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Implication of the recent observations of Markarian 421 and 1H1426+428 by the Whipple IACT on the inter-galactic diffuse infrared background field.

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Abstract. Identification of two nearby active galactic nuclei, Markarian 421 (Mrk 421, $z = 0.031$) and Markarian 501 (Mrk 501, $z = 0.033$), as TeV γ-ray emitters has opened a possibility to study the diffuse intergalactic photon field in the wavelength range $\sim 0.5 - 50\ \mu$m. We were fortunate that the BL Lacertae object Mrk 421 has been particularly active during the spring of 2001 showing episodes of extraordinary intense flares in January, February, and March. The Whipple Imaging Atmospheric Cherenkov Telescope (IACT) has continuously monitored this object through the season and collected more than 45×10^3 photons, available now for detailed spectral studies. Another active galactic nuclei (AGN), 1H1426+428, is a newly discovered TeV γ-ray source. It is distinguished for its distance ($z = 0.129$), the largest among the X-ray selected BL Lacertae objects detected at TeV energies. 1H1426+428 has been intensively observed by the Whipple γ-ray telescope during the 1999, 2000, and 2001 seasons. Although the flux of this source is low, the photon statistics poor, and the cosmic ray background large, we found indications that the spectrum of this source may be steep comparing to Mrk 501. In this paper we identify the framework for studying the low energy intergalactic diffuse photon background based on the spectral properties of these two AGN. We will present our results in detail at the conference.

1 Introduction

Gould and Schreder (1967) pointed out that there is a connection between propagation length of high energy photons from distant quasars and intensity of the low energy intergalactic diffuse photon field. These two energy regions, separated by twelve orders of magnitude, are coupled via electron-positron pair production, which generates frequency dependent attenuation of the intrinsic AGN spectrum. Thus the low energy photons of $\sim 4 \times 10^{-2}$ eV to 4 eV may produce an absorption signature in the 25 to 0.25 TeV region of a quasar spectrum. The characteristic optical depth scale is given by the product of the redshift to the nearby object and the ratio of the diffuse photon density to the characteristic density $n_0 = [3/8\sigma_{\rm t} c/H_0]^{-1} = 2.8 \times 10^{-4}$ cm^{-3}, where $\sigma_{\rm t} = 6.67 \times 10^{-25}$ cm^2 is the Thomson cross-section, and $H_0 = 65$ km sec^{-1} Mpc^{-1} is the Hubble constant. Thus, a very rough estimate tells us that an object at $z = 0.03$ can probe intergalactic photon densities $> 10^{-2}$ cm^3, which are expected from theoretical considerations for $\lambda > 10\ \mu$m. If such an astrophysical object is capable of emitting appreciable amount of photons with energy above ~ 10 TeV, this part of the source spectrum will be strongly attenuated. Similarly, approximate predictions can be made for an object at $z = 0.129$, suggesting that the testable diffuse photon densities are $> 2.2 \times 10^{-3}$ cm^{-3}, which should be likely to occur at wavelengths larger than a few micrometers, producing a strong signature in the source's spectrum above ~ 1 TeV.

The portion of the diffuse photon spectrum from a fraction of micrometer to a few hundred micrometers contains a wealth of cosmological information. It is the second largest energy reservoir in the Universe after the CMB (Ressel and Turner , 1989), populated by the photons produced during nucleosynthesis in the stars and during the the final stages of stars' evolution. It also consists of infrared photons generated in accretion discs of black holes and perhaps relic photons from decays of more exotic objects of the early Universe. It is somewhat ironic, however, that we are now extracting fundamental cosmological information from less than 10^{-5} relative fluctuations in the density of the CMB field, while we hardly know the energy density of its next "shorter wavelength neighbor" to within an order of magnitude, and for some wavelengths the situation is even worse. The direct measurements of intergalactic diffuse photons in this spectral region were attempted by the DIRBE experiment on the Cosmic Background Explorer (Boggess et al. , 1992). Due to a strong contamination from Zodiacal and galactic IR backgrounds this mission failed to identify the faint intergalactic signal in wavelength bands from 1.25 to $50\ \mu$m (Hauser

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et al. , 1998). The method of indirect detection of these photons by means of TeV gamma ray astronomy provides, at the moment, the best upper limits in this wavelength region (Biller et al. , 1998) , (Aharonian et al. , 1999), (Guy et al. , 2000), (Aharonian et al. , 2001).

2 Spectral measurements and expectations

Our inability to fully disentangle the intrinsic spectrum of an AGN from an attenuation effect due to diffuse photon field constitutes the a main difficulty in constraining the density of intergalactic radiation. Advances can be made via both multi-wavelength observations and modeling of flaring mechanisms of AGN, and understanding the mechanism of attenuation via pair production itself. This situation is complicated additionally due to peculiar degeneracy between these two effects: a broad class of realistic spectral densities of low energy photons can produce an attenuation effect which doesn't change the typical power-law type AGN spectrum (Vassiliev , 2000).

The summary of the observations of Mrk 421 to be used in our analysis as well as spectrum measurements and its dynamical properties are reported in a separate submissions to this conference (Holder et al. , 2001), (Jordan et al. , 2001), (Krennrich et al. , 2001). During observations with the Whipple telescope the photon data base was collected at various zenith angles allowing the extension of spectral measurements to above 10 TeV where the attenuation effect may be identified with less ambiguity. The high photon statistics at lower energies may provide sufficient constraint to limit the static part of curvature in the AGN spectrum and consequently improve upper limits on the diffuse photon field in the wavelength region between ~ 20 and 2 μm. Analysis of these data is in progress.

In addition to analysis of the Mrk 421 spectral features, which together with Mrk 501 became a subject of intense discussions recently, we plan to derive constraints from the newly detected 1H1426+428 BL Lac object (Horan et al. , 2001). Due to the fact that this AGN is four times more distant than previously detected Mrk 501 and Mrk 421, its spectral properties provide a probe of visible and near infrared intergalactic photons. Although, the diffuse photon field in the region around 1 μm is not expected to be large enough to attenuate substantially the ~ 400 GeV photons detected by the Whipple telescope, it might be enough to steepen the power-law spectral index for observed photons (Vassiliev , 1999). The preliminary results indeed indicate a softer spectrum of this object than Mrk 501, for example.

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