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Search for variability and QPO activity from SgrA* from H.E.S.S observations

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Abstract: One interesting possibility is that the galactic center (GC) source HESS J1745-290 is associated with the galactic center source Sgr A*, the galactic center black hole, in which case we may expect variability as seen in IR and X-rays, with QPO frequencies predicted by Aschenbach et al. (2006). We will present the results of a search for such variable signatures using HESS observations of this source.

Introduction

H.E.S.S (High Energy Stereoscopic System) [1] consists of four imaging atmospheric-Cherenkov telescopes (IACT's) located in Namibia. The Cherenkov light emitted by γ-induced air showers is detected by a camera of 960 photomultiplier tubes, located at the focus of the four 12 m diameter telescopes. The field of view of a camera is 5° in diameter. A description of the H.E.S.S. instrument and operation can be found in [2, 3].

A strong signal was detected by H.E.S.S. toward the GC [4, 5]. A refined analysis of the HESS J1745-290 source position is presented in [8]. Given the HESS J1745-290 source position uncertainties, several sources are plausible candidates. Among them, the black hole SgrA* located at the center of our galaxy [6, 7] is one of the most popular candidate. The dark matter origin of the H.E.S.S. signal has also been strongly constrained in [5]. Thus, it is important to study the flux variability of the source to constrain the emission mechanisms of the detected TeV signal. X-ray flares of SgrA* were detected with periods ranging from 100 s to 2250 s [9]. Here we report a search for similar variabilities in the TeV energy range using H.E.S.S. GC data.

The observations presented here were obtained during the 2004, 2005 and 2006 observing seasons of the GC. Photons were selected and reconstructed with the so-called "model analysis" [10, 11]. Spectra are presented elsewhere [12]. Results were checked with a different reconstruction method based on Hillas statistical moment of the images [13]. The total live time of the whole data set is 97 h. The total significance corresponds to a 59.8 σ deviation above the background using a point-like source analysis (i.e. using a cut on the angular distance θ between the reconstructed direction of the γ-rays and the pointed direction: $\theta < 0.14^\circ$.).

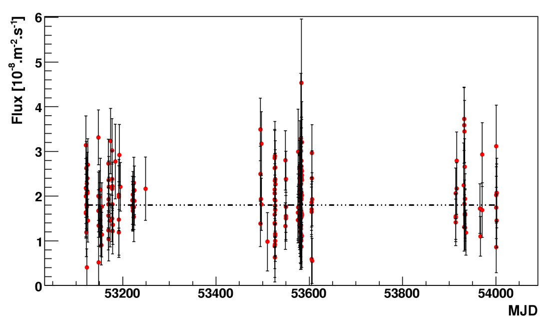

Figure 1: Run by run light curve of HESS J1745-290. Data cover the 2004-2006 time period.

The run by run integral flux of γ-rays above 1 TeV is shown on Fig.1. A run corresponds to a 28 min observation time. The χ^2 of a constant fit to data is 228/211 d.o.f. This is consistent with a constant flux of:

$$\Phi(>1\ \mathrm{TeV}) = 2.14\ 10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

No significant variations are detected on timescales longer than 28 min.

Flare sensitivity

As mentioned in the introduction, the flaring of SgrA* has been detected in various passbands such as IR or X-rays. Simultaneous H.E.S.S./Chandra observations were carried out during an X-ray flare. No flare was detected by H.E.S.S. as reported in [14]. Because of the large error bars implied by low statistics, the H.E.S.S. signal is sensitive to relatively larger amplitude flares. The flare sensitivity was estimated by adding a fake gaussian with variable duration σ_t and maximum amplification time t_0 to the H.E.S.S. light curve (LC). The modified LC is thus represented by:

$$\mathrm{LC}_{mod}(\mathrm{t}) = \mathrm{LC}(\mathrm{t}) \times (1 + A \times e^{\frac{(t-t_0)^2}{\sigma_t^2}}) \qquad (1)$$

Fig.2 shows the maximum amplification factor A compatible with no flare detection at the 3-σ confidence level as function of the flare duration. Typical numbers for A are of order unity. A decreases with the flare duration as expected.

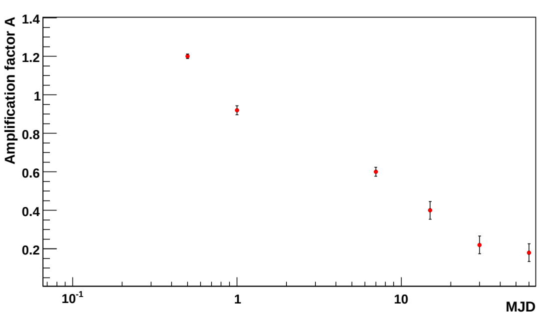

Figure 2: Mean sensitivity to a 3-σ flare detection as a function of the flare duration. The mean sensitivity decreases with the flare duration.

Search for QPO's at the X-ray periods

Four oscillation frequencies ranging from 100 s to 2250 s have been observed in the X-ray light curve of SgrA* [9]. These frequencies are likely to correspond to gravitationnal cyclic modes associated with the accretion disk of SgrA*. We searched for the occurence of these frequencies in our data. First, we assume that the coherence time of oscillations is less than 28 min. We then perform a Rayleigh test [16] on photon time arrival distributions for continuous observations of 28 min. The Rayleigh power averaged over 2004-2006 data is shown on Fig.3 as a function of the frequency. The probed frequencies range from 1/28 min^{-1} to the inverse of the average time spacing between two consecutive events of 1.2 min^{-1}. The Rayleigh power is compatible with a flat function of frequency. No significant peaks are seen at the 100 s, 219 s, 700 s and 1150 s periods observed in X-rays.

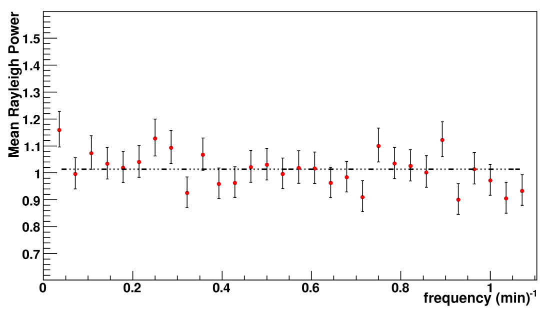

Figure 3: Rayleigh power plotted as a function of the frequency. A fit to a constant power gives a χ^2 of 35/29 d.o.f. compatible with a flat distribution.

Next, we assume that the coherence time of oscillations is of the order of a few hours. We then construct the Fourier power distribution using a Lomb-Scargle periodogram [15] for each night of our dataset. Data are binned into 5 min points. The Fourier power averaged over 2004-2006 data is displayed on Fig.4 as a function of the frequency. Frequencies tested range from 10^{-2} min^{-1} to 0.1 min^{-1}. No significant oscillation frequencies are detected, as shown on Fig.5.

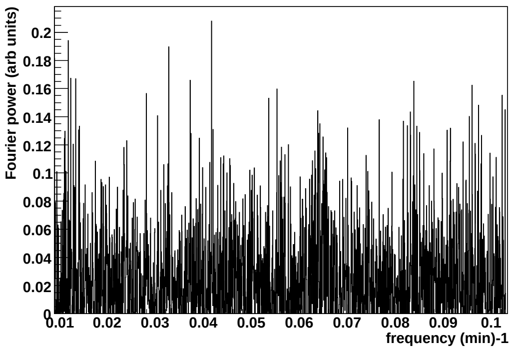

Figure 4: [10^{-2} min^{-1} - 0.1 min^{-1}] Lomb-Scargle periodogram of the H.E.S.S. SgrA* light curve averaged over the 2004-2006 nights of observation. No significant peak is visible.

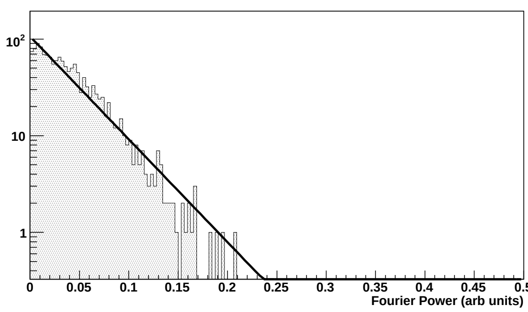

Figure 5: Fourier power distribution derived from the average Lomb-Scargle periodogram. The χ^2 of the exponential fit to data is 72/55 d.o.f.

Conclusions

The light curve of the very high energy source HESS J1745-290 observed towards the GC is compatible with a constant integrated flux above 1 TeV of $\Phi(>1TeV) = 2.14\,10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The source appears to be steady in time for timescales from a year down to 1 min. The flare sensitivity study shows that H.E.S.S. was sensitive to flux increases with amplification factor of order of the unity. As the flare duration increases, lower amplification factors are needed for a 3-σ detection. Searches for QPO's in the H.E.S.S. GC signal did not uncover any periodicities, in particular none of those observed by [9]. The constraints on the variability of HESS J1745-290 will be improved by new observations taken in 2007.

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References

[1] Hofmann, W. (for the H.E.S.S. collaboration), Proc.of the 28th ICRC (Tsubuka),(2003).
[2] Aharonian, F.A., et al. (H.E.S.S. collaboration), Astropart.Phys.22, 109 (2004)
[3] Funk, S., et al. Astropart.Phys.22, 285 (2004)
[4] Aharonian, F.A., et al. (H.E.S.S. collaboration), A&A 425, L13 (2004)
[5] Aharonian, F.A., et al. (H.E.S.S. collaboration), Phys.Review Letter (2006)
[6] Aharonian, F.A.& Neronov, A., ApJ 619, 306 (2005)
[7] Atoyan, A. & Dermer, C.D., ApJ 617, L123 (2004)
[8] van Eldik, C., these proceedings,(2007)
[9] Aschenbach, B., et al., A&A, (2006)
[10] de Naurois, M., et al., Proc.of the 28th ICRC (Tsubuka), (2003)
[11] de Naurois, M., et al., In *Towards a Network of Atmospheric Cherenkov Dectectors* (2005)
[12] Ripken, J., these proceedings (2007)
[13] Aharonian, F.A., et al., A&A 430, 865 (2005)
[14] Hinton, J., et al., these proceedings (2007)
[15] Scargle, J.D., ApJ 263, 835 (1982)
[16] de Jager, O.C., Swanepoel, J.W.H. & Raubenheimer, B.C.,(1989)