Astroteilchenphysik in Deutschland: Status und Perspektiven 2005. DESY, Zeuthen 04.-05. Oktober 2005

MAGIC
Major Atmospheric Gamma Imaging Cerenkov Telescope

OBSERVATION OF EXTRAGALACTIC SOURCES WITH THE MAGIC TELESCOPE

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Abstract

In this contribution, we demonstrate the feasibility of blazar observations at 100 GeV energies with a sensitivity of ~3% Crab flux in 50h of observation using the MAGIC telescope. We show the results for the well-known low-redshift sources Mrk 421 , Mrk 501, and 1ES1959+650. We also report on the discovery of the first new blazar seen by MAGIC at a redshift of z=0.182, 1ES1218+304, and the status of a mini-survey of the Northern hemisphere High Peaked BL Lac objects (HBLs).

Introduction

The large number of high-luminosity blazars discovered at GeV energies by EGRET onboard the CGRO-satellite has promted an intense search for extragalactic sources at very high energies (VHE) with ground-based Imaging Air Cherenkov Telescopes (IACTs). Up to the present time, the unambiguous detection of only 7 extragalactic sources at redshift much less than unity has been reported, all but one (the radio galaxy M87) belonging to the high-peaked BL Lac (HBL) subclass of blazars. The non-detection of the high-luminosity blazars seen by EGRET at VHE gamma rays is generally ascribed to attenuation due to pair production in the cosmologically evolving metagalactic radiation field (MRF, the present-day intensity being coined the extragalactic backround light, EBL). The attenuation is expected to increase strongly with redshift and gamma ray energy. By lowering the observation threshold energy and increasing the sensitivity compared with previous northern IACTs, a larger number of gamma ray emitting blazars at higher redshifts than previously detected is expected to show up for MAGIC. The absorption by the MRF leads to a steepening of the observed energy spectrum at very high energies. The original (intrinsic) shape of the emitted spectra can be infered using semi-empirical models for the far-infrared to ultraviolet MRF reflecting the cosmic history of the star formation [1,2]. Strong constraints on such EBL-models, on the other hand, can be derived by assuming some reasonable shapes of intrinsic blazar spectra [3,4,5].
The spectral energy distribution of extragalactic VHE gamma ray emitters holds the clue to the physics of the radiation processes and the dynamics of the relativistic jets in blazars. In case a hadronic and not leptonic origin of the induced radiation can be verified, the contribution of blazars to the observed flux of ultrahigh-energy cosmic rays will be assessed.

Markarian 421 (z=0.031)

Fig3: Correlation between MAGIC and RXTE ASM

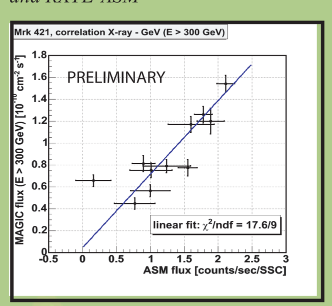
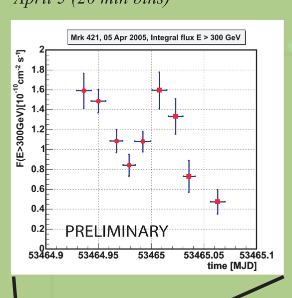


Fig2: Inter-night variations on April 5 (20 min bins)



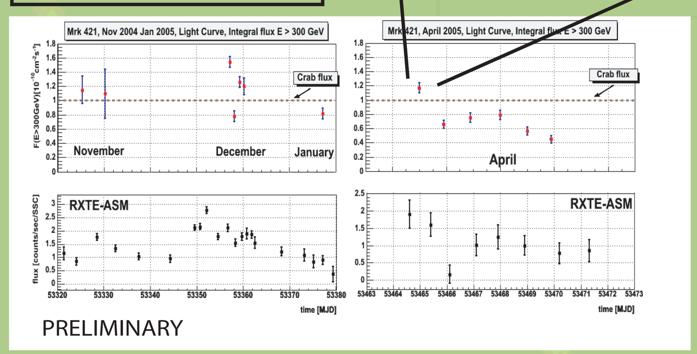


Fig1: Intra-night variations of the Mrk 421 flux above 300GeV (upper panel) together with RXTE-ASM flux (lower pannel)

Between November 2004 and April 2005 MAGIC accumulated almoset 30 hours of data on Markarian 421 (Mrk 421, z = 0.031). After data quality cuts on a run by run basis 23.6 h of data remained. For the analysis the data had to be divided into four different subsample, due to the different zenith angle regions of the observations and different hardware setups of the telescope. The results of the standard analysis are summarized in Table 1:

	On time	Zenith angle (deg)	E_{thr} (GeV)	N_{on}	$\langle N_{off} \rangle$	N_{excess}	Significance
I	4.70 h	9.3 - 31.2	100	7458	5084.0 ± 59.3	2374.0 ± 102.1	23.3 σ
II	1.41 h	42.4 - 55.0	300	593	315.9 ± 14.9	277.1 ± 27.3	10.1 σ
III	7.88 h	9.2 - 27.5	100	8116	5089.8 ± 59.4	3026.2 ± 104.5	28.3 σ
IV	9.57 h	9.4 - 32.4	100	9296	5668.3 ± 45.1	3627.7 ± 98.3	36.9 σ

Table1: summary of the standard analysis results of four sub samples

In all four subsamples a clear signal could be measured. The intra-night light curve above 300 GeV (Fig. 1) as well as the inter-night light curve (Fig. 2) show variations in the flux of about a factor 3. A clear correlation between the MAGIC flux and the X-ray flux in the RXTE-ASM [6] supports a leptonic origin of the gamma-ray emission. The MAGIC data have been further divided into "high" (3 nights in December and April 5th) and "low" state (one night in December and 6 nights in April). Both resulting differential spectra (Fig. 4) can be described by a simple power law with a spectral index of 2.5 +/- 0.2.

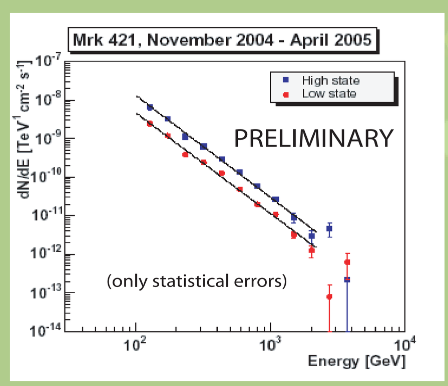
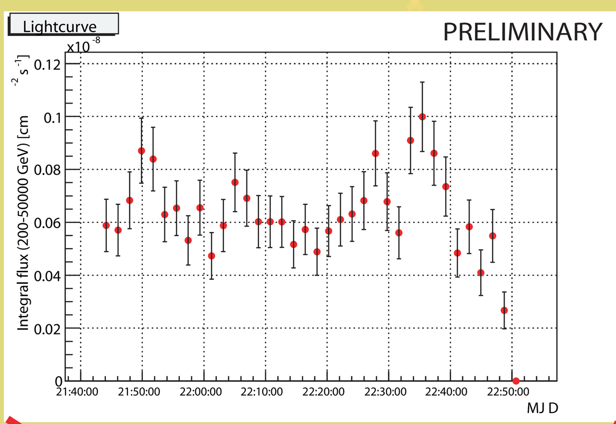


Fig.4: differential energy spectra in "high" and "low" states

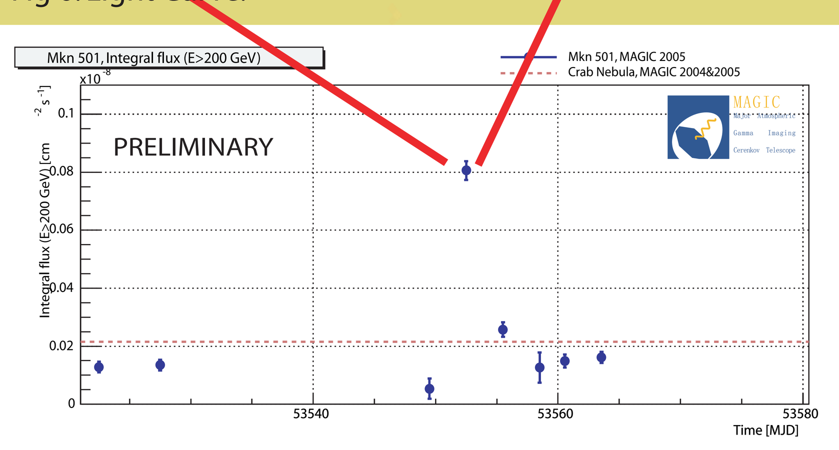
Markarian 501 (z=0.034)

Fig 5: Light Curve (~2 min bins) for the night of the big flare (June 30th, 2005).



Markarian 501 (Mrk 501) was observed during May, June, July, and August 2005. It was found mostly in quiescent state (0.3-0.5 Crab units, see Fig. 6).
Of special interest is the fact that on the night of June 30th, 2005 Mrk 501 was found in a big flare state with integral flux values up to 4 Crab units (See Fig. 6). In Fig. 5 the light curve in time bins of less than 2 minutes is shown. Fast variations are indicated. The observations show a clear signal above 200 GeV.
The spectrum for the day of the flare and two other days is shown in Fig 7. It can be seen that on the day of the flare the spectrum is slightly harder.

Fig 6: Light Curve.



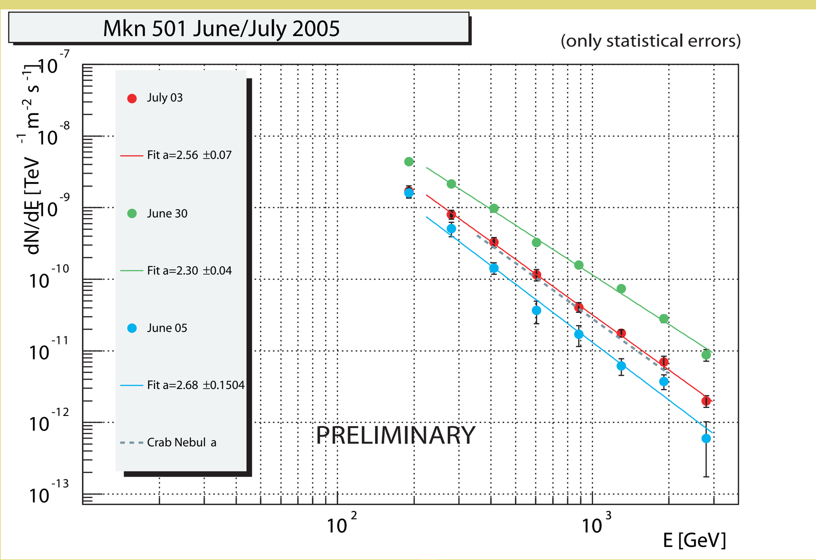
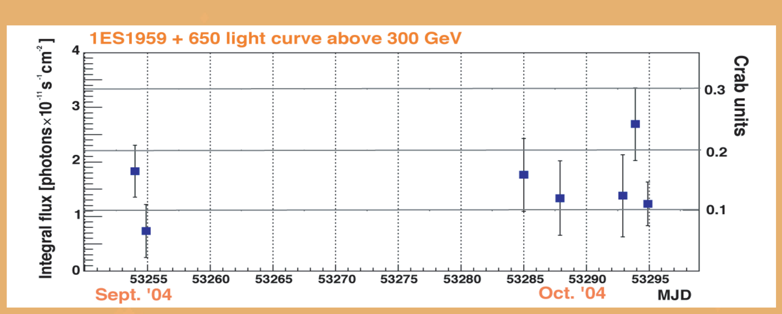


Fig 7: differential energy spectra of Mrk 501.

1ES1959+650 (z=0.047)

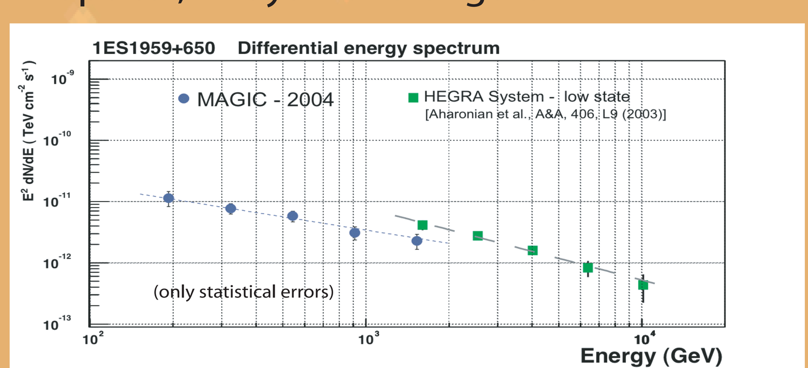
First blazar detected by MAGIC in quiescent state



September-October 2004
Effective observation time ~6h
Mean zenith angle ~ 40°

Low, stable flux
~ 15% Crab above 300 GeV

No flux variations observed in optical, X-rays wavelengths



Low state spectrum between 150 GeV - 2 TeV: simple power law with spectral index $\alpha = 2.72 \pm 0.14$
Maximum of Inverse Compton peak is not resolved

HEGRA System "low state": obtained from observations done between 2000 and 2002 during nights when the flux was lower than 50% Crab

1ES1218+304 (z=0.182)

The HBL 1ES1218+304 was observed at low zenith angles (7.5 -10 degrees) for about 9h in January 2005 and could be detected at the 7 sigma significance level (a sky plot is shown in Fig. 6). The energy spectrum of 1ES1218 +304 (Fig. 7) is well described by a simple power law with spectral index 3.3+/-0.4. Unfolding the effect of attenuation due to pair production in the EBL, the spectrum shows a slope similar to the one observed in the X-ray band [7].

Fig 6: Sky map of the number of excess events (smoothed with point spread function) in the region of 1ES1218+304

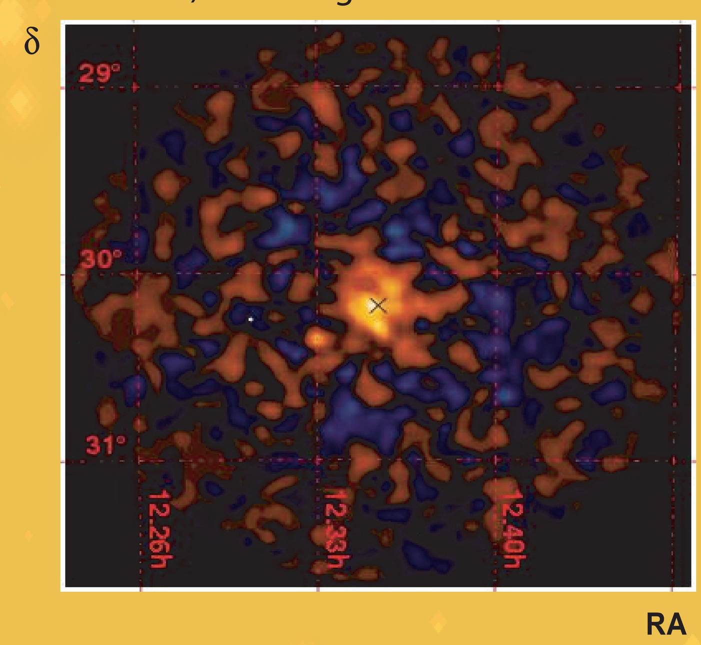
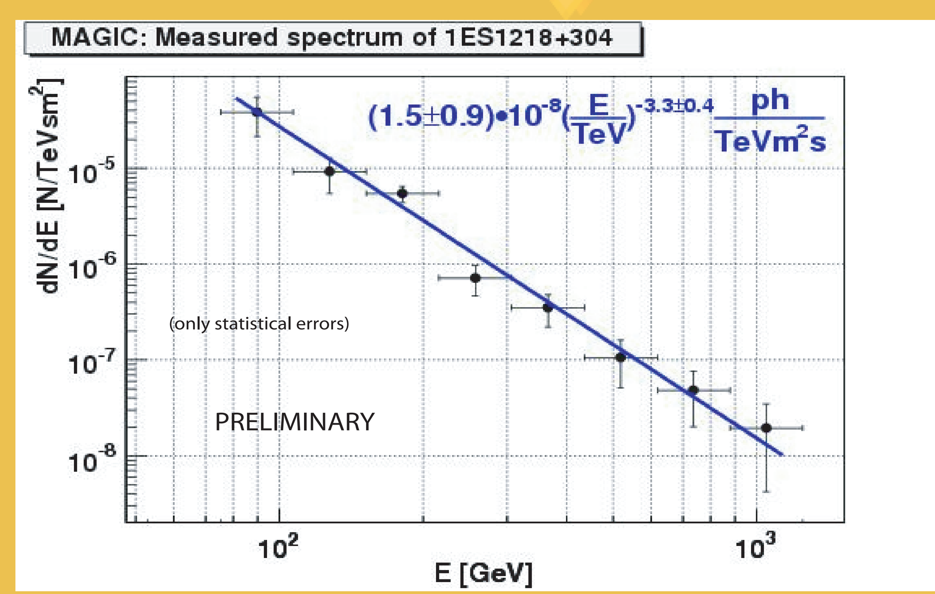


Fig 7. Differential energy spectrum of 1ES1218+304 as measured by MAGIC in January 2005



Planned and performed HBL observations

In the first observation cycle for the MAGIC telescope (April 2005-April 2006) 13 HBLs are scheduled for observation. In the table, the sources are listed with their catalog X-ray flux (Cite Donato), the redshift and their observation time already spent on these objects. In addition to the 13 HBLs - chosen with a certain criteria like a zenith angle of culmination, and maximum redshift - we list here the well-established blazars Mrk 421, Mrk 501, 1ES1959+650 and the radio galaxy M87. The scheduled observation time per source is usually between 10 and 20 hours. For the four sources (marked red) a clear signal was found. The analysis of the other data is ongoing. More observations will follow in the next observation cycle, where also more distant blazars may be included.

source	X-ray flux at 1keV [μJy]	redshift	Obs. Time [h]
0120+340	2.4 – 6.3	0.272	12
0317+1834	0.2 – 3.1	0.190	13
0323+022	0.7 – 6.8	0.147	4
0414+009	4.6 – 5.2	0.287	-
0806+524	4.9	0.138	-
0927+500	4.0	0.188	-
1011+496	2.2	0.200	-
Mrk 421	23.9 – 58.4	0.031	35
1218+304	7.5 – 10.1	0.182	9
1415+259	2.9 – 4.3	0.237	16
1426+428	4.6 – 13.4	0.129	20
Mrk 501	8.3 – 46.4	0.034	36
1ES1959+650	9.2	0.047	45
M87 *		0.0044	13
1722+119	3.6	0.018	6
1727+502	3.6 – 3.7	0.055	8
2344+514	3.4 – 6.9	0.044	15

* M87 may be considered a misaligned BL Lac

Legend: white: not observed yet; yellow: observed; red: detected

Conclusions

Due to its high sensitivity the MAGIC telescope allows to probe flux variations down to a few minutes and to resolve spectral changes on short time scales during high emission states (as for Mrk 501 and Mrk 421) or to search for baseline emission in a quiescent state of AGN (as for 1ES1959+650). The low energy threshold, on the other hand, significantly enhances the sample of detectable gamma-ray blazars towards larger redshifts (as for 1ES1218+304) and/or low peaked BL Lacs. The results from all these data will allow to test and constrain the different EBL-models and may also provide further insight into the gamma-ray production mechanisms in the jet. So far, more than 200h of data on HBL candidates with redshifts up to z=0.27 have been taken with MAGIC. While the analysis of some of the data is still ongoing, the results derived so far are quite promising.

Acknowledgements

We would like to thank the IAC for excellent working conditions. The support of the German BMBF and MPG, the Italian INFN and the Spanish CICYT is gratefully acknowledged.

References

[1] J.Primack, AIP Series Vol.745, 23-33 (2005); [2] Kneiske et al. A&A 413, 807 (2004); [3] M.Hauser& E.Dwek, ARAA, 39, 249(2001); [4] E. Dwek et al., astro-ph/0508133; [5] F.Aharonian et al., astro-ph/0508073; [6] http://heasarc.gsfc.nasa.gov/xte_weather/; [7] Bretz et al., this workshop

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