Observation of the BL Lac objects 1ES 1215+303 and 1ES 1218+304 with the MAGIC telescopes

PIERRE COLIN¹, JOSEFA BECERRA GONZÁLEZ², ELINA LINDFORS³, SAVERIO LOMBARDI⁴, JULIAN SITAREK⁵ ON BEHALF OF THE MAGIC COLLABORATION

¹Max-Planck-Institut fr Physik, Munich, Germany
²Instituto de Astrofisica de Canarias, La Laguna, Spain
³Tuorla Observatory, Piikki, Finland
⁴Università di Padova and INFN, I-35131 Padova, Italy
⁵University of Lodz, Poland

colin@mppmu.mpg.de

Abstract: The two BL Lac objects 1ES 1215+303 and 1ES 1218+304, separated by 0.8°, were observed with the MAGIC telescopes in 2010 and 2011. The 20 hours of data registered in January 2011 resulted in the first detection at Very High Energy (>100 GeV) of 1ES 1215+303 (also known as ON-325). This observation was triggered by a high optical state of the source reported by the Tuorla blazar monitoring program. Comparison with the 25 hours of data carried out from January to May 2010 suggests that 1ES 1215+303 was flaring also in VHE gamma-rays in 2011. In addition, the Swift ToO observations in X-rays showed that the flux was almost doubled respect to previous observations (December 2009). Instead, 1ES 1218+304 is a well known VHE gamma-ray emitter lying in the same field of view, which was then simultaneously observed with the MAGIC telescopes. The overall observation time of nearly 45 hours has permitted to measure the spectrum of this source with a much higher precision than previously reported by MAGIC. Here, we present the results of the MAGIC and the multi-wavelength observations of these two VHE gamma-ray emitting AGNs.

Keywords: VHE γ-rays, AGN, BL Lac, HBL, 1ES 1215+303, 1ES 1218+304, ON 325, MAGIC

1 Introduction

BL Lac objects are a special type of active galactic nuclei (AGN) with broad-band emission from radio waves to γ-rays dominated by non-thermal emission without (or with faint) lines. They show strong and rapid variability at all wavelengths and have a spectral energy distribution (SED) with a typical double bump shape. The emission is understood as originating from the relativistic electrons of the AGN jet which is pointing very close to our line of sight. The first and second bumps are associated respectively to synchrotron and inverse Compton emissions.

Most of the extragalactic Very High Energy (VHE, >100 GeV) γ-ray sources are BL Lac objects and more specifically High-frequency-peaked BL Lac (HBL) with the first SED bump peaking in the X-ray band. The second bump of the intrinsic SED of HBL should peak in the GeV-TeV γ-ray regime. However the VHE emission is attenuated by its interaction with the extragalactic background light (EBL) during its travel toward Earth and only nearby HBL (redshift<0.5) can be observed at VHE. In order to obtain the intrinsic VHE spectrum, the measured spectrum has to be corrected according to an EBL model and to the distance of the source. Constraints on the EBL models can also be derived from the measured VHE spectra.

1ES 1215+303 (also known as ON 325) is a HBL with an uncertain redshift (two values can be found in the literature: z=0.130 and z=0.237). The source was classified as promising candidate TeV blazar by Costamante & Ghisellini [1] and has been observed several times in VHE γ-rays prior to the observations presented here. The Whipple (10m telescope) and MAGIC (single telescope observation) reported respectively the following integral flux upper limits: \( F_{>100 GeV} < 1.89 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1} \) in 2000 [2] and \( F_{>100 GeV} < 3.5 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1} \) in 2007-2008 [3].

1ES 1218+304 is another HBL located only 0.8° away from 1ES 1215+303. It has a moderate redshift of 0.182. It was first detected at VHE by MAGIC [4] and confirmed by VERITAS [7] who reported also fast variability from this source in 2009 [8]. In the Fermi-LAT one year catalog [9], the source is flagged non-variable. It is an interesting object because the measured VHE spectrum is particularly hard for this redshift, indicating an intrinsic SED with an inverse Compton peak above 1 TeV. The emission is then strongly interacting with the EBL before reaching us. This makes it a good candidate to probe the EBL [6,7] or the extragalactic magnetic field [10].

This proceeding reports on the 2010 and 2011 measurements of the VHE γ-ray emission from both 1ES 1215+303 and 1ES 1218+304 with the MAGIC telescopes. We also
compare the VHE emissions with the longterm optical light curves obtained with the Tuorla blazar monitoring program (KVA telescope).

2 Observations and Data Analysis

2.1 MAGIC

MAGIC consists of two 17 m imaging air Cherenkov telescopes located at the Canary Island of La Palma, 2200 m above sea level. The stereoscopic system has been in operation since fall 2009 and reaches its best sensitivity above \( \sim 250 \text{ GeV} \) with 0.8% of the Crab Nebula in 50 h \([11]\). MAGIC cameras have a field of view of 3.5°.

1ES 1215+303 and 1ES 1218+304 were observed with the MAGIC telescopes in January-February 2010, May-June 2010 and January-February 2011 for a total of 48 h. The observations were done in wobble mode around 1ES 1215+303 with four pointing positions 0.4° away from this source. 1ES 1218+304 was not the primary target of these observations, but it is always inside the MAGIC camera field of view. It lies at different distances from the camera center in each pointing position: 0.36°, 0.84°, 0.87° and 1.15°. Hence, 1ES 1218+304 can be studied even if the MAGIC performance degrades at large offset \([11]\).

The data were taken during dark night and moderate moon conditions at zenith angles from 1° to 40°. For the analysis the data were divided into two samples corresponding to two observing epochs: 2010 (~26h) and 2011 (~22h).

The data were analyzed using standard MAGIC software \([12]\) with additional adaptations incorporating the stereoscopic observations \([13]\). Due to the presence of two sources in the same field of view, a special care has to be taken to estimate the background.

2.2 Tuorla blazar monitoring program

The 2011 MAGIC observations were triggered by an optical high-state of 1ES 1215+303 reported by the Tuorla blazar monitoring program \([14]\).

Since the beginning of its scientific operation, MAGIC has been successfully performing optically triggered Target of Opportunity (ToO) observations of AGNs. The triggers have been provided by the Tuorla blazar monitoring program using the 35 cm KVA optical telescope. The KVA telescope is located on La Palma, but is operated remotely from Finland. The observations are done in R-band and the R-band magnitude of the source is measured from CCD images using differential photometry.

1ES 1215+303 and 1ES 1218+304 have been part of the Tuorla blazar monitoring program from its beginning and then have been observed regularly since 2002. The core flux of the sources (shown Figure 3) is measured by subtracting the host galaxy contribution from the observed flux \([15]\).

3 Results

All the results presented here are preliminary and may evolve before the conference.

3.1 1ES 1215+303

The analysis of the 2010 data resulted in 3σ excess from 1ES 1215+303 while for 2011 data an excess corresponding to 10.1σ has been detected. Figure 1 shows the distribution of the square distance (\( \theta^2 \)) between the reconstructed shower directions and 1ES 1215+303 position, for data taken in January-February 2011 with MAGIC. The grey filled histogram represents the expected background estimated with 3 Off positions at the same distance from the camera center.

![Figure 1: Distribution of the square distances (\( \theta^2 \)) between the reconstructed shower directions and the 1ES 1215+303 position, for data taken in January-February 2011 with MAGIC.](image)

The significance skymaps of a point-like source detection based on the reconstructed shower directions and 1ES 1215+303 where a clear excess appears at small \( \theta^2 \). The energy threshold of this analysis is about 200 GeV. The 2011 \( \theta^2 \) plot represents the first significant detection of VHE γ-rays from this source \([16]\).

The significance skymaps of a point-like source detection inside the observed field of view are shown Figure 2 for both 2010 and 2011 data samples. These two samples contain about the same amount of data and both maps have almost the same sensitivity. 1ES 1215+303 is clearly visible at the center of the map in 2011 but did not show up in 2010, suggesting year scale variability.

The optical state of 1ES 1215+303 was also higher in 2011 than in 2010. The core flux measured with the KVA telescope was about a factor 2 higher (see the lightcurves in Figure 3).

1ES 1215+303 is the fifth BL Lac objects discovered by MAGIC during an optical high state \([17, 18, 19, 20, 16]\). This strongly suggests there is a connection between optical and VHE γ-ray high states in BL Lac objects. However, follow-up observations of the discovered sources have not been able to confirm such a connection \([21, 22]\).

1. \( \sigma = \) standard deviation
3.2 1ES 1218+304

The preliminary analysis of 1ES 1218+304 results in a clear detection of the source with a significance of $\sim 20\sigma$ for the full data set. As one can see in Figure 2, the source shows approximately the same significances in both maps suggesting a similar flux in 2010 and 2011. On the contrary, the optical emission reported in Figure 3 increases of about a factor 2 between 2010 and 2011. The possible connection between optical and VHE emissions seen in 1ES 1215+303 seems not to be present in 1ES 1218+304 data.

The lightcurve and spectrum of 1ES 1218+304 are still under study and will be presented at the conference.

4 Conclusion and prospects

The observation of the HBL 1ES 1215+303 with the MAGIC telescopes in 2010 and 2011 resulted in the discovery of VHE signal from this source (in 2011) and in the deep observation of the well-know neighboring TeV HBL 1ES 1218+304.

Concerning 1ES 1215+303, multiwavelength data simultaneous and quasi-simultaneous to MAGIC observations were collected from radio to the $\gamma$-ray regime including e.g. Metsähovi 37 GHz data, BVR optical data, optical R-band (presented here) and polarization data from KVA, Swift and Fermi-LAT data. The analysis and interpretation of these data are still ongoing.

For 1ES 1218+304 the simultaneous spectra from Fermi-LAT and MAGIC cover continuously more than 3 orders of magnitude in energy and could bring new constraints on the EBL and on intergalactic magnetic field (the study is ongoing).

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