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OPTICAL MONITORING OF GAMMA-RAY SOURCE FIELDS

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ABSTRACT

The three gamma-ray burst source fields GBS1028+46, GBS1205+24, and GBS2252-03 have been monitored for transient optical emission for a combined total of 52 hours. No optical events were seen. The limiting magnitude for the search was m_V=15.8 for transients of 1.1 s duration or longer and m_V=17.0 for 6.0 s or longer.

1. Introduction Although gamma-ray bursts have been observed for over a decade, the sources are not yet understood. The distance scale is undetermined, the burst repetition rate is highly uncertain, and the type of object producing the bursts is not firmly established. Several recent results have indicated that the detection with ground-based telescopes of optical emission from the bursts could be a powerful tool for addressing these questions.

One result is the discovery by Schaefer (1,2) of optical transients on archival plates from the directions of three gamma-ray bursts. The plates were taken in the first half of this century, so the optical transients were not simultaneous with the three gamma-ray bursts; they were presumably coincident with their own, at that time undetected, gamma-ray burst. These archival images have given for the first time precise enough (arcsec) source positions to allow deep searches to be made at other wavelengths for steady-state emissions from the sources.

Other new results concern the 1979 March 5 gamma-ray burst source, GBS0526-66. In the four years following the original event, 15 smaller ones were observed by the Venera spacecraft with positions, time profiles, and spectra consistent with a single source (3). For the 9 events detected simultaneously by Venera 13 and 14 (detection threshold $\sim 10^{-7}$ erg cm^{-2} for > 30 keV photons), the observation livetime was about 350 days (E. P. Mazets, personal comm., 1984) indicating an average repetition rate of approximately 9 yr^{-1}. Many of the events were near the detection threshold limit, indicating that even more events were probably occurring at lower fluences.

Recently Pederson et al. (4) have reported the detection of possible optical flashes from GBS0526-66. Simultaneous gamma-ray bursts were not observed by detectors in space, although, assuming the ratio of gamma-ray to optical fluence inferred by Schaefer et al. (2), we estimate that the gamma-ray bursts were too weak to be detected.

The 1979 March 5 event was different from typical bursts in many respects (5), and therefore may be a different kind of source. However, the observed recurrences and possible optical emission are sufficiently intriguing to motivate optical monitoring of other gamma-ray burst sources. In addition to offering positional information with arcsec precision, optical measurements are likely to be more sensitive for burst detection than current gamma-ray instruments, as will be discussed in Sec. 3. The future goal is to continuously monitor a number of burst sources, or ideally the whole sky, for optical transients (6,7). As a first step both instrumentally and scientifically, we have undertaken a program of monitoring a few known burst sources for modest amounts of time. We report here the results of 52 total hours of observation of three sources. Preliminary results have been previously reported (8).

2. Instrumentation and Observations All observations were made with the 0.9-m Newtonian F/5 telescope of the Steward Observatory on Kitt Peak (the "Spacewatch Camera"). It is equipped with an RCA SID 53612 CCD; the 320 x 512 pixels are 29.5 μm or 1.34 arcsec square, giving the chip a 7.2' x 11.5' field of view. The CCD is cooled with dry ice and has an rms readout noise of 120 to 150 electron-hole pairs per pixel per readout. The dark current is comparable to that from the night sky.

Background events due to cosmic ray penetration of the CCD and internal radioactivity were suppressed by using a new observation mode (9). CCDs are used at nearly all observatories by performing integrations with the readout inhibited and the telescope driving at the sidereal rate. The entire image is then quickly read out. In our new mode the telescope is driven at the sidereal rate, but the CCD is slowly read out throughout the observation. The readout is accomplished by shifting the electronic signal charges incrementally from one row of pixels to the next in a "bucket brigade" to the edge of the chip. This results in trailed images of stars and real transient events of sufficient duration, while background events are contained in single pixels. In addition to separating out background events, this mode would also give light curves for transient events. The time resolutions used for the present monitoring were 0.25 and 0.36 s per pixel; i.e., every 0.25 or 0.36 s all 512 rows were transferred by one row and the 320 pixels of the end row were read out.

Observations were performed by tracking the center of each gamma-ray burst error box and recording the CCD output on digital tape. The data were analyzed by visually inspecting each frame with a video display Grinnell system. The journal of observations is given in Table 1. The approximate observing times are not completely covered intervals as time was lost due to tape manipulation and poor sky. The total number of good hours of monitoring the three regions of Table 1 are, respectively, 24.4, 4.1, and 23.6 hours. The coordinates in the table are as read from the telescope dials with the epoch of the time of observation; they are the apparent right ascension and declination. The error-box references and additional comments for each source are as follows:

1) GBS2252-03 - Schaefer event from 1901 archival plate (2); 1979 November 5 gamma-ray burst (10). Telescope set on center of 18" by 27" error box from archival event. Time resolution = 0.36 s.

2) GBS1205+24 - 1978 November 24 gamma-ray burst (10). Telescope set on center of error box. Time resolution = 0.36 s.

TABLE 1. Journal of Observations

Name, Coordinates	Observation Date U.T.	Approximate Times U.T.
GBS2252-03	83.10.13	6 35 - 8 00
22 53.4	83.10.14	4 20 - 5 30
-2 21'	83.10.15	2 50 - 6 00
	83.11.07	2 20 - 7 00
	83.11.08	1 50 - 6 20
	83.11.28	2 50 - 6 20
	83.11.30	1 30 - 3 40
	83.12.06	2 00 - 4 40
	83.12.07	2 40 - 5 40
	83.12.08	1 40 - 5 30
GBS1205+24	83.12.07	11 00 -12 50
12 07.0	83.12.11	10 20 -13 10
+23 44'		
GBS1028+46	83.03.24	3 15 - 9 20
10 30.2	84.03.26	2 55 - 6 00
+45 40'	84.03.28	6 45 -11 00
	84.03.29	8 00 -10 05
	84.04.22	3 30 - 5 40
	84.04.23	3 00 - 8 30
	84.04.24	3 00 - 7 15

3) GBS1028+46 - 1979 March 29 gamma-ray burst (11). Telescope set on center of error box. CCD rotated by 25° for better alignment with error box. Time resolution = 0.25 s.

3. Results and Discussion No transient optical events were detected during 52.1 total hours of observation of the three source fields. For GBS2252-03 and GBS1205+24 the search criterion was that the event be visible in three or more adjacent time bins giving a lower limit for the event duration of 1.1 s for detection. For GBS1028+46 the data were first compressed in time by a factor of 8, and then the three-bin time requirement applied, giving an event duration lower limit of 6.0 s. In both cases it was also required that the image spread perpendicular to the trailing direction be consistent with the seeing profile of real sources, as discussed below. The limiting magnitude for the search was determined by analyzing stars of known magnitude (H. D. Ables and C. C. Dahn, personal comm., 1983) as if they were transients. The limiting magnitudes are m_V = 15.8 for the > 1.1 s search and m_V = 17.0 for the > 6.0 s search.

Several different types of background events were observed. The most common were the single-pixel events occurring at a rate of 1 to 2 per

100 s over the 1.4 cm^2 active area of the CCD. The rate is consistent with the incidence flux of cosmic-ray muons at the Earth's surface (12). This large background component was eliminated from the transient search by the image trailing technique. A small number of two-pixel events were seen that we ascribe to muons depositing ionization near a pixel boundary. There were approximately ten background events that had several saturated pixels in a row in the trailing direction but were only one to two pixels wide in the perpendicular direction. These may be caused by natural radioactive decays in the CCD. The decays deposit a large amount of ionization in one or two pixels which then spreads over the low potential barriers in the charge-transfer direction. These events had many of the characteristics expected of a real optical transient, but were identified as background because they did not have a wide enough spread in the perpendicular direction to be consistent with the telescope seeing profile of real optical transients. For a star just bright enough to saturate the CCD (11th mag.) and on a night of good seeing, the image is detectable over 6 pixels in the perpendicular direction. Similar events have also been seen with this instrument during other observing programs.

With a magnitude limit of 15.8 for a 1 s flash, this type of optical monitoring may be significantly more sensitive for detecting bursts than present-day gamma-ray instruments. Assuming the fluence ratio of S_γ(>30 keV)/S_{opt} ~10^3 inferred by Schaefer et al. (2) applies to all bursts, the m_v=15.8 optical limit corresponds to a > 30 keV gamma-ray fluence limit of ~ 10^{-9} ergs cm^{-2}. This limit is a factor of 100 lower than that of the best current gamma-ray burst instruments.

4. Conclusions No optical events were seen during 52.1 total hours of observation. The limiting magnitude for the search was m_v=15.8 for transients of 1.1 s duration or longer (28.5 hours searched) and m_v=17.0 for durations of 6.0 s or longer (52.1 hours searched).

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