GAMMA-RAY BURST MEASUREMENTS WITH A 6.3 m² ARRAY

K. BEURLE, A. BEWICK, J. S. MILLS, and J. J. QUENBY
Blackett Laboratory, Imperial College, London, England

(Received 7 November, 1980)

Abstract. Two flights from Alice Springs, Australia, were achieved in November 1977 and November 1978 with a plastic scintillator γ-burst detector, effective area 6.3 m², thickness 5 cm, energy response in the range 50 keV to 2 MeV. In 33 hr of good, high altitude data, two bursts were detected, yielding a rate corrected to an isotropic flux of $7.03 \times 10^3 \text{ yr}^{-1}$ at a size of $8.5 \times 10^{-9} \text{ erg cm}^{-2}$. One event, seen at 22.14 on 15 Nov 1978, was confirmed by spacecraft measurements. The second, too small to be detected by spacecraft, arrived from 0 hr RA, $-13.2^\circ$ Decl, $\pm 12^\circ$ and possibly comes from a confirmed γ-burst source location. A galactic origin with a source distribution originating from a relatively thick disk, is favoured by these results.

1. Introduction

Balloon and spacecraft measurements have shown significant deviations of the size spectrum of gamma-ray bursts at low energy fluxes from that expected for an isotropic source distribution. Results are described here from two balloon flights with a detector which is sensitive to burst sizes lower than previously investigated, thereby providing further information relevant to the origin of the bursts.

Since their discovery by Klebesadel et al. (1973), studies of cosmic gamma-bursts have concentrated on two approaches. Direction of arrival measurements by the triangulation technique now yield error boxes for the sources of a few arc minute square (Mazets et al., 1979b) although, apart from a possible origin of the 5 March 1979 event in the N49 supernova remnant in the LMC, no obvious identification of these locations with a known class of astronomical objects has been demonstrated. As a second approach, statistical information is being assembled on the size spectrum of the bursts to discriminate between various possible spatial distributions of the sources. An isotropic source distribution either on a very local or on an extragalactic scale, results in $N(S) \propto S^{-3/2}$ where $N(S)$ is the number of bursts per year of size greater than $S$ erg cm$^{-2}$. An infinite thin sheet, approximating the galactic disk, produces an $N \propto S^{-1}$ distribution while more realistic models, especially as discussed by Jennings and White (1980), in general, yield curves between these extremes. It is this second line of investigation which is the concern of this paper.

In a narrow size range between $5 \times 10^{-5} \text{ erg cm}^{-2}$ and $5 \times 10^{-4} \text{ erg cm}^{-2}$ Vela catalogue data (Strong and Klebesadel, 1974) and Imp 7 measurements (Cline et al., 1977) indicate an $S^{-3/2}$ size distribution, but a variety of balloon upper limits and apparent finite flux measurements tend to support a flattening of this law at sizes between $10^{-6}$ and $10^{-8} \text{ erg cm}^{-2}$ (see the summary of Hurley, 1979). An
unconfirmed balloon event, reported by Bewick et al. (1975), has a flux of just under $10^{-7}$ erg cm$^{-2}$ but Nishimura et al. (1978) and White et al. (1978) also report relatively weak balloon events at about the $10^{-6}$ erg cm$^{-2}$ flux level. Among the upper limits are those of Cline et al. (1977), who employed two balloons, each with a 1 m$^2$ plastic scintillator, flown simultaneously at different geographical locations to eliminate spurious bursts of geophysical origin and of Fishman et al. (1978) with a 1.8 m$^2$ sodium iodide crystal array, sensitive in the range 30 to 200 keV.

We report here the results of a total of 33 hr of high altitude balloon flight with a 6.75 m$^2$ gross area plastic scintillator array, flown from Alice Springs, Australia. Use of a large area was required to improve on current flux sensitivity limits while Australia was used as a launch site to improve the visibility of the galactic disk on the supposition that the bursts may be of galactic origin and to reduce the interference from geophysical effects which are more likely in regions where trapped particles are dumped easily. Crude arrival direction determination was available and proved usable in the case of one of the two bursts detected. The other burst was sufficiently large to be confirmed by a spacecraft network and this fact lends confidence in the operation of the detector and data analysis.

In view of the discussions in the past concerning the methods for making a determination of the absolute sensitivity of plastic scintillator $\gamma$-burst detectors (Cline and Schmidt, 1977; Carter et al., 1977), we start by carefully describing the experimental arrangement and method of calibration.

2. Experimental Description

The detector consisted of 18 slabs of Ne 102A plastic scintillator, each 75 x 50 cm in area and 5 cm thick and grouped together, three per tray. As shown in Figure 1, four of the trays were inclined at 30° to the horizontal to enable directional information to be obtained. Two 5" photomultipliers were directly coupled with silicon fluid to the surface of each slab to observe the light output and Alcan foil was used as the reflecting surface around the scintillator. From the viewpoint of maximising light collection efficiency rather than uniformity, the system described was shown by laboratory experiments to be superior to a diffusing box system.

Detector calibration was achieved by first finding the relative efficiency of all parts of a slab with a photodiode directly coupled in turn to each of a representative grid of positions on the slab surface and obtaining the summed output of the two phototubes from each position. An absolute value of the average efficiency was then obtained by observing the light output from secondary cosmic ray $\mu$-mesons passing through the scintillator at a known position as determined by a small aperture coincidence $\mu$-meson telescope. With a quantum efficiency of 0.2 at the phototube photocathodes and 200 photons resulting from a 25 keV electron, it was found that the average light collection efficiency was