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TeV observations of H1426+428 with HEGRA

Dieter Horns *, F.A. Aharonian, L. Costamante

Max Planck Institut für Kernphysik, Heidelberg, Germany

For the HEGRA Collaboration

Abstract

The blazar H1426+428 ($z = 0.129$) has been observed with the HEGRA stereoscopic system of imaging air Cherenkov telescopes for 270 h in the years 1999, 2000, and 2002. The object is detected with a significance of 7.5σ. The energy spectrum measured by HEGRA extends up to $\approx$8 TeV with indications for a change in the spectral slope at energies above 2 TeV. The integral flux above 1 TeV in 1999 and 2000 amounts to $\approx$8% of the flux of the Crab Nebula. In 2002, the flux drops to a level of 3% of the Crab Nebula. The extragalactic background light at wavelengths between 1 and 10 μm causes substantial ($\tau = 1, \ldots, 9$) absorption of photons in the measured energy spectrum. The intrinsic spectra after correction for absorption are discussed. Contemporaneous observations with the X-ray observatory RXTE in 2000 and 2002 indicate flux and spectral variability in the X-ray band between 2 and 20 keV.

1. Introduction

The ongoing exploration of blazar type objects over a broad region of the electromagnetic spectrum has revealed surprising properties that are of relevance for the study of injection, acceleration, and radiative cooling of particles in relativistic jets. However, a deep understanding of these objects based upon the observations at TeV energies suffers from the ambiguity of the observed spectrum with respect to absorption effects on the extragalactic background light (EBL). Currently, the object H1426+428 at a redshift of $z = 0.129$ is the most distant emitter of photons up to energies of $\approx$8 TeV detected. Unfortunately, the observational uncertainty on the measured energy density of the EBL is quite large (up to a factor of 10 at $\lambda \approx 1$ μm, see also Fig. 1(b)). Given the consequently large uncertainty on $\tau(E)$, a reasonably accurate (better to within a factor of 10) correction for the effect of absorption is not possible. Here, another approach is followed: Using widely different descriptions of the EBL, absorption corrections are applied to the observed energy spectrum to infer the intrinsic source spectrum. The intrinsic source spectrum is then checked for consistency with our current understanding of blazar physics.

* Corresponding author.
E-mail addresses: horns@mpi-hd.mpg.de, dieter.horns@mpi-hd.mpg.de (D. Horns), felix.aharonian@mpi-hd.mpg.de (F.A. Aharonian), luigi.costamante@mpi-hd.mpg.de (L. Costamante).
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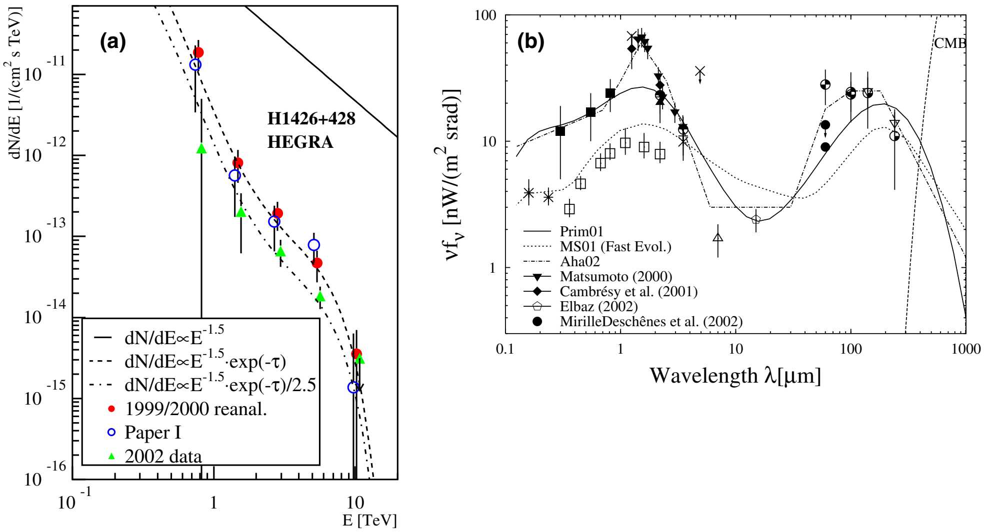

Fig. 1. (a) The differential energy spectrum of H1426+428 as measured by HEGRA in the two different flux states seen in 1999, 2000, and 2002. For comparison, the previously published results are included. (b) A selection of measurements and models for the EBL from UV to far-infrared (taken from Aharonian et al. (2003)).

2. Observations and results

2.1. X-ray observations

The instruments on-board the Rossi X-ray Timing Explorer (RXTE) have been used to measure the X-ray flux from H1426+428 during the years 2000, 2001, and 2002. The overall flux level is quite different between the observations, varying by a factor of ≈3 between 2000 and 2001 (see Table 1 for a summary of the pointed observations). During all three pointings a hard spectrum described by a power law with $\mathrm{d}N/\mathrm{d}E \propto E^{-\gamma}$ with $\gamma < 2$ is observed. The results indicate that the object is showing only weak spectral variations, remaining in a hard state for different flux levels. Interpreting the corresponding spectral energy distribution in the framework of a combined synchrotron and Compton dominated emission model, this would imply that the position of the synchrotron peak is at or beyond 10 keV, and possibly similar to previous observations (Costamante et al., 2001) located in the hard X-ray band. In 2000, the spectrum seems to soften above 8 keV. In 2002 the spectrum seems to harden beyond 15 keV. A pure power law does not satisfactorily describe the data in these cases.

The all-sky monitor (ASM) on-board the RXTE satellite offers continuous coverage of the object. Averaging the daily measurements of the flux for the HEGRA observational nights during the 1999 and 2000 data set results in an ASM rate of 0.33 ± 0.08 counts/s, whereas in 2002 the ASM count rate drops by a factor of 1.7 to

Table 1
Table of X-ray observations

Pointing (year)	Exposure (ks)	N_0 (keV^{-1} s^{-1} cm^{-2})	γ	χ^2/dof(dof)
2000	4	$(9.1 \pm 0.7) \times 10^{-3}$	1.96 ± 0.04	2.82(7)
2001	12.7	$(30.1 \pm 1.6) \times 10^{-3}$	1.81 ± 0.03	0.75(23)
2002	110	$(9.5 \pm 0.3) \times 10^{-3}$	1.82 ± 0.02	3.76(27)

The galactic column density has been kept fixed at $n_H = 1.38 \times 10^{20}$ cm^{-2}. The fit range for a power law $\mathrm{d}N/\mathrm{d}E = N_0(E/\mathrm{keV})^{-\gamma}$ starts at 4 keV.

0.19 ± 0.04 counts/s. In the context of a leptonic emission model, a correlation of the X-ray flux and the TeV flux is expected and is confirmed by the HEGRA data (see the following section).

2.2. TeV observations

The observations carried out with the HEGRA system of five imaging air Cherenkov telescopes detected the object in 1999/2000 during 40 h observation at a flux level of 8% of the Crab Nebula (Aharonian et al., 2002). In order to verify the observed energy spectrum with better statistics, an extended observational campaign has been carried out in 2002, accumulating 217 h of good data (Aharonian et al., 2003). However, the source showed a lower flux of merely 3% of the Crab Nebula. The spectral analyses presented here are based upon an improved analysis technique tailored for weak sources. The event-selection criteria have been adopted to weak sources by applying tighter cuts on the arrival direction and on *mean scaled width* in order to increase the signal-to-noise ratio. An improved energy reconstruction algorithm has been used which benefits from the stereoscopical reconstruction of the position of the shower maximum and achieves a relative energy resolution ($\Delta E/E$) of 15% at the threshold and of 10% at higher energies. The new method has successfully been used for data taken on the Crab Nebula and on the original 40 h data set of H1426+428 taken in 1999 and 2000. The resulting data points are shown in Fig. 1 Generally, good agreement between the previously published energy spectrum and the reanalysed data of 1999/2000 is seen. The 2002 data confirm a hardening in the energy spectrum above 1 TeV. Combining the excess above 2 TeV of all the data results in a significance of 6σ.

3. Conclusions

Based upon the fact that similar flux levels of H1426+428 have been observed by the CAT, Whipple, and HEGRA groups and that the ASM observations confirm a similar level for these observations at X-ray energies, it seems feasible to combine the different data sets to cover a wider energy band. Especially at energies below 1 TeV, a steep rise of the energy spectrum because of absorption effects is expected and confirmed by the

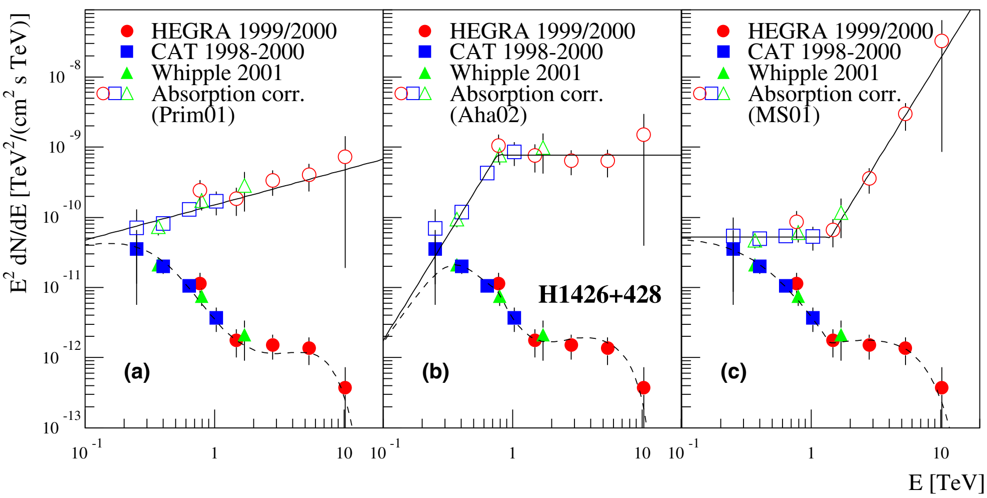

Fig. 2. The differential energy spectrum combined from the measurements of the CAT, Whipple, and HEGRA (1999/2000) groups multiplied by E^2 (filled symbols). From left to right (a)–(c): The observed and corrected spectra for three different models of the extragalactic background light (Prim01, Aha02, MS01, see also Fig. 1(b)). The open symbols indicate the corrected spectrum. The solid lines are power law and broken power law fits to the open symbols. The dashed lines are the same power laws after multiplying the absorption term $\exp(-\tau(E))$.

different groups (Petry et al., 2002; Djannati-Ataï et al., 2002). The resulting energy spectra are shown in Fig. 2(a)–(c) together with absorption corrected spectra using the SEDs of the EBL shown in Fig. 1(b). Note, the models Aha02 and MS01 result in an unreasonable rise of the source spectrum ($dN/dE \propto E$) either at the low energy part (Aha02, Fig. 2(b)) of the spectrum or the high energy part of the spectrum (MS01, Fig. 2(c)). Consulting Fig. 1(b) it becomes clear that the Aha02 description of the EBL data (especially the high flux between 1 and 2 μm) results in a steep rise of τ for $E > 100$ GeV. The high value of the SED in the near-infrared as given by MS01 causes a quickly increasing optical depth above 2 TeV.

In summary, the TeV observations of extragalactic objects offer an indirect approach to constrain the EBL. The HEGRA observations of H1426+428 with a clear detection of 6σ above 2 TeV are important to constrain the shape of the SED of the EBL in the near-infrared above 2 μm. Combined data from CAT, Whipple, and HEGRA constrain the EBL at wavelengths below 2 μm.

References

Aharonian, F.A. et al., 2002. A&A 384, L23.
Aharonian, F.A. et al., 2003. A&A 403, 523.
Costamante, L. et al., 2001. A&A 371, 512.
Djannati-Ataï, A., Khelifi, B., Vorobiov, S., et al., 2002. A&A 25, 391.
Petry, D., Bond, I.H., Bradbury, S.M., et al., 2002. ApJ 580, 104.