RXTE and the extensive multifrequency campaigns on the classical TeV blazars Mrk421 and Mrk501 in the Fermi era

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Outline of the talk

1 – Introduction

→ Why MW campaigns Mrk421 and Mrk501 ?

2 – Some selected results from the 2009/2010 campaigns

→ Role of RXTE

3 - Conclusions

1.1- Introduction: towards understanding blazars…

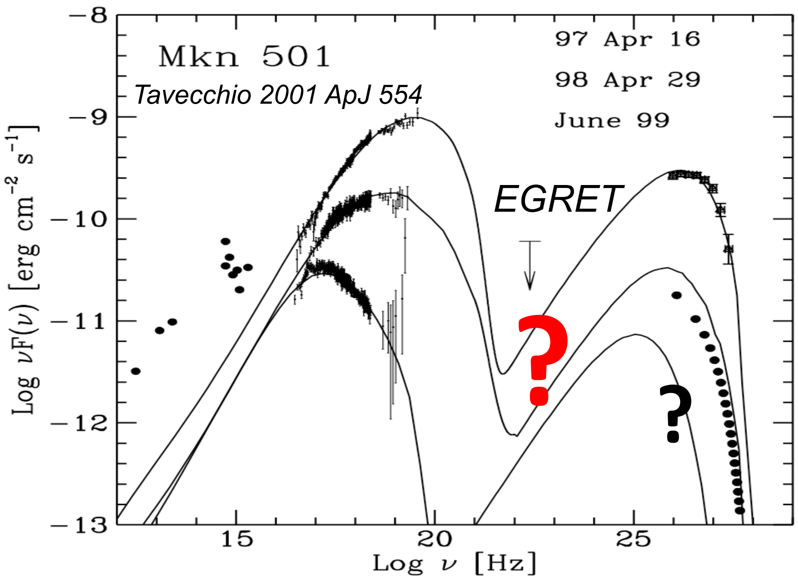
Culprits for the relatively poor knowledge of these objects

1 - Time-evolving broad band spectra

Coordination of instruments covering different energies needed

2 - Poor sensitivity to study high-energy part (E>0.1 GeV)

Large observation times (with EGRET and "old" IACTs) were required for signal detection *Data NOT simultaneous*, and *most of our HSP BL Lac knowledge regards the high state*



Sensitivity of gamma-ray instruments was poor even for the brightest gamma-ray sources

1.1- Introduction: towards understanding blazars…

Culprits for the relatively poor knowledge of these objects

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Recently, we had two "performance jumps" with respect to the past:

New Generation of IACTs online since 2004-2007 (low E_{th}, high sensitivity)

LAT in operation since fall 2008 (~30 times more sensitive than EGRET)

~100 times more sensitive at E>~10 GeV

Enhanced observational capability can be used to improve our knowledge on blazars

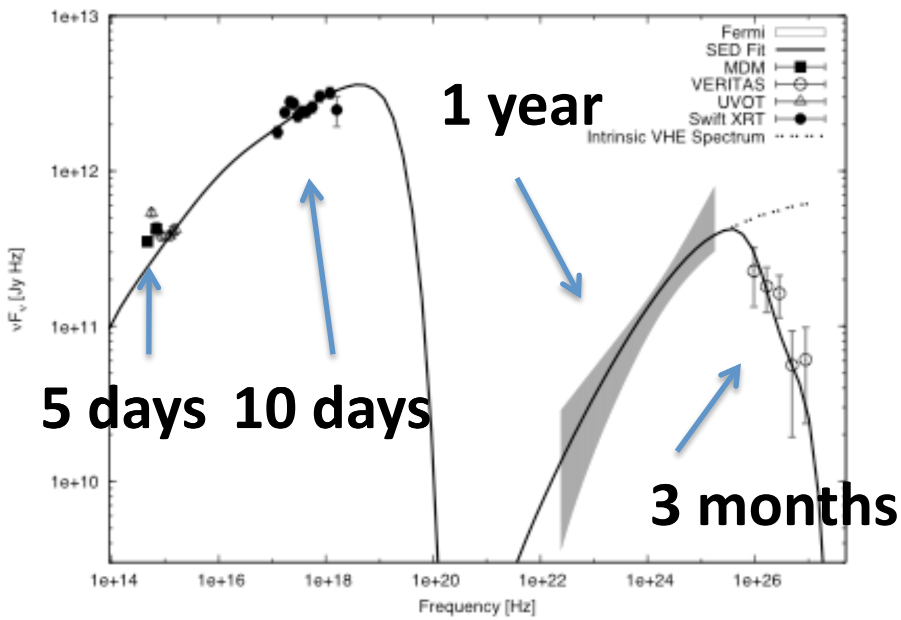
With Fermi and the new Cherenkov telescopes we boosted our technical ability to study blazars by opening (with sensitivity) a new portion (>5 orders of magnitude !!) of the electromagnetic spectrum

But scientific interpretation done in several papers must be taken with caveats due to the lack of simultaneity of the multi-instrument data

Astrophysical Journal Letters 715 (2010) L49-L55

It is a weak source; observations organized only after TeV detection

RGB J0710+591



It was not a planned-in-advanced campaign, but rather multi-instrument observations to complement a TeV detection

But because of that**, any conclusion from the SED modeling have to be taken with large caveats**

Instrument	Observing Period
VERITAS VHE	Dec 2008 - March 2009
Swift XRT & UVOT X-ray and O/UV	Feb 20 - March 2, 2009
MDM 1.3m tel R & B bands	Feb 19 - 24, 2009
Fermi HE	Aug 8 2008 - Aug 8 2009

1.2- Introduction: Campaigns on bright TeV blazars

It is difficult to organize truly contemporaneous observations of AGN sources and hence papers end up having "simultaneous" SED that are not that "simultaneous" (*different levels of simultaneity*)

Therefore, the SED modeling results have to be taken with caveats. The larger the non-simultaneity the larger the caveats

The approach we are following since 2009 is to substantially improve Temporal and Energy coverage of few sources in order to obtain SEDs as simultaneous as possible, as well as to be able to perform multi-frequency variability/correlation studies over a long baseline.

→ "easier" with the the brightest sources

→ TeV classical blazars: Mrk421 and Mrk501

1.3 – Intro: some info on Mrk421

RA =166.11 ; DEC=38.20
Z = 0.031
First extragalactic TeV emitter
(*Punch et al, 1992, Nature 358, 477*)

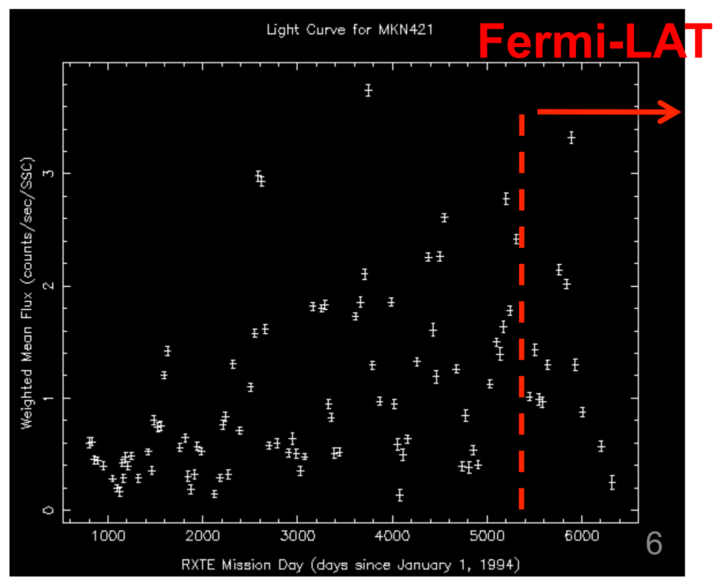
Known to be one of the fastest varying gamma-ray sources (*Gaidos, J.A. et al, 1996, Nature 383, 319; and many other publications*).

All detections of EGRET (9 years of operation)

Source VP[a]	(RA, Dec) MJD Range	Flux[b]	$\sqrt{(TS)}$[c]	Gamma[d]
Mrk 421	(166.10, 38.15)			
0.6	48383.7-386.8	19.7±11.3	2.2	. . .
4.0	48435.8-449.7	15.6±3.8	5.4	2.07±0.28
40.0	48882.7-903.6	21.6±6.9	4.0	2.01±0.34
V+218.0	49097.6-138.6	11.2±4.5	3.0	
V+227.0	49167.6-195.5	15.1±5.9	3.4	2.68±0.39
326.0	49482.7-489.6	24.4±6.7	5.3	1.47±0.29
V+322.0	49447.6-489.6	13.7±3.3	5.5	1.20±0.27

Detection significance (EGRET) <~ 5 sigma

RXTE/ASM Light Curve (2-10 keV)



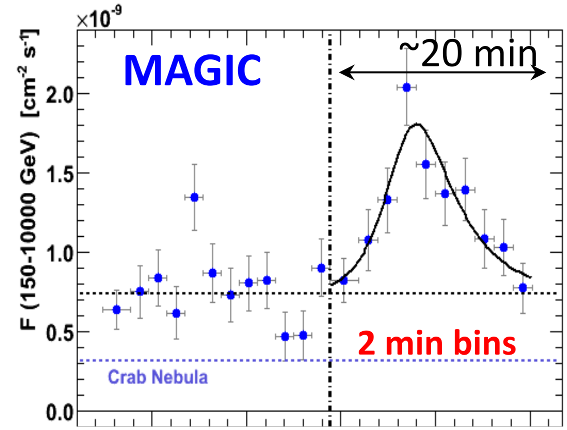
So far we lacked info on Gamma-ray emission

Fermi-LAT provides key/missing information

1.4 – Intro: some info on Mrk 501

RA =253.47 ; DEC = 39.76 , z = 0.034
2nd Extragalactic source detected at TeV
(*Quinn et al., 1996, ApJ, 456, L83*)

- Large flare in 1997 (many publications)
- Short flux variations detected in 2005
Albert et al., 2007, ApJ, 669, 862

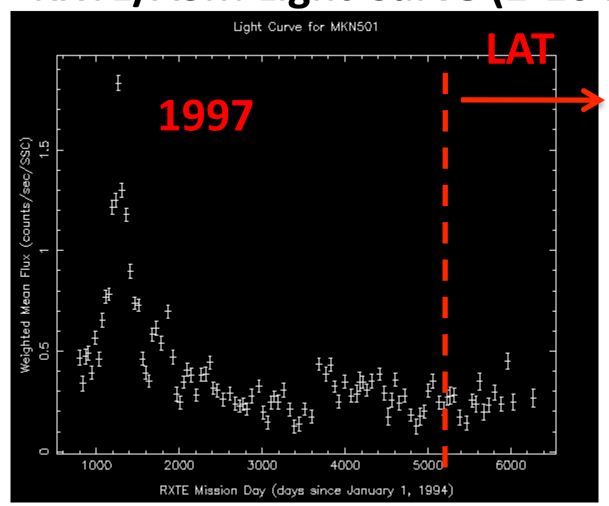


Not present in 3rd EGRET catalogue

The only detection (*~5 sigma at >500 MeV; 4 sigma at >100 MEV*) with EGRET was during a gamma-ray orphan flare in 1996 (Kataoka et al., 1999)

No EGRET detection during the big outburst in 97

RXTE/ASM Light Curve (2-10 keV)



Source is relatively low at X-rays since Fermi operation

1.5 – Intro: Advantages of studying Mrk421 and Mrk501

Exquisite characterization of the high energy component, which can be detected with Fermi and Cherenkov Telescopes over 5 orders of magnitude (0.1GeV – 10 TeV)

Excellent laboratory for studying High Energy blazar emission

Strong gamma ray source &
Nearby object; z = 0.03; "low" EBL absorption, we see "almost" intrinsic features

Knowledge acquired with Mrk421 and Mrk501 might be applied to other objects (fainter and/or larger z)*. Or maybe not… some sources might be special. CAVEAT (!!)*

Things we know about those classical TeV sources (and HBLs in general)

Dominant gamma-ray emission mechanism is believed to have a leptonic origin (SSC) , at least in high (flaring) state

- Fast variations (down to hours and sub-hours in VHE)
- X rays- Gamma-rays correlation (in general)

1.6 – Introduction : Extensive MW Campaigns

•More than 25 instruments participate covering frequencies from radio to TeV

Radio: VLBA, OVRO, Effelsberg, Metsahovi…
mm: SMA, IRAM-PV
Infrared: WIRO, OAGH
Optical: GASP, GRT, MITSuMe, Kanata…
UV: Swift-UVOT
X-ray: Swift/XRT, RXTE/PCA,RXTE/ASM
Swift/BAT
Gamma-ray: Fermi-LAT
VHE: MAGIC, VERITAS

Sources monitored regardless of activity

1.6 – Introduction : Extensive MW Campaigns

https://confluence.slac.stanford.edu/display/GLAMCOG/Fermi+LAT+Multiwavelength+Coordinating+Group

Past MW campaigns

Mrk421 (Jan19th, 2009-Jun1st ,2009: 4.5 months)- Planned observations: every 2 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2009/Obs.html

Mrk501 (Mar15th, 2009-Aug1st,2009: 4.5 months) -Planned observations: every 5 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk501_2009/Obs.html

Mrk421 (Dec8, 2009-Jun20 ,2010: 6 months)- Planned observations: every 1 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2010/Obs.html

Mrk421 (Dec1, 2010-Jun15 ,2011: 6 months)- Planned observations: every 2 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2011/Obs.html

Mrk501 (March1, 2011-Sep1,2011: 6 months) -Planned observations: every 3 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk501_2011/Obs.html

Current MW campaigns

Mrk421 (Dec23, 2011-May31 ,2012: 5.5 months)- Planned observations: every 2 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2012/Obs.html

Mrk501 (Feb15, 2012-June31,2012: 4.5 months) -Planned observations: every 4 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk501_2012/Obs.html

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Mrk421 (Dec8, 2009-Jun20 ,2010: 6 months)- Planned observations: every 1 days
http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2010/Obs.html

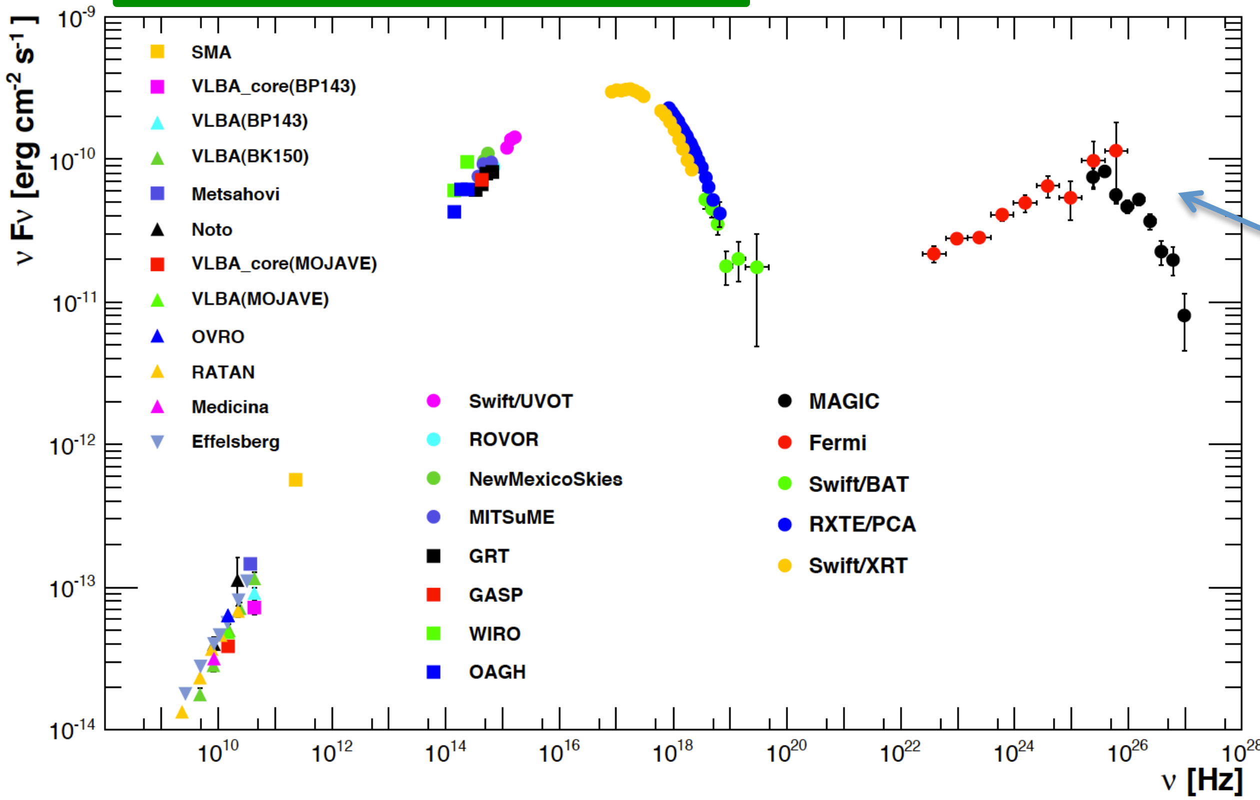
→ I will report some results from the 2009 and 2010 campaigns (→ recent and ongoing publications)

2 – Some Results from the 2009 and 2010 multi-instrument campaigns for Mrk421 and Mrk501

Broad Band (radio-TeV) SED of Mrk421

Average SED from the campaign observations

Abdo et al 2011, ApJ 736, 131



Mk421 was in relatively low state during the entire campaign

Fermi – MAGIC spectra cover, for the first time, the complete high energy component over 5 orders of magnitude without gaps

Most complete SED ever collected for Mrk421

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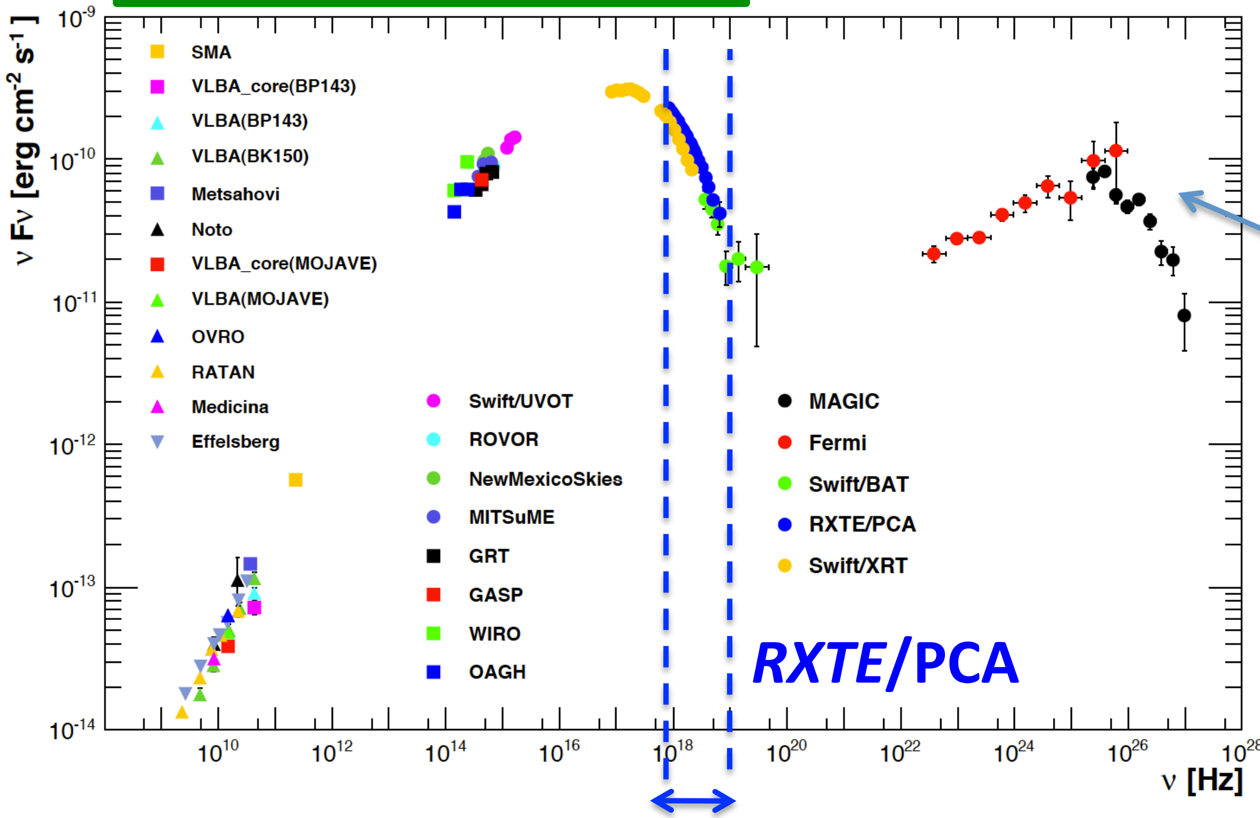

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RXTE/PCA brings important information:

BL Lacs (like Mrk421 and Mrk501)→ Synch. of high-energy electrons from Jet

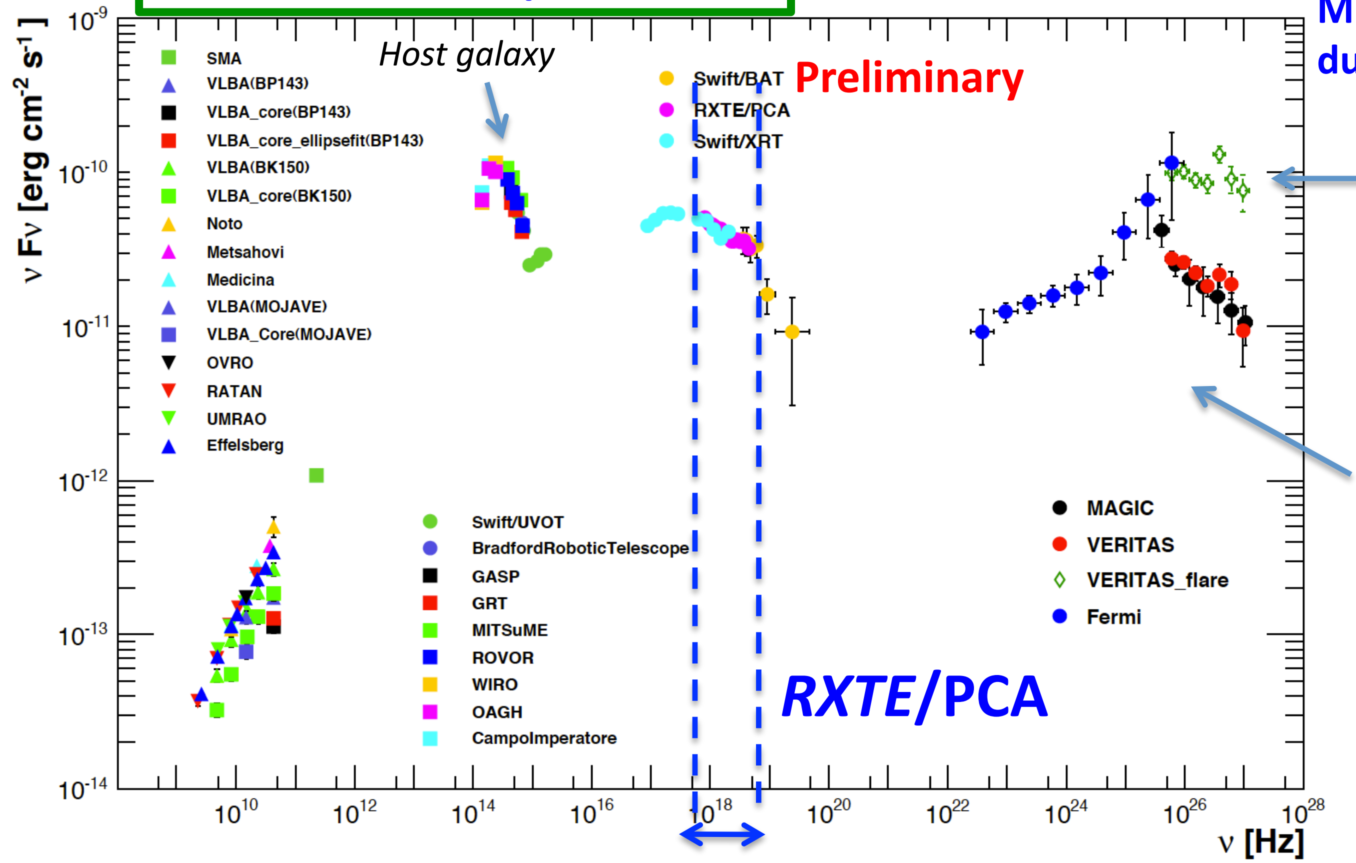
FSRQ → Inv. Compton of "low energy" elec. from Jet

Seyfert → Thermal comptonization from disk/corona

Broad Band (radio-TeV) SED of Mrk501

Average SED from the 2009 MW campaign on Mrk501

Abdo et al 2011, ApJ 727, 129



Mk501 was in relatively low state during most of the campaign

3-day spectrum from TeV flaring activity

For first time, Fermi–MAGIC/VERITAS spectra cover the complete high energy component over 5 orders of magnitude without gaps

Most complete SED ever collected for Mrk501

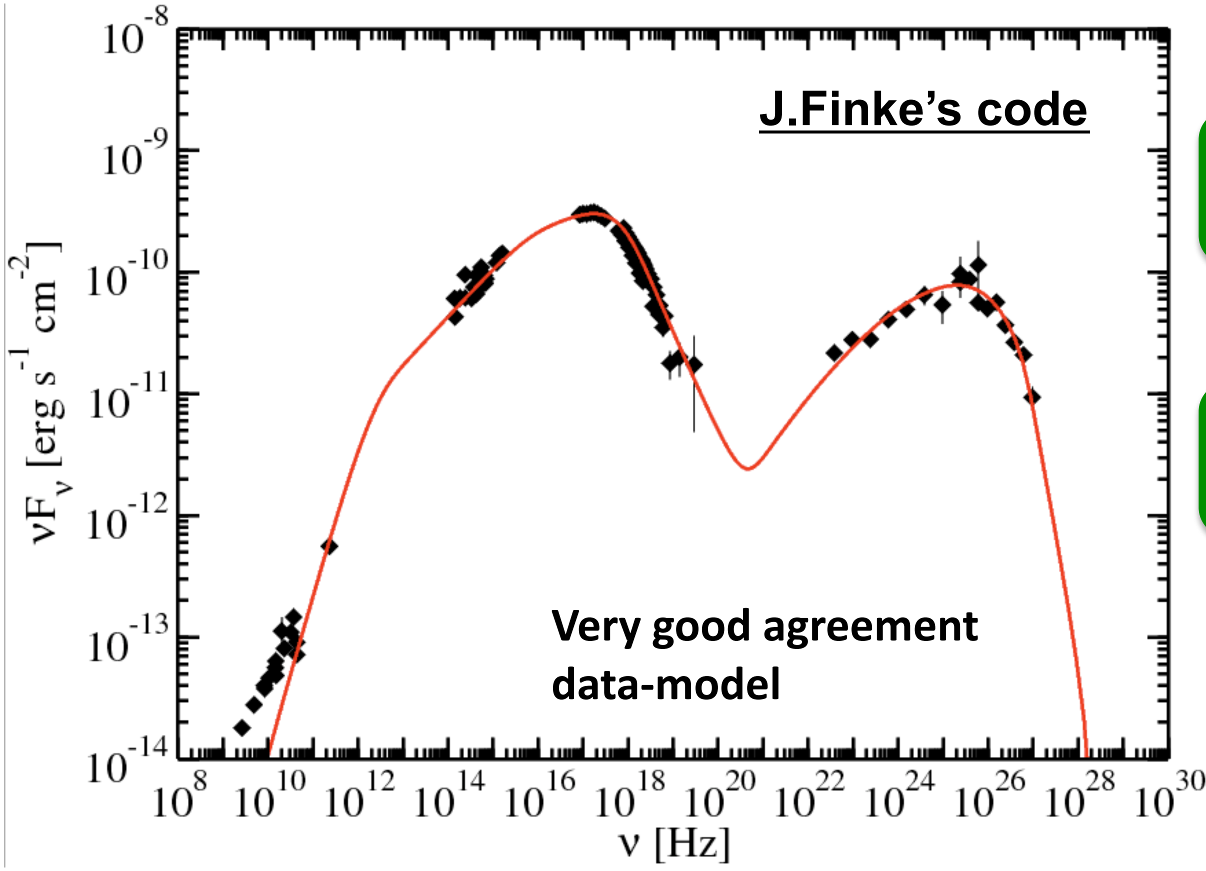
2.2 – Modeling the Mrk421 SED

"Standard approach" in modelling TeV-emitting BL Lacs:
one-zone homogeneous synchrotron self-Compton (SSC) scenario.

Two breaks in the electron energy distribution (EED) are required to fit the data

$$n'_e(\gamma) \propto \begin{cases} \gamma^{-s_1} & \text{for} \quad \gamma_{min} \leq \gamma < \gamma_{br,1} \\ \gamma^{-s_2} & \text{for} \quad \gamma_{br,1} \leq \gamma < \gamma_{br,2} \\ \gamma^{-s_3} \exp\left[-\gamma/\gamma_{max}\right] & \text{for} \quad \gamma_{br,2} \leq \gamma \end{cases}$$

2.2 – Modeling the Mrk421 SED



R [cm]	5.2e16
B [G]	3.8e-2
delta	21.0
η_e	10
γ_{min}	800
s1	2.2
γ_{brk_1}	5.e4
s2	2.7
γ_{brk_2}	3.9e5
s3	4.7
γ_{max}	1.0e8

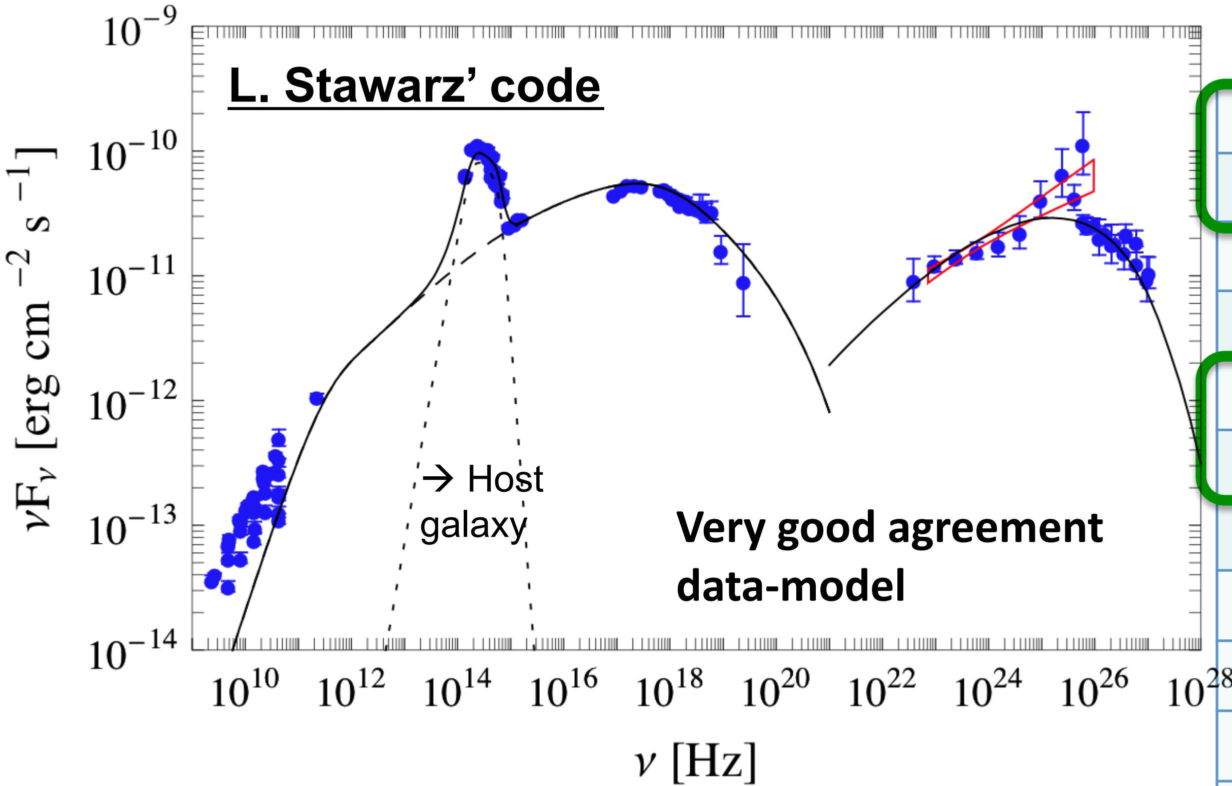
Modeling results differ with respect to previous Mrk421 modeling in several parameters (R,B, γ_{min} and s1)

Main reasons for the difference is that in the past:

- Mrk421 was modeled mostly during flaring activity
- The models typically considered only X-ray and TeV

In this work we used the entire broad-band SED during a low state

2.2 – Modeling the Mrk501 SED



R [cm]	1.3e17
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2.2 – Modeling the Mrk501 and Mrk421 SED

Mrk501: Stawarz' code

R [cm]	1.3e17
B [G]	1.5e-2
delta	12.0
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γ_{min}	600
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Mrk421: Finke's code

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Similar model parameters for Mrk421 and Mrk501 (both during relatively low activity)

Is it by chance ?? Or are we dealing with some common properties for those 2 objects ??
Can we extrapolate this to other HSP - BL Lacs ??

2.2 – Modeling the Mrk501 and Mrk421 SED

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s1	2.2
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γ_{brk_2}	3.9e5
s3	4.7
γ_{max}	1.0e8

High γ_{min} and s1=2.2 is consistent with the models of diffuse (1st order Fermi) particle acceleration in relativistic, proton-mediated shocks

Efficient acceleration for electrons above γ_{min} = 600-800

2.2 – Modeling the Mrk501 and Mrk421 SED

Mrk501: Stawarz' code

Abdo et al 2011, ApJ 727, 129

R [cm]	1.3e17
B [G]	1.5e-2
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s3	3.7
γ_{max}	1.5e7

Comparable within factor ~2–4 to the VLBA core size

Mrk421: Finke's code

Abdo et al 2011, ApJ 736, 131

R [cm]	5.2e16
B [G]	3.8e-2
delta	21.0
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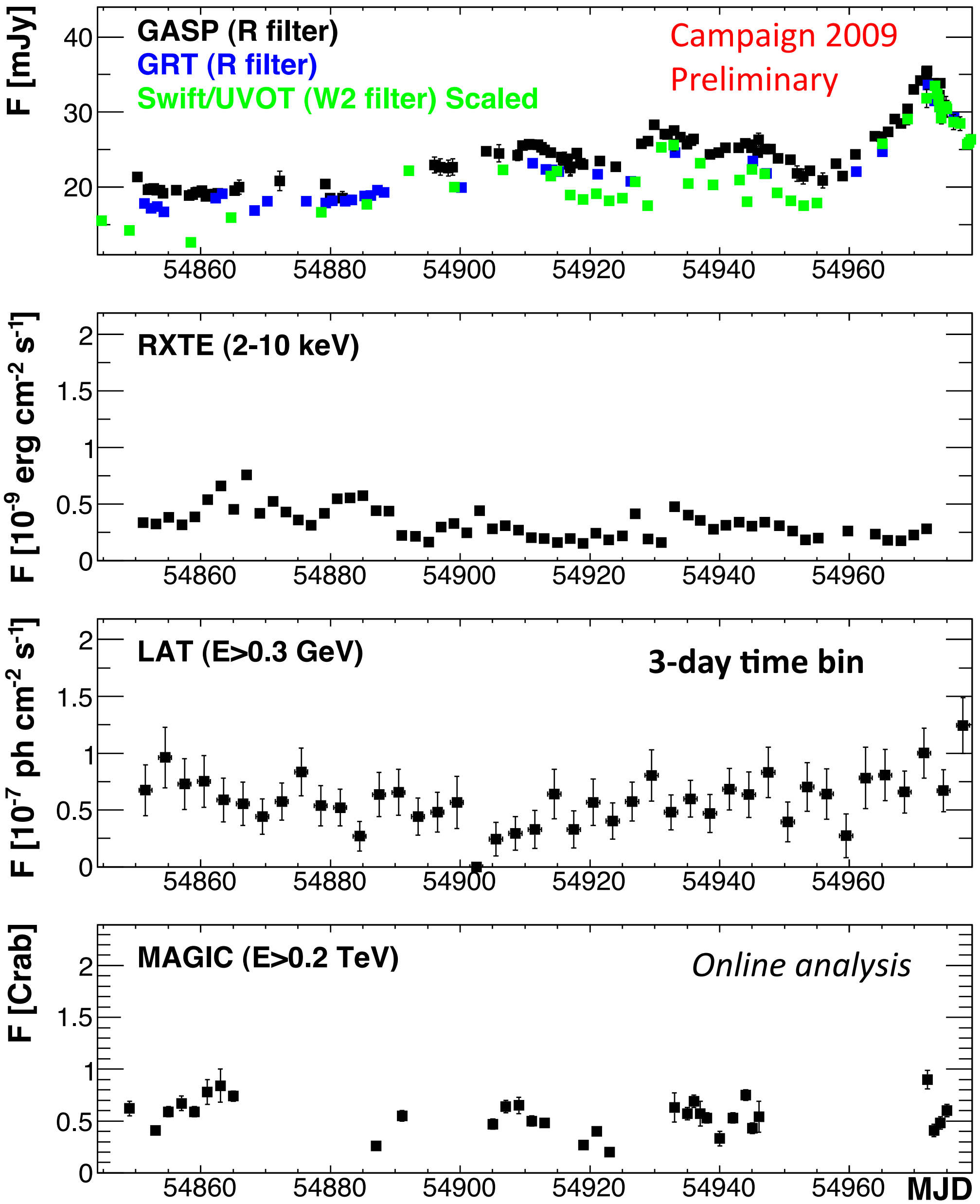
s3	4.7
γ_{max}	1.0e8

Mrk501: 0.15 mas ~ 3e17 cm , which is 3 times the size of the SSC blob
Mrk421: 0.06-0.12 mas ~ 1 – 2 e17 cm , which is 2 – 4 times the size of the SSC blob
Have we found the location of blazar emission for these objects ?
→ Variability/correlation studies will give us a definite answer

2.3 - Mrk421: Multi-frequency activity (2009 Campaign)

Preliminary



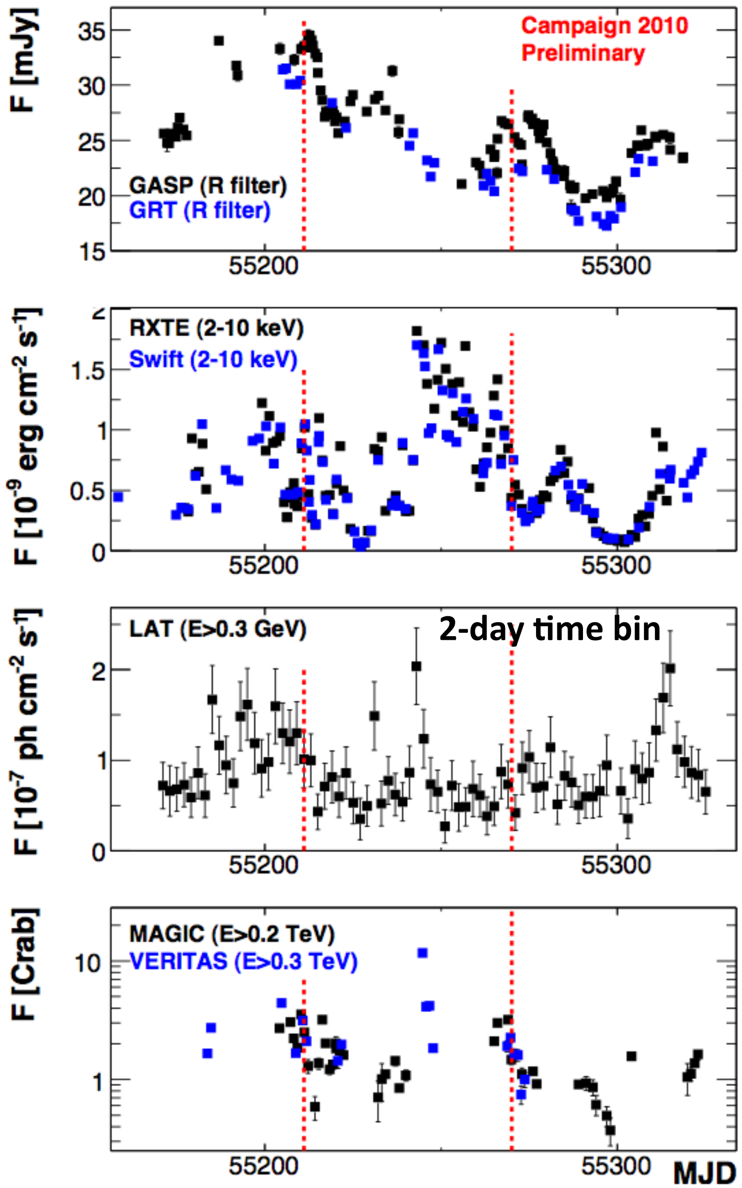
Only some instruments are shown !!!!

During the 2009 campaign the flux variations were relatively mild

2.3 - Mrk421: Multi-frequency activity (2010 Campaign)

Only some instruments are shown !!!!

Preliminary



MW Data shown in these plots spans from Dec2009 to May2010

→*large variability at all energies!!*

Great opportunity to study blazar variability

Large complexity in the multi-frequency variability. *Different flavors of flaring activity*

The only chance we have to advance our understanding of Mrk421 is to deal with all energy bands simultaneously during a long baseline

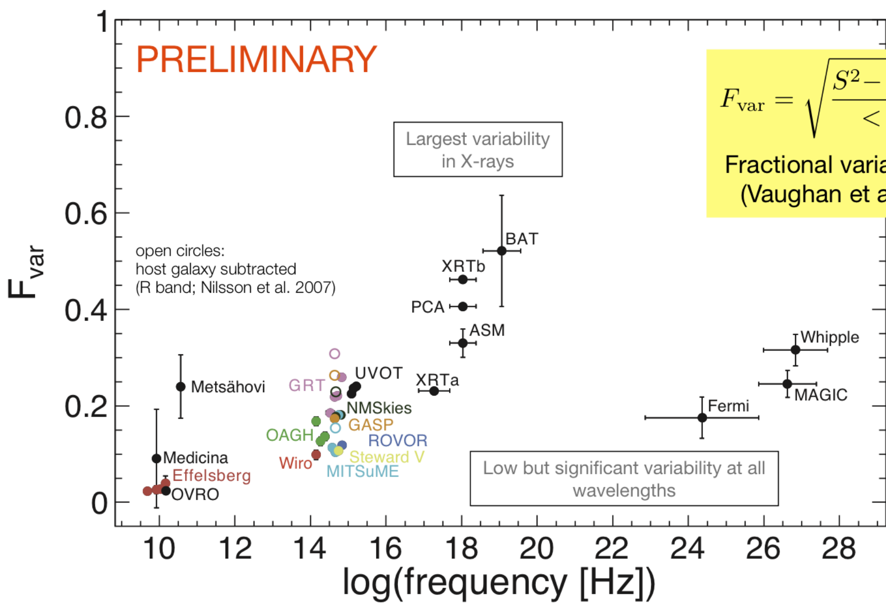
Log scale in vertical axis !!

2.3 – Mrk421: Multi-frequency activity

Fractional variability vs energy

Work in progress (Nina Nowak and Shangyu Sun, from MPI Munich)

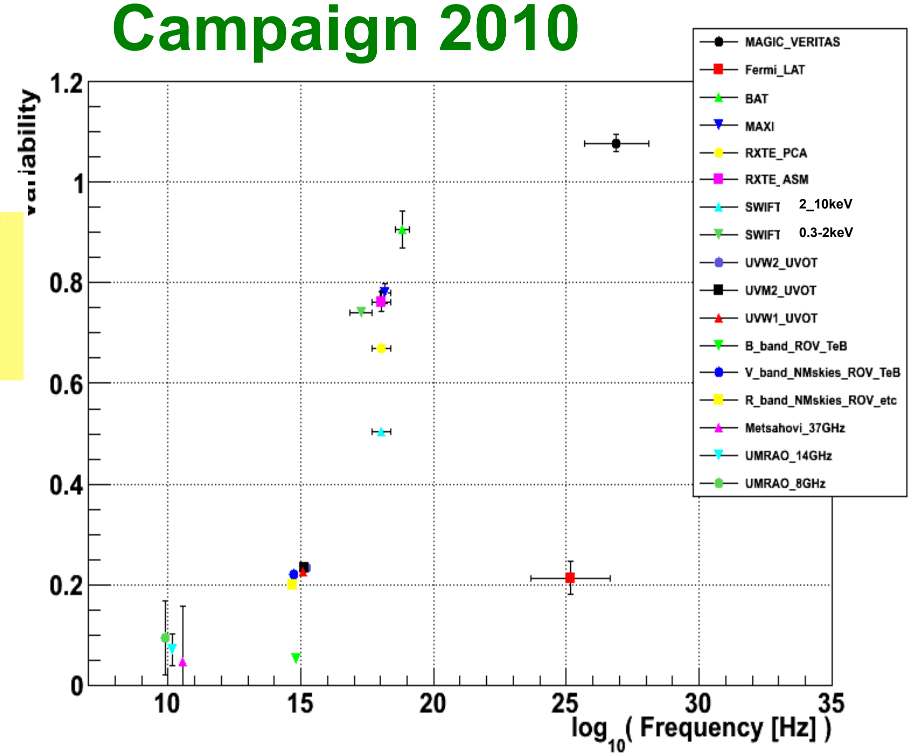
Campaign 2009



$$F_{\rm var} = \sqrt{\frac{S^2 - <\sigma^2_{\rm err}>}{<F_\gamma>^2}}$$

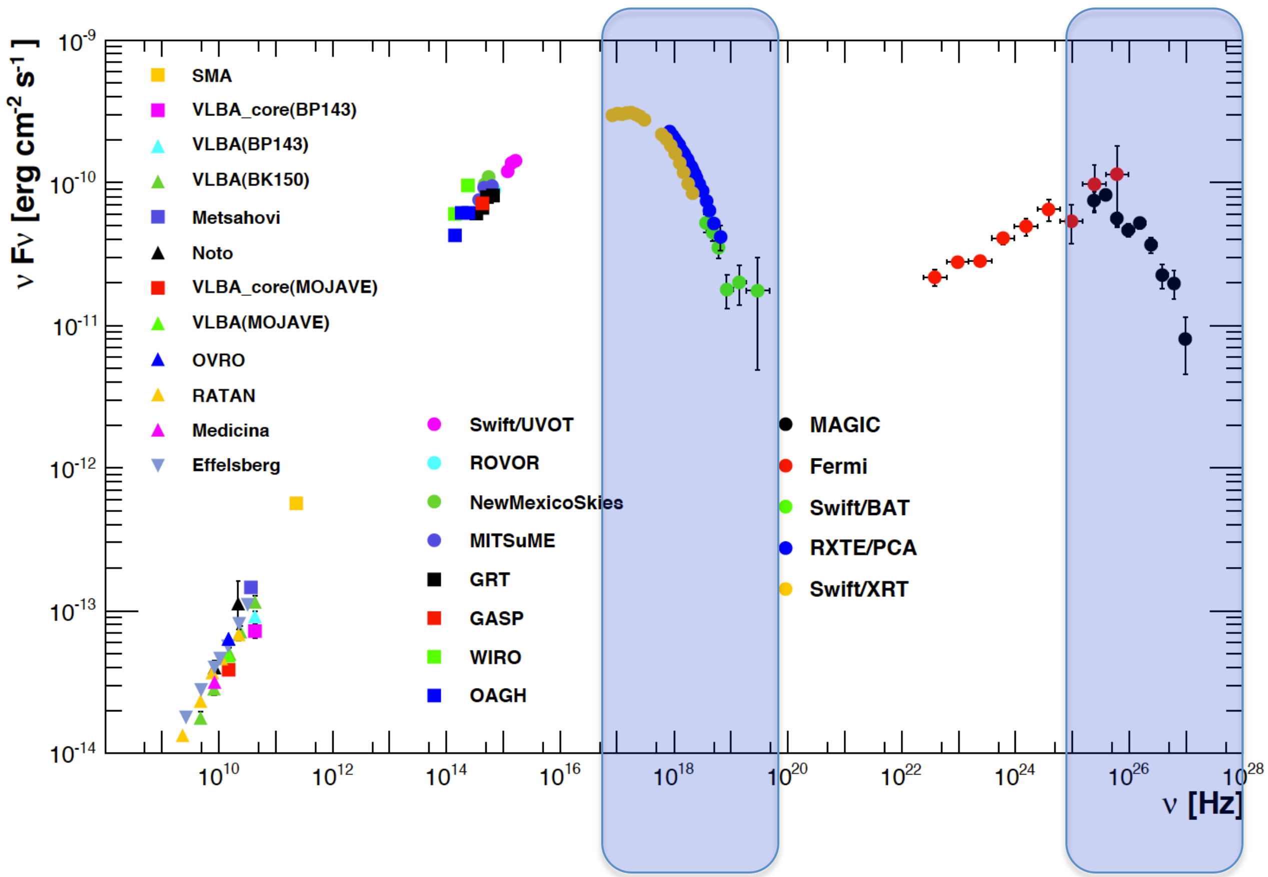
Fractional variability F_{var} (Vaughan et al. 2003)

Campaign 2010



Variability in radio, optical and GeV did not change much, but <u>variability in X-rays and TeV energies increased by a factor of ~2 and ~4 respectively</u>

2.3 – Mrk421: Multi-frequency activity

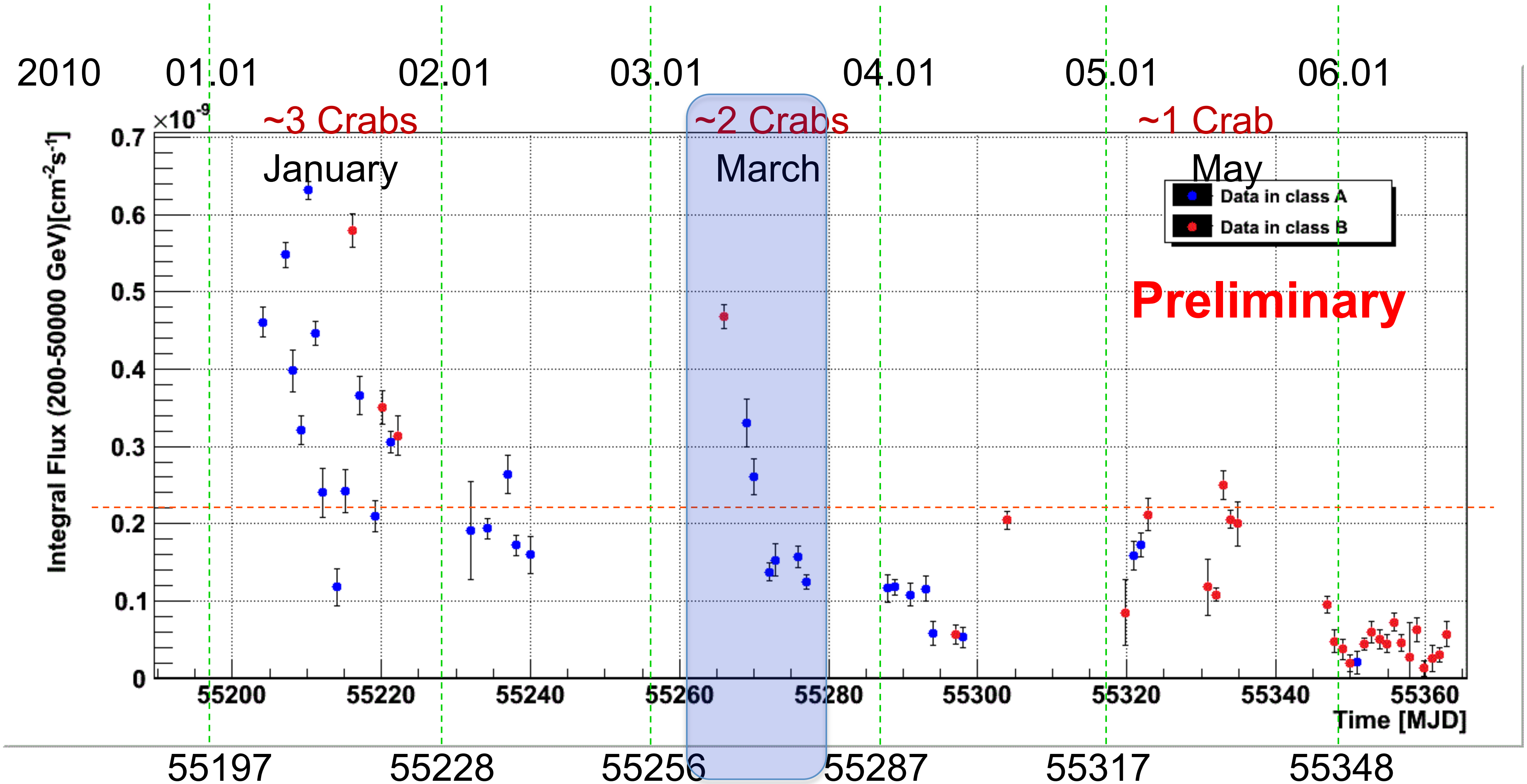


These are portions of the spectrum that vary most

→ In SSC scenario, these energies are produced by the highest-energy electrons

2.4 – Mrk421: Evolution of SED during flare

TeV-flux measured by MAGIC during the 2010 campaign



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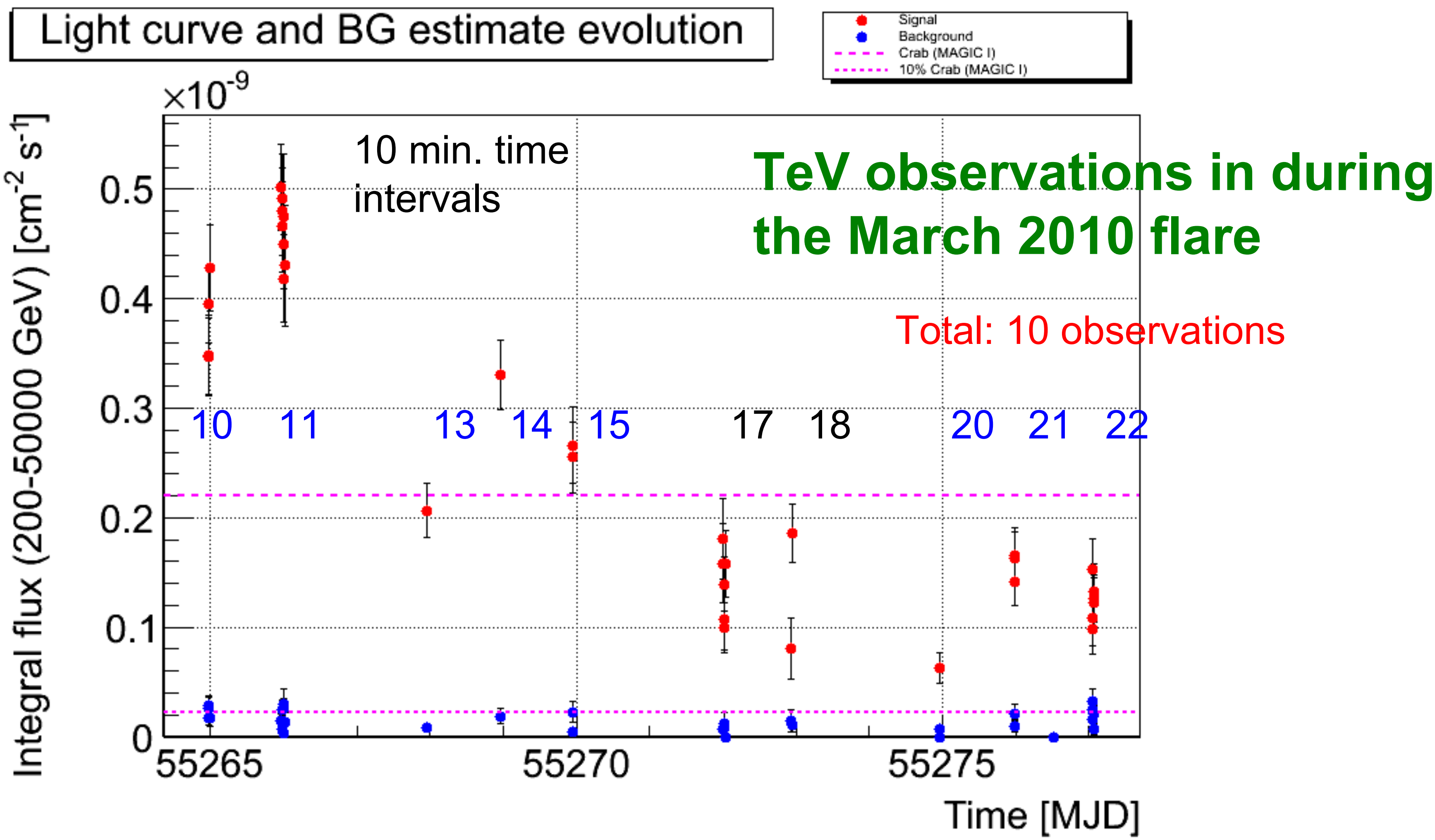
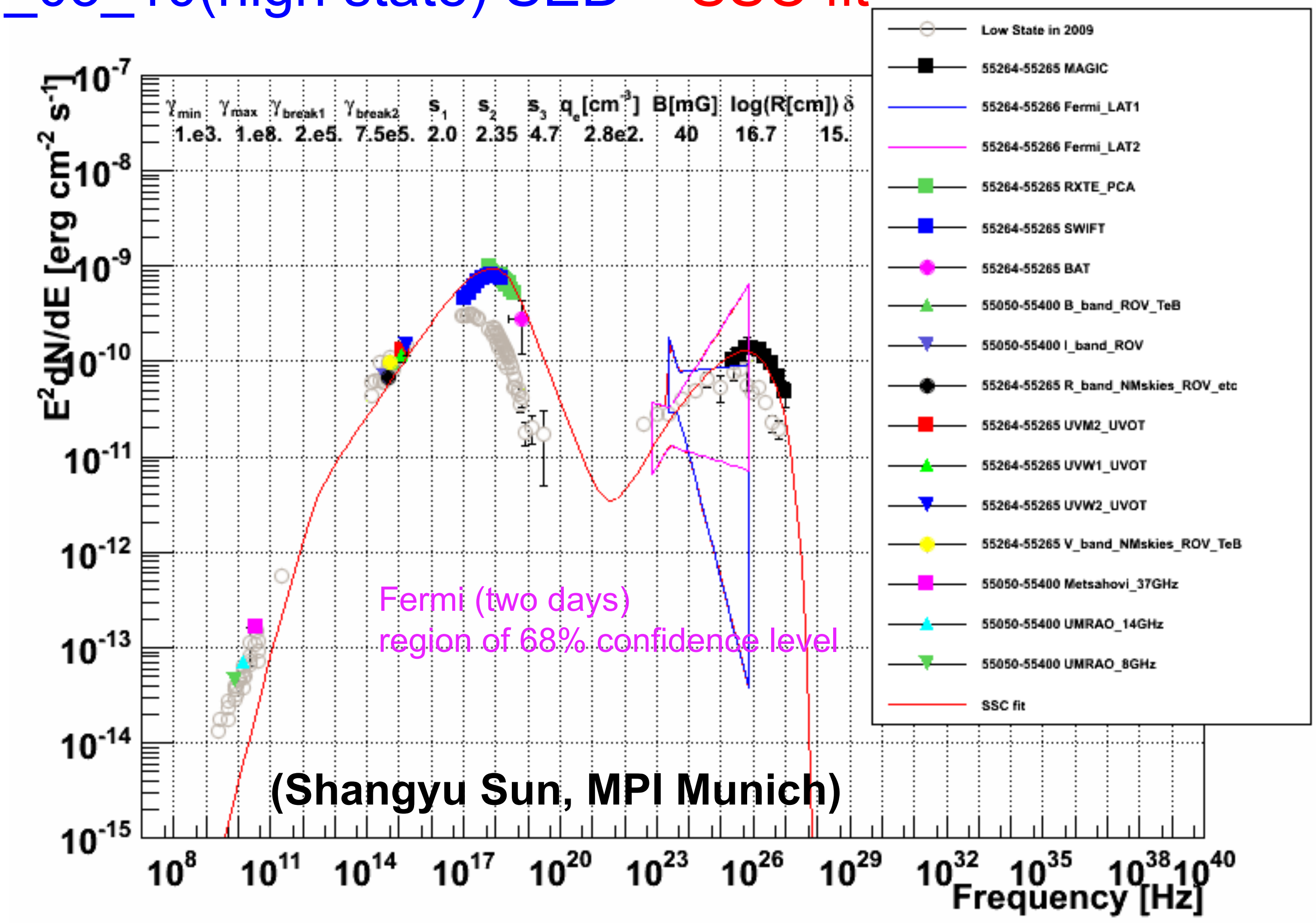
TeV-flux measured by MAGIC during the 2010 campaign (Shangyu Sun, MPI Munich)



Mrk421 MW 2010_03_10 (55265)

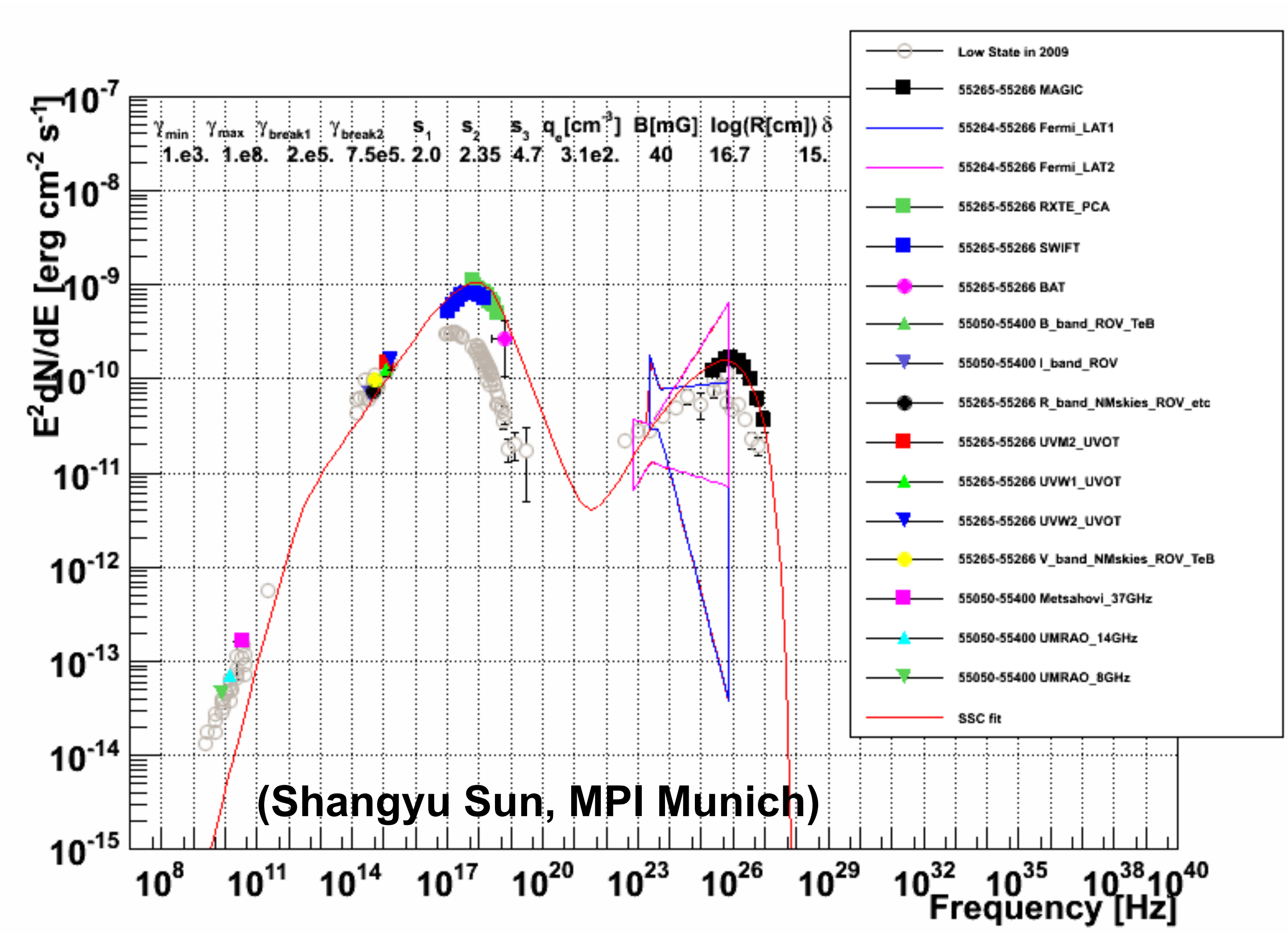
2009 average SED (low state) **Preliminary**

2010_03_10(high state) SED + SSC fit



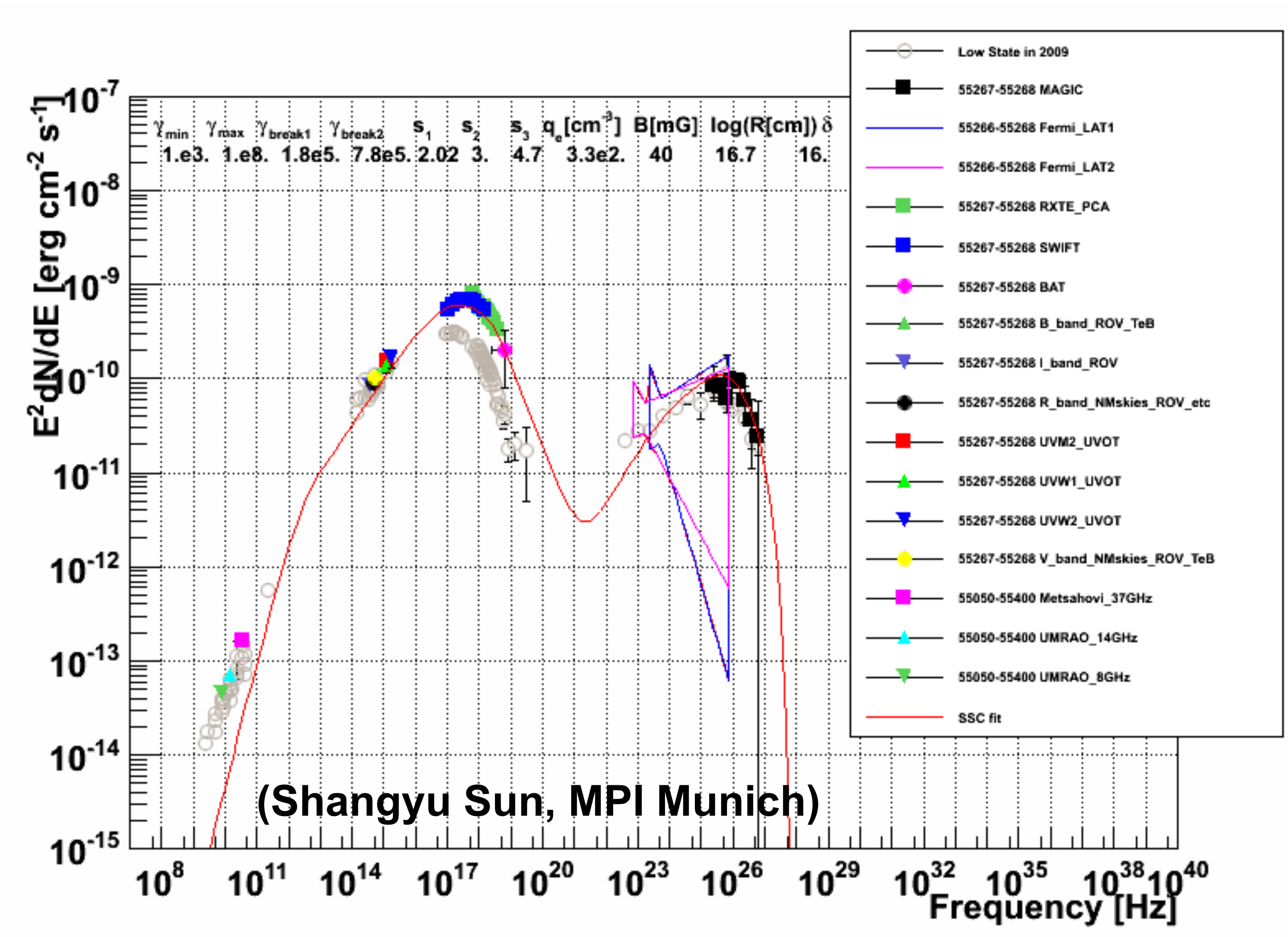
Mrk421 MW 2010_03_11 (55266)

Preliminary



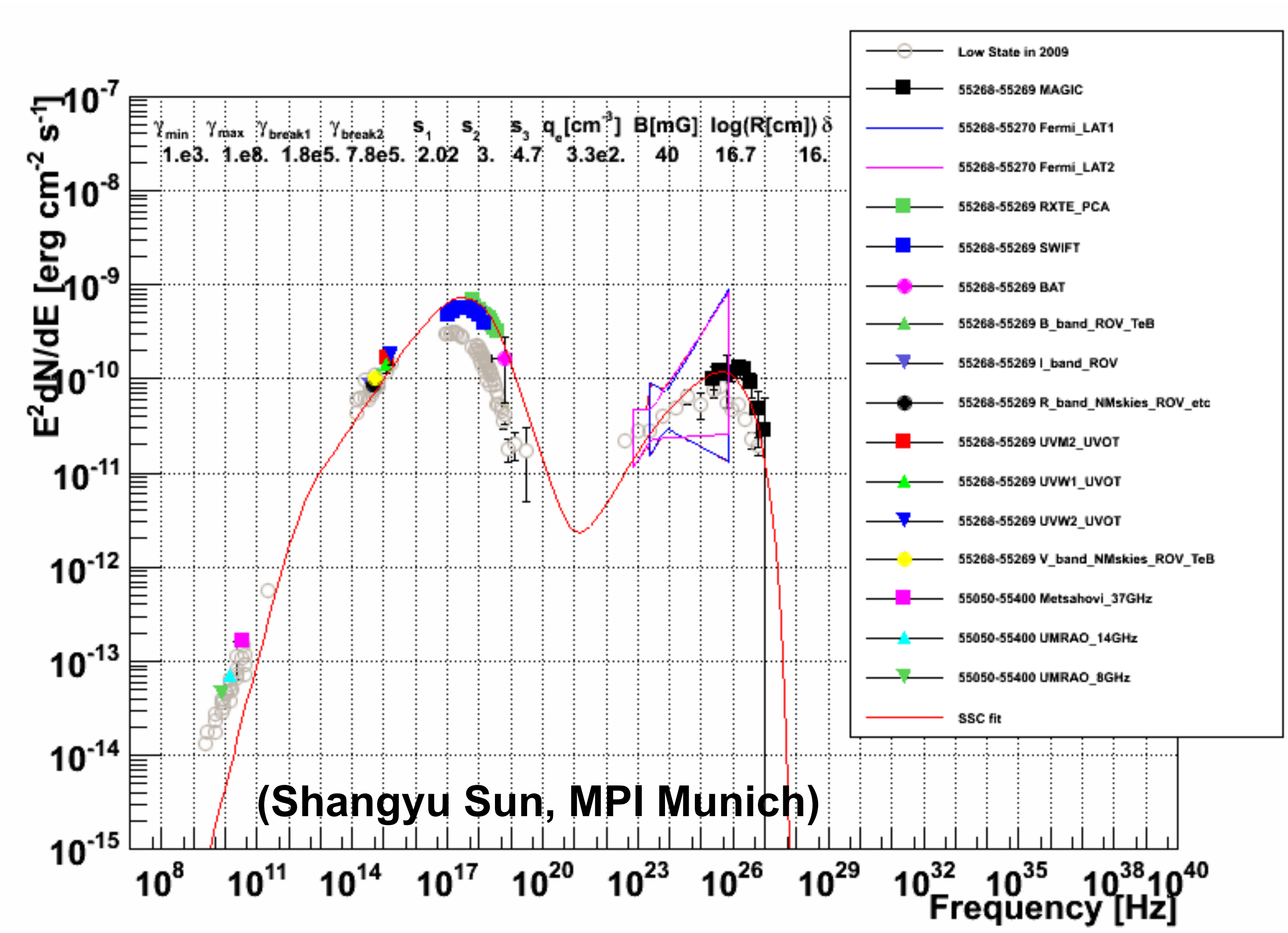
Mrk421 MW 2010_03_13 (55268)

Preliminary



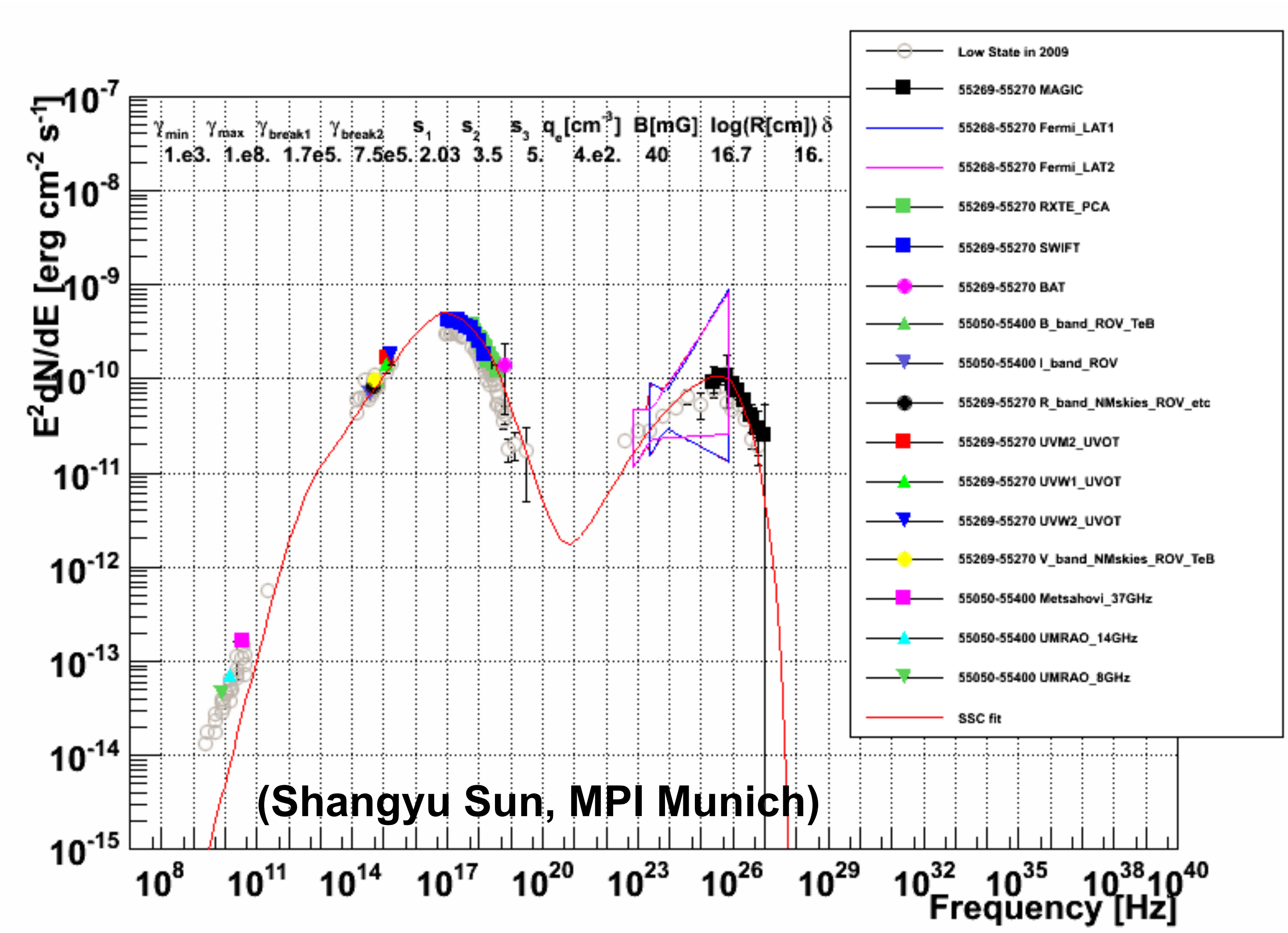
Mrk421 MW 2010_03_14 (55269)

Preliminary



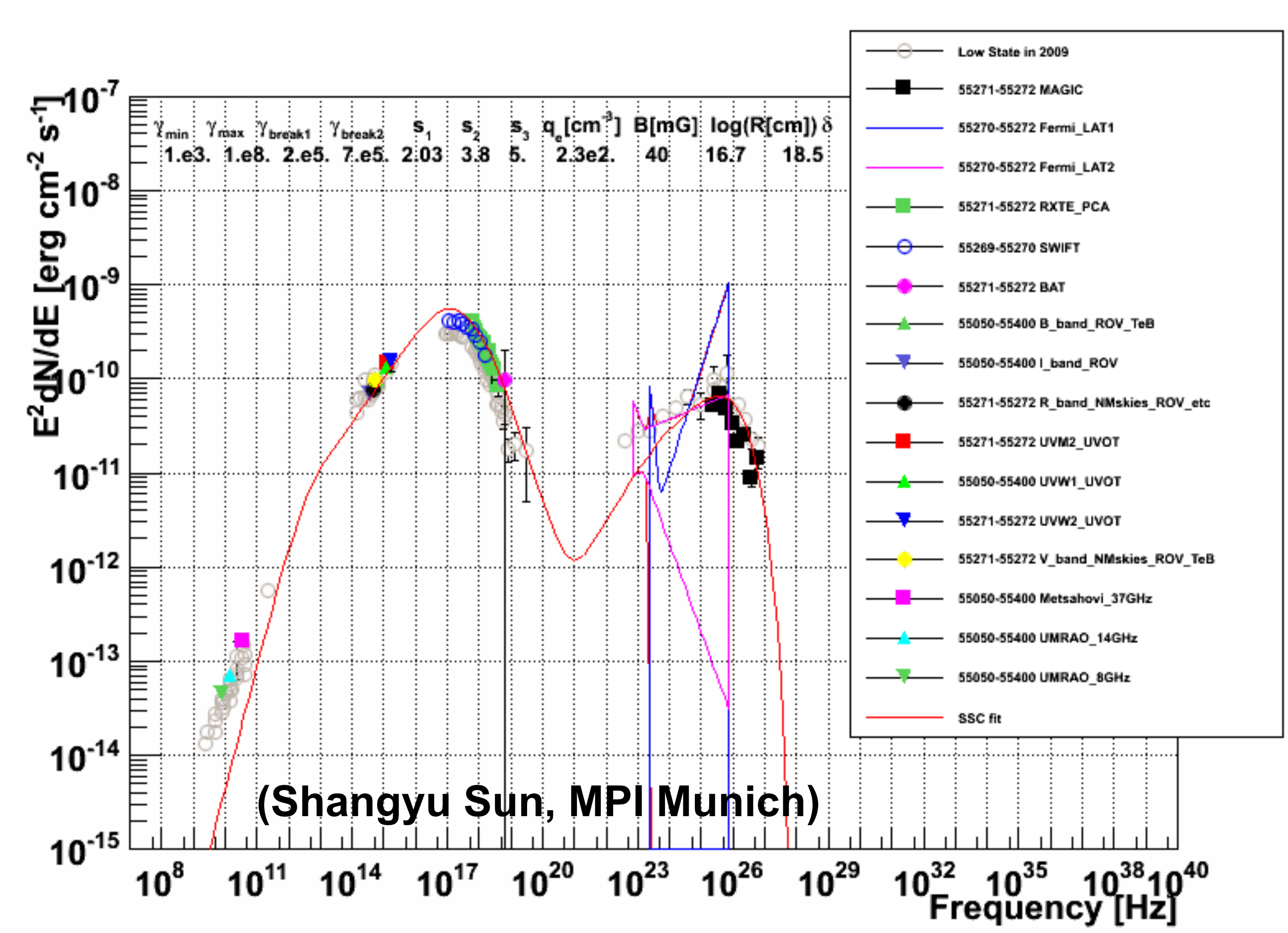
Mrk421 MW 2010_03_15 (55270)

Preliminary



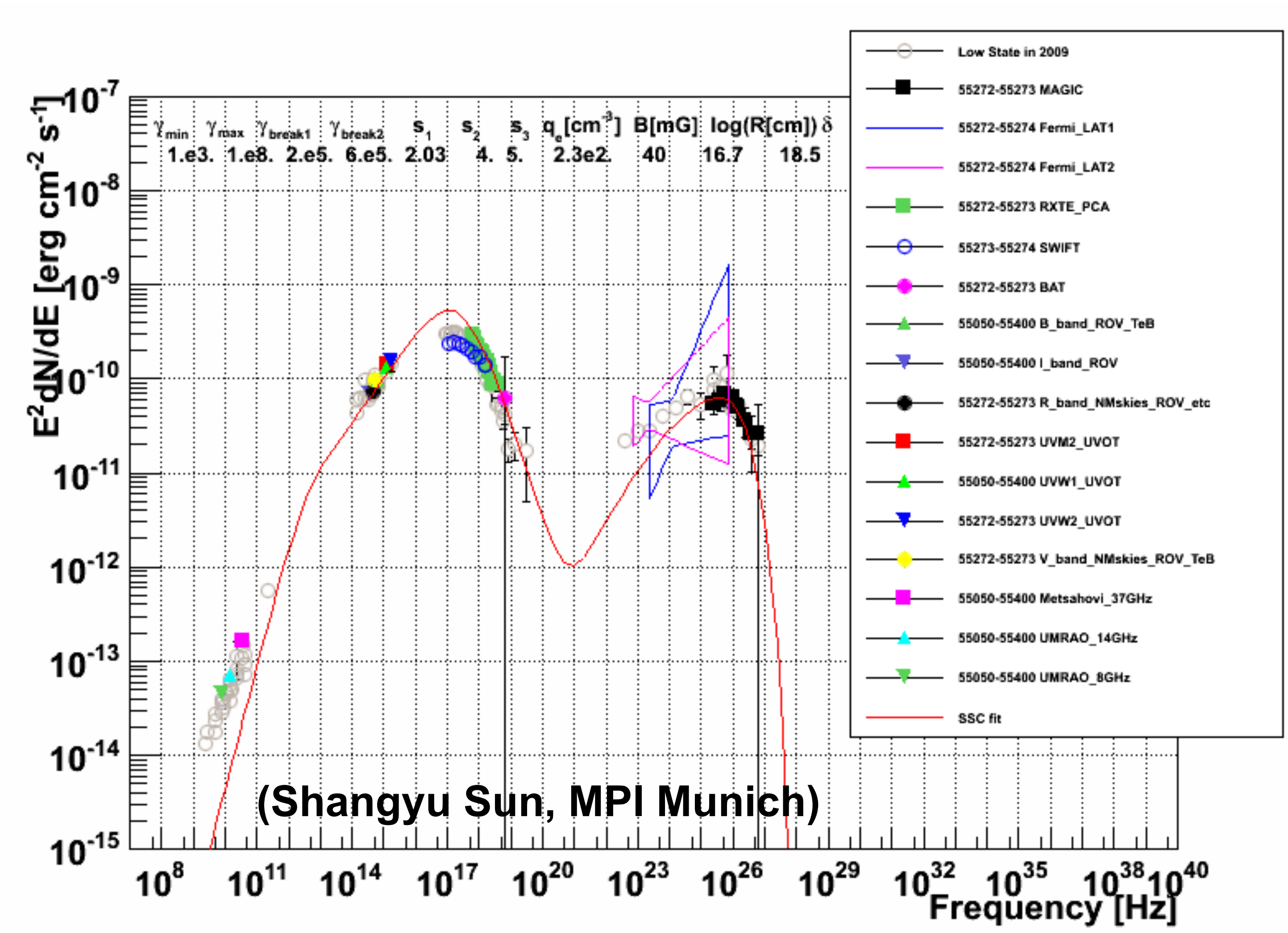
Mrk421 MW 2010_03_17 (55272)

Preliminary



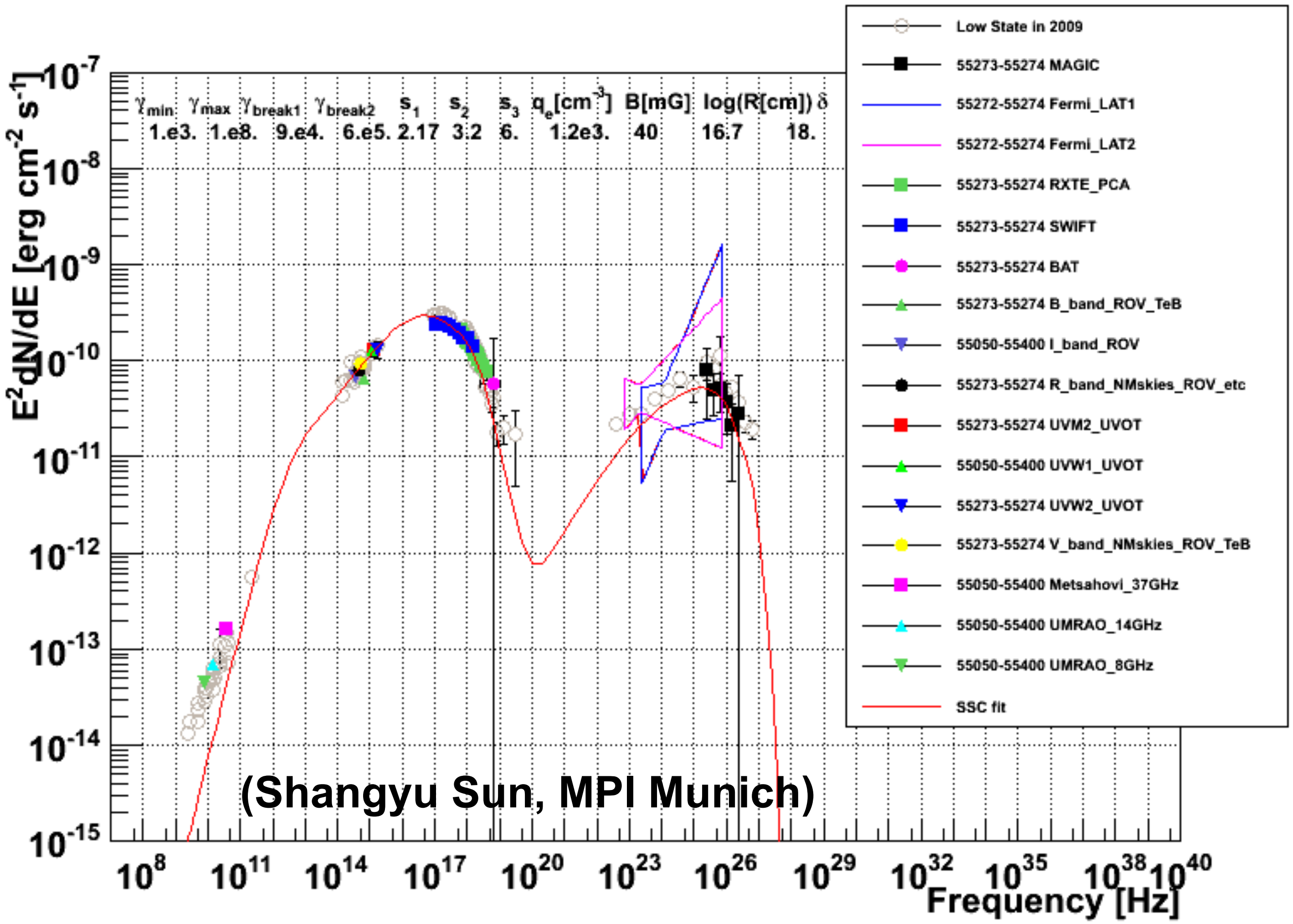
Mrk421 MW 2010_03_18 (55273)

Preliminary



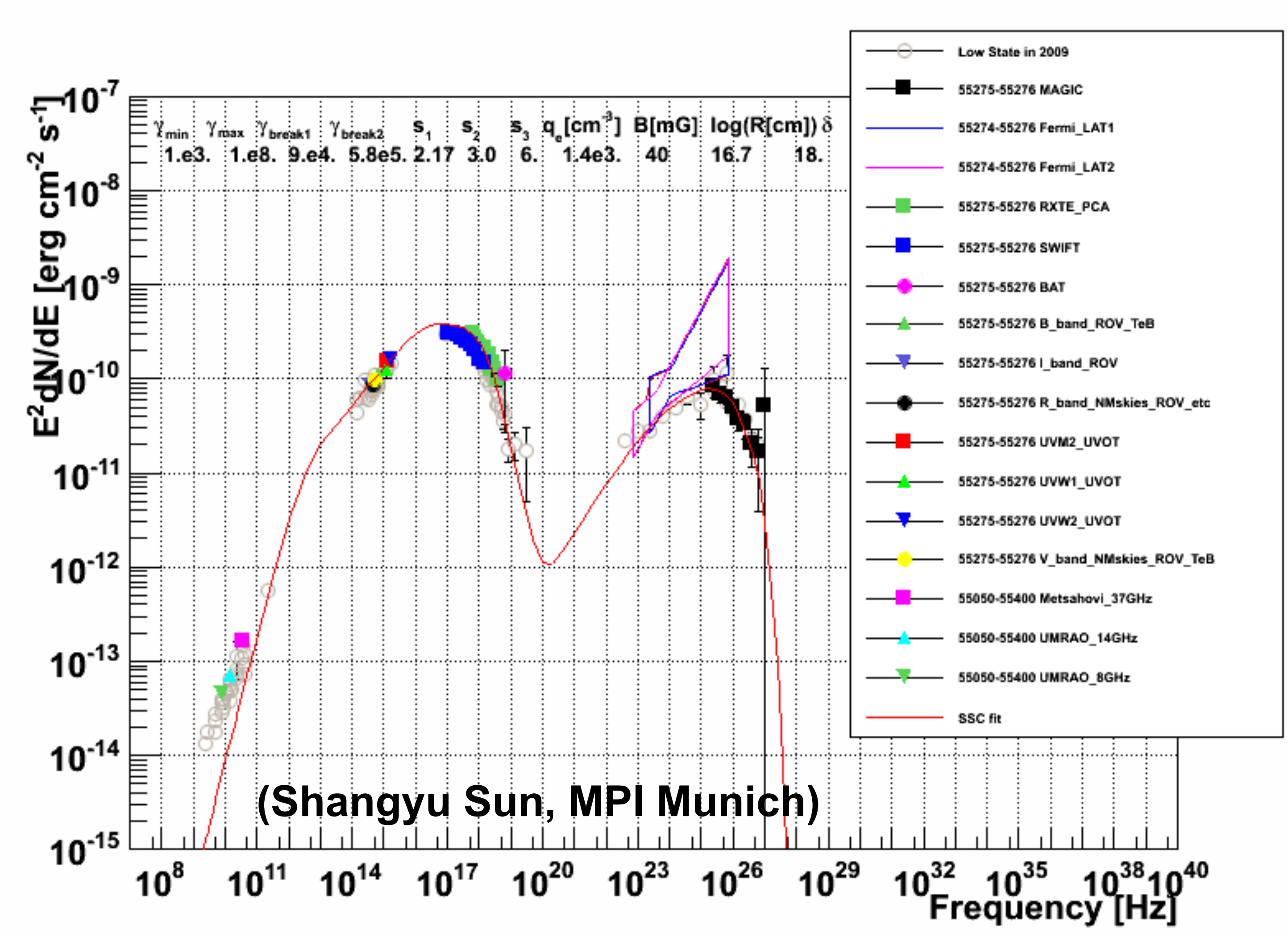
Mrk421 MW 2010_03_19 (55274)

Preliminary



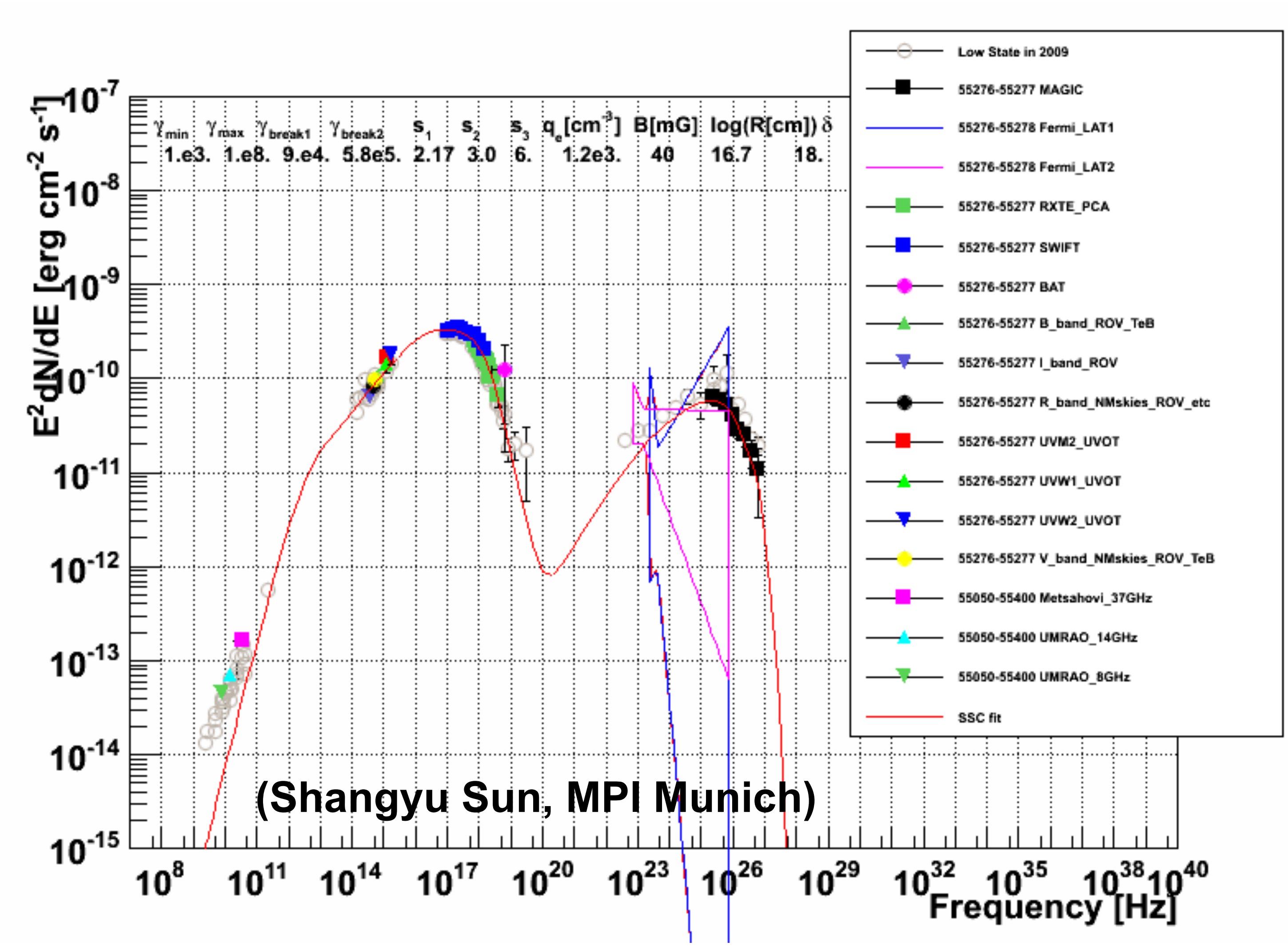
Mrk421 MW 2010_03_21 (55276)

Preliminary



Mrk421 MW 2010_03_22 (55277)

Preliminary

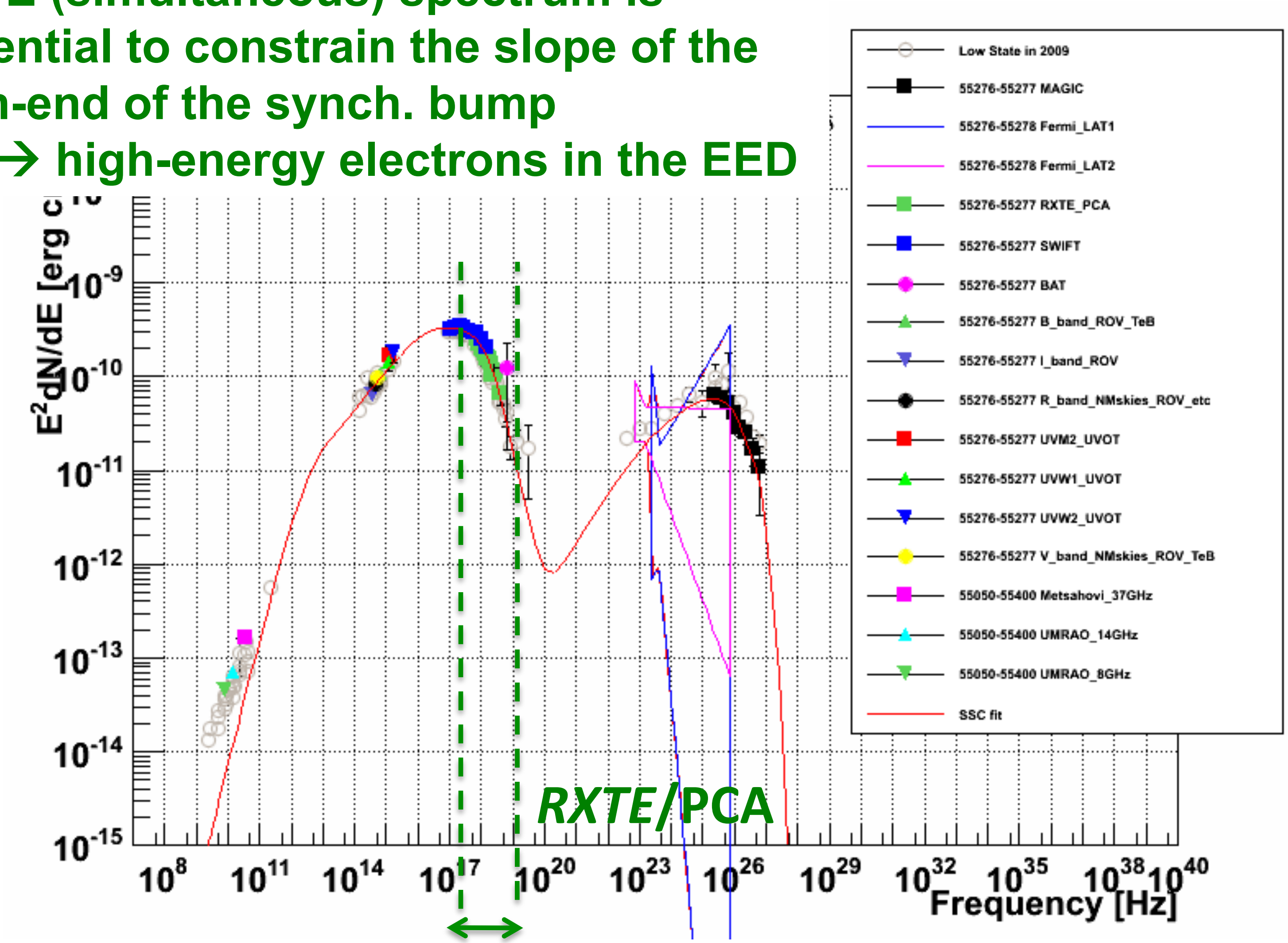


Mrk421 MW 2010_03_22 (55277)

Preliminary

RXTE (simultaneous) spectrum is essential to constrain the slope of the high-end of the synch. bump

→ high-energy electrons in the EED



SED described with Synchrotron Self-Compton Model

1-zone 2-break SSC model parameters

Preliminary

Environmental parameters

Injected electron spectrum parameters

fixed (γ_{min}, γ_{max}) — fixed (B, log R)

Decaying flare

date	γ_{min}	γ_{max}	γ_{break1}	γ_{break2}	s_1	s_2	s_3	n_e[cm^{-3}]	B[mG]	log(R[cm])	δ
03_10	1.e3.	1.e8.	2. e5.	7.5e5.	2.0	2.35	4.7	2.8e2.	40	16.7	15.
03_11	1.e3.	1.e8.	2. e5.	7.5e5.	2.0	2.35	4.7	3.1e2.	40	16.7	15.
03_13	1.e3.	1.e8.	1.8e5.	7.8e5.	2.02	3.	4.7	3.3e2.	40	16.7	16.
03_14	1.e3.	1.e8.	2.2e5.	8. e5.	2.02	3.	5.	3.3e2.	40	16.7	16.
03_15	1.e3.	1.e8.	1.7e5.	7.5e5.	2.03	3.5	5.	4. e2.	40	16.7	16.
03_17	1.e3.	1.e8.	2. e5.	7. e5.	2.03	3.8	5.	2.3e2.	40	16.7	18.5
03_18	1.e3.	1.e8.	2. e5.	6. e5.	2.03	4.	5.	2.3e2.	40	16.7	18.5
03_19	1.e3.	1.e8.	9. e4.	6. e5.	2.17	3.2	6.	1.2e3.	40	16.7	18.
03_20	1.e3.	1.e8.	9. e4.	5.8e5.	2.17	3.1	6.	1.2e3.	40	16.7	18.
03_21	1.e3.	1.e8.	9. e4.	5.8e5.	2.17	3.0	6.	1.4e3.	40	16.7	18.
03_22	1.e3.	1.e8.	9. e4.	5.8e5.	2.17	3.0	6.	1.2e3.	40	16.7	18.

Decaying phase of the flare can be explained by a reduction in the number of high-energy electrons

SED described with Synchrotron Self-Compton Model

1-zone 2-break SSC model parameters

Constrained by RXTE

Preliminary

Environmental parameters

Injected electron spectrum parameters

fixed (γmin, γmax) — fixed (B, log R)

Decaying flare

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03_10	1.e3.	1.e8.	2. e5.	7.5e5.	2.0	2.35	4.7	2.8e2.	40	16.7	15.
03_11	1.e3.	1.e8.	2. e5.	7.5e5.	2.0	2.35	4.7	3.1e2.	40	16.7	15.
03_13	1.e3.	1.e8.	1.8e5.	7.8e5.	2.02	3.	4.7	3.3e2.	40	16.7	16.
03_14	1.e3.	1.e8.	2.2e5.	8. e5.	2.02	3.	5.	3.3e2.	40	16.7	16.
03_15	1.e3.	1.e8.	1.7e5.	7.5e5.	2.03	3.5	5.	4. e2.	40	16.7	16.
03_17	1.e3.	1.e8.	2. e5.	7. e5.	2.03	3.8	5.	2.3e2.	40	16.7	18.5
03_18	1.e3.	1.e8.	2. e5.	6. e5.	2.03	4.	5.	2.3e2.	40	16.7	18.5
03_19	1.e3.	1.e8.	9. e4.	6. e5.	2.17	3.2	6.	1.2e3.	40	16.7	18.
03_20	1.e3.	1.e8.	9. e4.	5.8e5.	2.17	3.1	6.	1.2e3.	40	16.7	18.
03_21	1.e3.	1.e8.	9. e4.	5.8e5.	2.17	3.0	6.	1.4e3.	40	16.7	18.
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Decaying phase of the flare can be explained by a reduction in the number of high-energy electrons

5 – Conclusions

We can learn many things from dedicated studies of the classical (bright) TeV sources Mrk421/Mrk501. Fermi+ IACTs can characterize the entire high energy bump

- Fermi data opens a "new window" to study those objects
  → *Spectra reaching E>0.1 TeV; overlap with IACTs*
- Collection of MW data is ESSENTIAL for understanding those complex objects

This is a multi-instrument and multi-year program.

→ **These objects can be very different from season to season:**

→ **We need well-sampled, coordinated monitoring of the broad-band SED lasting several years.**

The lessons learnt with Mrk421/Mrk501 might be applied to other (HSP) blazars that are weaker of further away and hence more difficult to study/understand

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Since we started this program, RXTE has been a key player bringing information from a portion of the SED where the sources show a large dynamism

→ Excellent scheduling flexibility + Sensitive observations

→ *RXTE played a crucial role on constraining the high-end of the EED*

RXTE will surely be missed; but not forgotten

→ Excellent legacy: several scientific publications and PhD thesis in the pipeline

Backup slides

1.1- Introduction: Many open questions…

Pictorial description of an AGN

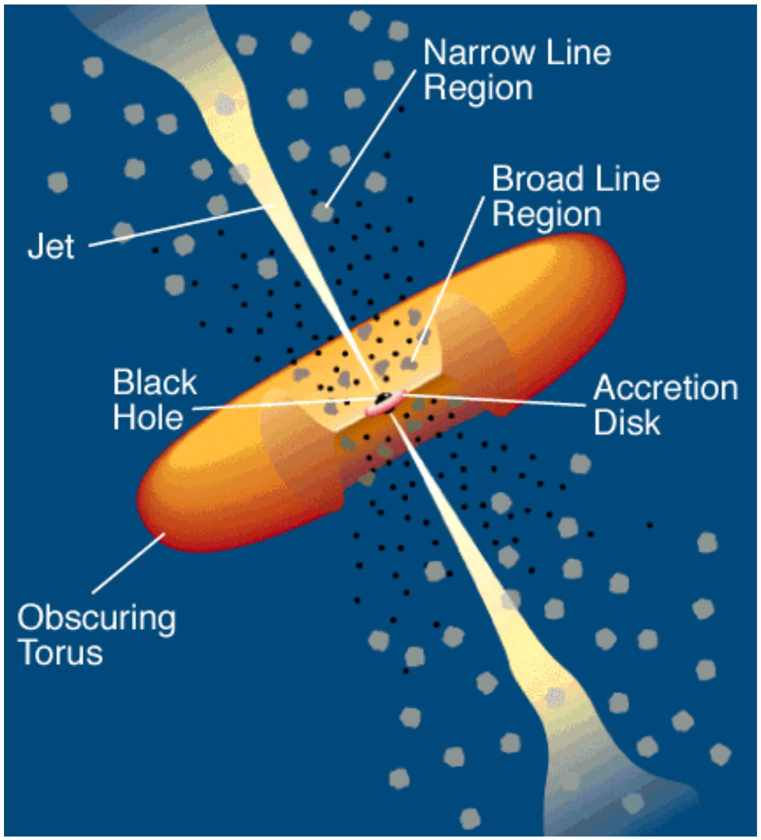


Image Credit: C.M.Urry & P. Padovani

- Location of the emission
  - Close or far away from Black Hole ?
- Leptonic vs hadronic emission models
- Acceleration/cooling in single or multi-zone
- Production of flares (which are the shortest timescales)
- Role of external photon fields
- Intrinsic spectra vs EBL-affected spectra
- Time-resolved emission models
- How jets are being formed
- How jets are kept collimated over kpc distances
- etc,etc, etc …

Roadmap → **Need population studies**
Need deep studies on individual sources

1.6 – Introduction : Extensive MW Campaigns

The goal is build a very complete pool of MW data that allows us to make detailed studies on the observables we have:

- Quantify the overall (entire SED) flux variability and correlations during long baseline
- Correlate with VLBA images and polarization measurements
- Put strong experimental constrains to the currently used emission models
  - → *Time dependent SED modeling !!*

These observations will allow us to address fundamental questions on how Mrk421 and Mrk501 (and perhaps HBLs in general) work:

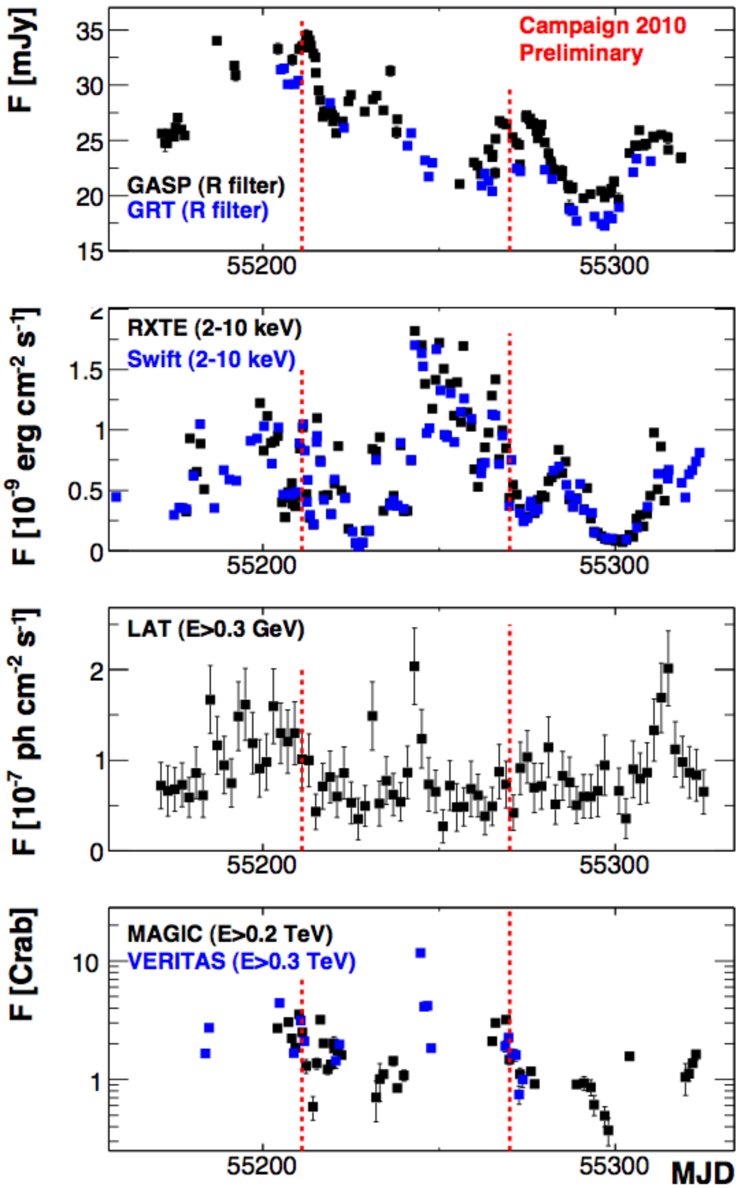
- Nature of the radiating particles
- Location of the blazar emission
- Acceleration and radiation processes
- How flux variations are being produced; what changes in the source
- etc, etc…

Multi-Instrument and multi-year effort

We plan to continue with these efforts during the coming years so that our pool of very complete MW data will grow and our knowledge on Mrk421 and Mrk501 (and perhaps blazars in general) will improve.

2.5 - Mrk421: Fast variability (2010 Campaign)

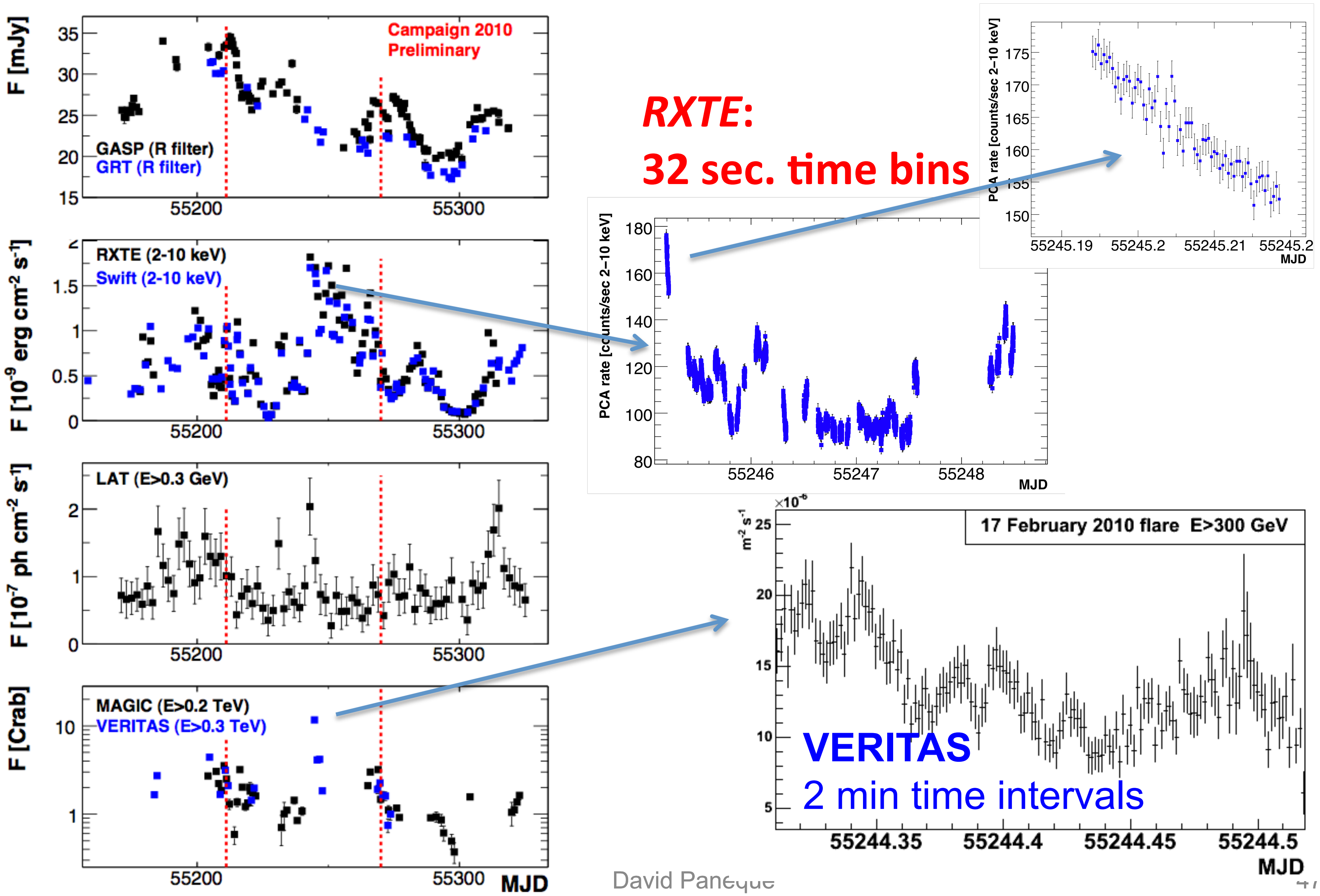
Only some instruments are shown !!!!



David Paneque

2.5 - Mrk421: Fast variability (2010 Campaign)

Only some instruments are shown !!!!

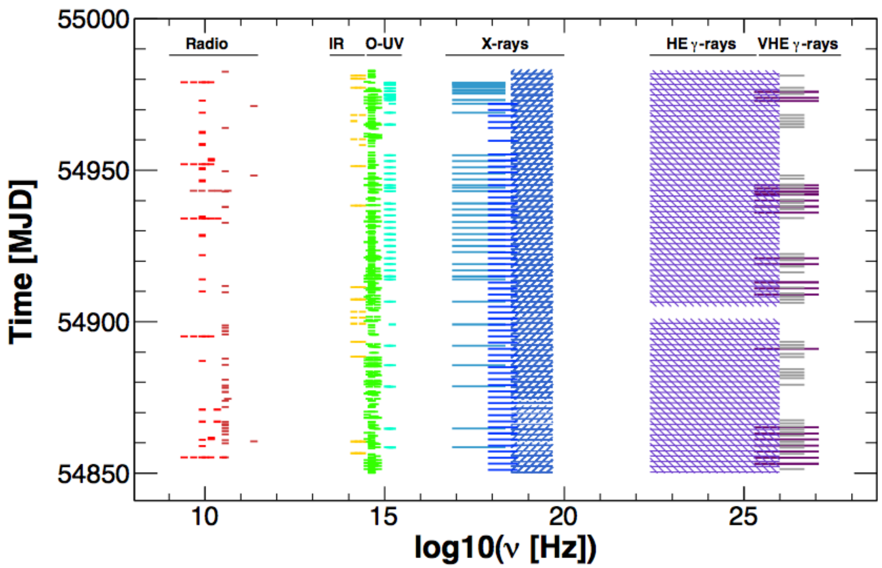


2.1 – Temporal and energy coverage

The instruments participating in the campaigns provided a very good time and energy coverage for both sources

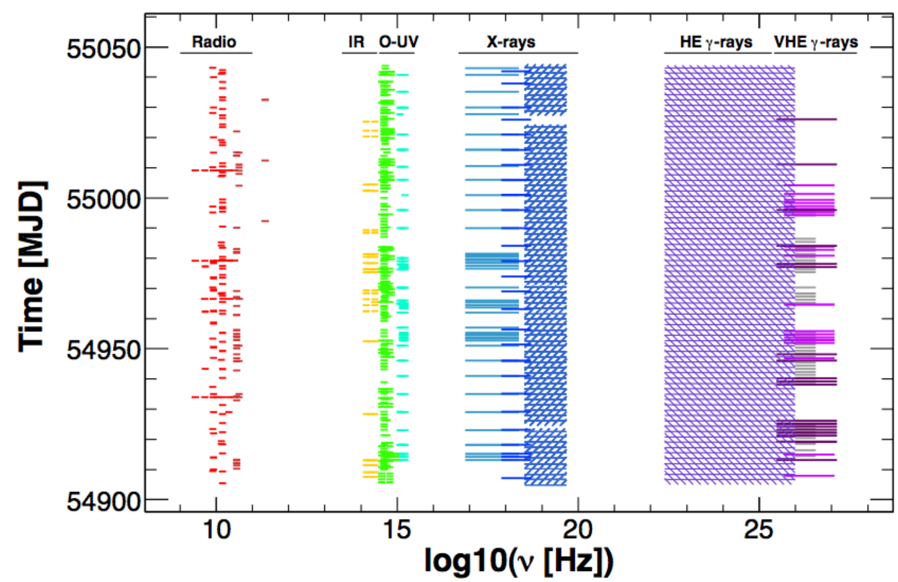
Abdo et al 2011, ApJ 736, 131

Mrk421 (campaign 2009)



Abdo et al 2011, ApJ 727, 129

Mrk501 (campaign 2009)



Most complete Time&Energy (published) coverage to date

Collected data can be used to produce a good representation of the TRUE SED

Reliable interpretation of the SED (!!)

2.1 – Broad Band SED of Mrk421

Extensive Campaign: Instruments that participated and energy covered by them

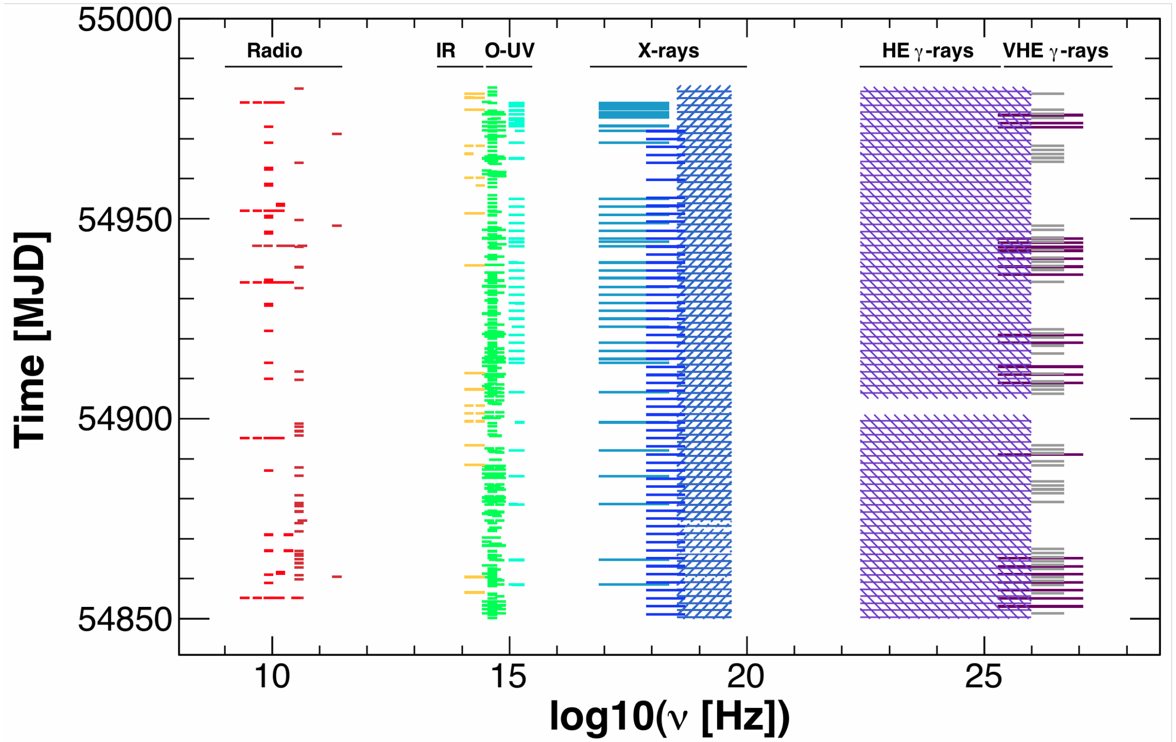
Instrument/Observatory	Energy range covered	Web page
MAGIC	0.08-5.0 TeV	http://wwwmagic.mppmu.mpg.de/
Whipple[a]	0.4-2.0 TeV	http://veritas.sao.arizona.edu/content/blogsection/6/40/
Fermi-LAT	0.1-400 GeV	http://www-glast.stanford.edu/index.html
Swift/BAT	14-195 keV	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html/
RXTE/PCA	3-32 keV	http://heasarc.gsfc.nasa.gov/docs/xte/rxte.html
Swift/XRT	0.3-9.6 keV	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html
Swift/UVOT	UVW1, UVM2, UVW2	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html
Abastumani (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Lulin (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Roque de los Muchachos (KVA) (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
St. Petersburg (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Talmassons (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Valle d'Aosta (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
GRT	V, R, B, I bands	http://asd.gsfc.nasa.gov/Takanori.Sakamoto/GRT/index.html
ROVOR	B, R, V bands	http://rovor.byu.edu/
New Mexico Skies	R, V bands	http://www.nmskies.com/equipment.html/
MitSume	g, Rc, Ic bands	http://www.hp.phys.titech.ac.jp/mitsume/index.html
OAGH	H, J, K bands	http://astro.inaoep.mx/en/observatories/oagh/
WIRO	J, K bands	http://physics.uwyo.edu/~chip/wiro/wiro.html
SMA	225 GHz	http://sma1.sma.hawaii.edu/
VLBA	4.8, 8.3, 15.4, 23.8, 43.2 GHz	http://www.vlba.nrao.edu/
Noto	8.4, 22.3 GHz	http://www.noto.ira.inaf.it/
Metsähovi (through GASP-WEBT program)	37 GHz	http://www.metsahovi.fi/
VLBA (through MOJAVE program)	15 GHz	http://www.physics.purdue.edu/MOJAVE/
OVRO	15 GHz	http://www.ovro.caltech.edu/
Medicina	8.4 GHz	http://www.med.ira.inaf.it/index_EN.htm
UMRAO (through GASP-WEBT program)	4.8, 8.0, 14.5 GHz	http://www.oato.inaf.it/blazars/webt/
RATAN-600	2.3, 4.8, 7.7, 11.1, 22.2 GHz	http://w0.sao.ru/ratan/
Effelsberg (through F-GAMMA program)	2.6, 4.6, 7.8, 10.3, 13.6, 21.7, 31 GHz	http://www.mpifr-bonn.mpg.de/div/effelsberg/index_e.html/

Note. — The energy range shown in column 2 is the actual energy range covered during the Mrk 421 observations, and not the instrument nominal energy range, which might only be achievable for bright sources and excellent observing conditions.

Note. — (*a*) The Whipple spectra were not included in Figure 8. See text for further comments.

2.2 – Broad Band (radio-TeV) SED of Mrk421

Temporal and Energy coverage during the campaign



Most complete Time & Energy coverage of Mrk421 to date

Collected data can be used to produce a good representation of the TRUE SED

Reliable interpretation of the SED (!!)

2.1 – Broad Band SED of Mrk501

Extensive Campaign: Instruments that participated and energy covered by them

Instrument/observatory	Energy range covered	Web page
MAGIC	0.12-5.8 TeV	http://wwwmagic.mppmu.mpg.de/
VERITAS	0.20-5.0 TeV	http://veritas.sao.arizona.edu/
Whipple[a]	0.4-1.5 TeV	http://veritas.sao.arizona.edu/content/blogsection/6/40/
Fermi-LAT	0.1-400 GeV	http://www-glast.stanford.edu/index.html
Swift-BAT	14-195 keV	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html/
RXTE-PCA	3-28 keV	http://heasarc.gsfc.nasa.gov/docs/xte/rxte.html
Swift-XRT	0.3-9.6 keV	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html
Swift-UVOT	V, B, U, UVW1, UVM2, UVW2	http://heasarc.gsfc.nasa.gov/docs/swift/swiftsc.html
Abastumani (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Lulin (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Roque de los Muchachos (KVA) (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
St. Petersburg (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Talmassons (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
Valle d'Aosta (through GASP-WEBT program)	R band	http://www.oato.inaf.it/blazars/webt/
GRT	V, R, B bands	http://asd.gsfc.nasa.gov/Takanori.Sakamoto/GRT/index.html
MitSume	g, Rc, Ic bands	http://www.hp.phys.titech.ac.jp/mitsume/index.html
ROVOR	B, R, V, I bands	http://rovor.byu.edu/
Campo Imperatore (through GASP-WEBT program)	H, J, K bands	http://www.oato.inaf.it/blazars/webt/
OAGH	H, J, K bands	http://astro.inaoep.mx/en/observatories/oagh/
WIRO	J, K bands	http://physics.uwyo.edu/~chip/wiro/wiro.html
SMA	225 GHz	http://sma1.sma.hawaii.edu/
VLBA	4.8, 8.3, 15.4, 23.8, 43.2 GHz	http://www.vlba.nrao.edu/
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OVRO	15 GHz	http://www.astro.caltech.edu/ovroblazars
Medicina	8.4, 22.3 GHz	http://www.med.ira.inaf.it/index_EN.htm
UMRAO (through GASP-WEBT program)	4.8, 8.0, 14.5 GHz	http://www.oato.inaf.it/blazars/webt/
RATAN-600	2.3, 4.8, 7.7, 11.1, 22.2 GHz	http://w0.sao.ru/ratan/
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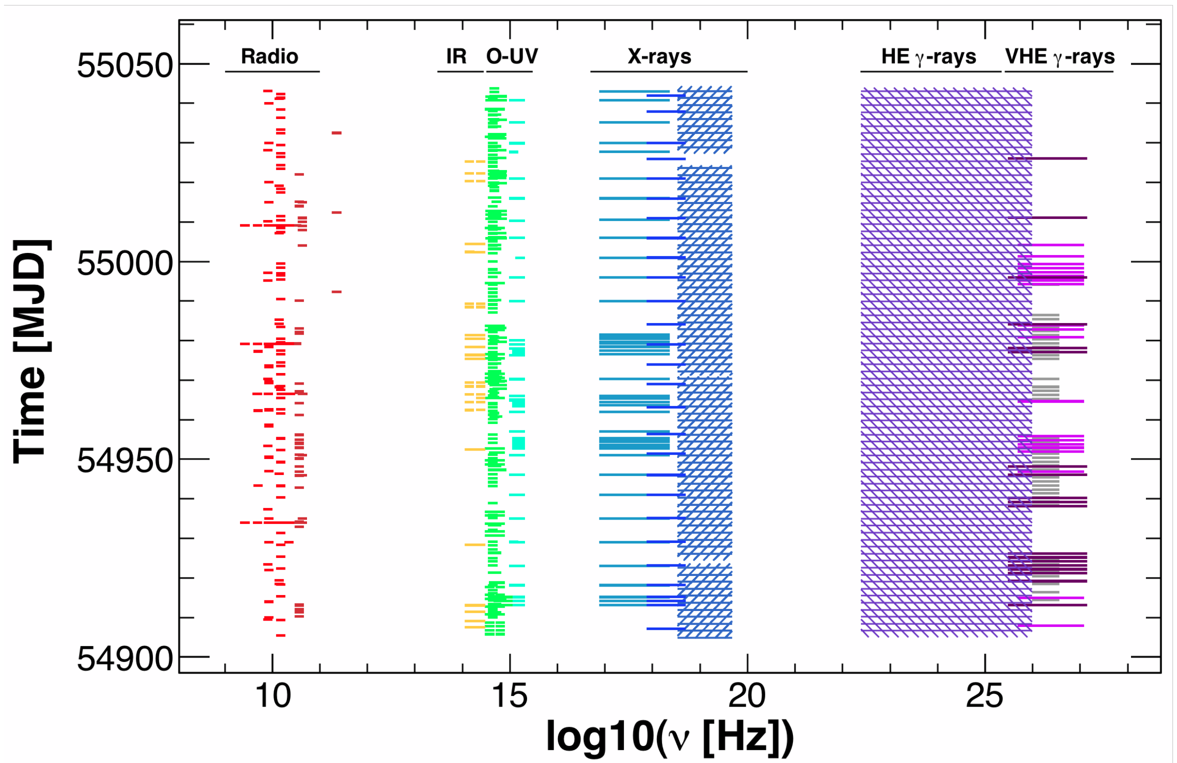
Note. — The energy range shown in column two is the actual energy range covered during the Mrk 501 observations, and not the instrument's nominal energy range, which might only be achievable for bright sources and excellent observing conditions.

Note. — (*a*) The Whipple spectra were not included in Figure 8. See text for further comments.

2.3 – Broad Band (radio-TeV) SED of Mrk501

Temporal and Energy coverage during the campaign



Most complete Time & Energy coverage of Mrk501 to date

Collected data can be used to produce a good representation of the TRUE SED

Reliable interpretation of the SED (!!)

3.5 – Discussion: First spectral break

The first spectral break located at ~25 GeV for Mrk421 and ~ 20 GeV for Mrk501
In both cases the break produces a change in index from 2.2 to 2.7

Is it by chance ???

This break must be internal to the acceleration mechanism.

(Internal) breaks observed in many blazars detected by Fermi

THE ASTROPHYSICAL JOURNAL, 710:1271–1285, 2010 February 20 doi:10.1088/0004-637X/710/2/1271

SPECTRAL PROPERTIES OF BRIGHT *FERMI*-DETECTED BLAZARS IN THE GAMMA-RAY BAND

A. A. ABDO[1,2], M. ACKERMANN[3], M. AJELLO[3], W. B. ATWOOD[4], M. AXELSSON[5,6], L. BALDINI[7], J. BALLET[8], G. BARBIELLINI[9,10], D. BASTIERI[11,12], K. BECHTOL[3], R. BELLAZZINI[7], B. BERENJI[3], R. D. BLANDFORD[3], E. D. BLOOM[3], E. BONAMENTE[13,14],

ABSTRACT

The gamma-ray energy spectra of bright blazars of the LAT Bright AGN Sample (LBAS) are investigated using *Fermi*-LAT data. Spectral properties (hardness, curvature, and variability) established using a data set accumulated over 6 months of operation are presented and discussed for different blazar classes and subclasses: flat spectrum radio quasars (FSRQs), low-synchrotron peaked BLLacs (LSP-BLLacs), intermediate-synchrotron peaked BLLacs (ISP-BLLacs), and high-synchrotron peaked BLLacs (HSP-BLLacs). The distribution of photon index (Γ, obtained from a power-law fit above 100 MeV) is found to correlate strongly with blazar subclass. The change in spectral index from that averaged over the 6 months observing period is < 0.2–0.3 when the flux varies by about an order of magnitude, with a tendency toward harder spectra when the flux is brighter for FSRQs and LSP-BLLacs. A strong departure from a single power-law spectrum appears to be a common feature for FSRQs. This feature is also present for some high-luminosity LSP-BLLacs, and a small number of ISP-BLLacs. It is absent in all LBAS HSP-BLLacs. For 3C 454.3 and AO 0235+164, the two brightest FSRQ source and LSP-BLLac source, respectively, a broken power law (BPL) gives the most acceptable of power law, BPL, and curved forms. The consequences of these findings are discussed.

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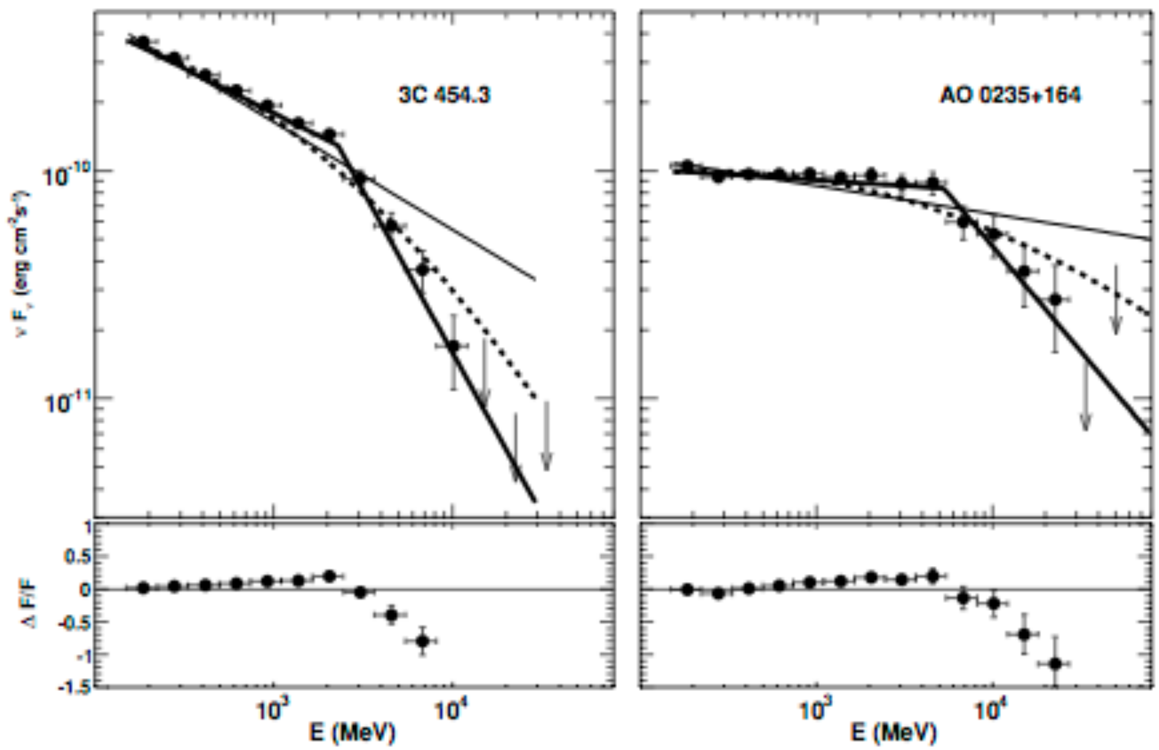

Figure 13. Upper panels: energy spectra of 3C 454.3 (left panel) and AO 0235+164 (right panel) compared with fit results obtained with different models: PL (thin solid), BPL (thick solid), and log-parabola (dashed).

Likely to be produced by breaks intrinsic to the electron energy distribution (see *Abdo, A. A., et al. 2009, ApJ, 699, 817*)

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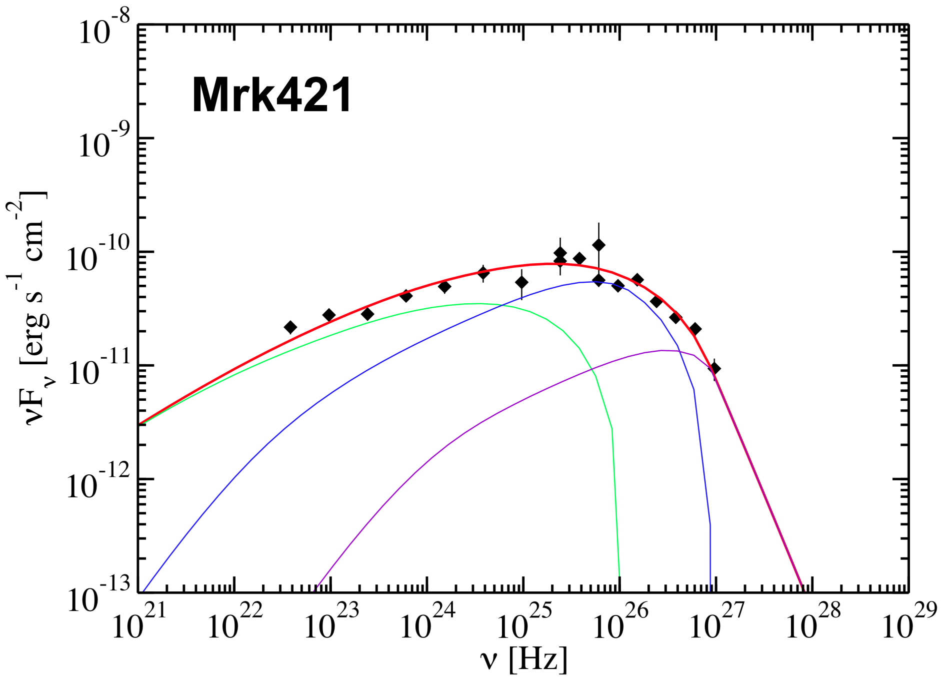
It seems that HSP BL Lacs ALSO show spectral breaks in the electron energy distribution, but those breaks are "not visible" in the (SSC) high energy bump, while they are visible in the (EC) high energy bump of FSRQs

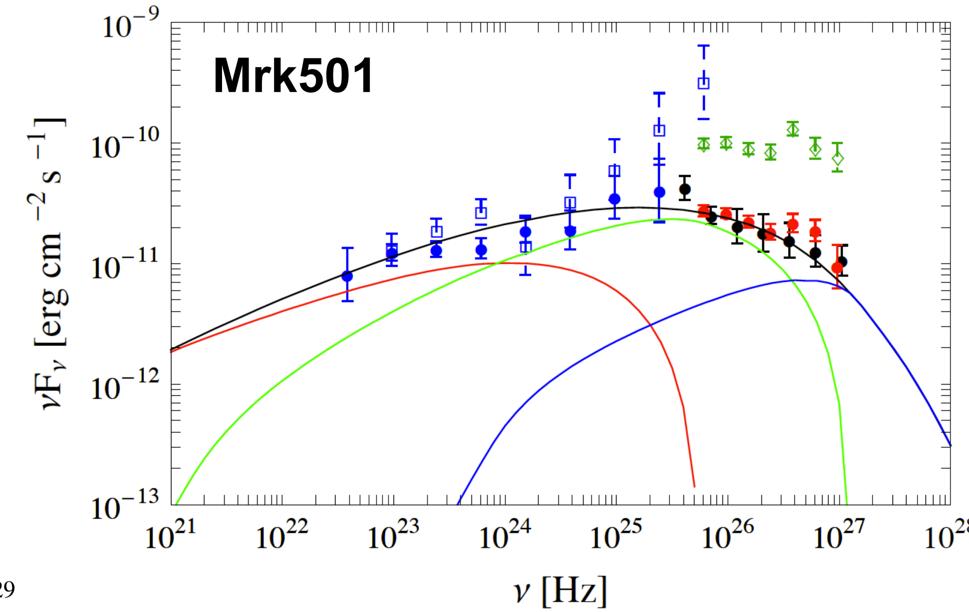
We may access those spectral breaks through the modeling of the SEDs

3.6 – Discussion: High Energy Component

Close look to the high energy component of Mrk421 and Mrk501

Contributions of the different segments of the electron energy distribution





Mrk421			Mrk501	
green	$\gamma_{min} < \gamma < \gamma_{br,1}$	↔	red	$\gamma_{min} < \gamma < \gamma_{br,1}$
blue	$\gamma_{br,1} < \gamma < \gamma_{br,2}$	↔	green	$\gamma_{br,1} < \gamma < \gamma_{br,2}$
purple	$\gamma_{br,2} < \gamma$ (emit at $\nu > 10^{17}$ Hz)	↔	blue	$\gamma_{br,2} < \gamma$ (emit at $\nu > 10^{17}$ Hz)

Electrons above $\gamma_{br,2}$ emit X-rays

3.6 – Discussion: High Energy Component

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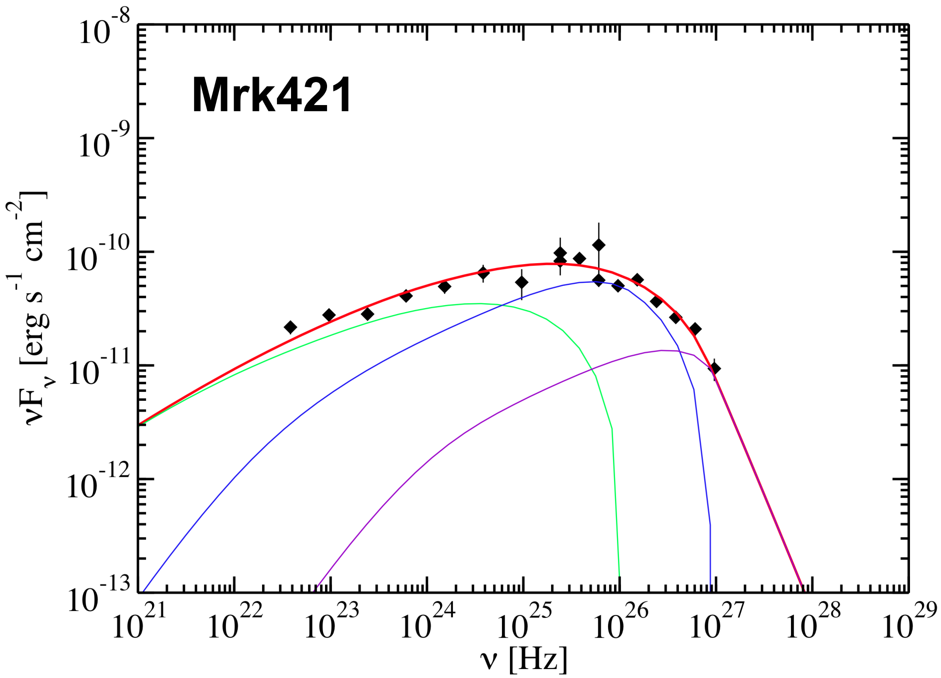
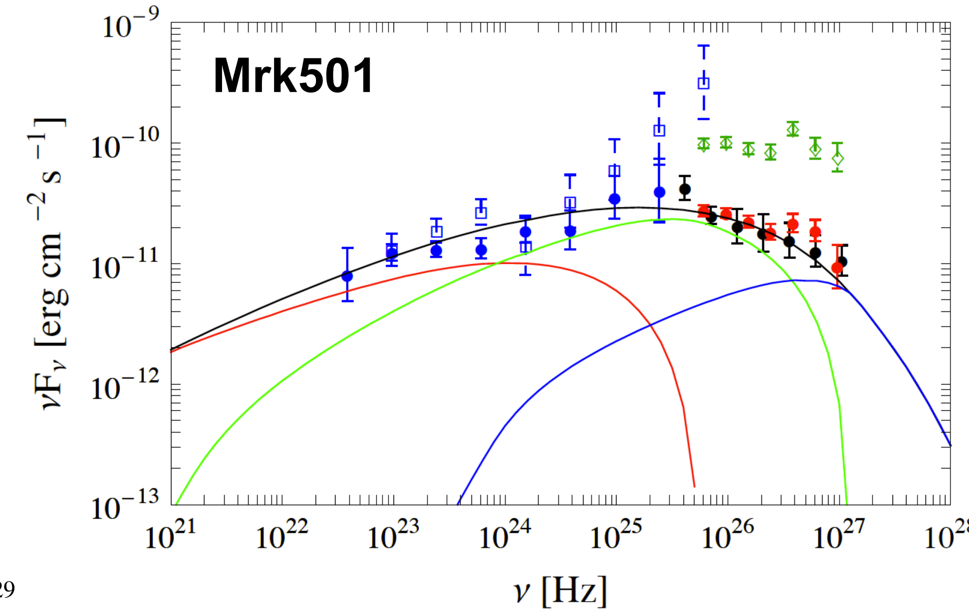




The electrons above 2nd break are responsible for the X-rays, and electrons above 1st and 2nd break responsible for the TeV

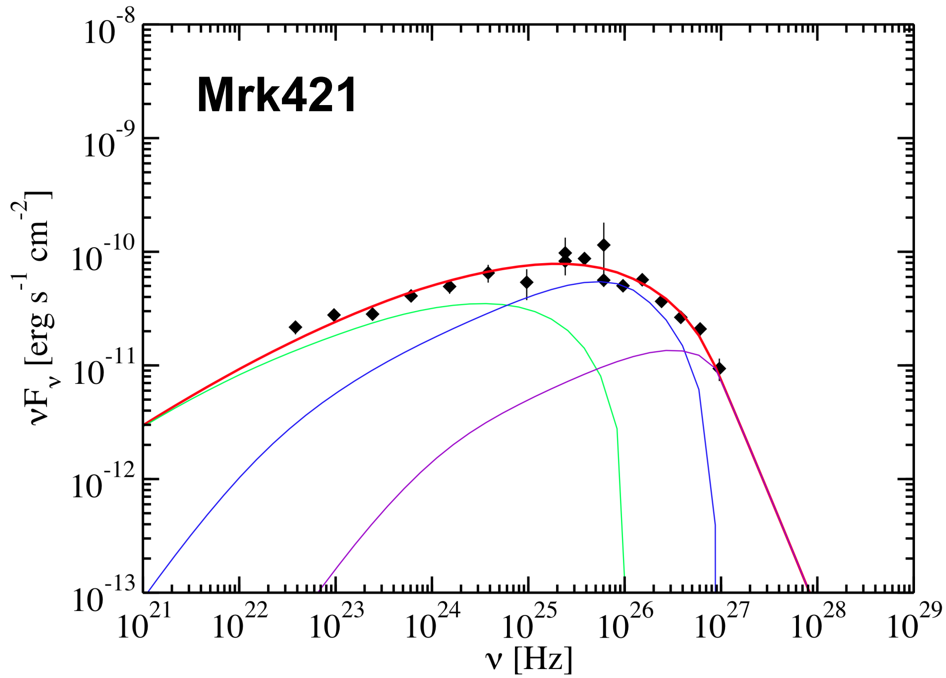
→ Correlation X-ray/TeV must exist but the relation is NOT trivial

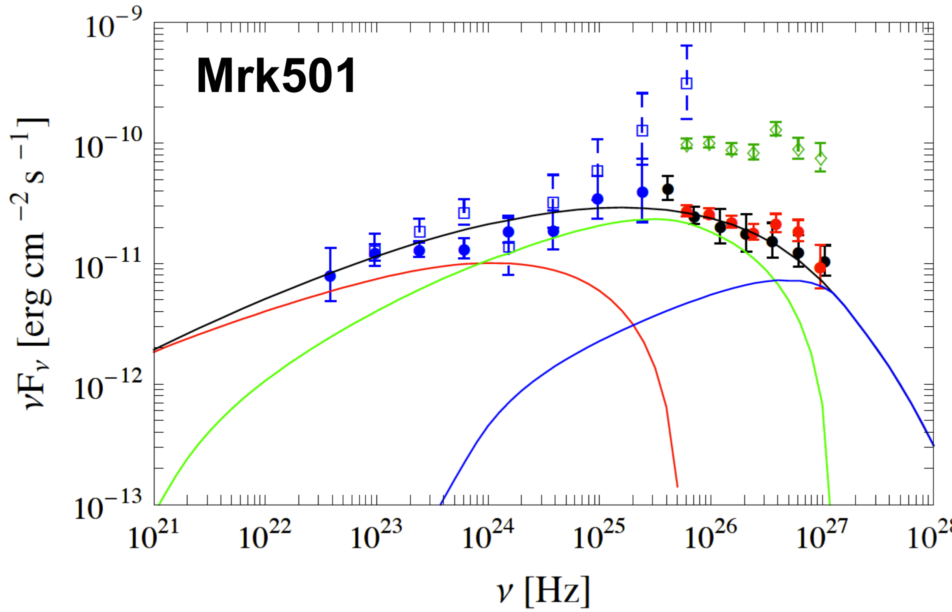
MeV/GeV Fermi photons produced mostly by electrons BELOW 1st break

3.6 – Discussion: High Energy Component

Close look to the high energy component of Mrk421 and Mrk501

Contributions of the different segments of the electron energy distribution





Larger flux variations above few GeV energies (as measured by Fermi/LAT during the first 1.5 years of scientific operation) could be produced by larger variations in the number of electrons above the first (internal) breaks $\gamma_{br,1}$ ~ 20-25 GeV