BROADBAND LONG-TERM VARIABILITY OF VHE BLAZARS

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ABSTRACT In recent years, more and more focus has been placed in broadband studies of blazars as a way to understand the mechanisms responsible for the acceleration of ultra-relativistic particles in these objects. We present in this work preliminary results of the study of the long-term lightcurve and Spectral Energy Distribution (SED) of the TeV blazar Mrk421. For this purpose, we have gathered together data spanning nearly two decades in five different energy bands, from the combined very high energy (VHE) lightcurve available from the literature from past and current ground-based Cherenkov Telescopes, to X-Rays and RADIO frequencies. The aim of this work is to provide a systematic study of the variability of blazars to further extend this work to other sources and therefore infer their physical properties from a statistical context.

Introduction

According to the unified scheme of active galactic nuclei (AGNs), blazars are radio-loud AGN that display highly variable, beamed, non-thermal emission, covering a broad range from radio to gamma-ray energies [1]. The blazar class encompasses BL Lacertae (BL Lac) and flat spectrum radio quasars (FSRQs) objects, whose main differences appear in their emission lines and their spectral energy distribution (SED) properties.

Observationally, blazars are characterized by core-dominated emission and rapid variability, and this feature provides limits to the size and the speed of the emitting region. The SEDs of blazars, in a νF_ν representation, shows two broad distinctive humps arising from different physical processes: synchrotron emission in low energies, and a high energy process of leptonic (i.e. [2] and [3]) or hadronic [4] nature still to be defined.

Strong effort is being placed in recent years on simultaneous multiwavelength campaigns in order to try and differentiate between these two competing models. In this work we put together archive multiwavelength data of several blazars to study variability over different timescales and the dependence of this variability with flux and energy, aiming to shred some light onto the physical mechanisms that drive blazar emission.

Data Sample

For this work we have compiled data spanning over 20 years from several blazars. Our blazar sample has been selected from the public list of BL Lac objects observed with the MAGIC ground-based gamma-ray Cherenkov telescope. Data at other wavelengths have been gathered using publicly available lightcurves and Virtual Observatory (VO) tools. These datasets will allow a systematic study of the variability on different timescales and correlation between different energy bands. We present in this work the preliminary results for one of the most studied sources: Mrk 421. The table below shows the instruments and public and private archives from where the data has been extracted.

Instrument	Energy Range	Start Time	End Time	Archive
VHE (*)	E>1TeV	1992-03-11	2008-06-07	DESY [a]
FERMI (LAT)	0.1-300 GeV	2008-08-01	2011-04-17	HEAVENS [b]
SWIFT (BAT)	15-150 keV	2005-02-13	2011-01-26	BAT Transient Monitoring [c]
RXTE	2-10 keV	1996-01-09	2011-02-10	ASM [d]
UMRAO	14.5 GHz	1992-01-01	2011-01-01	UMRAO (**)
UMRAO	8 GHz	1992-01-01	2011-01-01	UMRAO (**)
UMRAO	4.8 GHz	1992-01-01	2011-01-01	UMRAO (**)

[a] http://nuastro-zeuthen.desy.de/magic_experiment/proyects/light_curve_archive/index_eng.html

[b] http://www.isdc.unige.ch/heavens_webapp/heavens

[c] http://heasarc.nasa.gov/docs/swift/results/transients/

[d] http://xte.mit.edu/ASM_lc.html

(*) Data included in this regime coveres most of the past and present Cherenkov Telescopes, including: HEGRA, H.E.S.S., Whipple, VERITAS and MAGIC.

(**) University of Michigan Radio Astronomy Observatory private communication.

Data Analysis

A summary of the general data analysis procedure is as follows:

- **Lightcurves.**
  - Different lightcurves are produced over different timescales (1, 7, 14 and 30 day averages). In this work we present the products for the lightcurves with a 14 day time bin. Only significant points (>3σ) are considered.
  - Flux/counts distributions are produced for each one of the energy bands and different timescales.
  - The Excess Variance (σ_{xs}) is computed for the different energy/waveband ranges and timescales ($\sigma_{xs}$is a measure of the rms value of the fluxes within the corresponding time interval).
- **Cross-Correlation.**
  - Correlation plots are produced between different energy bands and timescales.

Long-Term Lightcurves for Markarian 421

Light curves are derived in several energy bands: In **Figure 1.** from top to bottom we have VHE (E>1TeV; ground based Cherenkov telesopes), HE (E>0.1KeV; FERMI, SWIFT and RXTE) and RADIO frequencies (14.5GHz, 8.0GHz, 4.8GHz, UMRAO) for a time bin of 14 days.

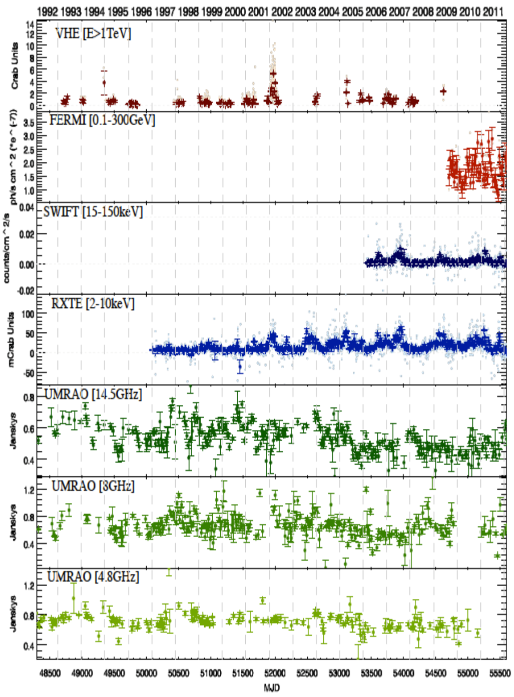

Figure 1. Lightcurves with a time bin of 14 days. From top panel: VHE (E>1TeV), FERMI (0.1-300GeV), SWIFT (BAT, 15.-150.keV), RXTE (2.-10.keV) and Radio (UMRAO) frequencies at 14.5GHz, 8.0GHz, and 4.8 GHz.

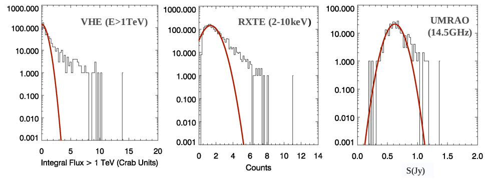

Figure 2. Flux (counts) distributions corresponding to the VHE, RXTE and UMRAO (14.5GHz) lightcurves. The red line indicates a Gaussian fit. The tail above this fit, more evident at higher energies, is an indication of the non-random nature of the underlying processes.

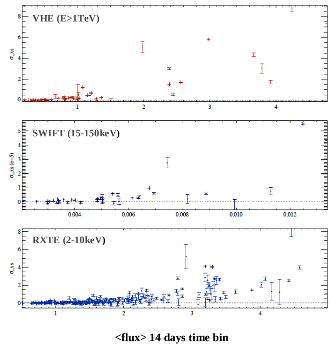

Figure 3. The excess variance σ_{xs} as a function of the average flux within equal-time intervals (14 days).

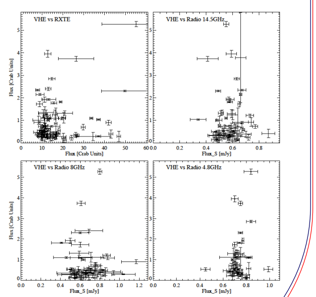

Figure 4. Correlation between the VHE Flux against 4 different energy/waveband ranges. From the top left panel, VHE vs.: RXTE, 14.5GHz, 8.0GHz and 4.8GHz. **Table 1** shows the results in terms of the Spearman's rank correlation coefficient.

Table 1. Value of the Spearman's rank correlation coefficient for the correlation between the VHE band and the 4 different energy/waveband ranges shown in **Figure 4**. A negative value of Spearman rho indicates anti-correlation. We see no evidence of significant correlation.

VHE vs	Spearman's correlation coefficient	Null hypothesis probability
RXTE	-0.02	0.83
14.5GHz	0.16	0.18
8.0GHz	0.06	0.63
4.8GHz	0.04	0.78

Spectral Energy Distribution of Mrk421: VO Tools

VO Tools allow us to retrieve public data from the Virtual Observatory (VO). In this case, we use VO Spec to plot the SED of Mrk421. In the righthand figure, no corrections have been applied to the data displayed.

Instrument	V.O. Tools	Legend
MAGIC Spectra	VOSpec [e]	
2XMMi photometry	VOSED [f]	
Hopkins UV Telescope Spectra	VOSpec	
International UV Explorer Spectra	VOSpec	
Hubble Space Telescope Spectra	VOSpec	
SDSS photometry	VOSED	
2MASS photometry	VOSED	
SPECFIND catalogue	Vizier [g]	
FIRST radio photometry	VOSED	

SED of MRK 421

[e] http://esavo.esac.esa.int/vospec [f] http://sdc.laeff.inta.es/vosed/index.jsp [g]http://vizier.u-strasbg.fr/viz-bin/VizieR

Future Work

We plan to expand the current study in the following areas:

- Identify and characterize specific time periods, like periods of flaring activity, within our data sets
- Investigate the possibility to derive time dependent SEDs for Mrk421 for specific periods (like flares, quiescent states, …)
- Expand the work done for Mrk421 to the rest of the MAGIC blazar data sample.
- Derive the Power Density Spectrum of Mrk421
- Apply the Discrete Correlation Function [7] in order to infer the possible correlation between energy regions including lag times

References

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