The characterization of the distant blazar GB6 1239+0443 from flaring and low activity period

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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%)

AGILE pointed the VIRGO field in dec. 2007 – Jan. 2008, and detected flaring activity of 3EG J1236+0457 (GB6 1239+0443)

For that observation there was a MWL campaign on the VIRGO field, with INTEGRAL pointing at the same field.

We searched for the optical counterpart in the INTERGRAL/OMC and found it.

In spite of the large amount of data available for the source, this FSRQ has not been studied so far.

We will show the available data and we will discuss the quiescent state and the remarkable flares of the distant source

CAMPAIGNS DETAILS

CAMPAIGN "A"

AGILE:

flare detected from 3EG J1236+045

(GB6 1239+0443),

F~60*10^{-8} ph/cm2/s, E>100 MeV

((public data)

INTEGRAL/OMC:

detection of SDSS J123932.75+0443.5

(GB6 1239+0443) (public data)

INTEGRAL/ISGRI:

U.L. of ~2 mCrab in hard X-rays

(public data)

CAMPAIGN "B"

Flare detected by FERMI/LA

and good positioning

(Tramacere ATEL 1888) (public data),

X-ray data from Swift/XRT (public data),

Optical data from Swift/UVOT (public data)

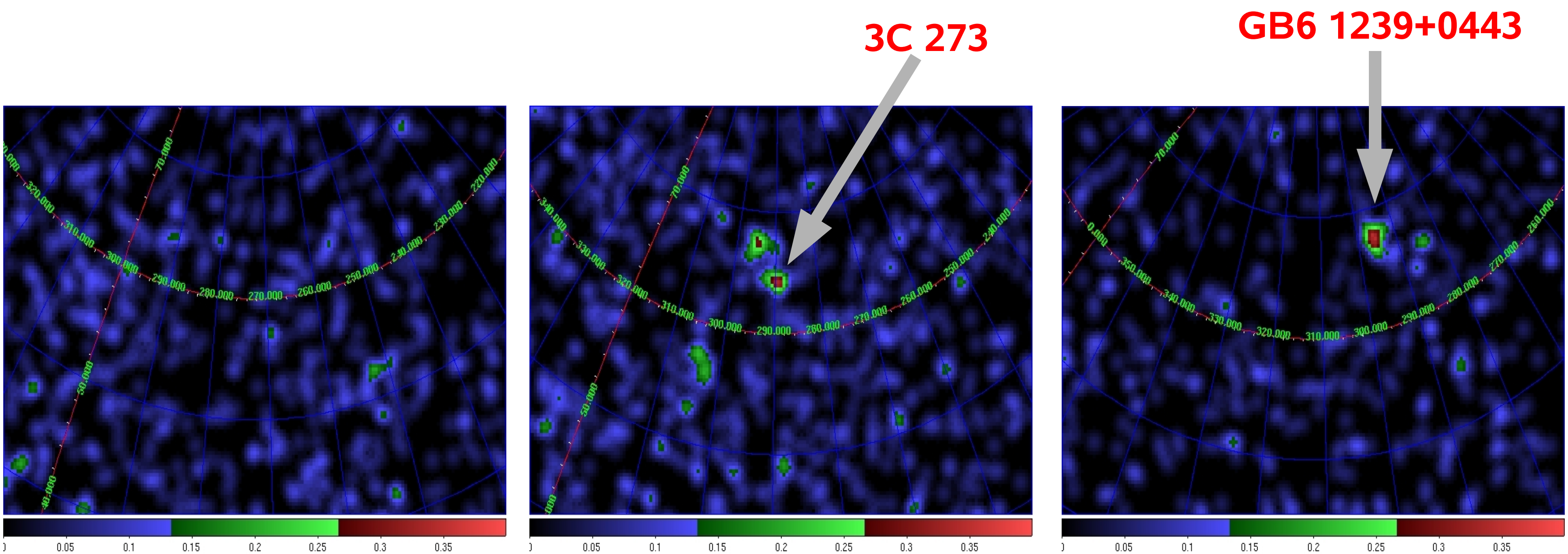
and KANATA (published data)

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: **$(62\pm9)*10^{-8}$ ph/cm^2/s**, E>100 MeV
Photon index **1.92 ± 0.14**, E> 100 MeV

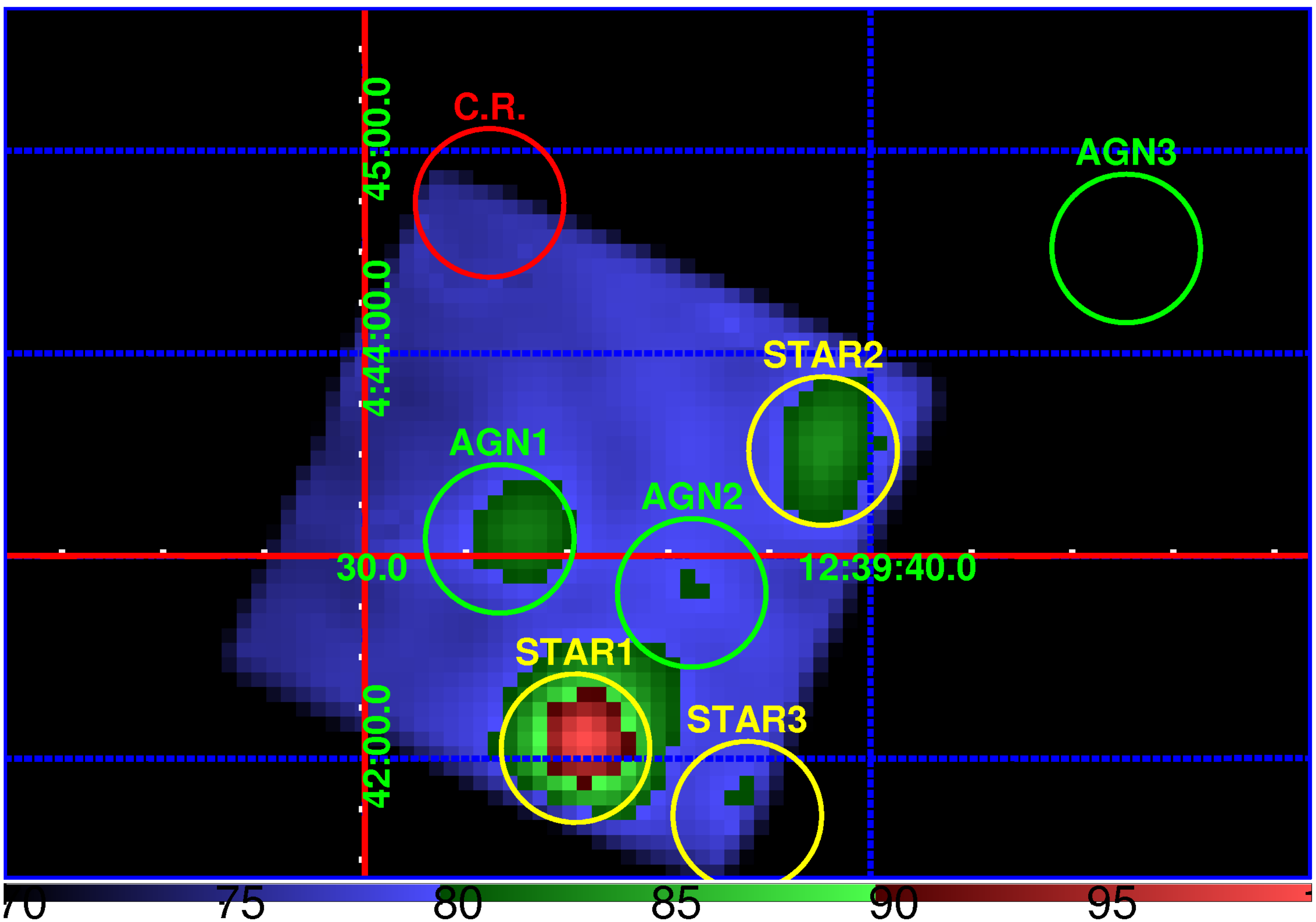


First week **Second week** **Third week**

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 15 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).

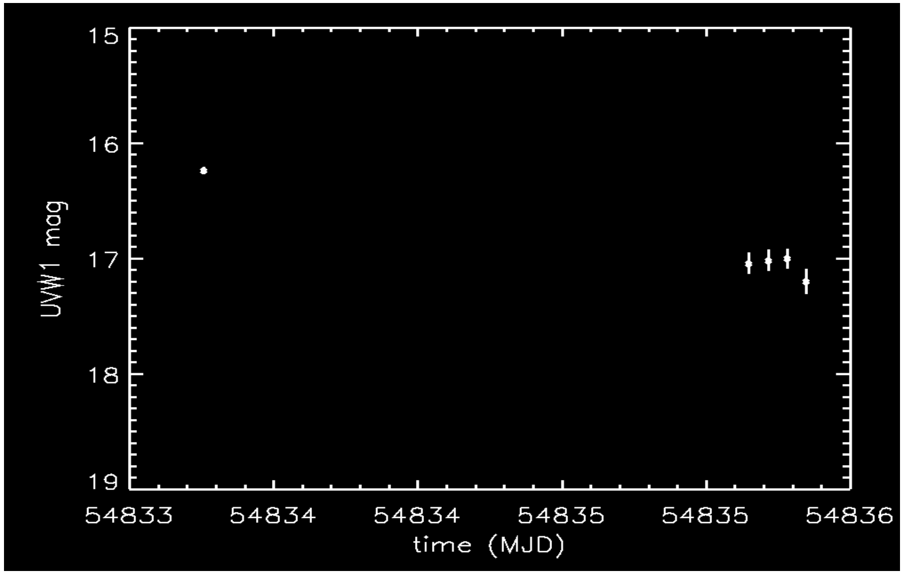
We detected the source with **SQRT(TS)~18**,
and obtained a photon index of **2.21±0.15** between 0.3-20 GeV
for an integration time of 4 days
centered around **2008 December 29 16:00 UT**.

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

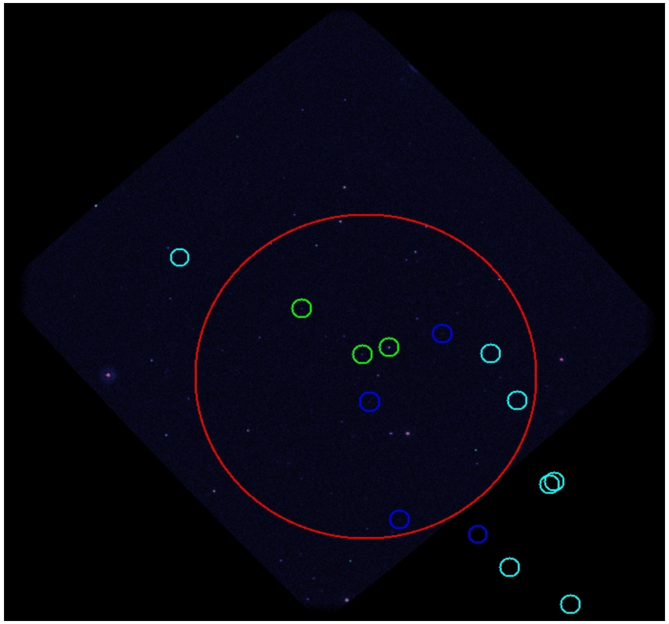
With the integration of 30 days period centered around the same date,
we detected the source with **SQRT(TS)~20**,
and we obtained a photon index of **2.15±0.11**

CAMPAIGN B
SWIFT/UVOT

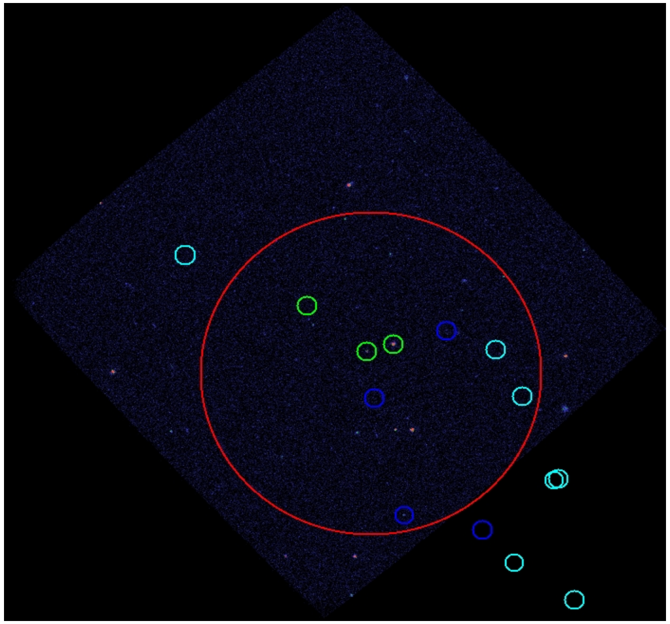
The UVOT observed the source with U, UW1, UM2, UW2 filters.
We obtained UVW1=16.24± 0.03 (extinction corrected)



U

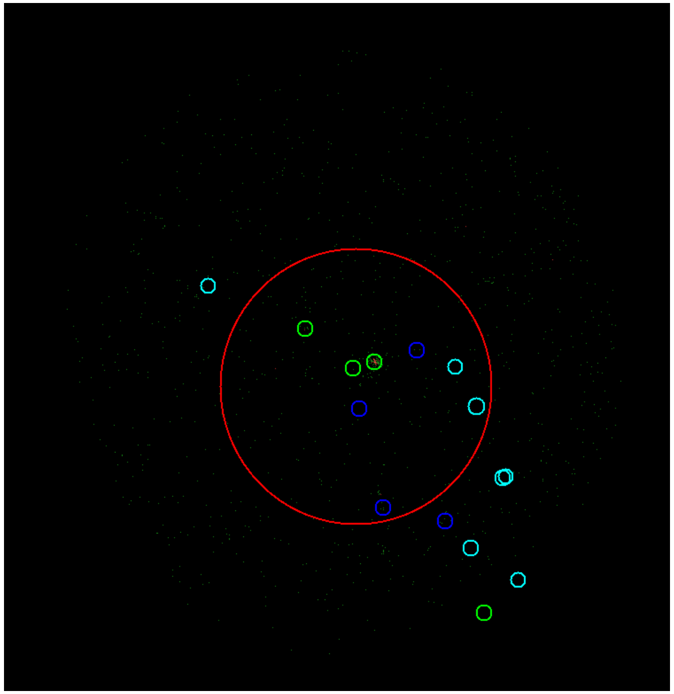


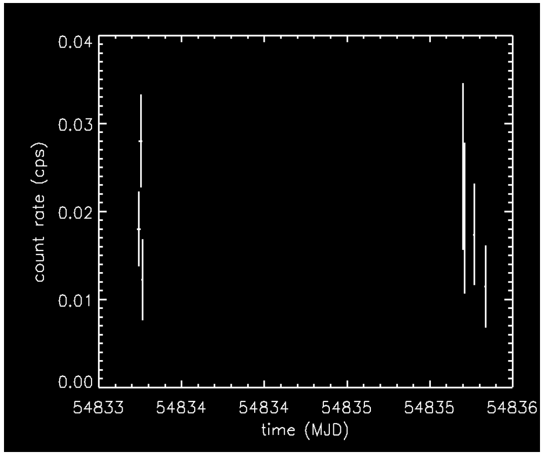
UM2

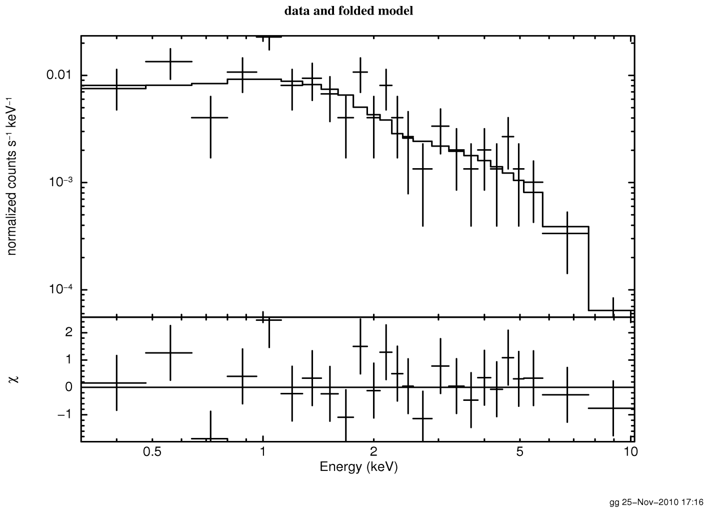


CAMPAIGN B
SWIFT/XRT

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 $(2.58 \pm 0.23)\cdot10^{-2}$ 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 $(8.8 \pm 2.7)\cdot10^{-13}$ $erg/cm^2/s$ (68% C.L.).

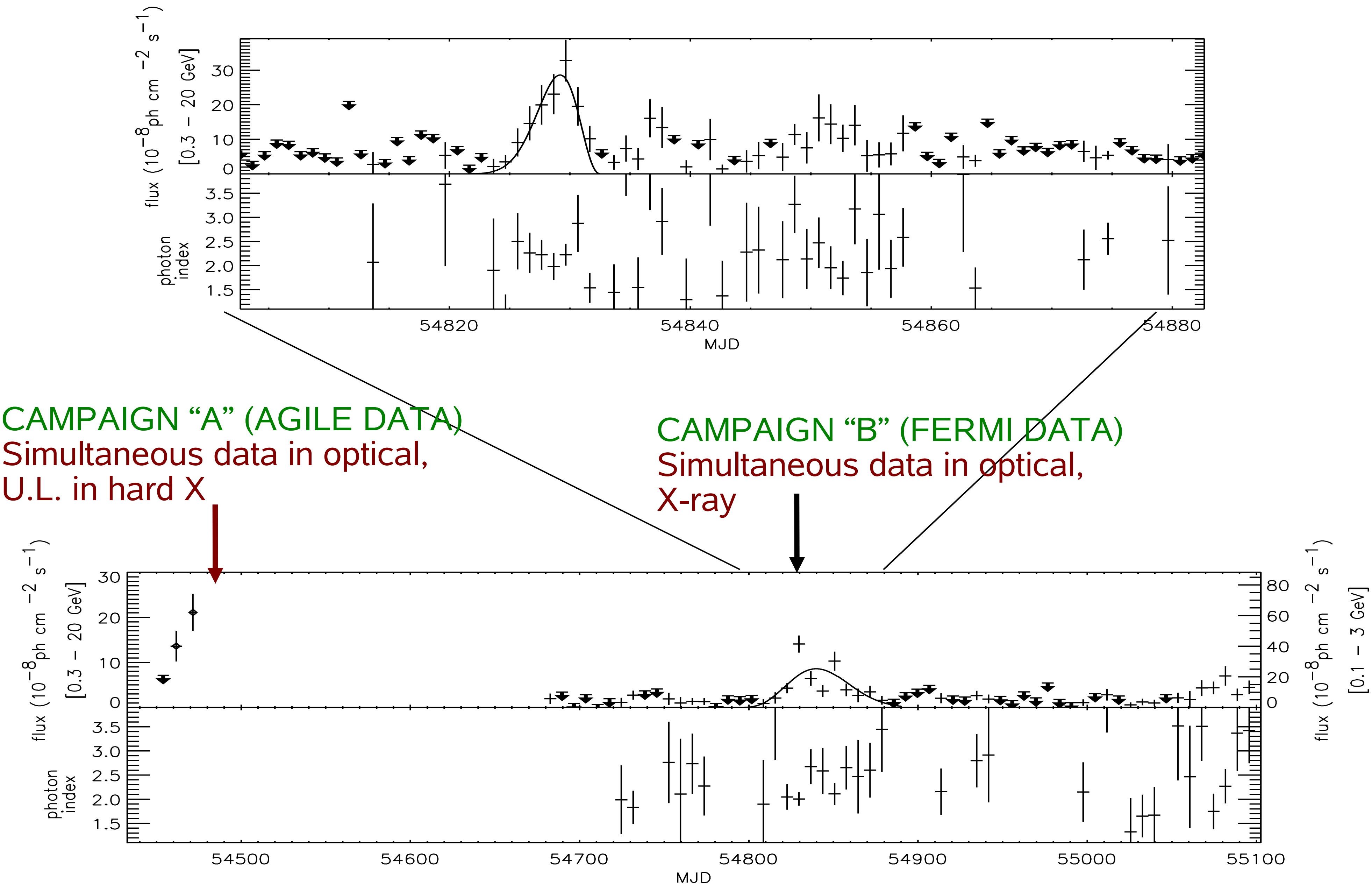




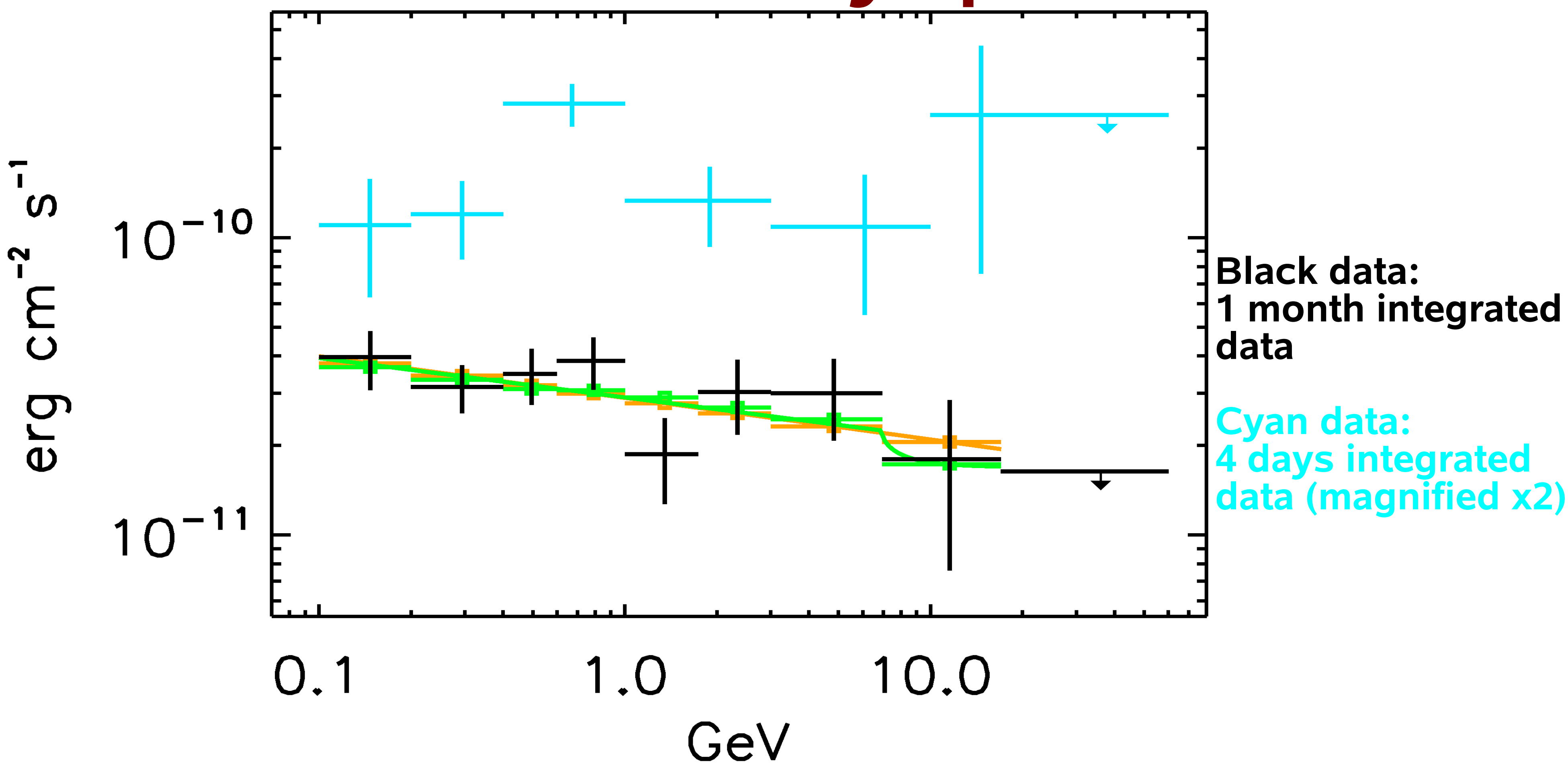


Gamma-ray Light curve
making use of the long term coverage of FERMI

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),

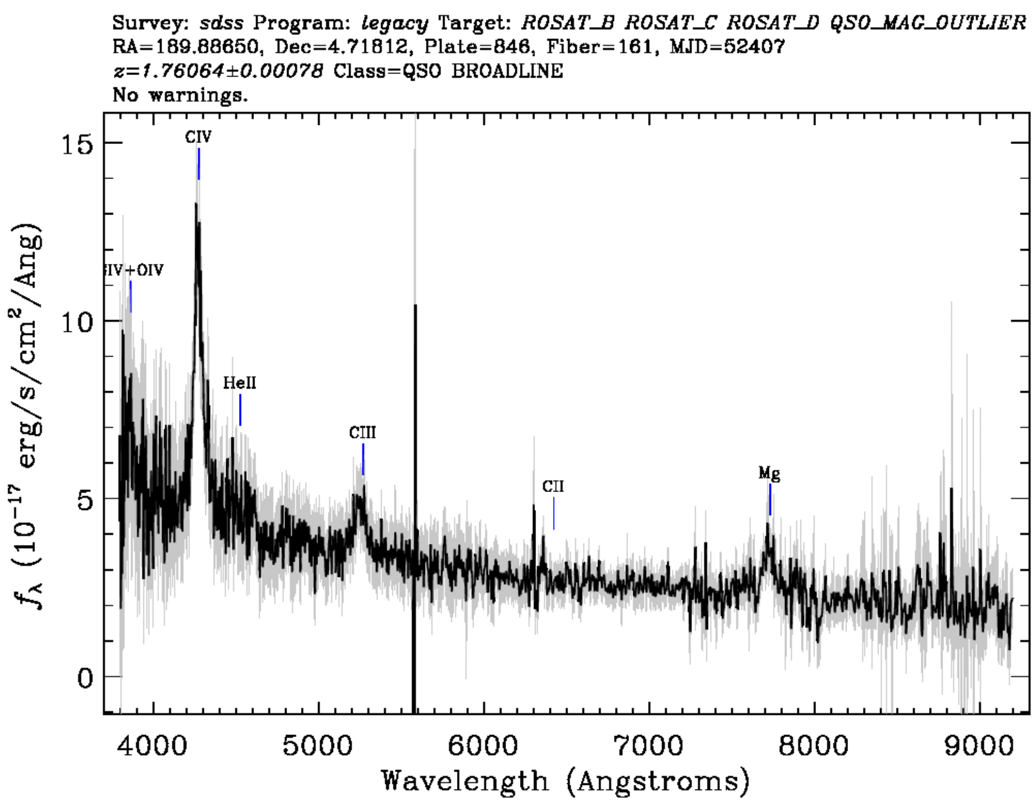
Metsahovi (May 2002)

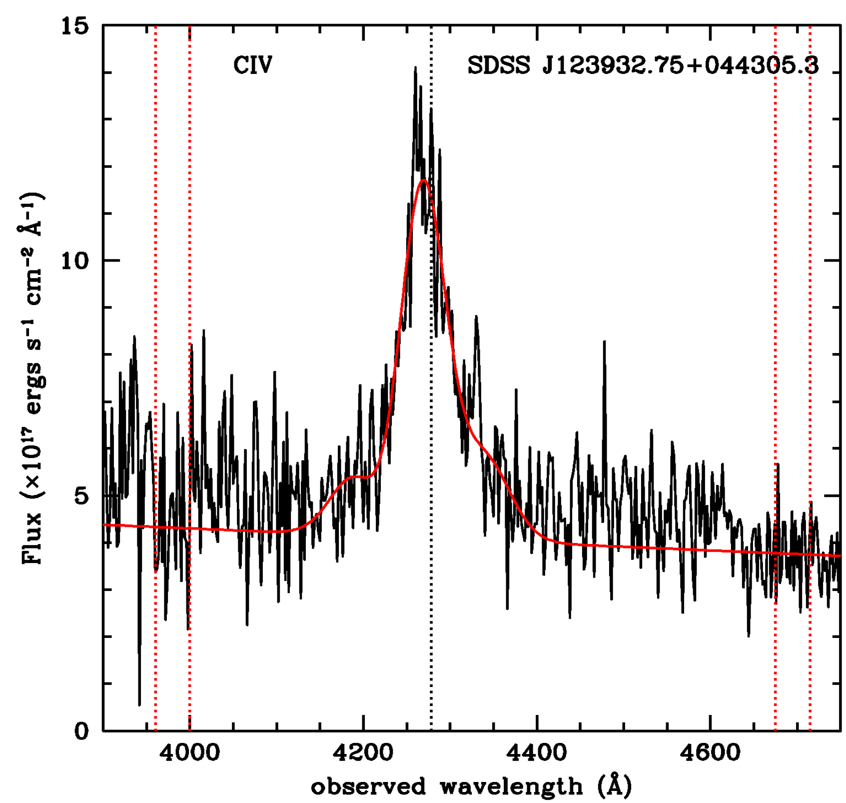
BH mass from C IV broad line width

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).

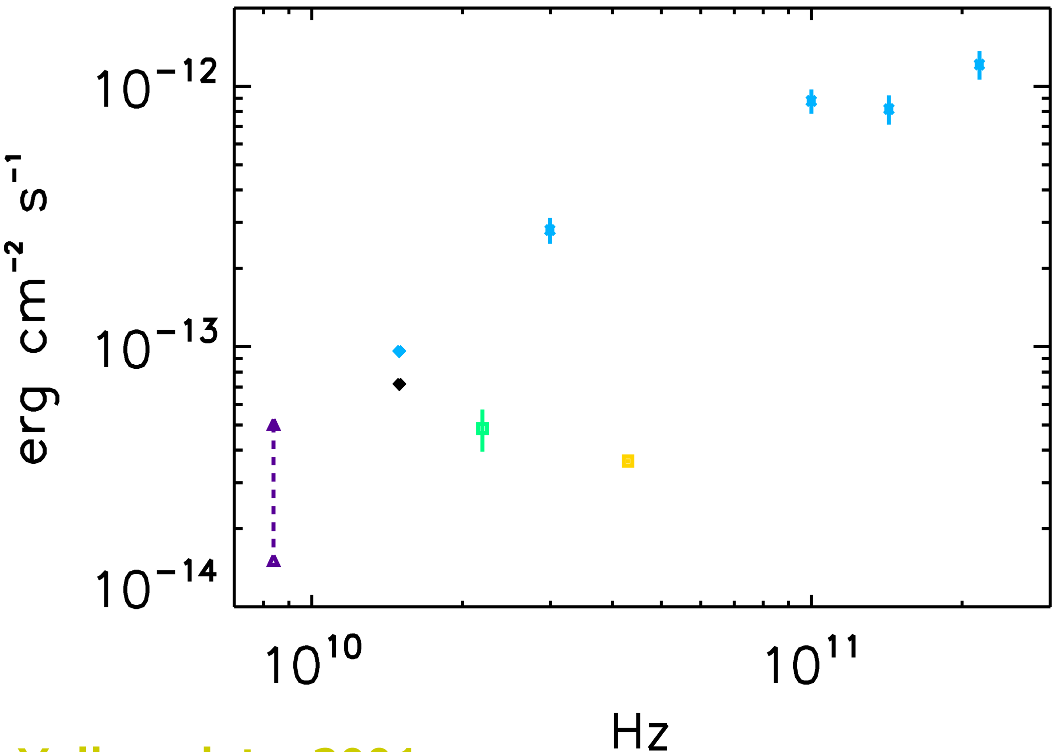
We used two methods to estimate the C IV broad line width: direct line width measurement (**FWHM=2860±910 km/s**) and Gauss-hermite polinomial fit (**FWHM=4710±390 km/s**). The first method is known to underestimate the line width, the other method to overerestimate (Denney et al. 2009).

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)

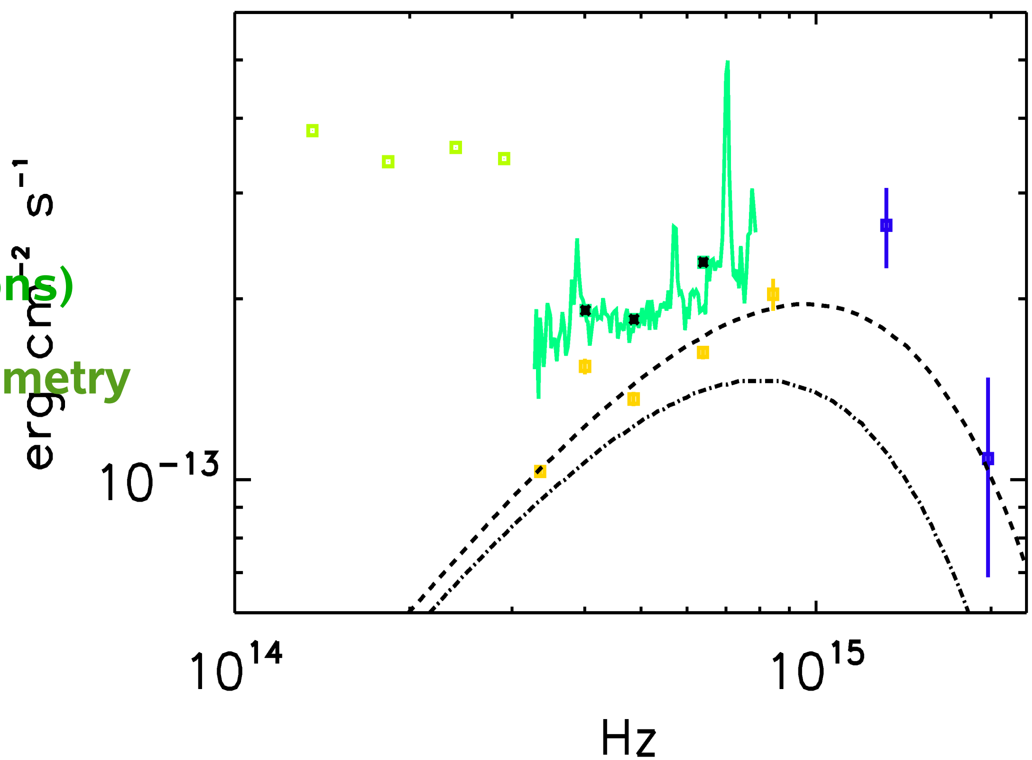
Green data: 2002 May
(simultaneous optical – radio observations)

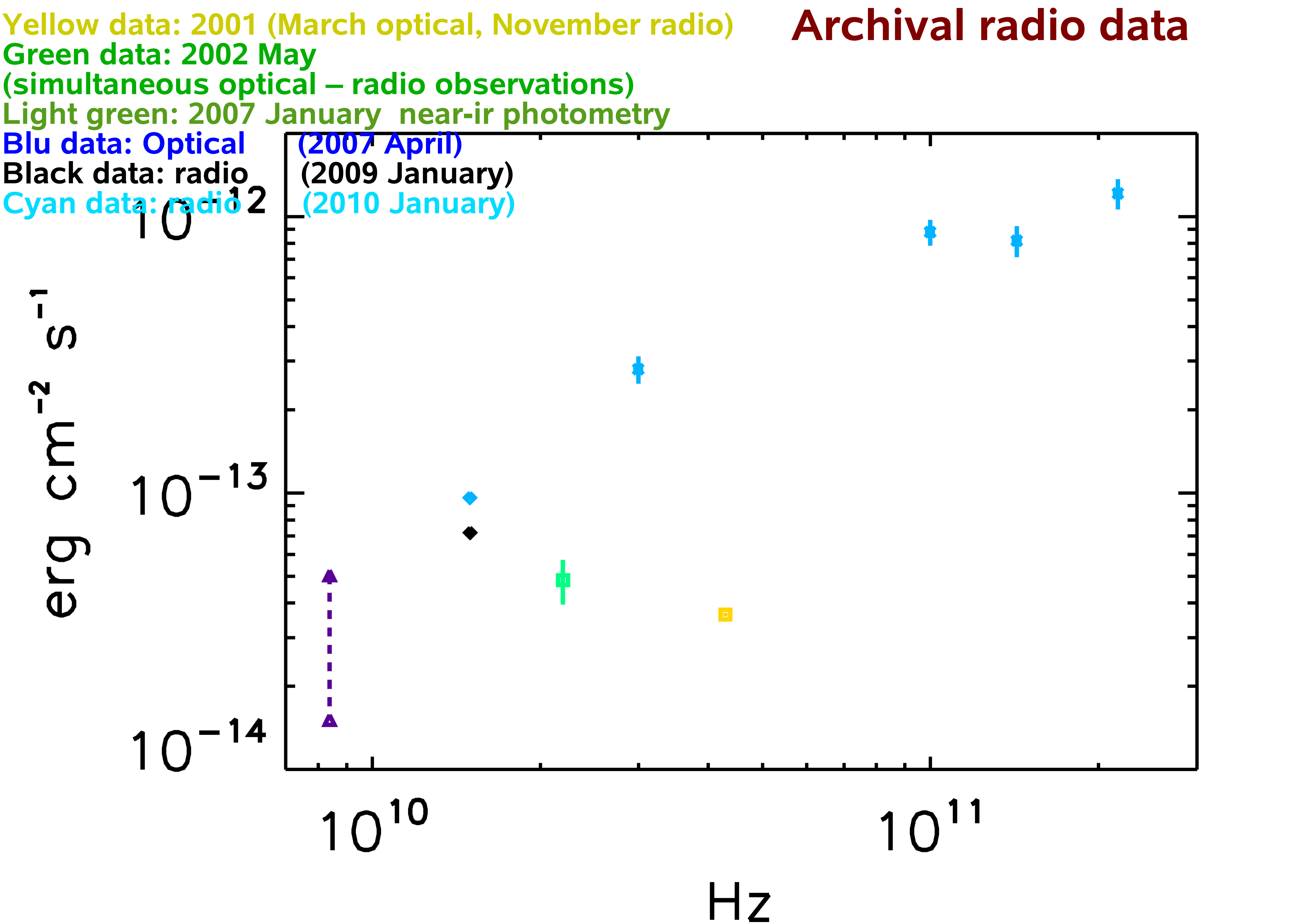
Light green: 2007 January near-ir photometry

Blu data: Optical (2007 April)

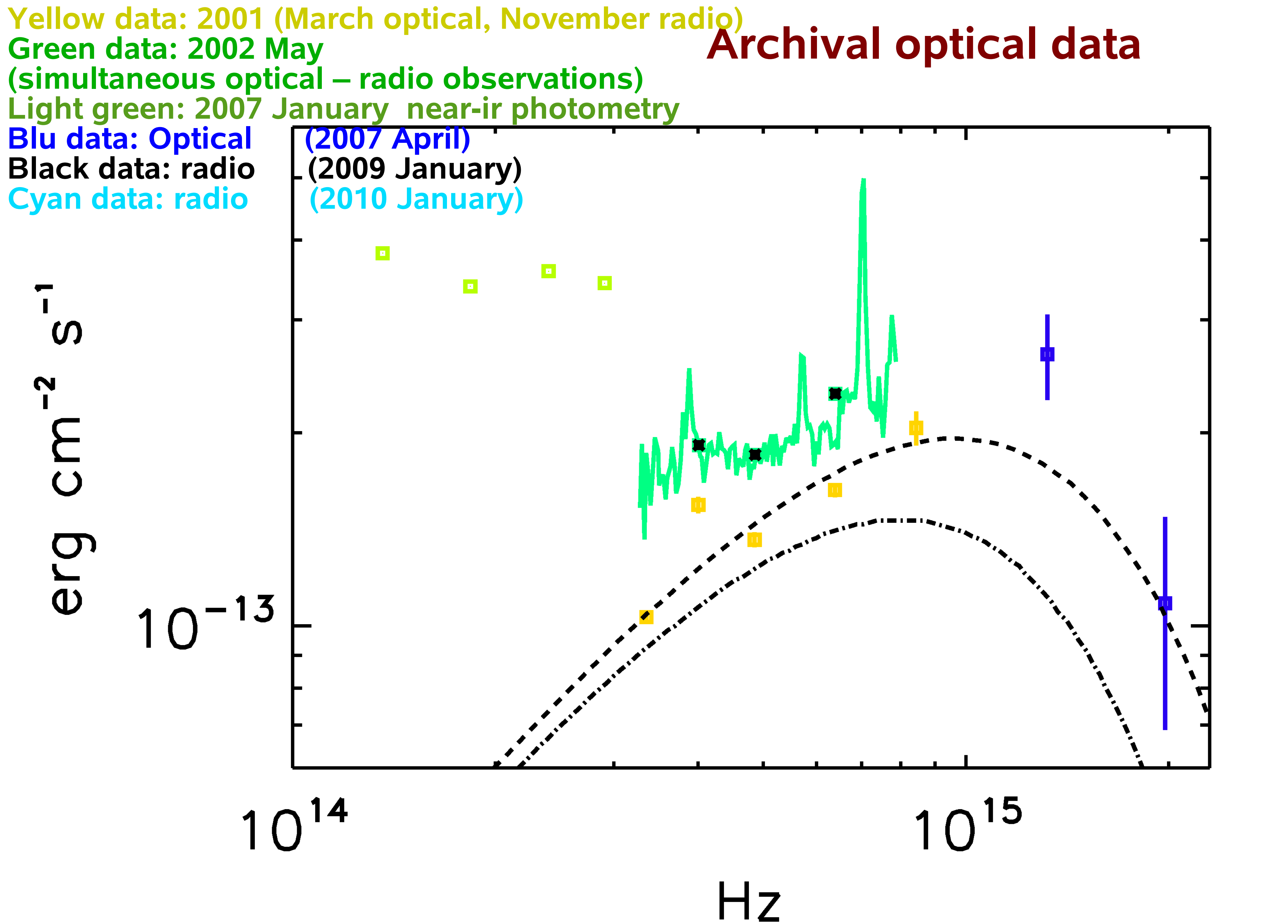
Black data: radio (January 2009)

Cyan data: radio (2010 January)





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 (2009 January)
Cyan data: radio (2010 January)
Archival radio data
10^{-12}
10^{-13}
10^{-14}
erg cm^{-2} s^{-1}
10^{10}
10^{11}
Hz


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 (2009 January)
Cyan data: radio (2010 January)
Archival optical data
erg cm-2 s-1
10-13
10^14
10^15
Hz

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).

The Non thermal dominance evaluated from CIV line emission and continuum, and from Mg II line give a value of 1, consistent with a pure disk emission.

We modelled the disk emisison 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
~$8.9*10^{45}$ erg/s,

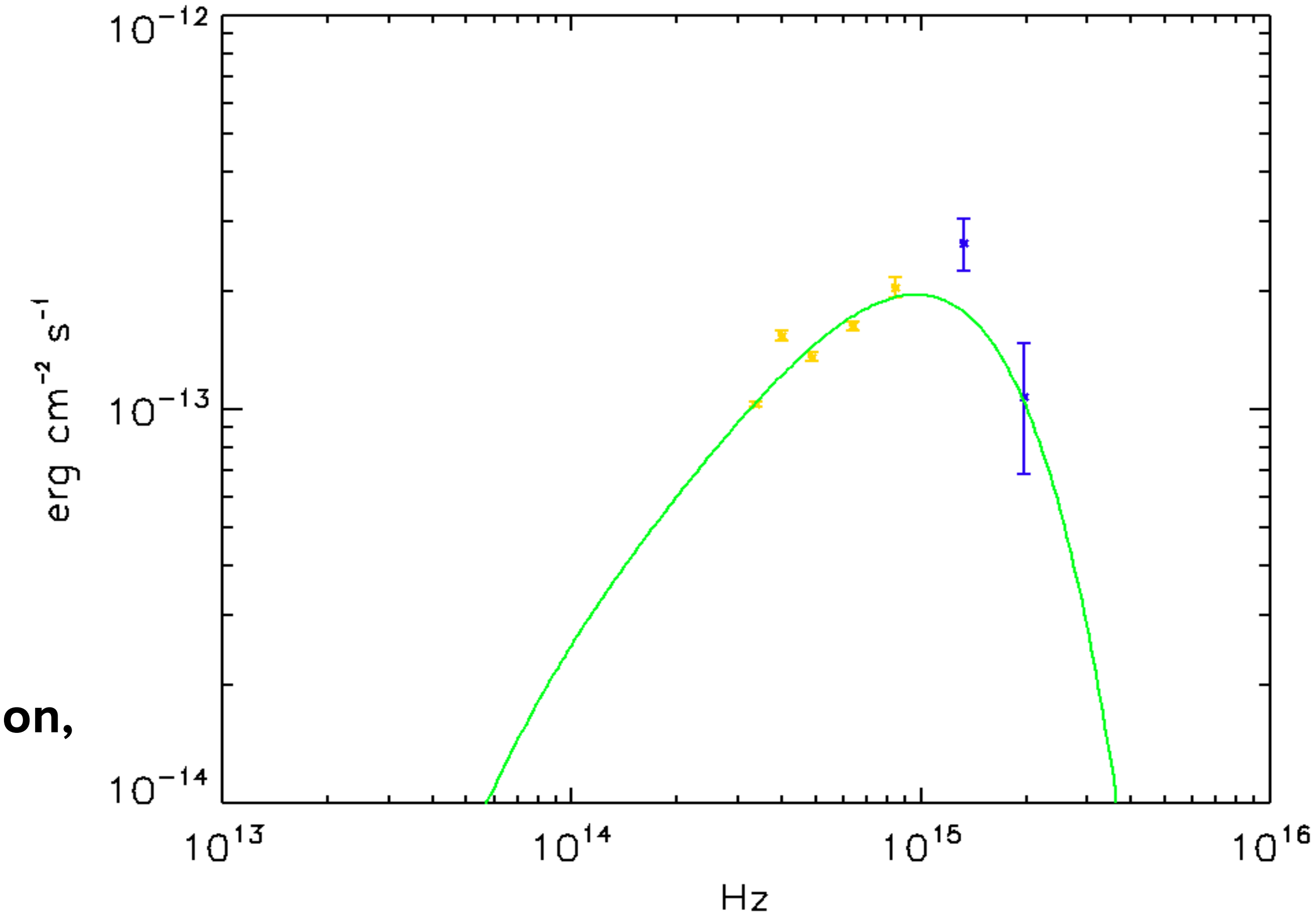
r_s~$2.4*10^{14}$cm

a max emitting Temperature of
~$5.4*10^{4}$K

m_{BH}~$8*10^{8}$ solar masses
(in agreement with the virial determination).

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

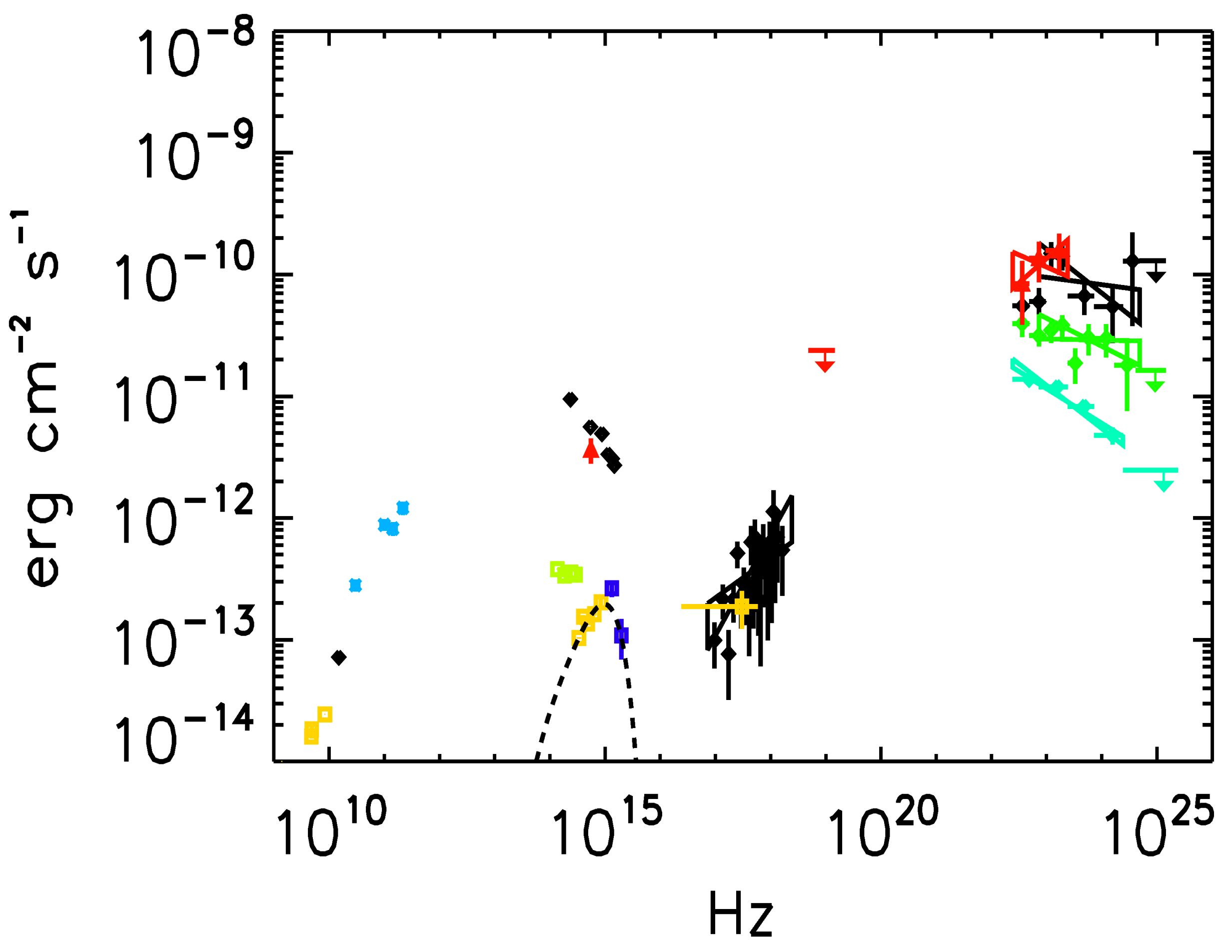
The NUV GALEX photometry Includes the Lyα



Multiepoch SED

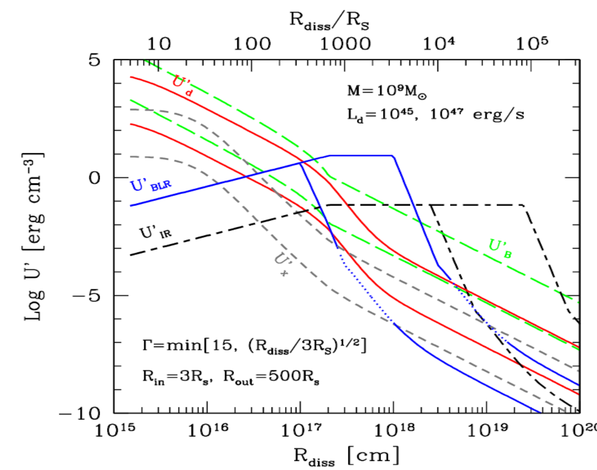
AGILE/GRID and simultaneous data in red

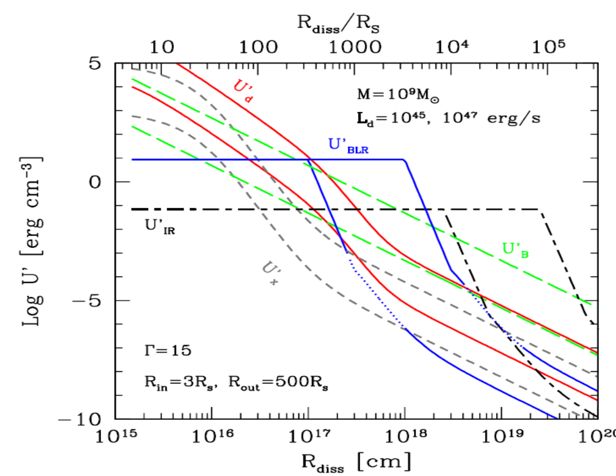
FERMI-LAT data
(4-day integration around the flare)
and simultanous data in black
Fermi-LAT data in green
(30-day integration around the flare)
Fermi-LAT data in cyan (2FGL catalog)



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

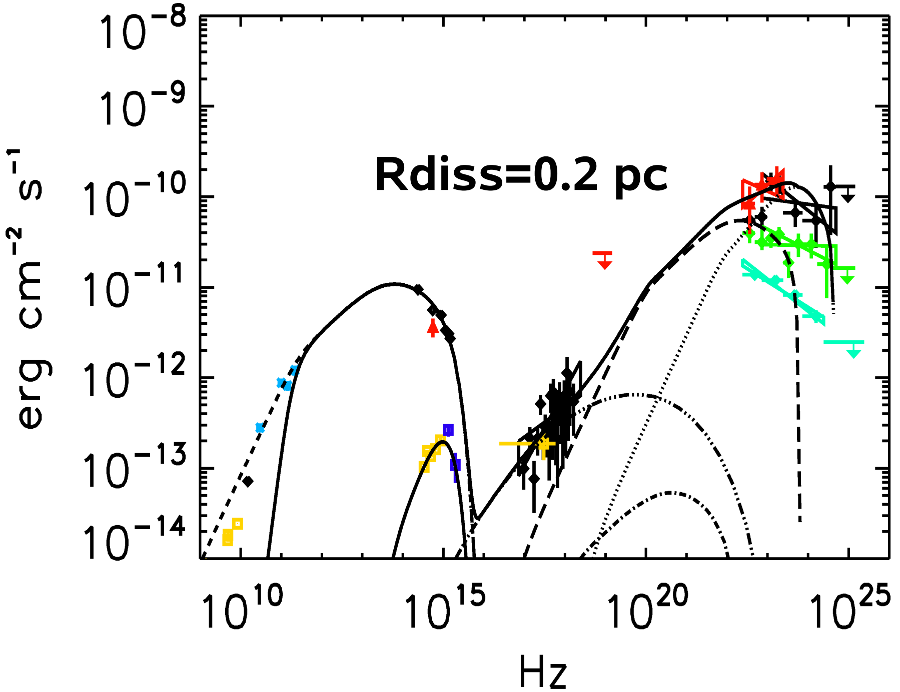


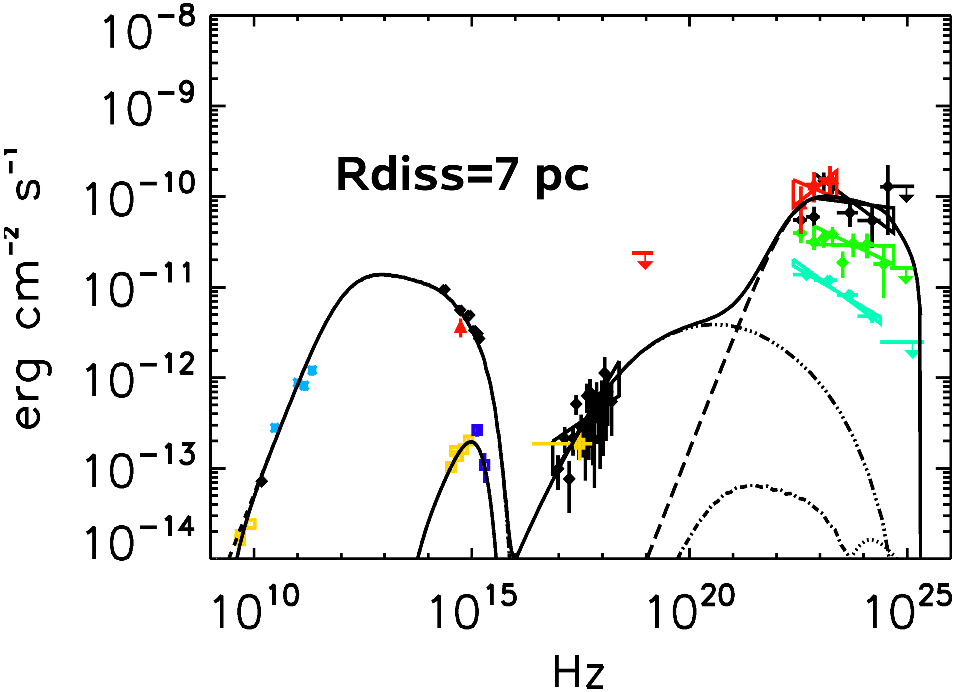


Multiepoch SED

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)





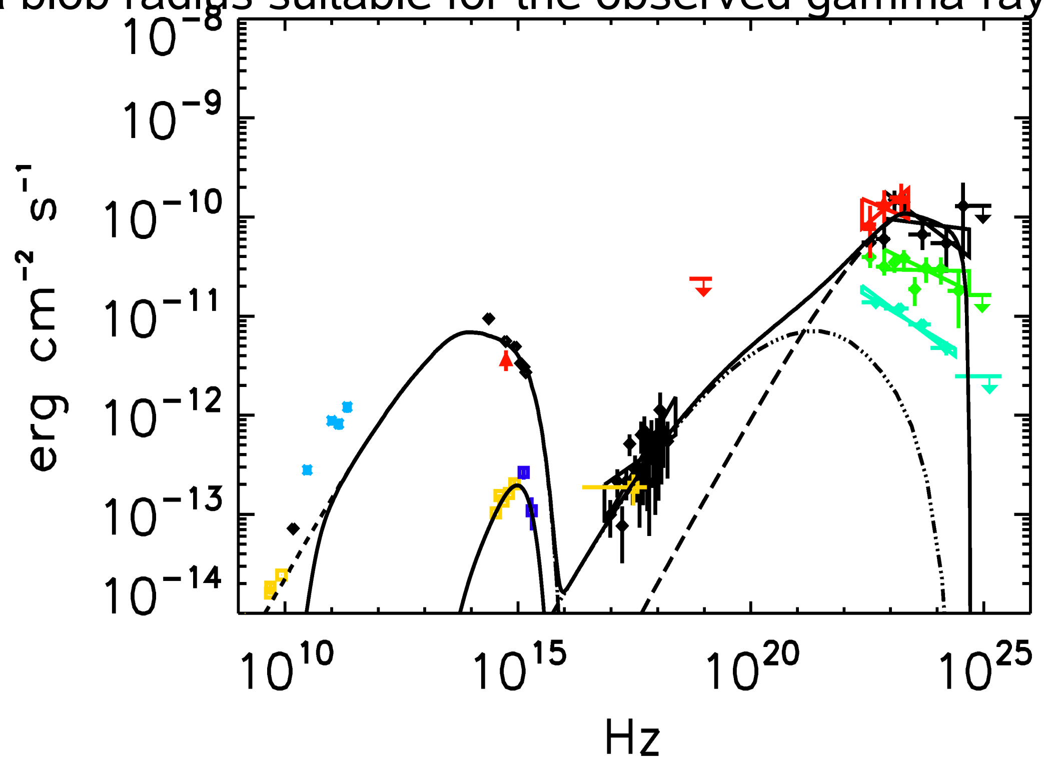
Dissipation region at 0.2 pc from the SMBH
(Just outside the BLR)
Rblob=6.7*10^{16}cm
B=0.6 Gauss

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

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 (**$\sim 8.9 \cdot 10^{45}$ erg/s,**) and from the disk emission we derived the BH mass (**$8 \cdot 10^{8}$ solar masses**)

We derived the BH mass from the CIV line width [Vestergaard 2006], [Assef 2011] (**$m_{BH}=(5.3^{+4.4}_{-3.3}) \cdot 10^{8}$ 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 **R_diss ~0.2 pc** and at **R_diss ~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: **$L_{jet}=3.5 \cdot 10^{46}$ erg/s**)

Prospects

We found in the Fermi-LAT sample, **about 10 FSRQ that have a gamma-ray spectrum similar to GB6 J1239+0443**: we are selecting those with an almost flat gamma-ray spectrum extended up to 20-40 GeV, and with a similar optical-UV SED shape during flares.

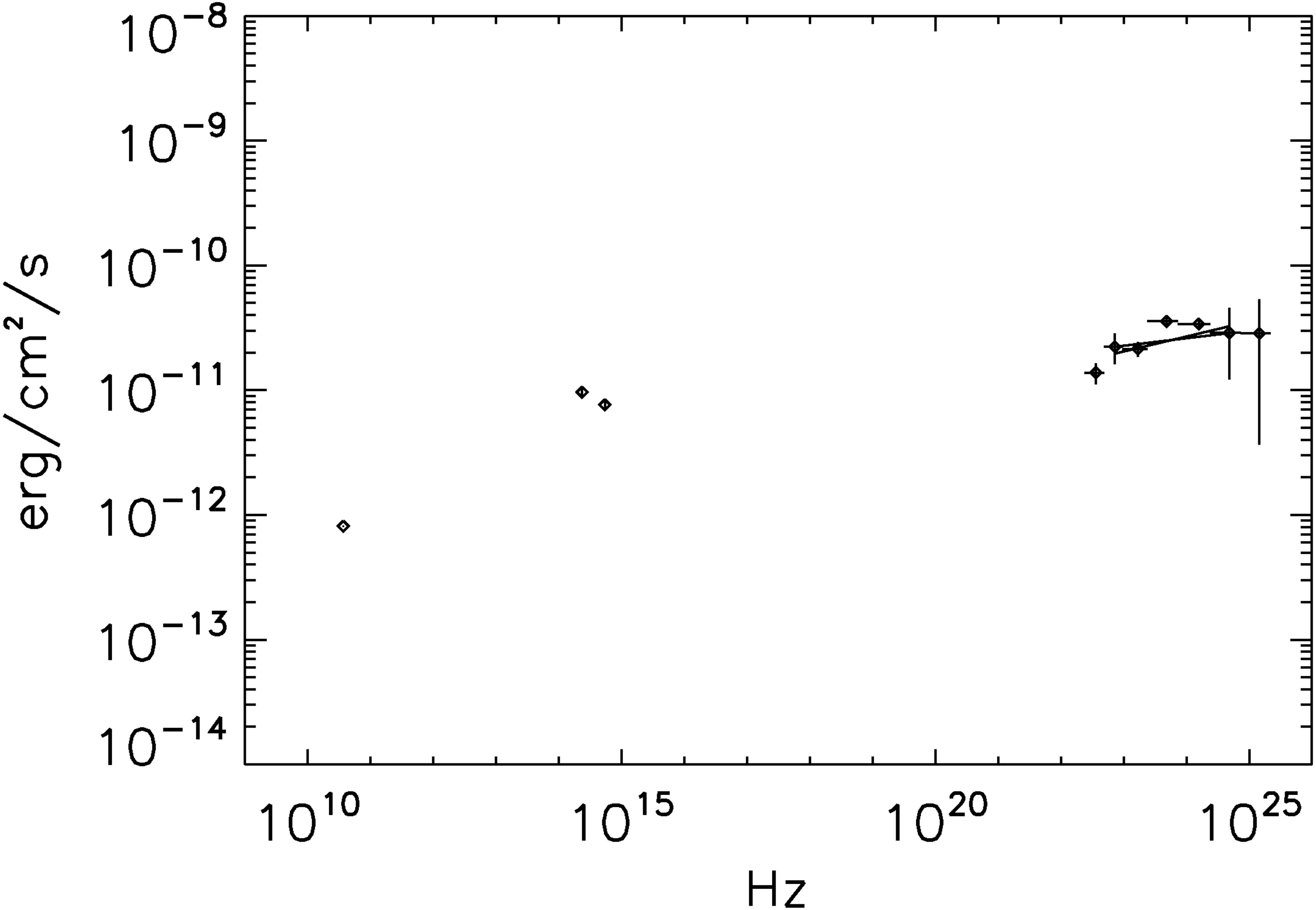
Radio observations will allow to disentangle between models (model 2 does not require self absorption in radio). Not only the **dissipation region location** could be obtained, but if models like model 3 could be confirmed, compliant with Bromberg and Levinson (2009), they will tell us about the **p/e number ratio**.

But we need an extensive radio/optical/X-ray monitoring program on the sample, **or at least radio observations just after the gamma-ray flare?**

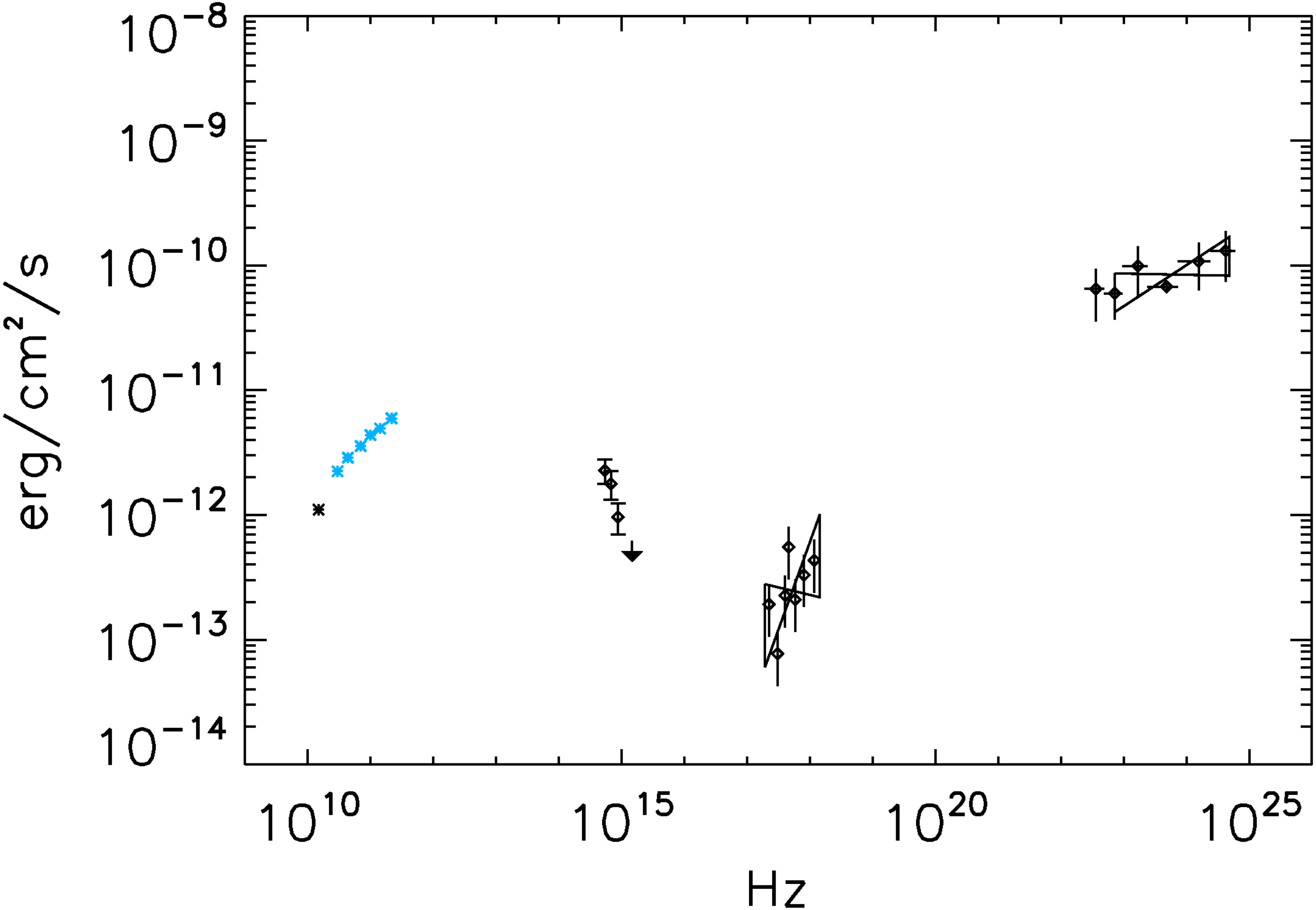
Trigger, starting from Fermi archived data, **is not time consuming** (starting from a list of candidates).

SED during flares

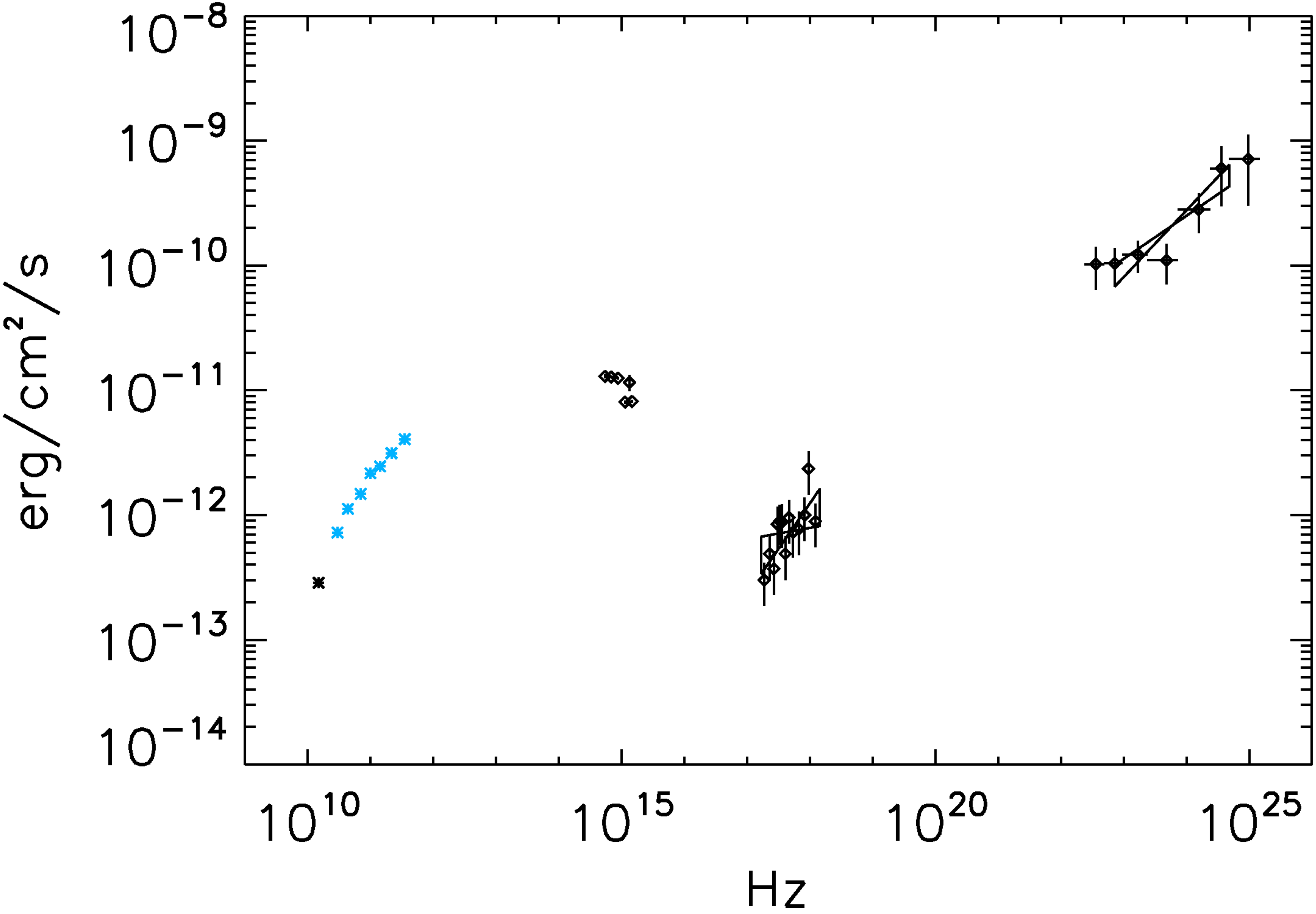
For some of the candidates



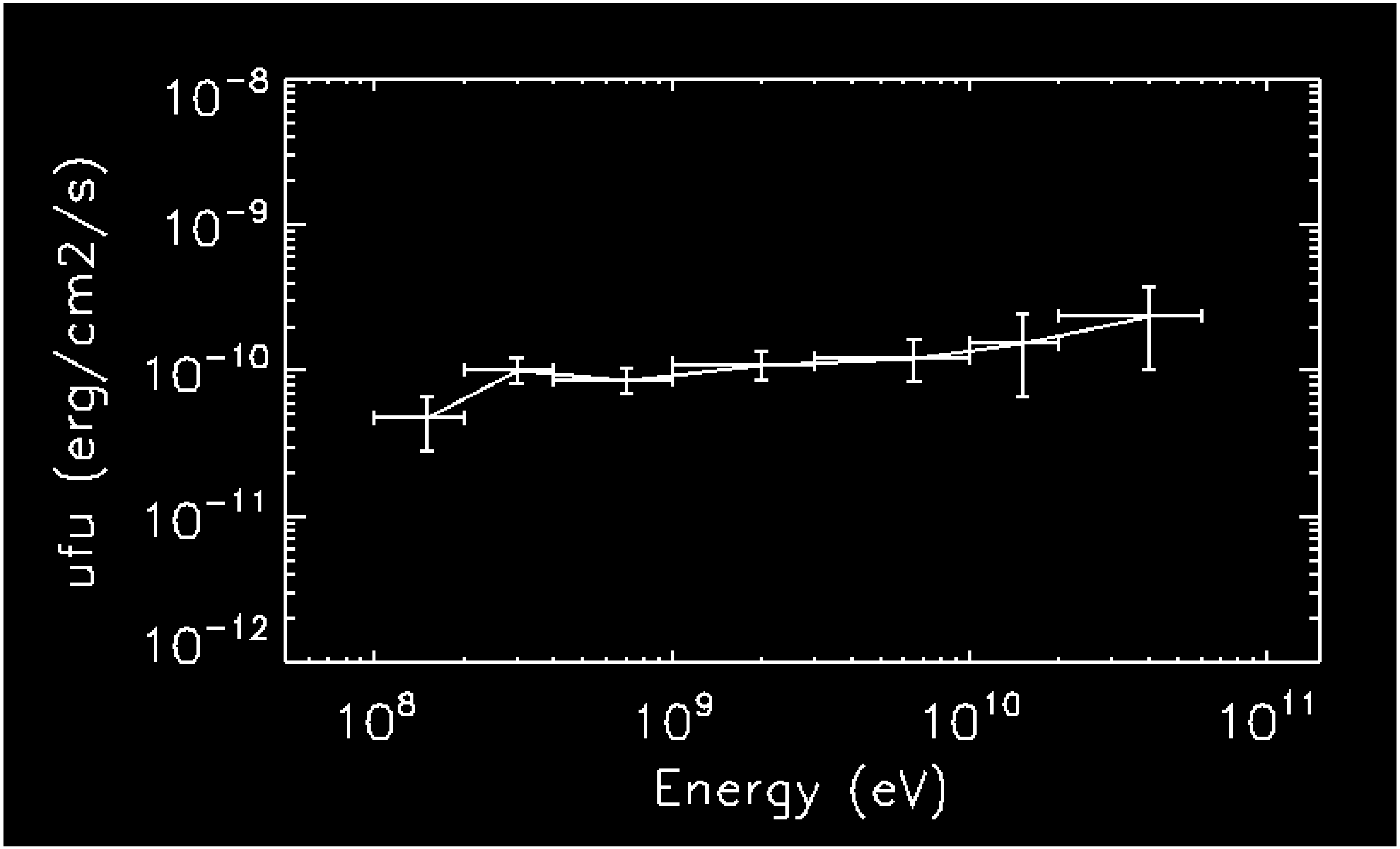
erg/cm²/s
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10¹⁰
10¹⁵
10²⁰
10²⁵
Hz

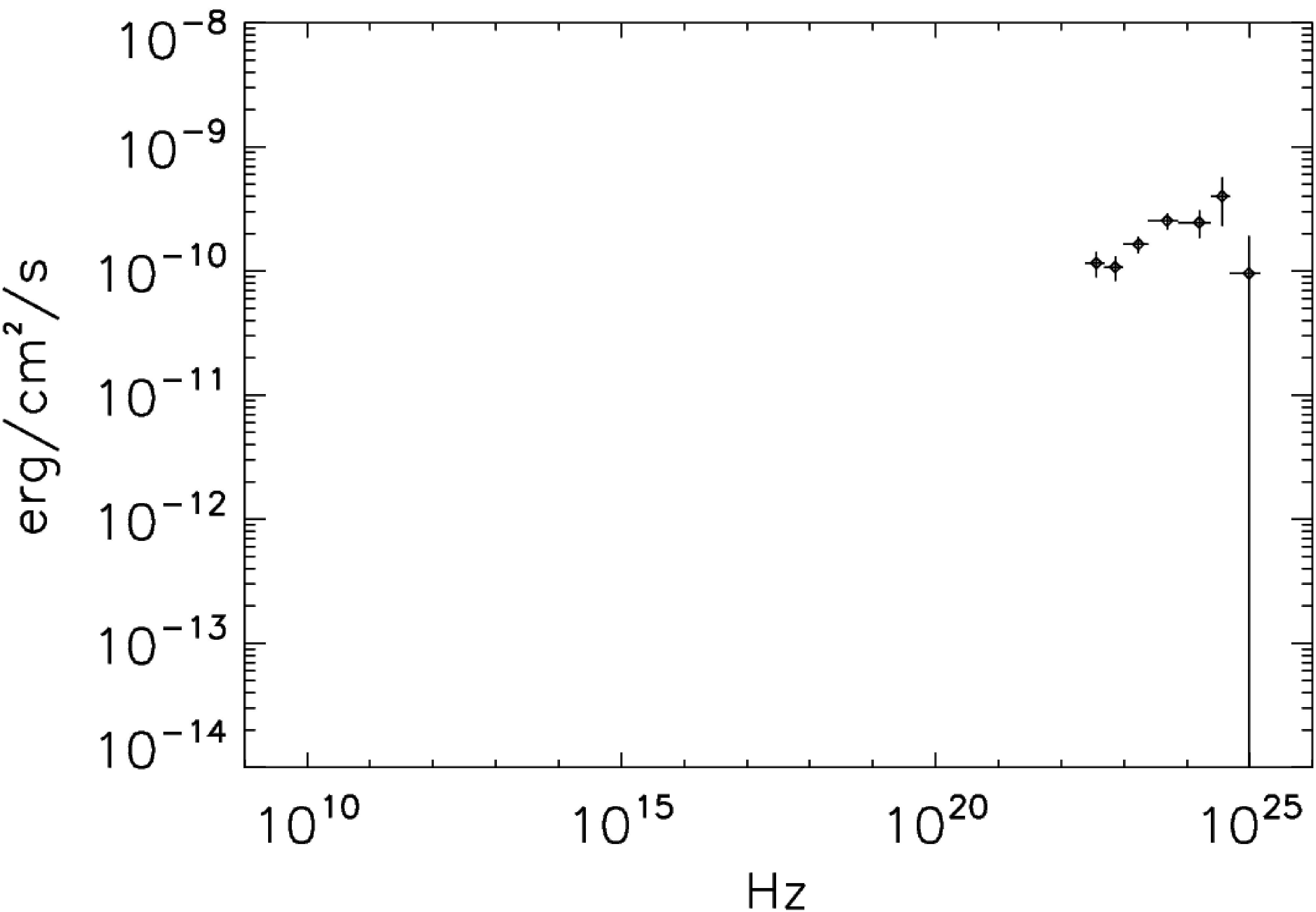


10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
erg/cm²/s
10^{10}
10^{15}
10^{20}
10^{25}
Hz

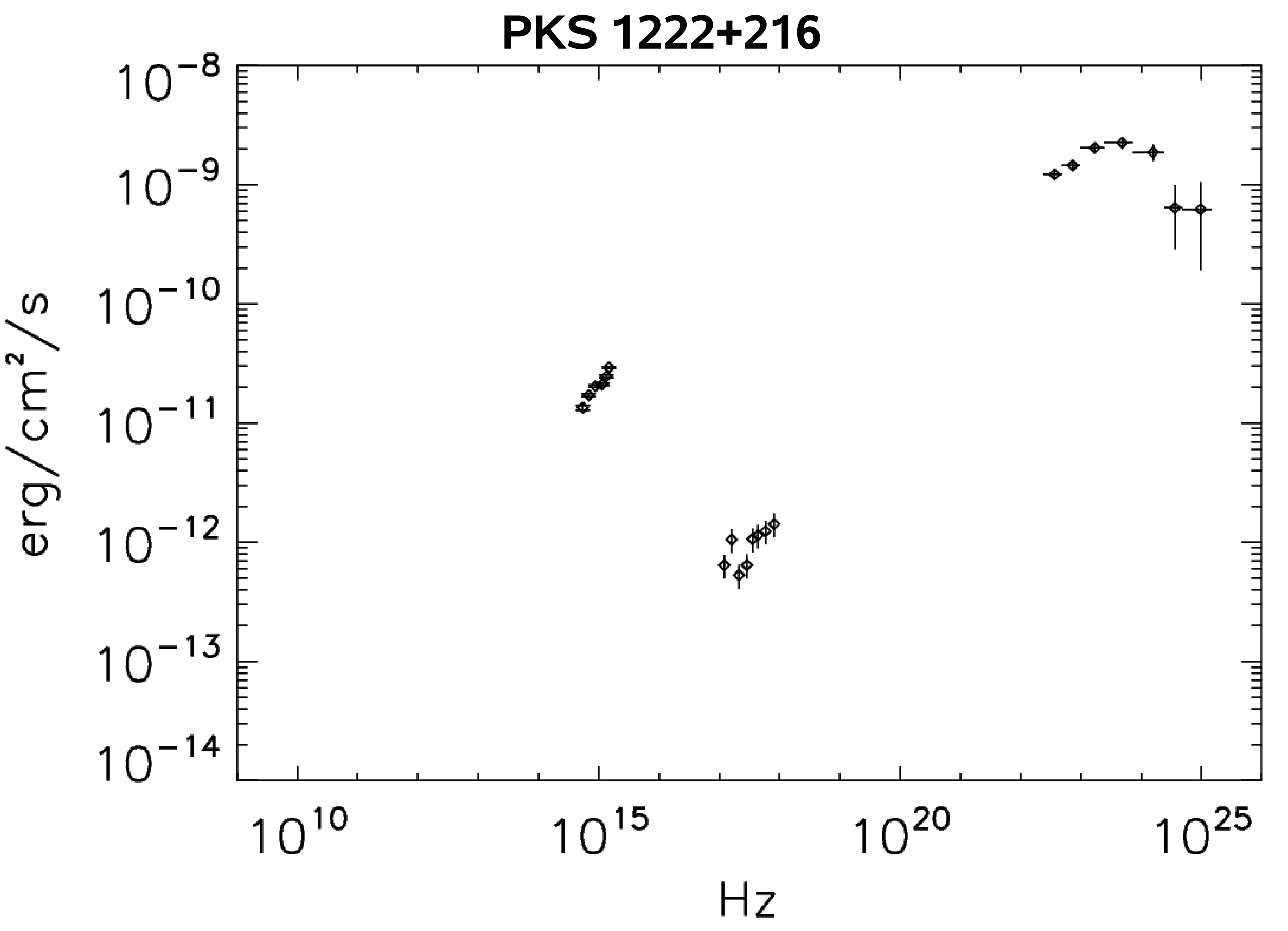


erg/cm²/s
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{10}
10^{15}
10^{20}
10^{25}
Hz


ufu (erg/cm2/s)
Energy (eV)
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{8}
10^{9}
10^{10}
10^{11}



10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
erg/cm^2/s
10^{10}
10^{15}
10^{20}
10^{25}
Hz


PKS 1222+216
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
erg/cm^2/s
10^{10}
10^{15}
10^{20}
10^{25}
Hz

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