Highlights of AGILE blazars

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Ten years of AGILE observations

Pointing mode

Intensive Multifrequency programs from radio to TeV energies on a large sample of blazars

- ✓ **Radio - Optical - Gamma-ray variability in FSRQs**
- ✓ **GeV – TeV connection in HBL objects**

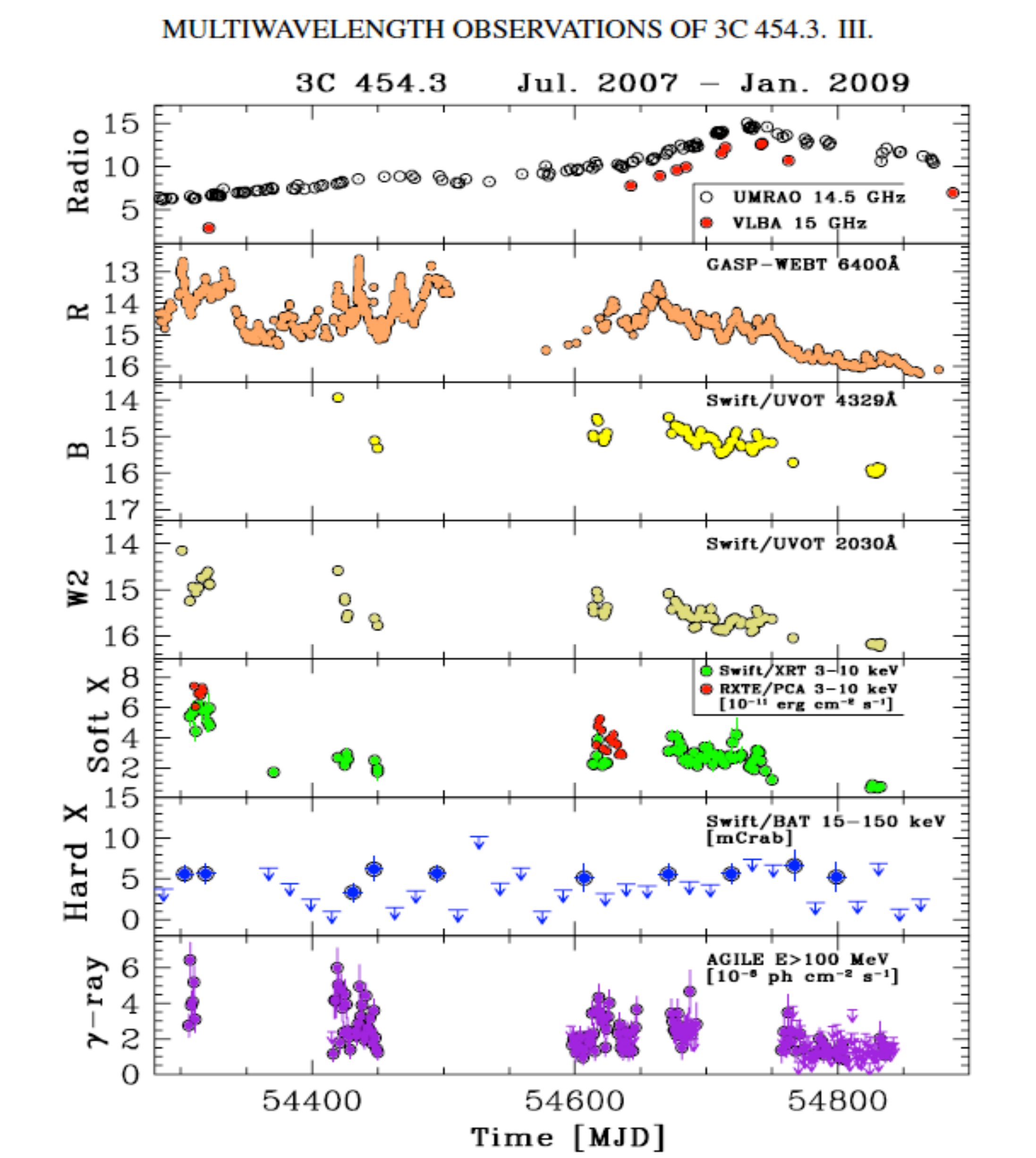
Spinning mode

Larger portion of the sky covered -> increase in the number of flares

- **Microlensing in gamma-ray blazars**
- **Extremely High Compton Dominance -> gamma-ray only flaring blazars -> The changing paradigm**
- **Monster blazars**
- **The discovery of Crab flares and its impact on blazars**

The long term gamma-ray monitoring in pointing mode

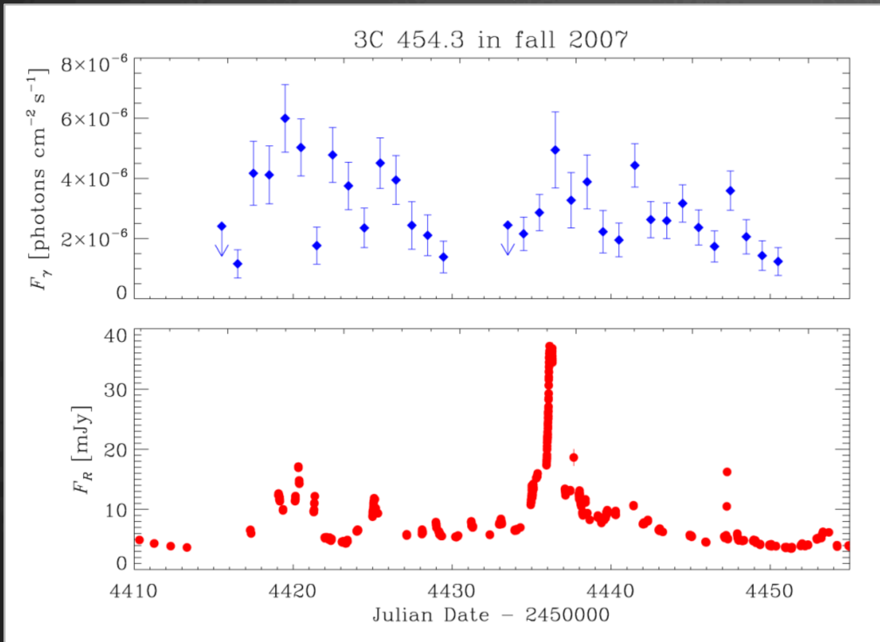
Long time-scale monitoring

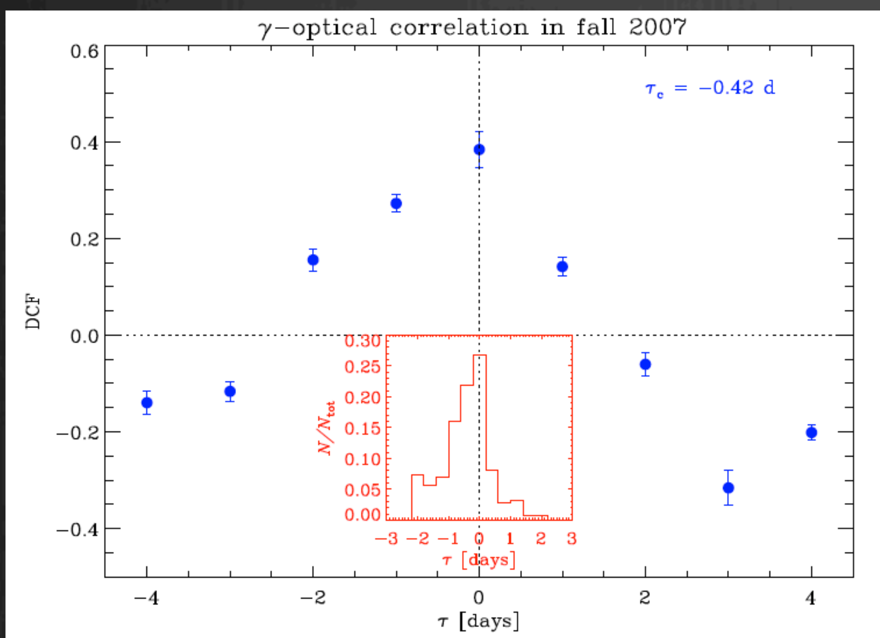


Vercellone et al., 2010, 18 months campaign on 3C 454.3

Time-lags: 3C 454.3

Vercellone et al., 2010





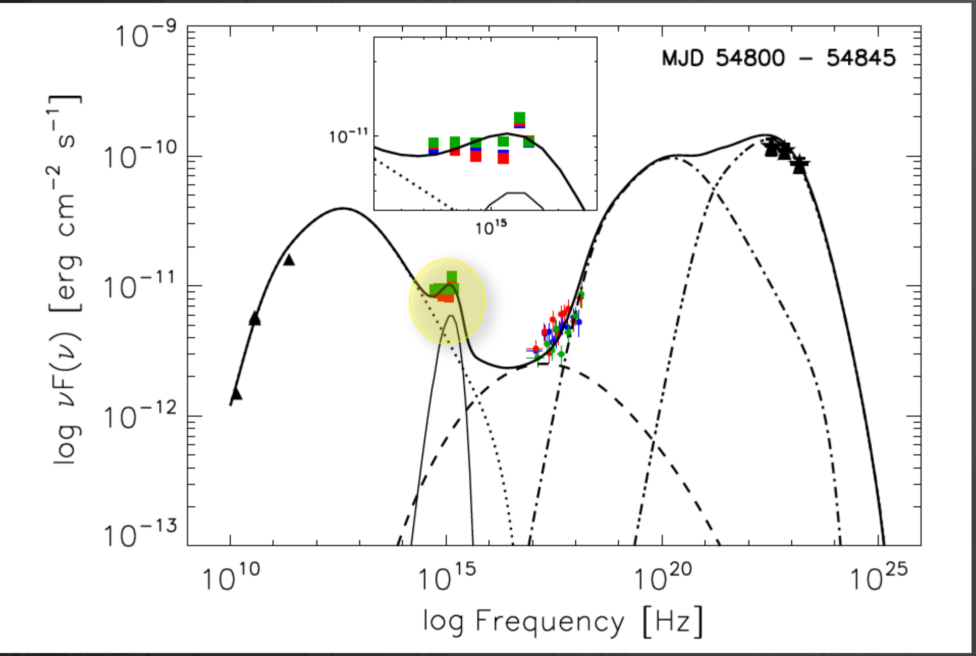
3C 454.3 – Nov.—Dec 2007 campaign

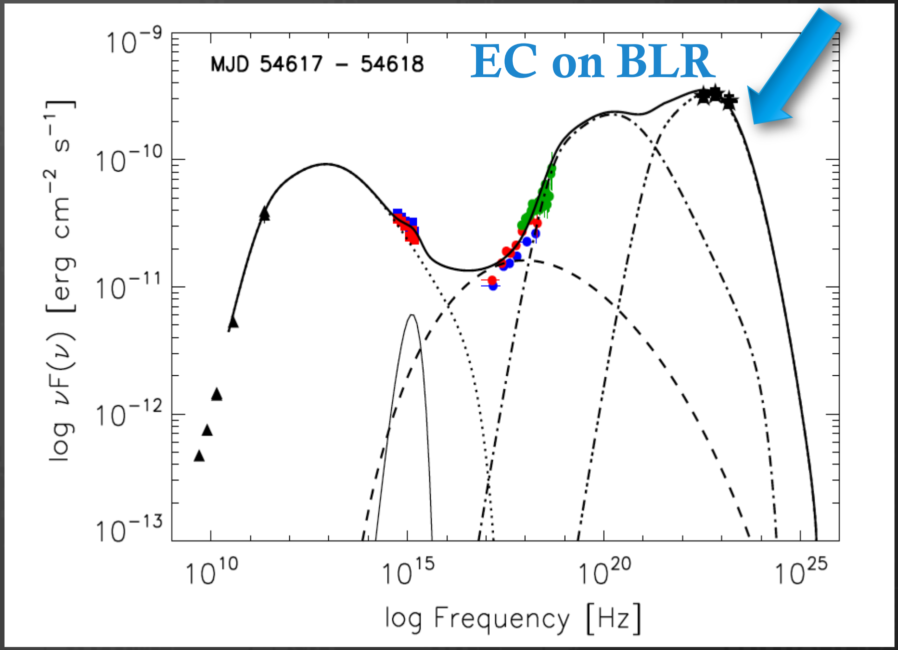
The shape of the DCF peak is asymmetric, and if we calculate the centroid distribution, we find that the time-lag is −0.42 days, i.e. the g-ray flux has a delay w.r.t the optical one of about half a day (see also Donnarumma et al. 2009)

first hint of EC at work

SED: 3C 454.3

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

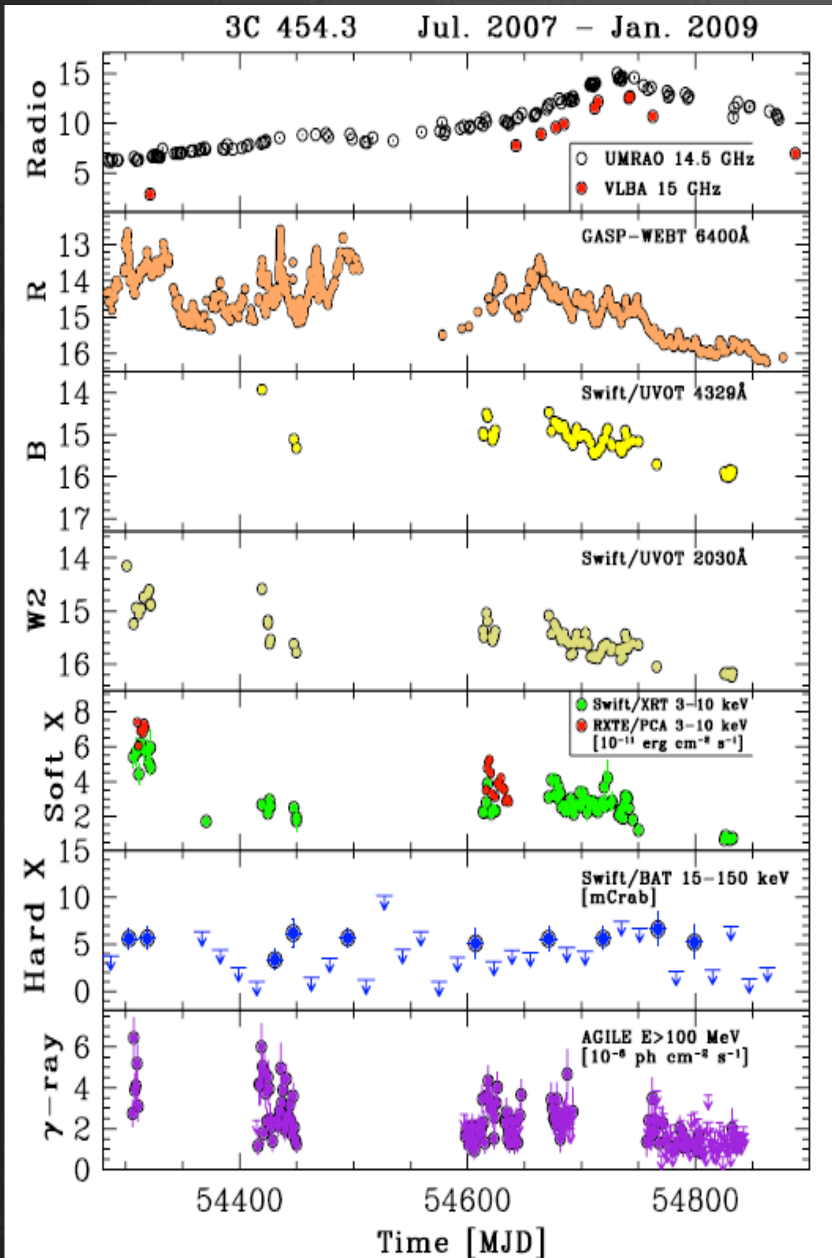


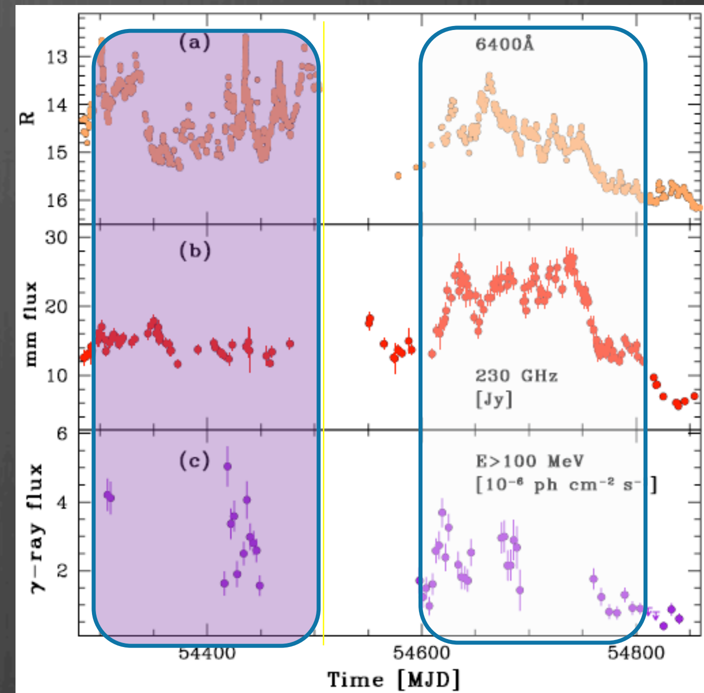


- Multi-epoch Spectral Energy Distribution (thermal compoment, long term trend of Optical and gamma-ray emission)
- IC scattering of external photons from the BLR clouds scattering off the relativistic electrons in the jet (disk luminosity measurement crucial)

Radio-Optical-UV & γ-rays observations

Radio, optical & γ-rays: 3C 454.3



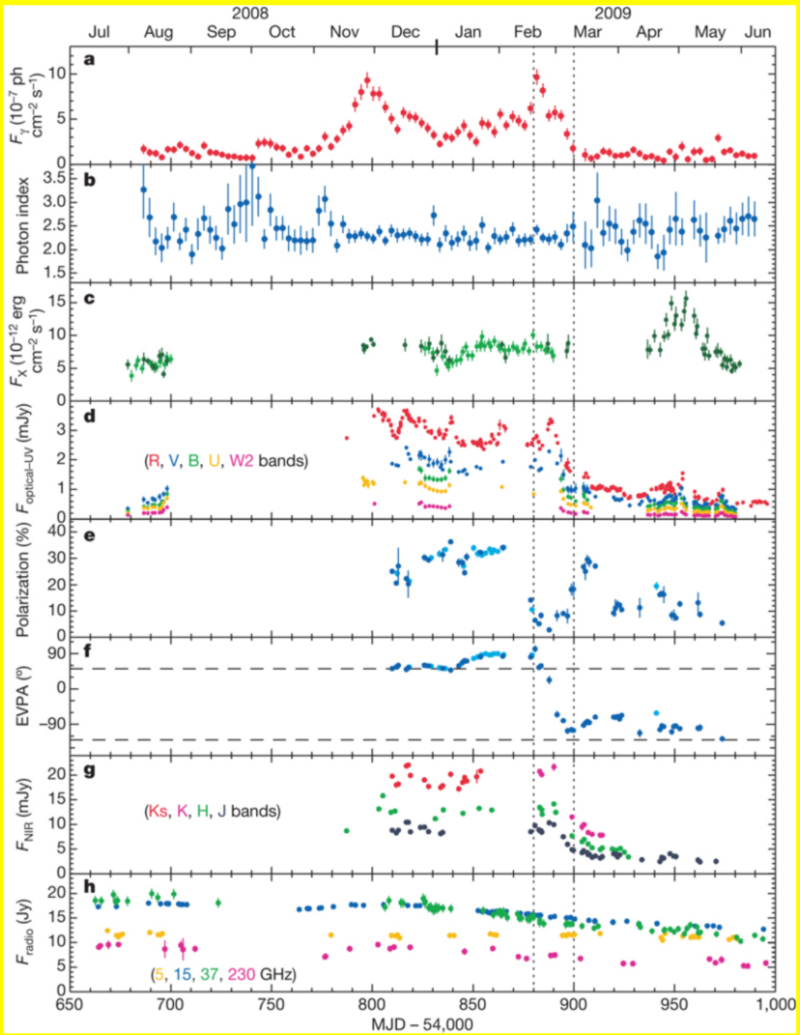


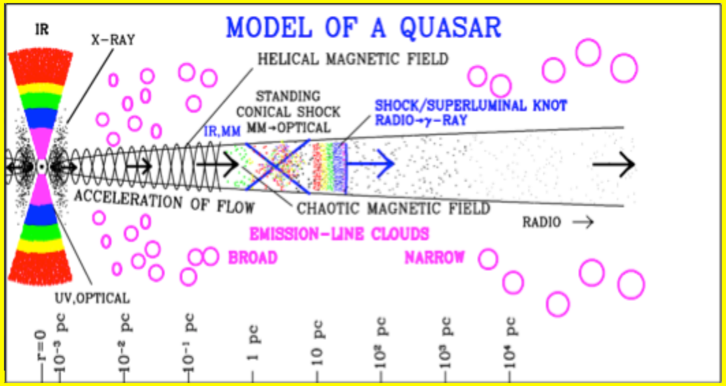
2007: the more pronounced fluxes and variability of the optical and γ-ray bands seem to favor the inner portion of the jet as the more beamed one.

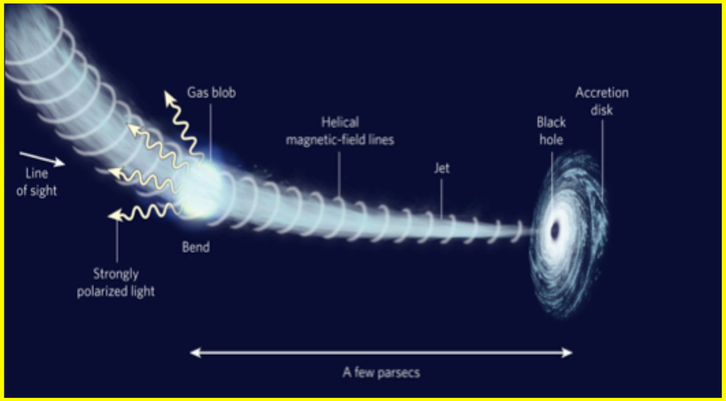
2008: the optical & gamma -ray dimming trend vs the higher mm flux emission -> the more extended region of the jet became more aligned w.r.t. the observer line of sight (no new jet component observed)

Optical polarization & γ-ray flare

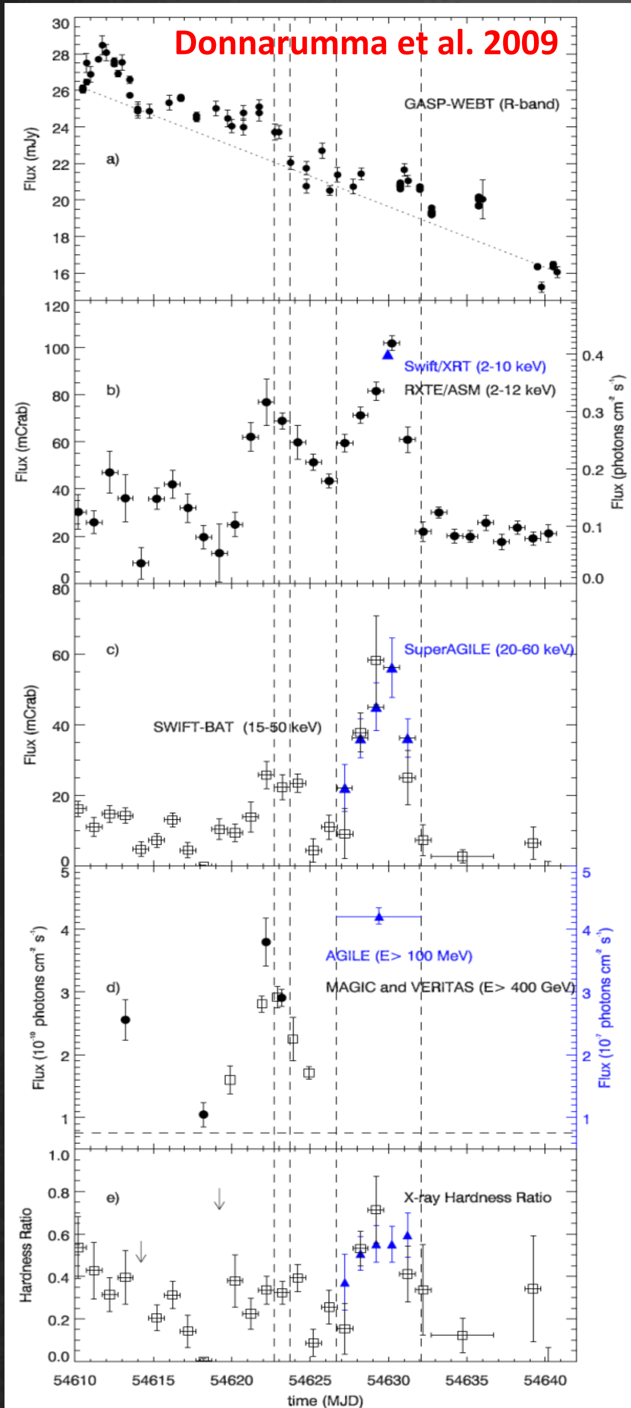
Abdo et al. 2010





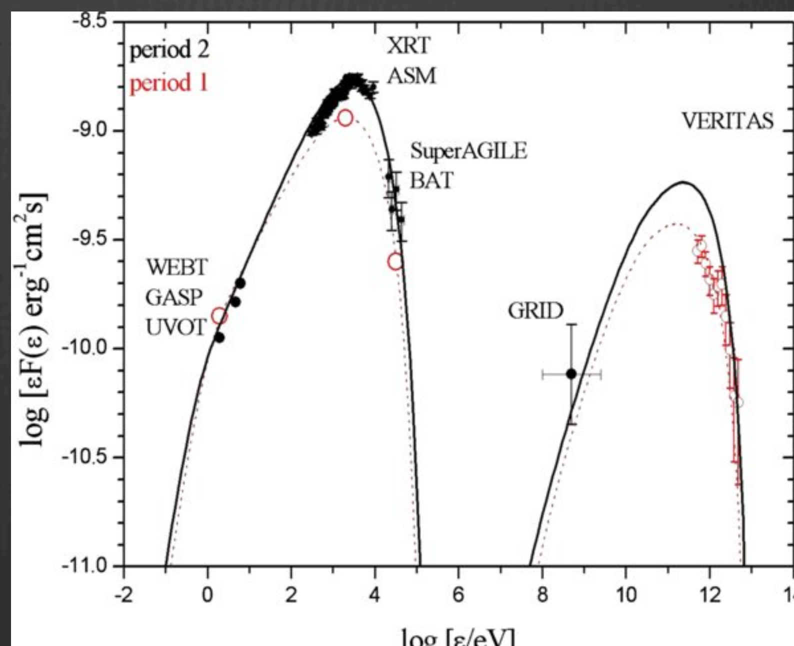


GeV-TeV connection



The GeV – TeV connection: MKN 421

- The optical light curve shows variations of the order of 10% in a few days, superimposed on a long decay during the entire period.
- Soft, hard X-ray and TeV emissions look 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.



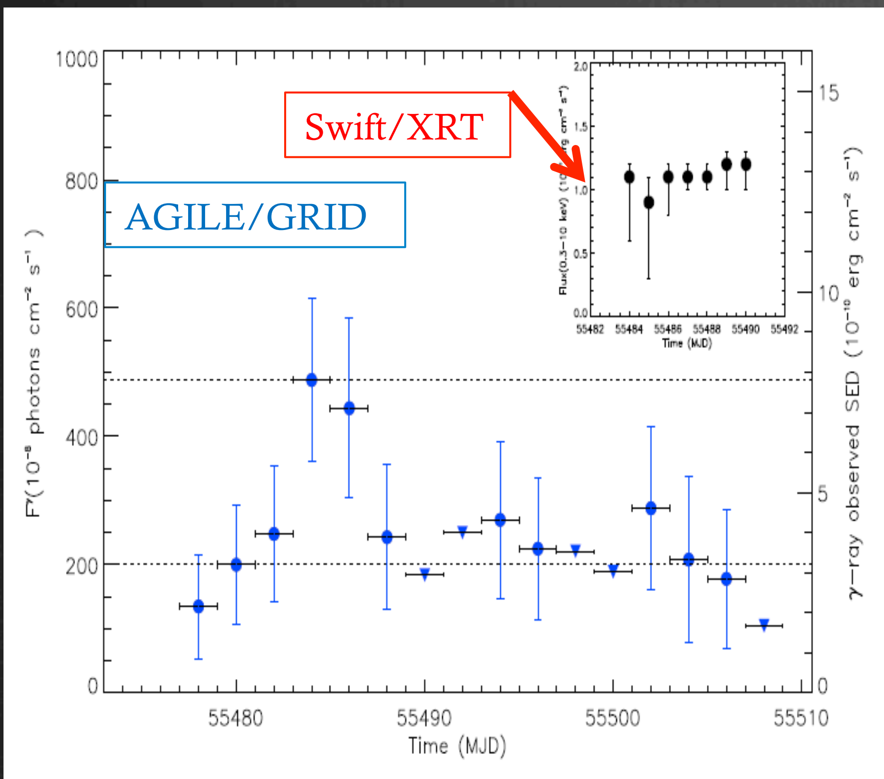
SED

1-zone SSC model; a rapid acceleration of electrons in the jet.

The "gamma-ray only" flaring blazar

The remarkable gamma-ray flare of PKS 1830-211 (z=2.507)

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.

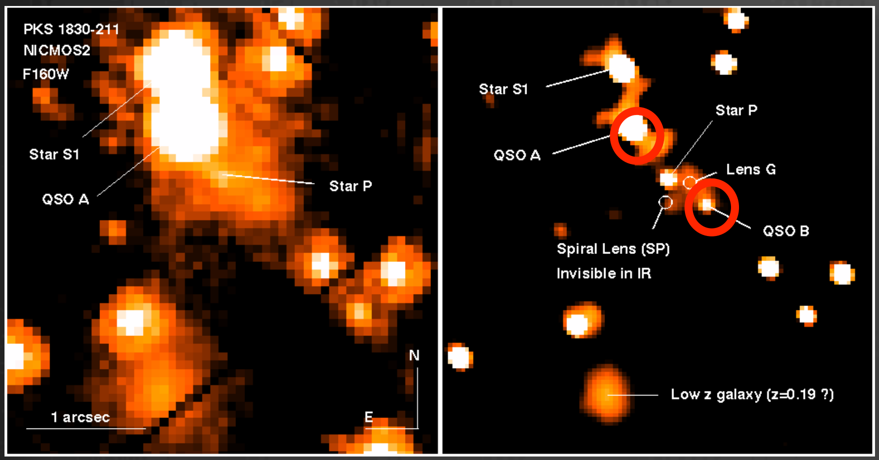
Hard X-rays: variations greater than a factor of 1.5 have to be excluded.

Soft X-rays variations greater than a factor of 1.6 ruled out

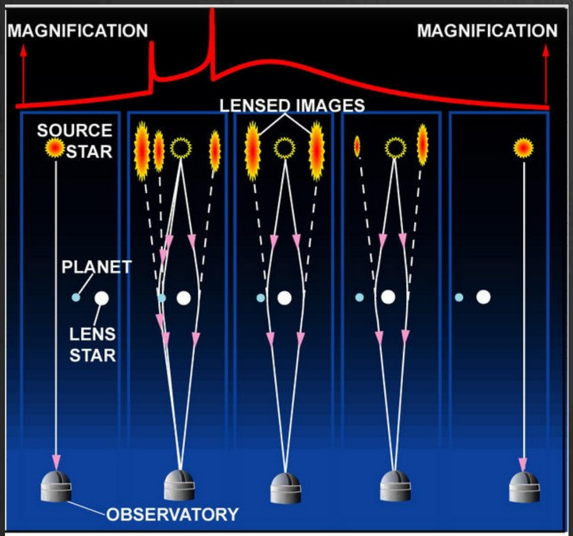
NIR/Optical: Variations greater than a factor of 2.5 in both synchrotron + non thermal emission of this source ruled out.

It is therefore a gamma-ray only flare

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

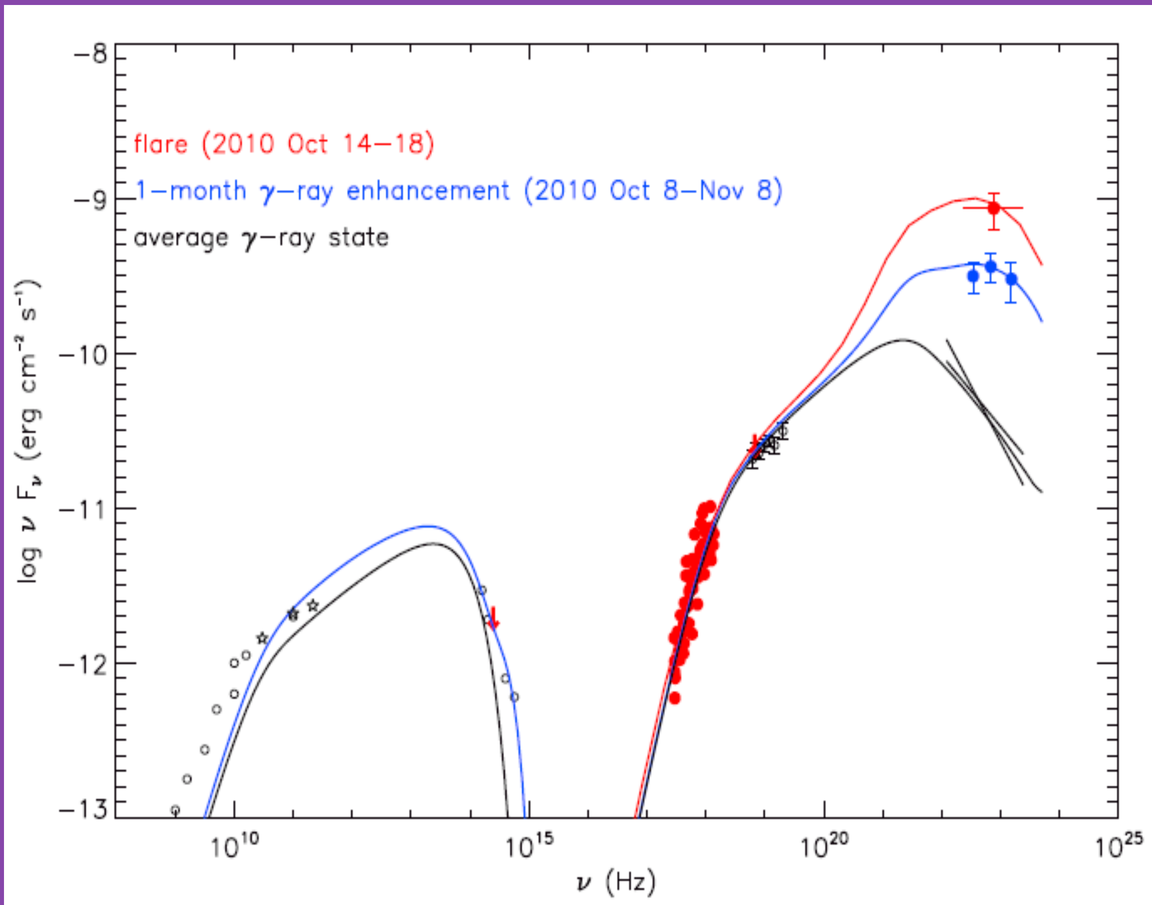


- **Macrolensing ruled out**, since its effects would be energy-independent.
- **Microlensing** disfavored because not compatible with the observed rapid variability. Useful **to justify lack of echo observed in gamma-rays.**



Therefore the gamma-ray enhancement is intrinsic to the source

1-zone SSC not applicable:
High Compton Dominance, uncorrelated variability



Donnarumma et al. 2011

•**Black**- a 1st electron population responsible of the average γ-ray state (black)

▪**Blue**- 1-month enhancement an additional electron population (a smaller size, higher electrons density and higher γ_{break}). EC on the photon density field crossed while moving inside the BLR

▪**Red** - flare still produced by EC of the second electron population on the BLR photon field, but a local increase of the seed photons is required (likely due to a blob-cloud interaction (see Araudo et al. 2010).

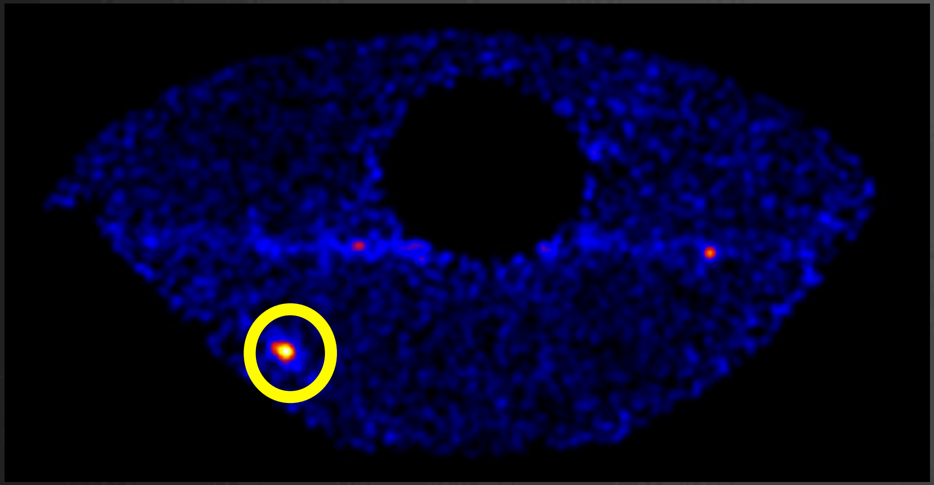
MODEL PARAMETERS FOR 2010 γ-RAY ACTIVITY OF 1830.

population	Γ	B(Gauss)	R(cm)	K(cm^{-3})	γ_b	γ_{min}	a_l	a_h	δ
1st	10	0.7	8×10^{16}	100	100	35	2.0	2.6	16
2nd	15	0.4	3×10^{16}	150	500	60	2.0	3.4	20

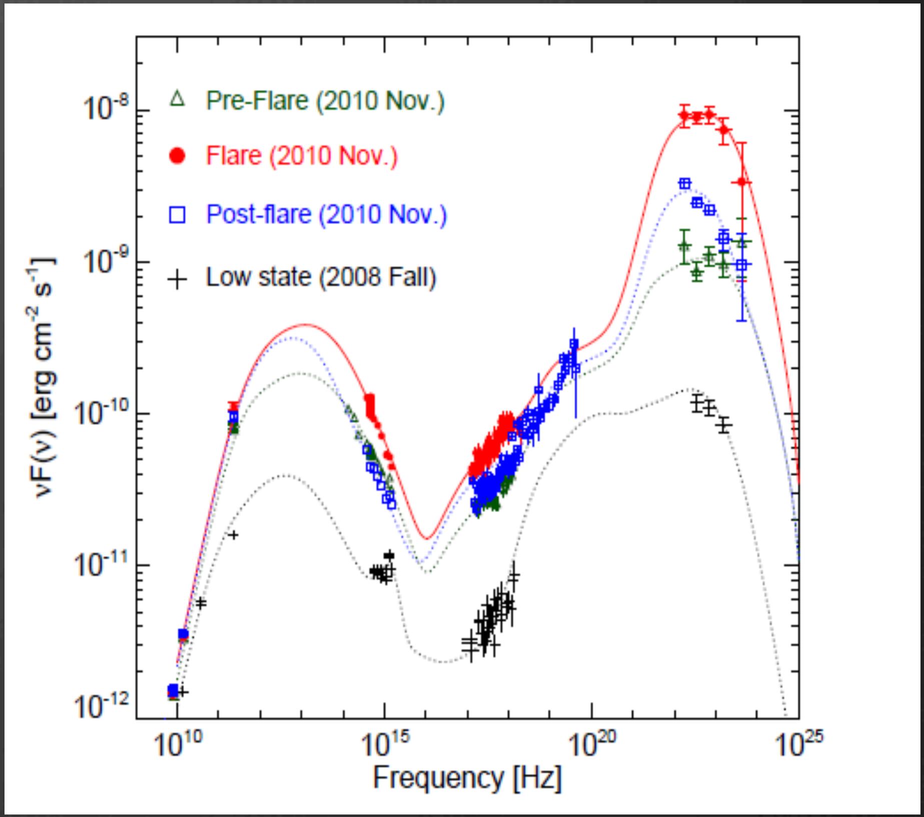
The monster flares

3C 454.3
The monster flare in 2010

16-19 Nov 2010→ 10σ in 5,8 days



Superflare may require two electron populations (see Pacciani et al., 2010)



Most intense gamma-ray source ever detected: 3C 454.3

z=0.859,

F_γ > 8000 10^{-8} ph. cm^{-2} s^{-1},

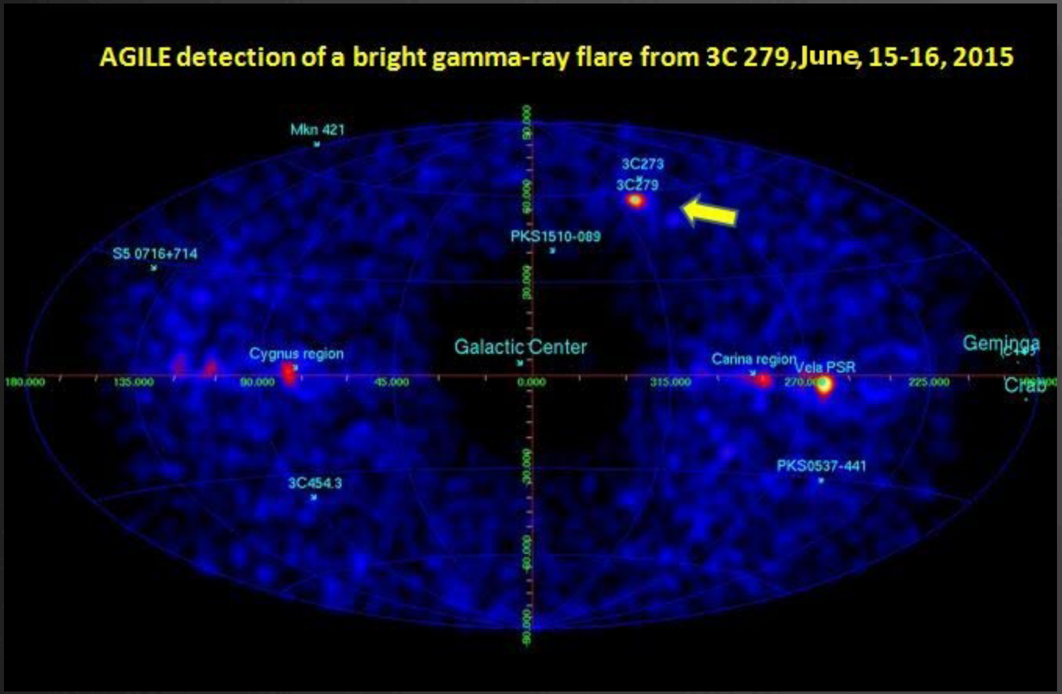
L_{iso}= 2x10^{50} erg s^{-1},

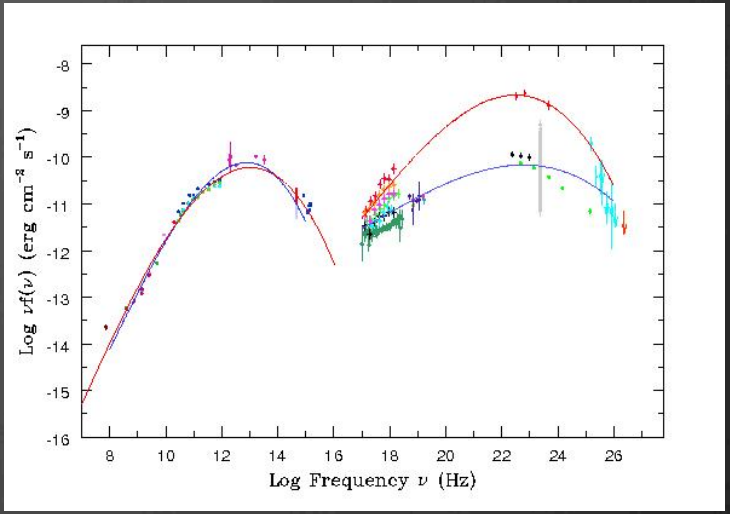
for δ = 10, $L_{jet} \approx$1 Earth/sec)

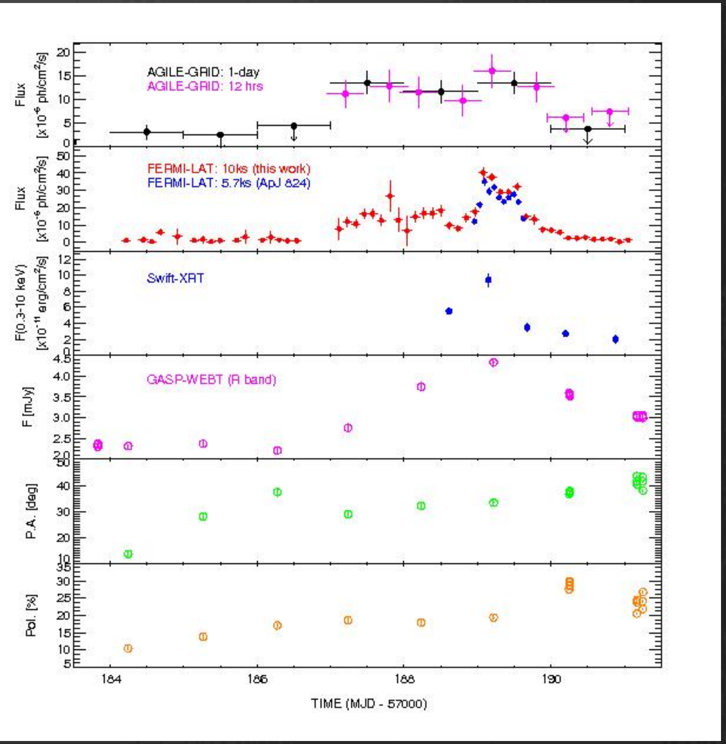
Vercellone et al., 2010, 2011

3C 279
The monster flare in June 2015

Pittori et al. in preparation







Most intense gamma-ray source ever detected: 3C 279

z=0.536,

$F_{\gamma} > 3000\ 10^{-8}$ ph. cm^{-2} s^{-1},

γ-ray emitting region at the outer edge of the broad line region or farther out from it

Minute timescale observed by Fermi

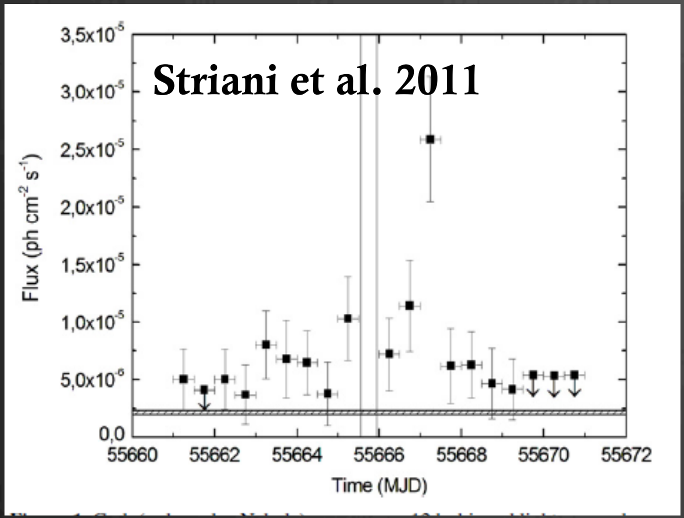
Many challenges for theory

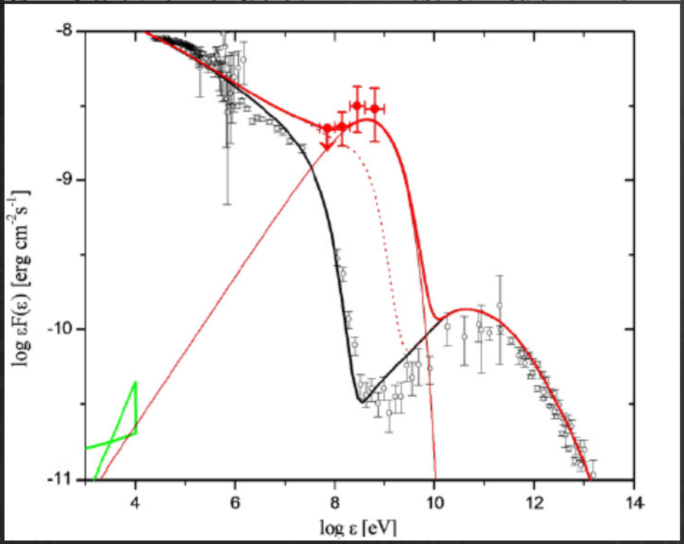
All the phenomenology challenges the standard models

- **Where is the γ-ray dissipation region and what is the nature of seed photons in IC emission?**
- **How many electron populations responsible for the Sync emission?**
- **What is the dominant particle acceleration mechanisms to simultaneously account for far emitting regions and rapid variability (even minute timescale)?**

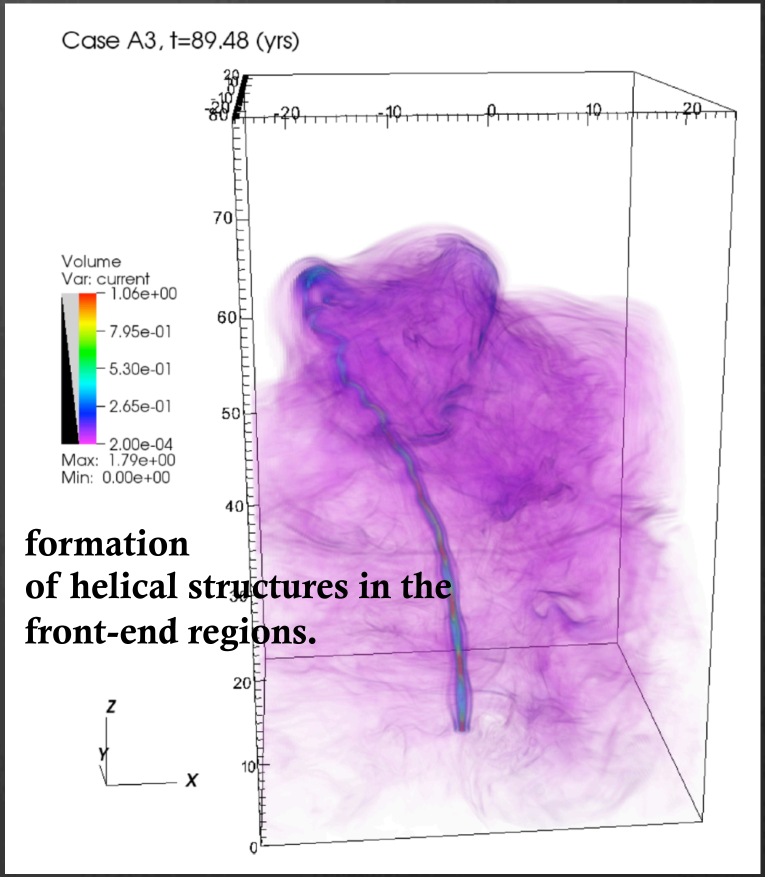
Lessons learned from the CRAB flare discovery

Similarity with the amazing Crab Nebula: 1-day flare
(helical magnetic field,reconnection)





Mignone et al. 2013



PKS 1830-211, 3C454.3, 3C 279

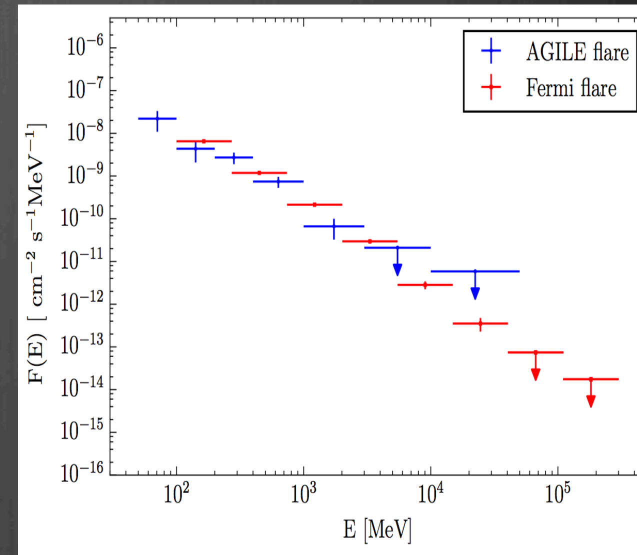
The theoretical activities in AGILE
Mirrored-Syncro-Compton scenario

- Strong and fast EC flares
- Large and localized density of soft photons
- Gamma-ray "only" flares
- Flares on the top of a large plateau
- Hard gamma-ray spectra (low gamma-ray opacity)

(see Vittorini/Tavani talk)

PKS 2023-07 (z=1.388) with AGILE

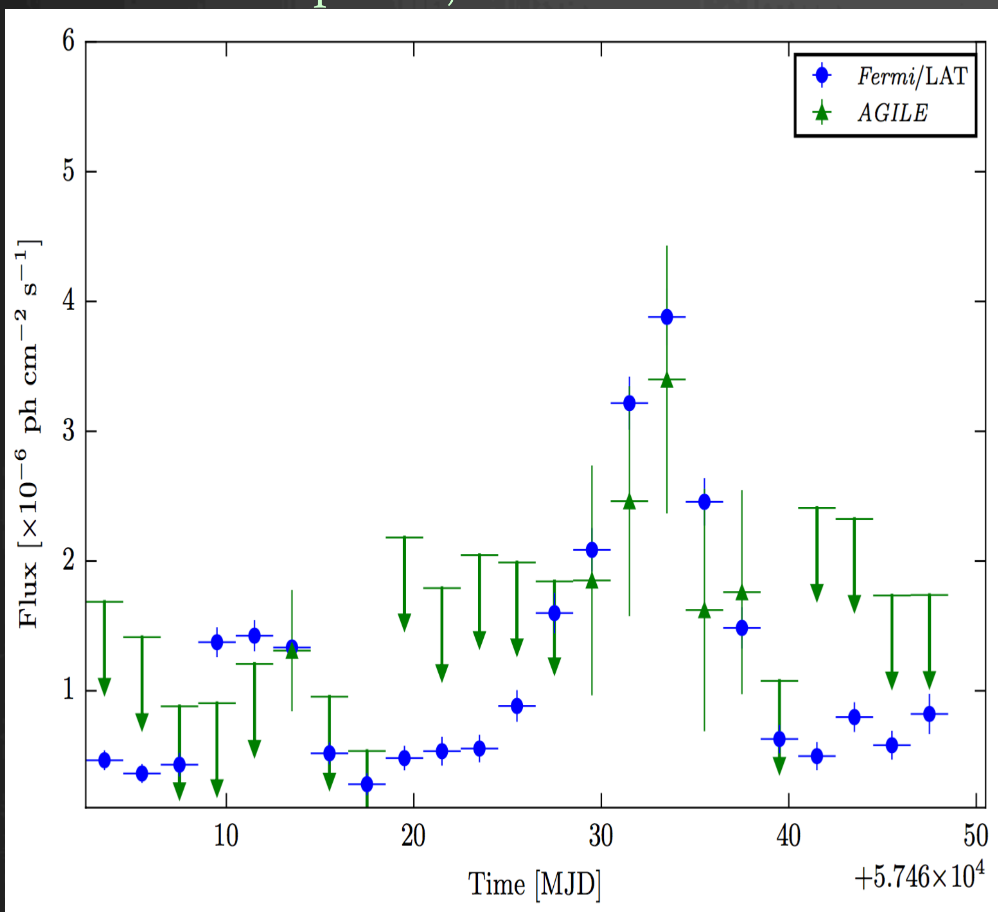
Differential flaring spectrum
AGILE – Fermi/LAT



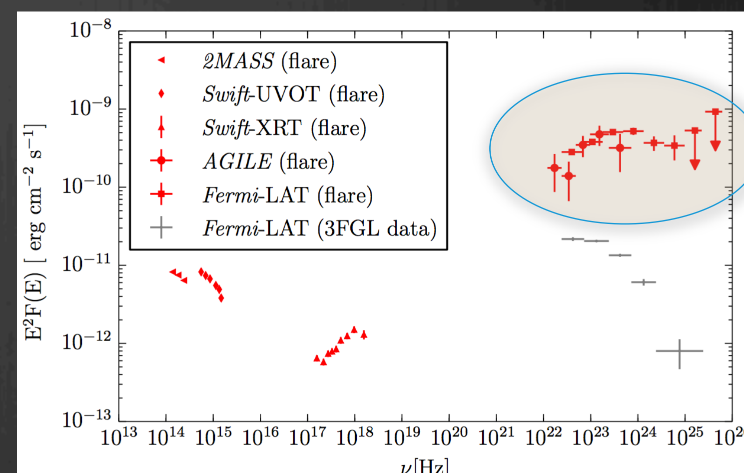
Giovanni Piano et al. in preparation

Light curve (E > 100 MeV)

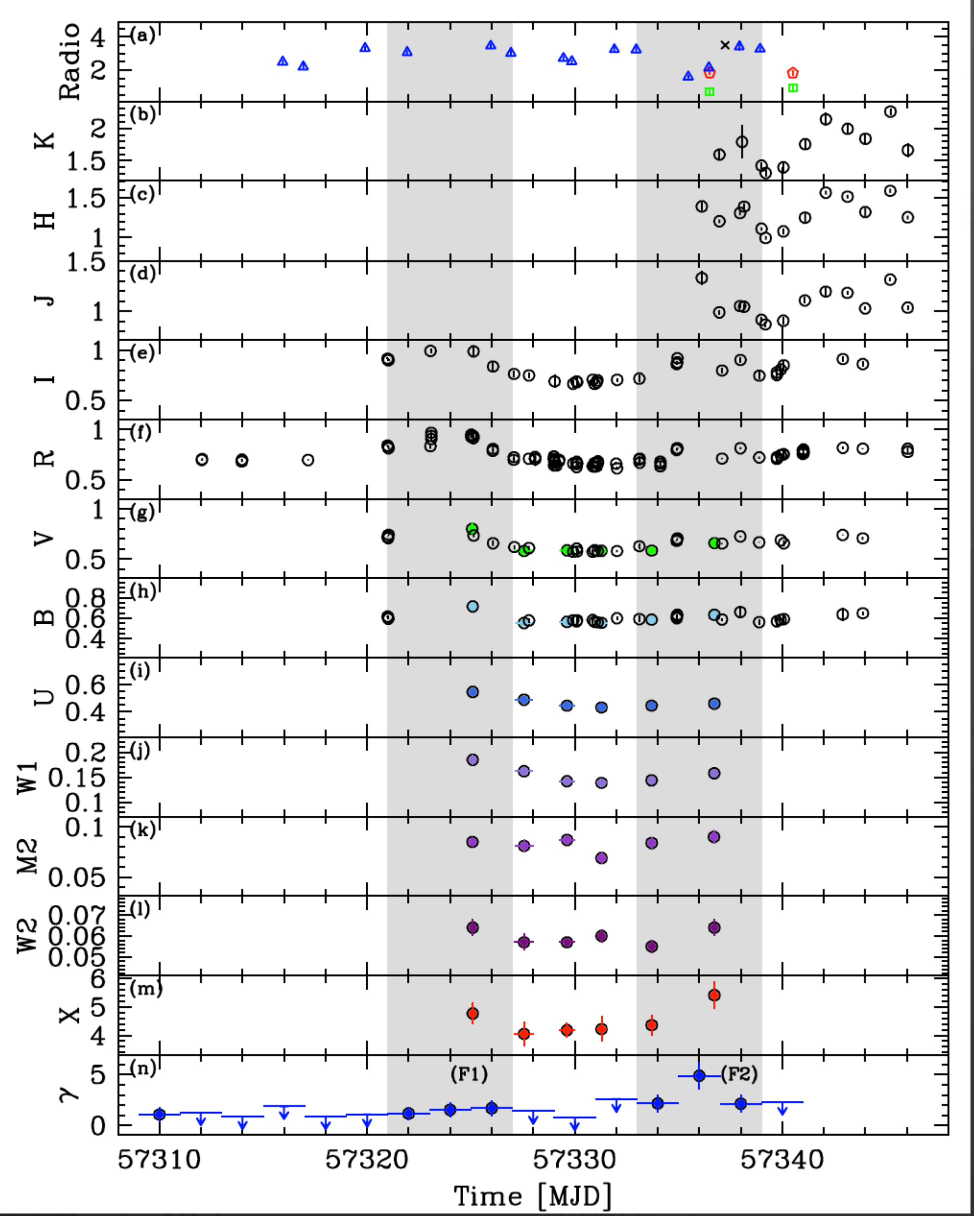
March 15 – April 28, 2016



SED



"AGILE, Swift, and GASP/WEBT multi-wavelength observations of the high-redshift blazar 4C +71.07 in outburst" – S. Vercellone et al., to be submitted to A&A

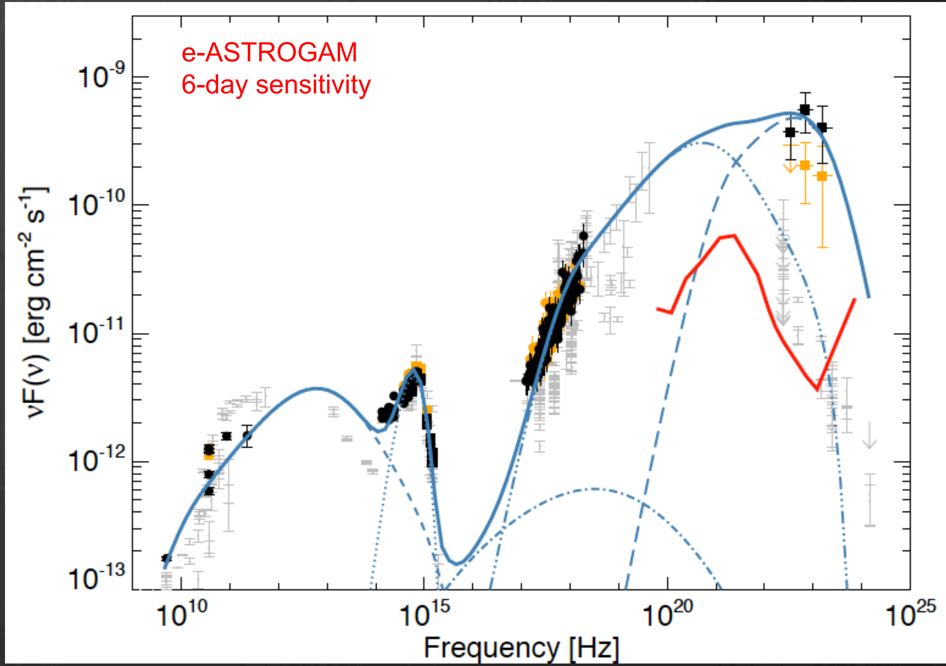


FSRQ: z=2.172, $M_{BH} \sim 5\times10^{9}\ M_{Sun}$

Strong blue bump peaking at about $10^{14.9}$ Hz

The dissipation region is within the BLR . Good target for e-ASTROGAM.

Paper almost ready for sign-in, collecting comments from main co-authors.



Possible Advances in blazars studies achievable by

<u>Connecting the long term behaviour with flare activities</u>

- Optical with the LSST survey (AGILE in in the loop)
- Radio with SKA and synergy with VLBI
- Obtaining multi-λ polarimetric measurements to investigate magnetic field topology, different electron populations (X-ray crucial, IXPE)

<u>Assessing the role of magnetic reconnection in fast particle acceleration</u>

- Dedicated simulations of the jet large scale structure in connection to the particle kinetics on small scales
- Exploring ultrafast variability in X-rays and TeV (eXTP, CTA)