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Multiwavelengths Observations with the MAGIC Telescope

T. M. Kneiske ⋆ and K. Mannheim

Lehrstuhl fuer Astronomie, Universitaet Wuerzburg, Am Hubland, 97074 Wuerzburg, Germany

Abstract This paper reports the observability of distant gamma-sources using groundbased imaging air-Cherenkov telescopes with low energy thresholds like the MAGIC telescope. In particular we focus on extragalactic sources at low and high redshift which are emitting gamma photons up to very high energies. AGN for example are one of the most promising candidates for multiwavelength observations. The presented calculation is easy to apply on any extragalctic source emitting gamma-rays in the GeV/TeV energy range e.g. gamma-ray bursts (GRB). The data taken with a gamma-telescope (groundbased or airborne), have to be corrected for extragalactic absorption due to the metagalactic radiation field (MRF). The multiwavelength compain of the MAGIC telescope is breavely discribed.

Key words: AGN: Blazars Spectra - Metagalactic Radiation Fields: UV-IR - Imaging Cherenkov Telescopes: MAGIC

1 INTRODUCTION

The MAGIC Telescope is an imaging air-Cherenkov telescope which is currently eing build on La Palma, Canary Islands. It is one large telescope which will be sensitive to energies from ≈30 GeV to ≈30 TeV. The first events had been seen and the first data had been taken. They will be analysed in the next months. For technical details and a current status see the contribution to this proceedings by Abelardo Moralejo, Cortina er al.(2001) or Martinez (2003). Beside the technical ability of detecting sources, absorption effects make it hard to see a sources in gamma-rays above 20 GeV. The high energy gamma-rays are absorbed by pair-production with low energy isotropic background photons. The following topics will be discussed. In Sec. 2 the absorption process including a model for the metagalactic radiation field is presented. The optical depth for gamma-rays, the Fazio-Stecker reslation and absorption corrected spectra for some blazars are shown.

Section 3 discribes the multiwavelength program of the MAGIC telescope. As not mentioned otherwise Friedman-cosmology parameters were fixed to the values $\Omega_\mathrm{m} = 0.3$, $\Omega_\Lambda = 0.7$, and $h = 0.65$ corresponding to the ΛCDM cosmology.

⋆ E-mail: kneiske@astro.uni-wuerzburg.de

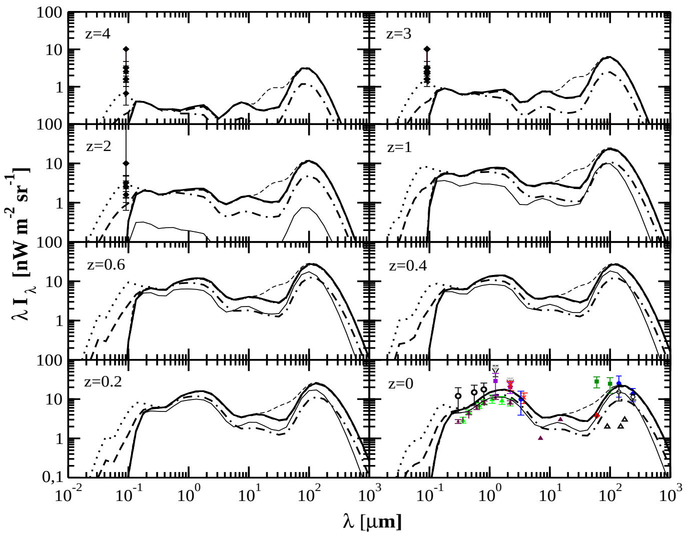

Fig. 1 Comoving-frame metagalactic radiation field (including UV component) at various redshifts. For an explanation of the different models shown in the panels see Kneiske et al. 2003. Data at $z = 2, 3, 4$ are taken from Scott et al. (2000); data at $z = 0$, see Kneiske et al. 2002.

2 THE OBSERVABILITY OF HIGH-ENERGY GAMMA-RAYS

Gamma rays of sufficiently high energy traveling through intergalactic space can produce electron-positron pairs in collisions with low energy photons from the MRF (e.g., Malkan & Stecker 1998). The pair creation cross section peaks sharply, so that collisions between photons near threshold $E_\gamma \epsilon_b \approx (2 m_e c^2)^2 \approx 1\mathrm{MeV}^2$ are favoured (where E_γ denotes the energy of the gamma ray, and ϵ_b the energy of the low energy photon). Gamma rays of energy (1–100) TeV typically interact with infrared photons in the (1–100) μm range. The bright, X-ray selected blazars Mkn 501, Mkn 421 and H1426+428 have been observed with various imaging air-Cherenkov telescopes (CAT, HEGRA, Telescope Array, WHIPPLE) at energies between 250 GeV and 15 TeV. They are all near-by (0.03< z <0.1) and their spectra, with and wihtout absorption, are shown in Section 2.4. Gamma rays of energy <1 TeV are interacting with GeV Photons. This process only takes place at high redshifts and can be used to probe isotropic, ultraviolet radiation fields.

2.1 Metagalactic Radiation Field (MRF)

Diffuse, isotropic radiation is known to exist from radio wavelengths to gamma rays. This radiation has an extragalactic component due to unresolved discrete sources and truly diffuse particle processes. Over most of the known energy ranges, the point source fraction seems to be rather close to unity, with the exception of the microwave band. The optical to infrared part of the extragalactic background light (EBL) is mainly produced by stars in galaxies. Part of the initial optical radiation is absorbed by dust and gas in the interstellar/intergalactic medium and reemitted in the infrared. The EBL is the present-day state of the general metagalactic radiation field (MRF) pervading the intergalactic medium. The comoving-frame energy density

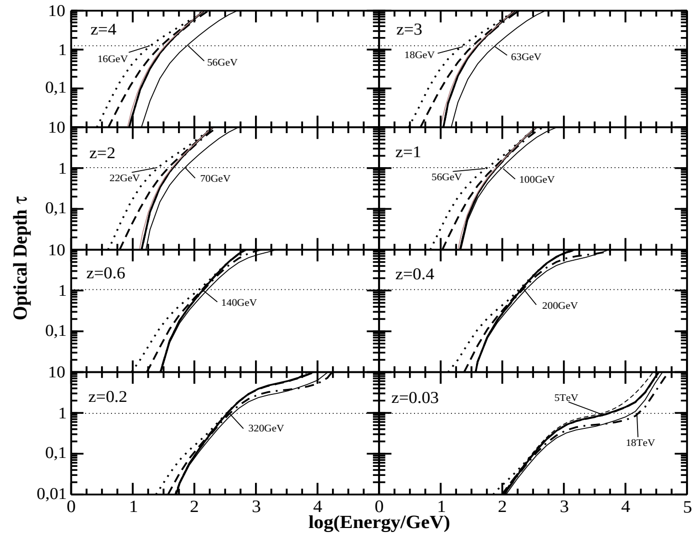

Fig. 2 Optical depth for various redshifts adopting a ΛCDM cosmology. The labeling of the line styles is the same as in Fig. 1. The crossing point with the line $\tau = 1$ defines the exponential cutoff energy.

of the MRF has gradually grown since the formation of the first stars. In spite of a great diversity of physics which must enter a theoretical description of the evolving MRF (see Hauser & Dwek 2001 for a summary of this topic), we have successfully developed a simple model (Kneiske et al. 2002, Kneiske et al. 2003) which keeps this diversity under the control of a few key parameters.

2.2 The Optical Depth

The optical depth for pair creation for a source at redshift z_q, and at an observed energy E_γ, is obtained from

$$\tau_{\gamma\gamma}(E_\gamma, z_q) = c \int_0^{z_q} \int_0^2 \int_{\epsilon_{gr}}^{\infty} \frac{dl}{dz'} \frac{\mu}{2} \cdot n(z,\epsilon) \cdot \sigma_{\gamma\gamma}(E_\gamma, \epsilon, \mu, z')\; d\epsilon\; d\mu\; dz'\,, \tag{1}$$

with the cosmological line element $\frac{dl}{dz'}$, the angle θ between the interacting photons $\mu = \cos(\theta)$, the number density of the MRF $n(z,\epsilon)$ as a function of reshift and MRF photon energy and the pair-production cross section $\sigma_{\gamma\gamma}$.

By comparing the generic MRF models (see Fig. 2), it can be seen that the optical depth from $0.2 < z < 1$ is rather insensitive to the choice of the parameters in the MRF model. A comparison with models of other authors is shown in Kneiske et al. (2003). At higher redshifts, the optical depth due to interactions with the UV part of the MRF become important. For example, the cut-off energy for a source at a redshift of $z = 4$ ranges between ~ 16 GeV for the high-stellar-UV model and ~ 40 GeV for the low-SFR model.

2.3 The Fazio-Stecker Relation

The energy-redshift relation resulting from the cosmic gamma-ray photosphere $\tau_{\gamma\gamma}(E_\gamma, z) = 1$ depends on the column-depth of the absorbing photons, as can be seen from inspection of Eq. (1).

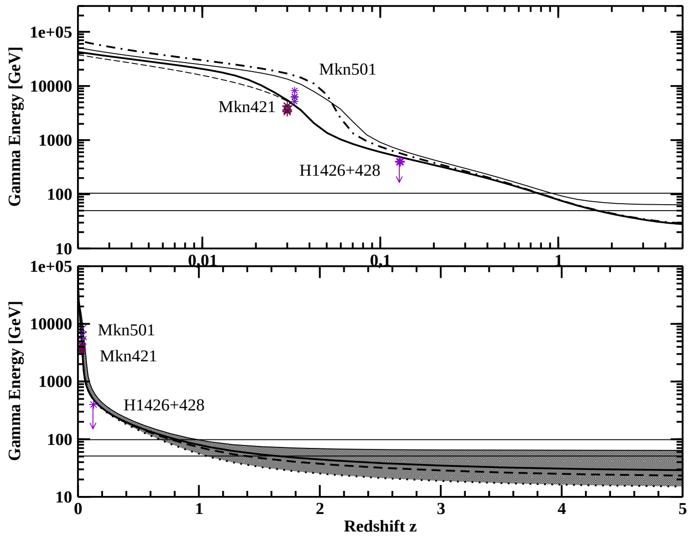

Fig. 3 *Upper panel:* Fazio-Stecker relation with logarithmic redshift axis. For explanation of different models see Kneiske et al. 2003. Also plotted are published cut-off energies of Mkn501, Mkn 421, and H1426+428 (for references, see Kneiske et al. 2003). The horizontal lines at 50 GeV and 100 GeV represent guide lines showing how the asymptotic branch of the Fazio-Stecker relation can be tapped by lowering the detection threshold to below 50 GeV (e.g. using the MAGIC telescope).

We coin this relation, plotted in Fig. 3, which proves to be very useful to study the MRF, the "Fazio-Stecker relation (FSR)" (first shown by Fazio & Stecker 1970) The theoretically predicted FSR (depending on the MRF model and cosmological parameters) can then be compared with a measured one, by determining e-folding cut-off energies for a large sample of gamma ray sources at various redshifts. Two important corollaries follow from inspecting the Fazio-Stecker relation: (i) gamma-ray telescopes with thresholds much lower than 40 GeV are necessary to determine the cut-off for sources with redshifts around the maximum of star formation $z \sim 1.5$, and (ii) gamma-ray telescopes with a threshold below 10 GeV have access to extragalactic sources of any redshift (see the proposed ECO-1000 telescope Martinez et al. 2003, Merck et al. 2003).

2.4 Modification of Gamma-Ray Spectra

A number of extragalactic gamma-ray sources have been detected with imaging air-Cherenkov telescopes (table 6, Horan et al. 2002). Three of them (with redshifts $z = 0.03, 0.03, 0.129$) were bright enough to resolve their spectra in the TeV energy band, as shown in Figure 4.

The observed spectra are modified by gamma ray attenuation, i.e.

$$F_{\rm obs}(E) = F_{\rm int}(E)\exp[-\tau_{\gamma\gamma}(E,z)]\,, \tag{2}$$

where $\tau_{\gamma\gamma}(E,z)$ is given by Eq. (1) (see Figure 3 for a number of examples). Note that we neglect secondary gamma rays arising from cascading in the metagalactic radiation field, which are discussed in a separate paper (Bretz et al. 2003). Looking at the intrinsic region we see that the location of the peak or even the spectral index highly depends on the absoption correction. A detailed discussion of the results are given in Kneiske et al.(2003). To further

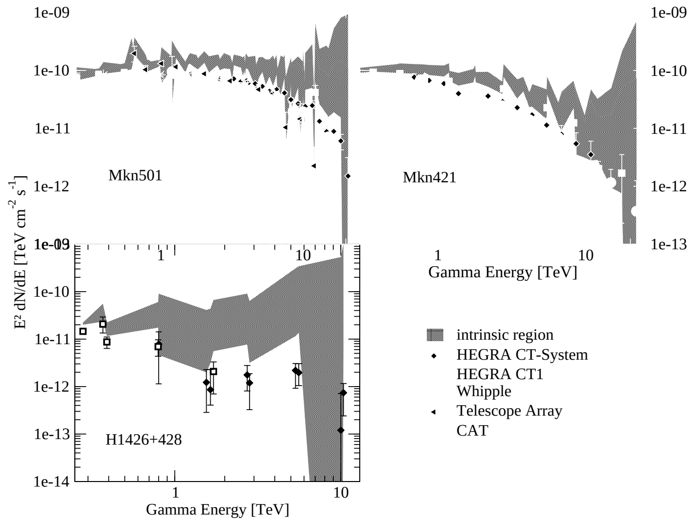

Fig. 4 World-data sets for three TeV blazars, and ranges of their intrinsic ("de-absorbed") spectra.

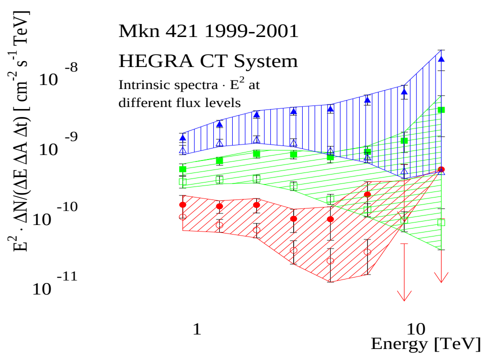

Fig. 5 Mkn 421 for three different flux levels, high, mid and low flux. The shaded regions are for each the intrinsic region. The data are taken with HEGRA.

disentangle observed and intrinsic spectra, it is helpful to look at flux-dependent spectra, using the defining blazar property of being highly variable sources. The Mkn 421 high-flux spectrum seems to be curved stronger than the low-flux spectrum which seems to be almost a power law. A conservative estimate to study the location of the peak at different flux levels is shown in Fig. 5 and introduced in Krennrich & Dwek (2003).

3 MULTIWAVELENGTH PROGRAM

The MAGIC collaboration is open to participate in any kind of multiwavelength program. Two kinds of observations mode are planned, the standard observation mode and ToO (target of oportunity) mode.

Table 1 This is a list of possible multiwavelength candidates taken from Costamante & Ghisellini 2002

Source	Coordinates		Dates
1ES 0033+59.5	$00^{h}\ 35^{m}\ 53^{s}$	$+59°50'05''$	Sep, Okt, Nov
RGB J 0214+20.0	$02^{h}\ 14^{m}\ 18^{s}$	$+51°44'52''$	Sep, Okt, Nov
1ES 0229+20.0	$02^{h}\ 32^{m}\ 49^{s}$	$+20°17'17''$	Okt, Nov, Dez
1ES 0323+02.2	$03^{h}\ 26^{m}\ 14^{s}$	$+02°25'15''$	Okt, Nov, Dez
1ES 0806+52.3	$08^{h}\ 09^{m}\ 52^{s}$	$+52°18'58''$	Dez, Jan, Feb
J 111706.2+201407	$11^{h}\ 17^{m}\ 06^{s}$	$+20°14'07''$	Feb, Mar
Mkr 180	$11^{h}\ 36^{m}\ 26^{s}$	$+70°09'27''$	Feb, Mar
BWE 1133+6753	$11^{h}\ 36^{m}\ 30^{s}$	$+67°37'04''$	Feb, Mar
QSO 1722+119	$17^{h}\ 25^{m}\ 04^{s}$	$+11°52'16''$	Jun, Jul
1ES 1727+50.2	$17^{h}\ 28^{m}\ 19^{s}$	$+50°13'10''$	Jun, Jul
1ES 1741+19.6	$17^{h}\ 43^{m}\ 58^{s}$	$+19°35'09''$	Jun, Jul
1ES 2200+42.0(Bl-Lac)	$22^{h}\ 02^{m}\ 43^{s}$	$+42°16'40''$	Aug, Sep
1ES 2344+51.4	$23^{h}\ 47^{m}\ 05^{s}$	$+51°42'18''$	Sep, Okt

1. Following the standard observation mode, the MW campaings should be planned early, should show clear scientific goals and should be inlcuded in the next observation period with 2 month lead time.
2. The ToO mode will trigger at any time (e.g. Gamma Ray Bursts). The telescope will need < 20 s to point to the coordinates of any source at the sky. This mode is only garanteed if it is planned in advance with fixed criteria.

If you have any questions, suggestions or proposals please contact our multiwavelength coodinator Dr. Martin Merck, merck@astro.uni-wuerzbrug.de.

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References

Bretz, T. (in preparation)

Cortina, J., 2001, astro-ph/0103393

Costamante, L. & Ghisellini, G. 2002, A&A, 384, 56

Fazio, G.G. & Stecker, F.W. 1970, Nature, 226, 135

Hauser, M.G. & Dwek, E. 2001, ARA & A, 39, 249

Horan et al. 2002, ApJ, 571, 753

Kneiske, T.M., Mannheim, K. & Hartmann, D. 2002, A & A, 386, 1 (Paper I)

Kneiske, T.M., Bretz, T., Mannheim, K. & Hartmann, D. 2003, A & A, (accepted for pub)

Krennrich, F. & Dwek, E. 2003, astro-ph/0305418, Proc. of the 28th ICRC

Malkan, M.A. & Stecker, F.W. 1998, ApJ, 496, 13

Martinez, M., 2003, Proc. of the 28th ICRC

Merck, M., et al., 2003, Proc. of the 28th ICRC

Scott, J. 2000, ApJS, 130, 67

Zdziarski, A & Svensson, R. 1989, A & A 344, 551