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STATUS AND RESULTS OF THE SEARCH FOR GAMMA-RAY BURSTS ABOVE 1 TEV WITH THE HEGRA EXPERIMENT

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ABSTRACT

An overview on the status and results of the search for gamma-ray bursts with the air shower detector complex HEGRA is presented. HEGRA is a multi-component detector system for the study of neutral and charged cosmic rays in the energy range from 500 GeV to 10 PeV. Emission associated with gamma-ray bursts registered by instruments on board of satellites has been searched in coincidence, preceding or following the trigger. An all-sky search for hypothetical gamma-ray bursts not detected by the instruments at space has also been performed. Furthermore immediate follow-up observations of burst locations received from BACODINE with the Cherenkov telescopes and the scintillator array operated in dedicated burst mode (HAST) are carried out.

INTRODUCTION

There are strong motivations for the search of TeV emission from gamma-ray bursts (GRBs), which can be summarized as follows. There are models which predict or at least allow TeV emission (Meszaros, Rees and Papathanassiou, 1994, Halzen et al., 1991); EGRET has detected GeV emission from 5 GRBs without a hint for a spectral cutoff (Hurley et al., 1994); it has been suggested that a population of bursters with very hard spectra may exist and be invisible to the instruments now in space (Piran and Narayan, 1995); some tentative positive evidence has been recently found (Amenomori et al., 1996, Padilla et al., 1997). A positive detection would constrain models in two senses: the emission mechanism (see above) and the distance, because no TeV photons are expected if the bursters are cosmological due to the interaction of the photons with the microwave and infrared backgrounds (Wdowczyk, Tkaczyk and Wolfendale, 1972, Mannheim, Hartmann and Funk, 1996, Stecker and de Jager, 1997).

THE HEGRA EXPERIMENT

The cosmic ray detector complex HEGRA is located at the observatory Roque de los Muchachos on the Canary island La Palma (28.8° N, 17.9° W, 2200 m a.s.l). It is a hybrid detector system for the registration of extended air showers (EAS) initiated by neutral and charged cosmic rays in the energy range from 500 GeV to 10 PeV (see session OG 10.3.36 of this conference). The following detectors are spread over an area of 40000 m^2:

The Array of Imaging Atmospheric Cherenkov Telescopes

A system of 6 imaging atmospheric Cherenkov telescopes is used for the observation of gamma-ray sources above 500 GeV. The system consists of one prototype with an energy threshold of 1 TeV plus 5 telescopes designed for stereoscopic observation of showers initiated by photons above 500 GeV. The field of view of each telescope is 5 msr and the duty cycle is 10% (see session OG 10.3.17 of this conference).

The BACODINE Alert. Whenever BATSE detects a GRB, it distributes within a few minutes the estimated position to the interested observatories around the world. The distribution system is called BACODINE (Barthelmy et al., 1995). If HEGRA receives a BACODINE warning when observation with telescopes is possible, then a follow-up of the GRB position is done provided it is visible and the uncertainty in the location is less than 10°.

The AIROBICC Array

AIROBICC is the name of an array of 77 wide angle Cherenkov counters. Each counter consists of a 20 cm diameter photomultiplier viewing 1 sr of the night sky and sampling the Cherenkov light disk produced in EAS initiated by a primary of energy above 11 TeV. Its mean angular resolution is 0.34° and has the same duty cycle as the telescopes (Karle et al., 1995).

The Scintillator Array

An array of 243 scintillator counters of 1 m^2 is used to continuously register the electromagnetic component of EAS above 20 TeV with a mean angular resolution of 0.9° (Krawczynski et al., 1996).

The HAST System. Whenever a BACODINE alert is received in which the GRB position lies within the field of view of HEGRA, the scintillator array starts taking data with a especial trigger mode in which only showers around 10° of the GRB are recorded. This lets the energy threshold go down to 2 TeV with a mean angular resolution of 2.7°.

The Geiger Tower Array

An array of 17 Geiger towers, each one with six layers and 18 m^2, continuously registers the muon content of the EAS, which helps in the discrimination between hadron and photon initiated showers (Westerhoff et al., 1995).

SEARCHES AND RESULTS

Data recorded with different HEGRA components from 1989 to 1996 have been used in the search for GRBs. The searches can be classified as satellite dependent or independent.

Satellite Dependent Searches

In this case we can distinguish between tracking and untracking searches.

Tracking Searches. The telescopes from the HEGRA collaboration have tracked 3 GRBs up to now. They are GRBs 950401, 960425 and 960528. Observations began approximately 10 minutes after the BACODINE alert. Unfortunately, IPN locations for these bursts received a couple of days after the initial BATSE observation showed that the field of view of the telescopes did not contain the true positions.

Untracking Searches. The wide field of view of the HEGRA arrays facilitates coincident observations of about 25 GRBs per year with the scintillator and about 3 GRBs per year with AIROBICC. Up to now nearly 150 GRBs detected by BATSE and/or WATCH have been searched for TeV emission by using data taken with the HEGRA arrays. Detailed descriptions of the searches can be found in Matheis (1994), Padilla et al. (1995), Padilla et al. (1997), Krawczynski et al. (1997), Funk et al. (1997). The searches focus on the exploration of the solid angle region of possible GRB arrival directions on different time scales (from seconds to days). TeV emission from the GRB is searched in coincidence, preceding or following the trigger given by the satellite. No convincing evidence for emission has been found and therefore flux upper limits are given. However in the case of the WATCH GRB 920925c a remarkable deviation from the expectation is found nearly coincident in time with AIROBICC (see Figure 1) but significatively deviated from the position given by WATCH and IPN (see Figure 2). It is interesting to note that if we compute the IPN ring using the time of the detection by AIROBICC instead of the WATCH trigger, the new IPN ring crosses the AIROBICC error circle. For details see Padilla et al. (1997).

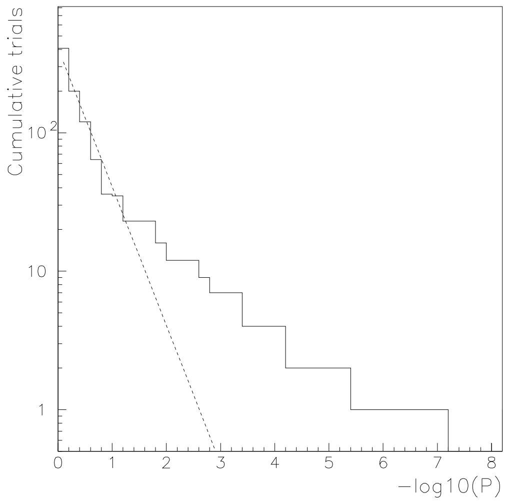

Fig. 1: Cumulative trials vs. probability in the search for emission in coincidence with WATCH GRB 920925c. The dashed line shows the expected behavior. A significative deviation can be seen.

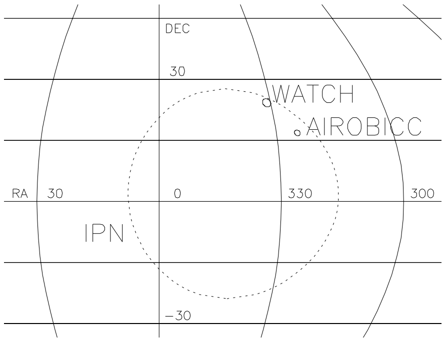

Fig. 2: Map which shows the arrival direction of GRB 920925c as determined by WATCH (3σ radius of 1°) and by the IPN ring (3σ width of 0.2°). Also shown is the position of the excess observed with the AIROBICC detector (uncertainty ∼ 0.2°).

Satellite Independent Searches

The data set of HEGRA has also been searched for emission coming from hypothetical GRBs not detected by satellites. Therefore an all sky search has been carried out. The searches are based on several time scales, from one second to one hour. Detailed descriptions of the searches can be found in Padilla et al. (1995), Padilla et al. (1997), Funk et al. (1995). No convincing evidence for emission has been found and therefore flux upper limits for short time emission in the HEGRA data are given. The absence of TeV GRBs of very short duration (less than ~ 1 second) allows to set an upper limit on the density of evaporating primordial black holes. For details see Funk et al. (1995).

Table 1: *90% confidence level upper limits on the integral flux of any hypothetical GRB occurred in the data sample described in the text. They are tabulated depending on the time window and the declination band. Uncertainties are ∼ 50%.*

Time scale	10 sec	1 min	4 min
$F_{UL}(E>16\text{TeV})$ (cm^{-2} s^{-1}) ($9° < \delta < 49°$)	$2.0 \cdot 10^{-8}$	$2.0 \cdot 10^{-8}$	$1.6 \cdot 10^{-8}$
$F_{UL}(E>25\text{TeV})$ (cm^{-2} s^{-1}) ($-6° < \delta < 9°$, $49° < \delta < 64°$)	$1.6 \cdot 10^{-8}$	$1.1 \cdot 10^{-8}$	$1.1 \cdot 10^{-8}$

Moreover, data recorded with AIROBICC from October 1994 to October 1996 have been analyzed specially for this conference, searching for short time emission independent of the detectors in space. The search has been performed in three time scales, 10 seconds, 1 minute and 4 minutes. The results are shown in Figure 3. No significative excesses are seen. The small excess seen in the 1 minute time scale comes from (J2000) $\alpha = 01^h{:}03^m{:}08^s$, $\delta = 33.6°$, MJD = 49934.18861, but it has chance probability of ∼90% to be a background fluctuation. However it is interesting to mention that this position coincides within the region of uncertainty of the BATSE GRB 930530B, although this burst has a large error ($1\sigma \sim 7.5°$) and therefore the

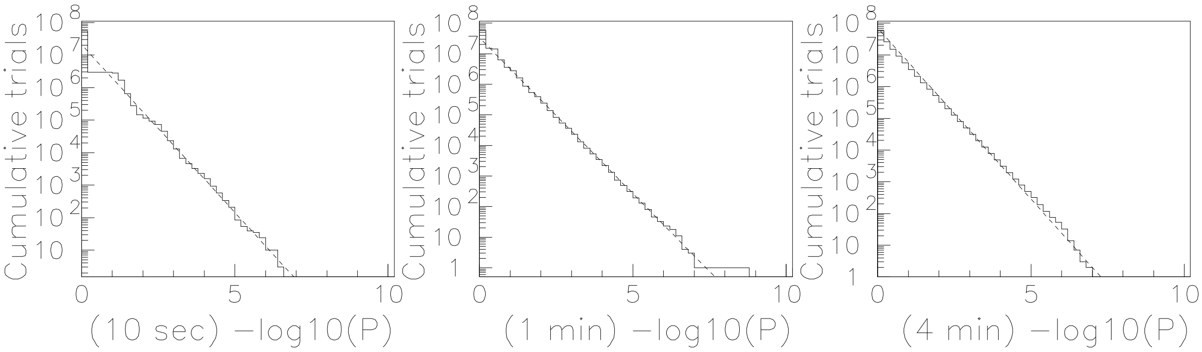

Fig. 3: Cumulative trials vs. probability in the satellite independent GRB search with AIROBICC. The time scale is indicated in brackets. Continuous line is real data and dashed line is the expectation. Deviations are not significant (see text).

coincidence may be just by chance. Upper limits with 90% confidence level on the integral flux of hypothetical GRBs included in this data set are given in Table 1.

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