

MAGIC observations of high-peaked BL Lacertae objects

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In a key observation program, the MAGIC Collaboration seeks to find new extragalactic sources at 100 GeV energies by observing bright X-ray selected BL Lacertae objects. Using results of the campaign, we can probe emission models for relativistic jets, the effects of gamma ray attenuation due to interactions with the metagalactic radiation field, and the origin of the extragalactic gamma ray background.

1. Introduction

Blazars are radio-loud active galactic nuclei (AGN) viewed at small angles between the jet axis and the line of sight. Due to relativistic beaming they are the brightest and most variable high-energy sources among AGN.

BL Lacertae objects represent a subclass of the blazars, in which broad emission lines are absent or very faint. Apart from the host galaxy's contribution, their spectral energy distribution (SED) is completely dominated by nonthermal emission. Based on the SED, the distinction between low-peaked BL Lacs (LBL), which emit most of their synchrotron power at low frequencies (far-IR, near-IR), and high-peaked BL Lacs (HBL), which emit most of their synchrotron power at higher frequencies (UV-soft-X) was introduced [12].

The observed TeV sources belong to the HBL class, in which the emitted power presumably shows a second peak at very high energies (VHE). An obvious possibility is that, the low-energy peak is due to synchrotron radiation by relativistic electrons, and the high-energy peak is due to inverse-Compton radiation of the same electrons [2]. There could also be two electron populations: a primary population consisting of in situ accelerated electrons, and a secondary one originating in electromagnetic cascades initiated by in situ accelerated protons and nuclei [10].

Despite all the observational differences among the various blazar sub-classes, a unified scheme, in which the luminosity is a fundamental parameter, is consistent with the data [4]. The SEDs of the different blazar types can be considered as a continuous sequence. As shown by [6] this sequence scheme would be consistent with the theoretical synchrotron self-compton (SSC) and external-compton (EC) models, where the EC component dominates at higher energies. However, the scheme is far from proven, it could also be a mere selection effect. The more luminous sources are more distant (due to redshift evolution), and thus suffer stronger from gamma ray attenuation rendering them invisible at TeV energies. The unified scheme can be tested, for instance, it predicts that sources emitting strongly in the TeV band have a relatively low intrinsic luminosity.

Absorption of γ -photons by pair production in photon-photon scattering with photons of the Metagalactic Radiation Field (MRF) gives rise to a Gamma Ray Horizon (GRH), which is dependent on the energy of the photons. The cut-off energy, defined as the energy where the optical depth becomes unity, as a function of the redshift of a source has been coined the Fazio-Stecker relation (FSR).

Due to uncertainties in the models of the MRF the FSR shows large differences below redshifts of 0.1, where the TeV γ -rays are absorbed by scattering off photons from the Cosmic Infrared Background (CIB), but also for redshifts higher than 1.0, where the attenuation is due to the photons of the diffuse UV radiation field [8]. For sources at redshifts between 0.1 and 1.0, the FSR converges for different models. Up to now, there are only three nearby blazars with published cut-off energies.

Measuring the γ -ray spectra from blazars at different redshifts allows to test the Fazio-Stecker relation. For nearby blazars, it allows also to distinguish between different models for the CIB.

As a defining property, blazars show time variability on various time scales at all frequencies. In a flaring state, the flux can be an order of magnitude or more higher than in a quiet state. The spectrum generally varies with the flux. At VHE Mkn 421 and Mkn 501 showed flux variability on short time scales, such as the 1996 γ -ray flare of Mkn 421 with a flux doubling time scale of less than 15 min [5]. Short time variability allows to discriminate between different theoretical models for the dynamic of the jets as well as for the generation of the radiation (SSC, PIC).

2. Sample

For the hard X-ray band, a high-sensitivity all-sky-survey does not exist. Therefore we decided to use the blazar hard X-ray compilation from Donato ([3]), which contains 421 continuum spectra from 268 blazars (136 HBL, 63 LBL, 69 Flat Spectrum Radio Quasars (FSRQ)). The list contains blazars with known spectral information in the radio, optical and X-ray band.

2.1 Selection criteria

From this 136 HBL objects, a sample of 13 objects is chosen, which satisfies several selection criteria. These criteria should assure, that the object is detectable in less than 20h, taken into account the current energy threshold of MAGIC (with the dependence on the zenith distance), the attenuation of the γ -rays by the MRF and the correlation between the X-ray flux and the γ -ray flux.

1. Redshift

The first selection criterium is a cut at redshift 0.3. From the FSR one expects a cut-off energy of about 300 GeV and optical depth of 0.1 at 100 GeV, which means, that the flux at this energy is attenuated by $\sim 20\%$.

2. X-ray flux

The different SSC models predict a strong correlation between X-ray and γ -ray fluxes. Based on the unified scheme we made the assumption for HBL, that the X-ray flux at 1 keV is equal to the gamma-ray flux at 200 GeV. A coarse estimation gives, that a X-ray flux of $2 \mu\text{Jy}$ corresponds to a γ -ray flux of $1.5 \cdot 10^{-11} \text{cm}^{-2} \text{s}^{-1}$ at 200 GeV. We select all objects with a maximum X-ray flux of more than $2 \mu\text{Jy}$.

3. Visibility

The energy threshold of an IACT depends also on the zenith distance. We require a maximum zenith distance of 30° at the culmination.

One object was skipped due to a very bright star in the field of view (FOV).

Table 1. List of targets with the name of the source (IAU), position, optical brightness, X-ray flux at 1 keV and the observation time of the data taken from August 2004 to June 2005. For Mrk 421 10.3 h are taken in wobble mode.

source	RA	δ	m_V	z	$F_x [\mu J]$	$t_{\text{obs}} [\text{h}]$
0120+340	01 23 08.9	+34 20 50	15.2	0.272	2.4 - 6.3	-
0317+1834	03 19 51.8	+18 45 35	18.1	0.190	0.2 - 3.1	14
0323+022	03 26 14.0	+02 25 15	16.5	0.147	0.7 - 6.8	4
0414+009	04 16 53	+01 04 54	16.4	0.287	4.6 - 5.2	-
0806+524	08 09 49.2	+52 18 58	14.8	0.138	4.9	-
0927+500	09 30 37.6	+49 50 24	17.2	0.188	4.0	-
1011+496	10 15 04.2	+49 26 01	16.2	0.200	2.2	-
Mrk 421	11 04 27.3	+38 12 32	13.5	0.031	23.9 - 58.4	25/10.3
1218+304	12 21 21.9	+30 10 37	16.5	0.130	7.5 - 10.1	10.5
1415+259	14 17 56.6	+25 43 25	16.	0.237	2.9 - 4.3	19.9
1426+428	14 28 32.5	+42 40 25	16.5	0.129	4.6 - 13.4	21
Mrk 501	16 53 52.2	+39 45 37	13.8	0.034	8.3 - 46.4	36
1722+119	17 25 04.4	+11 52 16	15.8	0.018	3.6	5.7
1727+502	17 28 18.6	+50 13 11	16.0	0.055	3.6 - 3.7	-
2344+514	23 47 04.9	+51 42 18	14.6	0.044	3.4 - 6.9	-

2.2 Targets and observation strategy

The target list contains 15 objects. Four objects, Mrk 421, Mrk 501, H 1426+428 and 1ES 2344+514, are known TeV sources. Eight of the other eleven objects are also suggested by Costamante & Ghisellini to be candidates of TeV emission [1].

The confirmed TeV source 1ES 1959+650 has also been observed by the MAGIC telescope. For this systematic study, it is not included in the target list, due to its higher declination, leading to a culmination at high zenith distance and therefore higher energy threshold. Table 1 contains the list of targets with their position, optical brightness, redshift and the X-ray flux. The visibility of the objects is spread over the whole year. For every object (except for Mrk 421, Mrk 501 and 1ES1959+650, where longer observations are scheduled) a observation time of 20 h is planned. In 20 h, we expect a 5σ detection for the weaker sources even with the more pessimistic flux estimate, while for stronger sources or sources in a flaring state, we expect to unfold spectra and light curves.

3. Results

From August to June 2005, nine targets have been observed with a total observation time of ~ 176 h. For Mrk 421 and 1ES 1959+650 we report a strong detection ([11],[13]). Mrk 501 has been strongly detected, too. As most of the observation took place in the last two months, the analysis of the other targets is still going on. First results will be shown at the conference.

4. Acknowledgements

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