Search for TeV Gamma-Emissions from BL Lacertae with the HEGRA equatorial mount Cherenkov telescope

O. Mang[1], G. Rauterberg[1], M. Schilling[1] for the HEGRA Collaboration
[1]*Institut für Experimentelle und Angewandte Physik, Universität Kiel, 24098 Kiel, Germany*

Abstract

BL Lacertae is a nearby active galaxy of the blazar class with a redshift $z = 0.069$ and therefore, within the unified model of AGN, a candidate for the observation of gamma emissions in the TeV range. During 1998, BL Lacertae has been observed by the HEGRA equatorial mount Cherenkov telescope. The reconstructed shower images have been subjected to Gamma-Hadron separation. The sample has been used to derive an upper limit of the energy flux from BL Lacertae carried by Gamma-Rays with energies greater than 1 TeV.

1 Introduction

The production of γ-rays in the TeV-domain by inverse Compton-scattering is assumed to originate in the relativistic jets of AGN. The unified model of AGN explains the differences between AGN subtypes by the orientation of the relativistic jets with respect to the observer. If the jets are oriented along the observer's line of sight, the object appears as a blazar. Blazars are therefore candidates for the emission of TeV γ-radiation. BL Lac objects form a subset of the Blazar class, which makes them interesting for the study of high energy γ-emissions. Furthermore, there are BL Lac objects that have already been established as sources of TeV γ-radiation, e.g. Mrk-421 and Mrk-501.

Ultra high energy photons can interact with the Cosmic Infrared Background (CIRB) in a pair production process. This limits the mean free path of TeV photons and causes considerable extinction of the photons, depending on the distance of the source. To determine this extinction and with it the hitherto unknown photon density of the CIRB, it is important to detect further BL Lac objects in the TeV regime.

The HEGRA experiment, located on the Canary Island of La Palma, has observed the object BL Lacertae with the equatorial mount Cherenkov Telescope CT1 for 44.7 hours in 1998. The data set was subjected to a standard Gamma-Hadron separation and compared to data of the Crab Nebula taken in 1998. From this an upper limit in units of the Crab flux was derived for the flux from BL Lacertae above 1 TeV.

2 The Active Galaxy BL Lacertae

BL Lacertae is an active galaxy of the HBL-type (high frequency BL Lac). The two nonthermal components of the spectrum, which are believed to be the synchrotron and inverse Compton emissions of relativistic electrons in the jets , peak at relatively high energies (Ghisellini et al., 1998) and thus make HBLs candidates for the emission of TeV gamma radiation. In addition, the object BL Lacertae has a redshift $z = 0.069$, so the attenuation of UHE radiation by the CIRB is not considered to be a limiting factor. The degree of extinction by the CIRB is still under investigation, therefore the influence of the CIRB is not considered in this analysis.

Observations of BL Lacertae in the GeV and optical regimes showed a strong flare of the source around July 19^{th} 1997 (MJD 50648) (Bloom et al., 1997). The established TeV-sources Mrk-421 and Mrk-501 also show irregular activity, most remarkably the outburst of Mrk-501 during 1997, reaching diurnal flux levels of 10 Crab units (e.g. Aharonian et al., 1999b). Therefore the monitoring of BL Lacertae is of high interest.

3 Experimental Setup

The HEGRA experiment is located at the Observatorio Roque de los Muchachos on the Canary Island *La Palma* (2200 m a.s.l., $28.75°$N, $17.89°$W). The experiment consists of several arrays of particle and Cherenkov detectors dedicated to cosmic ray research, and of six Cherenkov Telescopes (Lindner, 1997). Five of these telescopes have an Alt/Az-mount and are operated as a stereoscopic system of telescopes.

Parameter	Cut
DISTANCE	$> 0.7^\circ, < 1.05^\circ$
LENGTH	$< .30^\circ$
WIDTH	$< .15^\circ$
CONCENTRATION	$> .39$
SIZE	$> 60\ photoelectrons$
ALPHA	$< 10^\circ$
θ	$< 30^\circ$

Table 1: The cuts on Hillas parameters and on the zenith angle θ (e.g. Deckers, 1998).

The other telescope, the HEGRA equatorial mount Cherenkov Telescope *CT1* is equipped with a camera consisting of 127 photomultipliers, with a field of view of 3.25°. Each pixel has an angular diameter of 0.25°. Further details of the Telescope hardware can be found in Rauterberg et al., 1995. The tracking of the telescope is accurate to 0.1°; correction functions to improve the accuracy will be available soon and will be used for a refined analysis. The telescope has been equipped with new hexagonal mirrors in October 1997. This has increased the reflective area to $10\,\mathrm{m}^2$ and thus the sensitivity of the telescope, but since Monte Carlo statistics for the new configuration are not yet sufficient, the energy threshold can only be estimated to ≈ 700 GeV close to the zenith and, using $E_{thresh} \sim \cos^{-2.5}(\theta)$ with θ representing the zenith angle, ≈ 1.0 TeV at $\theta = 30^\circ$. The limited Monte Carlo statistics imply that an absolute measurement of the flux is not possible. The method of determining the flux in Crab units has the advantage of being free from systematic uncertainties due to Monte Carlo simulations.

4 Data sample

BL Lacertae has been observed by CT1 from May 29^{th} to September 24^{th}, 1998 for 44.7 hours. The data were obtained during moonless nights, with zenith angles less than 30°. The Crab Nebula has been monitored in Feb/Mar 1998 and in the fall/winter of 1998, yielding 64.9 hours of observation time. Both sources have been observed in ON-ON and ON-OFF mode. For the determination of background we used a data sample covering the same range of zenith angles, consisting of the OFF-runs and other measurements from regions where no source of gamma-rays is expected. First steps in the data processing include flatfielding of the camera, finding and excluding defective pixels, application of dynamical and topological tailcuts and computation of the Hillas parameters.

The analysis was done using the well established method of Supercuts (Hillas, 1985) imposed on the Hillas parameters of the shower image. The cuts used for this analysis are summarized in table 1. Data from each source were combined with the background data to calculate the significance of a possible gamma excess and upper and lower limits (Helene, 1983).

5 Results

The analysis of the Crab Nebula data showed an excess of TeV-photons with a significance of 18σ, with a total observation time of 64.9 hours. The data from BL Lacertae did not show a significant excess in the lower alpha bins ($\alpha < 10^\circ$). The significances and limits are shown in table 2. A comparison of the excess, normalized w.r.t. observation time, gives an upper limit of the gamma ray flux from BL Lacertae of 9.3% of that of the Crab Nebula at a confidence level of 99%. Another upper limit of 11% Crab on TeV emisson from BL Lacertae has been determined by the HEGRA System of Imaging Atmospheric Cherenkov Telescopes (Aharonian et al., 1999a). The respective observation windows overlap only in May 1998 and thus complement each other to give a consistent long-term picture.

	BL Lacertae		Crab Nebula	
	Counts [h^{-1}]	Significance [σ]	Counts [h^{-1}]	Significance [σ]
Excess	-0.9960	-1.162	19.83	18.03
Upper Limit (99% CL)	1.601	1.867	22.39	20.35
Lower Limit (99% CL)	$5.194 \cdot 10^{-3}$	$6.060 \cdot 10^{-3}$	17.27	15.70
Observation time	44.7 h		64.9 h	

Table 2: Measured excess, upper and lower limit for BL Lacertae and the Crab Nebula

6 Conclusion

The analysis of 44.7 hours of data from BL Lacertae, taken in 1998, did not show a significant excess of gamma-like events from the direction of the observed object. A data sample of the Crab Nebula taken during the same year yielded an excess of gamma-like events with a significance of 18σ and was used as a flux unit.

For the flux from BL Lacertae an upper limit of 0.093 Crab-Units was derived at a confidence level of 99%.

Since it was shown that BL Lacertae is a variable source in the GeV and optical regime (Bloom et al., 1997), it is important to continue the monitoring of BL Lacertae in the future.

7 Acknowledgements

The support of the German Ministry of Research and Technology (BMBF) and of the Spanish Research Council CYCIT is gratefully acknowledged. We thank the Instituto de Astrofísica de Canarias (IAC) for hosting the HEGRA experiment and for supplying excellent working conditions at the Observatorio Roque de los Muchachos (ORM), La Palma.

References

Aharonian, F.A., Akhperjanian, A.G., Barrio, J.A. et al. 1999a, submitted to A&A (astro/ph 9903455).
Aharonian, F.A., Akhperjanian, A.G., Barrio, J.A. et al. 1999b, A&A 342, 69.
Bloom, S.D., Bertsch, D.L., Hartmann, R.C. et al. 1997, ApJL 490, L145.
Deckers, T. 1998, PhD thesis, Universität Kiel.
Ghisellini, G., Celotti, A., Fossati, G., Maraschi, L., Comastri, A. 1998, MNRAS 301, 451.
Helene, O. 1983, NIM 212, 319.
Hillas, A.M. 1985, Proc. 19^{th} ICRC, La Jolla, 3, 445.
Lindner, A. 1997, Proc. 25^{th} ICRC, Durban, 5, 113.
Rauterberg, G. et al. 1995, Proc. 24^{th} ICRC, Rome, 3, 460.