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Observation of γ-ray emission above 200 GeV from the AGN 1ES1959+650 during low x-ray and optical activity

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The AGN 1ES1959+650 has been observed with the MAGIC telescope in September and October 2004, at the end of the commissioning phase. The MAGIC Telescope is currently the IACT with the lowest energy threshold, which is well suited for observations of weak γ-ray sources with soft spectra, like AGNs in a quiescent state. During the first observations by MAGIC, 1ES1959+650 was in a low state of activity both in optical and in X-ray wavelengths. The preliminary analysis of VHE γ-ray data showed a highly significant γ-ray signal, while no significant variation of emission during the examined period has been found. The results of the analysis and the comparison with previous observations will be presented.

1. Introduction

The first γ-ray signal at very high energy coming from the Active Galactic Nucleus 1ES1959+650 was reported in 1998 by the Seven Telescope Array in Utah, with a 3.9 σ significance [19]. Later, other successful observations of the source were reported, but the observed flux was weak in both, γ-rays and in X-rays.

The AGN 1ES1959+650 is part of an elliptic galaxy at a redshift distance z = 0.047. Observing the source from 2000 until early 2002, the HEGRA collaboration reported only a marginal signal [14]. In May 2002, the X-ray emissions of the source had increased. Both the Whipple [13] and HEGRA [1] collaborations subsequently confirmed also a higher VHE γ emission. Further periods of high γ-ray activity followed in the same year. An interesting aspect of the flaring activities in 2002 was the observation of an orphan flare recorded in June with the Whipple telescope [16, 9], and confirmed by HEGRA [20]: high γ-ray activity in the absence of high activity in X-rays. Non observation of a significant X-ray activity could be interpreted by the suppression of electron acceleration and inverse Compton scattering as production mechanism for VHE γ-rays in favor of hadronic models, and would thus deserve special interest. The models for the hadronic component of the 1ES1959 jet (see for example [4]) lead us to also check for neutrino emissions coming from this source. The AMANDA collaboration, operating a neutrino telescope in the southern hemisphere, reported at the recent Cherenkov 2005 meeting at Palaiseau [2] the observation, over a total observation period of four years, five neutrino events, of which three were clustered over a short period coinciding with 1ES1959 flares and one is coincident with the orphan flare. While this observation is statistically insignificant and no more than an indication, even absence of neutrino detection would not rule out the hadronic model in explaining the γ emission. The predicted neutrino flux simply is below the sensitivity of present-day neutrino detectors [11]. Future neutrino detectors and extended collaboration between experiments should be able to shed more light on this question.

The MAGIC telescope represents a new generation of IACTs for γ-ray astronomy. Its design has been optimized to achieve a low energy trigger threshold (eventually down to 30 GeV at zenith), never reached with previous IACTs. The low threshold will make it the instrument of choice for the study of faint VHE γ-ray sources such as pulsars, medium redshift AGNs, etc. The MAGIC mirror has a diameter and focal length of 17m, its camera is made of 576 hemispherical photo-multiplier tubes with specially shaped light collectors and coated with a diffuse lacquer that enhances their quantum efficiency [6, 7]. The camera has a field of view (FOV) of 3.5°. For more details on the MAGIC telescope and its performance see [8]. The MAGIC telescope is located in the Canary Island of La Palma (28.2°N, 17.8°W, at 2225 m asl). From this location, 1ES1959 is visible from May to October under a zenith angle of 36° at culmination.

2. Analysis of the recorded data

This analysis is restricted to γs with an energy threshold of $\sim$180 GeV, estimated from the Monte Carlo (MC) γ energy peak after analysis. At such energies, we can follow classical techniques for discriminating hadronic and electromagnetic showers, which have been pioneered by Whipple, and described in [10]. The camera image is parameterized to obtain several test statistics describing the image shape and orientation (image parameters or discriminant quantities [12]) in the camera. The number of parameters used in this analysis is eight. The image parameters are used to reject hadronic background events by means of cuts that discriminate between γ- and hadron-induced images. The parameters also permit reconstructing the arrival direction and the energy of the original γ-ray.

The period in 2004 where the 1ES1959 data has been taken corresponds to the end of the MAGIC commissioning phase. Generally, the Crab Nebula with its very stable flux is considered a reference source (standard candle) for VHE γ-ray astronomy. For that reason, Crab data observed with MAGIC were selected such as to match telescope operation conditions, in time and zenith angle range (36° - 47°), to those during the observation of 1ES1959. So called off-source data are collected by pointing the telescope to a sky section near the source, where no γ-ray signal is expected in the field of view. These data are used as a crosscheck of the recorded cosmic ray background. After quality cuts, $\sim$6.5 hours of observation data (before dead time subtraction) from 1ES1959 remained ($\sim$4.1 M events) and were analyzed. The optimal subspace of image parameters for the γ-hadron separation was obtained with the Random Forest method [3], using MC γ and hadrons recorded during normal ON source data taking. The cut in the discriminant variable provided by the Random Forest (the so-called *hadronness*) was optimized to obtain a signal with the maximum significance from the $\sim$2 hours of Crab Nebula data observed at the same zenith angle. These optimized cuts were then applied to the entire 1ES1959 data sample, without further optimization. Two of the image parameters are of general interest: the variable SIZE, given in number of photons of wavelength between 290 nm and 650 nm entering the camera, is to first order proportional to the energy of the incoming γ, and ALPHA, the angle between the image major axis and the line connecting the center of gravity of the image with the source position in the camera, shows most clearly the existence of a signal. ALPHA is not used for the optimization process; instead, we derive from the resulting ALPHA distribution the significance of the signal (using [17], formula 17). Finally, data with ALPHA $> 9°$ have been rejected.

3. Results

3.1 Alpha plot and comparison with Crab Nebula

In figure 1 (left) we show the distribution of the image parameter ALPHA for the Crab Nebula together with the normalized distribution of the off-source data, after a selection of events with SIZE $>$ 1800 photons ($\sim$ 325 photo-electrons), for an energy threshold $\sim$ 300 GeV. At lower SIZE cuts (required to reach the energy threshold of 180 GeV) the alpha distribution is wider, due to a worse reconstruction of the image orientation and larger fluctuations in the atmospheric shower development.

In the right diagram, the ALPHA distribution of the 1ES1959 data sample is shown, after the same parameter

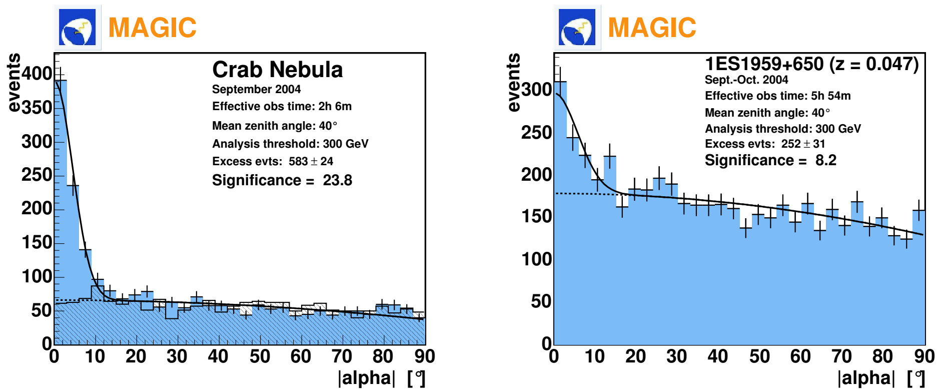

Figure 1. ALPHA plots after γ-hadron separation. Left: Crab, Off data histogram is superimposed for comparison. Right: 1ES1959. The background has been determined with a fit in the region of ALPHA $> 20°$, with a polynomial function of second order.

cuts. The significance of the 1ES1959 detection is $\sim 8\sigma$, with 252 excess events in $\sim$6 hours of effective observation time, while the signal from Crab Nebula corresponds to $\sim$24 sigma and 583 excess events in $\sim$2 hours for the same analysis. A coarse estimate yields a flux of 0.14 crab units.

VHE γ ray detection of blazars mostly refer to blazars during a flaring state in other wavelength bands, in particular X-rays [18, 5]. With 6 hours observation time, only modest tests of the flux variation are possible. The data sample of 1ES1959 has been subdivided into 3 sub-samples of $\sim$2 hours each, one sample in September and two in October. The results did not show any significant flux differences during these 3 periods, indicating that the source was basically in the same state during the time covered by our observation.

A strong γ-ray emission from an AGN leads to the question whether the source was active also at other wavelengths. In case of one zone Synchrotron Self Compton models (see for example [15]), one should also observe a significant activity in the X-ray domain. Indeed, time correlations of the γ-ray and X-ray fluxes are normally seen in other γ-ray emitting AGNs. Information of X-ray and optical activity level are based on published RXTE-ASM X-ray flux data (http : //heasarc.gsfc.nasa.gov/xte weather/), the optical light curve being provided by the Tuorla Observatory Blazar Monitoring Program (http : //users.utu.fi/kani/1m/1ES 1959 + 650.html). No strong activity in X-ray or in optical was observed during the period of our VHE γ-ray detection.

3.2 Preliminary 1ES1959 VHE spectrum and comparison with the Crab spectrum

For the spectral flux determination, we used a simple approach of comparing the spectrum of 1ES1959 to that of the Crab nebula, which has been measured by many experiments from data above 400 to 500 GeV, and with MAGIC down to 100 GeV [21].

There is strong evidence of the spectrum of the AGN being steeper than that of the Crab in the same energy range. 1ES1959 is at $\sim$20% of the Crab level at about 200 GeV, while at higher energies ($\sim$ 2 TeV) the flux drops to $\sim$6% Crab. This observation is compatible with the results of the HEGRA System measurement in a higher energy range of the γ-ray emissions of 1ES1959 in its steady state of (5.3 $\pm$ 1.1) % Crab [1]. However, our results are still preliminary; a full spectral analysis will be presented elsewhere.

4. Conclusions

The AGN 1ES1959 has been clearly detected with the MAGIC telescope after a few hours of observation in September - October 2004, at a mean zenith angle of 40°. During that period, the AGN was in quiescent state both in X-rays and at optical wavelengths.

For an analysis threshold of 300 GeV, the preliminary results yield a 1ES1959 signal at a significance level of 8σ. A simple flux comparison with Crab Nebula in different energy bins from 180 GeV up to 2 TeV indicates that 1ES1959 drops from ∼20% around 200 GeV to ∼6% Crab flux at around 2 TeV. The full spectral analysis is still in progress, and will be presented elsewhere. The present observation is characterized by lack of strong time variability in γ-rays, as well as in the X-rays and the optical domain. Therefore, we assumed that 1ES1959 was observed in quiescent state. It is worth noticing that this is the first time ever that this AGN is significantly detected in the VHE domain in quiescent state in only ~ 6 hours of observation time. This experimental result can be seen as a confirmation that MAGIC is suited for observing weak γ-ray sources with soft spectra, like AGNs in non-flaring state.

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References

[1] F. Aharonian et al.,A&A 406, L9 (2003)
[2] E. Bernardini for the AMANDA/IceCube Collaboration, in: Toward a Network of Atmospheric Cherenkov Detectors VII, April 27-29, 2005, Ecole Polytechnique, Palaiseau (France) (in press)
[3] R.K. Bock et al., Nucl. Instrum. Meth., A516 (2004) 511
[4] M. Boettcher, ApJ. 621, Issue 1, 176-180 (2005)
[5] M. Catanese et al., ApJ 480, 562 (1997)
[6] D. Paneque et al., Nucl. Instrum. Meth., A504 (2003) 109
[7] D. Paneque et al., Nucl. Instrum. Meth., A518 (2004) 619
[8] J.Cortina et al., these Proceedings (2005)
[9] M. K. Daniel, for the VERITAS collaboration, ApJ 621 181 (2005)
[10] D.J. Fegan, J. Phys. G: Nucl. Part. Phys. 23 1013 (1997)
[11] F. Halzen and D. Hooper, High Energy Neutrinos from the TeV Blazar 1ES 1959+650, astro-ph/0502449
[12] A. Hillas, in NASA, Goddard Space Flight Center 19th International Cosmic Ray Conference, Vol 3, 445-448, August 1985
[13] J. Holder et al., ApJ 583, 9 (2003)
[14] D. Horns et al., contr. to International Symposium Tokio, (2002)
[15] S.Inoue and F. Takahara, ApJ 463, 555 (1996)
[16] H. Krawczynski et al., ApJ 601, 151-164 (2004)
[17] Li & Ma, Astroph. Journ. 272 (1983) 314-324
[18] D.J. Macomb et al., ApJ 449, L99 (1995)
[19] Nishiyama et al., the Utah Seven Telescope Array coll., Detection of a new TeV gamma-ray source of BL Lac object 1ES1959+650, in AIP Conf. Proc., 516, Proc. 26th ICRC, ed B.Dingus, D.B. Kieda, M. H. Salamon (Melville:AIP)370 (OG.2.1.21) (2002)
[20] N. Tonello PhD thesis, in preparation (2005)
[21] R.M. Wagner et al., these Proceedings (2005)