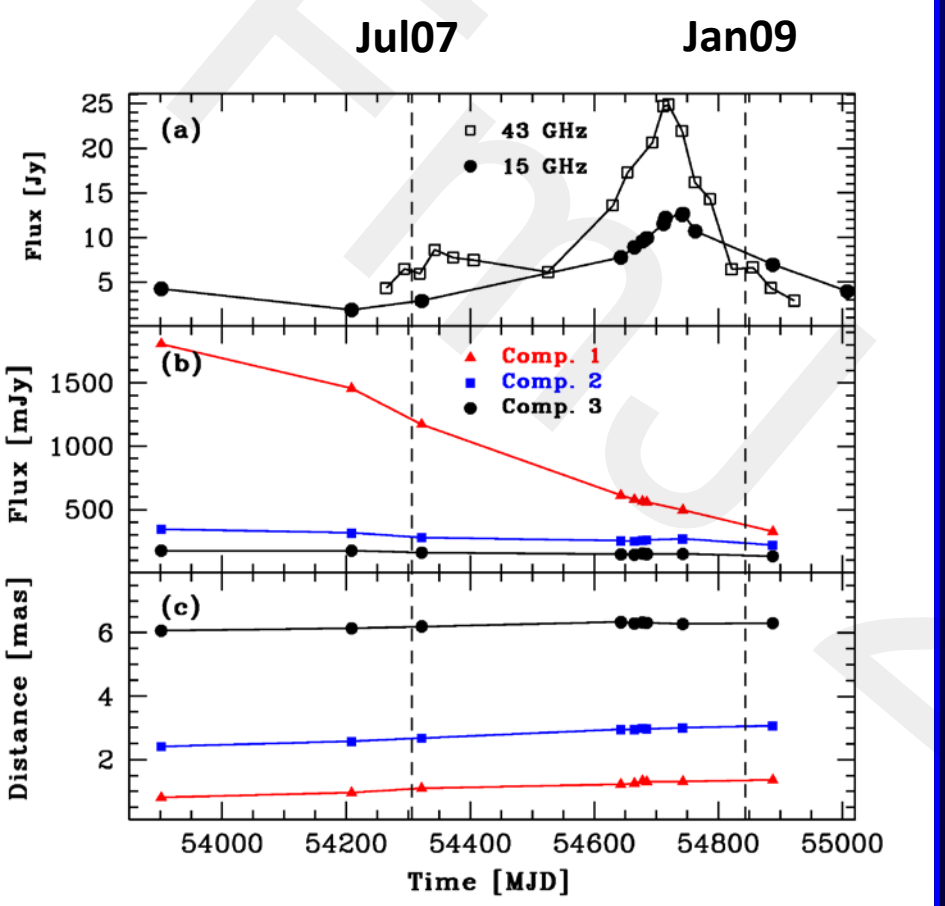
Light curves show a different behavior starting from the end of 2007 among the different energy bands. **Change in the orientation of a curved jet** → different alignment configurations within the jet itself (see also Villata et al., 2009)



2007: the inner portion of the jet might be the more beamed one given the higher fluxes and variability in optical and gamma-rays

2008: the higher mm flux emission and its enhanced variability seems to indicate that the more extended region of the jet became more aligned w.r.t. the observer line of sight

3C 454.3: radio-gamma connection



The presence of one or more new jet components is NOT revealed in the high resolution VLBA images.

The most recent VLBA images at 43 GHz suggest a jet expansion near to the radio core starting from MJD 54600 (2008-05-14)

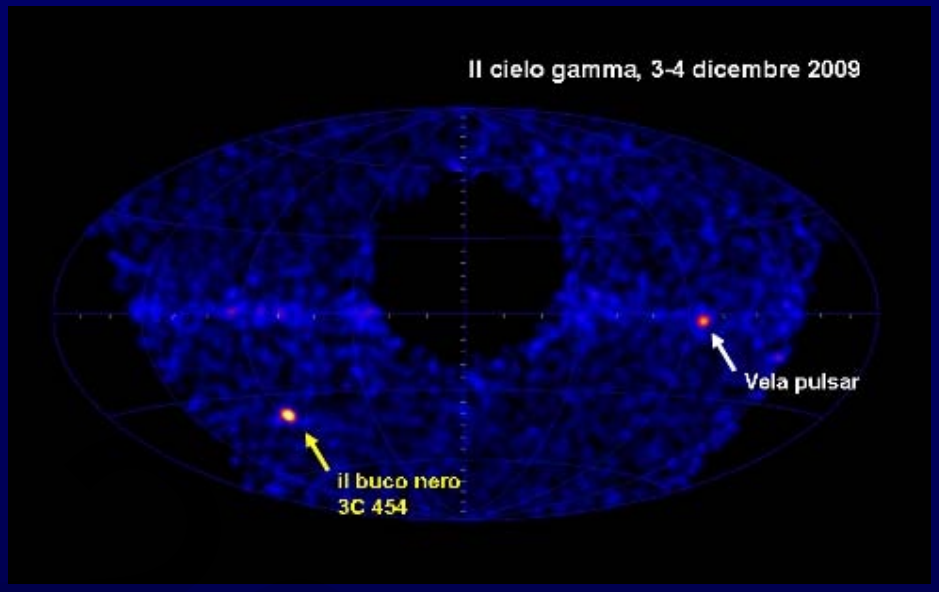
It is not possible to correlate the radio peak with a single γ-ray or optical burst → a multiple source activity in the optical and γ-ray bands is integrated in the radio emitting region in a single event on MJD 54720 (2008-09-11).

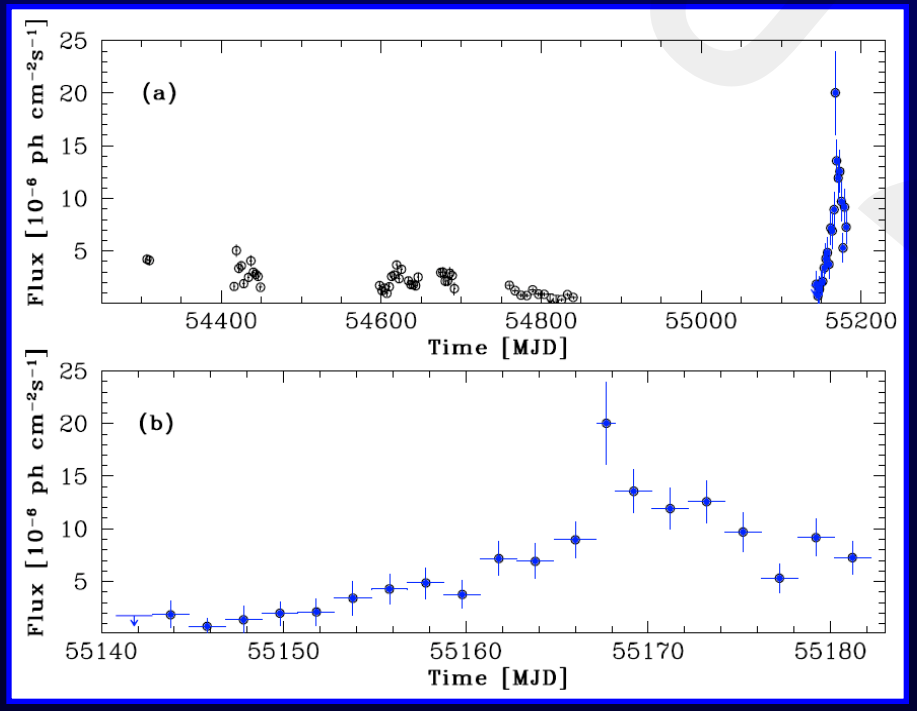
Strong core flux density variability possibly connected to the γ -ray activity.

Jet components are moving away and slowly decreasing in flux density, not affected by the recent core activity (see also Kovalev et al., 2009).

The extraordinary gamma-ray flare of December 2009

At the end of November 2009, AGILE detected a prolonged flaring gamma-ray activity from 3C 454.3. On December 2–3, the source became the brightest gamma-ray source in the sky

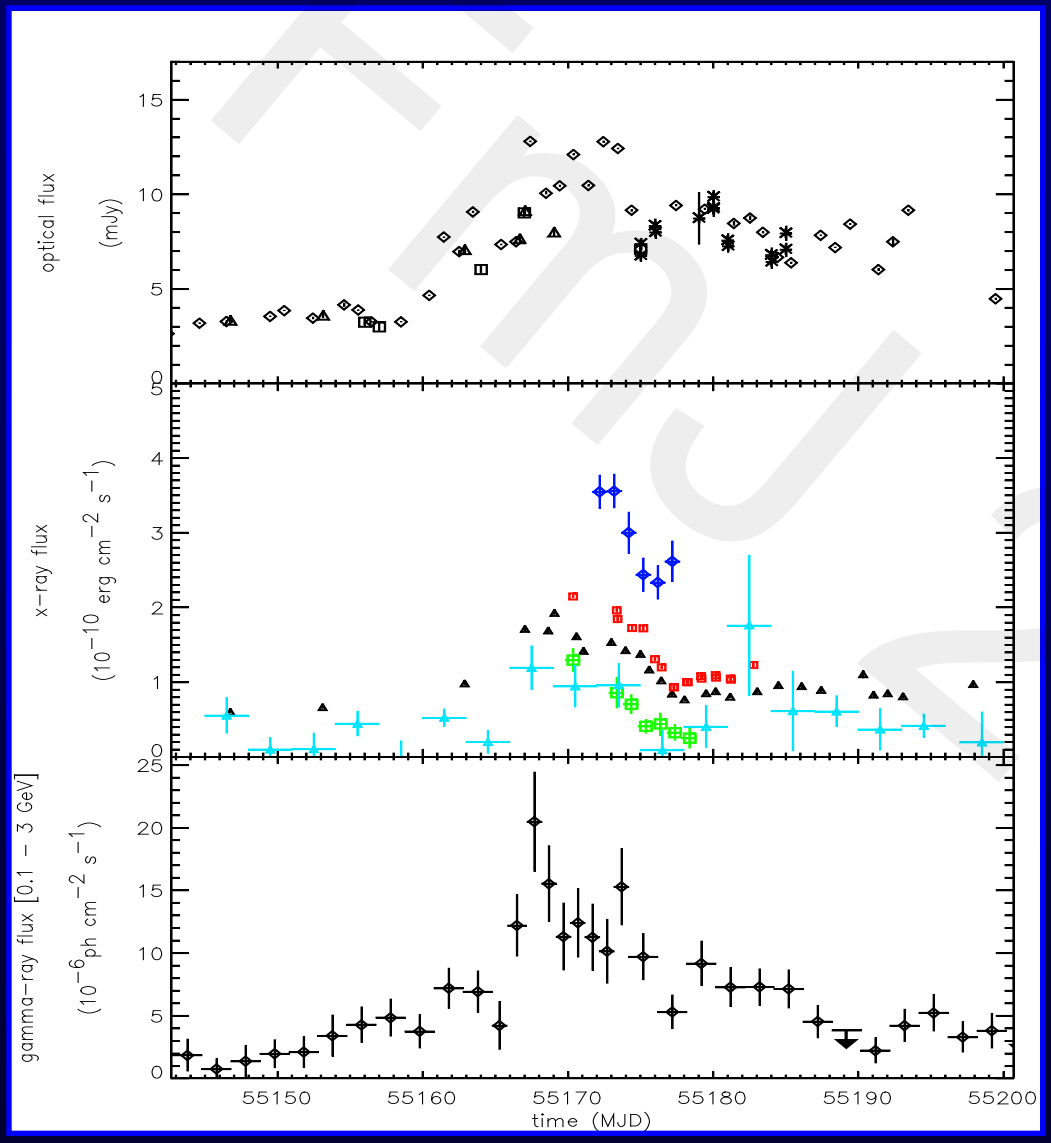




Striani et al. 2010, ApJ accepted

The γ-ray flux observed by 3C 454.3 on 2–3 December 2009 is the highest flux ever observed by a blazar, and even more amazing is the persistent state of very high γ-ray activity of the source on timescales of about 2 weeks

MW coverage of 3C 454.3 in Nov-Dec 2009



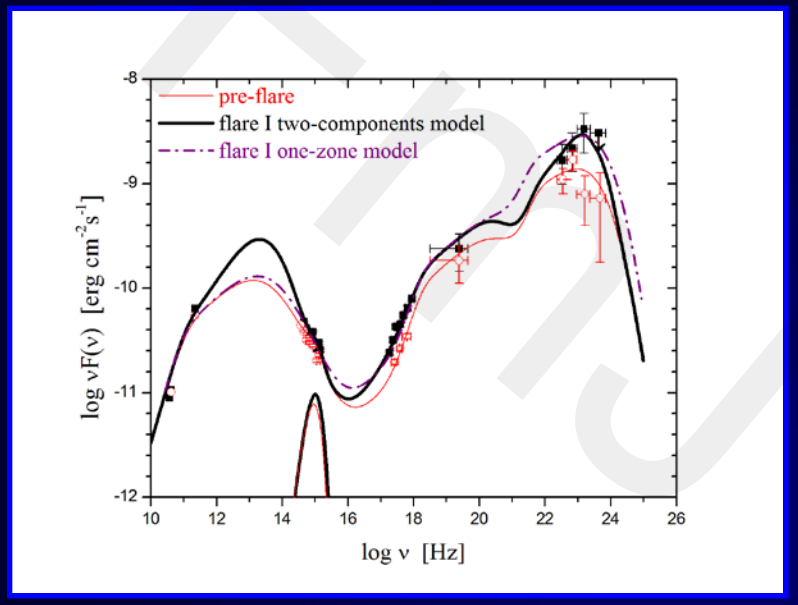
During the 2-month period the optical and X-ray fluxes varied within a factor 3, whereas the gamma-ray flux grows by a factor 5-10 compared to the pre-flare value.

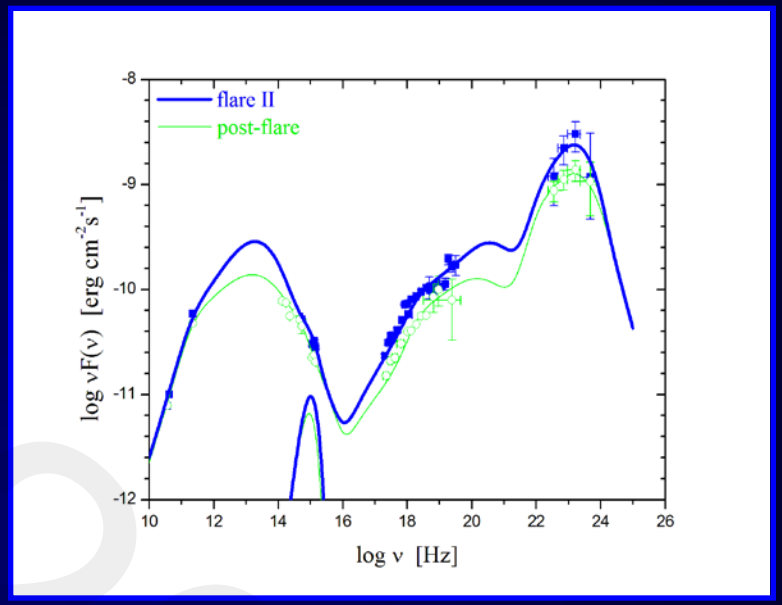
During the rapid super-flare around MJD 55167.7 the gamma-ray flux doubles within 1 day, with the optical and average X-ray increase of 50% and 30%, respectively.

The multifrequency light curves show an overall agreement for both long and short time scales.

Pacciani et al., 2010, ApJL, 716, L170

Modeling the SEDs of 3C 454.3 in Dec 2009





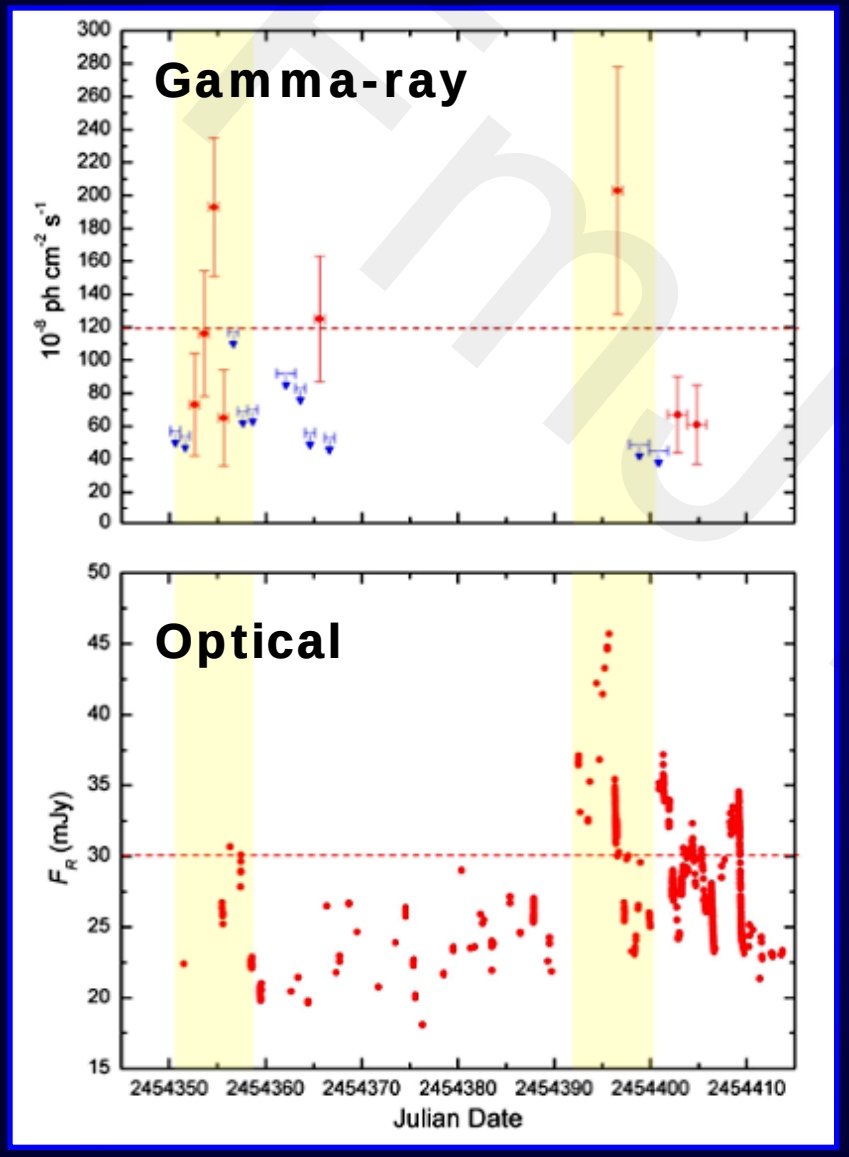
Pacciani et al., 2010, ApJ, 716, L170

Pre- and post-flare SEDs are adequately represented by a simple one-zone SSC model plus External Compton (disk + BLR).

Two models have been adopted for the super-flare: one zone SSC+EC, two zones SSC+EC.

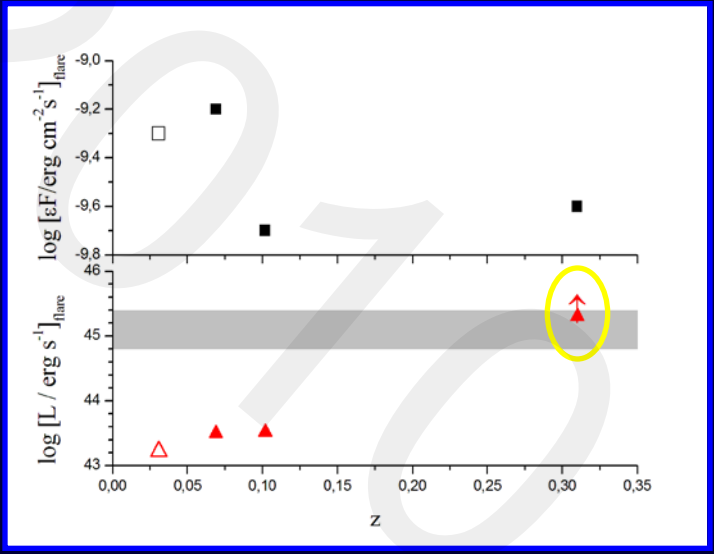
The 2nd electron population has been added to account for the hardness of the gamma-ray spectrum. It is likely related to additional particle acceleration and/or plasmoid ejection near the jet basis.

0716+714 in Sept-Oct 2007 approaches the BZ limit



The fluxes detected during the gamma-ray flares of September and October 2007 are among the highest for a BL Lac object

The total power transported in the jet during these episodes is $P_{tot,\ flare}$ = (3.5 ± 1.0) × 10^{45} erg s^{-1}, approaching or slightly exceeding the maximum power generated by a spinning black hole of 10^9 $M_\odot$



Chen, D'Ammando, et al. 2008, 489, L37

Vittorini et al. 2009, ApJ, 706, L1433

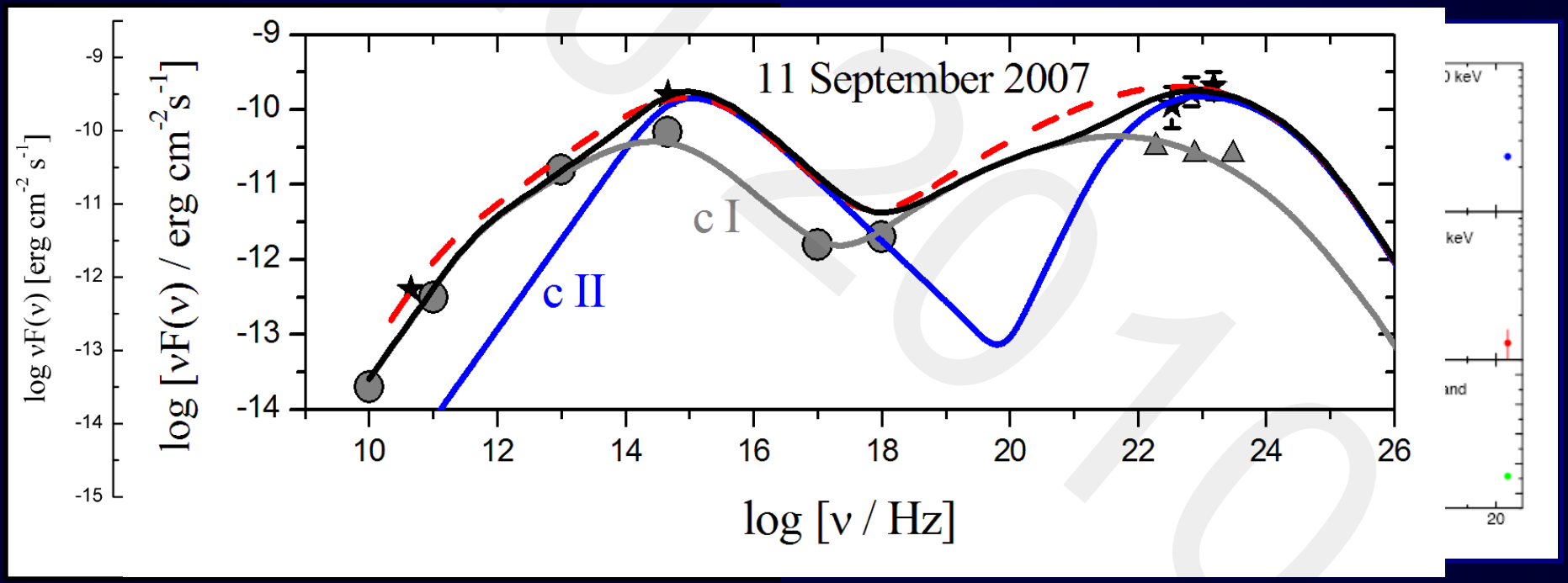
Two SSC components in the spectrum of S5 0716+714

A one-zone SSC model fails to reproduce the SED of the two gamma-ray flares occurred on September and October 2007

Two SSC components reproduce the complex variability observed:

- a *fast variable component* responsible for the optical, soft X-ray and gamma-ray emission

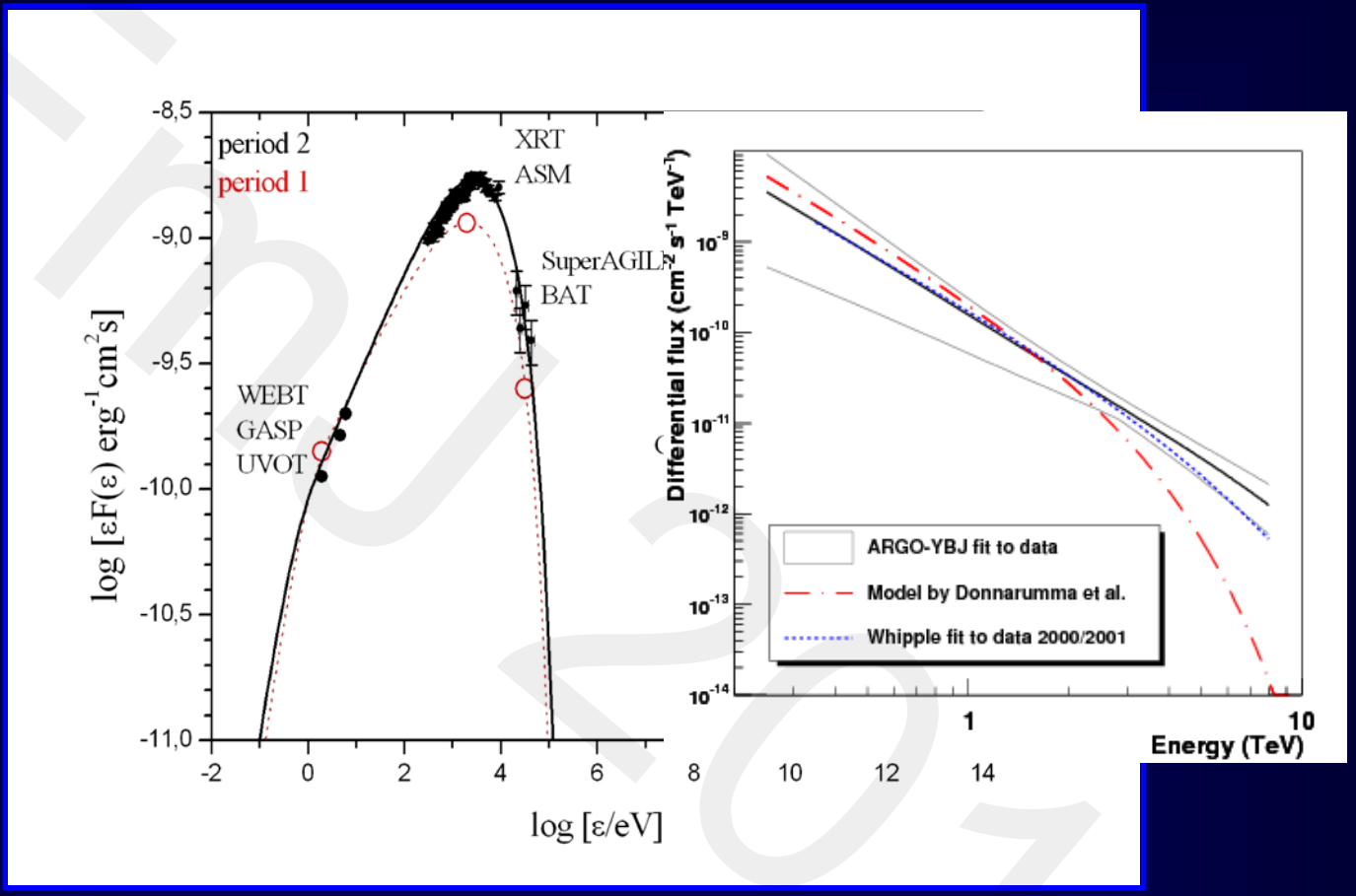
- a *slow variable component* responsible for the radio and hard X-ray emission



Chen, D'Ammando, et al. 2008, A&A, 489, L37

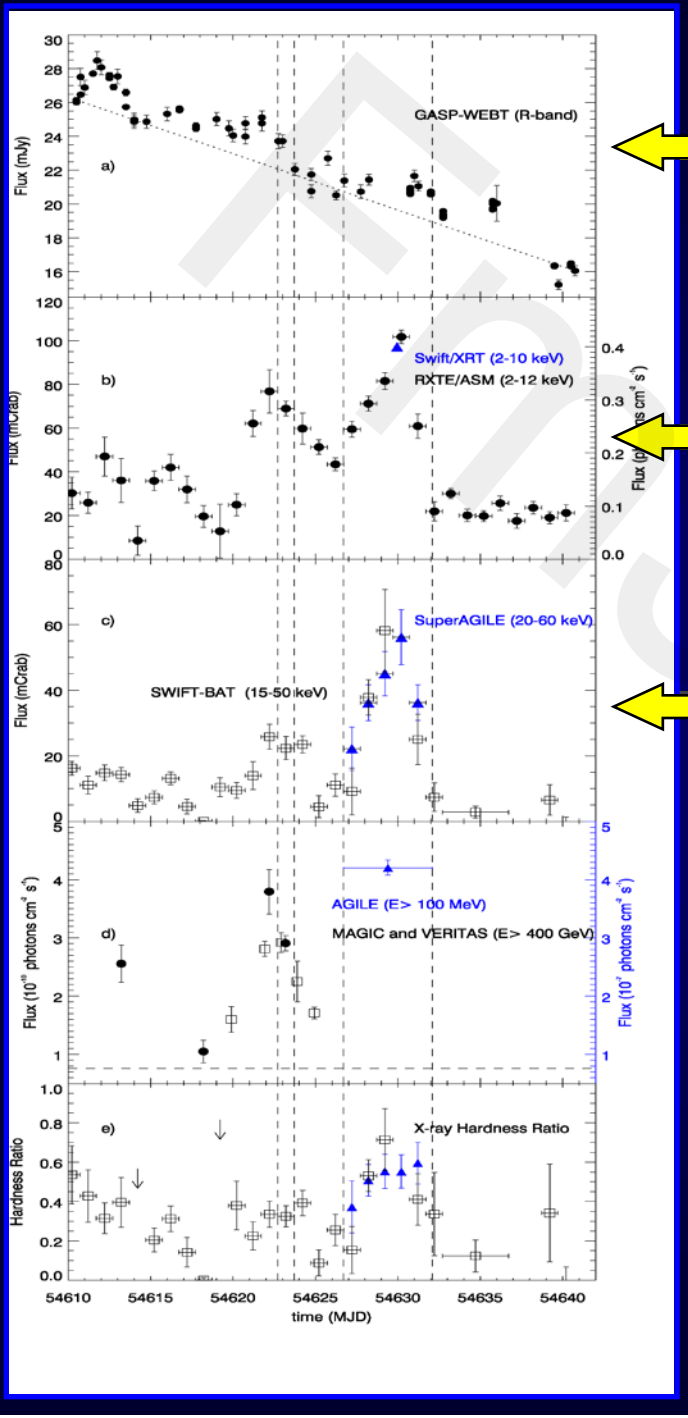
Adapted from Giommi et al., 2008, A&A, 489, L49

The broad band spectrum of Mrk 421 from optical to TeV



Donnarumma, et al. 2009, ApJ 691, L13

The gamma-ray flare can be interpreted in the framework of the SSC model in terms of *a rapid accelerations of leptons* in jet, in accordance also with the X-ray and VHE correlation observed



optical

Soft, hard X-ray and TeV emissions seem to be correlated in agreement with the SSC scenario..

soft X-ray

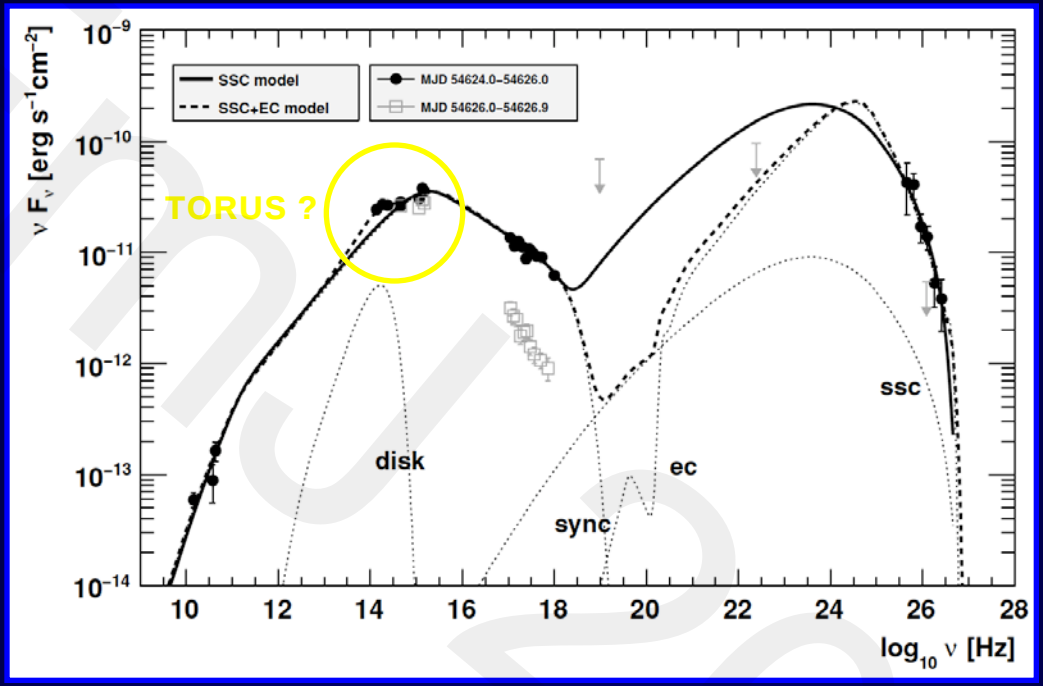
..but the different behaviour at optical and X-rays could suggest a more complex scenario

hard X-ray

The optical and X-ray radiation could be produced in different regions of a helical jet, with the inner jet region that produces the X-rays and it is partially transparent to the optical radiation, whereas the outer region produces only the lower-frequency emission

Donnarumma, et al. 2009, ApJ, 691, L13

The GeV - TeV connection: W Comae



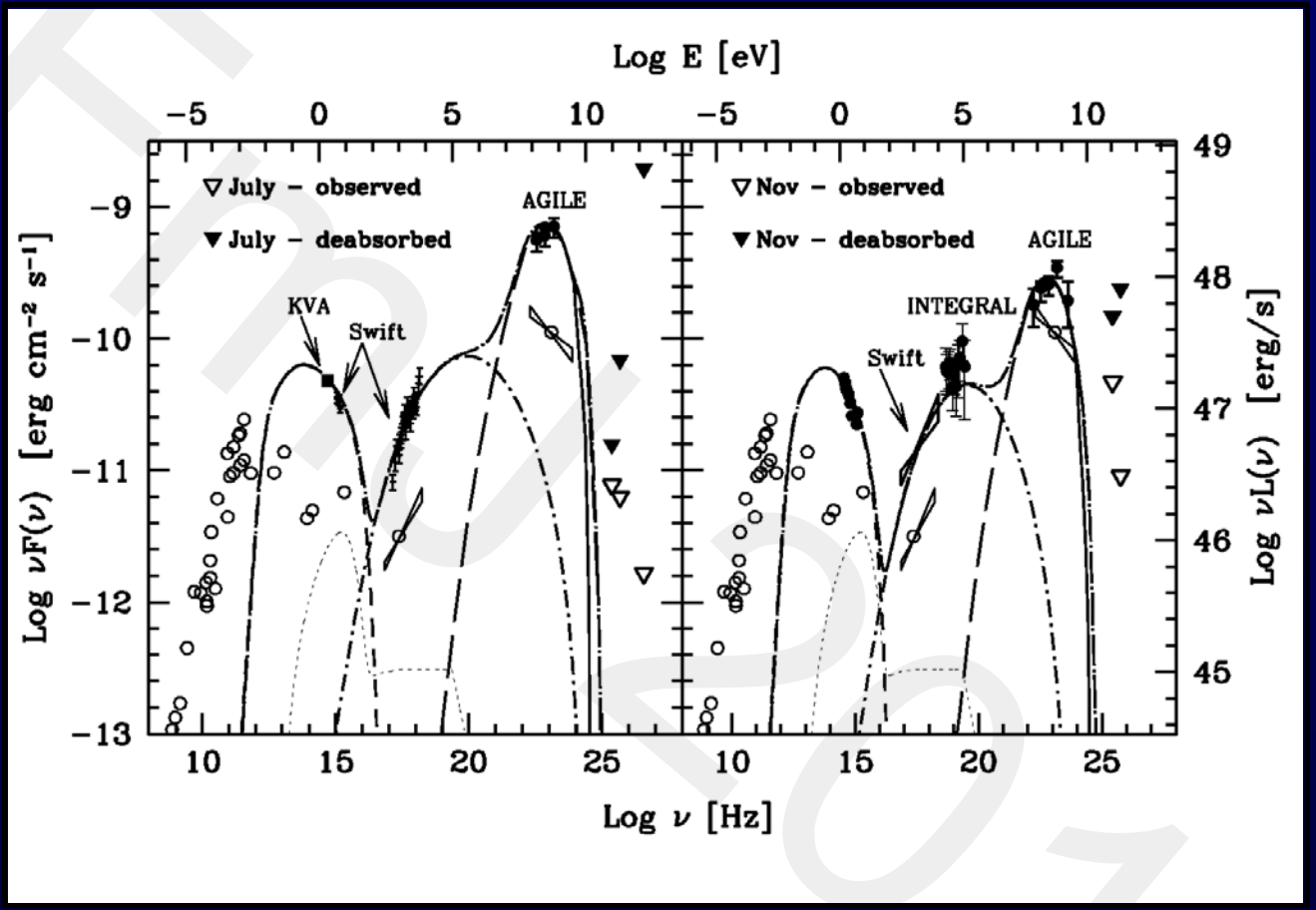
Acciari et al. 2009, ApJ, 707, 612

W Comae discovered by VERITAS during a strong outburst on 2008 June 7–8, with a three times flux higher than that observed in March 2008.

The SED can be modeled by a simple SSC model, but the wide separation of the peaks requires a rather low ratio of the magnetic field to electron energy density.

Adding an EC component the fit returns a magnetic field parameter closer to equipartition. The external radiation field could be produced by a torus whose emission peaks at 1.5 x 10^{14} Hz.

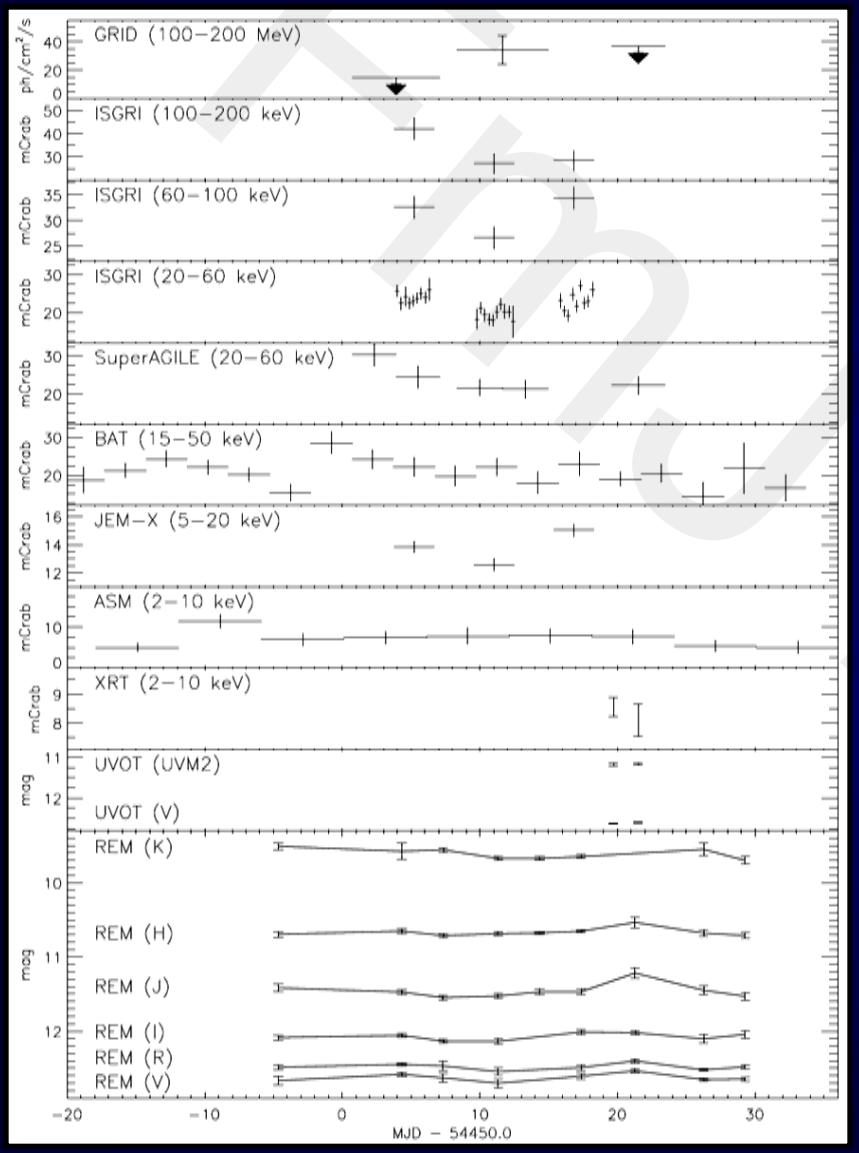
MAGIC upper limits to VHE flux of 3C 454.3



Anderhub et al., 2009, A&A, 498, 83

ULs are consistent with the model expectations based on IC scattering of the ambient photons from the BLR by relativistic electrons. This model predicts a sharp cut-off above 20-30 GeV due to internal absorption of gamma-rays and the decreased efficiency of the IC emission at high energy

3C 273: simultaneous detection by GRID & SA



16 December 2007 – 8 January 2008

Pacciani et al. 2009, A&A, 494, 49

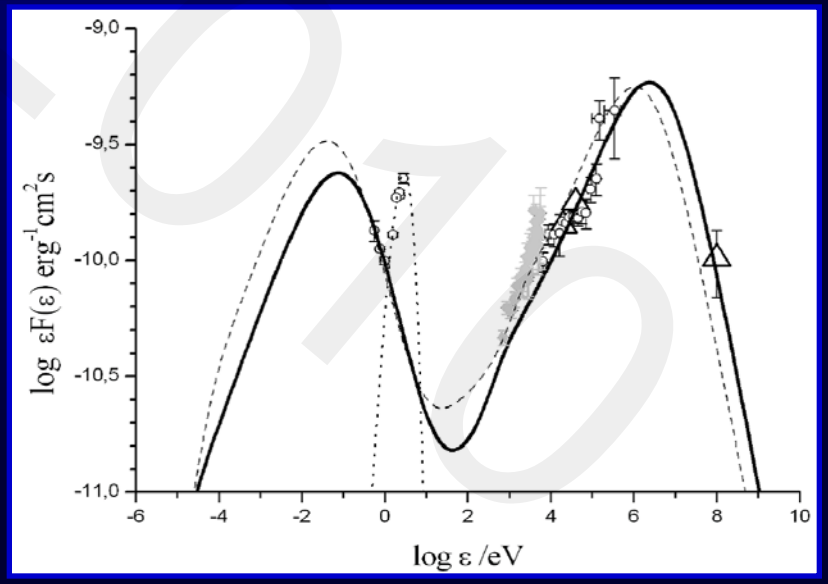
$\langle F_\gamma \rangle = (22 \pm 6)\ 10^{-8}$ ph cm^{-2} s^{-1} E >100 MeV

F_γ [peak] $= (33 \pm 11)\ 10^{-8}$ ph cm^{-2}s^{-1} E >100 MeV

Multiwavelength campaign: REM, *Swift*, RXTE, INTEGRAL and AGILE

Hint of an anti-correlated variability between X-rays and gamma-rays

SSC + EC: spectral variability consistent with an *acceleration episode of the electron population*



Concluding remarks (I)

- With the advent of AGILE and *Fermi* satellites a new window on the observations of blazars is now opened, not only for the observations in gamma-rays but also for further coordinated investigations over the whole electromagnetic spectrum

- We have investigated in detail the emission mechanisms of the AGILE blazars through multiwavelength studies, uncovering in some cases a more complex behaviour with respect to the standard emission models

- SSC vs EC vs more complex models? How to distinguish?

- The study of multiwavelength correlations is the key to understanding the structure of the inner jet and the origin of the seed photons for the IC process

Concluding remarks (II)

• MW observations of the blazars detected by AGILE has brought to light some complex behaviour w.r.t. canonical SSC and EC frameworks:

- the presence of two emission components in some BL Lacs
- the signature of little and big blue bumps in FSRQs
- some behaviour typical of HBLs also in FSRQs (harder-when-brighter, shift of the synchrotron peak)
- extreme energetics of BL Lacs approaching the BZ limit

• Notwithstanding 20 yrs of observation and the increasing knowledge about individual and collective properties of these objects, some questions on the emission mechanisms of blazars are already open

• Long term monitoring over all the electromagnetic spectrum and the study of sources in different activity states, not only during flaring states, could provide new important informations

Thanks for your attention!!!