GRB Coordinates Network (GCN): A Status Report

Scott D. Barthelmy*, T.L. Cline*, P. Butterworth*,
R. Marc Kippen′, M. Briggs′, V. Connaughton′, G. Pendleton′

*NASA-GSFC, Greenbelt,MD 20771
′NASA-MSFC, Huntsville,AL 35812

Abstract. The GRB Coordinates Network (GCN) was designed to deliver locations of GRBs to instruments and observers in real-time (a few seconds) – while the burst is still bursting – so that they can make multi-band simultaneous follow-up observations. This goal has been realized with the optical detection of the burst counterpart for GRB990123 by the ROTSE instrument [1]. A brief review of the function and capabilities of the GCN system is given; the types of GRB location information available plus the distribution methods are described. Complementing the real-time location Notices, the GCN Circulars allow the follow-up observers to share the results of their observation rapidly with the community. A status report on recent improvements to the GCN system and a list of future improvements is given. One of the key improvements will be the conversion of the semi-manual RBR LOCBURST locations into the fully automated LOCFAST Notices.

INTRODUCTION

The original BATSE Coordinates Distribution Network (BACODINE) started operations in 1993 by distributing GRB locations calculated from the real-time telemetry from the CGRO-BASTE instrument [2]. It has since grown into the GRB Coordinates Network (GCN) by distributing location and light curve information for GRBs detected by all spacecraft capable of detecting GRBs. There are four basic components of the GCN system (the details of GCN are described in Barthelmy et al. [3]). The GCN is a system of computers and programs which: 1) Monitor the CGRO-BATSE real-time telemetry for bursts, calculate their locations, and distribute the locations to interested parties within 5 sec after the BATSE trigger. 2) Distribute raw CGRO data to BATSE, COMPTEL, and auto-IPN. 3) Collect GRB location information from other sources (other spacecraft) and distribute them to interested parties. 4) Collect reports from burst follow-up observers and distribute them to the GRB community (the Circulars).

The GCN system is all encompassing and all automatic. GCN collects all the information on GRB locations from all the various sources into a single point and transmits that information to all the various sites. Each site need only develop and maintain one connection for all their GRB needs. There are no humans involved (within the GCN system proper), so there is minimal delay (3-5 sec for BATSE information and only a 1-60 sec delay after receipt of the information from the other sources (e.g. BeppoSAX, RXTE, COMPTEL, etc.).

The original goal of the GCN (BACODINE) system of observing a GRB in a non-gamma-ray bandpass while the GRB is still busting has been realized. At 9:46:59 UT (T+3sec) on 23 Jan 99, the GCN system detected a GRB in the CGRO-BATSE telemetry stream, calculated a rough location, and distributed that location to the ROTSE instrument located at LANL [1]. The ROTSE instrument is a fully computer-controlled, fast slewing, wide FOV CCD camera instrument connected to the GCN system. ROTSE received the GCN burst location and was on-target and integrating the first of a series of exposures at T+22 sec. During the 90-sec duration of the burst, ROTSE recorded open-filter magnitudes of 11.8, 8.9, and 10.1. The idea of making observations of GRBs in bandpasses other than the gamma-ray while the burst is still bursting has been proven.

NOTICE TYPES AND DISTRIBUTION METHODS

Table 1 shows all the Notice types available through the GCN system. The time delay after the burst, size of the error box, occurance rates, and a comment about which types of instruments are suitable to make use of the type is given.

TABLE 1. Sources of GRB locations within GCN.

SOURCE	TIME DELAY	ERROR BOX SIZE	RATE	COMMENTS
Original	5 sec	6-20° dia	1/day	Dedicated, automated, wide FOV
Final	37 sec	6-18° dia	1/day	Dedicated, automated, wide FOV
LOCFAST	2 min	3-5 dia	50/year	Medium response, medium 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	15-30 min	4-8° dia	10/month	Medium response, medium FOV
COMPTEL	15-30 min	3-5° dia	5/year	Medium response, medium FOV
RXTE-ASM	1-2 hr	4′x15-150′	8/year	Small FOV telescopes
SAX-WFC	2-3 hr	6-20' dia	8/year	Small FOV telescopes
RXTE-PCA	2-5 hr	6′-40′ dia	6/year	Small FOV telescopes
SAX-NFI	12-48 hr	100" dia	4/year	Small FOV telescopes
IPN	0.5-3 day	4′x4-8°	2/month	Small FOV with tiling
ALEXIS	12 hr	0.6 dia	20/year	Small FOV telescopes

All of the Notice types listed in Table 1 are available via the 5 distribution methods: Internet socket, phone/modem, e-mail, pagers/cellphones, and the GCN web site; plus the light curves are also on the web site. The Internet socket connection directly couples the site's instrument control program to the GCN program with a

TCP/IP socket connection. It is fast – 0.1-2 sec. All the software required at the "site"-end of the connection has been developed and is available [9]. The dedicated phone line is slightly faster (0.3 sec) than the socket method, but seldom worth the expense. The e-mail method uses the standard e-mail protocols with the body of the e-mail having a "TOKEN:value" format suitable for human or computer parsing. The delivery times are typically less than 30 sec, which is fine for human destinations. There are several forms of pager and cell-phone methods – you can get beeped by the Universe. There are normal and terse formats, subject-line-only formats, and decimal degrees vs hh:mm:ss formats. The alpha-numeric pagers are convenient because you can get the RA,Dec,Time,Intensity of the burst no matter your location. They have the same time delays as the e-mail method.

The web site [9] is an archive facility. There are pages within the site that contain all the Notices for each Source instrument (BATSE, COMPTEL, RXTE-PCA/-ASM, BeppoSAX-WFC/-NFI, IPN, and ALEXIS). There are also pages which contain the lightcurves from the CGRO-BATSE, Wind-KONUS, and NEAR-XGRS instruments in alpha-numeric text, JPEG, GIF, and Postscript formats. All of the various web archive pages are updated within 60 sec of the Notice being distributed to the community. The web site also archives the published GCN Circulars. It also has the detailed technical description of the system.

GCN FILTERING METHODS

There is a wide range of filters available to sites wishing to customize the quantity and quality of the notices they receive. There are 4 main filtering categories and each filter category acts independent of the other 3 categories. 1) Source type – sites can elect to receive each of the following Source types: BATSE, COMPTEL, RXTE, BeppoSAX, IPN, ALEXIS. Within each Source type, there are one or more sub-types for the instrument and/or the Original, Updated, Final, Will-observe, Won't-observe, Saw-something, Didn't-see-something sub-types. 2) There is a filter category based on the location of the burst on the sky: ALL, VISIBLE, or NIGHT. The VISIBLE filter requires that the RA,Dec location of the bust have an elevation angle at the site greater than 10degrees. The NIGHT filter further requires nautical twilight at the site. There are also customized versions which can include declination-based, Sun angle, UT window, and proximity to previous GRBs constraints. 3) There is also a filter based on the size of the uncertainty in the locations, and 4) a filter based on the amount of time from burst to Notice availability – the details for both are discussed in the Improvements section.

SOME GCN STATISTICS

Currently, the GCN system distributes Notices to 112 "sites" involving 290 researchers. There are 45 locations with 65 instruments (24 optical, 12 radio, 16 gamma-ray, 7 x-ray, 3 gravity wave and 3 neutrino). There are 9 fully automated instruments; the rest are manual. There are 64 heads-up and/or cross-instrument correlation operations. Approximately 500 burst follow-up observations have been made by the GCN sites on about 380 GRBs. As of Dec 99 the afterglow from 42 GRBs have been detected using GCN Notices and Circulars, plus the truly simultaneous detection of GRB990123 by the ROTSE [1]. As of 30 Dec 99, 512 Circulars were distributed to a list of 416 recipients.

IMPROVEMENTS TO THE GCN SYSTEM

The GCN system is an evolving and improving system. It is continuously adding new capabilities and new sources of GRB information to provide a better system to the clients. The GCN system is funded by NASA through the CGRO Guest Investigator and SR&T programs. It is envisioned that it will have a long and productive future, and therefore can be counted on for long-range plans of the follow-up community. The following are improvements made within the last 2 years – the dates in parentheses are when the feature was added to the system.

In the past the BeppoSAX-WFC/-NFI burst location notices had been distributed semi-automatically, such that the last step in the sequence involved the GCN Operator formulating a message to be imported into the GCN system for distribution. Now this last step has been automated too (Dec 99), resulting a decrease in the time delay of 0.5 to a few hours.

The GCN system captures the periodic telemetry down-loads from the Wind and NEAR spacecraft and extracts the data from the KONUS (Oct 98) and XGRS (Mar 99) [4] instruments, respectively. It then scans these data looking for sudden increases in the background counting rates. A 2 minute section of this count-rate lightcurve is extracted and sent to the IPN system operated by K.Hurley [5]. These lightcurves are cross-correlated with the Ulysses burst detections to produce automated IPN annuli and IPN boxes. The IPN solutions are then sent back to the GCN system for distribution to those sites requesting this type of Notice. The time delay on these IPN solutions is dependent on the rate of telemetry dumps from the spacecraft; typically 1-25 hours for Wind and 1 hour to 3 days for NEAR. (Note that NEAR will enter into orbit around the EROS asteroid in Jan 2000 and the telemetry dump rate will increase to once per day.) There have been total of 4 IPN solutions using KONUS data and 3 solutions using the XGRS data, including the IPN solution for GRB991208 which resulted in a radio and optical counterpart detections based on the small error-box of the IPN solution [6]. These IPN solutions based on the Wind-KONUS and NEAR-XGRS contributions are significant because they provide the third node in the IPN triangulation technique to yield true error boxes, instead of the annuli segments using only the Ulysses and BATSE data.

The ASM instrument on RXTE scans about 80 percent of the sky every 90 minutes. D. Smith et al. [8] has created a real-time data analysis system to scan the count-rate data from the ASM to look for hard x-ray transients. When a location of detected, the location and error box is sent to the GCN for distribution to those sites requesting this Notice type (Jan 99). It is expected generate about 8/year with 4x15-150' arcmin locations at 5-60 minute delays.

Since the number of sources producing small error-box locations is increasing and these error boxes are comparable to the FOV of traditional telescopes, a filter based on the size of the location uncertainty was added. At first, the filters were set at fixed values of 1 deg and 2 arcmin (Feb 99 and Oct 99, respectively), and they were exclusive of the standard ALL, VISIBLE, and NIGHT filters. However, this error-box-based filtering was later changed (Dec 99) to be continuously adjustable (1 arcsec to 360 degrees) and to be independent of all other filtering criteria.

A filter was added (Dec 99) that allows sites to filter the Notices they receive based on the time delay between the start of the burst and the time the location Notice is available for distribution. This is useful for the non-automated sites that have a sensitivity limit such that they would not be able to detect an afterglow N hours after the burst. It is continuously adjustable from 1 sec to 1000 days.

The GCN has had a system in place since May 97 that sends the BATSE data to the BATSE team at MSFC where they quickly produce a location within 15-30 minutes, which is significantly better than the "ideal physics" locations calculated by the GCN system alone. This LOCBURST procedure [7] (which includes the full response function for the BATSE LADs) will be fully automated and incorporated into the GCN system, thus reducing the time delay to 2 minutes. The LOCFAST errors are smaller by a factor of 2 compared to the Original, Final, and MAXBC locations. The manual LOCBURST procedure has been automated into computer code by MSFC and it will soon (Feb 00) be incorporated into the GCN program.

HETE-2 will be launched in late May of 2000, work is already in progress to incorporate the GRB locations detected by the Wide-field X-ray Monitor and Soft X-ray Camera instruments into the GCN system. There will be about 40/yr and with error box sizes of 0.2-30 arcmin. And when INTEGRAL launches (Apr 2001), the GRB locations imaged by the SPI and ISGRI instruments (20/yr at few arcmin with delays of less than 60 sec) will be distributed by GCN. And when Swift launches in late 2003, the locations from the BAT, XTR, and UVOT instruments will be also distributed (150-300/yr at 4arcmin at T+10sec and 1-2arcsec at T+60sec).

REFERENCES

1. Akerlof,C., et al., Nature, 398, pp 400, 1999.
2. Barthelmy, S.D., et al.; Huntsville 3rd GRB Workshop, AIP, 384, pp 580, 1996.
3. Barthelmy, S.D., et al., Huntsville 4th GRB Workshop, AIP, 428, pp 99, 1998
4. Barthelmy, S.D., et al., SPIE Conference Proceedings, 3768, pp 444, 1999
5. Hurley, K. et al., these proceedings, IP-27.
6. Hurley, K., et al., GCN Circular 450, 1999.
7. Kippen, R. M., et al.; Huntsville 4th GRB Workshop, AIP, 428, pp 119, 1998
8. Smith, D.A., et al.; ApJ, 526, pp 683, 1999.
9. The GCN Web Pages URL: http://gcn.gsfc.nasa.gov/gcn.