Frascati Physics Series Vol. VVV (2004) pp.1-7
Frontier Science 2004, Physics and Astrophysics in Space
Frascati, 14-19 June, 2004

DETECTION OF THE BINARY SYSTEM PSR B1259-63/SS 2883 AT TEV ENERGIES WITH THE H.E.S.S. CHERENKOV TELESCOPES

M. Beilicke[a], for the H.E.S.S. collaboration[b]

[a] *Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany*

[b] *http://www.mpi-hd.mpg.de/hfm/HESS/HESS.html*

Abstract

The first detection of the unique binary system PSR B1259-63/SS 2883 at TeV energies close to its 2004 periastron passage is reported. The observations have been performed with the array of four imaging atmospheric Cherenkov telescopes (IACTs) operated by the High Energy Stereoscopic System (H.E.S.S.) collaboration in Namibia. The observations were motivated by theoretical predictions of TeV emission with an expected maximum near the periastron passage. Following the detection in February/March 2004 the observations have been extended up to June 2004. In this paper the results of the observations between February, 26th and March, 5th 2004 taken before periastron are reported.

1 Introduction

The 48 ms radio pulsar PSR B1259-63 orbits its massive Be companion star SS 2883 ($\sim 10\,M_\odot$) on a highly eccentric orbit ($\epsilon \approx 0.87$) with a period of ~ 3.4 years [1]. The system is located at $\alpha = 13^h02^m47^s.68$ and $\delta = -63°50'08''.6$ (J2000.0) at a distance of about 1.5 kpc [2]. The companion star is surrounded by a stellar matter outflow disk which is assumed to be inclined with respect to the orbital plane suggested by pulsar-timing data [3]. The distance between the pulsar and the companion star at periastron is only $\sim 23\,R_*$ whereas the matter disk of the companion star reaches out to nearly $20\,R_*$ (with R_* being the radius of the companion star). This geometry makes the PSR B1259-63/SS 2883 binary system a very unique and interesting object for studying the interaction of a pulsar wind with an environment of – due to the motion – varying matter and photon density.

The PSR B1259-63/SS 2883 system was observed at previous periastron passages in 1994 and 1997 at radio wavelength which yielded detection of only an unpulsed radio component for some weeks around periastron [4]. Also X-ray observations showed orbital dependency of the emission [5, 6] and suggest a synchrotron component produced by an electron population accelerated to very high energies. TeV emission has been predicted by different models: Inverse Compton (IC) scattering of the local companion star photon field by shock accelerated high energy electrons/positrons originating from the pulsar wind leading to TeV γ-emission up to $\sim 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ at 100 GeV [7]. Additionally, IC scattering in the unshocked pulsar wind can be taken into account [8]. More models exist (see for example references in [18]) partially taking into account the stellar disk geometry and nearly all of them predict a characteristic orbital dependency of the TeV γ-emission.

The PSR B1259-63/SS 2883 binary system has been observed at TeV energies with the CANGAROO experiment for the first time in 1994 with the 3.8 m telescope resulting in indications for TeV γ-ray emission ($\sim 4.8\,\sigma$ in 26.5 h of observations ~ 120 d after periastron, but no signal in 8.6 h of observation near the 1994 periastron) [9]. A third observation campaign was done in 2000/2001 with the 10 m telescope resulting in upper limits of 0.13 Crab roughly 47 d and 0.54 Crab roughly 157 d after the 2000 periastron within 3.2 h resp. 10.4 h of observation [10], see also Fig. 1.

Recent observations at TeV energies have been performed with the 4 imaging atmospheric Cherenkov telescopes (IACTs) operated by the High Energy Stereoscopic System (H.E.S.S.) collaboration in Namibia [11]. Already the first observation period between February, 26th and March, 5th 2004 – close to the periastron passage of the binary system on March, 7th – led to a significant detection of the system at TeV energies [12] prompting the extension of the observations up to June 2004. In this paper the results of the H.E.S.S. pre-periastron 2004 data are reported.

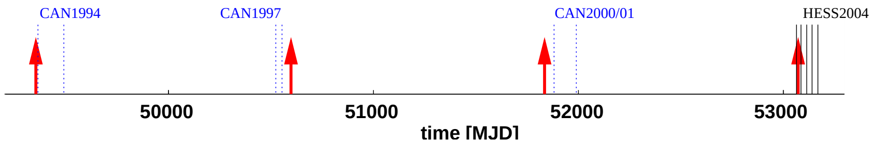

Figure 1: Illustration of the TeV observations of PSR B1259-63/SS 2883 over the past ten years. The arrows indicate the periastron passages of the system, the dotted lines mark the CANGAROO observations taken from [9, 10] and the solid vertical lines show the H.E.S.S. observations from March to June 2004; only the pre-periastron data is described in this paper.

2 Data analysis & results

2.1 Detector & data acquisition

Cherenkov telescopes record the Cherenkov light flash from extended air showers (EAS) initiated by high energy particles (γ-photons or hadrons) penetrating the earth's atmosphere. Each of the 4 H.E.S.S. telescopes has a 108 m^2 tesselated mirror surface and is equipped with a 960 photomultiplier tube (PMT) camera with a field of view diameter of $\sim 5^\circ$ [13]. The telescopes are operated in a stereoscopic (coincident) mode which means that an event is only read out if at least two telescopes have triggered [14]. This ensures that an event is always seen by more than one telescope and therefore allows the stereoscopic reconstruction of the shower geometry derived from the recorded Cherenkov images in each telescope [15]. The event-by-event angular resolution is 0.1° and the energy resolution about 15 % with an energy threshold of 100 GeV for observations close to the zenith. The data are taken in runs of 28 min duration in the moonless part of the nights in the so-called *wobble* mode displacing the telescopes tracking position with respect to the nominal object position by an alternating offset of 0.5° in Right Ascension or Declination allowing for an unbiased simultaneous background determination in the camera's field of view. Before the image analysis is applied the data are calibrated as described in [16].

2.2 Data set

Quality cuts have been applied to the data requiring stable weather and detector conditions. The PSR B1259-63/SS 2883 data reported in this paper have been taken between February, 26th and March, 5th 2004 and comprise 10.6 h of observation time. The periastron passage of the binary system was on March, 7th 2004. 8.6 h of the data passed the data quality cuts. The

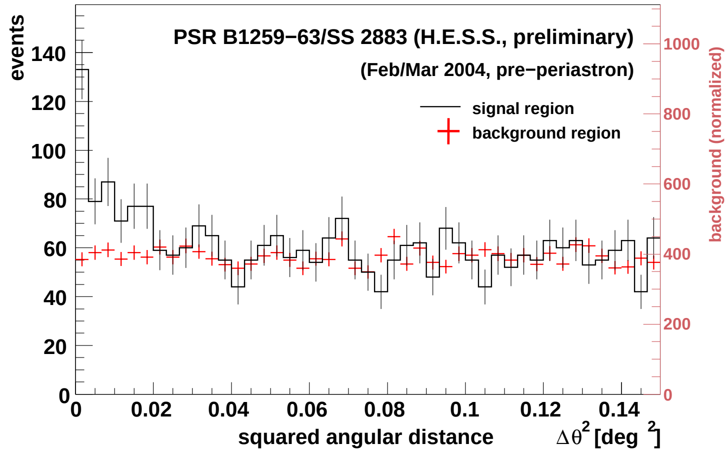

Figure 2: Number of events vs. the squared angular distance $\Delta\Theta^2$ between reconstructed shower direction and the nominal source position for the signal region (histogramm) and for the normalized background region (single points). The excess accumulating at small $\Delta\Theta^2$ values is compatible with a point-source which is expected for the given distance of the binary system.

observations were performed at zenith angles between 40° and 45° resulting in an energy threshold (pre-cuts) of $E_{\mathrm{thr}} \approx 200\,\mathrm{GeV}$. For the data presented here one of the four telescopes (CT01) was excluded from the analysis due to technical reasons.

2.3 Results

In the data set described above 168 ± 23 excess events from the direction of the PSR B1259-63/SS 2883 binary system have been recorded, corresponding to a significance of $8.2\,\sigma$ (calculated following [17]). The distribution of events as a function of the squared angular distance $\Delta\Theta^2$ measured between the reconstructed shower direction and the nominal source position (for the signal and the background region) is shown in Fig. 2. The integral flux above threshold of this observation has been estimated to be on the 5 % level of the Crab nebula flux. The skymap showing the 2D distribution of excess events in RA/Dec coordinates is shown in Fig. 3.

These encouraging results triggered an extension of the H.E.S.S. observation campaign on PSR B1259-63/SS 2883 up to June 2004 with meanwhile more than 75 h of data. The results of this whole data set (including energy spectrum and lightcurve) will be described in an upcoming paper [18].

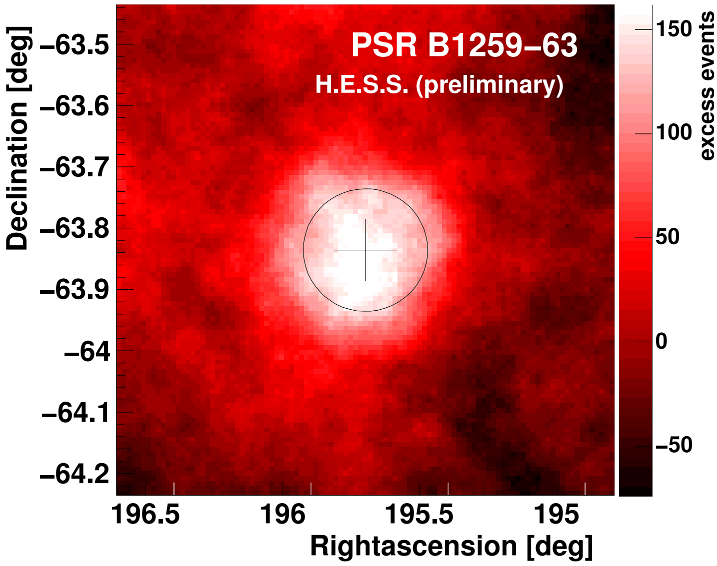

Figure 3: The 2D sky plot of excess events centered on the position of PSR B1259-63/SS 2883. The events are integrated within the angular cut of 0.14° for each bin. The circle indicates the event-by-event angular resolution of the H.E.S.S. telescopes.

3 Summary & Conclusion

The unique binary system PSR B1259-63/SS 2883 has been detected at TeV energies with the H.E.S.S. Cherenkov telescopes between February, 26th and March, 5th 2004 (near the periastron passage on March, 7th 2004) at an energy threshold of $E_{\rm thr} \approx 200\,{\rm GeV}$ at the significance level of $\sim 8\,\sigma$. The measured integral flux above threshold was estimated to be on the 5 % level of the Crab nebula. This detection – being in agreement with the earlier reported upper limits by the CANGAROO collaboration [9] – gave rise to extend the H.E.S.S. observation campaign up to June 2004. The results of the whole data set including the energy spectrum and the lightcurve will be subject of an upcoming paper [18]. Together with observations at other wavelength the TeV observations allow for detailed comparisons between data and the various model predictions (i.e. [7, 8]). This might open a new window in the understanding of pulsar wind nebulae interactions with the surrounding environment which in this case is time-variable.

Acknowledgement

The support of the Namibian authorities and of the University of Namibia in facilitating the construction and operation of H.E.S.S. is gratefully acknowledged, as is the support by the German Ministry for Education and Research (BMBF), the Max Planck Society, the French Ministry for Research, the CNRS-IN2P3 and the Astroparticle Interdisciplinary Programme of the CNRS, the U.K. Particle Physics and Astronomy Research Council (PPARC), the IPNP of the Charles University, the South African Department of Science and Technology and National Research Foundation, and by the University of Namibia. We appreciate the excellent work of the technical support staff in Berlin, Durham, Hamburg, Heidelberg, Palaiseau, Paris, Saclay, and in Namibia in the construction and operation of the equipment.

References

[1] Johnston, S., Manchester, R.N., Lyne, A.G., et al. (1992), *ApJ, 387, L37*

[2] Johnston, S., Manchester, R.N., Lyne, A.G., et al. (1994), *MNRAS, 268, 430*

[3] Wex, N., Johnston, S., Manchester, R.N., et al. (1998), *MNRAS, 298, 997*

[4] Johnston, S., Manchester, R.N., McConnell, D., and Campbell-Wilson, D. (1999), *MNRAS, 302, 277*

[5] Kaspi, V.M., Tavani, M., Nagase, F., et al. (1995), *ApJ, 453, 424*

[6] Hirayama, M., Cominsky, L.R., Kaspi, V.M., et al. (1999), *ApJ, 521, 718*

[7] Kirk, J., Ball, L., Skjæraasen, O. (1999), *Astropart. Phys., 10, 31*

[8] Ball, L., Kirk, J.G. (2000), *Astropart. Phys., 12, 335*

[9] Sako, T., Dazeley, S.A., Edwards, P.G., et al. (1997), *Proc. 25th ICRC, 3, 193*

[10] Kawachi, A., Naito, T., Patterson, J.R., et al. (2004), *ApJ, 607, 949*

[11] Punch, M. (2004), *Proc. FrontierScience2004, see these proceedings*

[12] Beilicke, M., Ouchrif, M., Rowell, G., Schlenker, S. (2004), *IAU Circular #8300*

[13] Vincent, P., Denance, J.-P., Huppert, J.-F., et al. (2003), *Proc. 28th ICRC (Tsukuba), Univ. Academy Press, Tokyo, p.2887*

[14] Funk, S., Hermann, G., Hinton, J., et al. (2004), *submitted to Astropart. Phys., see astro-ph/0408375*

[15] Aharonian, F., et al. (2004), *submitted to A&A (H.E.S.S. obs. of PKS2155-304)*

[16] Aharonian, F., et al. (2004), *submitted to Astropart. Phys., see astro-ph/0406658*

[17] Li, T., and Ma, Y. (1983), *ApJ, 272, 317*

[18] Aharonian, F., et al. (2004), *A&A, in preparation*