A SEARCH FOR COSMIC GAMMA RAY BURSTS AT GeV ENERGIES FROM SIMULTANEOUS OBSERVATIONS WITH GRAPES II AND GRAPES III ARRAYS AT OOTY

S.C. Tonwar[1], Y. Aikawa[2], S.K. Gupta[1], Y. Hayashi[2], N. Ikeda[2], N. Ito[2], S. Kawakami[2], S. Miyake[2],
D.K. Mohanty[1], M. Sasano[2], K. Sivaprasad[1] and B.V. Sreekantan[1] [1] *Tata Institute of Fundamental Research, Mumbai 400 005, India*
[2] *Faculty of Science, Osaka City University, Osaka 558, Japan*

ABSTRACT

New observations on cosmic $\gamma - ray$ bursts with space borne detectors continue to provide fascinating details though a satisfactory understanding of their sources continues to elude us. Recent observations on the presence of high energy photons in a small fraction of the bursts has generated considerable excitement in the cosmic ray community as this observational feature puts severe constraints on the mechanisms which could be responsible for the generation of these bursts. In addition, theoretical ideas on evaporation of primordial black holes predict generation of short duration bursts of high energy photons. With these considerations in mind, we are making simultaneous observations with the GRAPES II and GRAPES III extensive air shower arrays at Ooty, which are separated by a distance of about 10 kilometres. We present here the details of the two arrays and the triggering system designed to detect short duration bursts of MeV photons at ground level, which may be produced by cosmic $\gamma - ray$ bursts whose energy spectrum extend into GeV region.

INTRODUCTION

The phenomenon of Cosmic Gamma Ray Bursts (GRB's) discovered by Klebesadel et al (1973) evoked intense interest since these bursts were so strong that they temporarily dominate all other sources of cosmic gamma rays. Typical bursts detected by satellite-borne detectors in the MeV energy range have energy fluxes $\sim 10^{-6}$ to 10^{-4} erg cm^{-2}, varying in intensity over time-scales from milliseconds to seconds. Recent observations (Mukherjee et al 1996) on the presence of GeV photons in a small fraction of the bursts has generated considerable excitement in the cosmic ray community as this puts severe constraints on the source models for these bursts. It is difficult to study the GeV part of the spectrum of cosmic gamma ray bursts with satellite-borne detectors due to practical limitations. However, it is possible to extend the observations on GRB's to energy regions of $\geq fewGeV$ by ground based detectors as suggested by Porter (1973). One of the first attempts to detect GRB's through ground-based detectors was made at Ooty by Bhat et al (1982). More sensitive searches have been made in recent years, for example, by Aglietta et al (1996), Connaughton et al (1997). We describe here the new experimental system operational at the mountain altitude laboratory at Ooty (2200 m altitude, 11° 23′ N, 76° 39′ E), which is expected to provide a significant increase in sensitivity for detection of cosmic $\gamma - ray$ bursts whose energy spectrum extends into the GeV energy range.

METHODOLOGY

GeV $\gamma - rays$ incident on the top of the atmosphere initiate electron-photon cascades producing many MeV energy $\gamma - rays$ which propagate through the atmosphere to mountain altitudes, mainly due to the relatively small cross-section for Compton scattering. Monte Carlo simulations (Bhat et al 1982) have shown that a 5 GeV photon incident at the top of the atmosphere yields, on the average, 0.02 photons of energy ≥ 1 MeV at mountain altitude. Therefore, a burst of MeV photons could be expected at ground level due to a burst of GeV photons due to any high energy $\gamma - ray$ burst. The sensitivity for the detection of such a MeV photon burst, against the normal background of uncorrelated photon flux, depends on the total sensitive detector area. Observations of temporal correlation between nearby but independent stations helps in identification of the burst phenomenon.

Using this methodology, we are operating two air shower arrays, GRAPES II and GRAPES III at Ooty to search for bursts of MeV photons at mountain level and studying temporal correlations between the sum of the counting rates of all the detectors in each array over short time intervals.

GRAPES II ARRAY

The GRAPES II array, located at the Raj Bhavan campus at Ooty, consists of a total of 100 electron density/timing detectors, with a total of 80 m^2 sensitive area for detection of low energy photons. Most of these detectors are 1 m^2 area, 5 cm thick plastic scintillators, viewed by a 5 cm diameter fast photomultiplier. These density detectors are arranged in an equilateral triangle pattern with 10 m separation between adjacent detectors. A muon detector with 200 m^2 sensitive area and a detection energy threshold of 1 GeV is also operational alongwith the electron array. While not useful directly for detection of GRB's, the signals from this detector can be used to distinguish the GRB's from nearby man-made noise.

GRAPES III ARRAY

The GRAPES III array is located at the Radio Astronomy Centre campus, about 10 kms from Ooty. The array has 217 electron density/timing detectors operational at present, whose design is similar to the detectors used in the GRAPES II array. It is proposed to expand the array to 721 detectors during the next 3 years. These detectors are also arranged in an hexagonal configuration with 8 m separation between adjacent detectors. This array also has a very large area, 560 m^2, muon detector ($E_\mu \geq 1$ GeV) operational for studies on the composition of ultra-high energy cosmic ray flux, which serves a useful, though indirect, role in the detection of GRB's as mentioned above.

Burst Trigger

A burst trigger has been installed in each of the two arrays in the following manner. The counting rate from each of the density detector is monitored continuously over time intervals of 1 millisecond and readout to a computer system. The burst program looks for 'abnormal' increase in the counting rate summed over all the detectors and flags out any significant increase alongwith its absolute time of occurrence, as recorded by a precision clock based on GPS signal. A correlation between the enhancement in the observed counting rates at the two arrays is searched for a possible signal of a GRB. Since the two arrays are separated by about 10 kms and have fully independent power supplies, a detection of significant enhancement in the counting rates over short time intervals simultaneously in the two arrays would constitute a signal for the detection of a GRB.

DISCUSSION AND CONCLUSIONS

The sensitivity of the system described above for detection of bursts of MeV photons at mountain altitude level, which may be caused by the incidence of GeV photons above the atmosphere, depends crucially on the efficiency of detection of MeV photons by the scintillator detcetors of the two EAS arrays. This efficiency is a function of the energy of photons and becomes nearly 10% for photons of energy ≥ 5 MeV for the plastic scintillator detectors in use at Ooty. The two arrays are operational round the clock, using reliable battery-backed uninterrupted power supplies. Detection of even a few bursts with this system in time-coincidence with bursts detected by the satellite-borne detectors would be of enormous interest for understanding the physics underlying the models of GRB's discussed in the literature.

ACKNOWLEDGEMENTS

The authors are thankful to the Ministry of Education, Japan, for partial financial support for this experiment. We are also happy to acknowledge valuable contributions of N.V. Gopalakrishnan, G. Paul Francis, A. Peter, K. Pratheep, K.C. Ravindran, B. Sreenivasa Rao, H. Suresh, S. Thirunavukkarasu, K. Viswanathan and V. Viswanathan during the installation, operation and maintenance of the instrumentation for the GRAPES III array. The help and cooperation of the Radio Astronomy Centre for providing site facilities for the GRAPES III array are gratefully acknowledged.

REFERENCES

M. Aglietta et.al., Astrophys. J. 469, 305 (1996)
P.N. Bhat et.al., Mon. Not. R. Astr. Soc. 199, 1007 (1982)
V. Connaughton et.al., Astrophys. J. 479, 859 (1997)
R.W. Klebesadel et.al. Astrrophys. J. 182, L85, 1973
R. Mukherjee et.al., Astrophys. J. 470, 831 (1996)
N.A. Porter, Nature 245, 366 (1973)