Discovery of Very High Energy gamma-ray emission from the distant BL Lac object H2356-309 with the H.E.S.S. Cherenkov Telescopes

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DISCOVERY OF VERY HIGH ENERGY GAMMA-RAY EMISSION FROM THE DISTANT BL LAC OBJECT H2356-309 WITH THE H.E.S.S. CHERENKOV TELESCOPES

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Abstract. The H.E.S.S.(High Energy Stereoscopic System) array of imaging Cherenkov telescopes has recently discovered the most distant extra-galactic Very High Energy (VHE, E>160GeV) gamma-ray emitters. Located at a redshift of z=0.165, the extreme synchrotron BL Lac object H2356-309 was observed with H.E.S.S. in a simultaneous multi-wavelength campaign including radio, optical and X-ray observatories. Using a single zone model, we will describe the constraints on VHE emission parameters such as the maximal Lorentz factors of accelerated electrons, and the magnetic field. We will also show the constraints that this source, as well as the other VHE gamma-ray emitter 1ES1101-232, puts on the density of extragalactic background light, which is an important cosmological topic.

1 Introduction

The H.E.S.S (High Energy Stereoscopic System) experiment is an array of four imaging atmospheric Cherenkov telescopes located on the Khomas Highlands in Namibia. It is fully operational since December 2003 and dedicated to the detection of γ-rays above 100 GeV. Among the sources of interest, the extreme synchrotron BL Lacs, which are AGNs with jets pointing at a small angle to the line of sight. The spectral energy distribution(SED) of AGNs covers a large range of frequencies, from radio to high energy γ-rays. The SED shows a double-humped structure, with the first hump located in the X-ray band generally explained by synchrotron emission of high energy electrons, and the second due to Inverse Compton or hadronic emission. Multi-wavelength campaigns are needed to put constraints on emission models.

We present here the discovery of VHE γ-rays from H2356-309 with the H.E.S.S telescopes. With a redshift of z=0.165, H2356-309 is one of the most distant AGN detected at VHE energies so far. For H2356-309, observations simultaneous with the H.E.S.S campaign were performed in radio (NRT, June and October 2004), optical (ROTSE, June to December 2004) and X-ray (RXTE, November 2004 11th) wavelengths.

2 Data analysis and results

2.1 H.E.S.S. observations and results

H2356-309 was observed from June to December 2004 for a total exposure time of nearly 40 hours after run quality selection. It was detected for the first time at GeV/TeV energies (Aharonian et al. 2006a). The data are taken at an average zenith angle of 20° with the telescopes pointing with an offset of 0.5° relative to the object position.

The data analysis is performed using the 3D Model reconstruction (Lemoine-Goumard et al. 2006). This method is based on a 3-dimensional (3D) shower model. It uses the stereoscopic information from the telescopes to reconstruct the direction, energy and 3D-width of the detected shower. Fig. 1 shows the distribution of the squared angular distances θ^2 from H2356-309, where θ is the angular distance between the direction of the candidate γ-rays and the nominal position of the source. An excess for $\theta^2<0.01°$ of 453 γ-rays at a significance-level of 11.6σ indicates emission from the direction of H2356-309.

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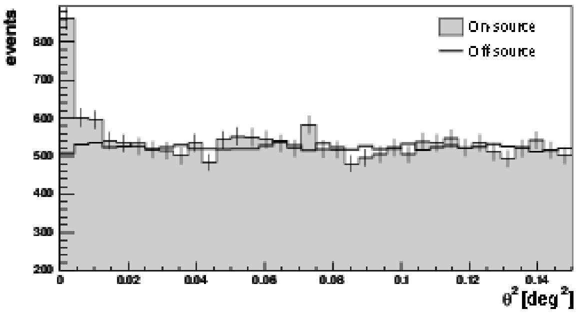

Fig. 1. Distribution of squared angular distances θ^2 for H2356-309, using the 3D Model reconstruction. The distribution from the on-source region is represented by the filled histogram, the distribution from the off-source background is given by the black line.

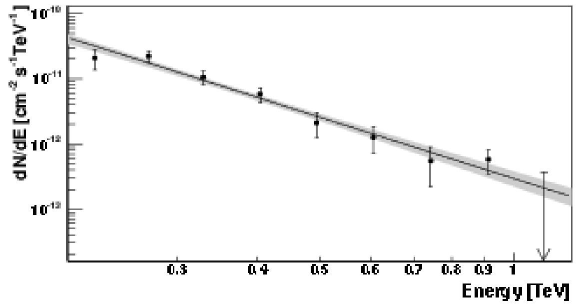

Fig. 2. Differential energy spectrum of H2356-309. The shaded area gives the confidence region (1 standard deviation) for the spectral shape under the assumption of a power law. The upper limit (arrow) is given with a 99% confidence level.

The differential energy spectrum is shown in Fig. 2. It is well described by a power-law with a flux-normalisation $N_0 = (3.00 \pm 0.80_{stat} \pm 0.31_{sys}) \times 10^{-13}\,\mathrm{cm^{-2}s^{-1}TeV^{-1}}$ and a spectral index of $\Gamma = 3.09 \pm 0.24_{stat} \pm 0.10_{sys}$. Assuming this spectral shape, variability characteristics have been investigated at different timescales. For each time interval, the number of ON and OFF events is determined as well as the expected number of gammas, given the spectral shape, the acceptance and angular resolution. Then a normalisation factor is calculated to match the observed number of excess events to the expected one. Lightcurves are consistent with a constant emission over time as shown in Fig. 3 with a timescale of one night and Fig. 4 with a timescale of one month.

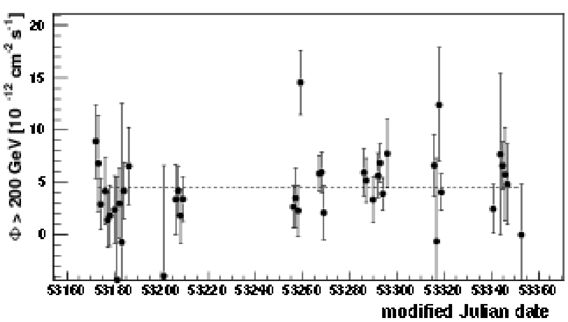

Fig. 3. Nightly flux above 200 GeV: the lightcurve is compatible with a constant flux.

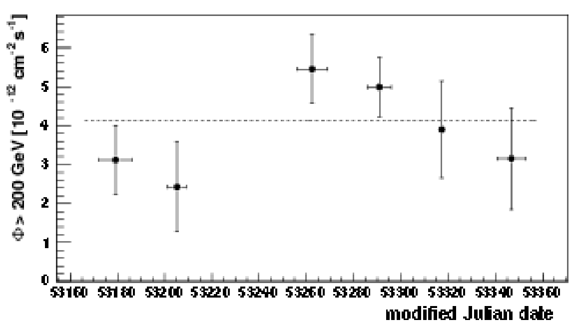

Fig. 4. Flux above 200 GeV: averaged flux in six different time windows from June to December 2004. No evidence for variability is present.

2.2 Multiwavelength results

The average flux for the measurements carried out with the Nançay Radio Telescope is 40±8 mJy. This flux represents an upper limit for the total SED since the radio emission is supposed to come from regions further out in the jet. In optical, the ROTSE-IIIc telescope located on the H.E.S.S site carried out a monitoring of the source. During the observation periods covered by H.E.S.S the apparent R-band magnitude m(R) measured from H2356-309 has its maximum at m(R)=16.1 and its minimum at m(R)=16.9 with a contribution of the host galaxy to the observed flux estimated to be m(R)=17. The RXTE/PCA analysis yields an X-ray photon index $\Gamma_X = 2.43 \pm 0.11$ and a flux of $9.7^{+0.3}_{-1.3} \times 10^{-12}\mathrm{erg\,cm^{-2}\,s^{-1}}$ in the 2-10 keV band. No significant variability is seen.

3 Discussion

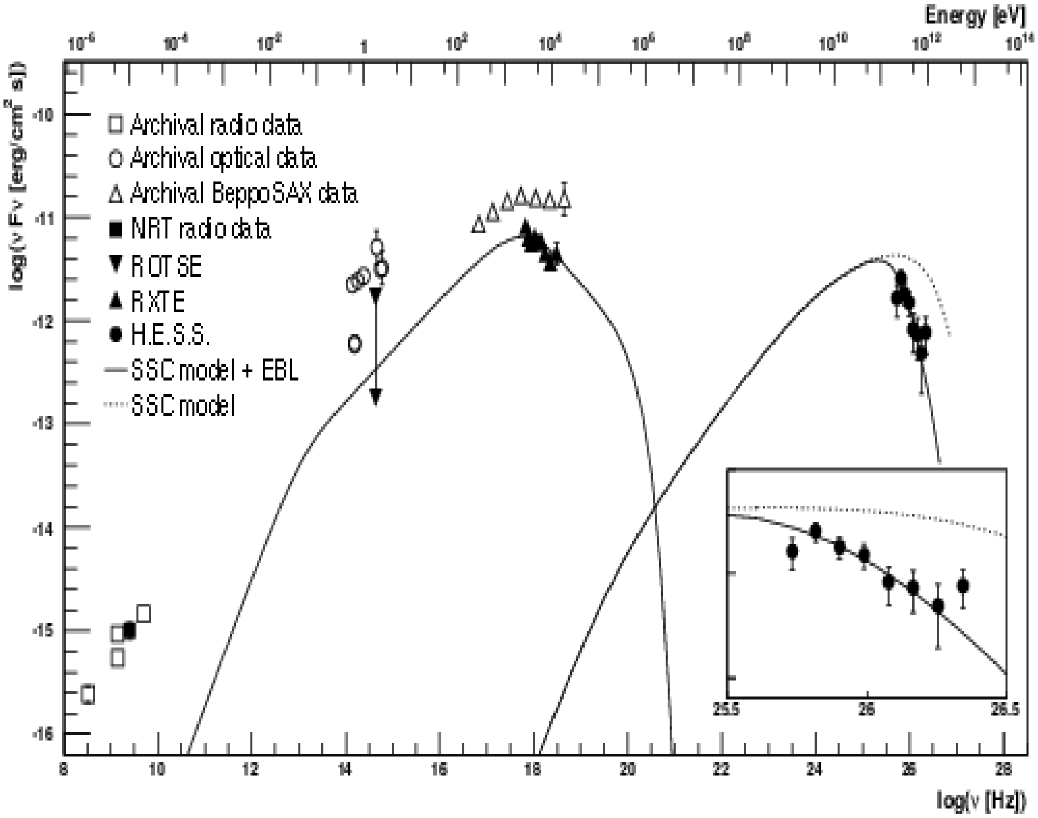

Fig. 5. Spectral Energy Distribution of H2356-309. Data simultaneous to the H.E.S.S observations are shown as filled symbols. Archival data are shown as open symbols. The single-zone homogeneous SSC model is shown as a solid line. The dashed line shows the SSC model without absorption.

The SED of H2356-309 is presented in Fig. 5 together with archival data. The 2-10 keV flux level of this campaign is lower than previous BeppoSAX observations (Costamante et al. 2001) . Optical measurements are also lower than archival data. Associated with the fact that in the VHE and X-ray lightcurves no significant variability is seen, the observations suggest a low state of emission of the source, similar to the one of 1ES1101-232, the most distant AGN discovered so far (Aharonian et al. 2006b).

Additionnally, given its high redshift, H2356-309 is an ideal candidate to put constraints on the density of extragalactic background light (EBL). In fact, TeV spectra are affected by absorption of high energy photons by the diffuse EBL according to $F_{obs} = F_{int} \cdot e^{-\tau}$ with the attenuation factor τ depending on the redshift of the source and the density of EBL. The unexpectedly hard spectra of H2356-309 and 1ES1101-232 provide an upper limit on the background light at optical/near-infrared wavelengths that appears to be very close to the lower limit given by the integrated light of resolved galaxies (see Aharonian et al. 2006b for more details). Taking into account the absorption by the EBL, a one-zone homogeneous, time independent, synchrotron self-Compton (SSC) model is adjusted to the data. One obtain an emitting region characterised by a spherical emission region of R=3.4×10^{15} cm, a magnetic field of B=$0.16\,G$ and a Doppler factor of δ=18. This set of parameters is reasonable for this kind of objects and comparable with the one obtained for PKS2155-304 (Aharonian et al. 2005).

The sensitivity of H.E.S.S. (5σ in 25 hours for a 1% Crab Nebula flux source at 20° zenith angle) allows for detection of VHE emission from objects at previously undetectable flux levels. However, future observations are needed to increase the statistics and improve the accuracy of the spectral measurements.

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References

Aharonian et al. 2006a, A&A, 455, 46

Aharonian et al. 2006b, Nature, 440, 1018

Aharonian et al. 2005, A&A, 442, 895

Costamante et al. 2001, A&A, 371, 521

Lemoine-Goumard M., Degrange B. and Tluczykont M. 2006, Astroparticle Physics, 25, 195