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Discovery of Two New TeV Blazars with the H.E.S.S. Cherenkov Telescope System

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Abstract: Since the new generation of imaging atmospheric-Cherenkov telescopes came online with the commissioning of the four telescopes of the H.E.S.S. experiment in 2004, the number of known extragalactic γ-ray emitters in the very high energy (VHE) domain has more than doubled. All of the sources detected so far are active galactic nuclei and all but one belong to the class of BL Lac objects. The emission process for VHE γ-rays in this class of objects is not fully understood and a large sample of sources and multi-wavelength data is needed to discriminate between different models. Furthermore, VHE photons from these distant sources are attenuated via pair production with the extragalactic photon field in the optical to infrared wavelength band (extragalactic background light, EBL), which contains cosmological information on the star and galaxy formation history. With assumptions about the source physics, limits on this photon field can be derived. We report the detection of VHE gamma-rays from the BL Lac 1ES 0229+200 (z = 0.14) and 1ES 0347-121 (z = 0.1880) with the H.E.S.S. Cherenkov telescope system. 1ES 0347-121 is among the most distant source detected in VHE gamma-rays to date.

Introduction

The H.E.S.S. collaboration operates an array of four large imaging atmospheric-Cherenkov telescopes (107 m^2 mirror area per telescope; $\sim$5° field of view) located in the Southern hemisphere in Namibia (1800 m a.s.l.) [1]. H.E.S.S. observes very high energy (VHE; >100 GeV) γ-rays from many types of astrophysical objects. About one third of the H.E.S.S. observation time ($\sim$300 hours) is dedicated to study active galactic nuclei (AGN). In the following the detection of VHE γ-rays from two AGNs of the BL Lac class 1ES 0347-121 and 1ES 0229+200 is reported. Details on the discoveries and the implication for the extragalactic background light (EBL) are discussed in [2] and [3]

Methods

H.E.S.S. takes data during dark moonless nights. The data are calibrated [4] and an image analysis provides properties of the primary particle like arrival direction, energy and particle type. The telescopes operate in coincidence mode to allow a stereoscopic event reconstruction [5]. Usually the data is recorded in *wobble mode* where the telescope point with and offset of 0.5° to the nominal source position to allow a simultaneous estimation of the background. The data presented here has been analyzed with a standard Hillas-type analysis as described in [6]. The signal is extracted from a circular region around the source position, the background (off-source data) is estimated using the *Reflected-Region* method [7]

1ES 0347-121

1ES 0347-121 was discovered in the Einstein Slew Survey and was later classified as an BL Lac object [8, 9]. Located at a redshift of $z = 0.1880$ it harbours a super massive black hole of mass $\log(M_{\rm BH}/M_{\rm Sun}) = 8.02 \pm 0.11$ [10]. [11] used simple physical considerations about the syn-

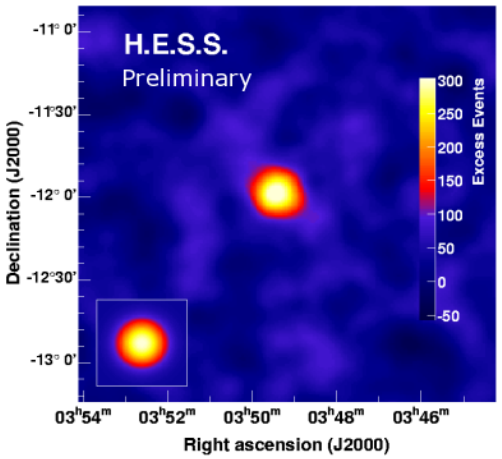

Figure 1: Smoothed sky-map of excess events centered on the position of 1ES 0347-121 (ring background). An excess of 327 γ-ray candidates is detected corresponding to a statistical significance of 10.1 standard deviations.

chrotron and inverse Compton component of the spectrum to predict the flux above 0.3 TeV of $3.8 \times 10^{-12}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which should easily be detectable with H.E.S.S. An upper limit on the integral flux above an energy threshold of 1.46 TeV of $5.14 \times 10^{-12}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (0.56 Crab) has been reported by the HEGRA collaboration [12], considerably higher than the flux estimate from [11].

The H.E.S.S. observations of 1ES 0347-121 were carried out between August and December 2006. 25.4 h (corrected for the detector deadtime) of good-quality data was recorded. The zenith angles of the observations ranged from 12 to 40°, with a mean zenith angle of ∼19°. The analysis energy threshold for the observation is ∼250 GeV.

An excess of 327 γ-ray candidates was, found corresponding to a statistical significance of 10.1 standard deviations (Fig. 1). The extension of the excess is compatible with a point-source whose position coincides with that of 1ES 0347-121. The VHE flux is constant during the H.E.S.S. observation period (Fig. 2).

The VHE energy spectrum, ranging from ∼250 GeV to >3 TeV, is well described by a power law with a photon index of $\Gamma \sim 3.1$. The integral flux above 250 GeV corresponds to ∼2%

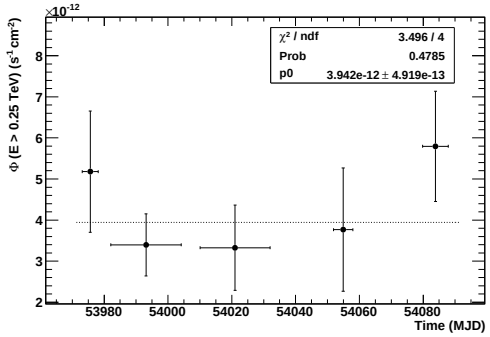

Figure 2: Monthly averaged light-curve of 1ES 0347-121. No significant variability is detected in the H.E.S.S. data-set. The dashed line is the fit of a constant function to the light-curve (parameters are given in the figure).

of the flux of the Crab Nebula above the same threshold.

1ES 0229+200

The active galactic nucleus (AGN) 1ES 0229+200 was initially discovered in the *Einstein* IPC Slew Survey [8] and later identified as a BL Lac object [9]. It is now classified as a high-frequency peaked BL Lac (HBL) due to its X-ray-to-radio flux ratio [13]. The HBL is hosted [14] by an elliptical galaxy $M_R = -24.53$ located at a redshift of $z = 0.14$ [9]. Based on its spectral energy distribution (SED) and its relative proximity, 1ES 0229+200 was suggested [15, 11] as a potential source of VHE γ-rays. However, despite several attempts, it has not been previously detected in the VHE regime. The HEGRA [12], Whipple [16, 17], and Milagro [18] collaborations have each reported upper limits on the flux from 1ES 0229+200 during various epochs. The most constraining upper limit (99.9% confidence level) on the flux is I(>410 GeV) $< 2.76 \times 10^{-12}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, based on ∼1 hour of HESS observations made in 2004 [19].

1ES 0229+200 was observed with the H.E.S.S. array for a total of 70.3 h (161 runs of ∼28 min each) in 2005 and 2006 [3]. After applying the standard HESS data-quality selection, 98 runs remain yielding an exposure of 41.8 h live time at a mean zenith angle $Z_{\mathrm{mean}} = 46°$. The event-selection criteria

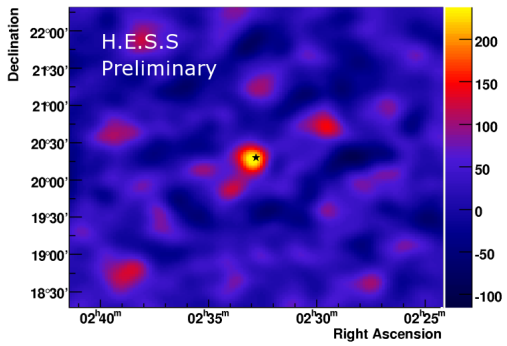

Figure 3: Smoothed sky-map of excess events centered on the position of 1ES 0229+200 (ring background). An excess of 261 γ-ray candidates is detected corresponding to a statistical significance of 6.6 standard deviations.

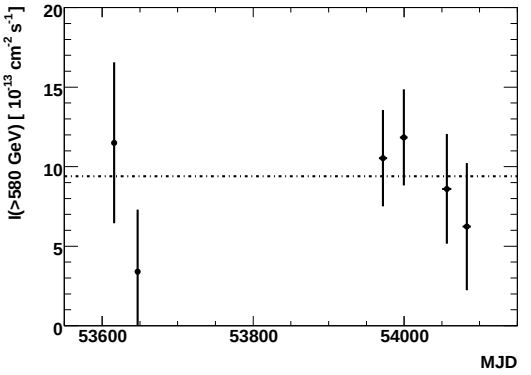

Figure 4: Monthly averaged light-curve of 1ES 0229+200. No significant variability is detected in the H.E.S.S. data-set. The dashed line corresponds to the average flux.

are performed using the *standard cuts* [20] resulting in a post-analysis energy threshold of 580 GeV at Z_{mean}. Results consistent with those presented below are also found using independent calibration and/or analysis chains.

A significant excess of 261 events (6.6σ) from the direction of 1ES 0229+200 is detected in the total data set (Fig. 3). The VHE flux is constant during the H.E.S.S. observation period (Fig. 4) and the integral flux above 580 GeV corresponds to $\sim$2% of the flux of the Crab Nebula above the same threshold. The VHE energy spectrum, ranging from $\sim$500 GeV to $\sim$10 TeV, is well described by a hard power law with a photon index of $\Gamma \sim 2.5$.

Discussion & Conclusion

BL Lac objects show highly variable emission in many wavelength bands. To understand and model the VHE emission processes in these objects contemporaneous multi-wavelength observations are necessary.

1ES 0347-121 has been observed by the SWIFT satellite at X-rays and UV/optical wavelengths and by the ATOM optical telescope during the H.E.S.S. observation periods [2]. The resulting broadband spectral energy distribution (SED) can be described by a simple one-zone synchrotron-self-Compton model, though the data does not strongly constrain the model parameters. Due to the lack of contemporaneous X-ray data for 1ES 0229+200 an accurate modeling of the source is not possible.

The VHE spectra from both sources enable the determination of stringent upper limit on the extragalactic background light (EBL) in the ultraviolet to near-IR wavelength region. These limit are reported in [2] and [3].

Future VHE monitoring of 1ES 0347-121 and 1ES 0229+200, to search for high flux states (flares), is highly desirable. To derive stronger constraints on the emission models, further contemporaneous multiwavelength observations are also necessary.

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