Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 3 (OG part 2), pages 1115–1118

Simultaneous observation of GRB060602B with the H.E.S.S. Air Cherenkov array

PAK-HIN TAM[1], KONRAD BERNLÖHR[2], PAULA CHADWICK[3], JIM HINTON[1,2,4], DALIBOR NEDBAL[2], GERD PÜHLHOFER[1], STEFAN WAGNER[1] FOR THE H.E.S.S. COLLABORATION
[1]*Landessternwarte, Universität Heidelberg, Königstuhl, D 69117 Heidelberg, Germany*
[2]*Max-Planck-Institut für Kernphysik, P.O. Box 103980, D 69029 Heidelberg, Germany*
[3]*University of Durham, Department of Physics, South Road, Durham DH1 3LE, U.K.*
[4]*School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, U.K.*
phtam@lsw.uni-heidelberg.de

Abstract: On June 2, 2006, the *Swift* Burst Alert Telescope (BAT) triggered a bursting event in the 15-350 keV energy band. The burst position was being observed with the H.E.S.S. array of IACTs before the burst, throughout the duration of the burst, and after the burst. In particular, the burst position accidentally fell in the f.o.v. of the H.E.S.S. camera when the burst occurred. This is the first completely simultaneous observation of a soft gamma-ray bursting event with an IACT instrument. A search for VHE gamma-rays coincident with the burst event as well as that during the afterglow period was performed. No signal was found during the period covered by the H.E.S.S. observation. The *Swift* X-ray Telescope, which started observation 83 seconds after the BAT trigger, detected an X-ray counterpart of the event. No optical/infrared counterpart was found. Due to the very soft BAT spectrum (photon index $\Gamma \approx 5$) of the burst compared to other *Swift* GRBs and its proximity to the galactic center, the burst might have been caused by a galactic X-ray burster (e.g. a low-mass X-ray binary). However, the possibility of it being a cosmological GRB cannot be ruled out. Since the nature of the event is still unclear, we discuss the implications according to the two different bursting scenarios.

Introduction

The temporally and spatially unpredictable, and fast-fading nature of gamma-ray bursts (GRBs) makes it operationally rather difficult to study the prompt phase of GRBs simultaneously in other wavelengths. There are two operational techniques currently employed in the very-high-energy (VHE; $100\,\mathrm{GeV} - 100\,\mathrm{TeV}$) γ-ray regime: (1) To slew quickly to the GRB position provided by a burst alert from satellites. This technique is suitable for IACTs such as H.E.S.S. which have a field of view (f.o.v.) of several degrees. However, there is always a delay in time for IACT operating in this GRB-follow-up mode, as long as the GRB position lies outside the camera f.o.v. at the GRB onset. The MAGIC telescope, operating in this mode, was able to slew to the position of GRB 050713a, 40 seconds after the GRB onset, while the prompt keV emission was still active. A total of 37-minute observation was made and no evidence of emission above 175 GeV was obtained [1]; (2) To observe a large part of the sky continually, at the expense of a much lower sensitivity at the GRB position than the IACT technique. This technique is used, e.g. by the water Cherenkov detector Milagro [2].

Here we report on the first completely simultaneous observation of a soft γ-ray bursting event (a possible GRB) with H.E.S.S., an IACT instrument. The burst position accidentally fell in the f.o.v. (albeit with a large offset from the center of the f.o.v.) of the H.E.S.S. camera when the burst occurred.

GRB 060602B

At 23:54:33 UT on 2 June, 2006 (denoted by t_0), the Burst Alert Telescope (BAT) on board *Swift*, which operates in the 15-350 keV energy band, triggered a bursting event. This event was announced as a gamma-ray burst (GRB) and designated GRB 060602B (e.g. [3, 4, 5]). The refined BAT position was (RA,Dec) = $(17^{\rm h}49^{\rm m}28^{\rm s}.2, -28^{\circ}7'15".5)$ (J2000, [6]). The BAT light curve showed a single-peaked structure lasting from $t_0 - 1.0\,{\rm s}$ to $t_0 + 12.0\,{\rm s}$. The peak was the strongest in the 15-25 keV energy band among other bands and was absent above 50 keV. T_{90} (defined as the duration when 90% of the total fluence of the 15-350 keV was emitted) is $9.0 \pm 2\,{\rm sec}$. The time-averaged energy spectrum from $t_0 - 1.1\,{\rm s}$ to $t_o + 8.8\,{\rm s}$ can best be fit by a simple power law (PL), with a photon index of 5.02 ± 0.52 (one of the softest among *Swift* GRBs). The fluence in the 15-150 keV band was $(1.8{\pm}0.2){\times}10^{-7}{\rm ergs\,cm^{-2}}$ [6].

Although no counterpart was found in the optical/IR bands [4, 7, 8, 9], an X-ray counterpart was found using *Swift*/XRT and was fading as a PL with an index 1.05 ± 0.07 for at least 11 hours, after a small rise before $t_0 + 200\,{\rm s}$ [10].

The time-averaged X-ray energy spectrum during $100{\rm s} - 11.4{\rm ks}$ after t_0 can be fit equally well by an absorbed PL or an absorbed blackbody (BB) model. A photon index of $2.6^{+1.0}_{-0.8}$ and a hydrogen column density of $3.8^{+2.1}_{-1.4} \times 10^{22}{\rm cm^{-2}}$ were obtained for the PL model. For an absorbed BB model, a temperature of $0.90^{+0.23}_{-0.17}$ keV and a column density of $1.8^{+1.2}_{-0.8}{\times}10^{22}{\rm cm^{-2}}$ were obtained.

The galactic coordinates of the source were (lon, lat) = $(1.15^{\circ}, -0.30^{\circ})$. This position has raised up a possibility of the event originating from a galactic source (eg. an X-ray burster). The fact that the BAT spectrum was one of the softest *Swift* GRBs could be used to argue for this scenario [6].

The H.E.S.S. Observations

The H.E.S.S. array is a system of four 13m-diameter imaging atmospheric Cherenkov telescopes located in the Khomas Highland of Namibia. The system has a point source sensitivity above 100 GeV of $\sim 3.0 \times\, 10^{-13}{\rm cm^{-2}s^{-1}}$ (1% of the flux from the Crab nebula) for a 5σ detection in a 25 h observation. Its has a f.o.v. of radius $\sim\; 2.6^{\circ}$ (at this radius the relative gamma-ray acceptance is about 10% of that at the targeting position of the telescopes), thus enabling it to detect serendipitous sources, as have been demonstrated in the galactic scan survey [11].

The position of GRB 060602B was being observed with H.E.S.S. before the burst, throughout the duration of the burst, and after the burst. The source offsets from the observation positions were large (up to $\sim\;\; 2.8^{\circ}$) in the beginning. A total of 4.9 hours of observation was obtained during the night of 2-3 June, 2006. This includes 1.7hr *pre-burst*, 9s *prompt*, and 3.2hr *afterglow* epochs. An additional 4.7 hours of observation at the burst position was obtained during the next 3 nights. All data were taken in good weather conditions and good hardware status. The observations were taken with the source position placed at different offsets relative to the center of the f.o.v. of the telescopes. This is because most observational runs were not dedicated to the position of the event GRB 060602B.

The source position fell into the H.E.S.S. f.o.v. during other H.E.S.S. observations (which targeted objects like Sgr A*) as well. This allows us to investigate a possible long-term emission of the source at VHE energies. It is of particular interest in the X-ray burst (XRB) scenario, which we will discuss later.

Data Analysis

Calibration of data, event reconstruction and rejection of the cosmic-ray background (i.e. γ-ray event selection criteria) were performed as described in [12]. On-source data were taken from a circular region of radius $\theta_{\rm cut}$ centered at the source. The background was then estimated using the reflected-region model as described in [13], which makes use of the off-source data obtained during the same observation period.

Two sets of analysis cuts were applied to search for a signal. These include standard cuts (as described in [12]) and soft cuts (with lower-energy thresholds, as described in [14]). Furthermore, for the periods with large offsets, we also used larger $\theta_{\rm cut}$'s to match the larger point spread functions (PSFs).

Figure 1 shows the independent events observed within a circular region of radius $\theta_{\rm cut} = 0.32^{\circ}$ (for $t < t_0 + 500{\rm s}$) and $\theta_{\rm cut} = 0.2^{\circ}$ (for $t_0 + 600{\rm s} < t < t_0 + 2050{\rm s}$) centered at the source. The $\theta_{\rm cut}$ values were chosen to match the different PSFs for observations with different source offsets.

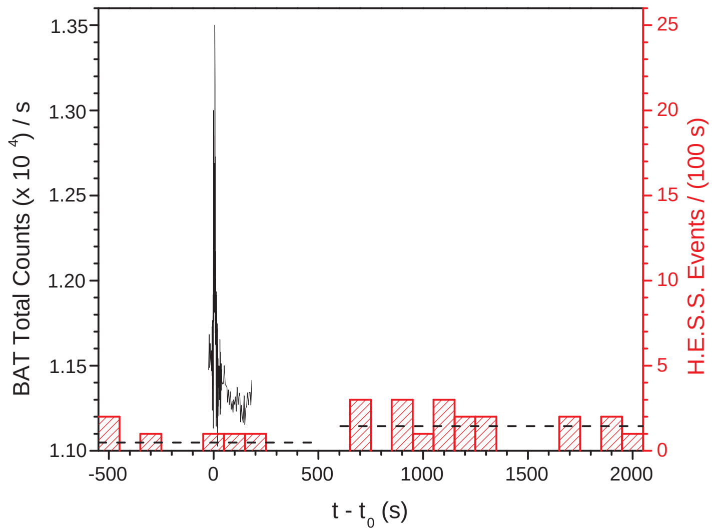

Figure 1: Shaded, red histogram: Events observed with H.E.S.S. within a circular region of radius $\theta_{\rm cut} = 0.32^\circ$ (for $t < t_0 + 500$s) and $\theta_{\rm cut} = 0.2^\circ$ (for $t > t_0 + 600$s) centered at the *Swift*/XRT position in 100-second bins. The dashed horizontal lines indicate the expected number of background events in the circular regions, using the reflected-region background model [13]. The difference in event rates is due to the different offsets, zenith angles, and $\theta_{\rm cut}$ for different periods. The gap between 500s and 600s is due to the transition of observation runs. Solid, black curve: *Swift*/BAT light curve in the 15-150 keV band.

Results

No evidence of excess events as observed with H.E.S.S. in any time before, during, or after the soft-gamma-ray bursting event is seen. There was no hint of radiation in the next 3 nights as well.

We also looked into the H.E.S.S. observations from 2004 to 2006 containing the XRT position in the f.o.v. Again no emission was found and the 99% confidence level (c.l.) upper limits using the method of Feldman & Cousins [15] derived from 128.3 hours of observation using standard cuts is $1.06 \times 10^{-12}\,\mathrm{photons\,cm^{-2}\,s^{-1}}$ above 200 GeV (i.e. 0.5% of the Crab flux).

Discussions

The nature of the bursting event that occurred at 23:54:33 UT on 2 June, 2006 is unclear. It was firstly announced as a GRB by [3] and several other teams including [4, 5]. Thus the event has been designated GRB 060602B. However, its very soft spectrum (photon index $\Gamma \approx 5$) in the 15-150 keV band and its galactic position support a galactic origin of the event, as first suggested in [6]. A faint XMM-Newton source was detected on 23 September 2000 in the proximity of the *Swift*/XRT position, as first noticed by [16]. Whether this source is related to the bursting event on 2 June, 2006 is unclear. However, the possibility of the event as a cosmological GRB is not ruled out. Since the results are still not conclusive, we briefly discuss the implications of the H.E.S.S. observations according to these two scenarios.

The gamma-ray burst scenario

If GRB 060602B were a cosmological GRB, it would be a GRB with a very steep keV spectrum and happened to be to the direction next to the galactic center. Our observation with H.E.S.S. would be the first strictly simultaneous observation of a GRB with an IACT instrument during its prompt phase.

High-energy components from GRBs have been predicted (e.g. [17, 18]) and observed (e.g. in the case of GRB 940217 up to ~ 18 GeV [19]) in the prompt and afterglow phases. The H.E.S.S. data can be used to constrain the level of such a high-energy component of GRB 060602B at VHE energies.

The X-ray burst scenario

If GRB 060602B were a galactic XRB, it would be the first simultaneous observation of an XRB with an IACT instrument. Its galactic position suggests that it is quite near the galactic center and thus probably at a distance of ~ 8 kpc. Any optical emission would have been absorbed.

XRBs have only been detected from low-mass-X-ray binaries [20]. Early claims of persistent detections in the VHE regime of this class of objects were not confirmed with more sensitive experiments (see e.g. [21]). Our long-term upper limit of the burst position is among the most constraining ones. Possible models which suggest continual VHE emission from X-ray binaries were proposed [22] (see also [23] for a review).

Conclusions

For the first time, a strictly simultaneous observation of a soft γ-ray bursting event with an IACT instrument without time delay were obtained on 2 June, 2006.

The burst position was being observed with H.E.S.S. at VHE energies before the burst, throughout the duration of the burst, and after the burst. This was also the first time a soft γ-ray bursting event was observed with an IACT instrument before its onset. A search for TeV signal coincident with the burst event as well as that during the afterglow period was performed. No signal has been found during the period covered by the H.E.S.S. observation. The data analysis is still ongoing and final results will be published elsewhere [24].

References

[1] Albert, J. et al. (MAGIC collaboration) 2006, ApJ, 641, L9

[2] Saz Parkinson, P. M. et al. 30th Proc. ICRC, Mexico, 2007.

[3] Jalinek, M., Kubánek, P., & Vítek, S. 2006, GCN Circ. 5198

[4] Kubánek, P., Jalinek, M., & French, J. 2006, GCN Circ. 5199

[5] Schady, P., Beardmore, A. P., Marshall, F. E. et al. 2006, GCN Circ. 5200

[6] Palmer, D., Barbier, L., Barthelmy, S. et al. 2006, GCN Circ. 5208

[7] Khamitov, I., Bikmaev, I. & Sakhibullin, N. 2006, GCN Circ. 5205

[8] Blustin, A. J., Schady, P. & Pandey, S. B. 2006, GCN Circ. 5207

[9] Melandri, A., Distefano, E., Covino, S. et al. 2006, GCN Circ. 5229

[10] Beardmore, A. P., Godet, O., Sakamoto, T. et al. 2006, GCN Circ. 5209

[11] Aharonian, F. A. et al. (HESS collaboration) 2005a, Science, 307, 1938

[12] Aharonian, F. A. et al. (HESS collaboration) 2006a, A&A, 457, 899.

[13] Berge, D., Funk, S. & Hinton, J. A. 2007, A&A, 466, 1219

[14] Aharonian, F. A. et al. (HESS collaboration) 2006b, A&A, 448, L19

[15] Feldman, G. J. & Cousins, R. D. 1998, Phys. Rev. D., 57, 3873

[16] Halpern, J. 2006, GCN Circ. 5210

[17] Wang, X. Y., Dai, Z. G. & Lu, T. 2001, ApJ, 556, 1010

[18] Pe'er, A. & Waxman, E. 2005, ApJ, 633, 1018

[19] Hurley, K., Dingus, B. L., Mukherjee, R. et al. 1994, Nature, 372, 652

[20] Lewin, W. H. G., Paradijs, J. van & Heuvel, E. P. J. van den 1995, X-Ray Binaries (Cambridge University Press, Cambridge) 178

[21] Weekes, T. C., 1992, Space Sci. Rev., 59, 315

[22] Cheng, K. S. & Ruderman, M. 1991, ApJ, 373, 187

[23] Moskalenko, I. V., 1995, Space Sci. Rev., 72, 593

[24] Aharonian, F. A. et al. (HESS collaboration), in preparation