What can we learn from High Energy flares of FSRQ, from a case study to dozens of sources

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GB6 J1239+0443
z=1.76

Association of the unidentified gamma-ray source 3EG J1236+0457 With the distant FSRQ GB6 1239+0443 At z=1.76

Tramacere et al., 2009, Atel 1888 (FERMI+SWIFT),
Ikejiri et al., 2009, Atel 1892 (FERMI+SWIFT+KANATA),
Fermi catalogs: Abdo et al., 2010 & 2011, (1FGL & 2FGL)

Fermi observed the source to flare at the end of 2008 with a gamma-ray flux arising of a factor ~10 with respect to quiescent state

The only optical source with a optical flux enhanchement with respect to archival data was GB6 1239+0443 (flux enhanchment of a factor ~30).
All the other optical/uv candidates in the Swift/UVOT F.O.V. remained at a level comparable to the archival data (with a flux change of a factor < 30%)

CAMPAIGNS DETAILS

CAMPAIGN "A"

- AGILE: flare detected from 3EG J1236+0457 (GB6 1239+0443), F~60*10^{-8} ph/cm2/s, E>100 MeV
- INTEGRAL/OMC: detection of SDSS J123932.75+0443.5 (GB6 1239+0443)
- INTEGRAL/ISGRI: U.L. of ~2 mCrab in hard X-rays

CAMPAIGN "B"

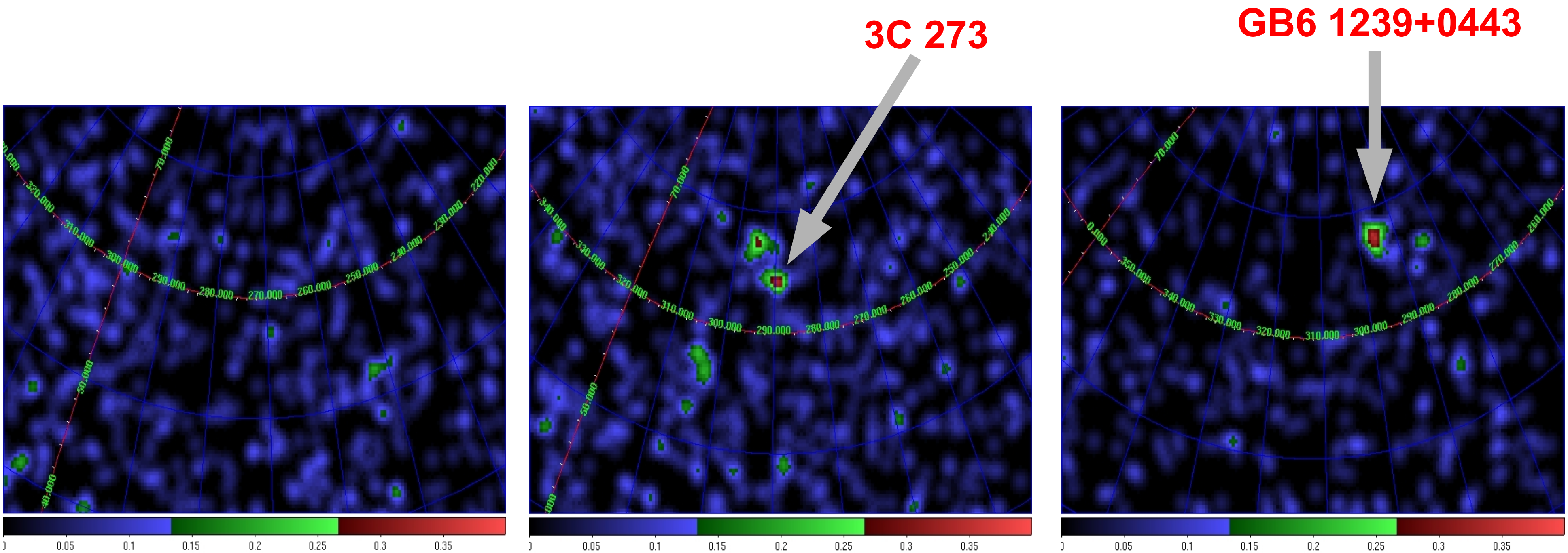
- Flare detected by FERMI/LAT and good positioning (Tramacere ATEL 1888)
- X-ray data from Swift/XRT,
- Optical data from Swift/UVOT and KANATA

Campaign A
AGILE data

Data analysed with the AGILE Standard Analysis Pipeline (BUILD20) and the AGILE Scientific Analysis Package

Integrating the GRID data for 4 days between 2008 January 4 13:35 and 2008 January 8 11:16 we detected a source (AGL J1238+0406 in the AGILE catalog, see Pittori et al. 2009, and Verrecchia et al. 2011) with SQRT(TS)~6 positionally consistent with GB6 1239+0443.

Flux: **$(62\pm9)\times10^{-8}$ ph/cm^2/s**, E>100 MeV
Photon index **1.92 ± 0.14**, E> 100 MeV

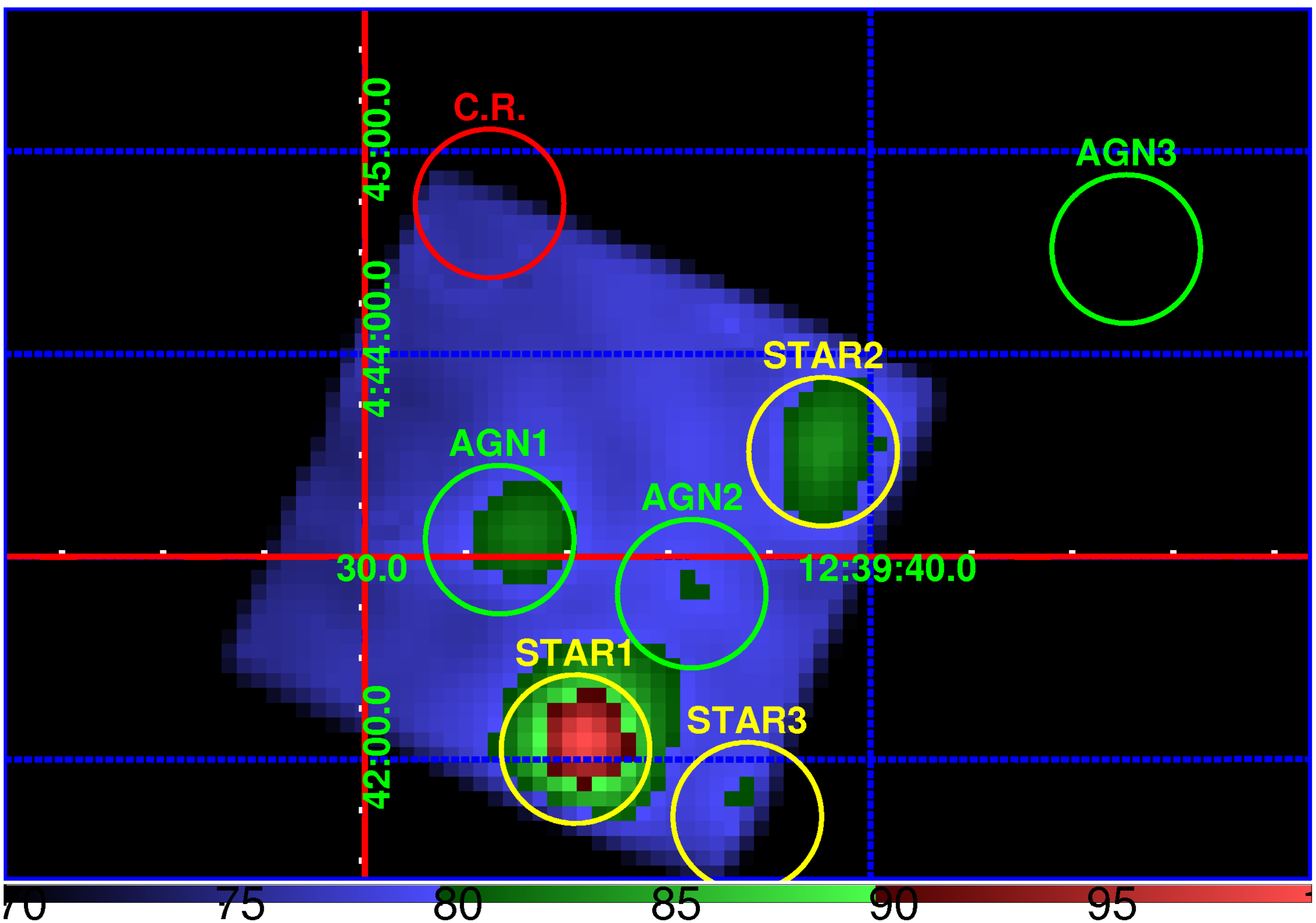


First week | **Second week** | **Third week**

CAMPAIGN A:

The image from INTEGRAL/OMC simultaneous to the gamma-ray flare detected with AGILE

AGN1 is GB6 1239+0443, detected with V magnitude ~17.5 (S/NR=4, integrated for all the longest shots of the 3 weeks campaign), to be compared with the archival V magnitude of ~19.9 (V magn evaluated from u and g magnitude from SDSS)



CAMPAIGN B
FERMI-LAT

We performed the STANDARD FERMI-LAT analysis as explained in http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation.

Data were analysed with P7_V6 response functions.
The analysis has been taken inside a circular region with radius 20 deg, and taking into account the sources of the 2FGL in the analysis region, the galactic diffuse emission (gal 2yearp7v6 v0) and the isotropic extragalactic emission (iso p7v6source).

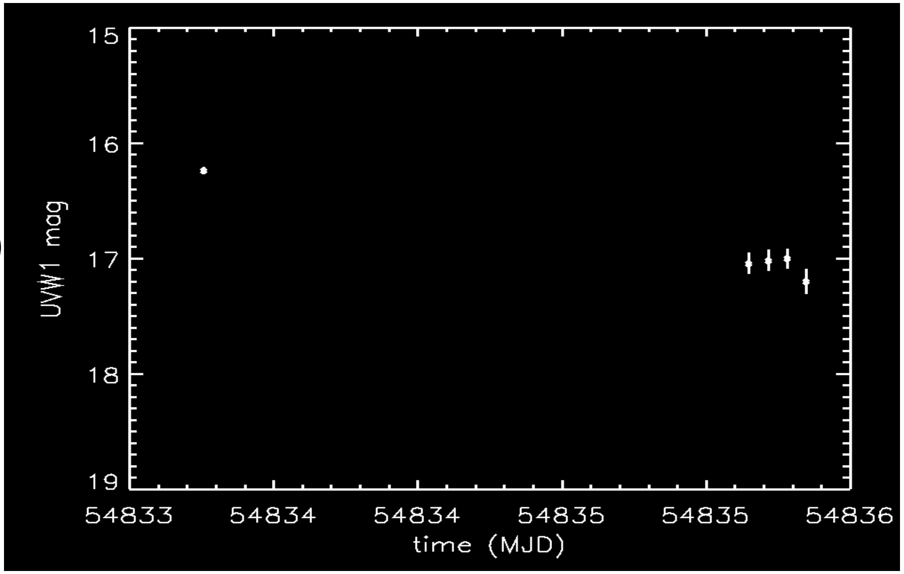
We detected the source with **SQRT(TS)~18**, and obtained a photon index of **2.21±0.15** between 0.3-20 GeV for an integration time of 4 days centered around **2008 December 29 16:00 UT**.

During the flare GB6 1239+0443 is revealed up to the energy bin 10-20 GeV with a **SQRT(TS)~5.8**

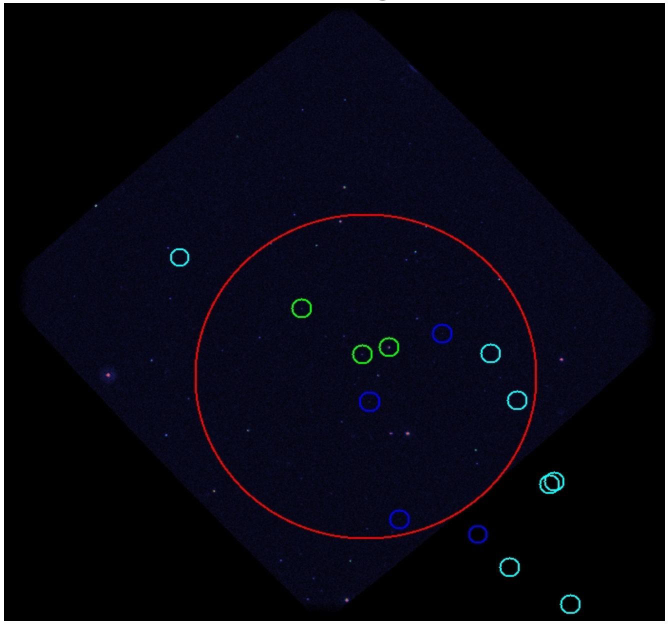
With the integration of 30 days period centered around the same date, we detected the source with **SQRT(TS)~20**, and we obtained a photon index of **2.15±0.11**

CAMPAIGN B
SWIFT/UVOT

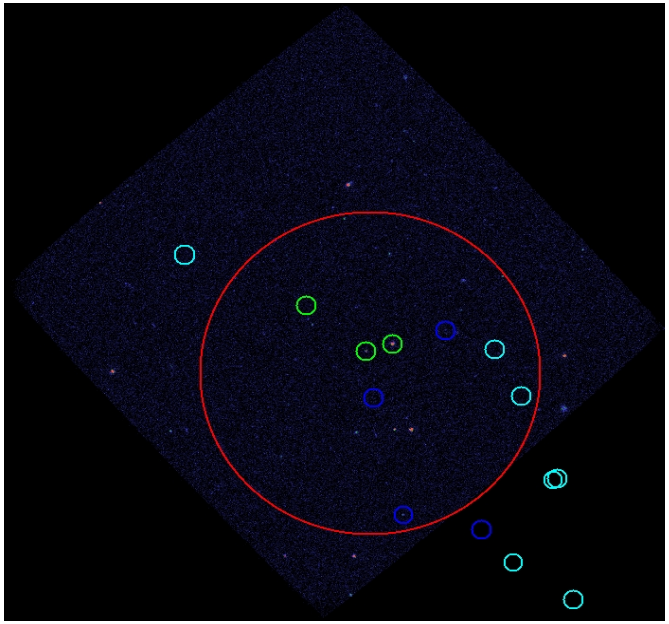
The UVOT observed the source with U, UW1, UM2, UW2 filters.
We obtained UVW1=16.24± 0.03 (extinction corrected)



U image

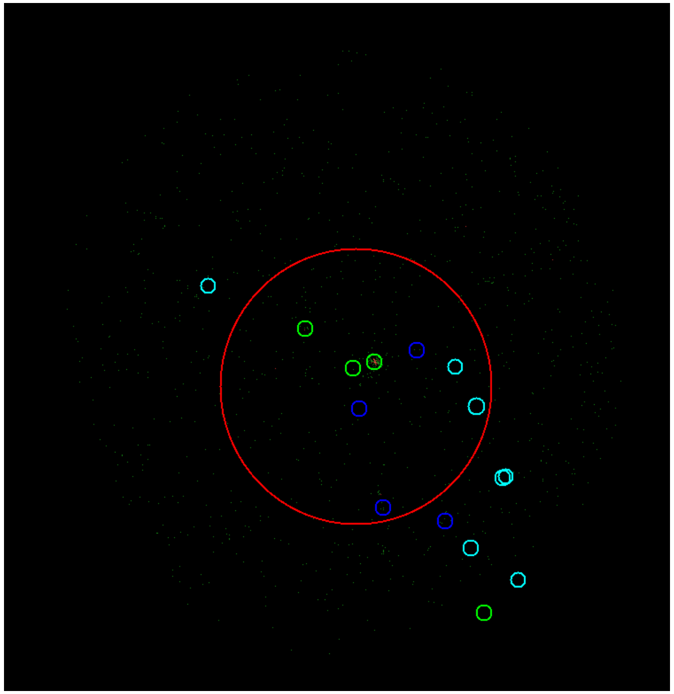


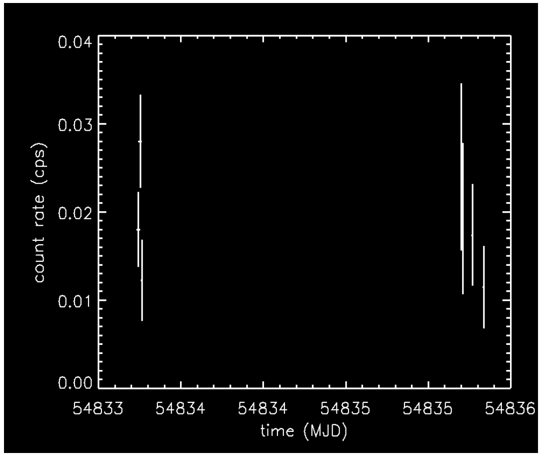
UM2 image

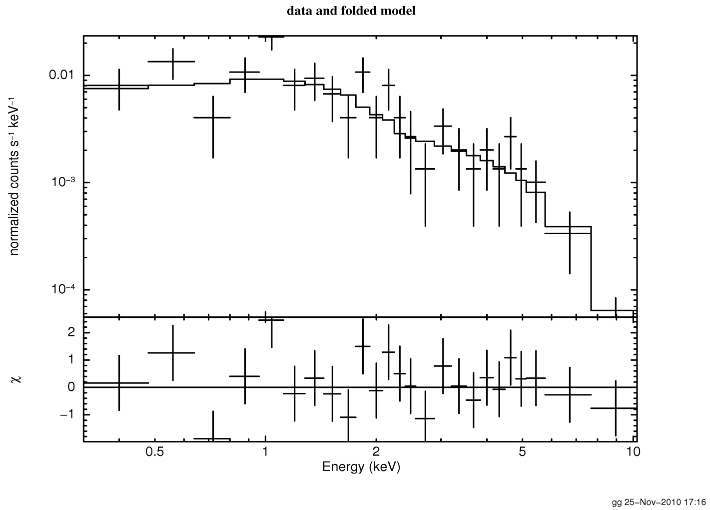


CAMPAIGN B
SWIFT/XRT

Swift/XRT observed the source at 2009 Jan 2 and 2009 Jan 4.
We analysed data collected in photon counting mode, for a total observing time of 4.7 ks.
The mean source count rate is $(2.58 \pm 0.23) \cdot 10^{-2}$ cps.
We fitted the x-ray data with an absorbed power law, fixing the absorption to the intrinsic value of $1.85 \cdot 10^{20}$ cm^{-2} . We obtained a photon index of 1.42 ± 0.25 (90% C.L.).
The extimated flux in the range 2-10 keV is $(8.8 \pm 2.7) \cdot 10^{-13}$ erg/cm^2/s (68% C.L.).

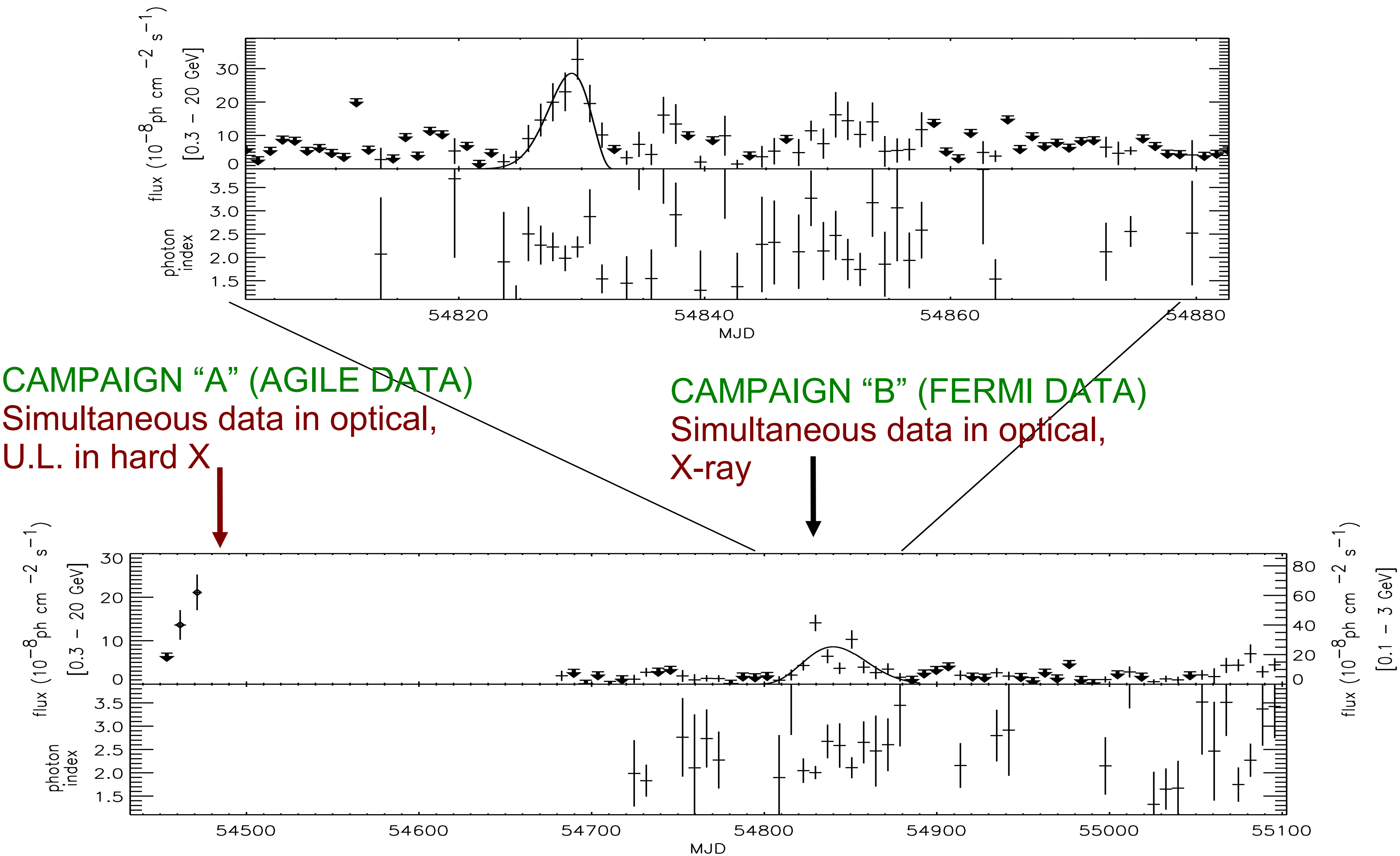




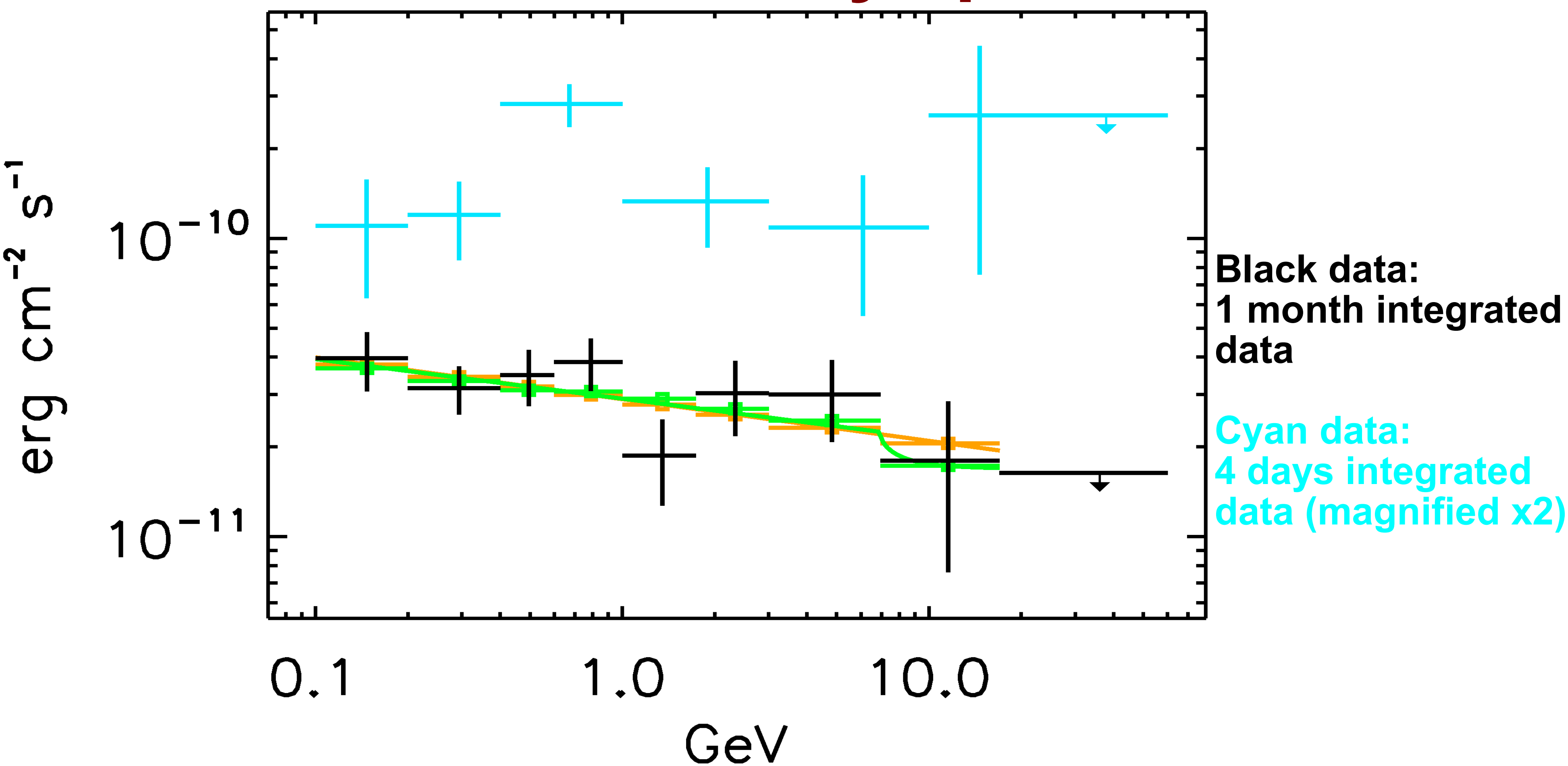


Gamma-ray Light curve
making use of the long term coverage of FERMI

I use two different flux scales in the plots below, one for AGILE/GRID, the other for FERMI-LAT



The Gamma-ray spectrum



No sizeable gamma-gamma absorption

Red line is the fit with a power-law only (chi2=1.1), ph ind=2.13

green line is the result of the fit including gamma-gamma absorption (chi2=1.6)

(τ_{HI} =$1.0^{+4.6}_{-1.0}$ τ_{He} =$^{+0.9}_{-0.0}$ compared with the total opacity= 25 for 3C 454.3 (Poutanen & Stern 2010),

F test (to test the hypothesis of the need of absorption component) gives F=0.15, prob.=85%: absorption is not necessary.

ARCHIVAL DATA

- Sloan digital sky survey: optical photometry (March 2001) and optical spectrum (May 2002)
- UKIDSS-Large Area Survey Near-ir photometry (January 2007)
- GALEX UV photometry (April 2007)

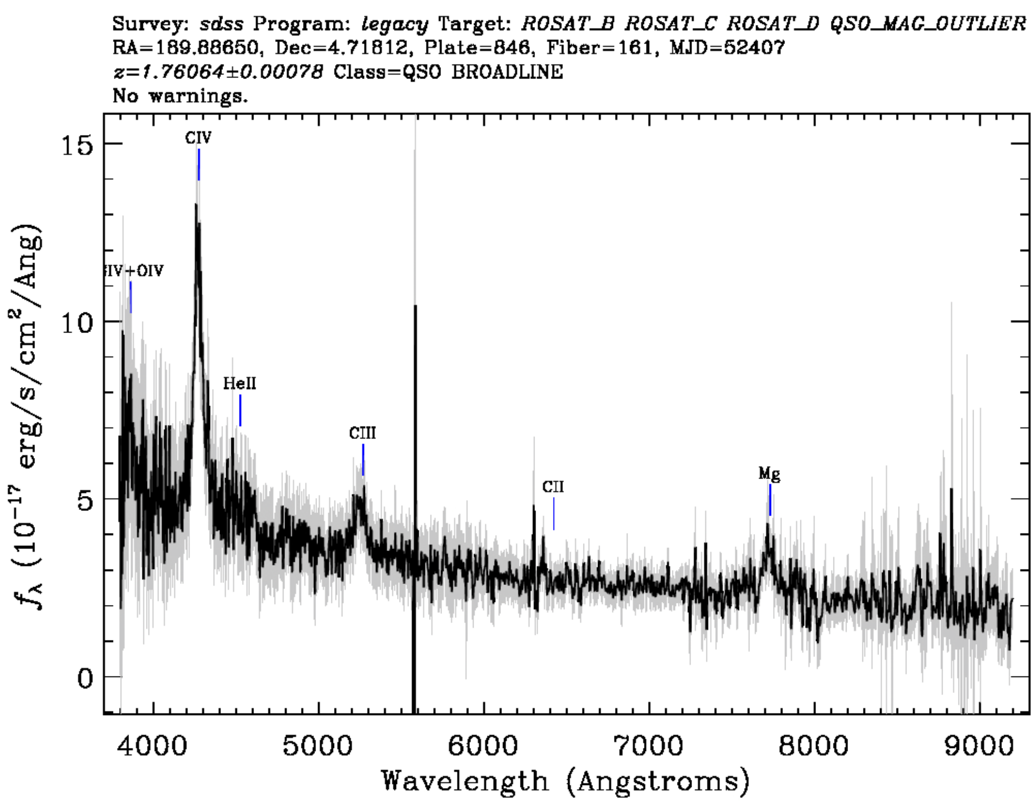
- RADIO data from MOJAVE (2009 January 30),
- PLANCK (January 2010),
- VLA (November 2001),
- Metsahovi (May 2002)

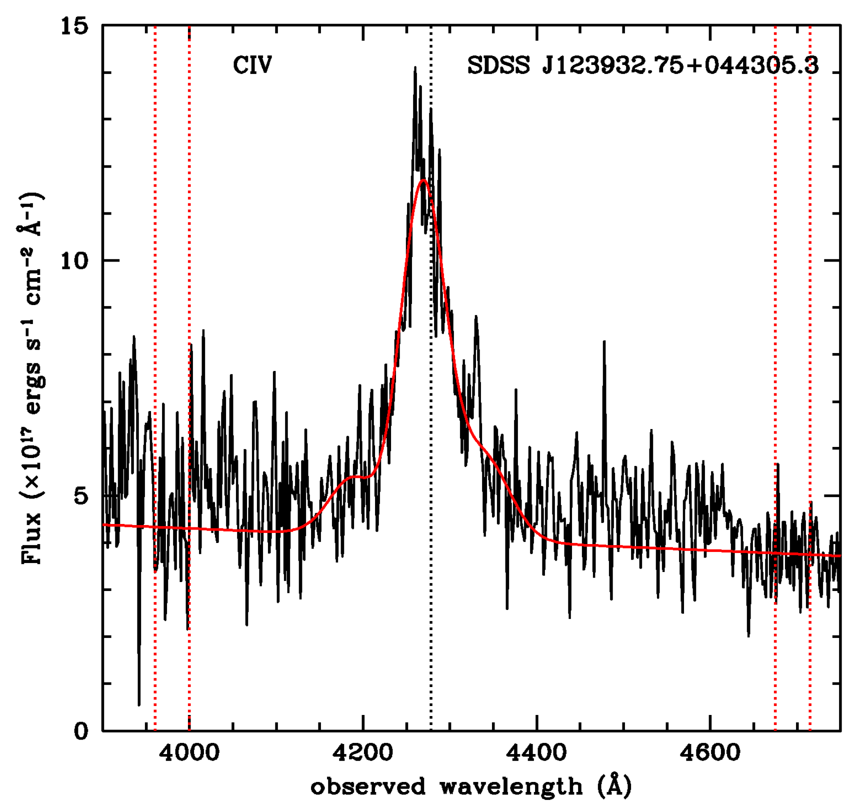
BH mass from C IV broad line width

BH mass can be derived with the single epoch BH mass scaling relationship for C IV derived by Vestergaard and Peterson (2006), and applying the corrections in Assef. et al. (2011). The S/NR of the optical spectrum is low: S/NR~3 for the continuum, and this can bring to systematics (for example unrecognized absorption, see Vestergaard and Peterson 2006, Assef et al. 2011, Denney et al. 2011).

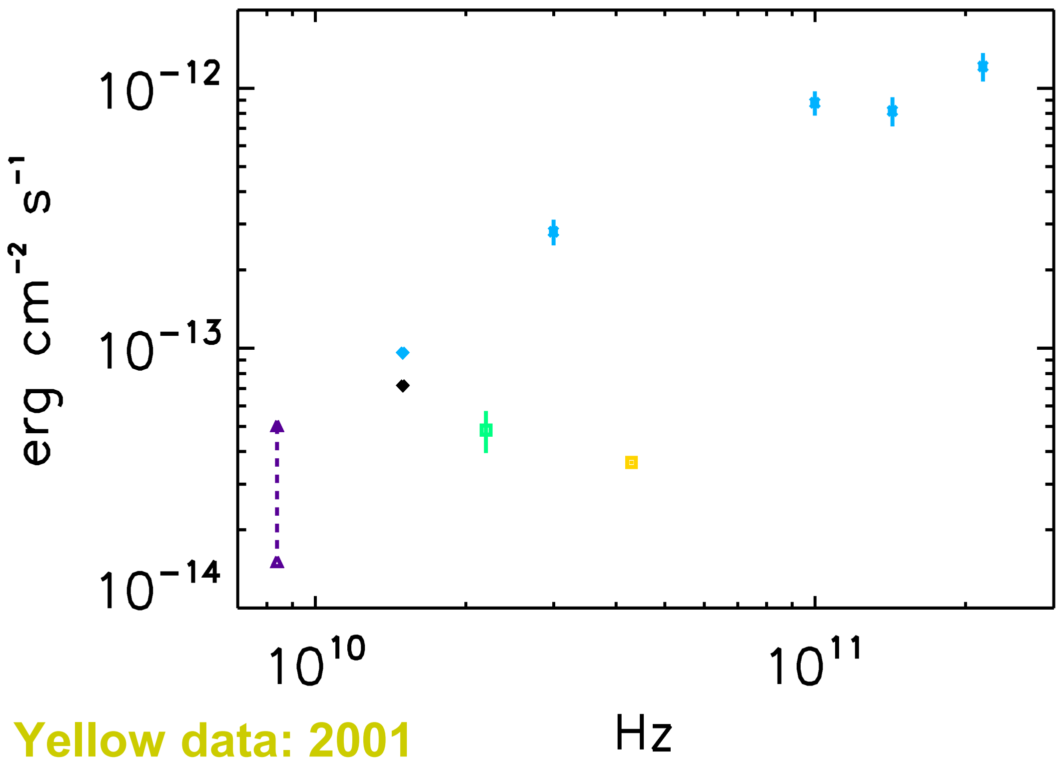
We used two methods to estimate the C IV broad line width: direct line width measurement (**FWHM=2860±910 km/s**) and Gauss-hermite polinomial fit (**FWHM=4710±390 km/s**). The first method is known to underestimate the line width, the other method to overerestimate (Denney et al. 2009).

From the mean of the two estimates we obtain: **$m_{BH}=(5.3^{+4.4}_{-3.3})*10^8$ solar masses**





Disk luminosity and BH mass from archival SDSS + GALEX photometry



Yellow data: 2001
(March optical, November radio)

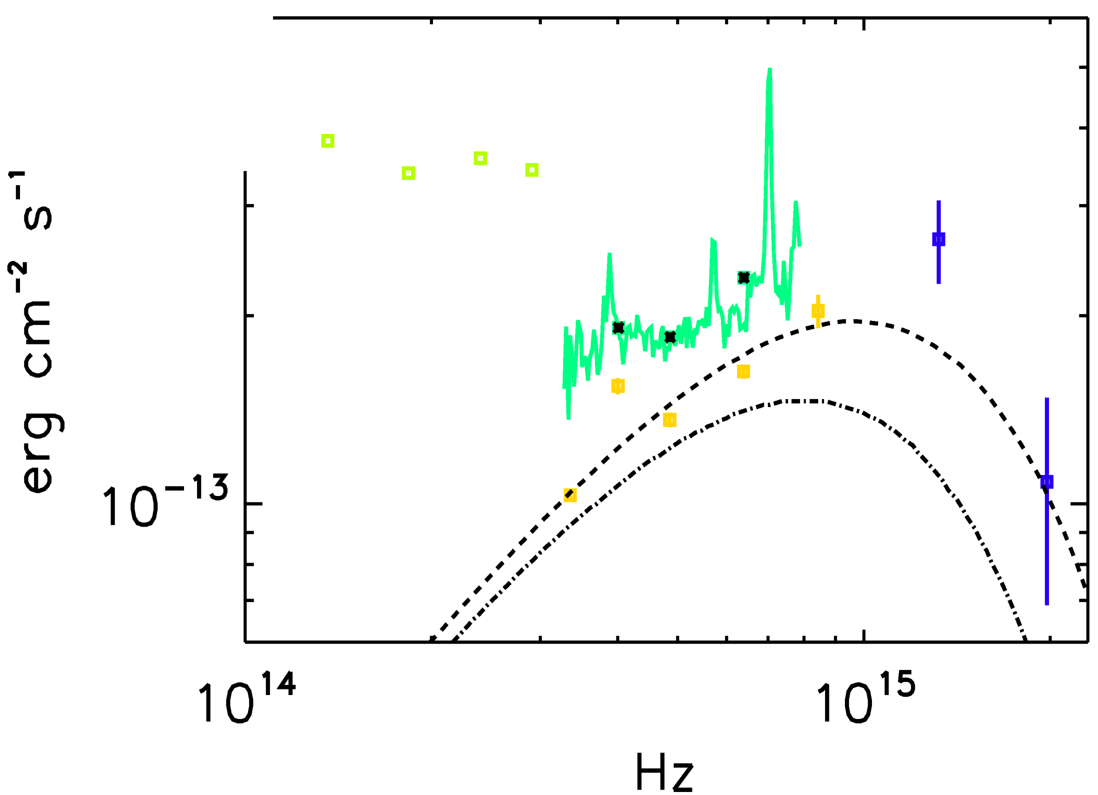
Green data: 2002 May
(simultaneous optical – radio observations)

Light green: 2007 January
near-ir photometry

Blu data: Optical (2007 April)

Black data: radio (January 2009)

Cyan data: radio (2010 January)



Disk luminosity and BH mass from archival SDSS + GALEX photometry

We assumed these SDSS+GALEX data to be obtained during a low activity Period, dominated by a Shakura-Sunyaev accretion disk (Shakura-Sunyaev 1974) That we modelled with the prescriptions in Ghisellini & Tavecchio (2009), with inner Radius of 3 r_s and outer radius of 500 r_s.

We obtained:
a disk luminosity of

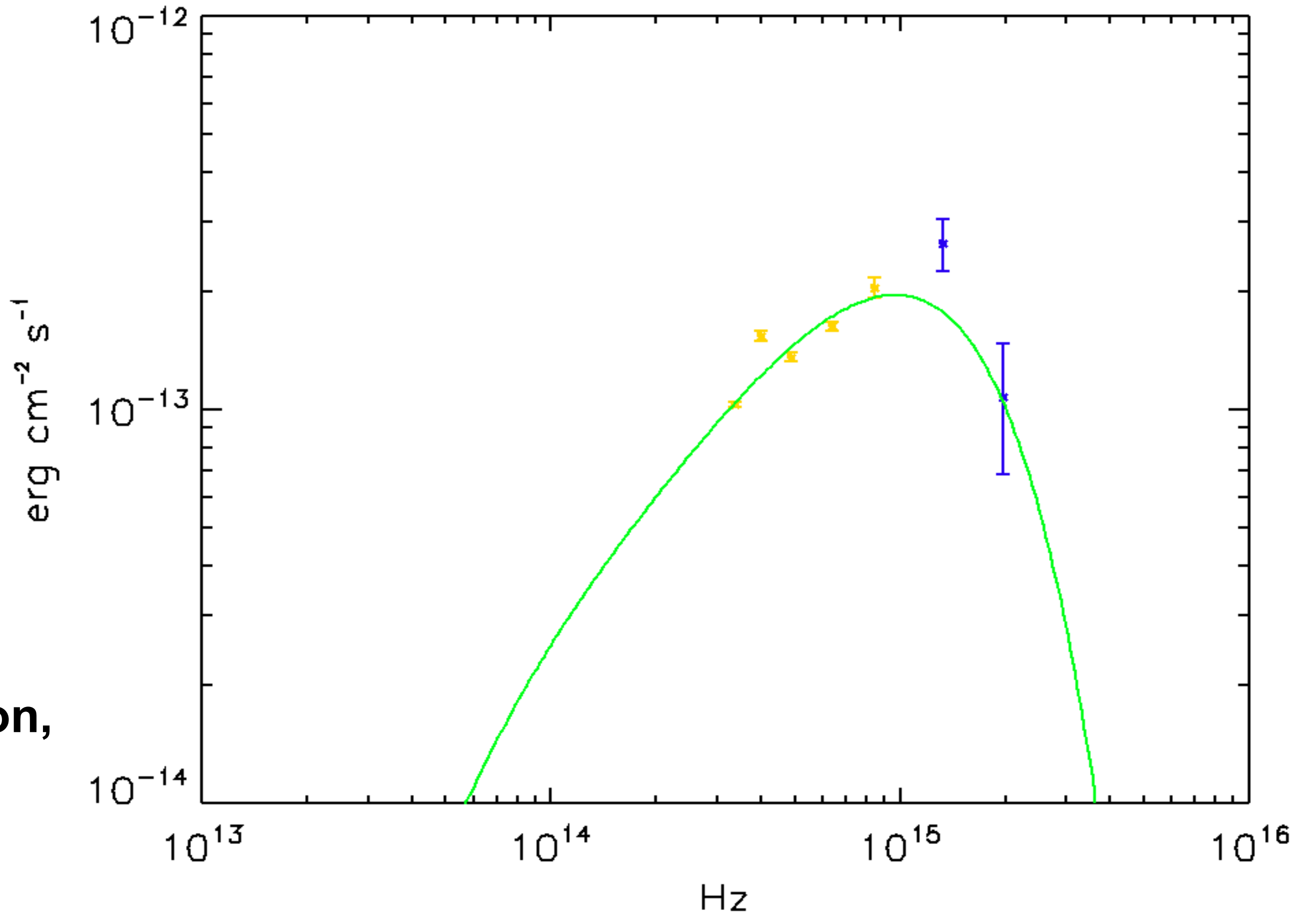
$\sim 8.9 \times 10^{45}$ erg/s,

$r_s \sim 2.4 \times 10^{14}$ cm

a max emitting Temperature of

$\sim 5.4 \times 10^{4}$ K

$m_{BH} \sim 8 \times 10^{8}$ solar masses
(in agreement with the virial determination).



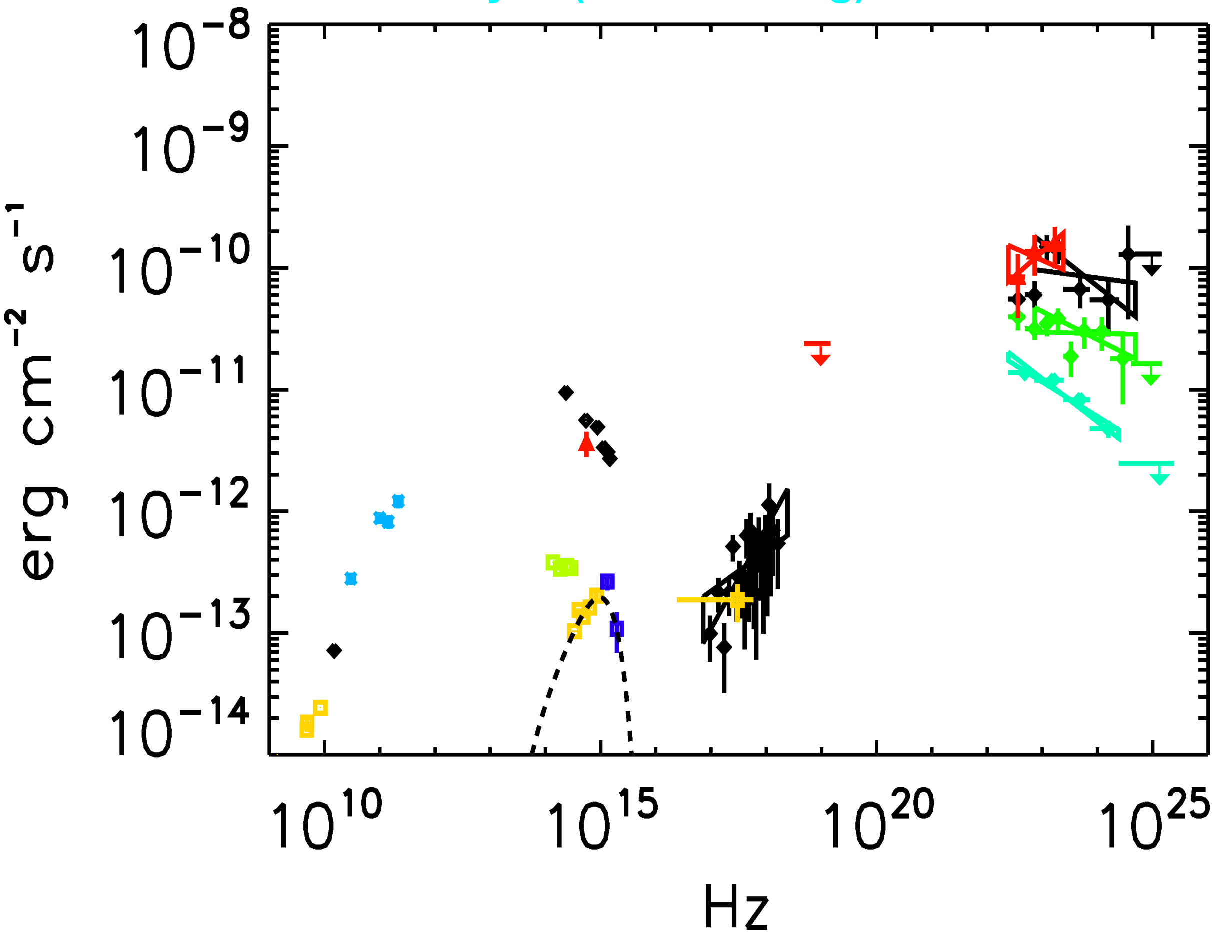
The *i* filter SDSS photometry Includes the Mg II line emission,

The NUV GALEX photometry Includes the Lyα

Multiepoch SED

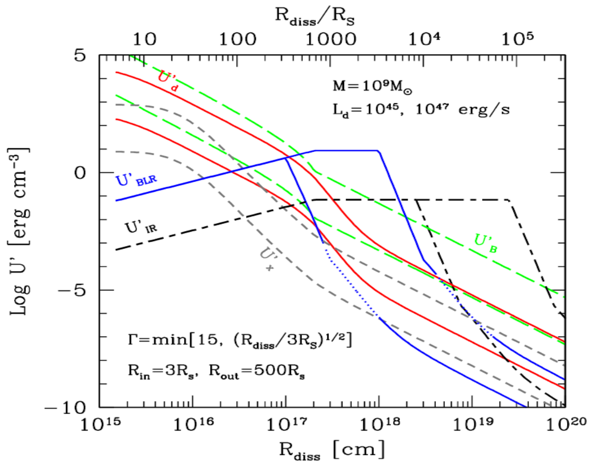
AGILE/GRID and simultaneous data in red

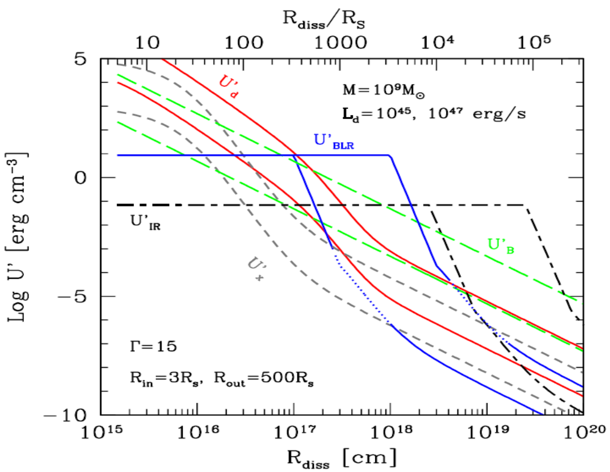
FERMI-LAT data
(4-day integration around the flare)
and simultanous data in black
Fermi-LAT data in green
(30-day integration around the flare)
Fermi-LAT data in cyan (2FGL catalog)



For the EC contribution we adopted the parametrization in Ghisellini & Tavecchio 2009

And we assumed the disk luminosity during the flares of the same amount as measured during low states of 2001

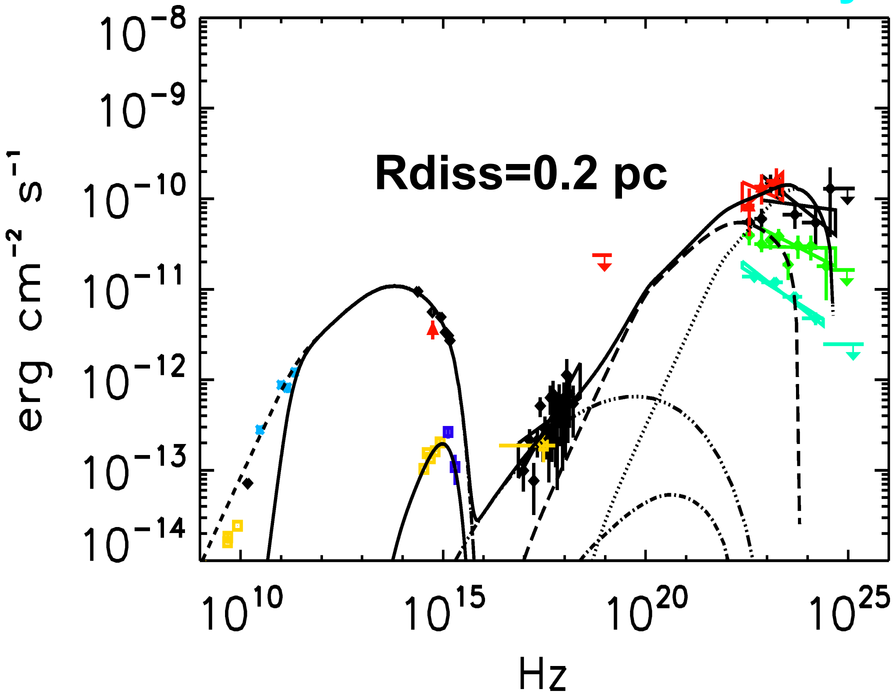


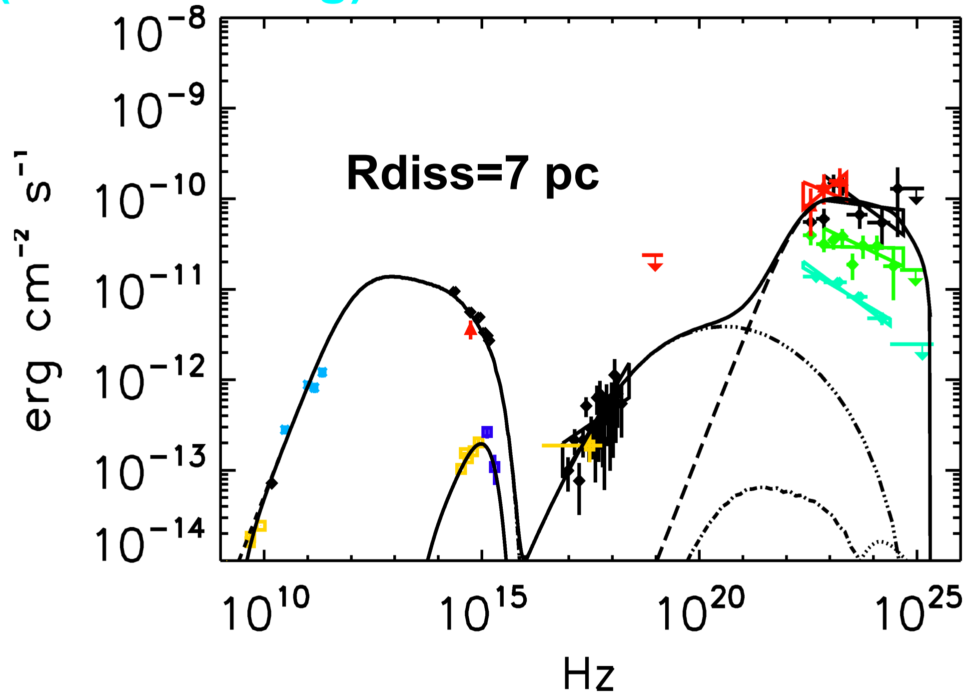


Multiepoch SED

AGILE/GRID and simultaneous data in red

FERMI-LAT data (4-day integration around the flare)
and simultanous data in black
Fermi-LAT data in green (30-day integration around the flare)
Fermi-LAT data in cyan (2FGL catalog)





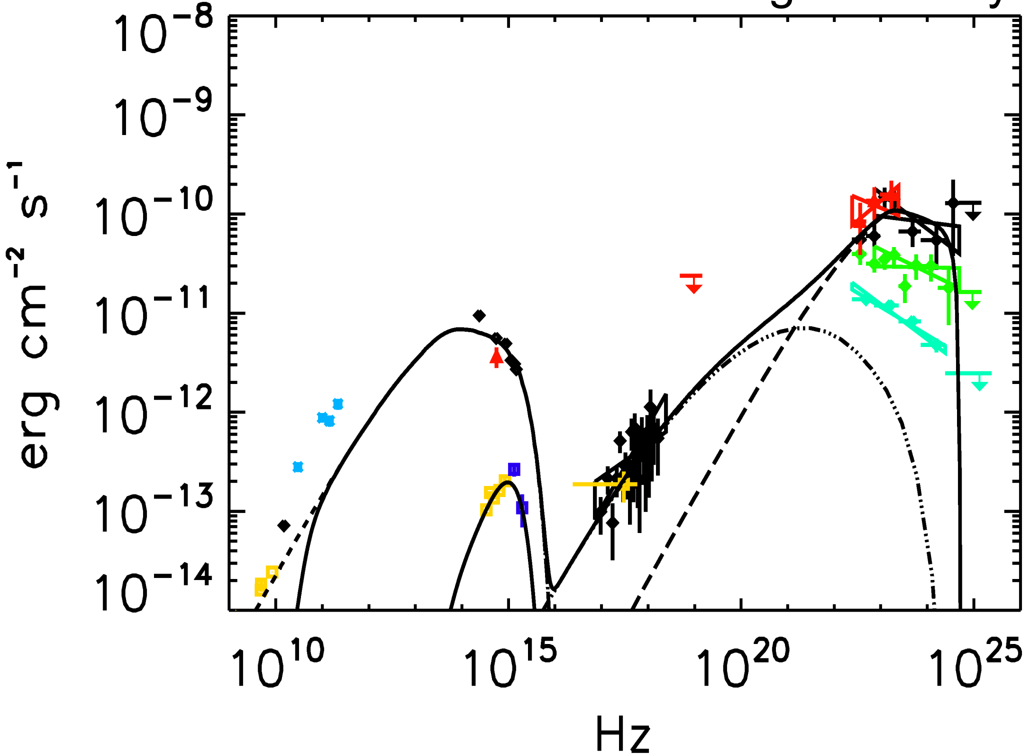
Dissipation region at 0.2 pc from the SMBH
(Just outside the BLR)
Rblob=6.7*10^{16}cm
B=0.6 Gauss

Dissipation region at 7 pc from the SMBH
Rblob=2*10^{18}cm
B=1*10^{-2} Gauss

This model gives a satisfactory gamma-ray spectral shape, but the expected variability is ~10^2 days

Multiepoch SED

Relaxing the relation between blob radius and dissipation region (as in Tavecchio 2011), and using a blob radius suitable for the observed gamma-ray variability



Model is for a dissipation region at 5 pc from the central BH, a blob radius of $1*10^{17}$ cm, B=$7*10^{-2}$ Gauss

R_{blob}=0.0067*R_{diss} in agreement within a factor 2 with Bromberg and Levinson 2009 ($R_{blob}=10^{-2.5}$ R_{diss})

inverting $R_{diss}=2.5*L_{jet,46}(R_{BLR}/0.1\ pc)^{-1}$ and using R_{diss} =5 pc, we obtain $L_{jet}=3.5*10^{46}$ erg/s.

We need to assume that the p/e number ratio is ~0.1 to accomplish such a luminosity.

$R_{diss}(pc)$	6.8	0.22	4.8
Blob radius (cm)	2.1×10^{18} *	6.7×10^{16} *	1×10^{17}
m_{BH} ($m_{\odot}$)		5.3×10^{8}	
L_d (erg/s)		8.8×10^{45}	
R_{BLR} (cm)		3.0×10^{17}	
$R_{Torus}(cm)$		7.4×10^{18}	
f_{BLR}		0.1	
f_{torus}		0.3	
ϵ_{accr}		0.1	

Γ_{bulk}	20	20	20
angle of view (deg)	2	2	2
γ_{min}	1	1	1
γ_{max}	3.4×10^{4}	3.9×10^{3}	1.3×10^{4}
γ_{break}	1×10^{3}	0.95×10^{3}	1×10^{3}
density at γ_{break} (cm^{-3})	1.5×10^{-4}	3.0×10^{-2}	9.6×10^{-3}
s_1	0.5	1.1	1.3
s_2	3.3	3.1	2.5
B (Gauss)	1.1×10^{-2}	6.1×10^{-1}	7.6×10^{-2}

$\gamma_{cooling}$	1.1×10^4	60	2.4×10^3
electron power (erg/s)	4.5×10^{46}	2.2×10^{45}	1.1×10^{46}
magnetic power (erg/s)	7.9×10^{44}	2.5×10^{45}	8.6×10^{43}
proton power(**) (erg/s)	1.6×10^{47}	1.1×10^{47}	3.0×10^{47}
radiated power (erg/s)	2.5×10^{45}	3.1×10^{45}	2.1×10^{45}

**) Assuming p/e=1

Results for GB6 J1239+0443

- The INTEGRAL/OMC detection of GB6 1239+0443 in optical high state further confirms the association of GB6 1239+0443 with the gamma-ray emitting source
- The low optical state in March 2001 and April 2007 allowed the observation of the direct disk emission. We derived the disk luminosity (**~8.9*10^{45} erg/s,**) and from the disk emission we derived the BH mass (**8*10^{8} solar masses**)
- We derived the BH mass from the CIV line width [Vestergaard 2006], [Assef 2011] (**$m_{BH}=(5.3^{+4.4}_{-3.3})*10^{8}$ solar masses**)
- The 30 days integrated gamma-ray spectrum lacks absorption features as predicted by [Tavecchio & Mazin 2009] at 10-20 GeV/(1+z) and [Poutanen & Stern2010] at 5 GeV/(1+z)
- We assume a blob dissipating beyond the BLR. Making use of the parametrization of the external fields energy denisties in Ghisellini & Tavecchio (2009) we obtained two canonical solutions of the SED modeling: at **dist ~0.2 pc** and at dist **~7 pc** from the central BH.
- Neither the lack of absorption features nor the parametrization of Ghisellini & Tavecchio (2009) allow for blazar-zone closer to the SMBH.
- Relaxing the relation Rblob =0.1Rdiss, and asking for a Rblob such that the variability time scale is mantained, **we almost reproduce the Bromberg & Levinson (2009) blob radius to distance ratio**. If we assume that model correct, we have to require **p/e number ratio =0.1**. (To satisfy $R_{diss}=L_{jet,46*}(0.1\ pc/R_{BLR})$ pc, and with the knowledge of R_{diss}, we obtain: **$L_{jet}=3.5*10^{46}$ erg/s**)

PKS 1424-41

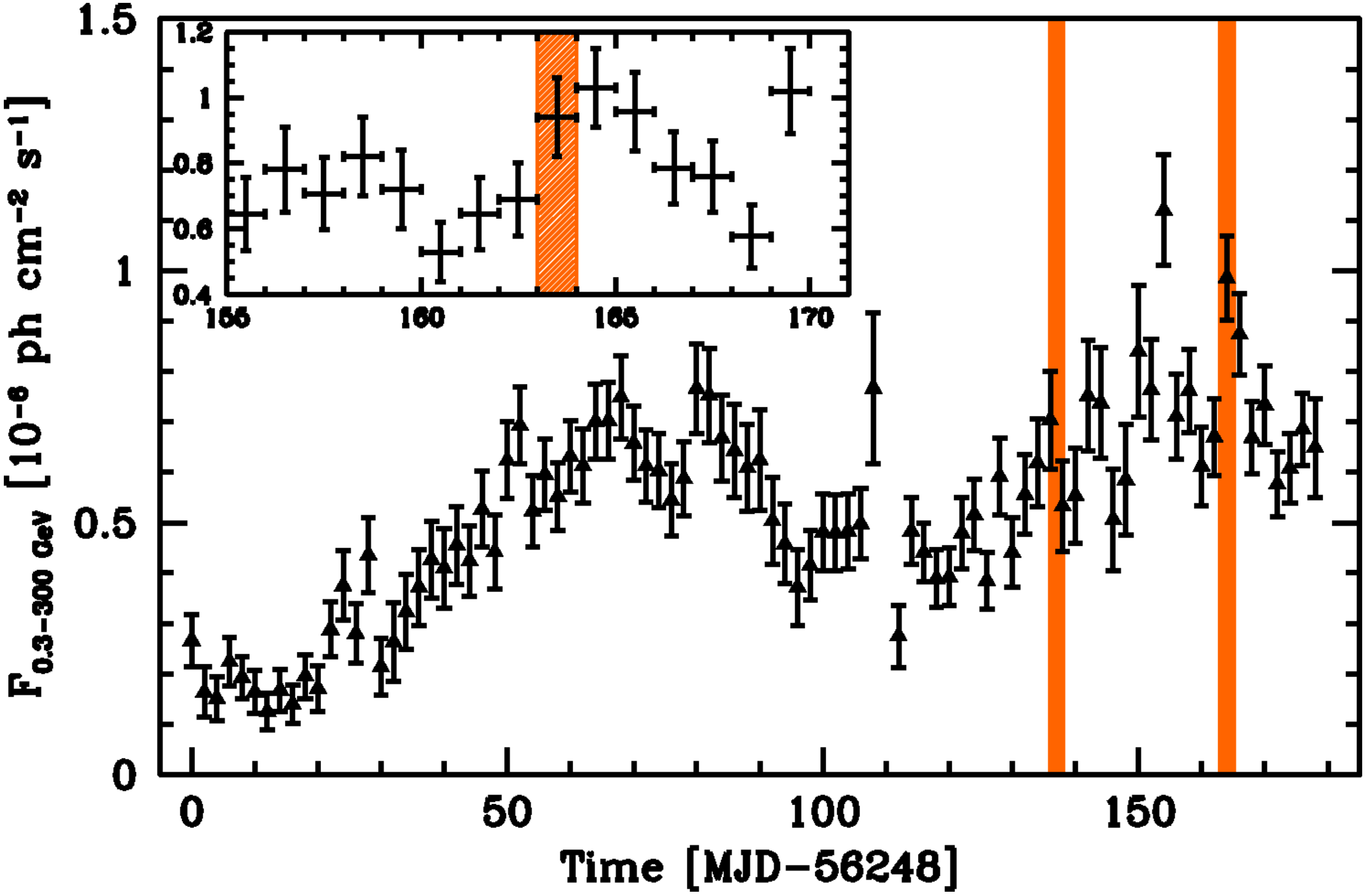
z=1.52

(Tavecchio, Pacciani, et al,
MNRAS submitted, 2013arXiv1306.0734)

from the flaring period of april – may 2013

PKS 1424-41

z=1.52

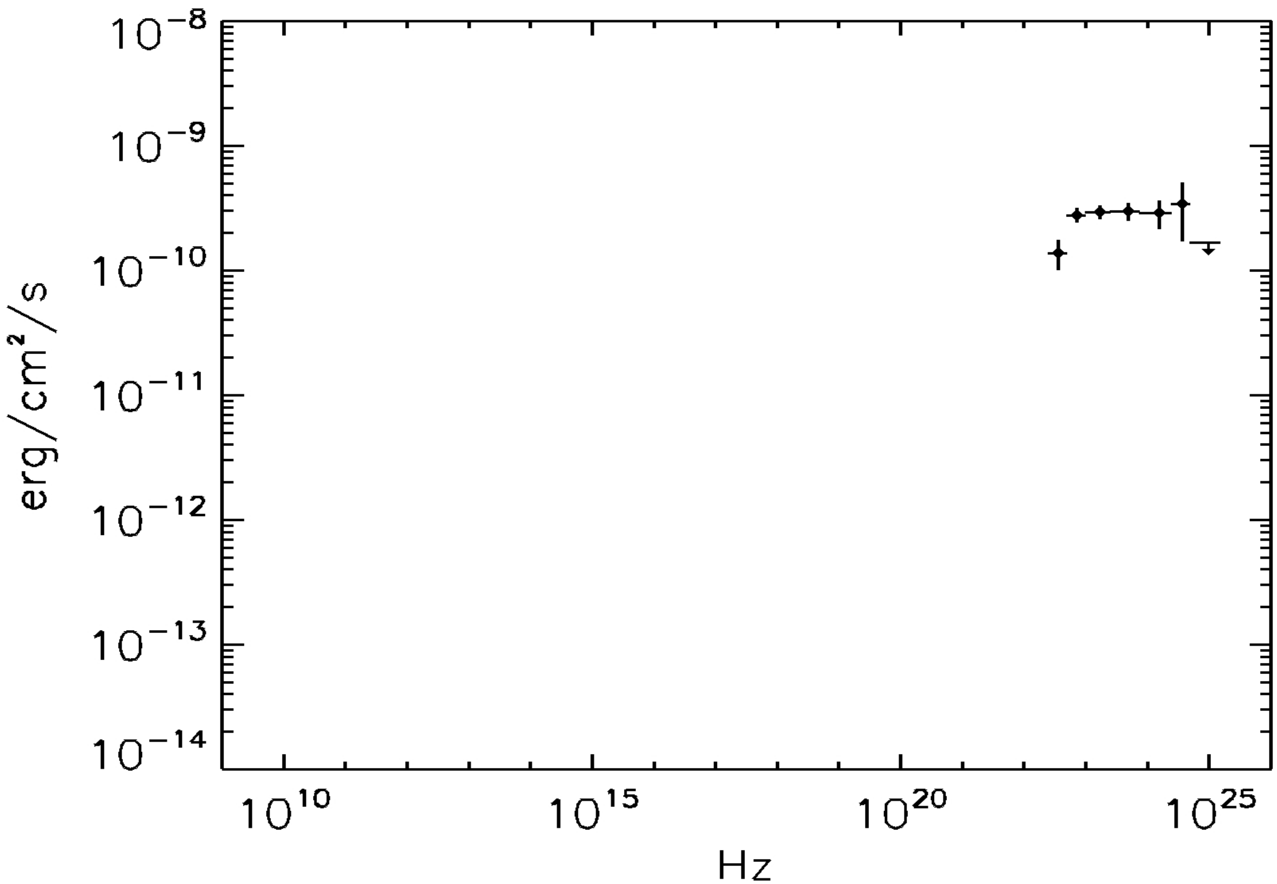


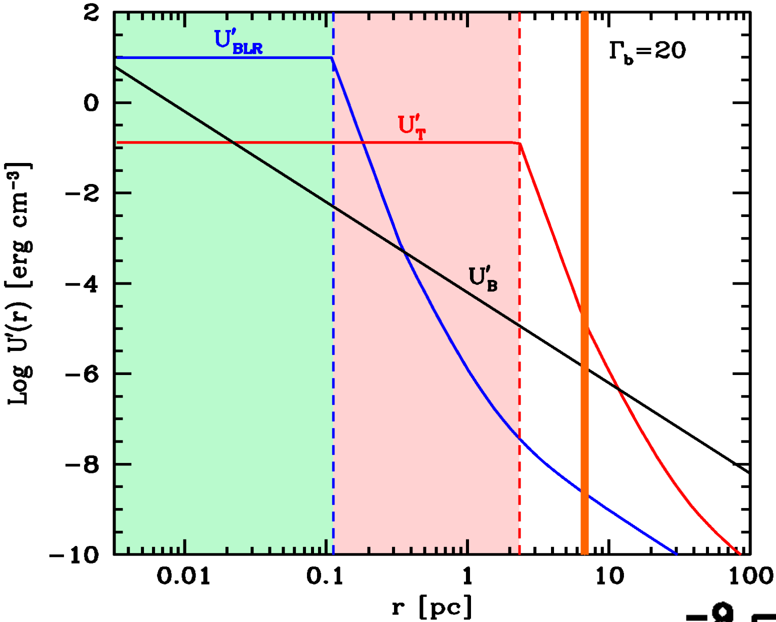
PKS 1424-41

From the broad Mg II line:
$L_{Mg\ II}$=5.4*10^{43} erg/s (Stickel 89)
we derived the BLR luminosity (Celotti 1997)
and in turn the disk luminosity
(we assumed a BLR/disk luminosity ratio 0.1)

L_{disk}=1*10^{46} erg/s

With this L_{disk},
the optical depth for
the Lyα is τ=7,
and
the high energy radiation
above 25 GeV/(1+z)
will be supressed by
a factor 10^3
if emitted inside the BLR

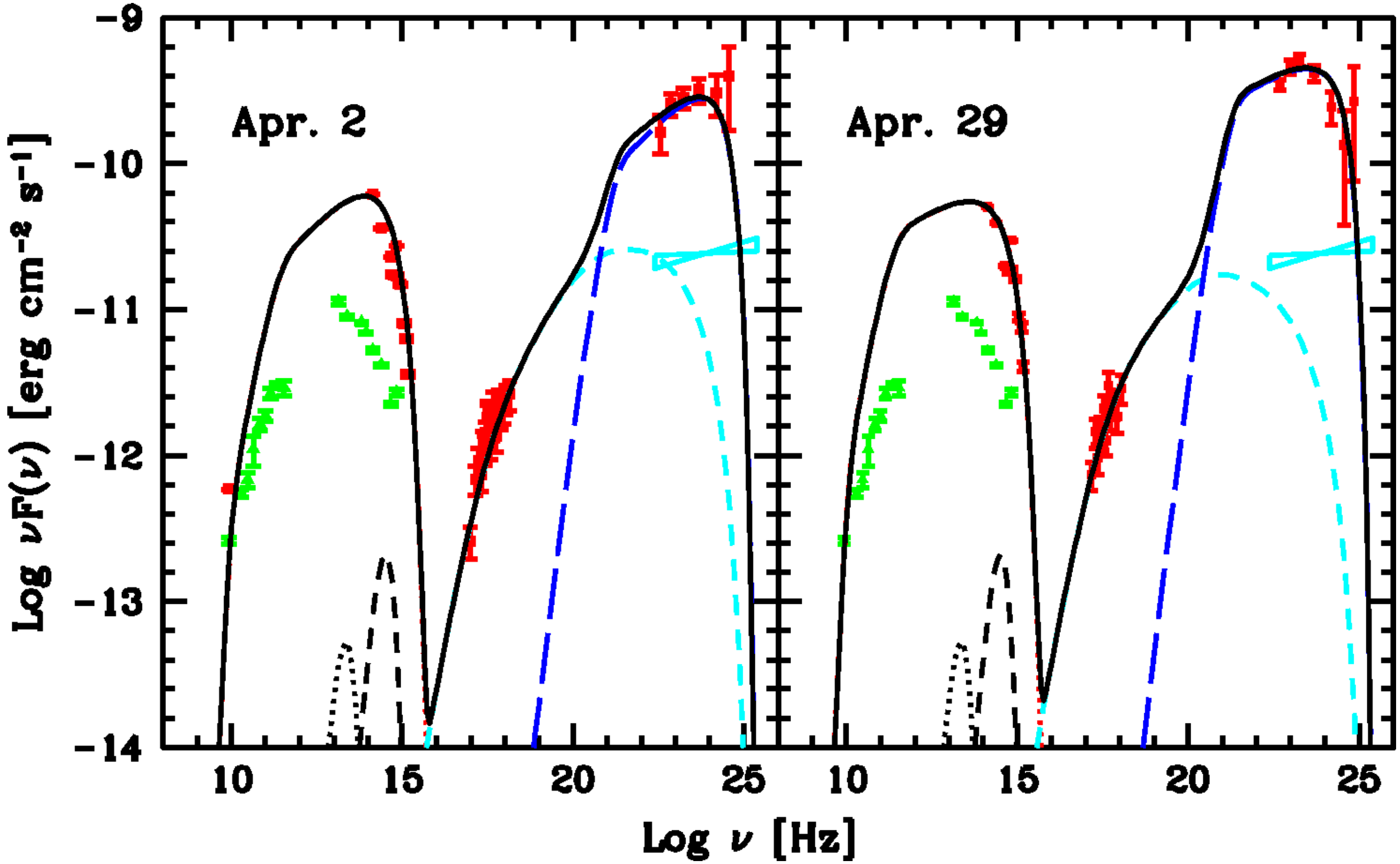




PKS 1424-41

optical data from SMARTS

B =6*10^{-3} G
Γ=20
Dist = 7 pc
R=1 pc
Variability time Scale 30 d, comparable with long term modulation of the light curve



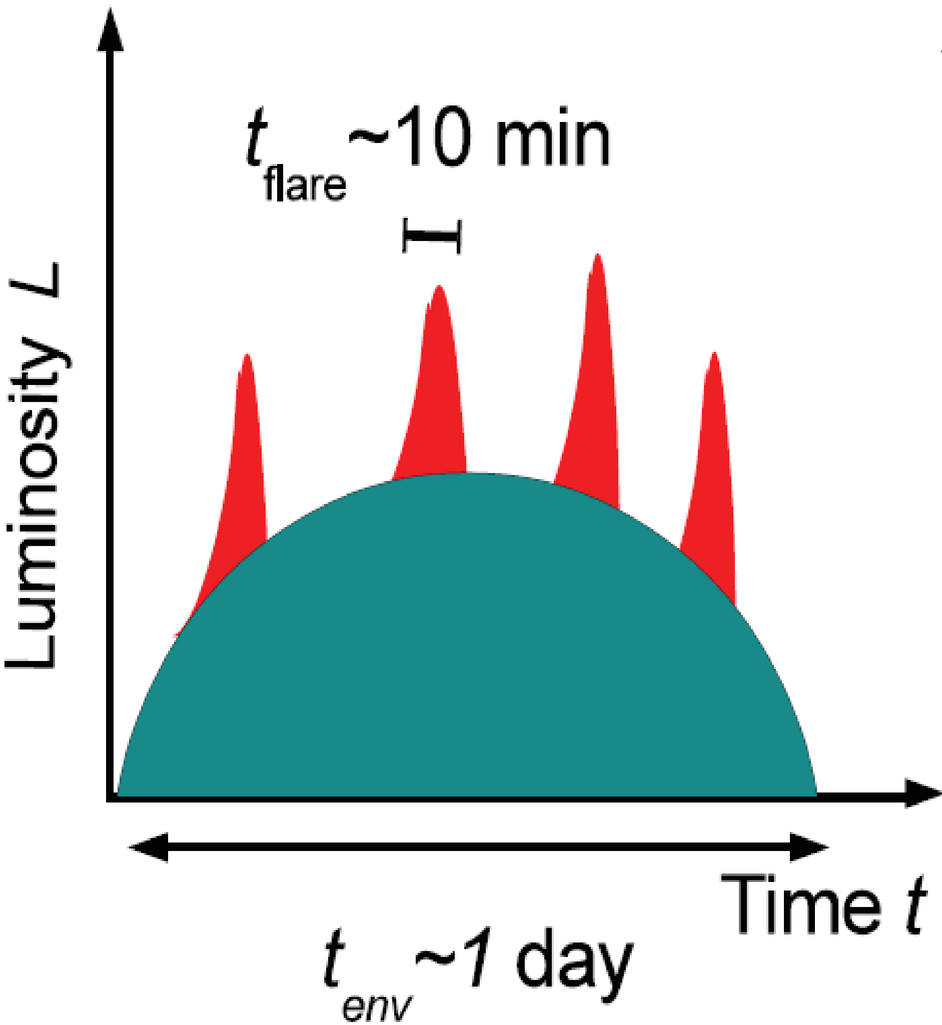


Figure 2. A sketch of the envelope-flare structure of the emission from a reconnection layer. The envelope duration corresponds to that of the reconnection event: $t_{env} = l'/\Gamma_j \epsilon c$. Monster plasmoids power fast flares which show exponential rise and last for $t_{flare} = 0.1 l'/\delta_p c$. For an envelope of $\sim$1 d blazar flaring, the model predicts that monster plasmoids result in $\sim$10-min flares.

Giannios 2013

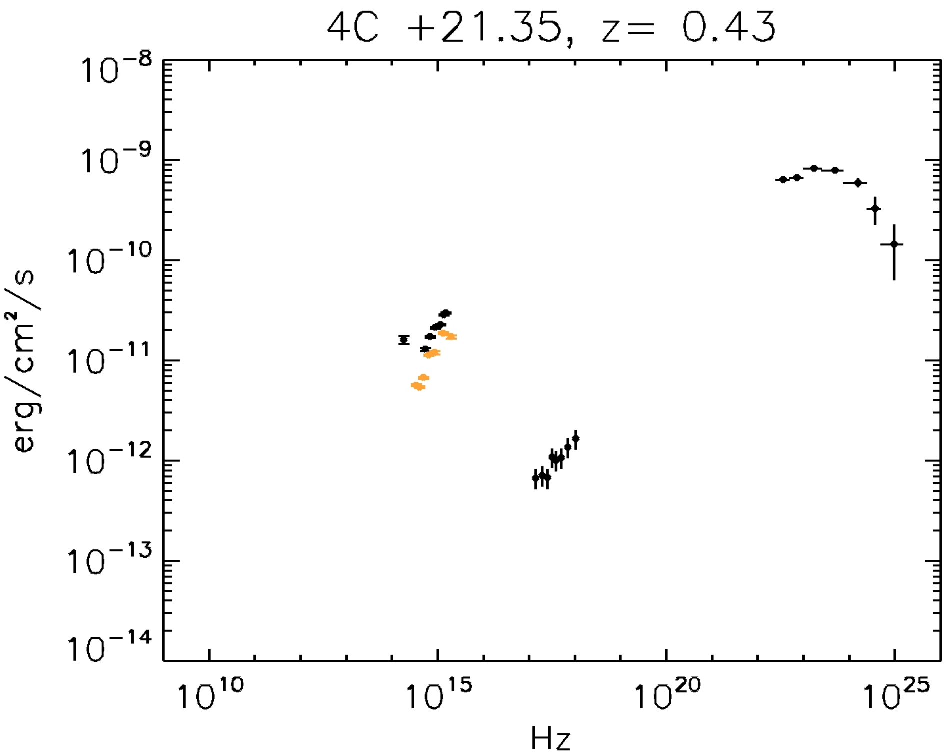
Variability time scale from the SED modeling is ~30 d, comparable with long term modulation of the light curve, but we observe also daily variability.

Recent scenario for magnetic reconnections proposed for strongly magnetized jets (Giannios 2013) includes an envelope emission (lasting ~1 day) powered by plasmoids, together with fast flares (lasting ~10 min) generated by grown “monster plasmoids”.

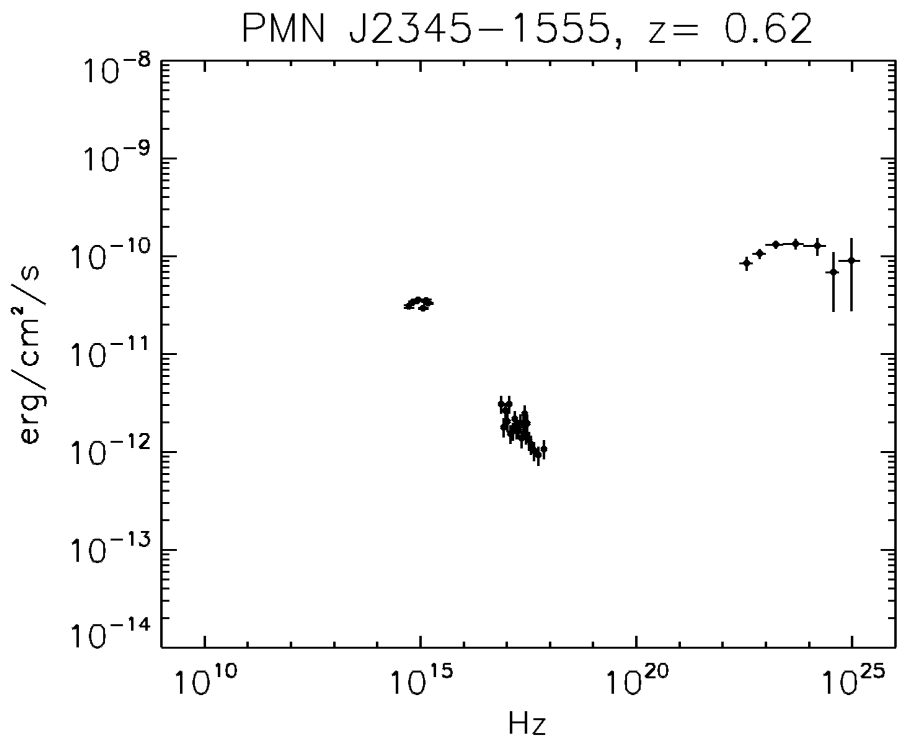
In low magnetized plasma (such as at several parsec), reconnection time scales are longer and longer flares (days to weeks) could arise (Giannios 2013).

“Monster plasmoids” contain energetic particles freshly injected by the reconnection event (Uzdensky et al. 2010)

And other already studied sources:



Aleksic 2011,
Tavecchio 2011
dist > 0.1 pc



Ghisellini 2013
dist=0.1 pc

and 3C 279 (Abdo 2010),
And PKS 1510-08 (Nalewajko 2012)

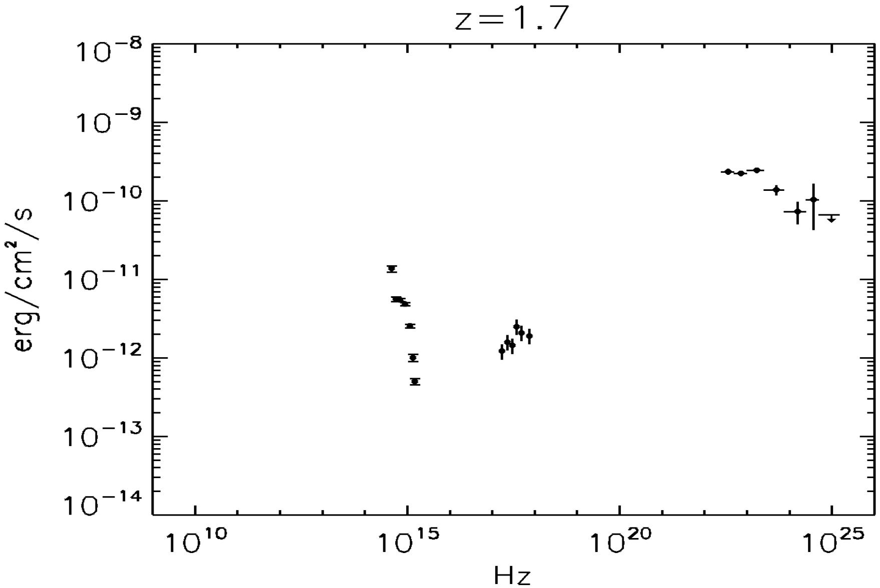
And other candidates during flares

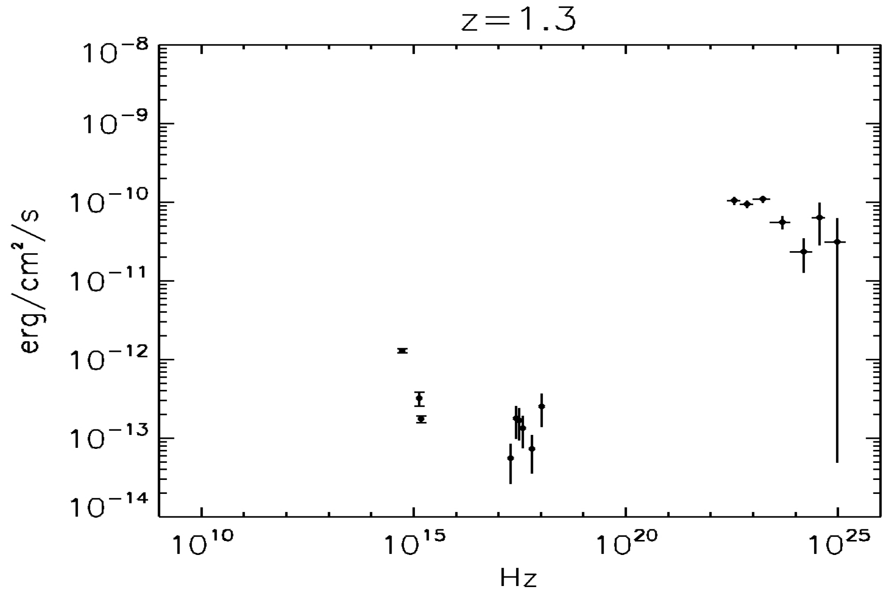
(work in progress)

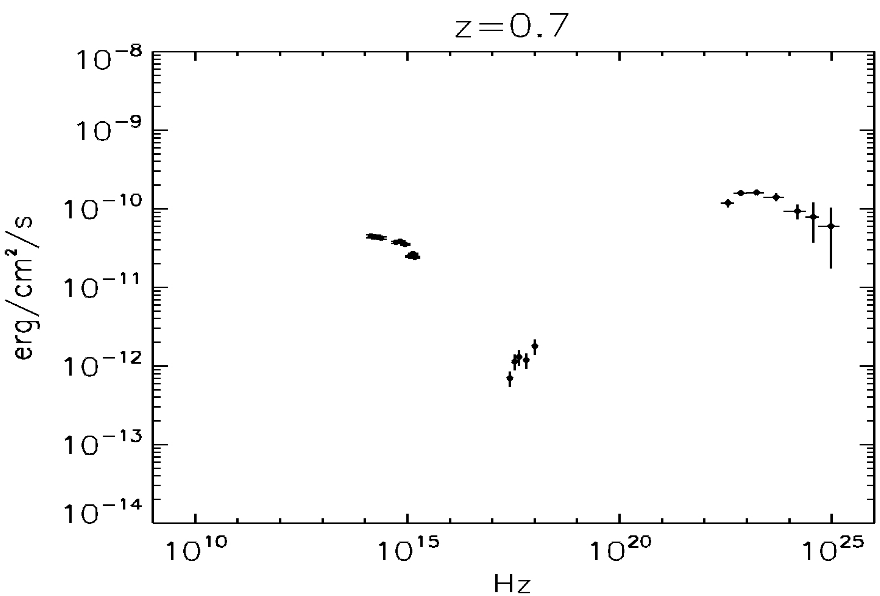
optical data from SMARTS, CANICA, Swift-uvot

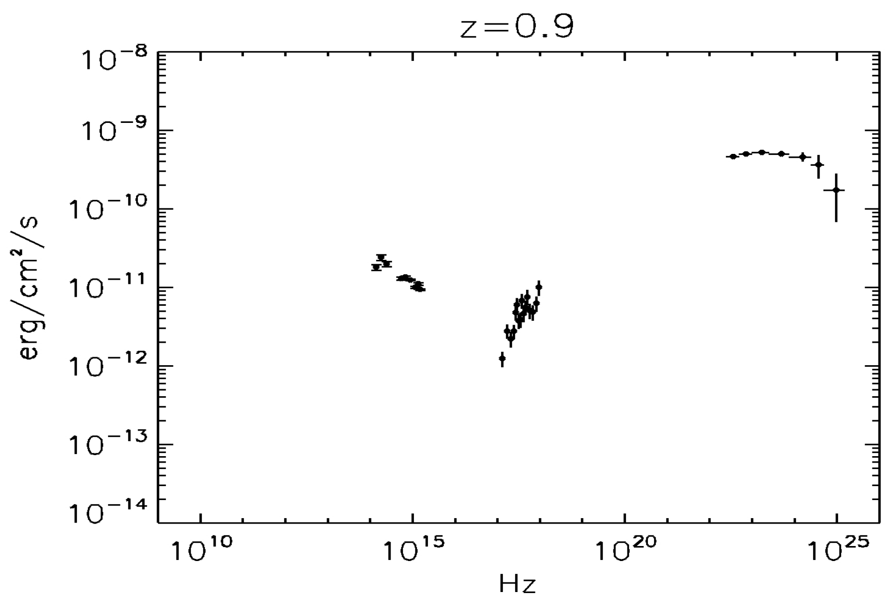
x-ray data from Swift-xrt

And other candidates during flares (1)

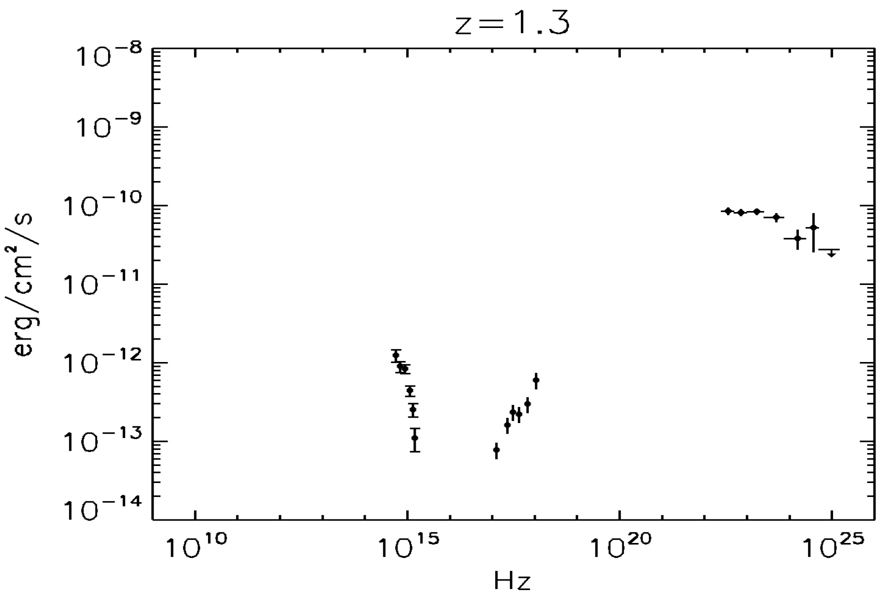


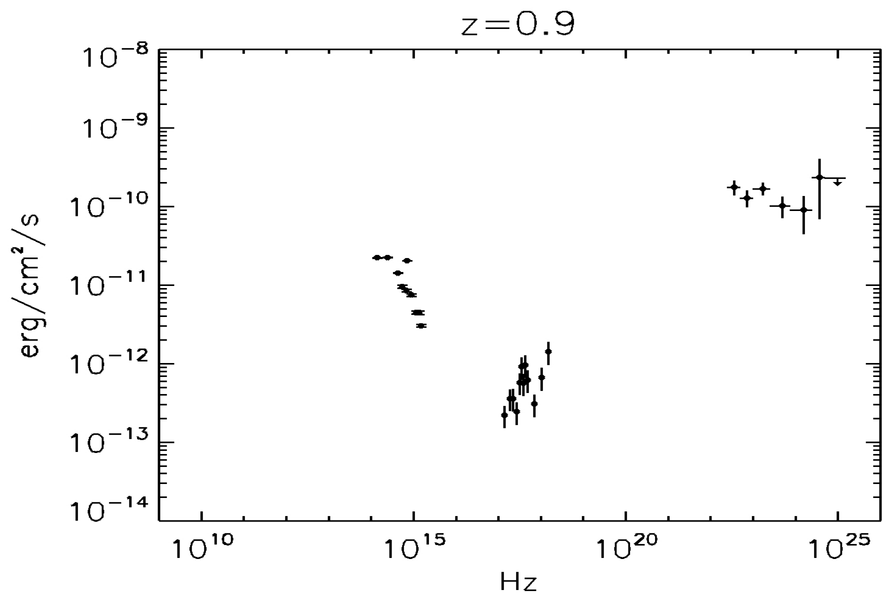


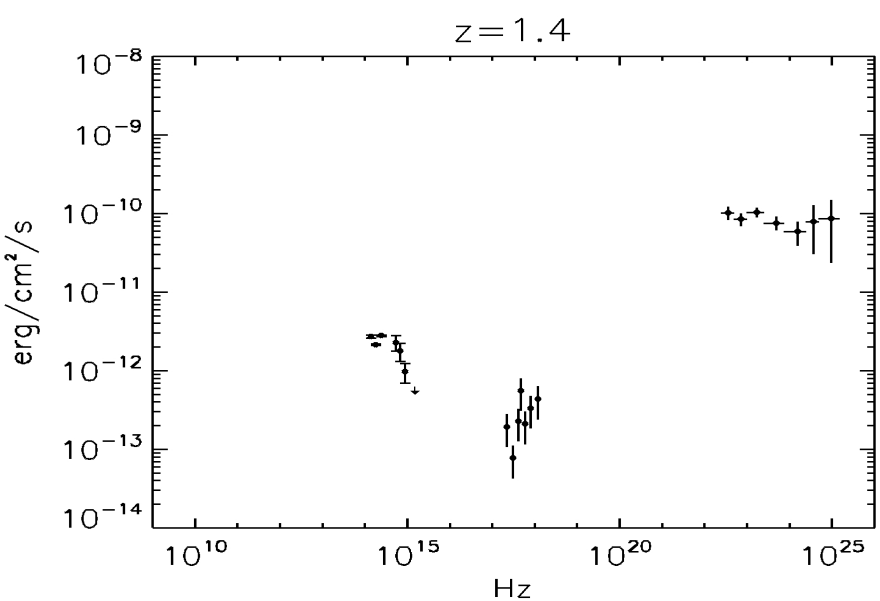


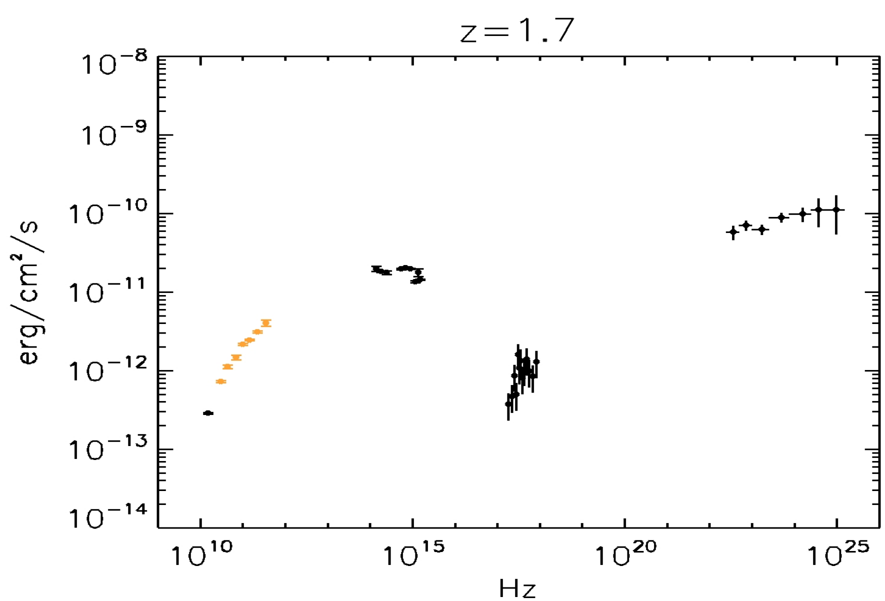


And other candidates during flares (2)

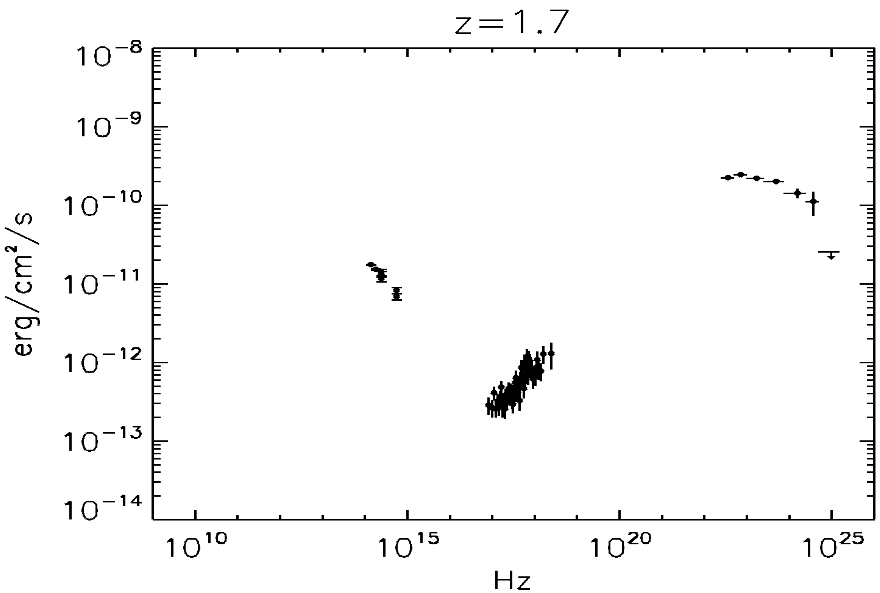


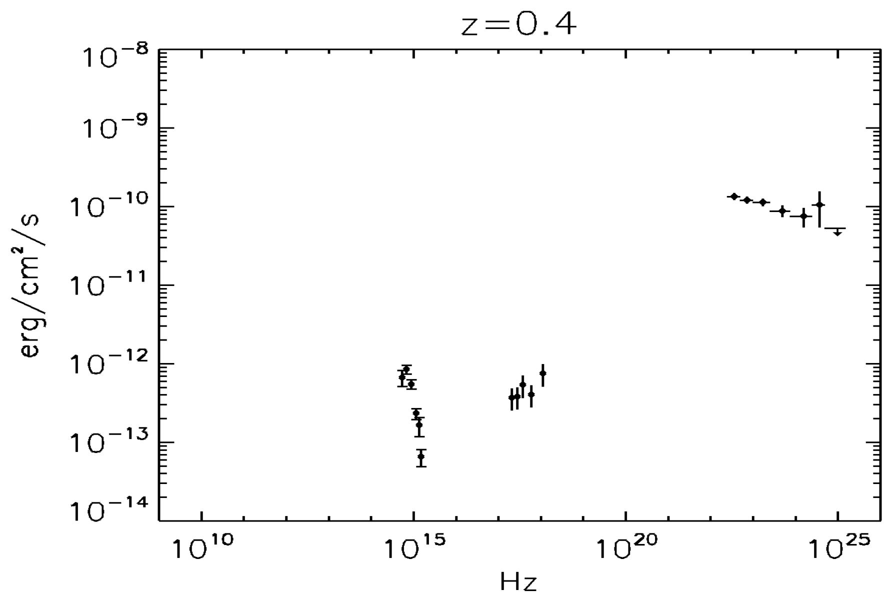


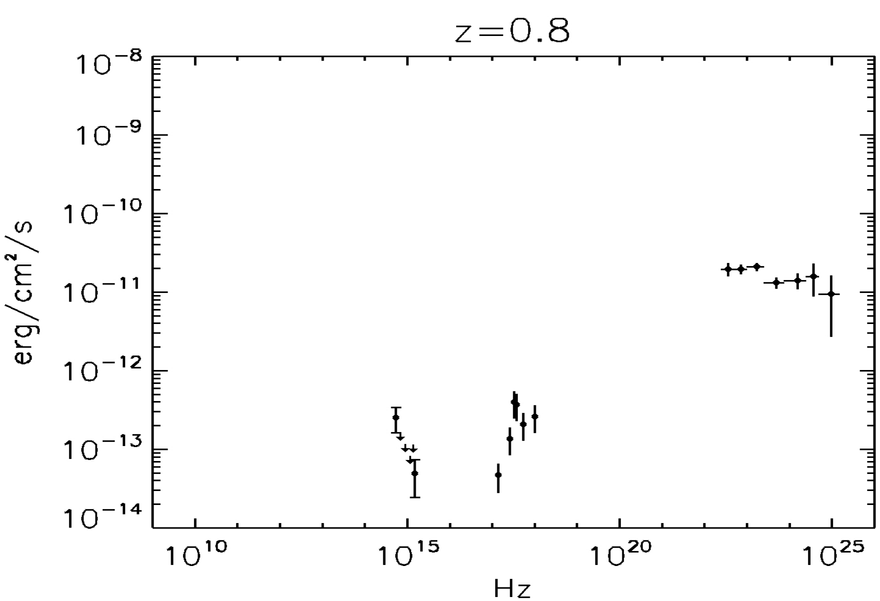


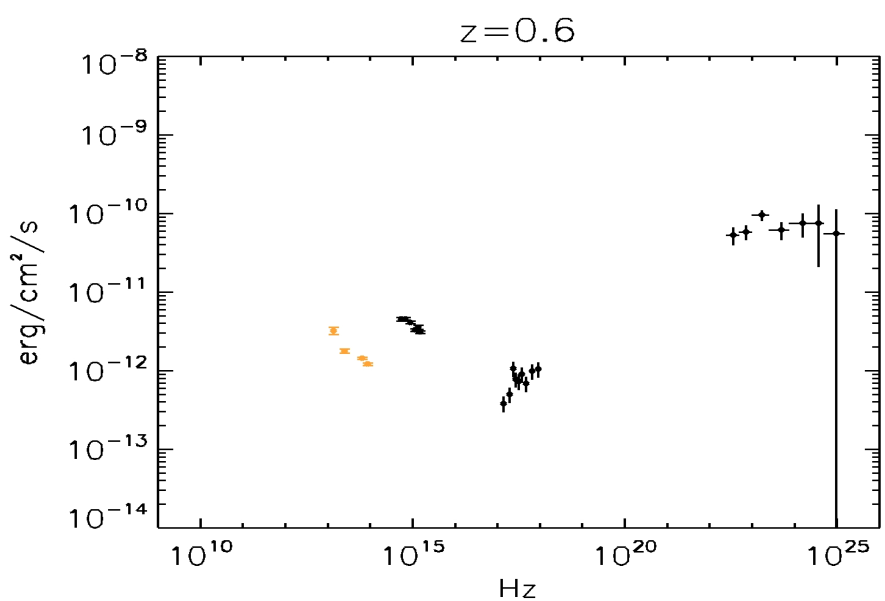


And other candidates during flares (3)

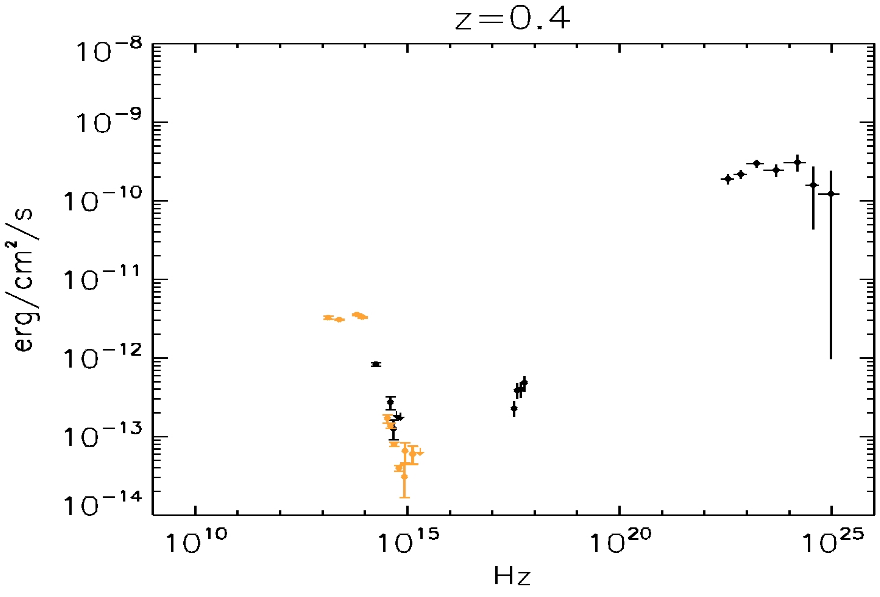




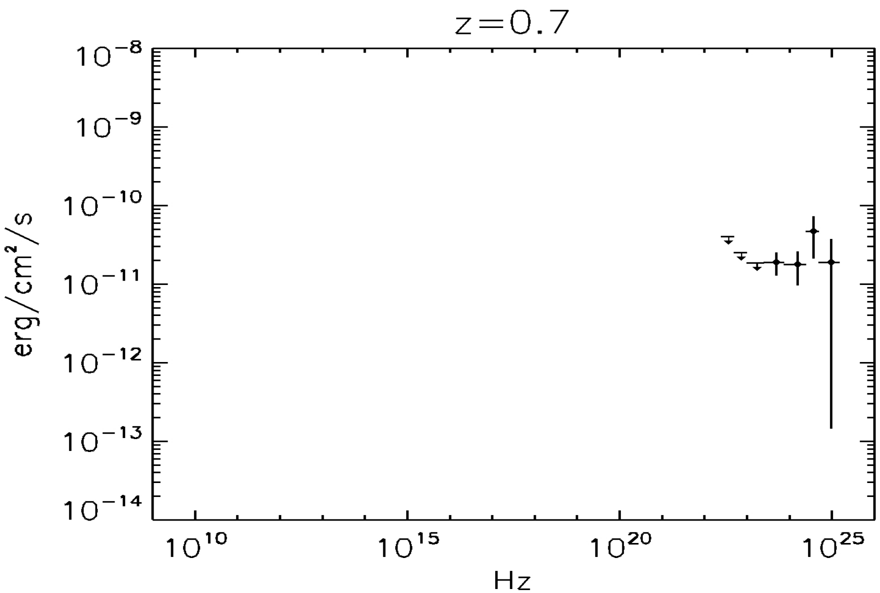


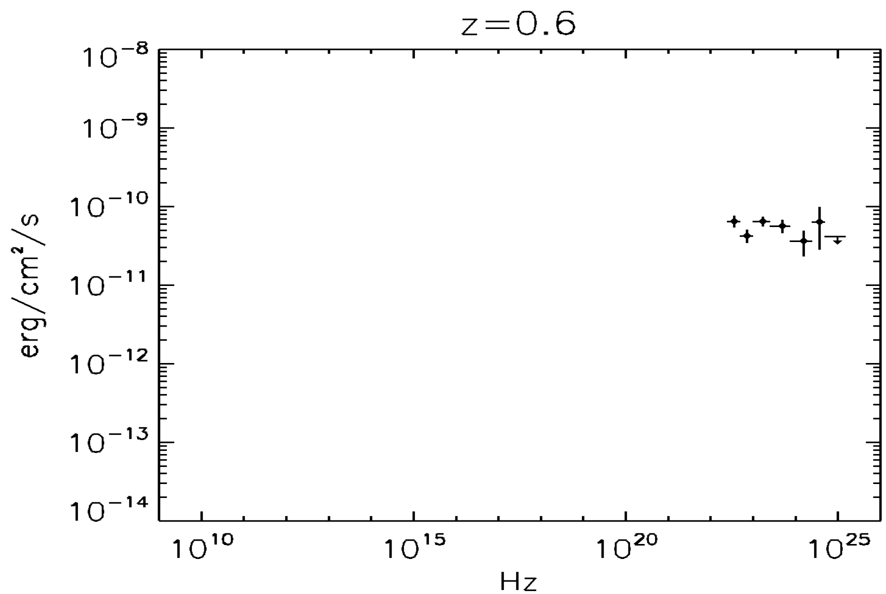


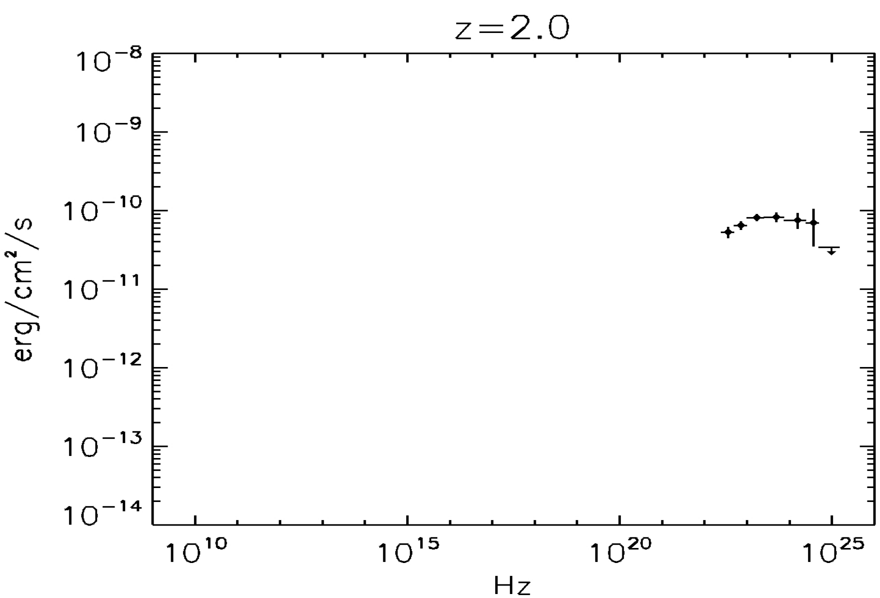
And other candidates during flares (4)

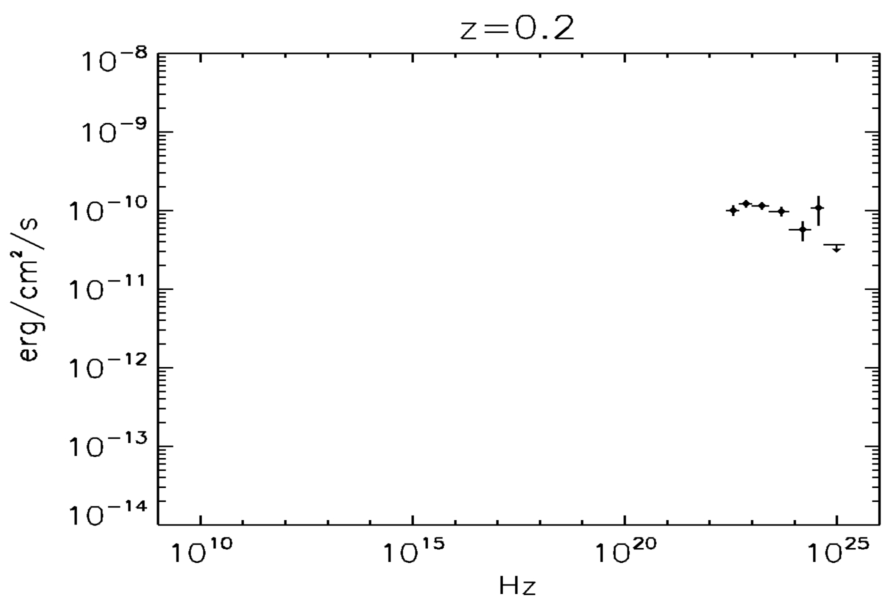


And other candidates during flares without simultaneous mwl obs (1)

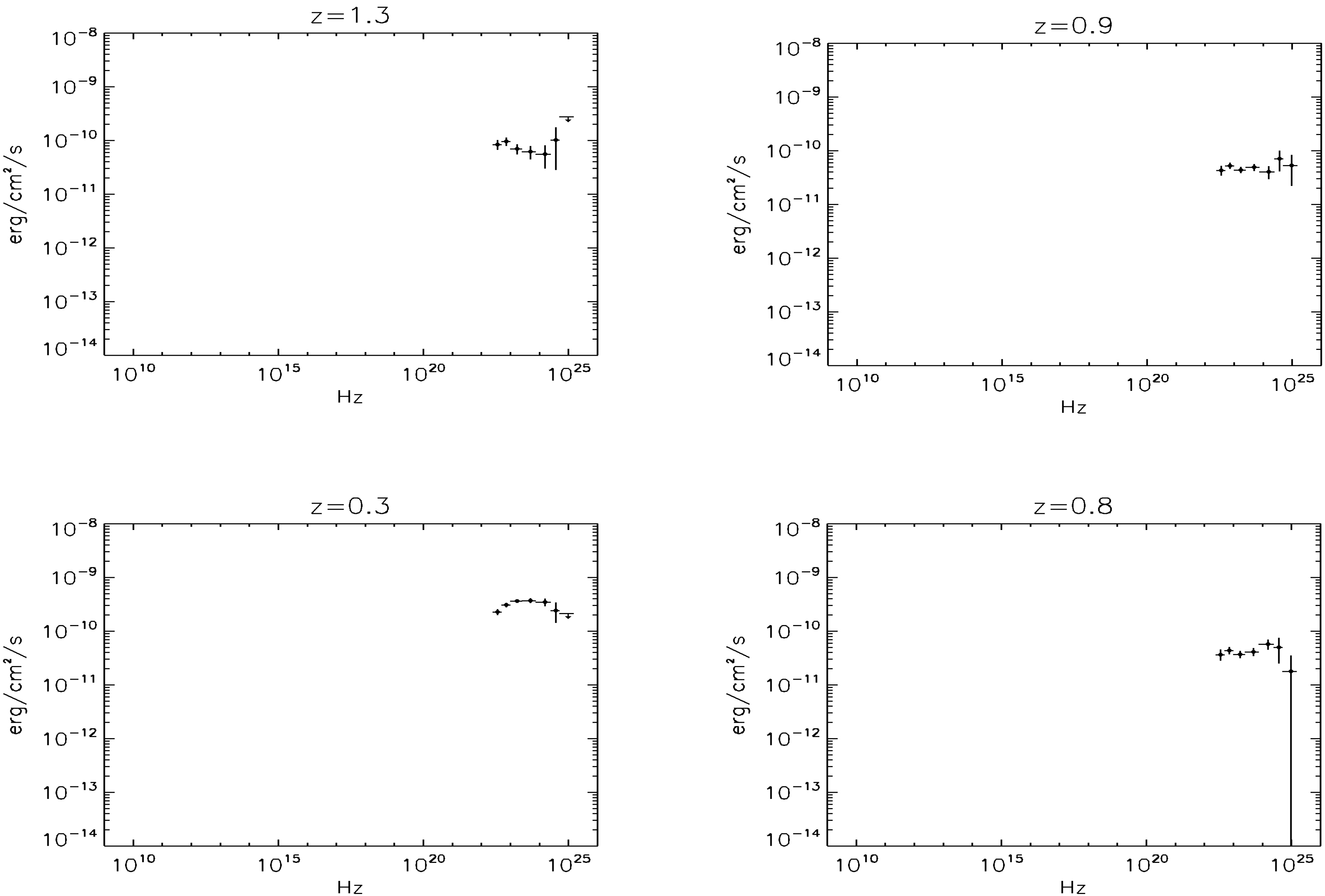




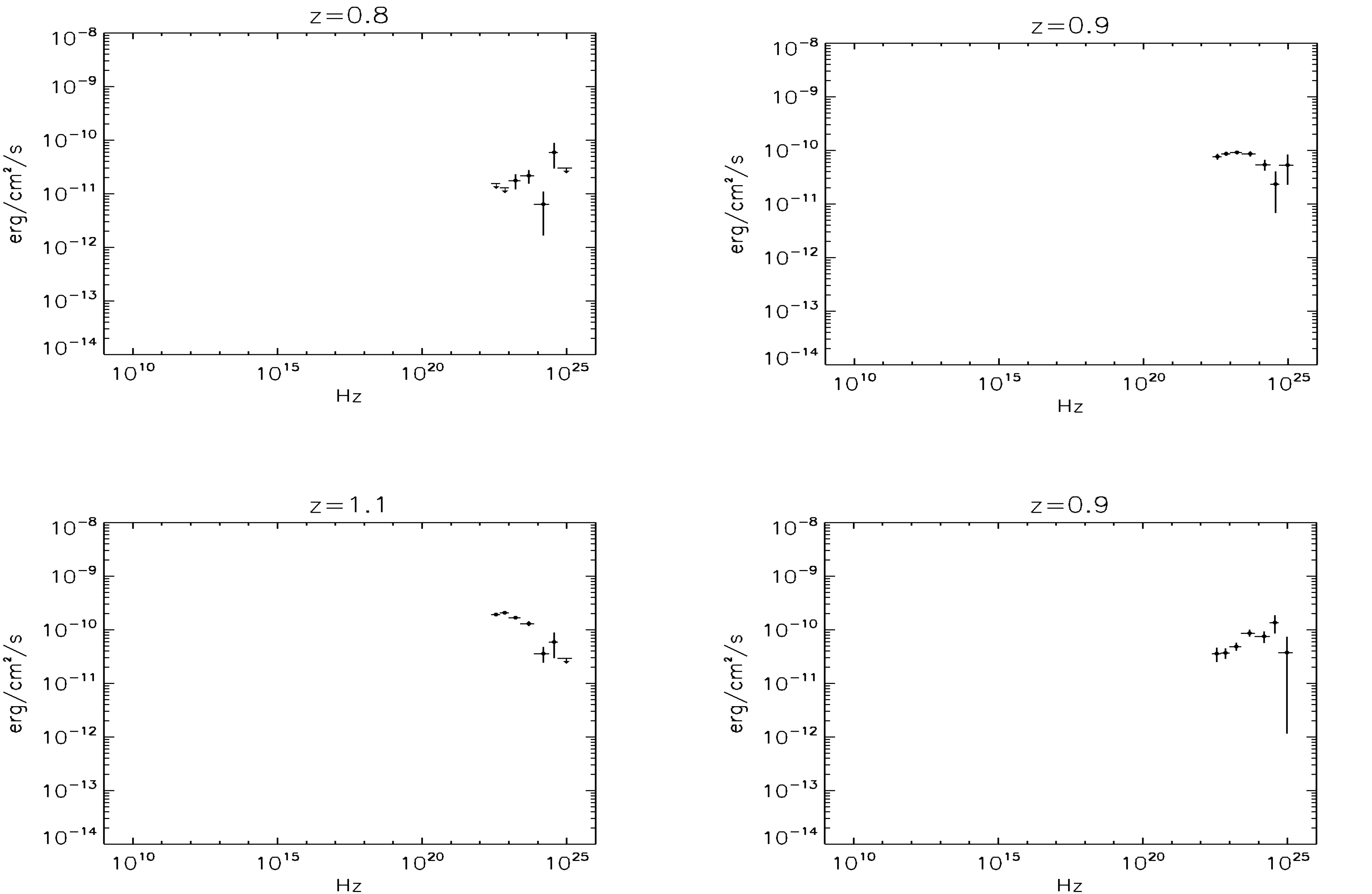




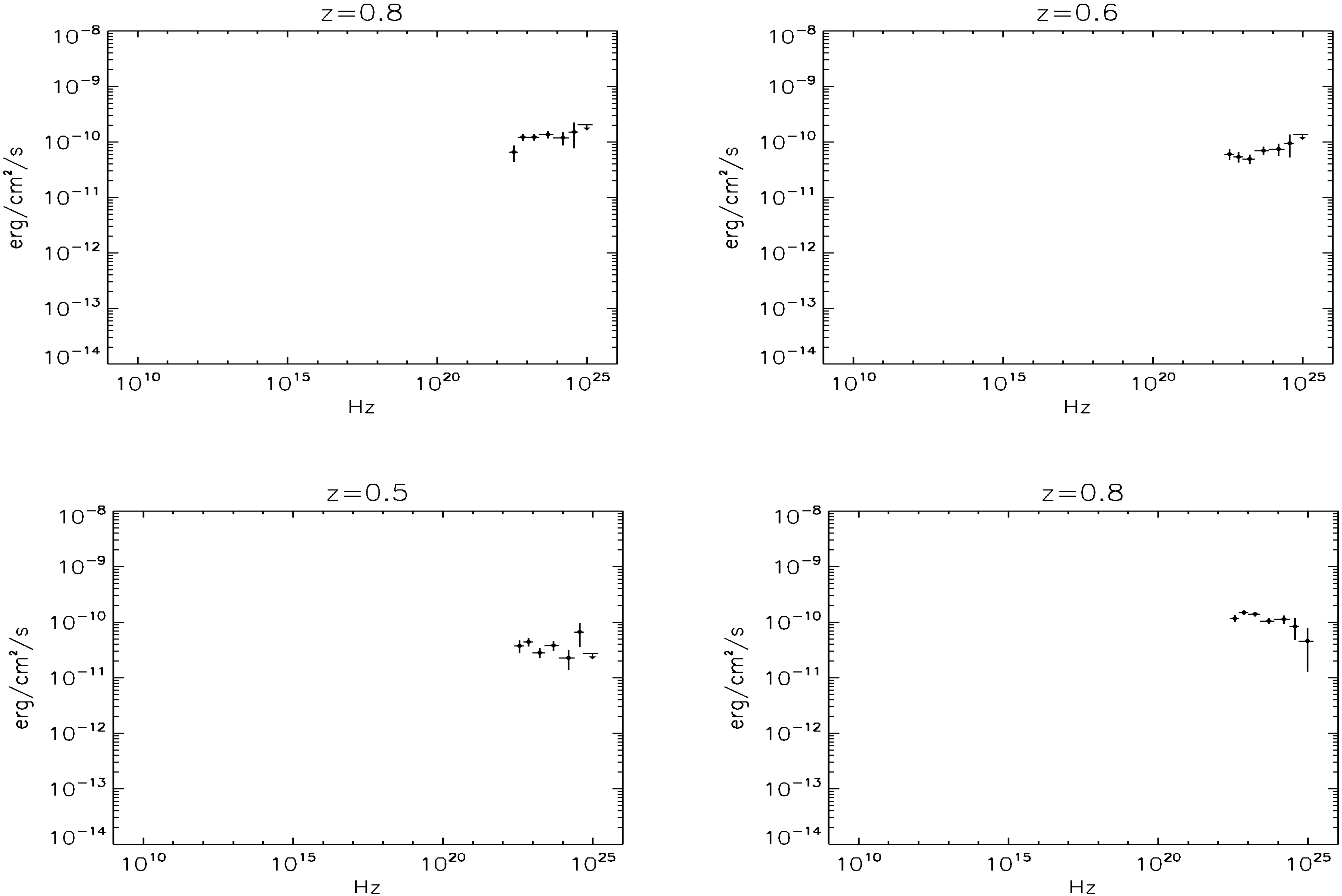
And other candidates during flares without simultaneous mwl obs (2)



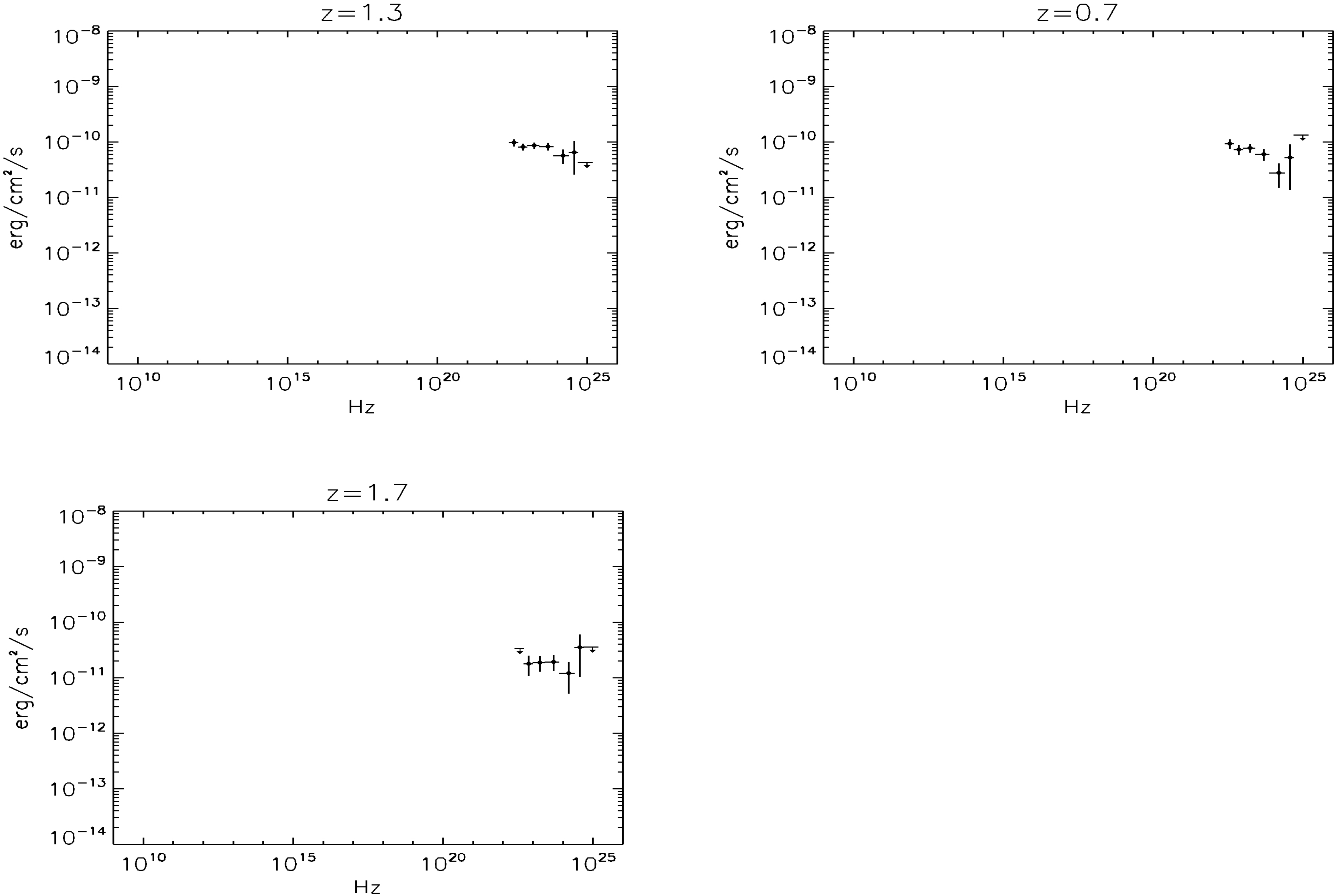
And other candidates during flares without simultaneous mwl obs (3)



And other candidates during flares without simultaneous mwl obs (4)



And other candidates during flares without simultaneous mwl obs (5)



Conclusions

At least 7% of FSRQ show gamma ray flares without absorption from the BLR photons

Their emision region must be located outside the BLR

For half of them we are trying to localize the emitting region with the strategy adopted in Pacciani et al. 2012 (GB6 J1239+0443), in Ghisellini et. al. 2013 (PMN J2345-1555), Tavecchio, Pacciani et al. 2013 (PKS 1424-41).

This investigation will allow us to study the jet physics at parsec scale (Reconnection, recollimation, ...)

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