OBSERVING STRATEGIES USING GCN

S. D. Barthelmy

NASA-GSFC (USRA), Greenbelt Maryland 20771

Abstract. Given the broad range of error box sizes available from the GRB Coordinates Network (GCN) and the range of time delays involved, there is now the opportunity for many more instruments, than could use the old BACODINE system, to make follow-up observations to detect the GRB counterpart. We present a set of scenarios (some taken from existing GCN site operations and some from anticipated operations) to guide the potential new observer in matching his/her instrument's capabilities with the GCN burst location information and in setting up the follow-up observing procedures.

INTRODUCTION

The GRB Coordinates Network (GCN) has become an extensive system [1]. GCN delivers a wide range of GRB location error box sizes over a wide range of time delays (see Table 1). The error boxes range from 10's of square degrees down to 10's of square arcminutes. The delay times range from a few seconds to a few days. These times, while inversely correlated with the error box size, are not always strictly correlated (e.g. the RXTE-PCA locations are the smallest and yet have an intermediate time delay of a few hours). It may not be easy to see all the ramifications of GCN's capabilities and the potential observing strategies. The dominant factors which determine which notice types are appropriate for each given instrument are the FOV and the response time. The sensitivity versus time_delay phase space is open to everyone – from the very shortest of delay times (with the concomitant poorest sensitivities) to the long delay times (with the best sensitivity limits).

This paper describes some of the major observing strategies. One of them may match the instruments you have access to and be applicable to your current research programs.

The recent x-ray afterglow detections by Beppo-SAX [2] and the subsequent optical and radio emissions (GRB970228 [3]; GRB970508 [4]) have proven that the follow-up observation technique is a sound one for GRB counterpart identification.

FOLLOW-UP OBSERVING SCENARIOS

Table 2 shows, by example, many ways (scenarios) to make follow-up observations of GRBs using various GCN notices. The purpose is to guide the already-participating observers to maximize their scientific return and to encourage new observers to participate. By seeing what is available and what particular sites with specific instrumental parameters are doing, the new observer may see a match-up with his/her existing situation.

TABLE 1. GCN Notice Type Descriptions.

NOTICE TYPE	TIME DELAY	ERROR BOX	RATE	COMMENTS
Original	5 sec	5-20° dia	1/day	Dedicated, auto, wide FOV
Final	37 sec	5-18° dia	1/day	Dedicated, auto, wide FOV
Light Curve	5 min	n/a	1/day	Useful for burst assessment
MAXBC	10 min	5-20° dia	1/day	Fast response, wide FOV
LOCBURST	15-35 min	4-8° dia	10/month	Medium response, med. FOV
COMPTEL	20-30 min	3-5° dia	5/year	Medium response, med. FOV
RXTE-ASM	1-2 hr	4′x10-150′	8/year	Small FOV
RXTE-PCA	3-5 hr	6-40′ dia	6/year	Small FOV
IPN	0.5-3 day	4′x4-8°	2/month	Small FOV with tiling
Admin Report	1-3 day	2-5° dia	1/day	MFSC's final report

The column definitions and explanations for Table 2 follows:

Mode of Operation: This lists whether a site runs under automatic computer control (no humans-in-the-loop) or manually with humans initiating and controlling the observations.

FOV: The angular size that the instrument can image in a single tiling. The scenarios are divided into 3 major groups based on the FOV (wide: >10°, medium: 1-5°, and narrow: <1°).

Response Time: How quickly the telescope can be on-target making observations (the time delay from receipt of the GCN notification). The automated systems tend to be fast responding as well as fast slewing and the manual systems tend to have slower response times.

Suitable Notice Types: Based on the FOV and slightly on the response time, this lists which GCN notices are appropriate for the site.

Observing Plan: Whether a site does a single pointing or multiple tiling to cover the error box. Also, if a time-series of repeated observations is made on the tiling pattern. The purpose of the time series for a given observing

TABLE 2. Some Example GRB Follow-up Observation Scenarios.

Mode of Operation	FOV	Response Time	Suitable Notice	Observing Plan	Example Sites	Lim Mag of Flux
Full auto$^{(1)}$	Wide (>10°)	seconds	Original MAXBC ALL	Single tiling; short time series of exposures	LOTIS ROTSE APT	11-14 mag
Full auto$^{(2)}$	Medium (1-5°)	seconds	Locburst COMPTEL	Single, 2x2, 3x3 tiling; time series		16-17 mag
Full auto	Narrow (<1°)	minutes	XTE-ASM XTE-PCA	1-3x1-3 tiling; time series	Super-LOTIS	18 mag
Manual$^{(2)}$ (remote)	Medium (1-2°)	1 hour	Locburst COMPTEL XTE-PCA XTE-ASM	~3x3 tiling	GEODSS NEAT	18-19 mag
Manual$^{(3a)}$ (on-site)	Narrow (<1°)	10's of minutes	XTE-PCA XTE-ASM	single or limited tiling	USNO Apache Pt.	21 mag
Manual$^{(3b)}$ (remote)	Narrow (<1°)	hour minutes	XTE-PCA XTE-ASM	single or limited tiling	VLA Keck	0.1 mJy 24 mag
Manual$^{(4)}$, other spacecraft	~1°	hours	XTE-ASM	ToO on the GRB error box	XTE-PCA ASCA ROSAT	0.5 mCrab 10^{-13} erg/cm^{2}sec
Manual$^{(5a)}$, other spacecraft	any	n/a	ALL	GRB validation error box	XTE-ASM ALEXIS DMSP OSSE	n/a
Manual$^{(5b)}$, other spacecraft	any	n/a	ALL	Elide that portion of their data	XTE-PCA ALEXIS	n/a

session is to look for fading or variability in any potential counterpart. Later sessions (e.g. the next night, in two nights, etc.) may be repeated to check for longer baseline variability.

Example Sites: A few sites (not exhaustive) chosen from the GCN list are given as examples to guide the reader about what type of system is appropriate for the particular scenario.

Limiting Magnitude/Flux: The best the example site can do given their aperture and FOV and typical integration time.

A FEW SCENARIOS EXPLAINED

The next five paragraphs explain a selected subset of scenarios. The numbers refer to the superscripts on the entries in the first column of Table 2.

(1) Some dedicated and automated instruments, like LOTIS and ROTSE, have the FOV and response time to be on-target while the burst is still bursting. They can (potentially) detect the optical emission during the flaring phase. As second generation instruments, the technology has advanced to yield impressive limiting magnitudes for their large FOVs and short integration times.

(2) Dedicated and automated instruments with a medium FOV (1-5°) can quickly tile the LOCBURST and COMPTEL error boxes to a fairly deep limiting magnitude in a, as yet, poorly sampled portion of phase space.

(3a) Observers at large, narrow-FOV telescopes (optical and radio) doing their normal observing programs can quickly switch over to take snapshots of the small RXTE-ASM/PCA error boxes. Arrangements can be made to have the notices sent directly to the "operator's consol" at the telescope.

(3b) Observers not at the telescope can still call the current observer and arrange for a follow-up or invoke a previously approved ToO program.

(4) Several spacecraft (e.g. RXTE-PCA, ASCA, ROSAT) can be used for ToO observations of the RXTE-ASM flaring-phase detections or the RXTE-PCA fading-phase detections.

(5) And on a related note, some spacecraft teams use the GCN notices to know when in their data to look for a possible detection either (a) to study the GRB itself or (b) to elide that portion of their data from the analysis of their normal targets. The former provides an independent confirmation that the transient they saw is in fact a GRB, and the later allows for the removal of the GRB contamination to their main science.

MISCELLANEOUS COMMENTS

IPN annuli come later and greatly reduce the area of the previously recorded images that needs to be scanned/analyzed. They can also support or refute potential counterpart candidates which were singled out in previous images because of their "variability" or strange color. If confirmed, these can be followed up in more detail (e.g. spectroscopy).

LOCBURST Notices can be used as a heads-up (forewarning) that an RXTE-PCA position may be forthcoming (if the burst is bright enough and therefore has a small enough error box). The activity sequence might go something like: check if it is in a favorable location on the sky, talk to the scheduled observer to plan a ToO, get the right instrument mounted, be ready when the RXTE position comes. The RXTE-PCA ALERT notices can be used as an intermediate heads-up. Follow-up observers can also use Final as a heads-up for LOCBURST.

The time series of exposures under the Observing Plan can be "short" for those fast-responding sites (who, by their nature, tend to have limited sensitivity) so their strategy would be to go for the counterpart identification in the later stages of the flaring phase or the early stages of the fading phase. Or it is "long" for those sites with more time and more sensitivity, so their strategy could be to detect variability in the fading counterpart.

Some telescopes (e.g. BRADFORD) have both wide and narrow FOV instruments mounted on the same automated system. They can use several notice types in their follow-up observing efforts.

Amateurs can get involved with their narrow-FOV instruments and through the use of pagers (see below) they can be continuously responsive to any recent well-localized bursts.

HOW TO BE ALWAYS INFORMED

Now that small error boxes are being produced within hours after the burst, it is critical that the observer community be notified when a small location is available. Since the typical observer is not in front of his e-mail terminal 24 hours a day, another notification procedure is needed.

Pagers fill this need completely and easily. The pager will notify you that an "interesting" burst has occurred (one that meets your selection criteria), and then you will know to check in to your regular e-mail account or the GCN web page [6] to get the full details to plan and start an observing program.

Alpha-numeric pagers and e-mail-capable cell-phones allow you to receive automatic e-mails from GCN. These messages contain the important "first-cut" information (location, intensity and fluence of the burst, and the instrument that produced the location). And these messages can be individually filtered to suit your specific needs.

The companies currently used by GCN that provide e-mail-driven alpha-numeric pagers are: SkyTel, MobileComm (both true pager companies), and GSM Information Network (this company does cell-phones with paging capability). There are undoubtably more companies in your area than the few listed here.

REFERENCES

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