

MAGIC observations of PG 1553+113 during a multiwavelength campaign in July 2006 (Research Note)

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ABSTRACT

The active galactic nucleus PG 1553+113 was observed by the MAGIC telescope in July 2006 during a multiwavelength campaign, in which telescopes in the optical, X-ray, and very high energies participated. Although the MAGIC data were affected by strong atmospheric absorption (calima), they were analyzed after applying a correction. In 8.5 h, a signal was detected with a significance of 5.0σ . The integral flux above 150 GeV was $(2.6 \pm 0.9) \times 10^{-7} \text{ ph s}^{-1} \text{ m}^{-2}$. By fitting the differential energy spectrum with a power law, a spectral index of -4.1 ± 0.3 was obtained.

Key words. gamma rays: observations – galaxies: active – galaxies: BL Lacertae objects: individual: PG 1553+113

1. Introduction

The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) telescope, located on the Canary Island of La Palma at 2200 m a.s.l., is capable of extending very high energy observations to energies previously unreachable and detecting new sources at energies down to 50 GeV.

One of these sources is the BL Lac type object PG 1553+113, observed for the first time in this energy range in April and May 2005 by the MAGIC telescope and the High Energy Stereoscopic System (HESS). From these observations a faint signal was measured, and the detection was confirmed by further observations (Aharonian et al. 2006; Albert et al. 2007). In the subsequent years, additional VHE data were taken. From the combined data sets, strong signals were found: for HESS at 10.2σ significance (Aharonian et al. 2008) and for MAGIC at 15.0σ significance (Dorner 2008). In addition, the VHE measurements allowed the unknown redshift of the source to be constrained. Until now the redshift of PG 1553+113 has

been unknown, since neither emission or absorption lines could be found, nor the host galaxy resolved. Several lower limits were determined (Carangelo et al. 2003; Sbarufatti et al. 2005, 2006; Scarpa et al. 2000; Treves et al. 2007). With the MAGIC and HESS measurements, upper limits could be determined (Aharonian et al. 2006; Mazin & Goebel 2007; Dorner 2008).

To study the spectral energy distribution of a source, simultaneous data from different wavelengths are mandatory. Therefore, a multiwavelength (MWL) campaign was performed in July 2006 to observe PG 1553+113. This paper concentrates on the data taken by MAGIC during this MWL campaign.

2. Observations and data quality

Between April 2005 and April 2007, MAGIC observed PG 1553+113 for a total of 78 h. Part of these data were acquired during a MWL campaign in 2006 July with the HESS array of IACTs, the X-ray satellite Suzaku and the optical telescope KVA. Suzaku observed the source between 24 July, 14:26 UTC

and 25 July, 19:17 UTC, and HESS between 22 July and 27 July. From the KVA, data between 21 July and 27 July are available.

The MAGIC telescope observed PG 1553+113 between 14 July and 27 July for 9.5 h at zenith distances between 18° and 35° . The data were acquired in wobble mode, where the source was tracked with an offset of $\pm 0.4^\circ$ from the center of the camera, which enabled simultaneous measurement of the source and the background.

One hour of data was excluded due to technical problems. The quality of the entire data set acquired during the MWL campaign was affected by calima, i.e. sand-dust from the Sahara in the atmosphere. For the affected data, the nightly values of atmospheric absorption ranged between 5% and 40%. To account for the absorption of the Cherenkov light, correction factors were calculated and applied to the data (see Sect. 4).

3. Analysis

The data were processed by an automated analysis pipeline (Dorner & Bretz 2005; Bretz & Dorner 2005) at the data center in Würzburg. The analysis includes an absolute calibration with muons (Goebel et al. 2005), an absolute mispointing correction (Riegel et al. 2005), and it uses the arrival time information of the pulses of neighboring pixels for noise subtraction and background suppression.

In determining the background, three OFF regions were used, providing a scale factor of 1/3 for the background measurement.

To suppress the background, a dynamical cut in Area (Area = $\pi \cdot \text{WIDTH} \cdot \text{LENGTH}$) versus SIZE and a cut in ϑ were applied. More details of the cuts can be found in Riegel & Bretz (2005), and the aforementioned image parameters are described by Hillas (1985). To account for the steeper spectrum of PG 1553+113, the here presented analysis applied a cut in Area that was less restrictive at lower energies compared to the standard cut used by the automated analysis, which has been optimized for Crab Nebula data over several years.

In generating the spectrum, the cut in Area was selected to ensure that more than 90% of the simulated gammas survived. To study the dependency of the spectral shape on the cut efficiency, a different cut in Area with cut efficiencies of between 50% and 95% for the entire energy range was applied.

4. Correction of the effect of calima

Calima, also known as Saharan Air Layer (SAL), is a layer in the atmosphere that transports sand-dust from the Sahara in a westerly direction over the Atlantic Ocean. The SAL is usually situated between 1.5 km and 5.5 km a.s.l. (Dunion & Velden 2004). Since the Canary Islands are close to the North African coast, the MAGIC observations are probably affected by additional light absorption in the atmosphere when calima occurs.

From extinction measurements of the Carlsberg Meridian Telescope (Evans et al. 2002; Carlsberg Meridian Telescope 2007), which are available for each night, the loss of light due to calima was calculated. To correct the data for absorption by the atmosphere, the calibration factors were adapted for each night separately and the data were reprocessed. More details of the method are provided by Dorner et al. (2009).

5. Results

The 8.5 h of data from PG 1553+113 provided a signal with a significance of 5.0σ according to Li & Ma (1983). The ϑ^2

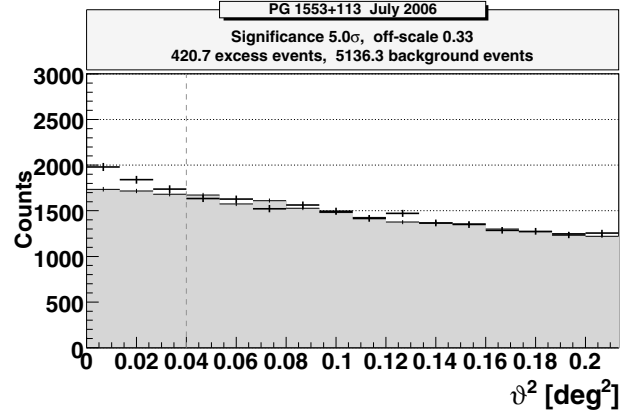


Fig. 1. Distributions of ϑ^2 for ON-source events (black crosses) and normalized OFF-source events (gray shaded area) from 8.5 h of data. The dashed line represents the cut applied in ϑ^2 .

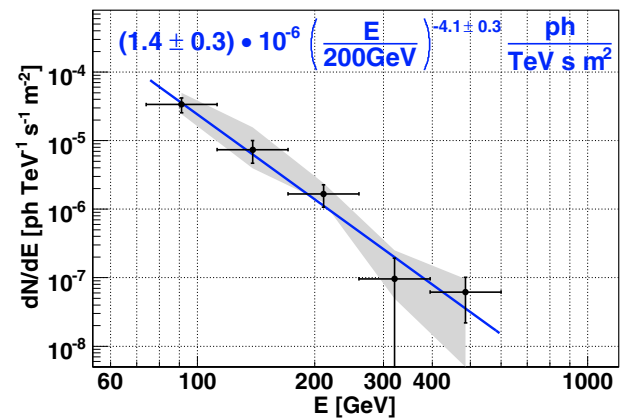


Fig. 2. Differential energy spectrum of PG 1553+113. The horizontal error bars indicate the width of the energy bins. The vertical error bars illustrate the statistical errors. The gray band corresponds to a set of spectra obtained with different cut efficiencies and simulated spectra.

distributions for the ON- and normalized OFF-source measurement are shown in Fig. 1.

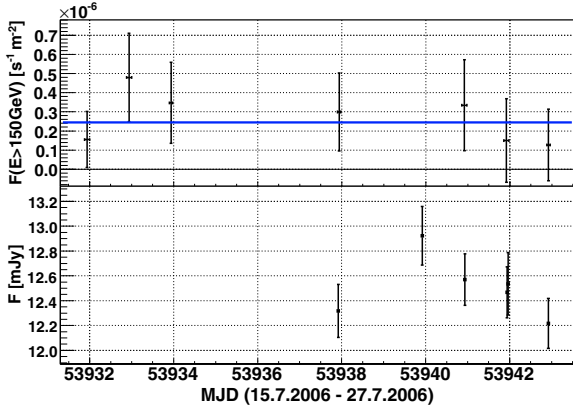
The differential spectrum measured by MAGIC is shown in Fig. 2. In this plot, a set of spectra obtained with different cut efficiencies and different simulated spectra is indicated by a gray band. The data points of the spectrum are given in Table 1 including the statistical errors. The systematic errors of the analysis are discussed in Albert et al. (2008).

Fitting the differential spectrum with a power law yields a flux of $(1.4 \pm 0.3) \times 10^{-6}$ ph $\text{TeV}^{-1} \text{s}^{-1} \text{m}^{-2}$ at 200 GeV and a spectral index of -4.1 ± 0.3 . This result is consistent with the data (fit probability 45%) and in good agreement with previous measurements in 2005 and 2006 (Aharonian et al. 2006; Albert et al. 2007). Within the errors, the simultaneous measurements of the HESS telescopes in the energy range above 225 GeV is in agreement with the MAGIC results, although the fit of the differential spectrum yields a spectral index of -5.0 ± 0.7 (Aharonian et al. 2008). The integral flux above 150 GeV obtained from this analysis is $(2.6 \pm 0.9) \times 10^{-7}$ ph $\text{s}^{-1} \text{m}^{-2}$.

To check whether a flare occurred during the eight nights of observation, the flux above 150 GeV was calculated on a night-by-night basis (see Table 2). The corresponding light curve is shown in the upper part of Fig. 3. Since the data sets for single days are of durations shorter than one and a half hours (0.62 h–1.4 h), the data points represent only signals of a significance level between 0.7σ and 2.1σ . Consequently, no strong

Table 1. Flux for the spectral points in Fig. 2 including the statistical errors.

E [GeV]	F [ph TeV ⁻¹ s ⁻¹ m ⁻²]	Statistical error [ph TeV ⁻¹ s ⁻¹ m ⁻²]
91	3.36×10^{-5}	8.11×10^{-6}
139	7.37×10^{-6}	2.68×10^{-6}
211	1.67×10^{-6}	6.04×10^{-7}
320	9.61×10^{-8}	9.61×10^{-8}
486	6.18×10^{-8}	4.00×10^{-8}

**Fig. 3.** Night-by-night light curve for the integral flux above 150 GeV in ph s⁻¹ m⁻² (upper part) and the flux in the optical R-band (lower part) between July 15th and 27th 2006. For the first nights of the MAGIC observations, no data by the optical telescope KVA were obtained.**Table 2.** Date, start time, duration, and flux above 150 GeV for the MAGIC observations carried out between July 15th and 27th 2006.

Observation [UTC]	$F (>150 \text{ GeV})$
Start time (Duration)	[ph s ⁻¹ m ⁻²]
15.7.2006 21:45 (1.4 h)	$(1.55 \pm 1.46) \times 10^{-7}$
16.7.2006 21:45 (1.37 h)	$(4.79 \pm 2.31) \times 10^{-7}$
17.7.2006 22:15 (0.85 h)	$(3.47 \pm 2.14) \times 10^{-7}$
21.7.2006 22:13 (0.62 h)	$(2.99 \pm 2.04) \times 10^{-7}$
23.7.2006 21:38 (0.88 h)	–
24.7.2006 21:50 (1.09 h)	$(3.34 \pm 2.38) \times 10^{-7}$
25.7.2006 21:38 (1.31 h)	$(1.50 \pm 2.18) \times 10^{-7}$
26.7.2006 21:37 (0.92 h)	$(1.27 \pm 1.87) \times 10^{-7}$

For one day, the flux level could not be determined because no signal for energies above 150 GeV was detectable in this data set.

conclusions about the night-to-night variability in the flux can be drawn. Within the errors, the measurement is consistent with a constant flux (fit probability 82%).

Contemporaneously with the MAGIC observations, the optical telescope KVA acquired data in the R-band. For the first nights, no data was available. The flux for additional nights is shown in the lower part of Fig. 3.

6. Conclusion and outlook

PG 1553+113 was observed in July 2006 as part of a MWL campaign with the MAGIC telescope. After correcting the data for the effect of calima, the analysis detected a gamma-ray signal of 5.0 standard deviations. Within the statistical errors, the differential energy spectrum is compatible with those derived by previous measurements including the one observed by HESS in this campaign. The inter-night light curve shows no significant variability.

The measured flux and reconstructed spectrum will be used in studies of the spectral energy distribution, which will include other data acquired during the MWL campaign (Reimer et al. 2008).

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