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OBSERVATIONS OF THE GALACTIC CENTRE SOURCE WITH H.E.S.S.

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Abstract. 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 (GC) 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 (Hofmann 2003) 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 (Bernlöhr 2003, Cornils 2003) and a $5°$ diameter field of view camera (Vincent 2003). More details on H.E.S.S. can be found in (Aharonian 2004, Funk 2004).

The detection of a VHE source at the GC with 2-telescope H.E.S.S. array in 2003 has been reported in (Aharonian 2003). 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 GC source down to 10-minute scales.

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

The observations presented here were obtained in 2003 and 2004 and are summarized in the Table 1. Two different analyses were used in order to select and reconstruct the γ-rays(Aharonian 2005, Rolland 2004a), and to compute the energy spectrum (Rolland 2004b). Both analyses yield consistent results and have an energy resolution of $\sim 15\%$.

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Data set	N_{tel}	Δt hours	E_{thr} GeV	N_γ	N_σ σ	Φ $10^{-12}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	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 GC in 2003 and 2004. For both data sets, the number of telescopes N_{tel}, live time Δt and energy threshold E_{thr} are given, as well as the number of detected γ-rays N_γ and the significance N_σ. The integral flux above 1 TeV Φ and the photon index Γ are given (only the statistical errors are quoted).

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 GC 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 of the source are under way. 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 GC 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 $\sim$ 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 (Rolland 2005).

4 Flux variability

The daily integral flux of γ-rays above 1 TeV is shown in the Figure 2 for both 2003 and 2004. The χ^2/dof (including 15% systematic errors) of fits with a constant flux are given in the Table 2 for time scales of day, night and 10-minute. 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

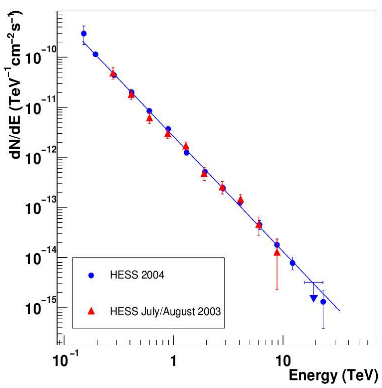

Fig. 1. Differential energy spectrum from the direction of the GC measured in 2003 and 2004.

that are seen in the light curves are consistent with statistical fluctuations: no flux has more than 3σ deviation from the average flux.

The GC source flux is hence consistent with a constant flux at all probed time scales. Note that only strong flares would have been detected at the level of 5 σ, with amplification factors higher than 2, 4 and 7 for durations of night, day and 10-minutes respectively.

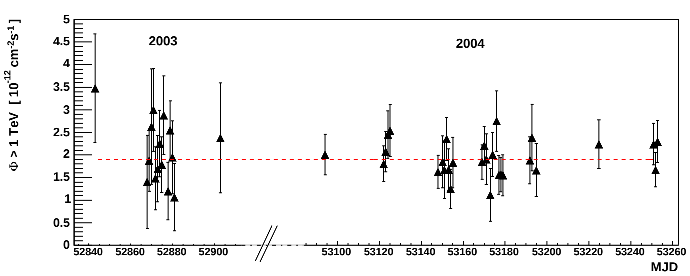

Fig. 2. GC source nightly average flux for both 2003 and 2004 observations. The integral flux above 1 TeV is given as function of time in modified Julian Days. The fit of the light curve by a constant is shown as a dashed line whose parameter is given in Table 2.

5 Conclusions

The spectrum of the very high energy source observed towards the GC 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

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.

statistical and sytematic errors from year down to 10-minutes time scales. The GC 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.

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