Study of the classical TeV blazars Mrk421 and Mrk501 with Fermi

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On behalf of the Fermi collaboration
and the people/instruments that participated in the multi-frequency campaigns
(MAGIC, VERITAS, RXTE, Swift, GASP, OVRO, Effelsberg …)

Outline

1 – Introduction (motivation to study "classical" TeV blazars)

2 – 4.5 months long MW campaigns on Mrk421 and Mrk501

3 – Results for Mrk421 → *Just a glimpse of some of the (preliminary) results*

4 – Role of RXTE in the MW campaigns

5 - Conclusions

1 – Short intro (motivation to study "classical" TeV 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 the 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 the knowledge we have on BL Lac-HSP relates to the high state*

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

New Generation of IACTs online since ~4 years (low E_{th}, high sensitivity)

LAT in operation since almost 1 year (~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 BL Lac-HSPs

1- Motivation to observe (again) Mrk421 and Mrk501

(same applies to other classical TeV sources like 1es1959+650 and PKS2155-304)

Exquisite characterization of the high energy component, which can be detected with Fermi and Cherenkov Telescopes (20 MeV – 20 TeV)

Excellent laboratory for studying High Energy blazar emission

Strong gamma ray sources &&
Nearby objects; z <~ 0.1; "low" EBL absorption, we see "almost" intrinsic features

Knowledge acquired with those objects could (in principle) be applied to other objects (fainter and/or larger z)

Things we know about those classical TeV sources (and BL Lac-HSP objects 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)**

2 – 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 al1996, Nature 383, 319; and many other publications*).

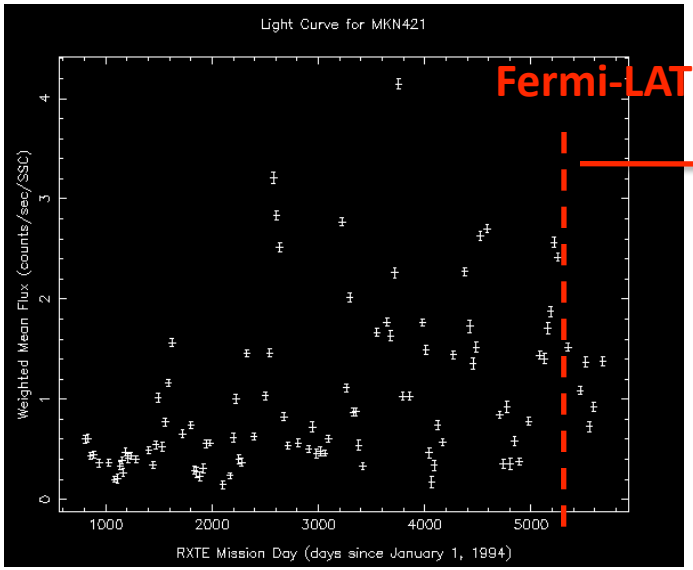
All detections of EGRET (9 years of operation)

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

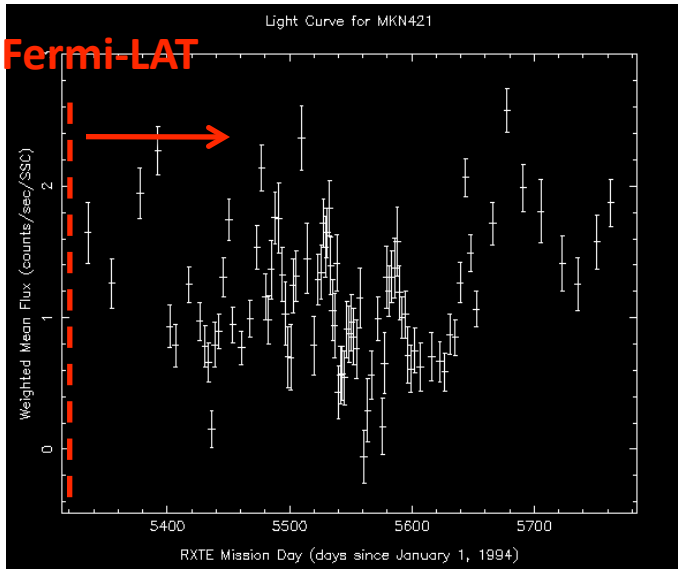
Detection significance (EGRET) <~ 5 sigma

So far we lacked info on Gamma-ray emission
Fermi-LAT provides key/missing information

RXTE/ASM Light Curve (2-10 keV)

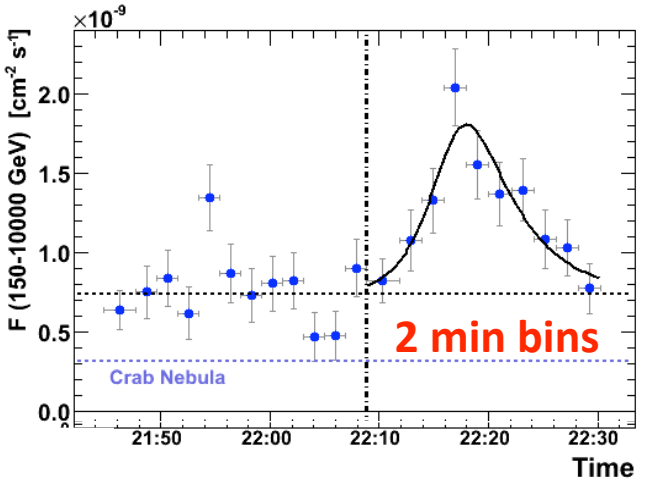


Since Fermi launch, Mrk421 is relatively low at X-rays.



2 – Mrk501

RA =253.47 ; DEC = 39.76
Z = 0.034
Discovery at VHE: Quinn et al., 1996
- Huge flare in 1997 (many publications)
- Short flux variations detected in 2005
MAGIC, Albert et al, 2007



Not present in 3rd EGRET catalogue
EGRET did not detect it during the big outburst in 97

Only detection (~5 sigma) with EGRET was during a flare in 1996 (Kataoka etal 1999)

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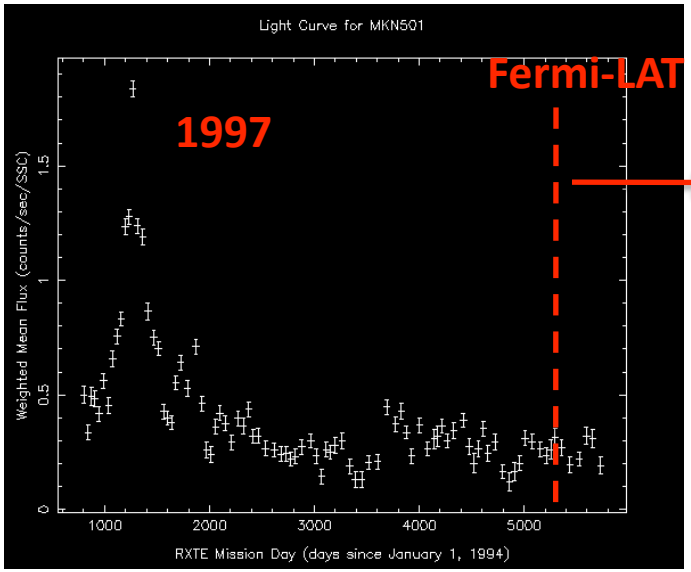
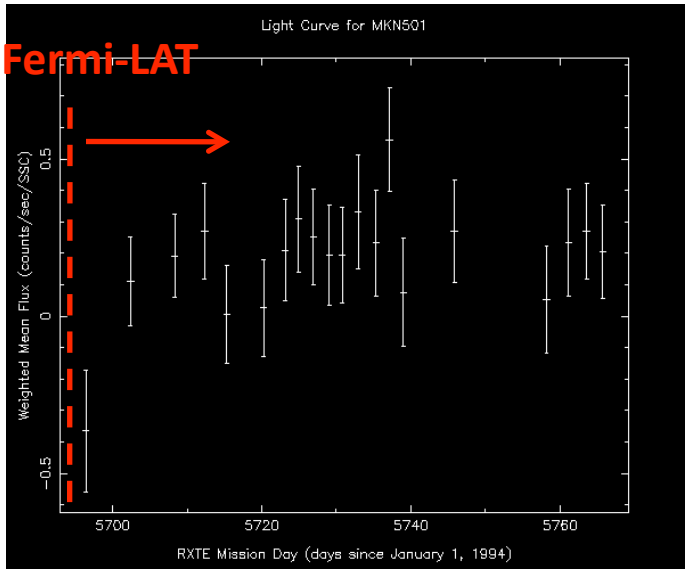


Mrk501 is relatively low at X-rays since several years



2 – MW campaigns on Mrk421 and Mrk501

Organized by the Fermi/AGN group. Open to all instruments/people.

URLs with campaign announcements and observing schedule from the instruments participating

Mrk421 (from January 19th, 2009 till June 1st ,2009)
https://confluence.slac.stanford.edu/display/GLAMCOG/Campaign+on+Mrk421+(Jan+2009+to+May+2009)

Mrk501 (from March 15th, 2009 till August 1st,2009)
https://confluence.slac.stanford.edu/display/GLAMCOG/Campaign+on+Mrk501+(March+2009+to+July+2009)

Sources monitored during 4.5 months, regardless of activity

•20ish instruments participated covering frequencies from radio to TeV

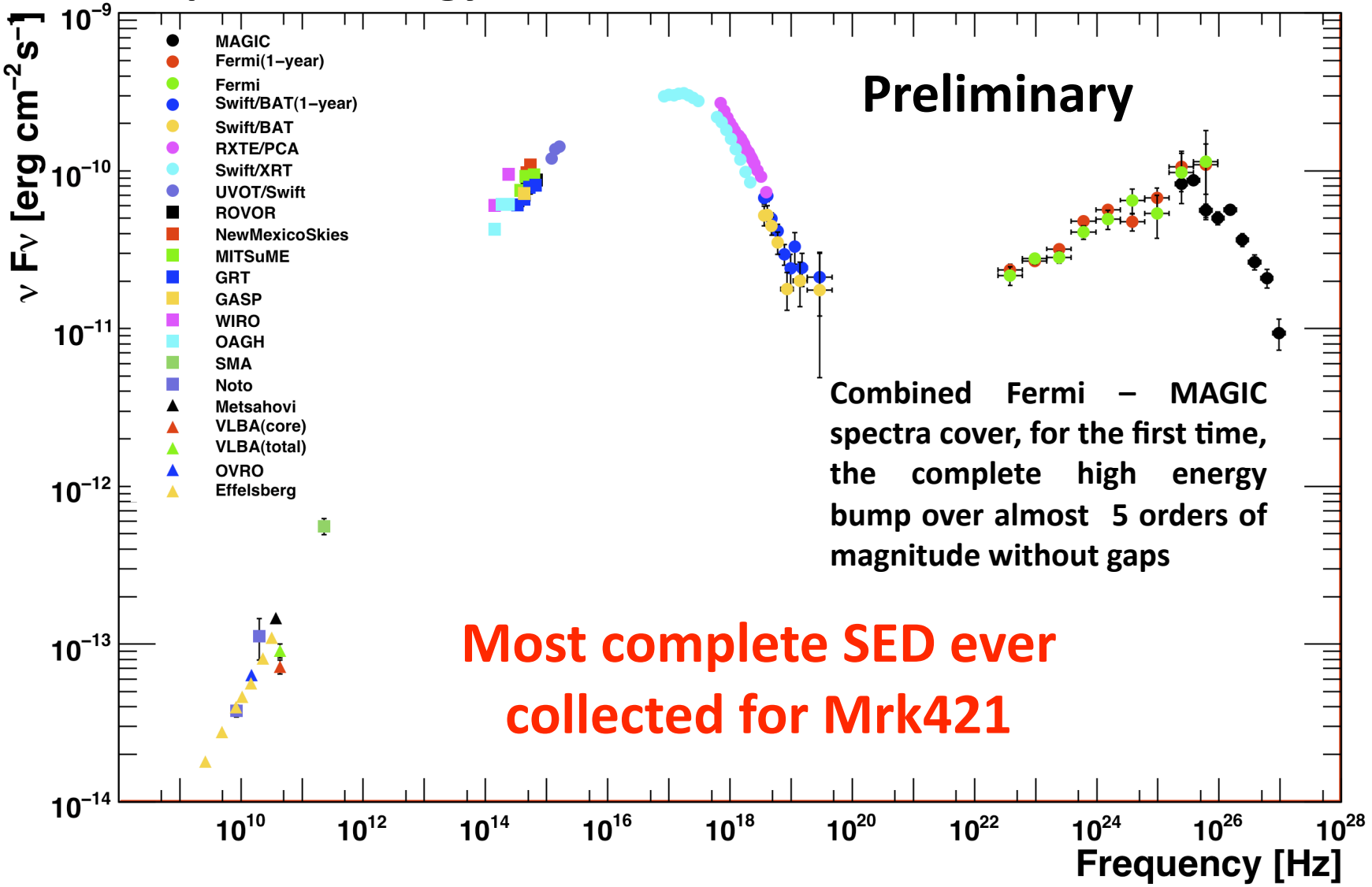
•2-day (Mrk421) and 5-day (Mrk501) sampling at optical/X-ray and TeV (when possible*; breaks due to moon, weahter…*)

Radio: OVRO, Effelsberg, Metsahovi, Noto…
Infrared: WIRO, OAGH
Optical: GASP, GRT, MITSuMe, Kanata…
UV: Swift-UVOT
X-ray: Swift-XRT, RXTE-PCA
Gamma-ray: Fermi-LAT
VHE: MAGIC, VERITAS, Whipple

3 – Preliminary results for Mrk421

Spectral Energy Distribution

Paneque et al, 2009 Fermi symposium

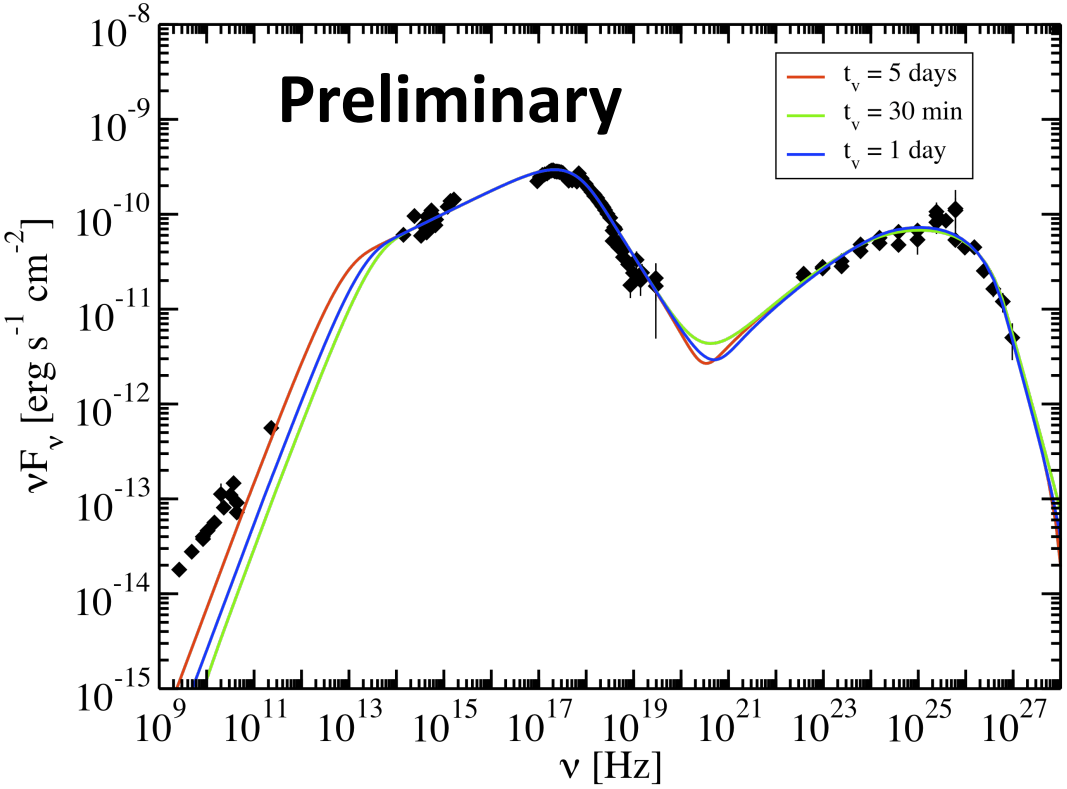


3 – Preliminary results for Mrk421

One zone SSC model fit

Paneque et al, 2009 Fermi symposium

The SED was modeled as prescribed in Finke, Dermer, & Boettcher, 2008, ApJ, 686, 181



This exquisite data set puts limits to the allowed range of parameters. But models are quite flexible and can accommodate these data

"Simple" One-zone SSC models can describe the overall SED

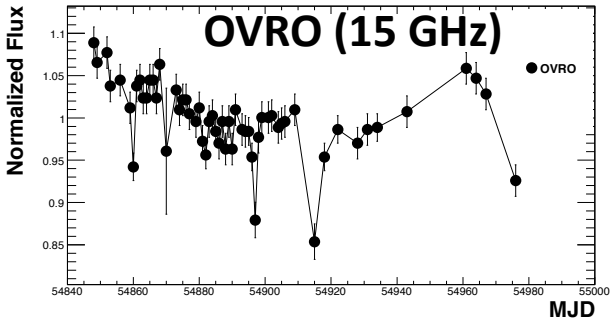
Further constraints to the emission models will come from multi-frequency variability and correlations

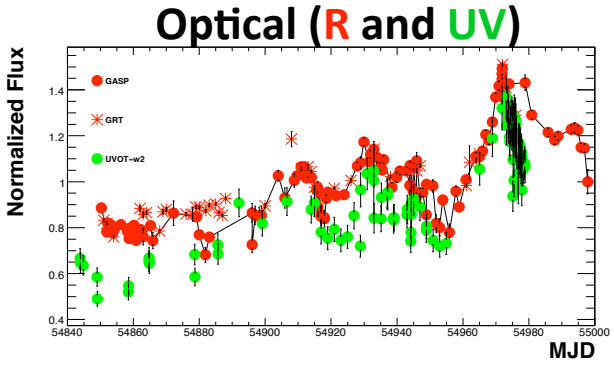
3 – Preliminary results for Mrk421

Preliminary (quick&dirty analysis) from various instruments

Some of the fluxes are the result of automatic procedures (no checks)

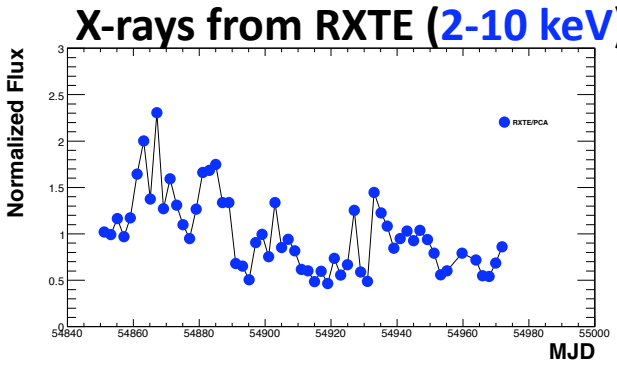
Proper multi-frequency data reduction will happen during the next months

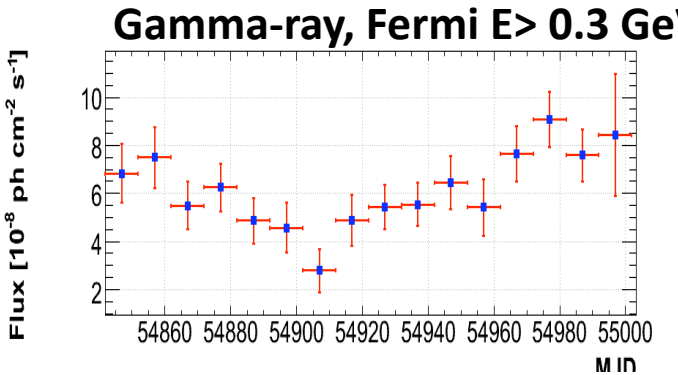


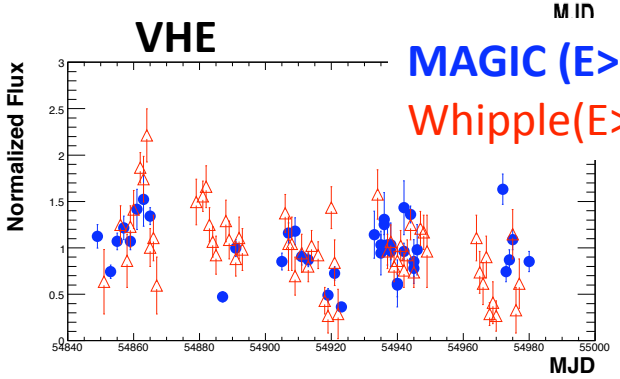


GASP
GRT
Swift-UVOT

Host galaxy not subtracted !!







MAGIC (E>0.15 TeV)
Whipple(E>0.4 TeV)

Low activity at VHE: ~ 0.5 Crab
But variability clearly seen:
Min/Max values: ~ 0.1-1 Crab

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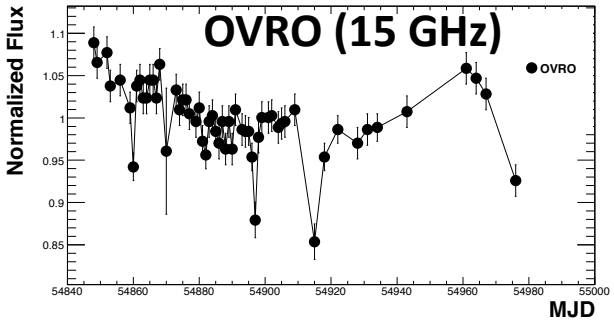

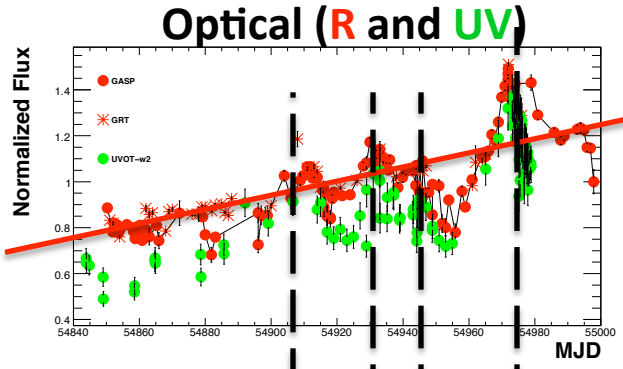

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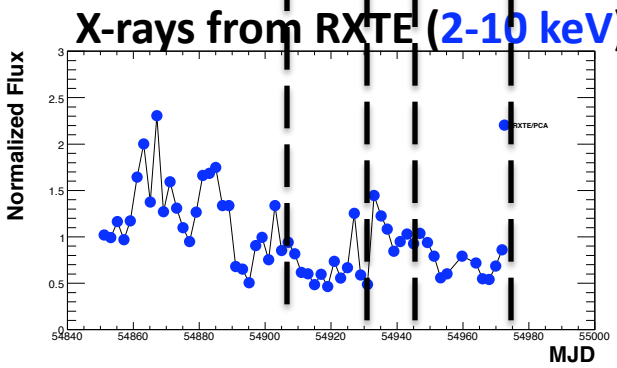

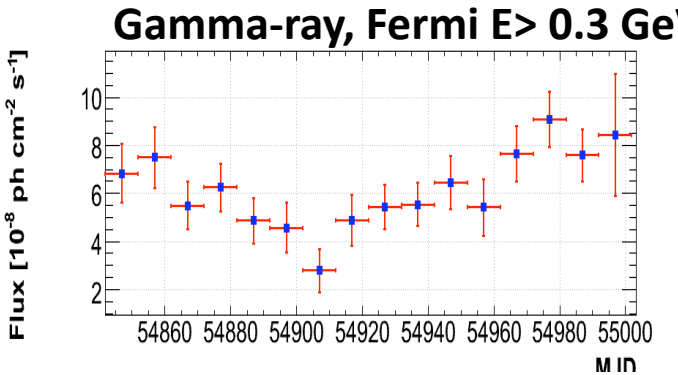

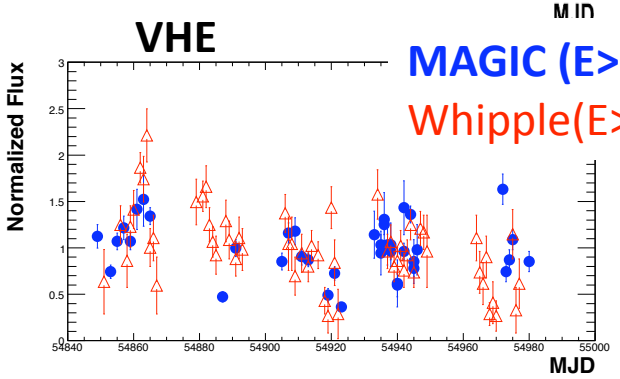

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Whipple(E>0.4 TeV)

Multi-frequency variability seems to indicate that the simple one-zone SSC is not sufficient

Low activity at VHE: ~ 0.5 Crab
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Min/Max values: ~ 0.1-1 Crab

4 – Role of RXTE in the MW campaigns

1 - Provide information from energy range 2-60 keV (*ready the following day; easy to analyze*)

2 – Provide great coverage of the source

No solar constrains, source can be observed any time of the year

3 - Excellent scheduling team which granted simultaneous observations with ground instruments

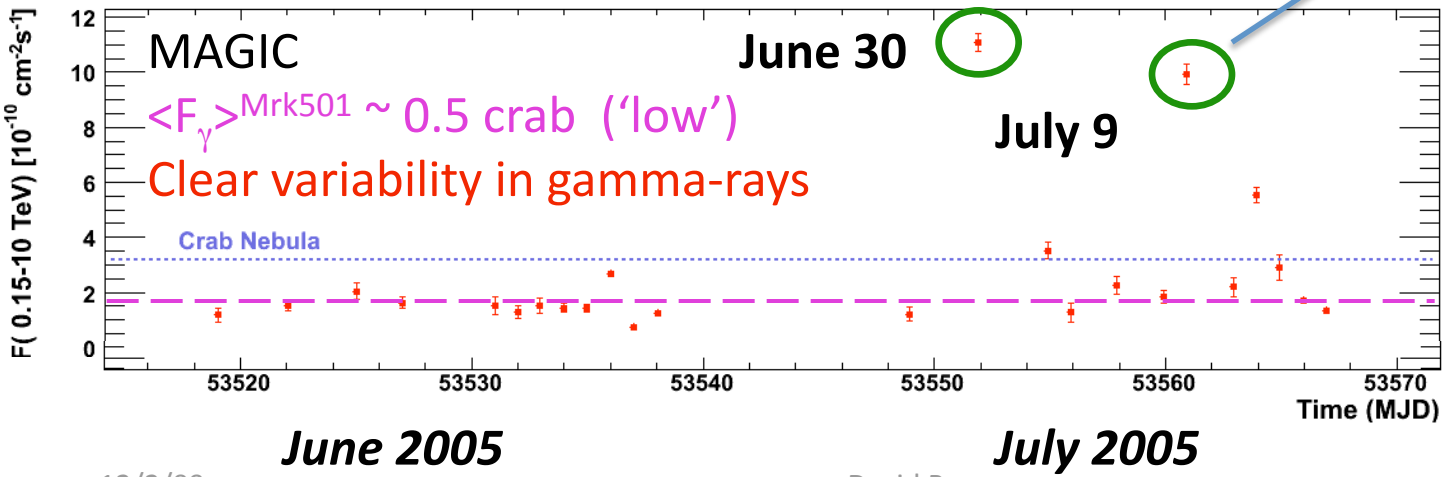
Best MW partners in terms of schedule flexibility AND reliability on data quality

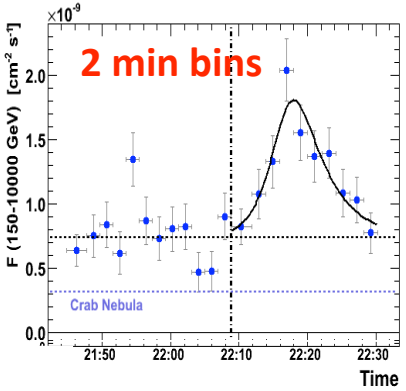
Points 2 and 3 are essential for reliable multi-frequency variability/correlation studies

→ **Powerful tool to break inter-model and intra-model degeneracy**

Specially important simultaneity with TeV observations (→IACTs)
Current IACTs have sensitivity to study those objects in quiescent state on ~1 hour timescales… and ~1 min timescales when flaring

J. Albert et al., ApJ 669 (2007) 862 **Mrk501; E>0.15 TeV**





Unluckily we did not take sensitive X-ray observations simultaneous to those TeV data from 2005

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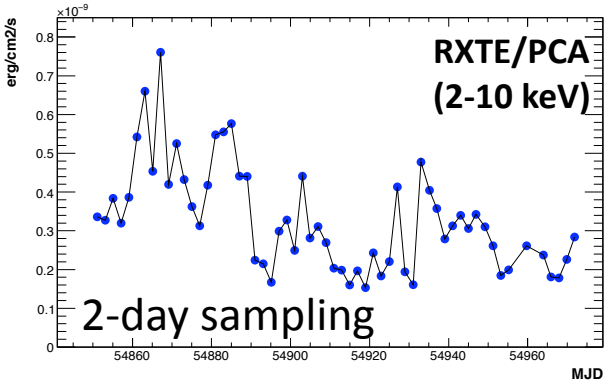
For the 4.5 months long MW campaigns on Mrk421 and Mrk501, almost ALL the sensitive TeV observations (~1 hour long) had SIMULTANEOUS RXTE observations (~20 min)

Mrk421

http://www.slac.stanford.edu/~dpaneque/MW_Mrk421_2009/Obs.html

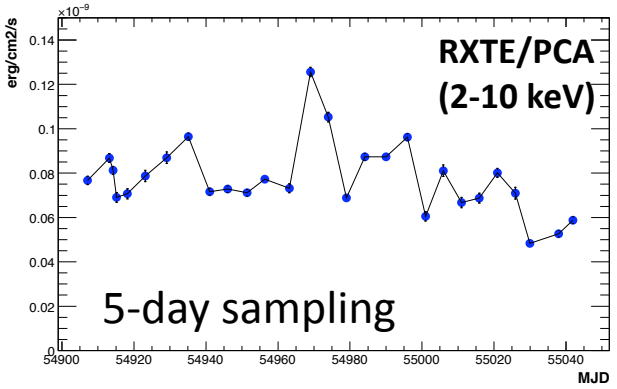


No big flares during these MW campaigns

But we can see very significant flux variability (errors hardly visible)

Mrk501

http://www.slac.stanford.edu/~dpaneque/MW_Mrk501_2009/Obs.html



Reduction of the MW data is still ongoing. Results on forthcoming publications

5 - Conclusions

Fermi operating in survey mode since beginning of August 2008, boosting our current capabilities to study AGNs.

Uniform exposure

Coverage of 20% sky at any time

Large effective area, small PSF …

It brings data that was non-existent before and thus it is expected to constrain the current theoretical models predicting the gamma-ray emission

In-depth study of individual sources is important to understand the physical processes occurring in those objects

Study of the classical (bright) TeV sources has the advantage that, together with the IACTs, Fermi data constrain the high energy bump

- Fermi data opens a "new window" to study those objects

→ Spectra reaching energies beyond 0.1 TeV; overlap with IACTs

- Collection of MW data is ESSENTIAL for understanding those complex objects.

We are collecting an exquisite data set that will surely help us to understand these extreme objects, and the blazar phenomenon. Some of the results already out, many others to come.

RXTE is playing an uniquely important role in these multi-frequency campaigns by providing high quality and simultaneous (to ground optical/TeV instruments) X-ray data

We really hope we can count on RXTE for future campaigns