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Citation: [AIP Conference Proceedings](#) **1505**, 534 (2012); doi: 10.1063/1.4772315

View online: <http://dx.doi.org/10.1063/1.4772315>

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Spectral variability and multiwavelength studies of the high-frequency-peaked BL Lacertae object 1ES 0806+524 with the MAGIC telescopes

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Abstract. We report observations of the high-frequency-peaked BL Lacertae (HBL) object 1ES 0806+524, $z = 0.138$ [1] carried out from January to March 2011 by the MAGIC stereoscopic system located on La Palma, Canary Islands, Spain. The MAGIC experiment consists of two 17 m diameter imaging Cherenkov telescopes allowing measurements down to a threshold as low as 50 GeV [2]. In particular, observations performed on February 24th, 2011, yielded a strong detection accompanied by a clear flux increase. The significantly lower flux the day before and after February 24th indicates a source variability on a time scale of approximately one day. During the previous VERITAS detection the observed flux was several times lower and no measurable variability on a monthly time scale was found [4]. We present a differential spectrum extended to lower energies in order to study the inverse-Compton peak. Simultaneous multiwavelength data are presented to complement the very high energy (VHE) observations by MAGIC.

Keywords: Gamma rays: galaxies - BL Lacertae objects: individual (1ES 0806+524)

PACS: 98.54.Cm, 95.55.Ka, 95.85.-e

MAGIC STEREO OBSERVATIONS OF 1ES 0806+524

While previous MAGIC observations did not result in a clear source detection but in integral upper limits only [5], [6], observations carried out in winter 2011 resulted in a flare detection on February 24th (7.6 σ above 250 GeV [3]) and a strong overall detection of $\sim 9.9 \sigma$ above 300 GeV (Fig.1). The observations were triggered by a high optical state of the source reported by the KVA telescope in the framework of the Tuorla blazar monitoring program. The sky map above 300 GeV shows a clear excess at the catalogue position of 1ES 0806+52 (Fig. 1)

FIGURE 1. Left: Distribution of the squared angular distance θ^2 for the On and Off source counts in the direction of 1ES 0806+524 observed by MAGIC ($E > 300$ GeV) in 2011. Right: Significance sky map ($E > 300$ GeV) derived from MAGIC observations in 2011 showing a clear point-like excess at the catalogue position of 1ES 0806+524.

VHE γ -RAY INTEGRATED AND DIFFERENTIAL FLUX

The daily light curve above 250 GeV yields a probability of $\sim 0.5\%$ of a constant flux (Fig. 2). During the flare of February 24th (MJD = 55616) the flux shows a significant

FIGURE 2. Left: VHE γ -ray flux ($E > 250$ GeV) of 1ES 0806+524 from 2011 MAGIC observations indicating a short term variability of the source. The arrows correspond to the 95% confidence upper limits. Right: Observed VHE γ -ray spectrum of 1ES 0806+524 (filled circles). The de-absorbed spectrum (blank circles) is corrected for EBL absorption using the model provided by [7]. The source spectrum observed by VERITAS (filled squares [4]) and the Crab Nebula spectrum (dashed line [8]) are shown for comparison.

(4.3σ) increase ($(8.6 \pm 1.9)\%$ Crab Units (C.U.) above 250 GeV [3]) with respect to the averaged flux of the previous and successive night ($(2.9 \pm 0.7)\%$ C.U. above 250 GeV). The averaged flux from January 7th to March 2nd excluding the night of February 24th is $(1.9 \pm 0.6)\%$ C.U. above 250 GeV and $(2.1 \pm 0.8)\%$ C.U. above 300 GeV respectively. Compared to this out-of-flare flux level, the flux of February 24th is several times higher; a hint of increasing flux towards March 2nd (MJD = 55622) is also observed

((7.5 ± 2.6)% C.U. above 250 GeV). The out-of-flare flux level is compatible with the flux previously observed by VERITAS (1.8% C.U. above 300 GeV [4]). The extended differential spectrum is well described from ~ 120 GeV to ~ 1 TeV by a simple power law with a spectral index $\Gamma = -2.61 \pm 0.22_{\text{stat}} \pm 0.15_{\text{sys}}$ (Fig. 2). In comparison to the spectrum observed by VERITAS ($\Gamma = -3.6 \pm 1.0_{\text{stat}} \pm 0.3_{\text{sys}}$ between ~ 300 GeV and ~ 700 GeV. [4]), the MAGIC spectrum seems to be harder, rotated around a pivot point in the vicinity of 200 GeV. Corrections for the attenuation due to pair production by the interaction with the extra galactic background light (EBL) of the observed spectrum by using the model of [7] provide an intrinsic spectral index Γ of $-2.0 \pm 0.31_{\text{stat}}$.

1ES 0806+524 SEEN IN A MULTIWAVELENGTH FRAMEWORK

Simultaneous observations in different energy bands by MAGIC, the *Fermi* LAT, the *Swift* satellite, the KVA telescope and the OVRO telescope have been collected to study the source variability across the electromagnetic spectrum (Fig.3). A smooth

FIGURE 3. Multiwavelength light curve of 1ES 0806+524 from fall 2010 to spring 2011. A flux increase has been observed in all energy bands except the radio band. The light curves in VHE γ -rays above 250 GeV (filled circles), X-rays (filled squares), in the R-band (filled triangles) and the radio (blank diamonds) band are daily binned. The HE γ -rays light curves above 1 GeV and 300 MeV (blank triangles and blank circles) are monthly binned. 95% confidence upper limits are indicated by errors.

flux increase in high energy (HE) γ -rays was observed later with respect to the other wavelengths which might be due to the long integration time of one month. The flare detected in X-rays [9] coincides with the outburst in VHE γ -rays. In the R-band a smooth flux increase is observed that reaches a maximum during the outburst in VHE γ -rays and

X-rays while no radio flare associated to the high states in other wavelengths was found.

CONCLUSION

MAGIC detected a strong activity in VHE γ -rays from 1ES 0806+524 in winter 2011 whose observation was triggered by an optical high state. The comparison of the differential flux with previous VERITAS observations indicates spectral variability. The simultaneous multiwavelength data show short term variability of 1ES 0806+524 across the electromagnetic spectrum. While the optical-VHE γ -ray outburst has been accompanied by an outburst in X-rays, the increase in flux in HE γ -rays has been observed later and on longer time scales. No clear variability in the radio band was found.

ACKNOWLEDGMENTS

We would like to thank the Instituto de Astrofísica de Canarias for the excellent working conditions at the Observatorio del Roque de los Muchachos in La Palma. The support of the German BMBF and MPG, the Italian INFN, the Swiss National Fund SNF, and the Spanish MICINN is gratefully acknowledged. This work was also supported by the Marie Curie program, by the CPAN CSD2007-00042 and MultiDark CSD2009-00064 projects of the Spanish Consolider-Ingenio 2010 programme, by grant DO02-353 of the Bulgarian NSF, by grant 127740 of the Academy of Finland, by the YIP of the Helmholtz Gemeinschaft, by the DFG Cluster of Excellence “Origin and Structure of the Universe”, by the DFG Collaborative Research Centers SFB823/C4 and SFB876/C3, and by the Polish MNiSzW grant 745/N-HESS-MAGIC/2010/0.

The *Fermi* LAT Collaboration acknowledges support from a number of agencies and institutes for both development and the operation of the LAT as well as scientific data analysis. These include NASA and DOE in the United States, CEA/Irfu and IN2P3/CNRS in France, ASI and INFN in Italy, MEXT, KEK, and JAXA in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the National Space Board in Sweden. Additional support from INAF in Italy and CNES in France for science analysis during the operations phase is also gratefully acknowledged.

The OVRO 40-m monitoring program is supported in part by NASA grants NNX08AW31G and NNX11A043G, and NSF grants AST-0808050 and AST-1109911.

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