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CCD imaging of gamma ray burster fields

S.G. Bhargavi, R. Cowsik, A.K. Pati and

Indian Institute of Astrophysics, Bangalore, India and

RamSagar

U.P. State Observatory, Naini Tal, India

Abstract. Gamma Ray Bursts (GRBs) have been known for almost three decades. The nature of the objects producing these bursts is yet unknown and no counterparts have been identified in any other wavelength band so far except for GB970228 recently. In an attempt to identify the optical counterparts of GRBs we obtain deep CCD images of selected, strong GRB fields through broad band filters. From these images we expect to be able to identify any peculiar objects on the basis of photometric colours and/or variability. In this paper we present the preliminary results of the data obtained during our observing run in November 1996 at the UP State Observatory, Nainital.

1. Introduction

The phenomenon of Gamma Ray Bursts (GRB) has been known for almost three decades. The nature of the objects producing these bursts is yet unknown despite the extensive studies in both theory and observations. The observed properties of the bursts such as short time variabilities, spectra, energies, and their distribution in the plane of the sky etc. have led to a debate over their origin and distance scales (Lamb 1995; Paczynynski 1995). There are two competing views for the origin of GRBs viz. cosmological or extended galactic halo. Only very recently the search for counterparts of GRBs in other wave bands has been successful, with the Beppo-SAX experiment. The quick determination of a burst location to within a few arcminutes (Boell et al. 1997) resulted in the detection of the fading counterpart of the burst GB970228 in X-ray (Costa et al. 1997) and optical (Groot et al. 1997) bands. The burst source appears to coincide with a galaxy, indicating a cosmological origin. Subsequently, a proper motion of the point source within the galaxy has been reported (Caraveo et al. 1997) and debated (Sahu et al. 1997). Thus it is not yet clear what GRB sources are, as a class. Rapid follow-up searches could tell us the source properties at the time of burst and/or until the accompanying emissions die out. But how do these sources behave in quiescence? If this property can be established statistically from observations, it would give us a clue as to what triggers the burst.

To explore the nature of GRB sources in quiescence, we initiated a program of deep CCD imaging of GRB fields using the 2.34m Vainu Bappu Telescope at Kavalur in 1994. Similar programs are also being carried out elsewhere (Vrba 1995; Hudec 1990). One of the objectives of our program is to identify the unusual objects in the GRB fields on the basis of their photometric colours and/or variability. Another objective is to make a comprehensive database (with astrometric as well as photometric data) of all the objects in the field, down to the limiting magnitudes of telescope. Though repeatability of GRBs is a debatable issue so far there has been no report of a burst being repeated at the same location. An identification of all objects in the GRB error boxes would be of a great use in the event of repetition of a burst. We have started observations recently also at the 1m telescope of UPSO at Nainital and here we present the data and analysis of one of the fields observed in November 1996.

2. Observations and analysis

Our target list consists of burst positions from three GRB catalogs: First Interplanetary network (IPN) GRB catalog (Atteia 1987), Third IPN GRB catalog (Hudee 1994; Hurley 1996) and the catalog of CGRO/COMPTEL triggered bursts (Kippen 1997). The 1m f/13 telescope of UPSO equipped with Tek 1024 CCD of 24μ sq. pixel at its cassegrain focus provides a FOV of 6'.5 × 6'.5. The readouts were binned by 2 pixels in both directions, since this provides adequate sampling for the mean seeing at Nainital and would give higher signal to noise of detection. The image scale was 0".76/pixel after binning.

We were allotted 6 observing nights between 2-11 November 1996 during which we observed GB910814, GB910503, GB940217, GB950208, GB790504, GB790514 and GB790418 all having positions with an error box < 0.25 sq.deg. The catalog positions were centered at the center of CCD frame. The actual error boxes are irregularly shaped and some of them are not completely sampled. The sky was clear and seeing varied from 1".2 to 2".0 FWHM. Each of these fields was observed in B, V, I filters with two or more deep exposures (typically 30m) followed by a short exposure to avoid saturating bright stars. Landolt standard star fields were observed every night for photometric calibration and to determine extinction. Here we report a preliminary analysis of one field (GB910814) as a sample. GB910814 was detected by COMPTEL and its J2000.0 coordinates (Kippen 1997) are: $22^h55^m7^s$ +29°18'36"with 99% confidence error circle (COMPTEL + IPN) of radius $0^o.018$. The total exposure times were 60m, 50m, 25m, in B,V, and I filters respectively.

The CCD frames were reduced in the standard manner, viz. bias subtraction, flat fielding, removal of cosmicrays and bad pixels etc., using the IRAF/CCDRED package. We chose to correct for flat field response separately for large scale illumination pattern and pixel-to-pixel variations since this enables detection of fainter limits. For each filter a master flat was prepared using images from all the nights. Object frames were aligned and combined to obtain a summed image in each filter. Fig. 1 shows the sum of two images of the field of GB910814 in I band, the total exposure being 50m. Brighter objects are labelled from A1 to A25 are in magnitude range 19.5 to 21.3 and were detected in a second iteration of reductions. The objects labelled B1 to B30 are fainter and were detected only in the V and I filters.

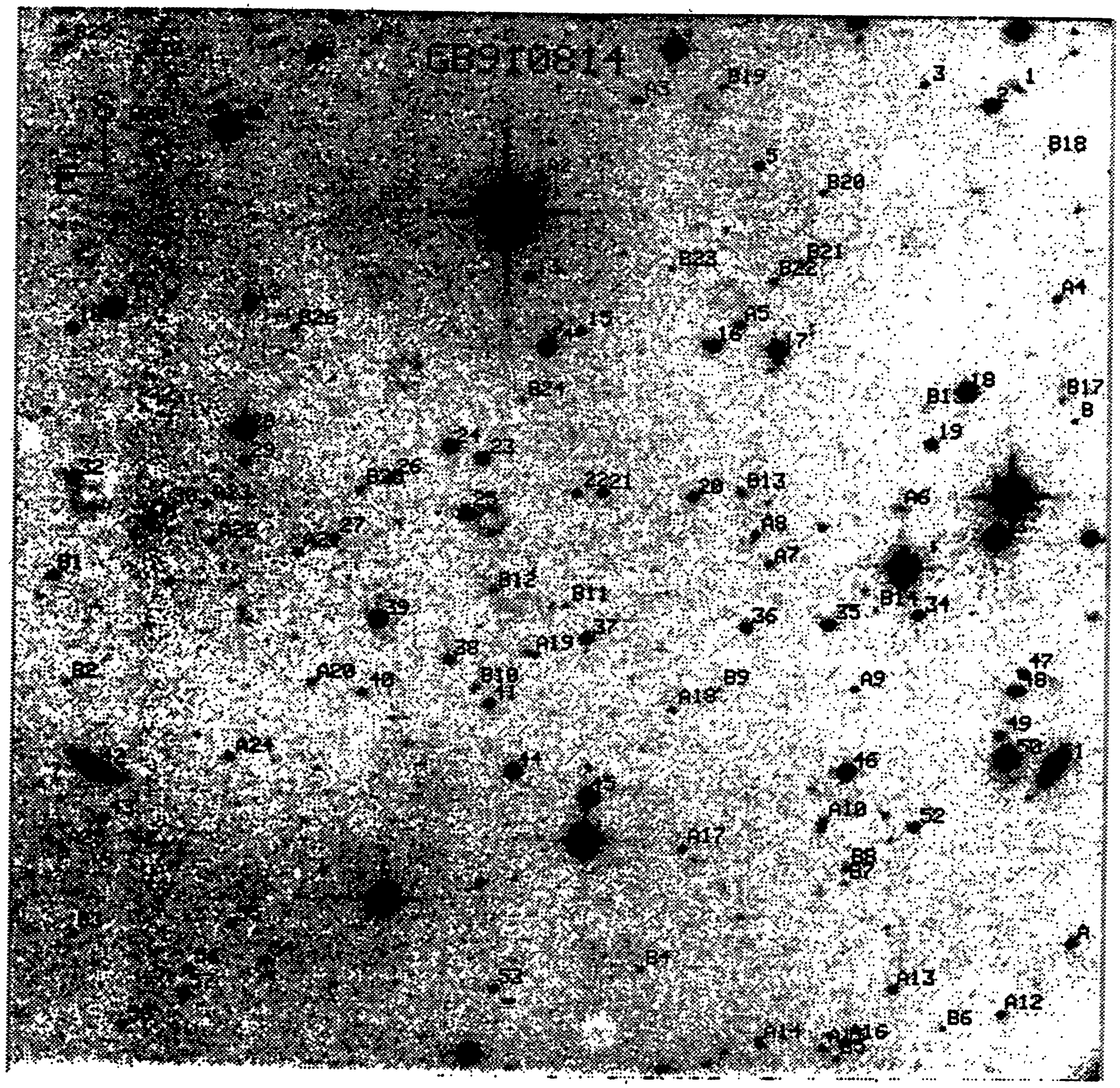

Fig 1. Field of GB910814 in I band with total exposure of 50m

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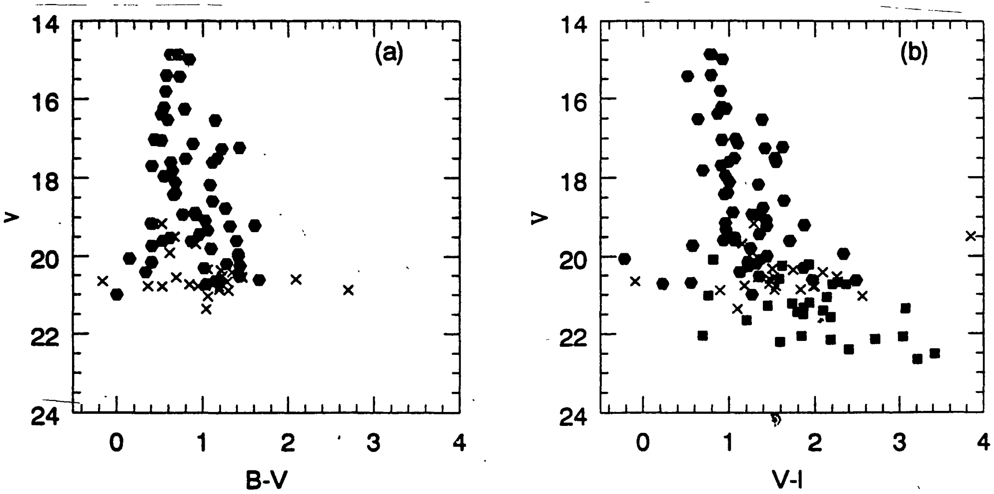

Fig 2. Color-Magnitude Diagram for the field of GB910814 (a). V vs (B-V). (b). V vs (V-I).

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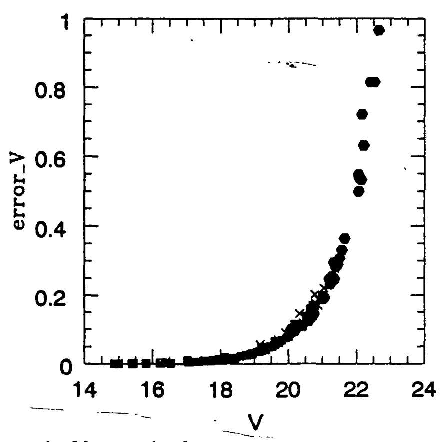

Figure 3. Errors in V magnitude.

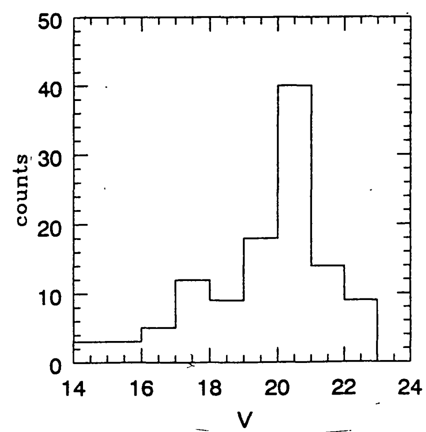

Figure 4. Number of detected objects in magnitude bins.

Photometry was done on these using the task PHOT in IRAF. We have chosen to do aperture photometry rather than PSF fitting, since our interest is not restricted to point sources. We have not listed the tables of photometry here due to lack of space. The magnitudes were determined at an aperture of 10 pixels. The values for bright stars were determined from single exposure frames. For the fainter objects (labelled A & B) the errors are somewhat higher for aperture of 10 pixels (See Fig. 3). The filled squares, crosses and filled hexagons correspond to numbered objects, objects with prefix A and prefix B respectively. The transformation coefficients for photometry were obtained for one of the nights where we had the maximum number of standard star observations using a standard field with 6 objects in the frame spanning a colour range of B-V = -0.3 to 1.5. We compared zero points obtained on this night with that obtained on other nights (where we had lesser number of standard star observations) and found good agreement (as expected, since all the nights were fully clear). We derived extiction coefficients of 0.28(B), 0.12(V), 0.08(I). The sky brightness obtained from our images is V=21.2, B=22.2 and I=19.5 (magnitudes/sq. arcsec).

Figs 2a and b show the colour-magnitude diagrams of all the objects detected. The filled hexagons, crosses correspond to numbered objects, objects with prefix A respectively. The filled boxes in Fig 2b correspond to objects with prefix B. We can clearly see that other than the objects lying in the central band which are probably galactic objects there are also faint blue objects on the lower left hand and very red objects on the lower right hand of diagram. We plan to do further investigations of these objects.

Number counts of objects are seen to peak between V=20-21 as shown in Fig 4. At this stage we have not classified the objects into stars and galaxies but from visual inspection we see that many of the faint objects are galaxies.

3. Summary

We have observed 4 of the CGRO/COMPTEL and 3 of the IPN GRB fields with small error boxes. The photometric analysis of one of the field is presented here as a sample. In this field we have measured 113 objects which include stars and faint galaxies. The colour-magnitude diagram would allow us to pick out the objects of unusual colours for future investigations. Further observations are needed for variability studies.

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