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Wide-range multiwavelength observations of northern TeV blazars with MAGIC/HESS, Suzaku and KVA

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Abstract: We conducted multiwavelength observations of the northern TeV blazars, Mkn501 and Mkn421, employing the ground-based γ-ray telescopes MAGIC and HESS, the Suzaku X-ray satellite and the KVA optical telescope. The observations for Mkn501 were performed in July 2006. The source showed one of the lowest fluxes both in very high energy (VHE) γ-ray and X-ray. No significant flux variability could be found in the VHE band while an overall increase of about 50% on a 1-day time scale could be seen in the light curve of the X-ray flux. A one-zone synchrotron self-Compton model can well describe our simultaneous spectral data of the VHE γ-ray and the X-ray emissions of Mkn501 in the quiescent state. The simultaneous observations of Mkn421 were carried out in April 2006. The source was clearly detected in all observations and showed a high state of activity both in VHE γ-ray and X-ray.

Introduction

Blazars, a sub-class of active galactic nuclei (AGNs) characterized by small angles between the jet axis and the line of sight, can provide excellent opportunities for studying particle acceleration mechanism in the jet. One of the most successful models for the emission mechanism in the jet for TeV blazars is the synchrotron self-Compton (SSC) models [1], in which the radiation is originated from relativistic electrons. Models based on the acceleration of hadrons can also sufficiently describe the observed emission [2]. Blazars often show strong flux variability. Hence, simultaneous multiwavelength observations over a wide-energy range in different states are essential to studying the evolution of physical conditions and the shock mechanism in the jet [e.g.][3]. However, most of the previous simultaneous multiwavelength observations could only be conducted during flaring states due to the low sensitivity of the participating γ-ray telescopes.

Multiwavelength campaigns for several northern TeV blazars were coordinated in 2006. A new generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) for very high energy (VHE; $>$100 GeV) γ-ray, the MAGIC and HESS telescopes, the Suzaku X-ray satellite and the KVA optical telescope were involved in those campaigns. In this paper we present the observational results of the campaigns for Mkn501 and Mkn421.

Involved Instruments

MAGIC

The MAGIC telescope is an IACT with a 17-m diameter dish, located on the Canary Island of La Palma (28.2° N, 17.8° W, 2225 m a.s.l.). The telescope is operating at a γ-ray trigger threshold of ~ 50 GeV and a spectral threshold of ~100 GeV. The telescope parameters and performance are described in detail in [4].

HESS

The HESS array consists of four IACTs, each with a tessellated 13-m diameter mirror, located in the Khomas highlands in Namibia (23.3° S, 16.5° E, 1800 m a.s.l.). Due to large zenith angle for northern objects, the observations with HESS array are sensitive to an energy range shifted towards higher energies. The telescope parameters and performance are described in detail in [5].

Suzaku

The joint Japanese-US satellite Suzaku [6], launched successfully into orbit on 10 July 2005, has four X-ray Imaging Spectrometers (XIS) and a separate Hard X-ray Detector (HXD). The XIS are sensitive in the 0.2-10 keV band with CCDs. The HXD's silicon PIN diode array is the most sensitive detector in the 10-70 keV band thanks to the good noise shielding. Its high sensitivity both in the soft and hard X-rays makes it an excellent instrument for studying the synchrotron component of TeV blazar emission, making the detection of the X-ray peak position feasible.

KVA

KVA[1] is a 35-cm optical telescope also situated on La Palma. Selected blazars are regularly observed with KVA as a part of the Tuorla Observatory blazar monitoring program. The KVA telescope can be fully committed to monitoring the target sources during the multiwavelength campaign.

Markarian 501

Mkn501 (z = 0.034) is the second established TeV blazar [7]. In 1997 this source went into a state of surprisingly high activity and strong variability, becoming 10 times brighter than the Crab Nebula in the TeV range [8]. In 1998-1999 the mean flux dropped by an order of magnitude [9]. Recently, rapid flux variability with flux-doubling times down to 2 minutes has been reported [10].

VHE γ-ray observations

Mkn501 was observed for 10.5 h with the MAGIC telescope in the night of 18th, 19th and 20th of July, 2006. The observations were performed in the so-called wobble mode [11], where the object is observed with an $0.4°$ offset from the camera center. After the data selection by the quality and zenith angle ($< 35°$), the remaining data of 9.1 h were analyzed using the MAGIC standard analysis chain. The detailed information can be found in [4, 12]. An observed excess signal corresponding to 13.4 σ excess was found.

The source was also observed with the HESS array during the campaign. The data analysis is currently ongoing.

X-ray observations

The X-ray observation window of Suzaku was between 53934.789 and 53935.727 in MJD time (from 18th to 19th of July, 2006). The net exposure times after screening are 35 ksec in both XIS and HXD detectors.

Light curves

Figure 1 shows the light curves in various energy bands. The source was rather quiet during the campaign. The fluxes in VHE γ-ray and optical R-band were consistent with constant levels, while the X-ray count rate was growing during the observations with an overall increase of about 50% on a 1-day time scale between the beginning and the end of the observations.

1. more information at http://tur3.tur.iac.es/

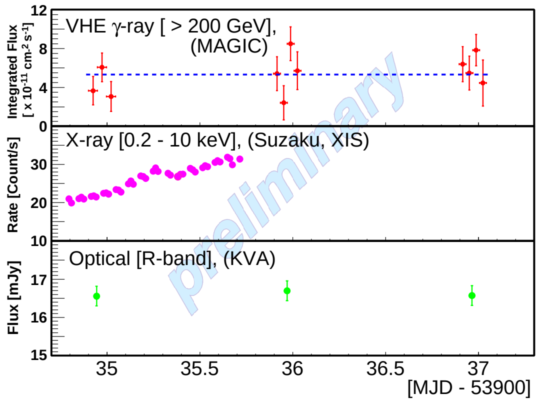

Figure 1: Light curves of Mkn501 in different energy bands during the campaign in 2006. **Top:** VHE γ-ray flux measured by the MAGIC telescope with 1-hour binning. A dotted horizontal line represents the average flux. **Middle:** The X-ray count rate recorded by the Suzaku XIS detectors. **Bottom:** Measured Optical R-band flux by KVA.

The average integrated flux above 200 GeV is $(5.3 \pm 0.5) \times 10^{-11}$ cm^{-2} s^{-1} (χ^2/dof $= 12.7/10$), which corresponds to about 27% of the Crab Nebula flux as measured by the MAGIC telescope [4].

Spectra

The spectrum in the VHE band is well described by a simple power law from 85 GeV to 2 TeV with $dN/dE = (1.24 \pm 0.11) \times 10^{-10} \, (E/300 \text{ GeV})^{-2.85 \pm 0.14}$ [TeV^{-1} s^{-1} cm^{-2}]. The flux level and the photon index of the measured spectrum are comparable to those in the lowest state among 2005 MAGIC observations ($dN/dE = (1.36 \pm 0.21) \times 10^{-10} \, (E/300 \text{ GeV})^{-2.73 \pm 0.29}$ [10]) for this object.

Spectral Modeling

Figure 2 shows the spectral energy distribution (SED) of Mkn501 with data of this multiwavelength campaign and some historical data [10, 14]. The "de-absorbed" data in blue points at the VHE band were corrected for the extra-galactic background light (EBL) absorption using the "Best" fit model of [15]. In optical, the host galaxy contributions (12.0 ± 0.3) [mJy] [16] has already been subtracted. Since systematic errors at soft X-ray energies are still under investigation, we use only X-ray data above 1 keV for the model fit.

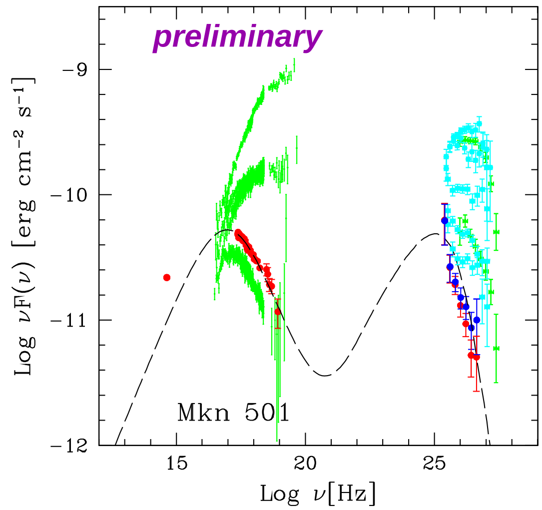

Figure 2: SED of Mkn501. The simultaneous spectral data in optical (KVA), X-ray (Suzaku) and VHE γ-ray (MAGIC) in the 2006 campaign are shown by red points. Blue points represent a "de-absorbed" spectrum corrected for the EBL absorption. The line describes the best fit to this campaign data with a one-zone SSC model developed by [13, 14]. See text for the fit parameters. For comparison, green points denote historical data taken by BeppoSAX for X-rays data from 1997 to 1999 and by CAT in the VHE γ-ray range in 1997 [14]. Flux levels from the MAGIC observations in 2005 are also denoted by cyan points [10].

Assuming a uniform injection of the electrons throughout a homogeneous emission region, we applied a one-zone SSC model for the campaign data to estimate the physical parameters of the emitting region using the code developed by [13, 14]. Briefly, a spherical shape (blob) is adopted for the emission region with radius R, filled with a tangled magnetic field with intensity B . An electron distribution is described by a smoothed broken power-law energy distribution with slopes s_1 from $\gamma_{\rm min}$ to the break energy $\gamma_{\rm b}$ and s_2 up to the limit of $\gamma_{\rm max}$ and with a normalization factor of

K. The relativistic effects are taken into account by the Doppler factor δ.

R is selected to be 1×10^{15} cm, which has been adopted in [10] for the SED during the rapid flare observed with MAGIC in 2005. Since no cut off can be seen both in the X-ray and VHE γ-ray spectra, $\gamma_{\rm min}$ and $\gamma_{\rm max}$ are fixed at 1 and 10^7, respectively. The best fit was achieved with the following parameters: $\delta = 20$, $B = 0.26$ G, $K = 1 \times 10^5\,{\rm cm}^{-3}$, $\gamma_{\rm b} = 6.7 \times 10^4$, $s_1 = 2$ and $s_2 = 4$. This one-zone SSC model can reproduce well the obtained X-ray and VHE γ-ray fluxes in the low state of activity during the campaign. However, it is apparent that the model underestimates the optical flux. This can be explained by the assumption that the emission from radio to UV has another origin than the high energy emission. This interpretation has already been applied to previous SEDs of Mkn501 by [17]. Compared to historical measurements our data show one of the lowest states both in X-ray and VHE γ-ray. The historical data suggest a correlation between the peak positions and the source luminosity [14]. Following [3, 14] we can assume this feature is related to the evolution of $\gamma_{\rm b}$. In that framework we can find our derived value of $\gamma_{\rm b}$ to be small compared to previous observation results [e.g.][10, 17, 18, 14]. More details on the analysis and the results will be found in [19].

Markarian 421

Mkn421 (*z* = 0.030) is the closest known source and the first extragalactic one detected in the TeV energy range using IACTs [20], and it is one of the best studied TeV γ-ray blazar.

Observations and Results

The multiwavelength observations for this source were conducted in the night of April 28th, 2006. The X-ray observations with Suzaku were carried out between 53853.267 and 53854.271 in MJD time. The source was observed by the MAGIC telescope for 3.8 h and by the HESS array for 1.5 h. Both observations were performed during the Suzaku pointing to the source. Clear detections of signals can be found in all observations. The X-ray spectrum is extracted from the data which are exactly coincident with the HESS or MAGIC observation times. The spectrum in the X-ray band as well as in the VHE γ-ray band indicates that the source showed a high state and a rather stable activity during the simultaneous observations. Details of the observational results of this campaign will be discussed in [21].

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