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Spectrum and variability of the VHE Galactic Centre source observed with H.E.S.S.

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The High Energy Stereoscopic System (H.E.S.S.) is an array of four imaging air-Cherenkov telescopes located in Namibia, in the Southern hemisphere. We report the detection of a source of very high energy γ-rays in the direction of the Galactic Centre in observations made in 2003 and 2004. The unprecedented sensitivity of H.E.S.S. enables to strongly constrain the VHE spectrum and variablity.

1. Introduction

The H.E.S.S. (High Energy Stereoscopic System) detector [1] is an array of four Imaging Atmospheric Cherenkov Telescopes, located in Namibia, at $23°16' \, S \, 16°30' E$ and 1800 meters a.s.l.. It is designed to study very high energy (VHE > 100 GeV) γ-rays. Each telescope is composed of a $107 \, \mathrm{m}^2$ mirror [2, 3] and a $5°$ diameter field of view camera [4]. More details on H.E.S.S. can be found in [5, 6].

The detection of a VHE source at the Galactic Centre with 2-telescope H.E.S.S. array in 2003 has been reported in [7]. The source was coincident with a point-like source situated within 1' of the black hole Sgr A*. Given the number of potential VHE sources in the central 4 pc of the Milky Way, it is important to constrain the energy spectrum and the flux variability of the source. Further observations have thus been carried out in 2004 with the complete 4-telescope array. The H.E.S.S. sensitivity (5 σ in 25 hours for a 1% Crab Nebula flux at $20°$ zenith angle) allows for studies of flux variation of the Galactic Centre source down to 10-minute scales.

2. H.E.S.S. observations and results

The observations presented here were obtained in 2003 and 2004:

- from July 22 to August 29, 2003, when two of the four telescopes were operational ;
- from March 30 to September 4, 2004, with the full H.E.S.S. array.

The live times for the data sets, after quality selection, are 11.8 h (wobbling $\pm 0.5°$ around Sgr A*) and 50 h (within $2°$ of Sgr A*), respectively. The Table 1 summarizes the configuration of the observations. Two different analyses were used in order to select and reconstruct the γ-rays [8, 9], and to compute the energy spectrum [10]. Both analyses yield consistent results and have an energy resolution of $\sim 15\%$.

A VHE source is detected in both data sets, at a level of 9.2 and $35 \, \sigma$, respectively, using point-like source analyses (i.e. a cut on the angular distance θ between the reconstructed events and Sgr A*: $\theta < 0.14°$). The Galactic Centre source as seen in 2003 and 2004 is located within $5'' \pm 10''_{stat} \pm 20''_{syst}$ from Sgr A* (assuming a point-like source). The higher sensitivity and angular resolution of H.E.S.S. in 2004 allows to constrain the size of the source, which appears slightly extended along the galactic plane. Accurate analyses of the morphology

Data set	$\mathrm{N}_{\mathrm{tel}}$	Live time [hours]	Threshold [GeV]	Excess	Significance [σ]	I($>$ 1TeV) [$10^{-12}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$]	Γ
2003	2	11.8	265	560	9.2	2.1 ± 0.3	2.21 ± 0.09
2004	4	50	125	2 740	35.0	1.8 ± 0.1	2.29 ± 0.05

Table 1. The observations of the Galactic Centre in 2003 and 2004. For both data sets, the number of telescopes, live time and energy threshold are given, as well as the number of detected γ-rays and the significance. The integral flux above 1 TeV and the photon index Γ are given (only the statistical errors are quoted).

of the source is given in another paper [11]. Given the source position and extension, several candidates are still possible, among them the black hole Sgr A*, the supernova remnant Sgr A East, cosmic-ray interactions in the dense medium of the Galactic Centre or dark matter annihilations. More information can be deduced from the spectrum and variability of the source which are now studied.

3. Energy spectrum

The measured energy spectrum derived for both years is shown in Figure 1. The spectrum is consistent with a power-law fit $dN/dE = F_0\, E_{TeV}^{-\Gamma}$ whose parameters are given in the Table 1. We estimate systematics errors of $\Delta\Gamma \sim 0.1$ and $\Delta F_0 \sim 15\%$. The improved statistics and energy threshold of the 2004 observations allow to fit a power-law spectrum over two decades in energy, from 125 GeV to ~ 20 TeV. An exponential cut-off $dN/dE = F_0\, E_{TeV}^{-\Gamma} e^{-E/E_{cut}}$ has been searched in the 2004 data set. There is no indication for any cut-off and we derived a lower limit $E_{cut} > 6$ TeV at 95% CL. Such a spectrum is hardly compatible with a dark matter annihilation signal as described in [12].

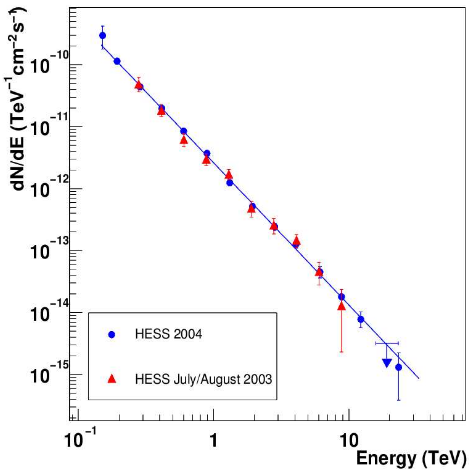

Figure 1. Differential energy spectrum from the direction of the Galactic Centre measured in 2003 and 2004.

Type	$\Phi(> 1TeV)$ $[10^{-12}\,cm^{-2}s^{-1}]$	χ^2/dof	$\mathcal{P}$	σ	χ^2/dof
nightly (2003)	1.96 ± 0.20	9.2/14	81.8%	0.78 ± 0.14	1.9/6
nightly (2004)	1.88 ± 0.09	15.3/27	96.5%	0.73 ± 0.10	11.9/6
nightly (all)	1.90 ± 0.08	24.6/42	98.5%	0.75 ± 0.08	6.9/7
28-minutes (2004)	1.85 ± 0.08	82.2/80	41.0%	1.02 ± 0.09	12.6/12
10-minutes (2004)	1.88 ± 0.05	227.4/242	74.1%	0.98 ± 0.05	12.6/11

Table 2. Parameters for fits of a constant flux to various time-averaged light curves. The integrated flux above 1 TeV, χ^2/dof and corresponding probability are given. Systematical errors of 15% were added before the fit.The Gaussian fits for the distributions of the reduced flux result in the width σ. The χ^2/dof of the fit is also given.

4. Flux variability

The daily integral flux of γ-rays above 1 TeV is shown in the Figure 2 for both 2003 and 2004, as well as the light curves in 28 and 10-minute slices in 2004. The χ^2/dof (including 15% systematic errors) of fits with a constant flux are given in the Table 2. To check that the variations are consistent with statistical fluctuations, we have computed the distribution of the reduced flux Φ_r for all light curves:

$$\Phi_r = \frac{\Phi(> 1\mathrm{TeV}) - \bar{\Phi}(> 1\mathrm{TeV})}{\Delta\Phi}$$

where $\bar{\Phi}(> 1\mathrm{TeV})$ is the average integrated flux above 1 TeV and $\Delta\Phi$ the flux uncertainty (statistical and 15% systematics). The distributions, whose mean and width are given in the Table 2, are consistent with normal Gaussian, indicating that the flux variations that are seen in the light curves are consistent with statistical fluctuations: no flux has more than 3σ deviation from the average flux.

The Galactic Centre source flux is hence consistent with a constant flux at all probed time scales.

5. Conclusions

The spectrum of the very high energy source observed towards the Galactic Centre did not change between 2003 and 2004, being compatible with a power-law from 125 GeV up to ~20 TeV, with a photon index $\Gamma = 2.29 \pm 0.05_{stat} \pm 0.1_{syst}$ and an integrated flux above 1 TeV of $(1.8 \pm 0.1_{stat} \pm 0.3_{syst}) \times 10^{-12}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. So far, the source appears to be steady within statistical and sytematic errors from year down to 10-minutes time scales. The Galactic Centre is currently being observed with the H.E.S.S. experiment in 2005, aiming at constraining the high energy part of the spectrum and monitoring the source steadiness.

References

[1] Hofmann, W. (for the H.E.S.S. collaboration), Proc. of the 28th ICRC (Tsukuba), 2811 (2003).
[2] Bernlöhr, K., et al. (for the H.E.S.S. collaboration), Astropart. Phys. 20, 111 (2003).
[3] Cornils, R., et al. (for the H.E.S.S. collaboration), Astropart. Phys. 20, 129 (2003).
[4] Vincent, P., et al. (for the H.E.S.S. collaboration), Proc. of the 28th ICRC (Tsukuba), 2887 (2003).
[5] Aharonian, F.A., et al. (H.E.S.S. collaboration), Astropart. Phys. 22, 109 (2004).
[6] Funk, S., et al., Astropart. Phys. 22, 285 (2004).
[7] Aharonian, F.A., et al. (H.E.S.S. collaboration), A&A 425, L13 (2004).

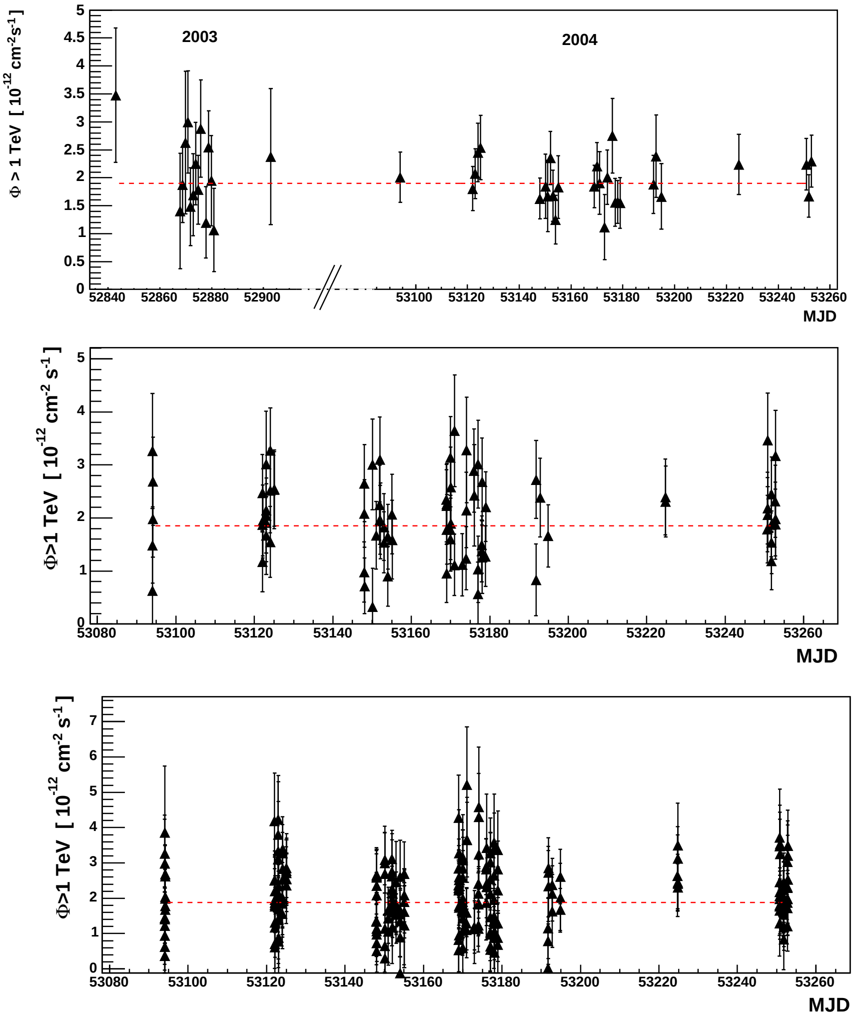

Figure 2. Galactic Centre source light curves. The integral flux above 1 TeV is given as function of time in modified Julian Days. (Top) Nightly average flux for both 2003 and 2004 observations. (Middle) Run by run (28 minutes) average flux in 2004. (Bottom) 10-minutes slices average flux in 2004. 15% systematic errors are added to each point. The fits of the light curves by a constant are shown as a dashed line and their parameters are given in Table 2.

[8] Aharonian, F.A., et al. (H.E.S.S. collaboration), A&A 430, 865 (2005).
[9] Rolland, L. & de Naurois, M., Proc. of the 2nd International Symposium on High Energy Gamma-Ray Astronomy (Heidelberg), 715 (2004).
[10] Piron, F., et al., A&A 374, 895 (2001).
[11] Hinton, J., et al. (for the H.E.S.S. collaboration), these proceedings.
[12] Ripken, J., et al. (for the H.E.S.S. collaboration), these proceedings.