Simultaneous Optical/Gamma-ray Observations of GRBs

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Abstract: This status report presents details on the project to search for serendipitous time-correlated optical photographic observations of γ-ray bursters. The ongoing photographic observations at nine observatories are used to look for plates which have been exposed simultaneously with a γ-ray burst detected by BATSE and contain the burst position. The results for the third year of BATSE operation are presented.

1 Strategy and instruments

We are correlating two independent surveys, namely the photographic plates (optical) of the observatories involved and the BATSE (γ-ray) burst data. At present the photographic sky patrols of the observatories Sonneberg, Tautenburg and Hamburg (all Germany), Calar Alto (Spain), Ondřejov (CR), Odessa and Crimea (Ukraine), Dushanbe (Tadshikistan) and Kiso (Japan) are used for the northern hemisphere, and the UK (Siding Spring, Coonabarabran, Australia) and the ESO (La Silla, Chile) Schmidt plates for the southern hemisphere GRBs. This network is still expanding. The instruments which are used for this search are described in Greiner et al. (1994).

2 Results

With BATSE detecting and localizing $\approx$ 1 GRB per day, and a spatial and temporal optical coverage with the observatories involved of about 80%, we are presently checking 280–300 GRBs per year.

Within the first, almost three years of BATSE observations (1991 April 23 – 1994 March 31) we have identified simultaneous photographic observations for

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49 GRBs. A first list of plates covering 29 GRBs was given in Greiner et al. 1994. The details for the additional 20 GRBs from the third year of BATSE operation are given in Table 1. For most of these hits, several simultaneously exposed plates from different observational stations are available. Most of these plates are taken in the framework of the Czech meteor patrol (see Hudec 1995 for details) which uses a red sensitive combination of objective and panchromatic emulsion (almost no sensitivity below 400 nm). All plates have been investigated by blink comparison. No optical flash or any brightening of an object was found which could be undoubtedly attributed to a GRB. Thus, any optical emission accompanying the high-energy burst must have been less than the minimum detectable optical flux ($erg/cm^2/s$) of the corresponding plate. Using the peak γ-ray flux in the 50–300 keV range reached on the 1024 ms timescale we derive a lower limit of typically $F_\gamma/F_{opt} > 0.5$–40.

Furthermore, near-simultaneous deep exposures (24 hours before or after GRB) are also registered in the course of the cross-correlation (Table 2). Since these plates have smaller fields of view, the large GRB error boxes are not always covered fully. The last column in Table 2 therefore contains the percentage of the GRB error box area which is covered by the plate. This has been calculated by adding in quadrature a systematic error of 4° to the statistical error of each burst. In addition to the partial coverage, these plates are mainly taken under programmes which are not related to variability studies; i.e. there is in most cases no plate of the same area (and same filter/emulsion combination) which could be used for blink comparison. Thus, only part of the near-simultaneous plates could be investigated for optical activity. Due to the deeper limiting magnitudes, the blink comparison of plates having suitable comparison plates revealed a number of known as well as new variable stars. However, this optical activity is presumably not related to the GRB phenomenon. We have found no optical flash event. When counting only those plates which contain 100% of the GRB error box and which have been checked by blink comparison, we can constrain the optical emission within 1–3 hours before or after the GRB to be fainter than 5–7th mag for a 1 sec duration flash or equivalently 12-14th mag for a fading counterpart.

3 Discussion

With an increasing number of simultaneous optical observations of GRB locations we can conclude with higher confidence that typical GRBs have (1) optical emission at the time of the burst at a level at least below $(F_\gamma/F_{opt})^{-1} \approx 2$ and (2) optical emission a few hours after the burst is lower by a factor of 200 than the simultaneous limits.

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Table 1. Simultaneous plates for BATSE GRBs in the third year

GRB	Time (UT)	Location (RA, DEC)	No. of simul-taneous plates[1)]	limiting magnitude m_{pg} (for 1s flash)	Peak flux F_γ ($ph/cm^2/s$) 50-300 keV 1024 ms	Limit[2)] for F_γ/F_{opt}
930424	19:19:00	67.0°,40.2°	O, 4	3.0	1.64	0.7
930514	00:26:16	170.1°+71.0°	O, 8	3.0	3)	
930816	00:52:24	58.5°+71.4°	O, 8	3.5	3)	
930911	23:16:01	268.36°,69.07°	O, 5	3.0	0.82	0.3
930916	20:19:23	282.67°,65.28°	O, 3	3.0	7.90	3.5
930924	01:02:55	312.28°,12.67°	O, 7	3.0	3)	
931001	01:23:11	256.95°,46.09°	O, 2	0.5	0.47	0.02
931006	21:31:50	59.89°,65.89°	O, 6	2.5	3)	
931101	23:23:38	133.77°,6.95°	O, 2	2.0	0.14	0.03
931126	04:46:46	156.74°,67.53°	O, 1	0.0	0.81	0.02
931126	19:31:39	1.58°,-16.62°	O, 1	-1.0	3)	
931223	23:34:20	256.31°,41.08°	O, 2	0.0	1.84	0.05
940112	19:53:32	47.85°,64.23°	O, 4	2.5	0.26	0.07
940114	21:28:20	98.19°,-13.58°	O, 2	1.0	3)	
940209	20:00:01	354.87°,9.02°	O, 2	1.5	3)	
940214	00:38:08	121.63°,57.02°	O, 3	2.5	1.91	0.5
940217	23:02:42	29.02°,5.93°	O, 2	2.0	36.21	6.4
940227	21:04:14	356.63°,43.01°	O, 3	1.0	1.05	0.07
940310	22:00:57	84.86°,49.57°	O, 6	3.5	1.58	1.1
940327	20:29:06	24.12°,52.07°	O, 5	1.0	0.43	0.03

[1)] Letters indicate the observatory: O=Ondřejov

[2)] For the conversion of the γ-ray fluxes from $ph/cm^2/s$ to $erg/cm^2/s$ we have used a power law model of index −1.4 which is the most frequent value (Pendleton et al. 1994). The burst spectra with extreme deviations in slope the error in the conversion can reach up to a factor of 2. In the case of several simultaneous plates the ratio F_γ/F_{opt} is calculated for the deepest plate. Note that F_γ/F_{opt} is a true flux ratio (peak γ-ray flux in $erg/cm^2/s$ divided by the optical flux limit in the same units) rather than the usually given "flux" ratio L_γ/L_{opt}, which is really a fluence ratio, i.e. depends on the burst duration (T_{90}) and the exposure time of the plate. F_γ/F_{opt} is always lower than L_γ/L_{opt} if the burst duration is larger than 1s.

[3)] F_γ not available due to some missing data types.

Table 2. Selected near-simultaneous (±1 day) plates for BATSE GRBs

GRB	Time (UT)	Location RA, DEC	Observatory[1]; Plate center (RA, DEC)	Time between GRB onset and exposure[2]	$m_{\rm lim}$	% of error box
910505	20:15:18	178°.6,33°.2	K 180°,30°	−7.5 h		25%
930511	3:47:38	270°.4,41°.0	Sa; 274°.96,36°.06	+19.0 h	16.0 pg	30%
930622	3:28:15	143°.4,14°.0	Od; 148°,+69°	+16.0 h	14.5 pv	100%
930724	2:21:50	287°.6,60°.0	Sp; 18h+60°	+18.9 h	13.5 pg	60%
			Sp; 18h+60°	+18.9 h	12.0 pv	60%
*930725	15:27:50	264°.9,8°.4	Sp; 18h+00°	+ 6.8 h	12.0 pg	90%
			Sp; 18h+00°	+ 6.8 h	11.0 pv	90%
			Sa; 263°.73,12°.56	−16.8 h	16.0 pg	30%
*930725	17:45:21	88°.5,65°.7	Sp; 6h+80°	+ 4.5 h	12.5 pg	50%
			Sp; 6h+80°	+ 4.5 h	11.7 pv	50%
930815	5:26:42	287°.9,−9°.3	Sp; 19h+00°	+16.6 h	12.0 pg	60%
			Sp; 19h+00°	+16.6 h	11.0 pv	60%
*930816	00:52:24	58°.5,71°.4	Sp; 2h+80°	+ 0.7 h	12.5 pg	70%
			Sp; 2h+80°	+ 0.7 h	12.0 pv	70%
931203	01:02:03	7°.63,19°.01	CA; 5°.5,+17°	− 4.7 h	19.5 pg	30%
*940310	22:00:57	84°.86,49°.57	Sp; 6h+40°	− 2.3 h	12.0 pg	100%
			Sp; 6h+60°	− 2.3 h	12.5 pg	100%
*940708	20:42:06	300°.2,22°.25	Sp; 20h+20°	+ 2.3 h	12.5 pg	100%
*940806	9:32:58	245°.2,10°.87	Sa; 246°.54,11°.41	+12.2 h	15.2 pg	80%

Notes: Plates marked with an asterisk have been checked by blink comparison.
[1] The letters indicate the observatory: CA = Calar Alto, Od = Odessa, Sa = Sonneberg astrograph, Sp=Sonneberg patrol, K = Kiso Schmidt.
[2] The shortest time is given corresponding to the start (end) of exposure for a plate taken after (before) a GRB. Typical exposure times are 30–60 min.

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