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MONITORING THE Mrk421 FLARING ACTIVITY BY THE ARGO-YBJ EXPERIMENT

Roberto Iuppa
INFN, Sezione Roma Tor Vergata
Dipartimento di Fisica, Università di Roma Tor Vergata
on behalf of the ARGO-YBJ collaboration

Abstract

ARGO-YBJ is an extensive air shower detector exploiting the full coverage approach at high altitude (4300 m a.s.l.), designed for gamma-ray astronomy and cosmic-ray physics in the 300 GeV - 30 TeV energy range. One of the most intense gamma-ray sources detected by ARGO-YBJ is Mrk421. It is a blazar close to the Earth (redshift: $z = 0.031$), intensively studied because of its highly varying flaring activity. During the last four years, three major flaring periods have been observed by ARGO-YBJ, in July 2006, in June 2008 and in February 2010. Thsee flares show interesting spectral features, mostly as far as the relation between the X-ray and the gamma-ray emissions is concerned. The status of the observation of Mrk421 is reported.

1 Introduction

In 1992 the blazar Markarian 421 (Mrk421) became the first extragalactic source observed at gamma-ray energy $E > 500$GeV [1]. It is classified as a radio-loud active galactic nucleus (AGN), a subclass of BL Lacertae objects (BL Lac), characterized by a non-thermal spectrum extending up to high energies and by rapid flux variability at nearly all wavelengths. So far, Mrk421 is the closest BL Lac detected above 100 GeV ($z = 0.031$), making it the most studied TeV-emitting AGN and the main benchmark for each model on the emission processes in AGNs and the attenuation of TeV gamma rays propagating through extragalactic space.

The flaring activity of Mrk421 spans over twelve decades of energy (from optical to TeV) and has been observed with variability timescales ranging from minutes to months. Such physical properties require data merging from different experiments in order to get observations as complete as possible.

TeV detection is especially challenging, because of the low emission rate and the short duration of most flares. Nonetheless, many efforts have been spent to observe Mrk421 at TeV energies, because these measurements provide important indications on the source properties and the radiation processes. Recently, several multiwavelength campaigns have revealed a strong correlation of gamma rays with X-rays, that can be easily interpreted in terms of the Synchrotron Self-Compton model [2] [3]. Altough significant variations of the TeV spectrum slope during different activity phases still remain unexplained, some hints have been found of the correlation between the spectral hardness and the flux intensity [4].

Since the emission flux at Very High Energy (VHE, above 100 GeV) is rather low, detections must be carried out with ground-based experiments, with large effective area. In addition, the strong variability of the flaring phenomena demands high duty-cycle and large field of view.

The ARGO-YBJ experiment, located at the Yangbajing Cosmic Ray Laboratory (Tibet, 4300 m a.s.l., $30° 0'38''N, 90° 3'50''E$), since 2007 December has been performing a continuous monitoring of the sky in the declination band from $-10°$ to $70°$. The detector was taking data also during summer 2006, and the ARGO-YBJ dataset represents a unique chance to report on the Mrk421 activity during the last four years.

2 The ARGO-YBJ experiment

The ARGO-YBJ detector, located at the Yangbajing Cosmic Ray Laboratory (Tibet, P.R. China, 4300 m a.s.l.), is the only experiment exploiting the *full coverage* approach at very high altitude. The detector is composed of a central carpet $\sim$74×78 m^2, made of a single layer of Resistive Plate Chambers (RPCs) with $\sim$92% of active area, enclosed by a partially instrumented guard ring that extends the detector surface up to $\sim$100×110 m^2, for a total active surface of $\sim$6700 m^2. The apparatus has a modular structure, described in [5].

The spatial coordinates and the arrival time of any detected particle are used to reconstruct the position of the shower core and the arrival direction of the primary [6].

The ARGO-YBJ experiment started recording data with the whole central carpet in June 2006. Since 2007 November the full detector has been in stable data taking (trigger particle multiplicity N_{trig} =20) with a duty cycle $\sim$ 90%. The trigger rate is about 3.6 kHz.

3 Signal maps

Showers induced by VHE photons coming from Mrk421 are collected when the source zenith angle with respect to Yangbajing is less than 40°. Extending the analysis beyond such limit would slightly increase the exposure time, but a general worsening of the angular resolution should be faced and the energy resolution would be poorer. Since the ratio signal/noise within 1° from the source is about $10^{-4} \div 10^{-5}$, a reliable method of background estimation is needed. The ARGO-YBJ successfully applied different background estimation techniques, each of them giving results consistent with the others.

In order to resolve the primary photons energy, the dataset is divided into multiplicity ranges, according to how many pads the induced shower fires on the central carpet. Fig. 1 reports the cumulative signal detected by ARGO until February 2010, obtained with showers having multiplicity greater than 60. As anticipated in the introduction, the importance of Mrk421 rests basically in the strong variability of its emission. During the last four years, several flares lasting up to tens of days occurred. A short description of the results concerning each flare follows.

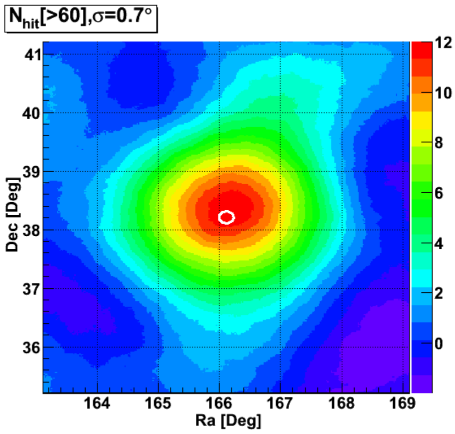

Figure 1: *Showers excess observed by ARGO-YBJ from Mrk421 (nominal position: white circle). It is obtained with events firing more than 60 pads within the central carpet. The angular resolution is about* 0.7° *degrees and the reached significance is about 12 s.d. (see the color scale).*

3.1 The July 2006 flare

It was a long flare, starting in mid-June and lasting up to the first days of September. The most active phase was observed in July, with a strong correlation with X-rays emission. The detection significance was 6 s.d. and the mode energy 500 GeV. The emission corresponded to $3 \div 4$ times the Crab flux intensity at the same energies.

3.2 The June 2008 flare

It was the first flare observed by ARGO-YBJ in stable data taking. Two flaring episodes were reported, in June 3-8 and 9-15. The second flare was not observed at TeV energies by any Cherenkov telescope, hampered by the moonlight, but ARGO-YBJ was able to collect data, contributing to the multiwavelength campaign [7] that was organized on purpose. The results are summarized in fig. 2.

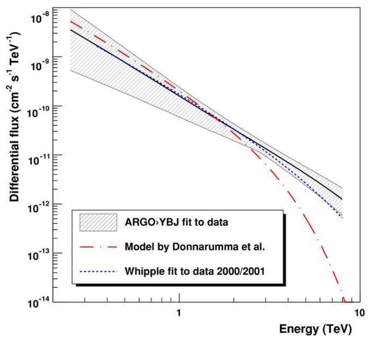

Figure 2: *Energy spectrum of Mrk421 emission as measured by ARGO-YBJ. It is compared with recent theoretical predictions and previous measurements* [8].

3.3 The February 2010 flare

On February, 16^{th} 2010, it took ARGO-YBJ only 6 hours to detect a 5 s.d. significant signal from Mrk421. Positive detections occurred in the following three days too. It was the first time an array-like EAS experiment reached such sensitivities in γ-ray astronomy. Altough further analyses are needed to take conclusions, the energy spectrum looked exceptionally softer, thus feeding the discussion in [4].

4 Correlations with X-ray emission

Fig. 3 illustrates the correlation between the TeV emission from Mrk421 obvserved by ARGO-YBJ and the X-rays fluxes reported by satellites in the same time. Both plots report the cumulative event rate from ARGO-YBJ as a function of time (red points). Integral fluxes in soft (left plot) and hard X-ray (right plot) are also reported (black lines). There is evidence that the VHE signal is more correlated with the hard X component than with the soft X. Deeper studies are in progress to understand the implications of such observations on the emission models.

5 Conclusions

ARG0-YBJ successfully monitored the VHE emission of Mrk421 over the last four years. In this period, three major flaring phases were observed, down to daily timescale, completing the experimental dataset available to the scientific

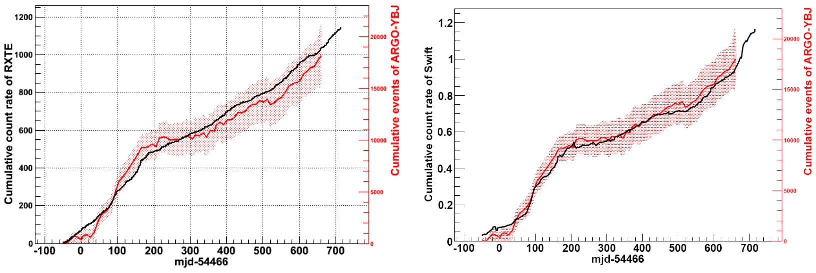

Figure 3: *Cumulative event rate from Mrk421 measured by ARGO-YBJ as a function of the time. In the left plot a comparison with the soft X-ray emission* $(2 \div 12 keV)$ *is reported (http://heasarc.nasa.gov/docs/swift/swiftsc.html). In the right plot a comparison with the hard X-ray emission* $(15 \div 50 keV)$ *is reported (http://heasarc.gsfc.nasa.gov/docs/xte/XTE.html).*

community. Some hints on a possible correlation of the TeV emission with the hard X-ray emission were found. Further analyses are in progress.

6 Acknowledgements

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