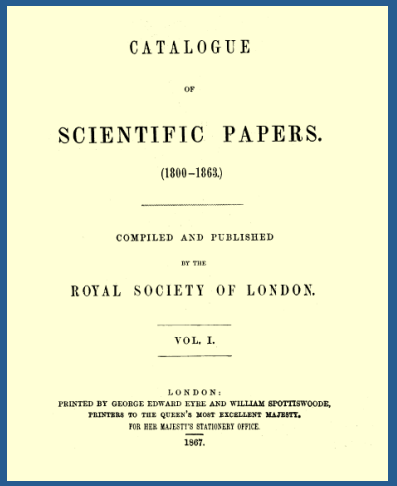
The AGILE multi wavelength program

Stefano Vercellone INAF-IASF Palermo

On behalf of the AGILE AGN Working Group

Talk outline

Introduction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1867.

Established results

New results

The multi color (λ) domain

The AGILE AGN Working Group

Name	Affiliation
A. Bulgarelli	INAF-IASF Bologna
A.W. Chen	INAF-IASF Milano
F. D'Ammando	INAF-IASF Roma & Univ. Tor Vergata
I. Donnarumma	INAF-IASF Roma
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L. Pacciani	INAF-IASF Roma
G. Pucella	ENEA Roma
S. Vercellone (*Chair*)	INAF-IASF Palermo
V. Vittorini	INAF-IASF Roma & Univ. Tor Vergata

The multi wavelength approach

Observatory	Energy domain
VLBA/UMRAO	Radio
Spitzer	IR
REM	IR-Optical
WEBT-GASP	Radio-Optical-mm-IR
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

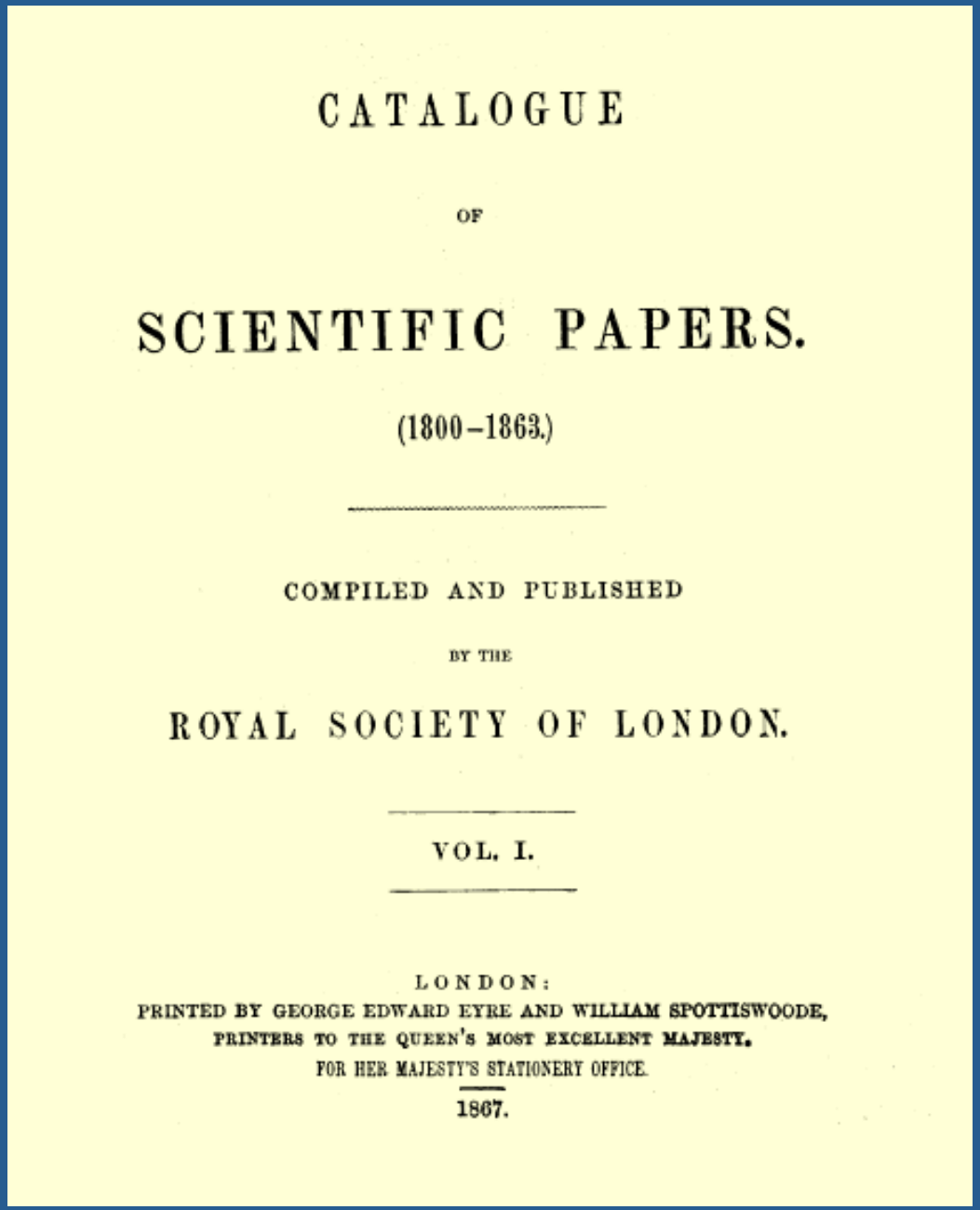
Gamma-ray flaring AGNs

Table 1. List of the AGILE flaring blazars. The numbers in boldface in the Reference column designate papers submitted and/or in preparation. *References*: 1. Chen et al., 2008, A&A, 489, L37; 2. Vittorini et al., 2009, ApJL, submitted; 3. Giommi et al., 2008, A&A, 487, L49; 4. Donnarumma et al., 2009, ApJL, 691, 13; 5. Acciari et al., 2009, in preparation; 6. Pucella et al., 2008, A&A, 491, L21; 7. D'Ammando et al., 2009, A&A, accepted; 8. D'Ammando et al., 2009, in preparation 9. Pacciani et al., 2009, A&A, 494, 49; 10. Giuliani et al., 2009, A&A, 494, 509; 11. Vercellone et al., 2008, ApJL, 676, 13; 12. Wehrle et al., 2010, in preparation; 13. Vercellone et al., 2009a, ApJ, 690, 1018; 14. Donnarumma et al., 2009, ApJ, submitted; 15. Vercellone et al., 2009b, in preparation; 16. Pucella et al., 2009, in preparation.

Name	Period *start : stop*	Sigma	ATel #	Ref.
S5 0716+714	2007-09-04 : 2007-09-23	9.6	1221	1, **2**
	2007-10-24 : 2007-11-01	6.0	-	3
MRK 0421	2008-06-09 : 2008-06-15	4.5	1574, 1583	4
W Comae	2008-06-09 : 2008-06-15	4.0	1582	**5**
PKS 1510–089	2007-08-23 : 2007-09-01	5.6	1199	6
	2008-03-18 : 2008-03-20	7.0	1436	**7**
	2009-03-01 : 2009-03-31	19.9	1957, 1968, 1976	**8**
3C 273	2007-12-16 : 2008-01-08	4.6	-	9
3C 279	2007-07-09 : 2007-07-13	11.1	-	10
3C 454.3	2007-07-24 : 2007-07-30	13.8	1160, 1167	11, **12**
	2007-11-10 : 2007-12-01	19.0	1278, 1300	13
	2007-12-01 : 2007-12-16	21.3	-	**14**
	2008-05-10 : 2009-01-12	17.9	1545, 1581, 1592, 1634	**15**
PKS 0537–441	2008-10-10 : 2008-10-17	5.5	-	**16**

The AGILE blazar flavours

AGILE detected at least one object for each blazar category:			
FSRQ → 3C 454.3	LBL → PKS 0537-441	IBL → S5 0716+714	HBL → MKN 421
A few sources were detected more than once:			
3C 454.3	PKS 1510-089	S5 0716+714	
Variability level could be very different:			
Extremely low → 3C 279		Extremely high → PKS 1510-089	
Gamma-ray activity could vary on different time scale:			
A few days → W Com		Several months → 3C 454.3	



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S5 0716+714

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

<F_γ> = (97 ± 15)E-8 ph/cm2/s E>100MeV

z = 0.31 ± 0.08 (Nilsson et al., 2008)

Total power transported in the jet is extremely high (L>3E45 erg/s).

This may exceed the max. power generated by a Kerr BH with M_{BH}~1E9 M_{Sun}.

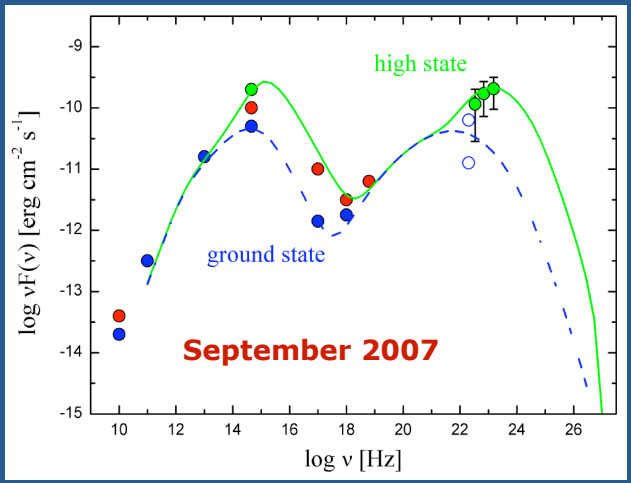
Giommi et al., 2008, A&A, 487, L49

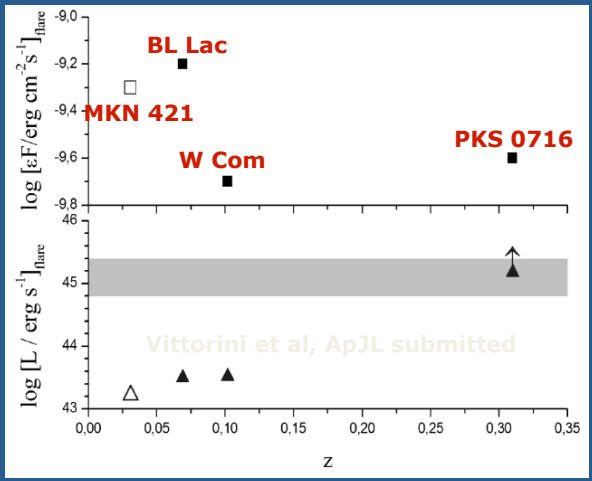
<F_γ> = (47 ± 11)E-8 ph/cm2/s E>100MeV

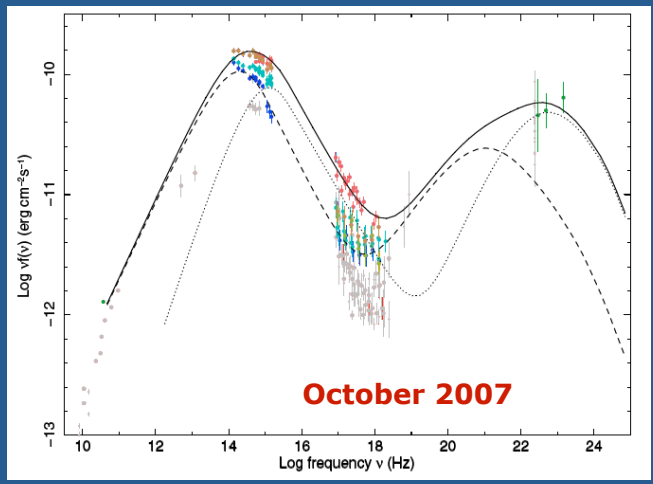
The γ-ray flux about a factor of 2 lower than in September.

Swift observed different variability in opt/UV, soft X-ray, and hard X-ray.

The SED is consistent with a two—components SSC model.



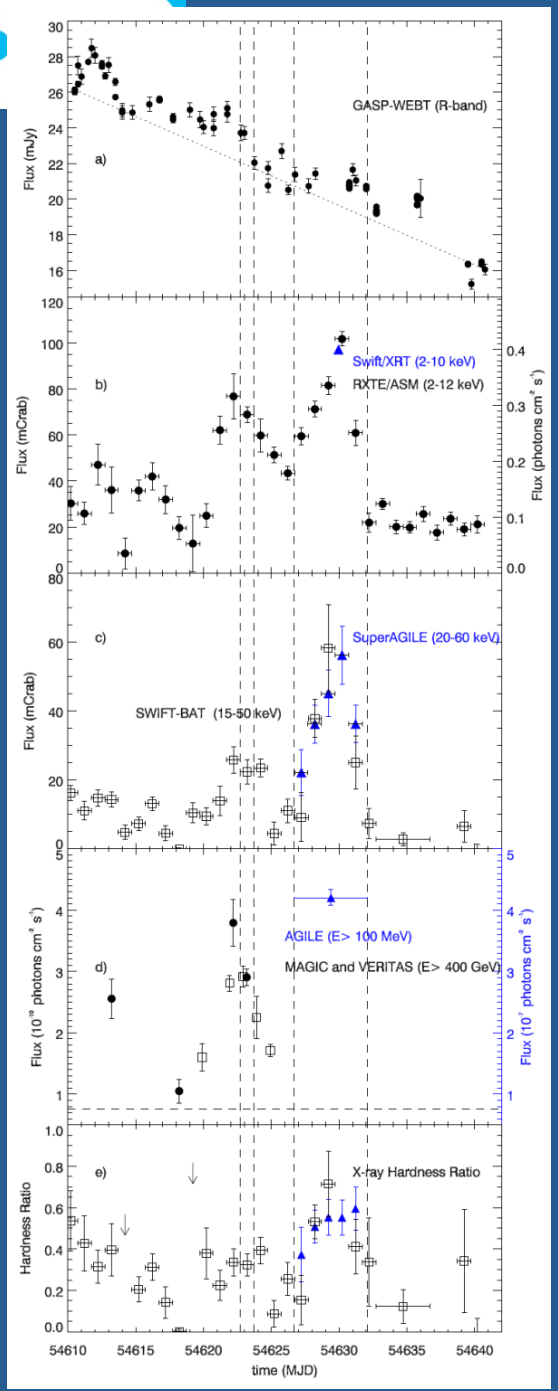




$$P_{tot,flare} = L_r + L_{kin} + L_B$$

The shaded area represents the BZ limiting luminosity range for a BH mass in the range (3E8 – 1E9)M⊙.

MKN 421



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

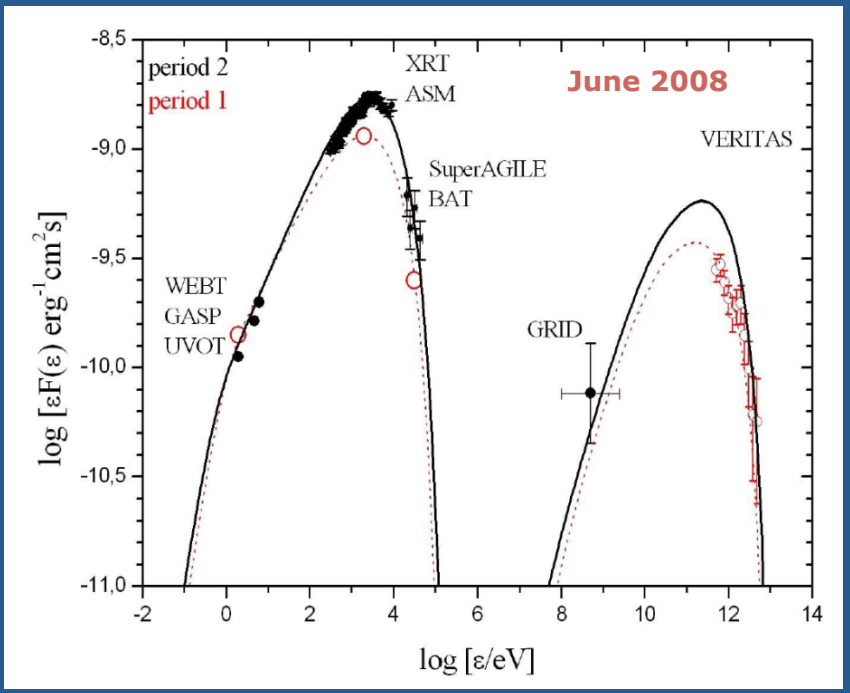
$\langle F_\gamma \rangle$ = (42 ± 13)E-8 ph/cm2/s E>100MeV

SA: 40mCrab (0.01 ph/cm2/s) 20—60 keV

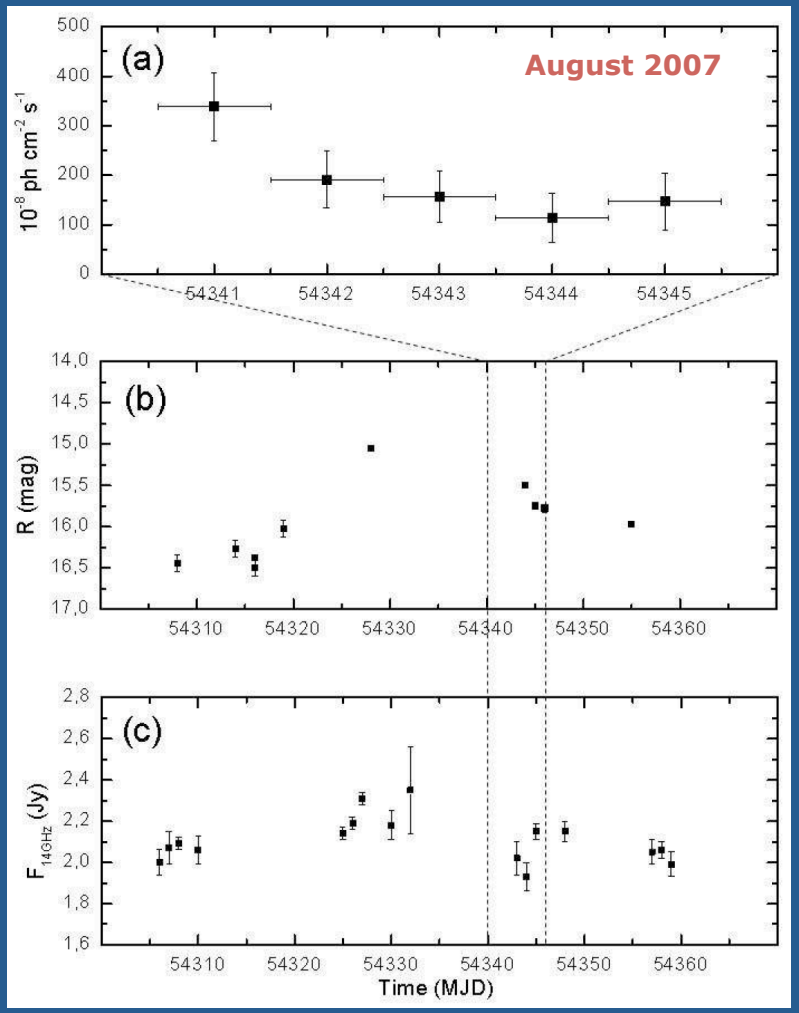
Swift/XRT: 2.6E-9 ph/cm2/s 2—10 keV

Correlated variability (optical, X-rays, HE, and VHE)

The γ-ray flare can be interpreted within the framework of the SSC model in terms of a rapid acceleration of leptons in the jet.



PKS 1510-089

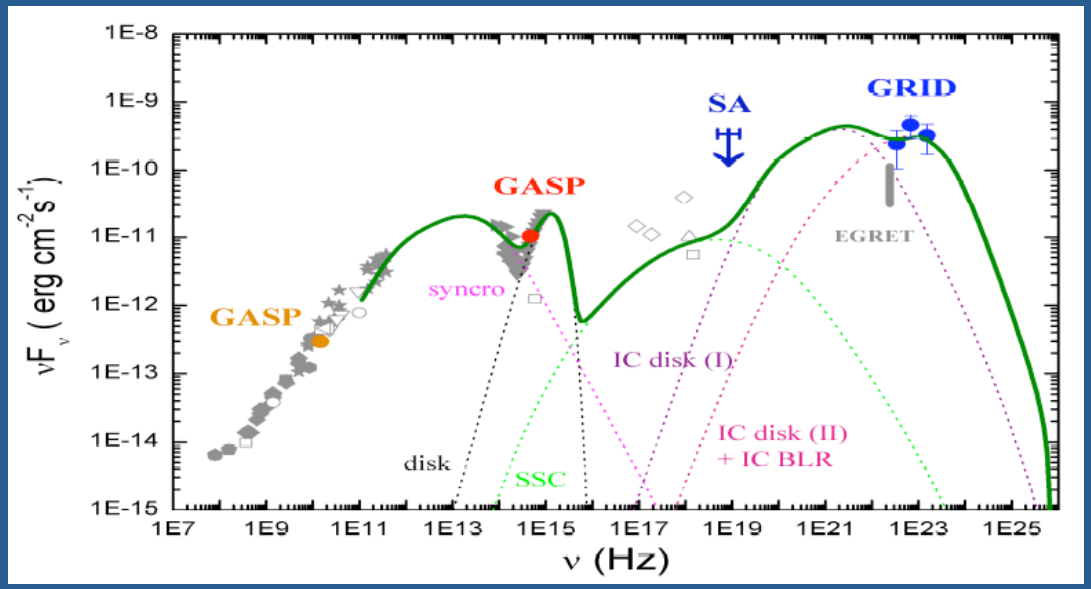


Pucella et al., A&A, 2008, 491, L21

<F_γ> = (195 ± 30)E-8 ph/cm2/s E>100MeV

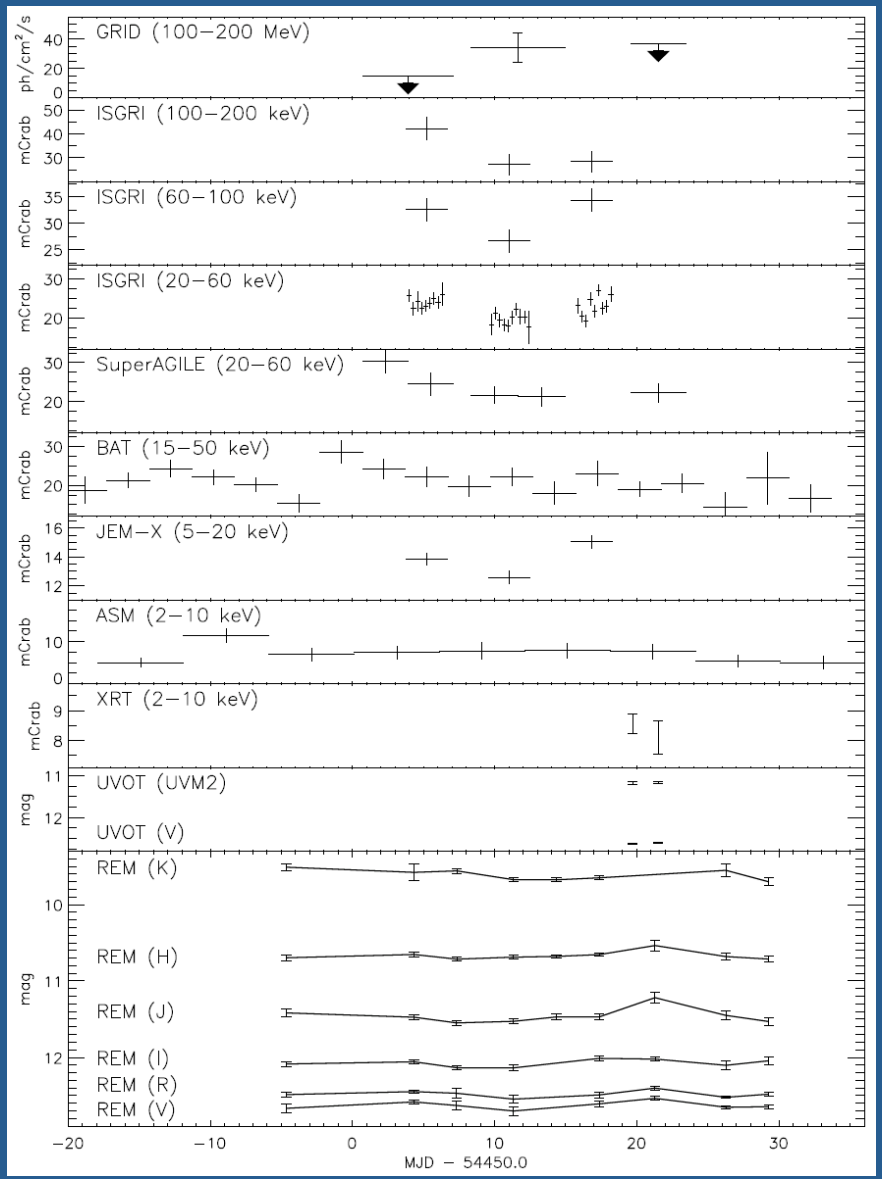
A common trend (fluxes decrease) in the optical and γ-ray LC seems to be present.

The overall SED can be fit by means of a leptonic model (SSC+EC on BLR clouds)



3C 273

16/12/2007 – 08/01/2008



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

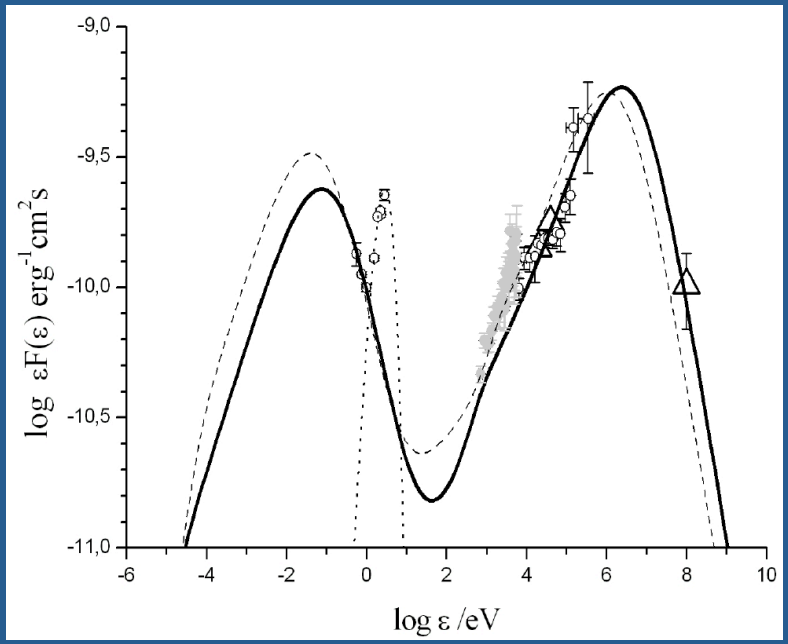
$\langle F_\gamma \rangle$ = (22 ± 6)E-8 ph/cm2/s E>100MeV

F_γ [peak] = (33±11)E-8 ph/cm2/s E>100MeV

First simultaneous detection by GRID & SA

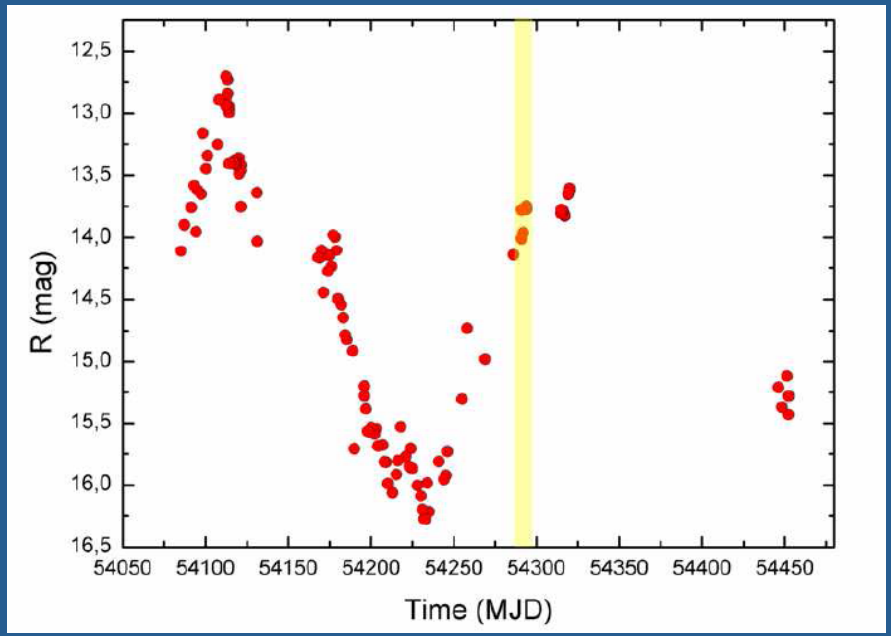
No optical variability during the whole campaign (possible anti—correlation between the γ -ray and the X-ray light curves ?)

Soft X-ray: SSC + EC. Hard X-ray and γ –ray: EC from thermal photons of the disk.



3C 279

Observation date	Flux 2-10 keV erg cm^{-2} s^{-1}	Spectral slope Γ	χ^2_r (d.o.f.)
10-Jul-2007	1.20×10^{-11}	1.42 ± 0.05	1.21 (73)
11-Jul-2007	1.17×10^{-11}	1.47 ± 0.07	0.86 (52)
12-Jul-2007	1.05×10^{-11}	1.47 ± 0.06	1.07 (57)
13-Jul-2007	1.13×10^{-11}	1.48 ± 0.06	0.96 (50)



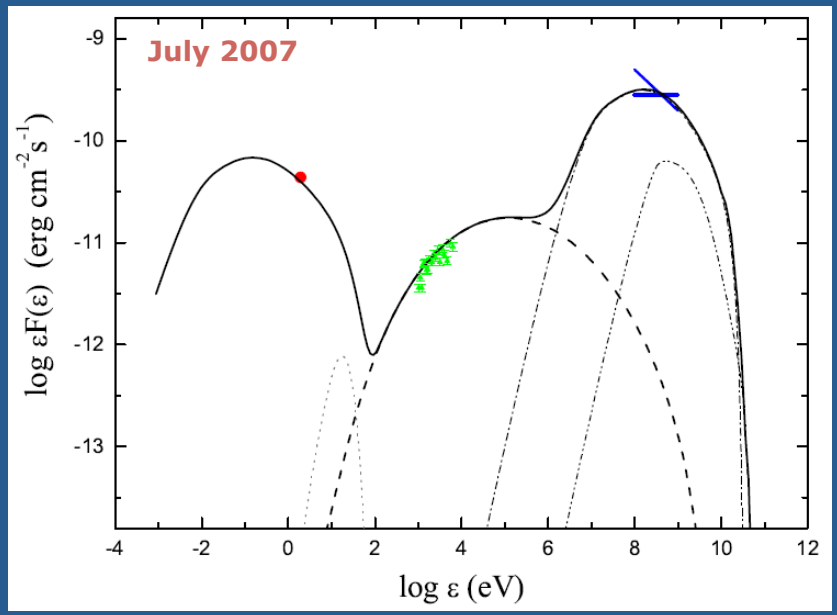
Giuliani et al., A&A, 2009, 494, 509

<F_γ> = (210 ± 38)E-8 ph/cm2/s E>100MeV

First extragalactic source detected by AGILE/GRID & first AGILE multi—λ campaign

Gamma—ray flux similar to the EGRET high state

Soft γ-ray spectrum ($\Gamma = 2.22 \pm 0.23$): low state of the accretion disk before the γ-ray observations, suggesting a dominant contribution of the EC of direct disk radiation compared to the EC scattering of the BLR clouds.



3C 454.3

Vercellone et al, 2008, ApJ, 676, L13

AGILE repointing at 36 deg off—axis

<F_γ> = (280 ± 40)E-8 ph/cm2/s E>100MeV

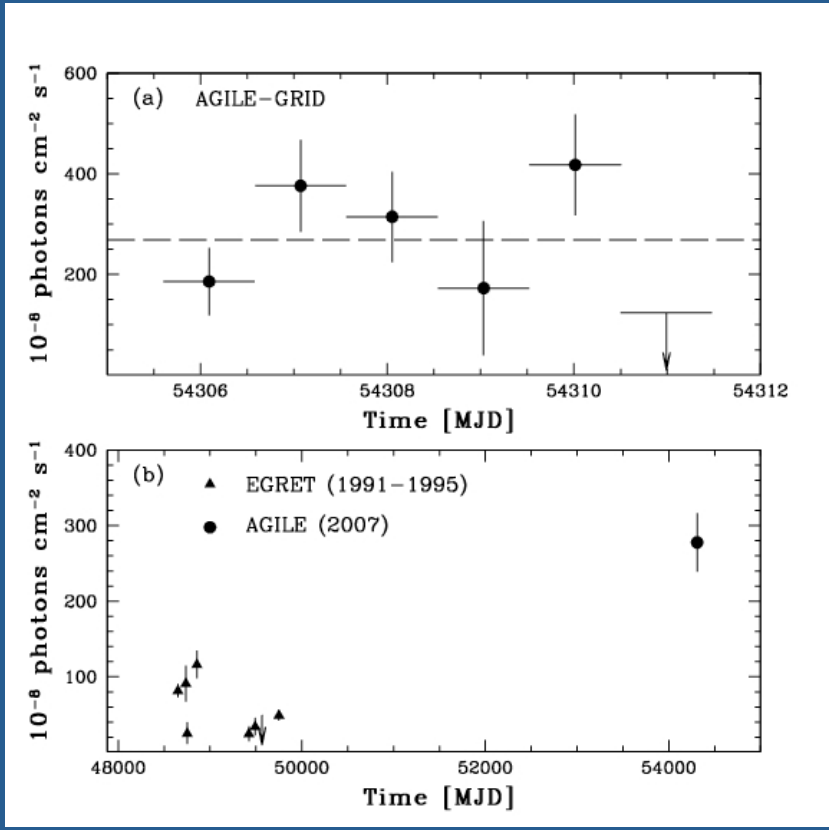
Highest published average flux (see Abdo et al. 2009 for the highest daily value)

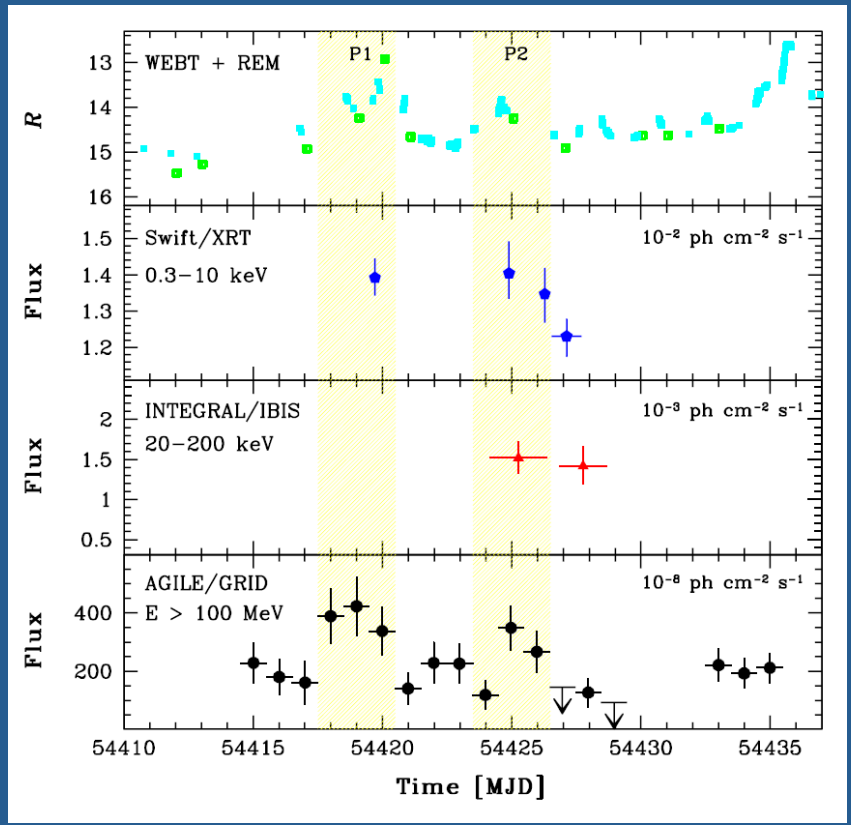
Vercellone et al., 2009, ApJ, 690, 1018

Result of a multi—λ campaign based on pre—approved ToOs and GI programs

<F_γ> = (170 ± 13)E-8 ph/cm2/s E>100MeV

Extremely variable behavior in the R band





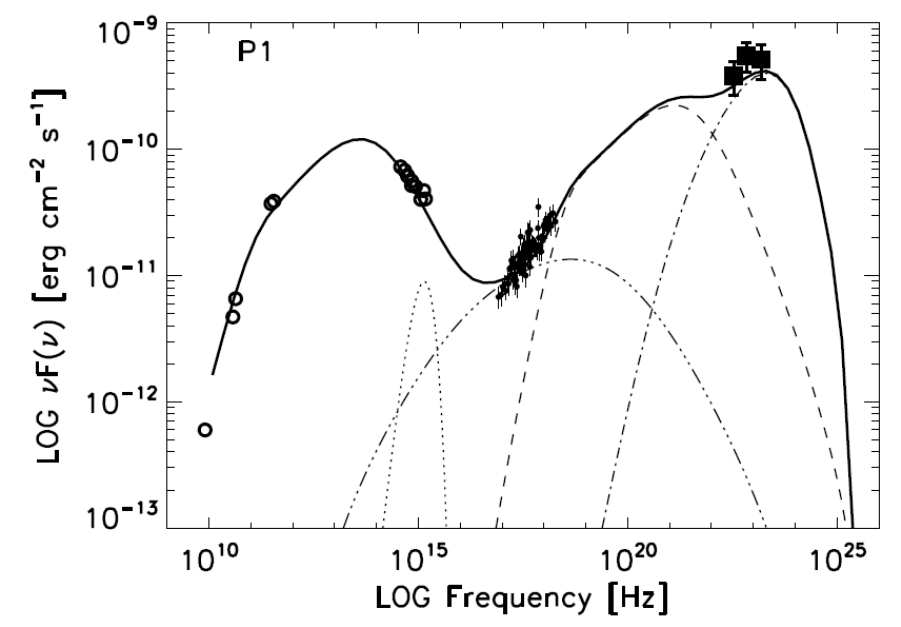
3C 454.3

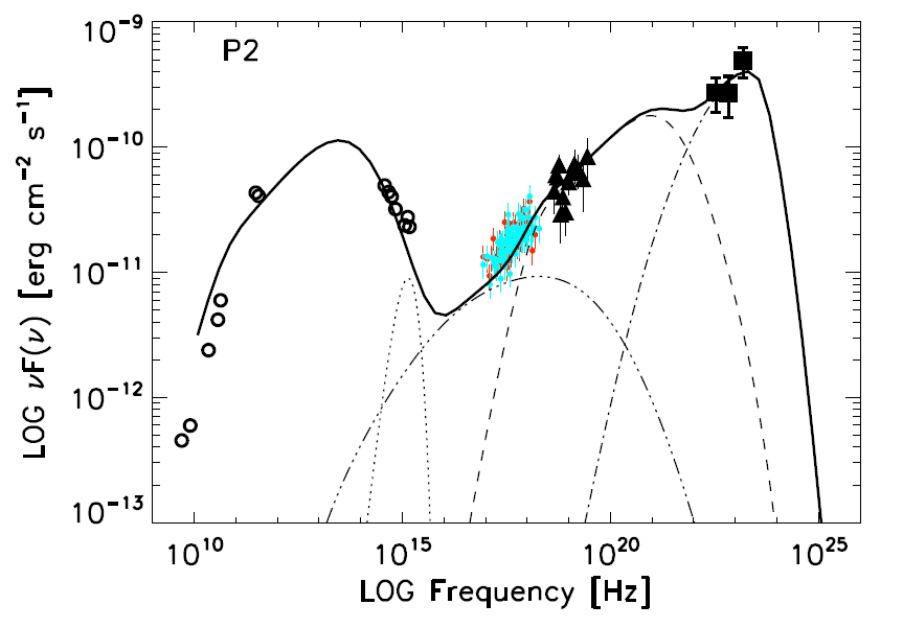
Parameter	SED P1	SED P2	Units
α_l	2.1	2.2	
α_h	4.5	5.0	
γ_{min}	10	10	
γ_b	500	500	
K	14	12	cm^{-3}
R	35	35	10^{15} cm
B	10	8	G
δ	14.64	14.64	
L_d	5	5	10^{46} erg s^{-1}
r	0.05	0.05	pc
Θ_0	2.6	2.6	degrees
Γ	8.4	8.4	

The average photon index ($\Gamma = 1.73 \pm 0.16$) is harder than the time–averaged one ($\Gamma = 2.22 \pm 0.06$) reported for EGRET (see also Abdo et al., 2009 for a broken PL model)

During intense γ-ray flares, the ECC and ECD play a major role and the softness/hardness of the resulting spectrum is controlled by the dominant component.

The emission between 30 MeV and 30 GeV is dominated by IC scattering of relativistic electrons in the jet on the external photons from the broad line region.

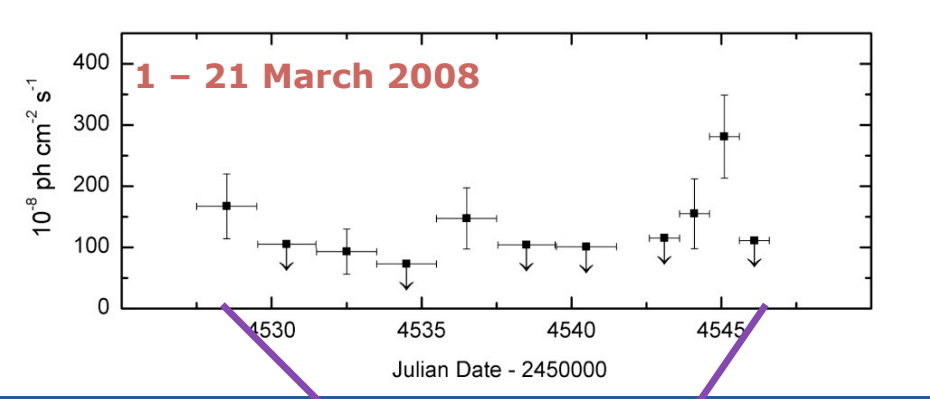




… and the latest results !

Mars and Orion over the Munument Valley. Credit: APOD

PKS 1510-089



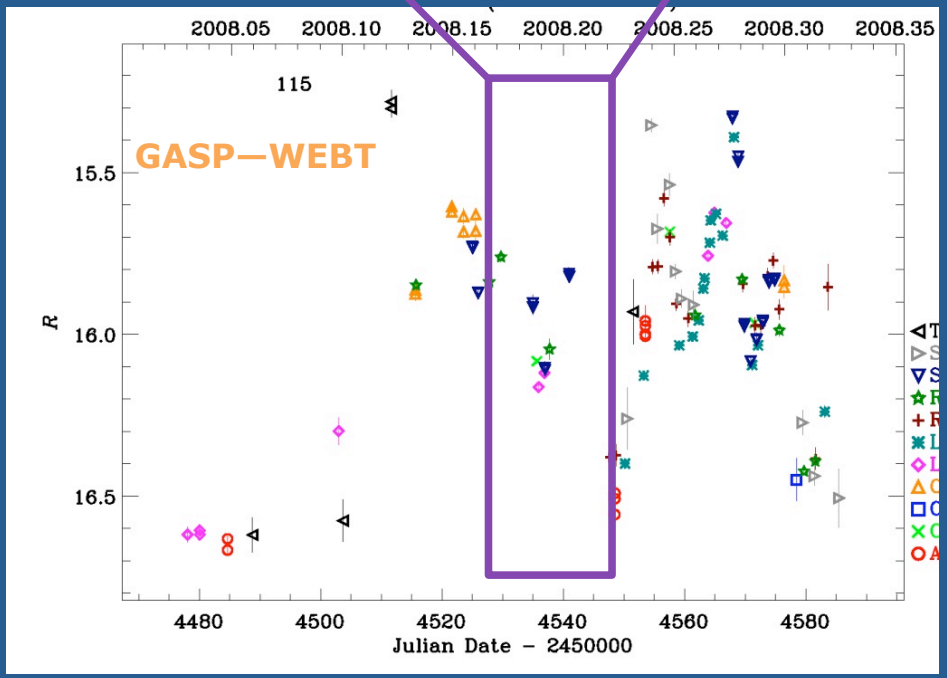
D'Ammando et al., A&A, in press [ArXiv:0909.3484]

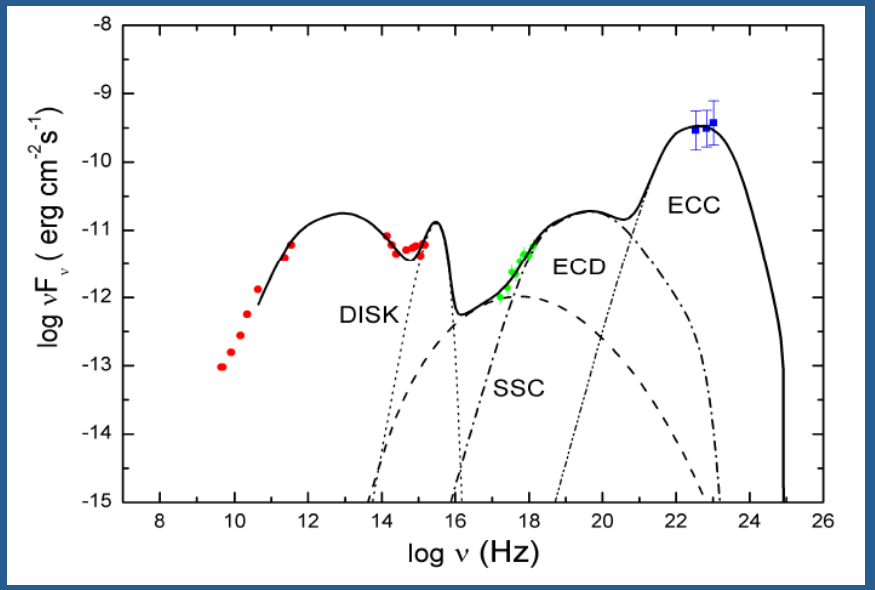
3 Optical flares: 15/02, 29/03, 11/04

The γ-ray photon index is Γ = (1.81 ± 0.34)

In the period March 17-21 the average flux was $<F_\gamma >$= (170 ± 13)E-8 ph/cm2/s

The SED is modelled with a multi-component SSC +ECC+ECD+black body (disk) model

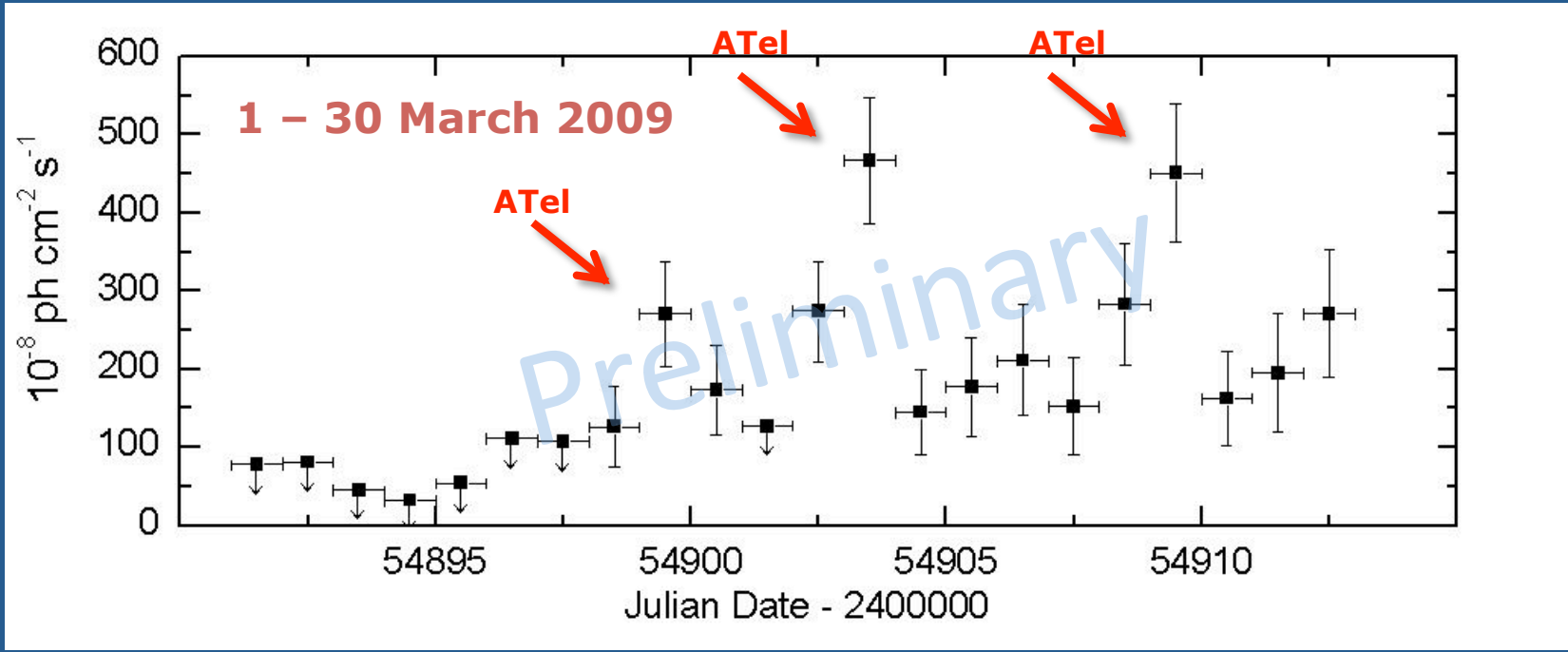




PKS 1510-089

D'Ammando et al., in preparation

- D'Ammando et al., ATel #1957, 2009-03-08 14:00 UT and 2009-03-10 4:00 UT flux in excess of 200 x 10^-8 ph cm^-2 s^-1.
- Pucella et al., ATel #1968, 2009-03-12 07:00 UT and 2009-03-13 05:00 UT flux in excess of 400 x 10^-8 ph cm^-2 s^-1.
- Vercellone et al., ATel #1976, 2009-03-18 05:45 UT and 2009-03-19 05:33 UT flux of about 400 x 10^-8 ph cm^-2 s^-1. This value represents an increase of more than a factor of 3 within 24 hours compared with the gamma-ray flux level detected during the previous three days.



W Comae

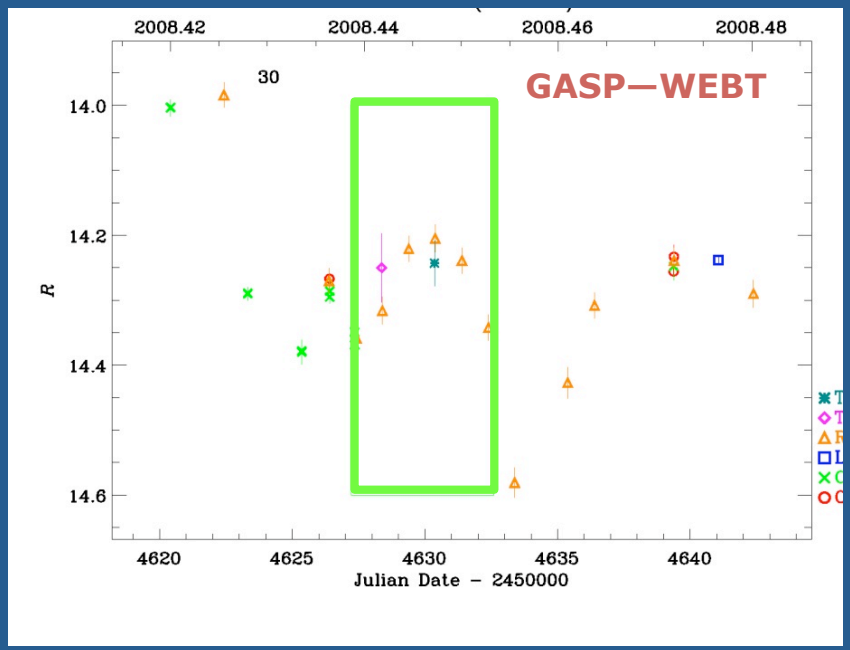
Acciari et al., submitted

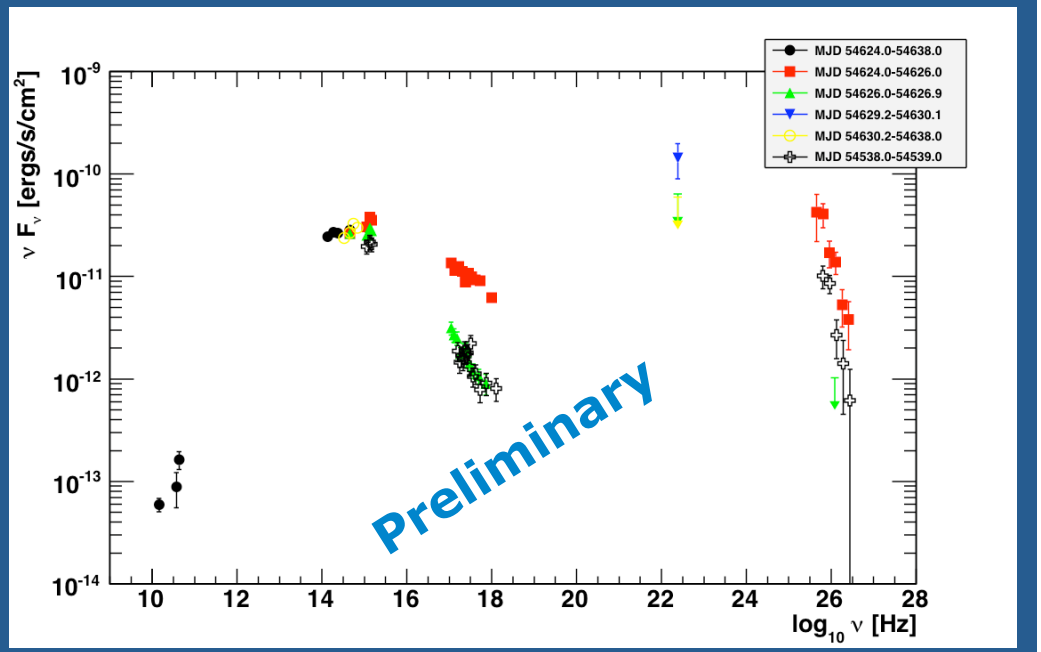
• Detection by VERITAS (Swordy et al., ATel #1565) on 2008-06-07 at a flux double w.r.t. the flux detected in March 2008.

• AGILE ToO and subsequent detection (Verrecchia et al., ATel #1582)

• Multi-l campaign, involving GASP—WEBT, Swift, AGILE and VERITAS

• This source belongs to an AGILE AO—1 GI (Pian).



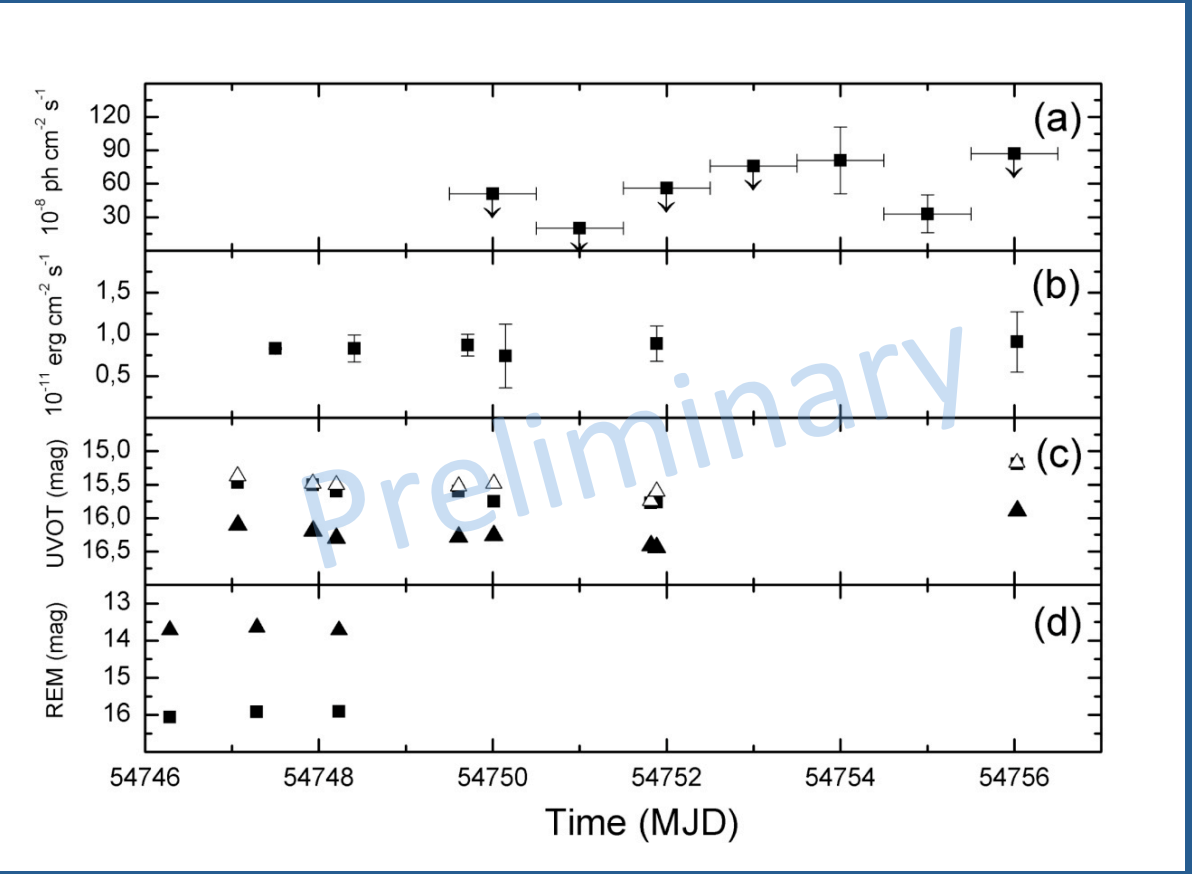


PKS 0537-441

Pucella et al., in preparation

• Fermi/LAT detection (Tosti, ATel #1759) between 2008-09-15 and 2008-10-02, at a flux level of the order of 100E-8 ph/cm2/s.

• AGILE ToO with almost simultaneous Swift and REM observations.



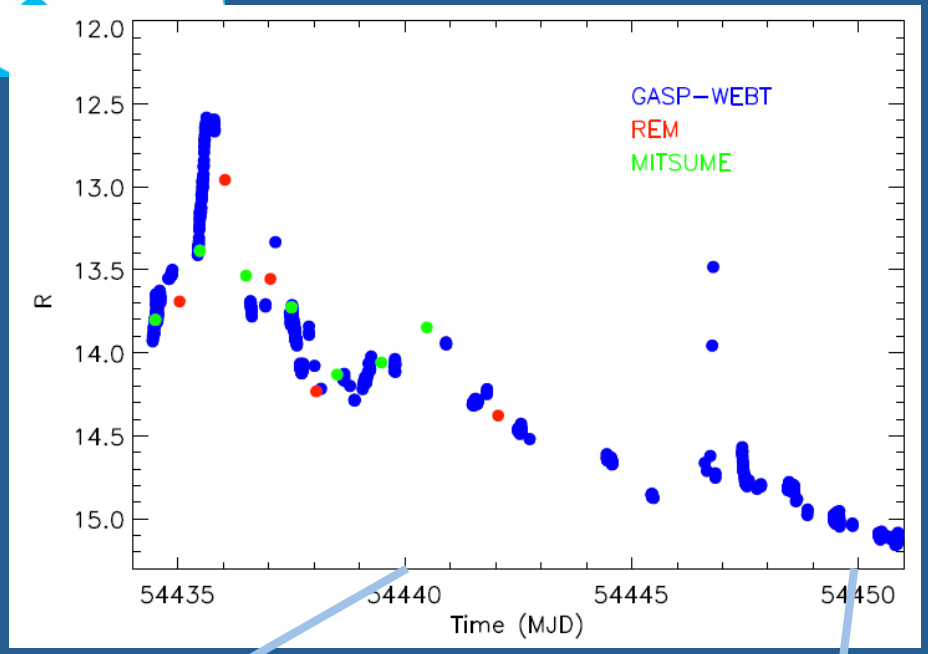
AGILE

Swift/XRT

Swift/UVOT

REM

3C 454.3

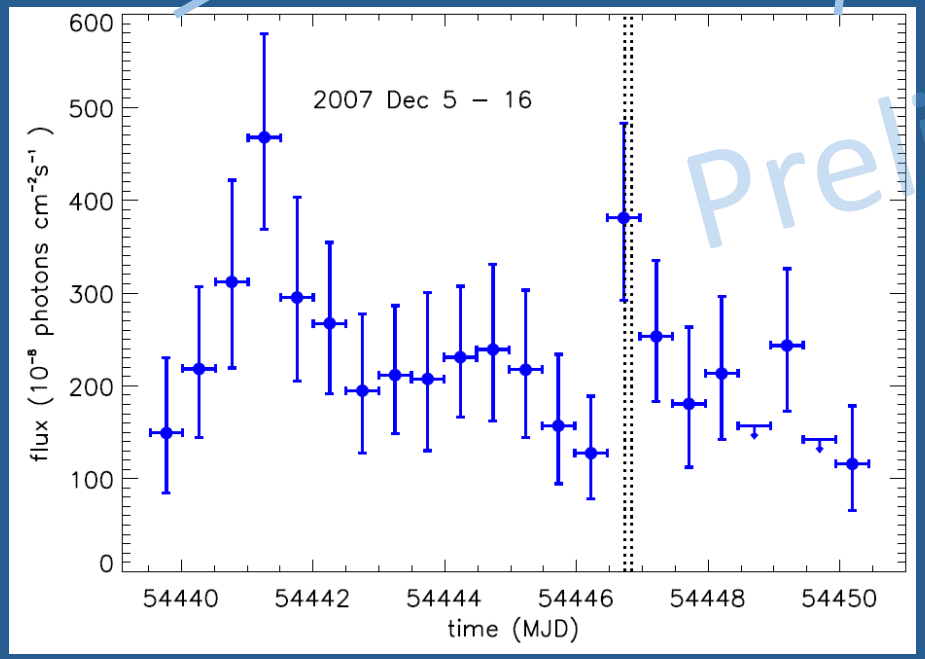


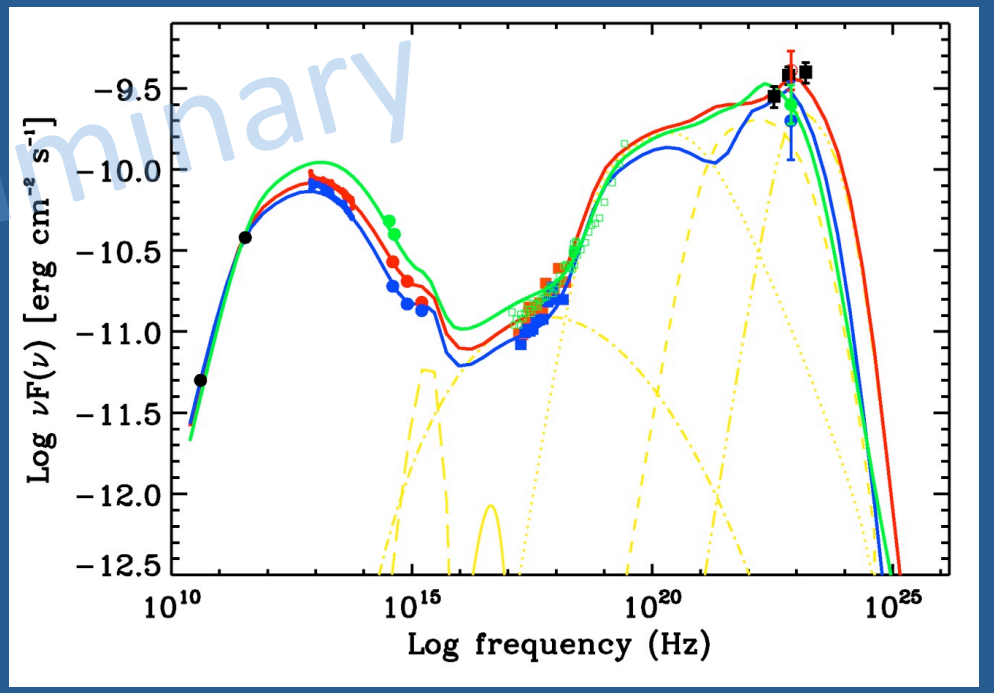
Donnarumma et al., ApJ, submitted

Multi-λ campaign with the contribution of Spitzer, REM, WEBT, MITSuME, Swift, Suzaku and AGILE

$\langle F_\gamma \rangle$ ~ 250 x 10^{-8} ph cm^{-2} s^{-1} E > 100 MeV

The SED may require EC emission of seed photons from a hot corona with T = 10^6 K





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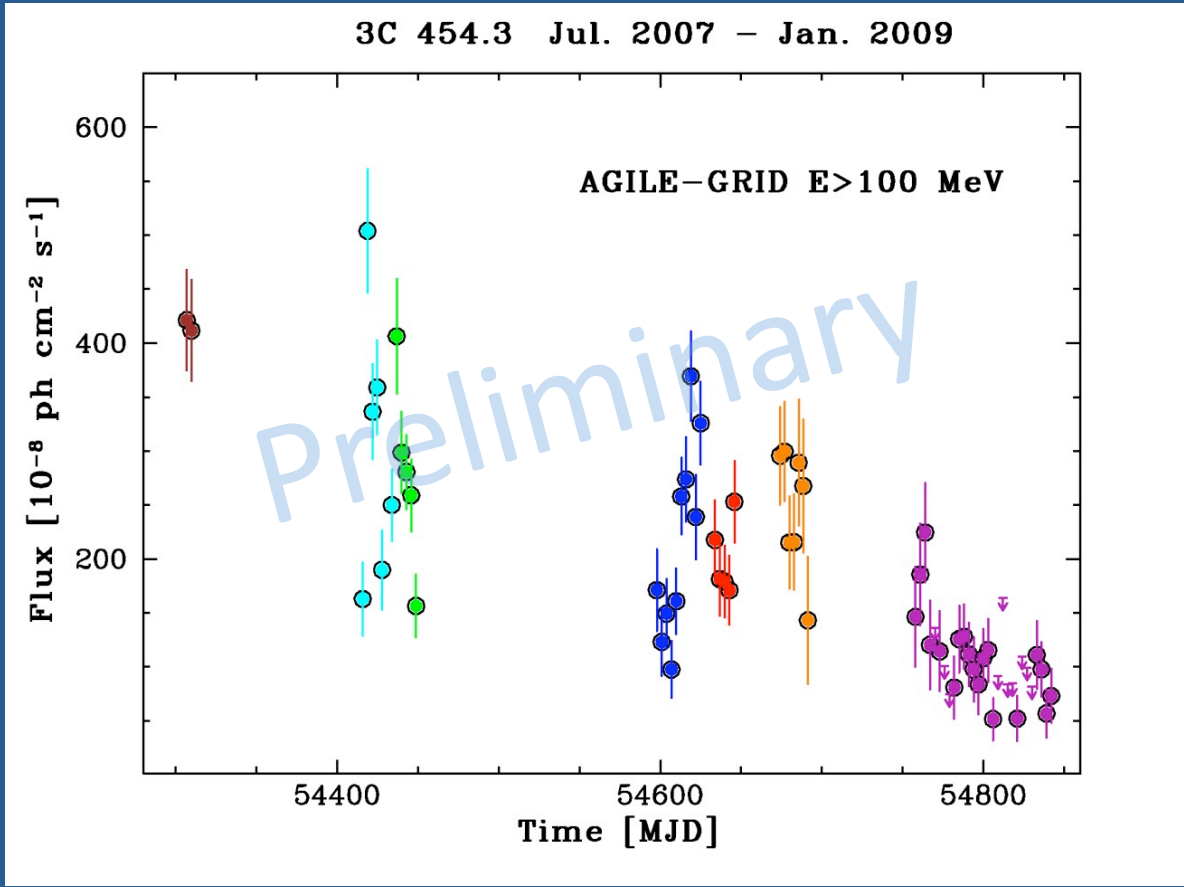
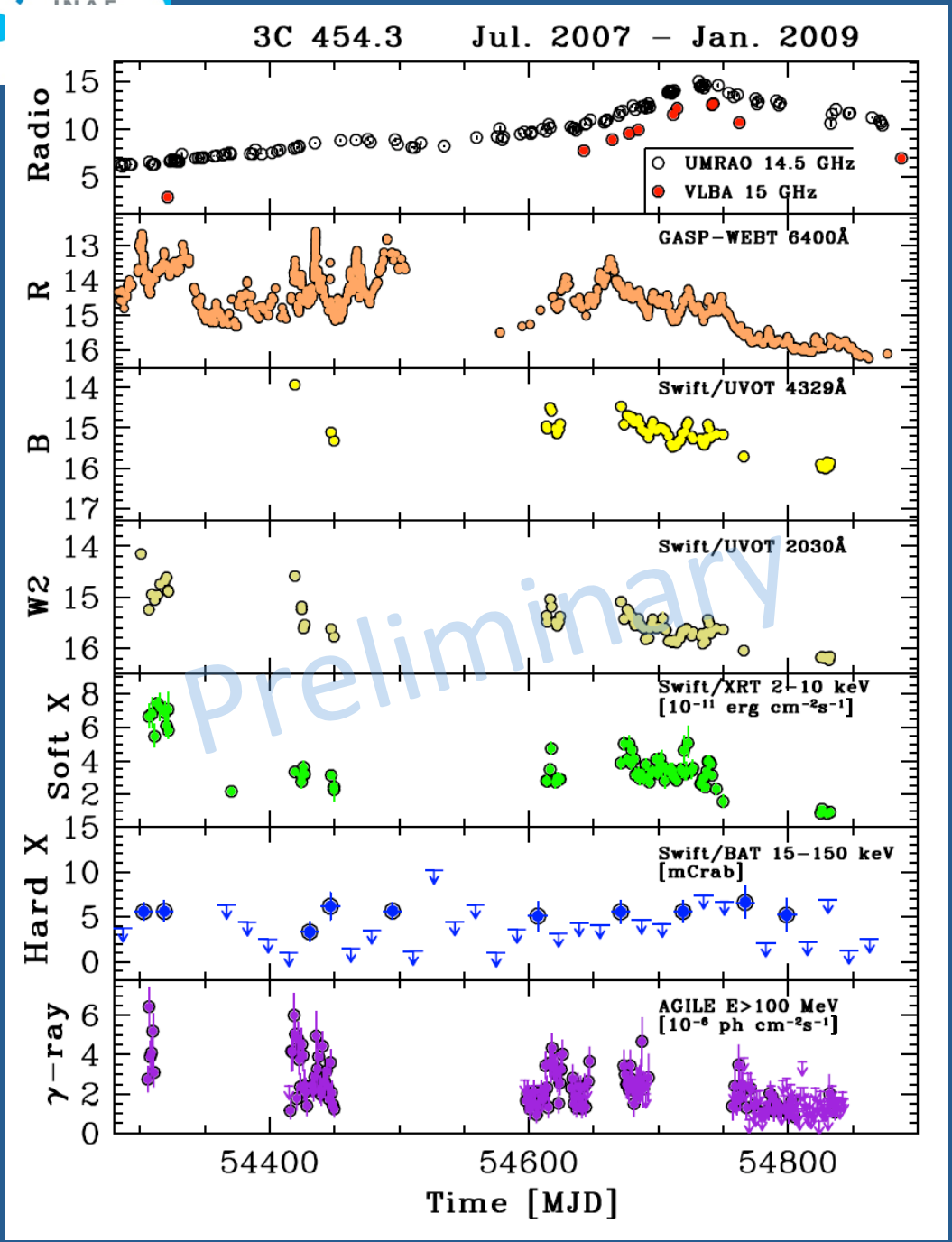


Vercellone et al., ApJ, submitted

The longest monitoring so far of a γ-ray blazar.

A factor of about 10 in dynamic range in about 2 years (if considering also the *Fermi* data).

3C 454.3

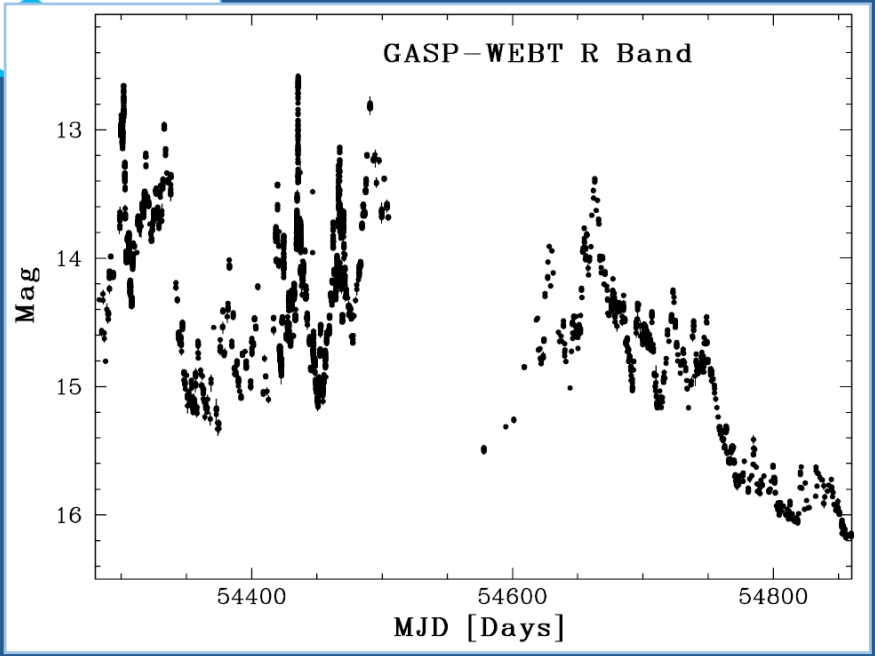


Vercellone et al., ApJ, submitted

Multi—λ: MOJAVE, GASP—WEBT, Swift/UVOT, Swif/XRT, Swift/BAT, AGILE/GRID

One year and half of AGILE monitoring: comparison of SEDs, LCs, time—lags, spectra, etc…

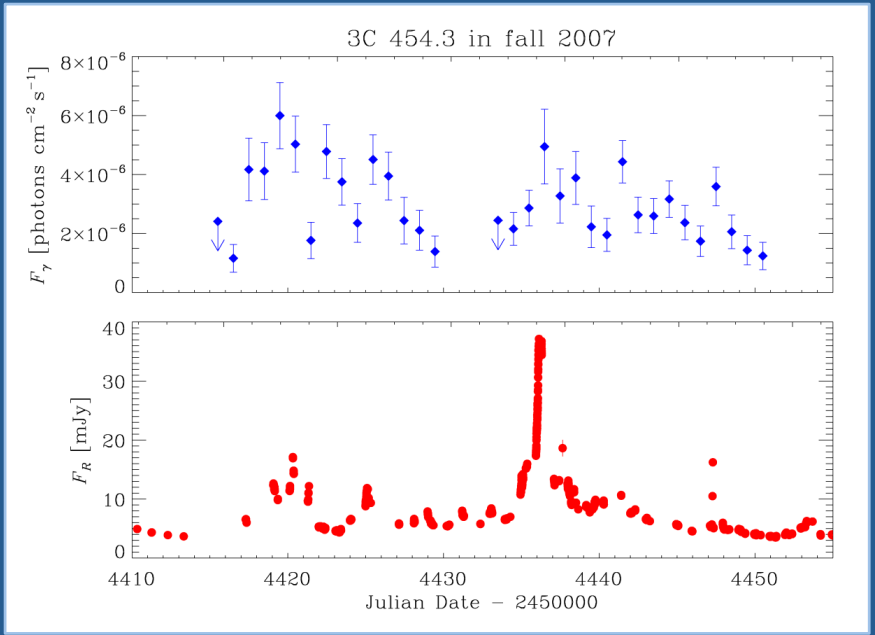
3C 454.3

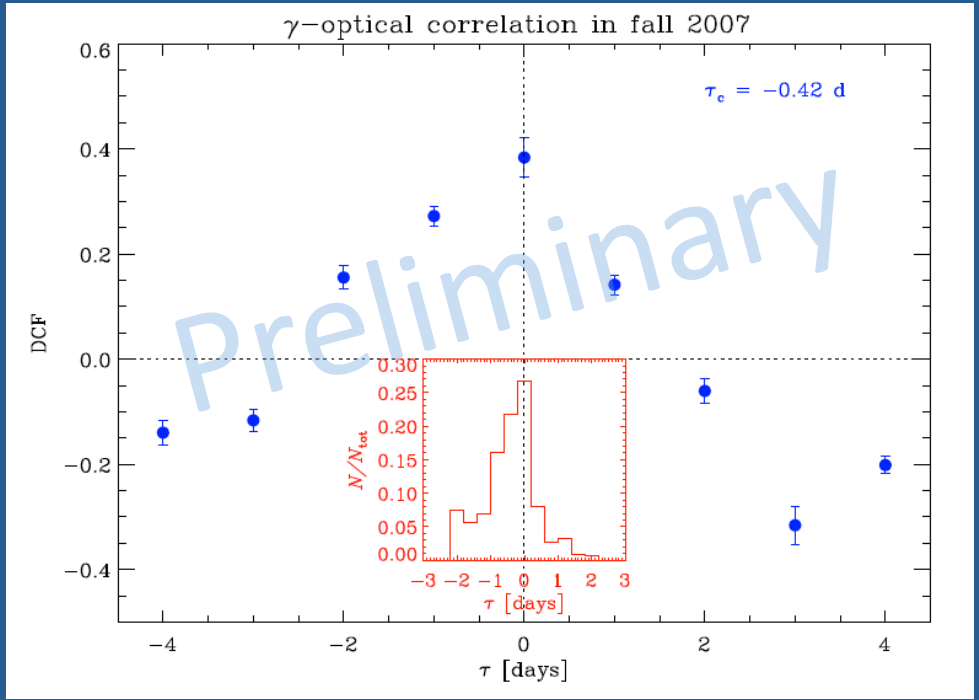


One of the longest and simultaneous optical and γ-ray coverage of a blazar

Dynamic range greater than 3 magnitudes with extremely fast intra-day variability

DCF analysis : shows a (possible) ≤ 1 day delay of the γ-ray emission w.r.t. the optical one.





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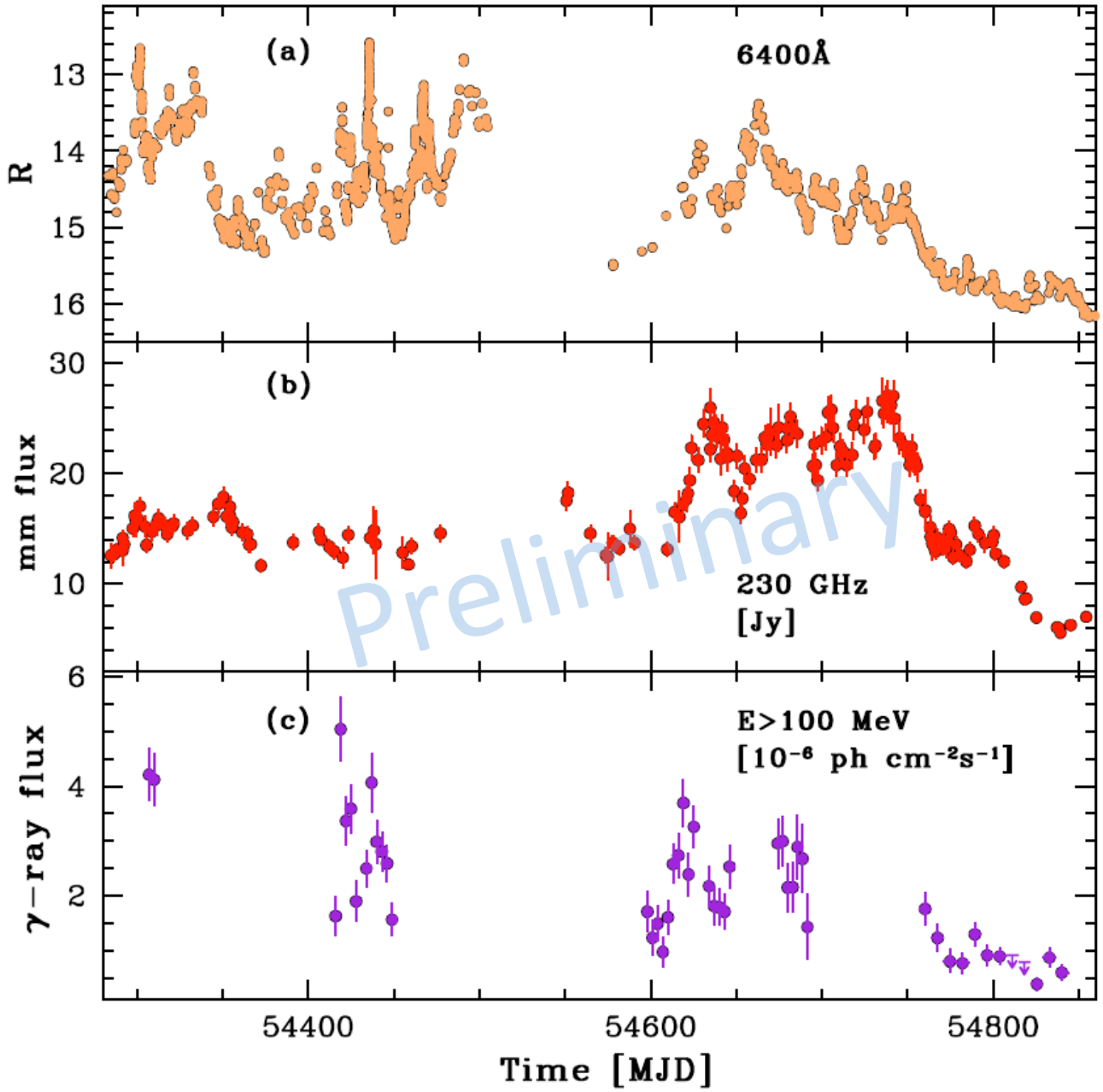

(a)
6400Å
R
13
14
15
16
(b)
230 GHz
[Jy]
mm flux
30
20
10
(c)
E>100 MeV
[10⁻⁶ ph cm⁻²s⁻¹]
γ−ray flux
6
4
2
54400
54600
54800
Time [MJD]
Preliminary

The multi—color domain

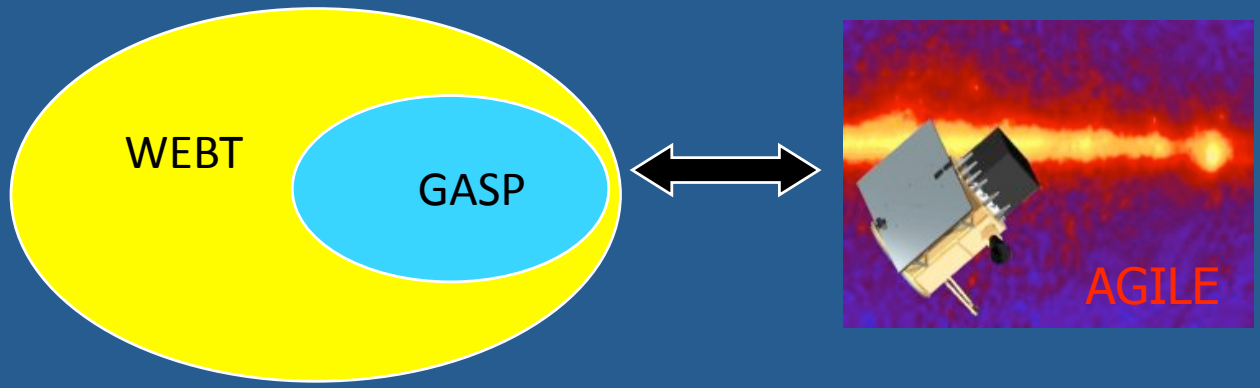
The GLAST-AGILE Support Program (GASP)

of the

Whole Earth Blazar Telescope (WEBT)

Contacts: M. Villata (WEBT President) & C.M. Raiteri INAF OA-To

http://www.oato.inaf.it/blazars/webt/



The WEBT-GASP

The WEBT was born in 1997, in the CGRO era, as an international consortium of astronomers devoted to blazar studies.

In 2007 the WEBT started the GLAST-AGILE Support Program (GASP)

Mostly optical, but also radio and near-IR observatories

Selected WEBTers perform continuous monitoring of 28 γ-loud blazars

Light curves are constructed almost in real time

The distribution in longitude allows 24 h/day continuous monitoring

The WEBT-GASP

On the big 2004-2005 optical outburst and delayed radio outburst:

Villata et al. (2006, A&A, 453, 817)

Villata et al. (2007, A&A, 464, L5)

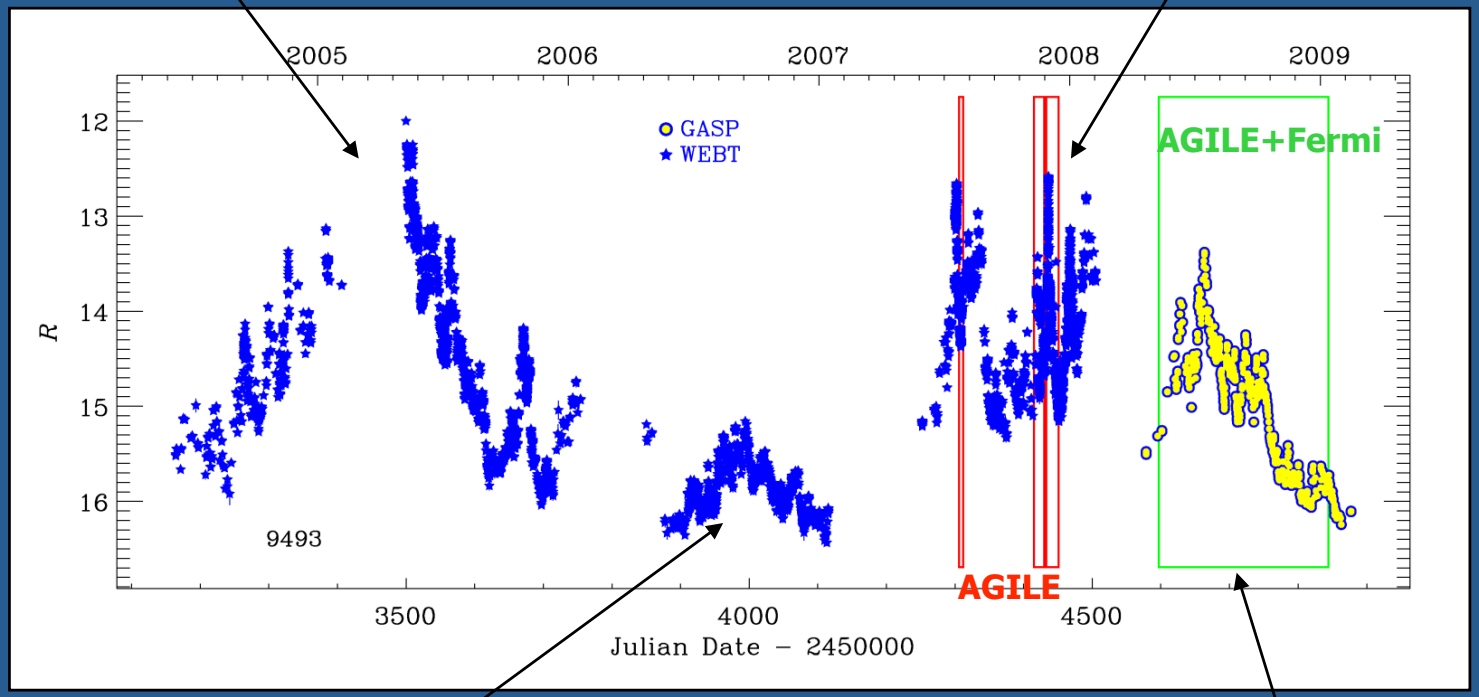
On the new activity phase in 2007-2008:

Raiteri et al. (2008, A&A, 485, L17)

Raiteri et al. (2008, A&A, 491, 755)

Vercellone et al. (2009, ApJ, 690, 1018)

Donnarumma et al. (ApJ submitted)

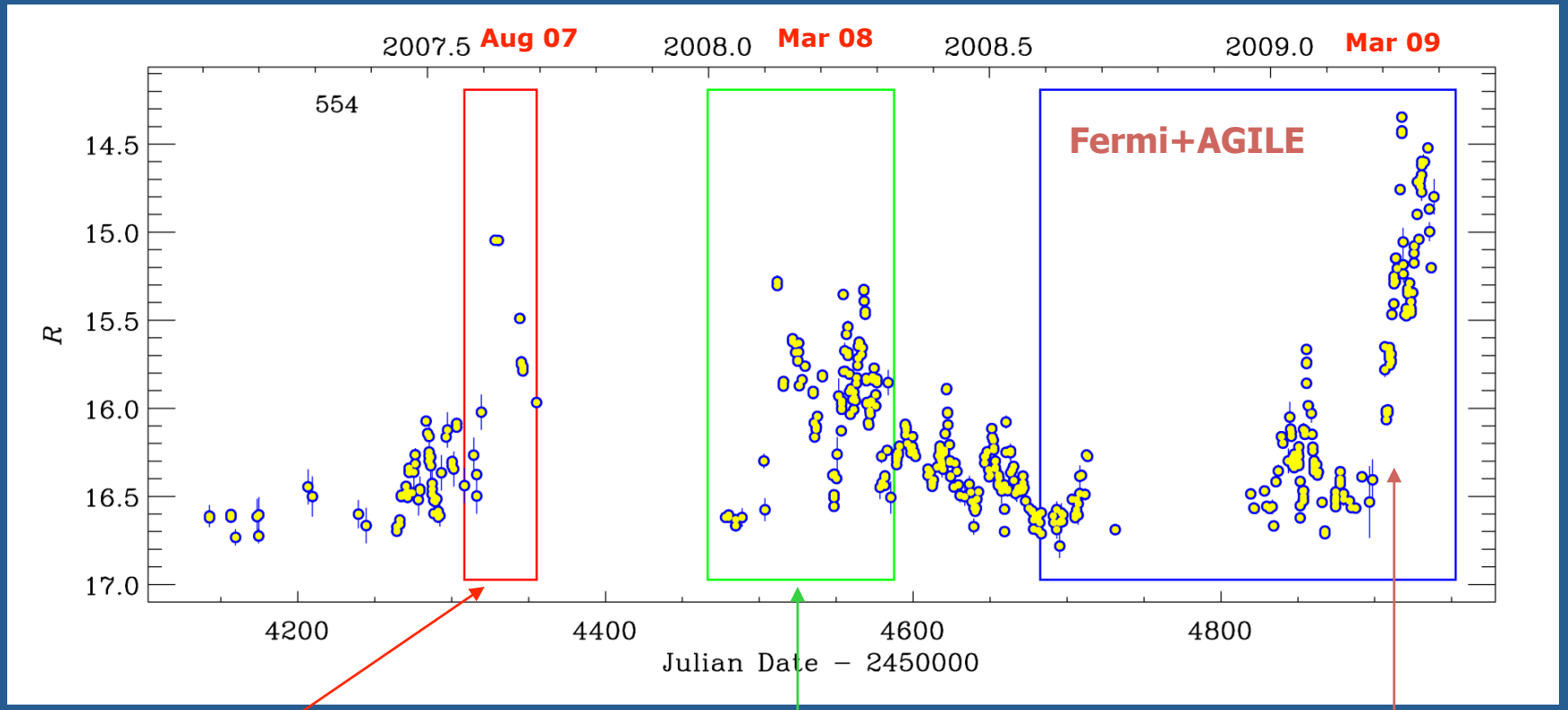


On the faint state in 2006-2007 and detection of little and big blue bumps:

Raiteri et al. (2007, A&A, 473, 819)

On the new observing season…

The WEBT-GASP

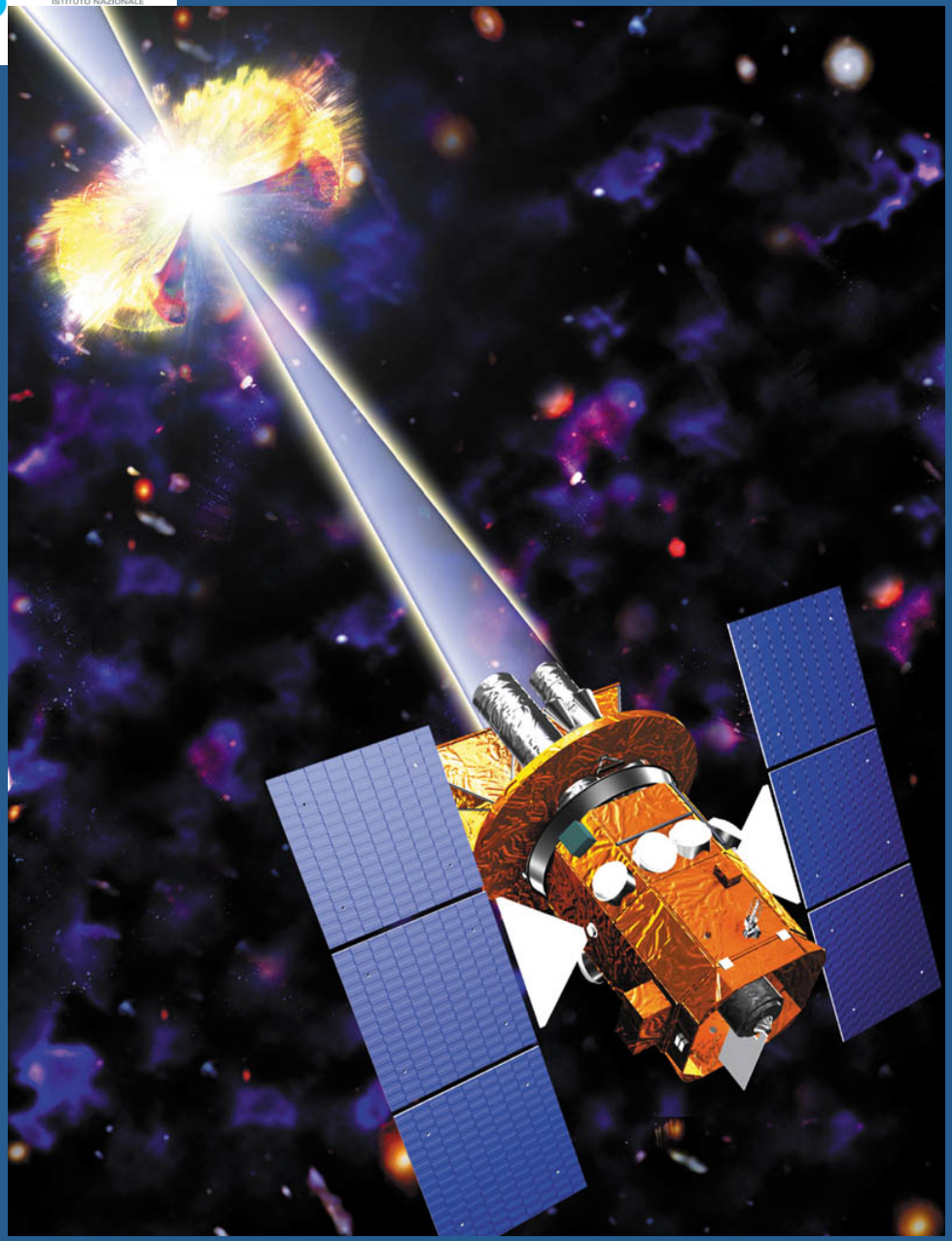


Pucella et al. (2008, A&A, 491, L21)

D'Ammando et al. (A&A, in press)

D'Ammando et al. (in preparation)

The *Swift* satellite



Swift—BAT
15-150 keV
F.o.V.: 1/6 of the sky

Swift—XRT
0.2-10 keV
F.o.V.: 24x24 arcmin

Swift—UVOT
1700-6500 A
F.o.V.: 17x17 arcmin

The *Swift* satellite

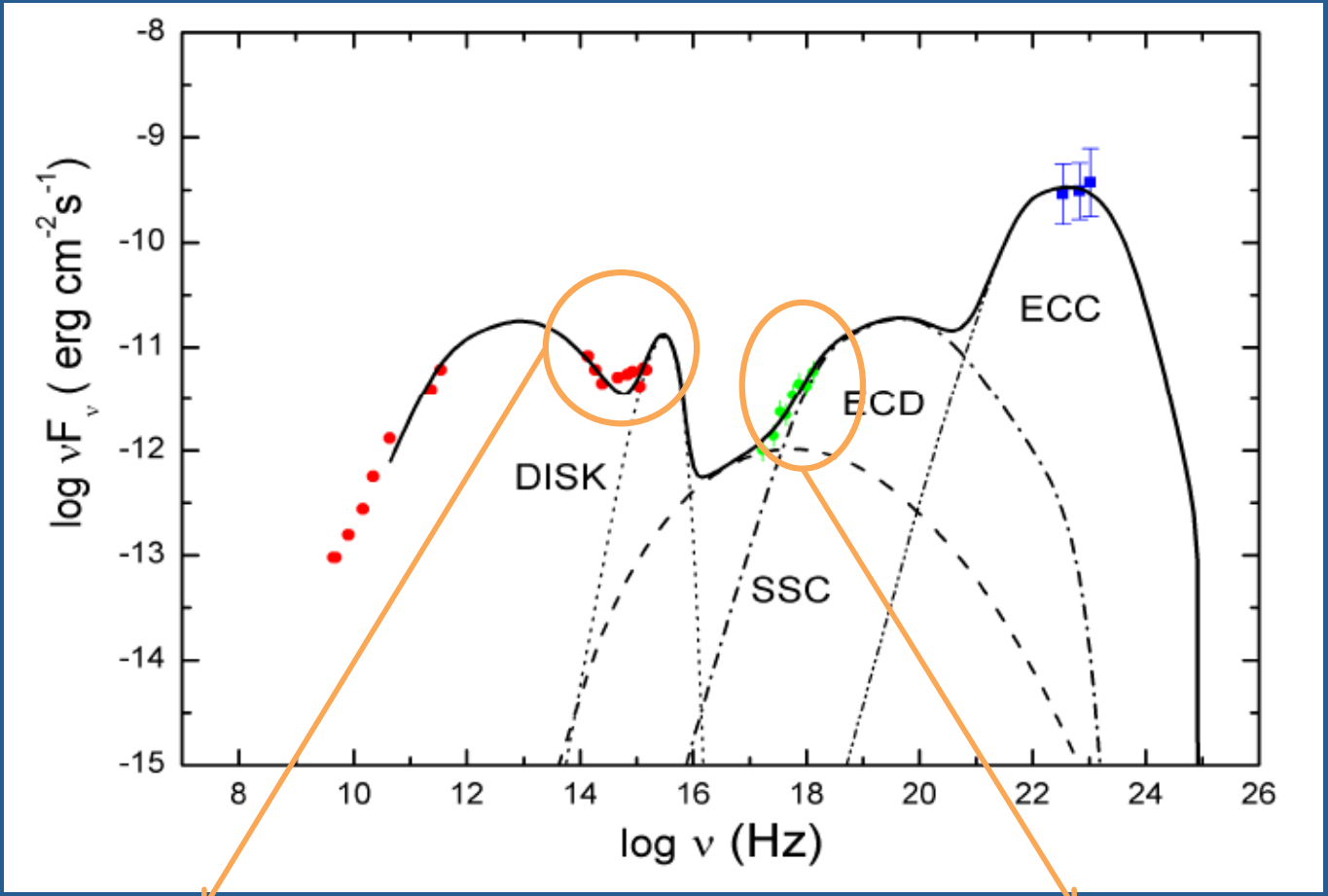
The AGILE Team has a very strong link with the *Swift* Team.

Up to now, more than a dozen of ToOs were awarded to the AGILE Team, as well as three GI programs.

Almost all the AGILE multi-wavelength papers contain *Swift* data.

AGILE exploited the unique *Swift* flexibility, obtaining almost simultaneous data from UV up to hard X-ray energy bands.

D'Ammando et al., A&A, in press

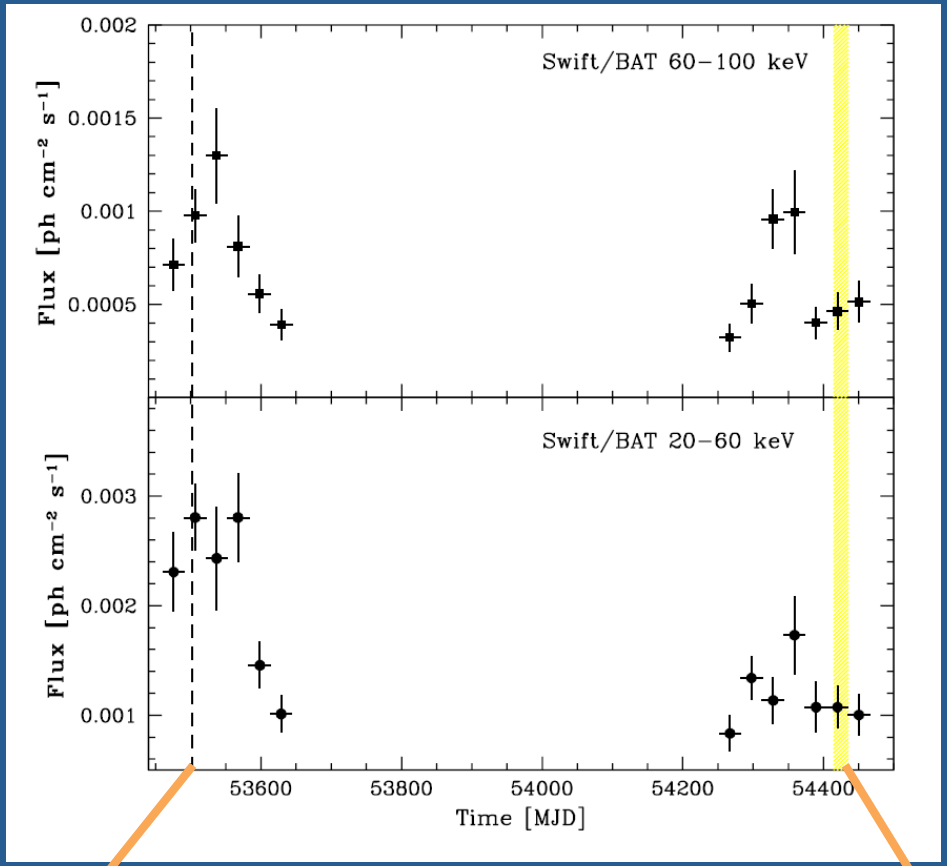


Possible signature of the disc blue bump ?

Possible presence of a soft excess ?

The *Swift* satellite

Vercellone et al, 2008, ApJ, 690, 1018



The short-dashed line marks the epoch of the giant optical flare in 2005, when the hard X-ray flux was about twice higher than in November 2007.

The yellow vertical area marks the AGILE November 2007 campaign.

The *Swift* satellite

The *AGILE* strength lies in its name

It promptly reacts to external alerts and triggers ToOs with other Observatories.

We obtain truly simultaneous, broad-band SEDs

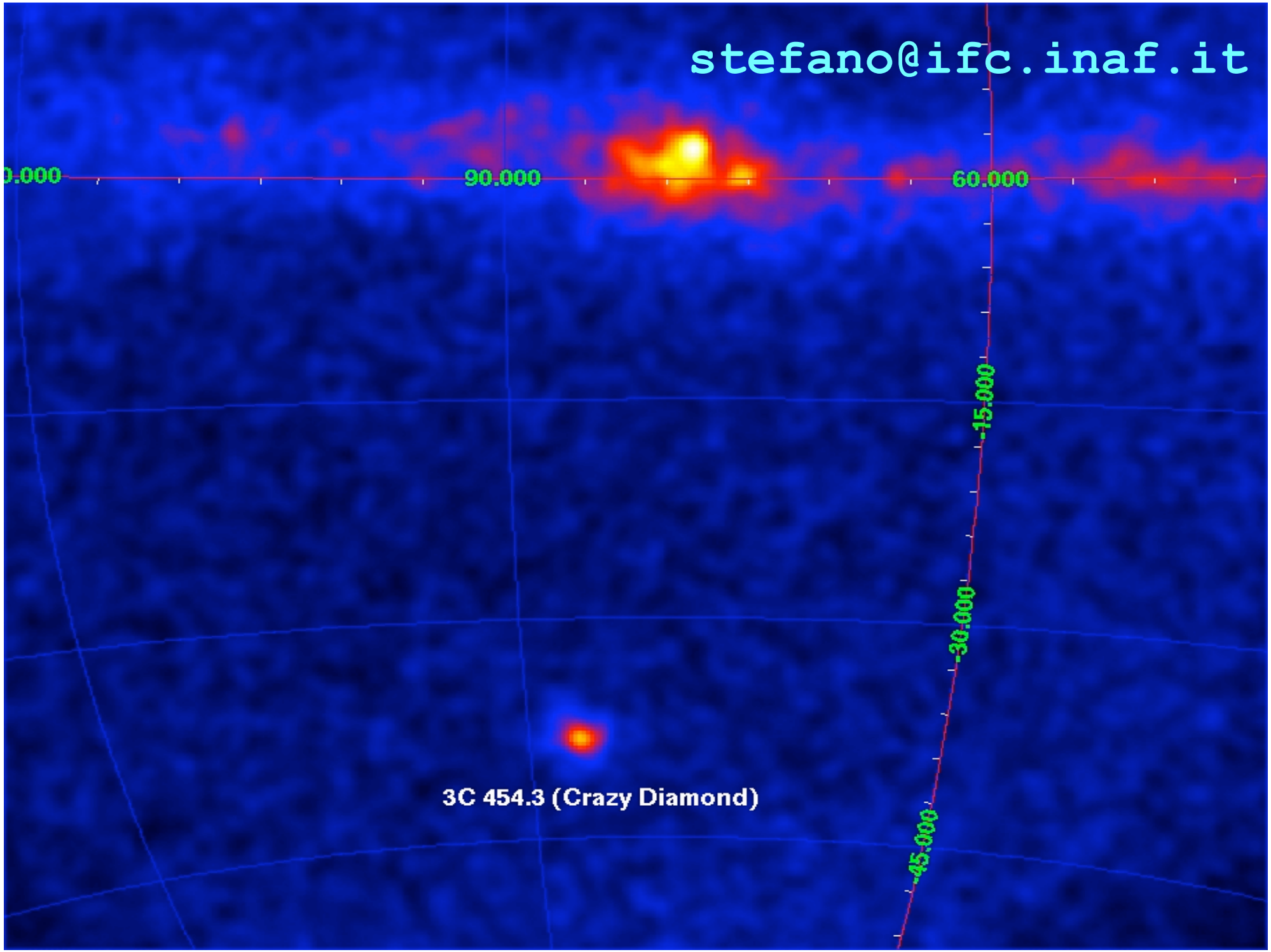
We can study the physics of different classes of blazars

Long-term studies of selected objects

We can monitor both high and low gamma-ray states

Archival data analysis is in process

We start detecting dim and steady sources


stefano@ifc.inaf.it
90.000
60.000
-15.000
-30.000
-45.000
3C 454.3 (Crazy Diamond)