THE SEARCH FOR GAMMA-RAY BURST COUNTERPARTS: A COORDINATED COMPTEL/BATSE RAPID RESPONSE APPROACH

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ABSTRACT

The COMPTEL experiment onboard CGRO can image cosmic gamma-ray sources in the energy range 0.7-30 MeV with an accuracy of about 1 degree. Within its 1 steradian field of view, COMPTEL detects several strong cosmic gamma-ray bursts per year. When combined with burst trigger notification from the BASTE experiment on CGRO, the COMPTEL data processing and imaging analysis can be accelerated to yield burst position localizations within hours of onset. This rapid response, coupled with good localization, can be exploited in searching for burst counterparts at other wavelengths. We present here a rapid response plan which will allow scans of COMPTEL gamma-ray burst localization regions at other wavelengths soon after detection. The majority of this plan has been successfully implemented and preliminary work is discussed.

INTRODUCTION

With few rare and questionable exceptions, attempts to identify gamma-ray burst (GRB) counterparts at other wavelengths in the past twenty-five years have failed. Most of these searches relied upon localizations determined through timing analyses between widely separated spacecraft; taking at least several days to obtain a localization precise enough to search for counterparts. No doubt, part of the problem is that there have been no deep searches of GRB localizations concurrent or soon after their detection in gamma-rays.

The Imaging Compton Telescope (COMPTEL) on the Compton Gamma Ray Observatory (CGRO) has the ability to directly image MeV gamma-rays[1], eliminating the need for coordination between multiple spacecraft, while preserving good spatial resolution. However, COMPTEL has no on-board transient event triggering system to quickly identify GRB events. Fortunately, the BATSE experiment on CGRO does incorporate such a system which can be used to notify COMPTEL when a GRB occurs in it's ~1 steradian field of view. Thus far, BATSE burst trigger notification has only been used to search existing COMPTEL data well after the events. During its first year of operation, COMPTEL images with ~1° positional accuracy have been generated for several of the most intense of these events[2,3]. This subset of 'imagable' bursts represents only a small fraction of all the bursts occurring within COMPTEL's field of view and an even smaller fraction of all BATSE GRB triggers. Thus BATSE GRB triggers indicating COMPTEL 'imagability' must be filtered with care.

If only the strongest events occurring near the COMPTEL field of view are filtered from the BATSE triggers a rapid response action can be initiated to accelerate COMPTEL data processing and analysis, yielding as its end result a localization which can then be scanned at other wavelengths. This rapid response approach will, under optimum circumstances, allow multi-wavelength scans of COMPTEL localization regions for several bursts per year within ~hours of GRB onset.

RAPID RESPONSE SCENARIO

A scenario of the COMPTEL/BATSE rapid response plan is schematically illustrated in figure 1. The scenario begins with the detection of a gamma-ray burst event which activates the BATSE transient event triggering system. BATSE trigger signals are continuously monitored in real-time at the CGRO Payload Operations Control Center (POCC) by the Flight Operations Team (FOT). Relevant BATSE data are automatically checked against thresholds to monitor data and instrument operation. One set of thresholds has been implemented to determine the COMPTEL detectability of any burst trigger based on BATSE data parameters. When this set of thresholds is exceeded, a limit violation message appears and the FOT immediately contacts the BATSE team. The event must be of cosmic origin, sufficiently strong with a hard spectrum from a direction near the COMPTEL axis to be acceptable. In addition, basic engineering checks such as whether COMPTEL was activated and transmitting real-time data at the time of the burst must also be made. The ultimate acceptability of events which trigger the POCC automatic thresholds is determined by the BATSE team.

If the event is acceptable, the BATSE team notifies the COMPTEL team at the University of New Hampshire (UNH), and then continues to analyze the BATSE data to compute a source direction. The BATSE-derived source direction is valuable in the process since it can be used later to aide in analysis of COMPTEL data. Ever since CGRO started transmitting all data during 'real-time passes' of the spacecraft (no longer relying on tape recorders to store data), approximately 60% of COMPTEL data can, or does go directly to UNH electronically in real-time. If the COMPTEL data containing the burst are

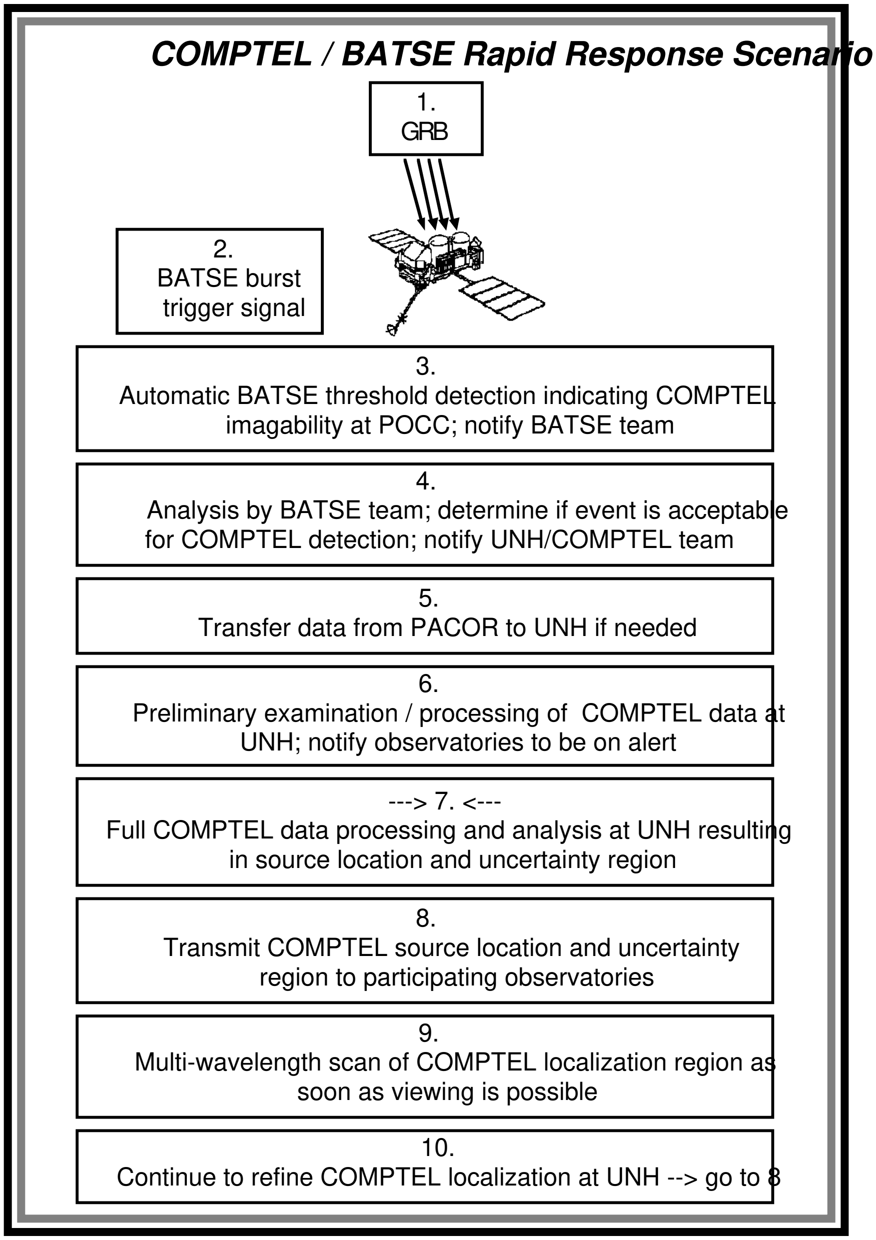

Fig. 1. Outline of the COMPTEL/BATSE GRB rapid response plan from burst trigger to multi-wavelength search. See text for details.

not already at UNH a request is made that they be transmitted from the Packet Processor (PACOR). Upon receipt of the data at UNH, raw count rates in the individual COMPTEL detectors (including COMPTEL's burst detectors[4]) and VETO domes are examined. This early check helps to identify obvious burst events in the COMPTEL data, however lack of a clear signal here is not sufficient to reject the possibility of a detection. Thus, for each BATSE notification, data is processed at least to a point where detection can be absolutely rejected. When acceptable detection is seen in the COMPTEL data, UNH notifies all participating observatories, such as the New Mexico State University team[5].

At this point, the COMPTEL team performs full data processing and imaging analysis at UNH[6]. This is by far the most time and resource consuming step in the entire plan. The amount of time required for full processing and analysis is being optimized, but will require at least a few hours. The end result of the COMPTEL data processing and analysis is a maximum likelihood ratio skymap[2,7] of the burst region containing the GRB position and uncertainty contours. The GRB localization from the COMPTEL skymap is then communicated to all participating observatories where the region can be scanned for counterparts if and when observing is possible. In the mean time, the COMPTEL imaging analysis is iterated to refine the localization.

PRESENT AND FUTURE STATUS

The implementation of the rapid response plan is now complete both with BATSE and with COMPTEL. One effort was to determine characteristics in BATSE data of 'COMPTEL imagable' bursts. This was done by examining BATSE data for the several GRB events which were successfully imaged by COMPTEL in its first year of operation. This allowed a set of POCC thresholds to be defined; the first, crucial step which filters out the majority of BATSE burst triggers. Other efforts included developing reliable communications between all participants and implementing all COMPTEL processing and analysis software at UNH. The COMPTEL portion of the rapid response procedure has been tested on several of the previously imaged GRB's; yielding source positions within ~hours. These tests served to measure/improve overall processing time, determine optimum default software settings, identify and correct software problems, optimize source location uncertainty and provide overall practice with the system. The full system was exercised on August 30, 1992 when the automatic thresholds were activated by GRB920830. Communication problems between BATSE and COMPTEL, coupled with the lack of an evident signal in raw COMPTEL data resulted in a source position ~days rather than ~hours after the burst. This 'first try' was, however, a valuable experience with the full rapid response process since it revealed several problem areas and verified that the automatic thresholds are appropriately set.

The ultimate success of the rapid response approach depends not only on the refinement of the plan outlined here (resulting in consistent, rapid and accurate GRB source locations), but also on the involvement of multi-wavelength observatories. There is currently only one dedicated observatory[5] and we therefore request more support from the multi-wavelength community.

SUMMARY

The lack of any conclusive observations of gamma-ray bursts at other wavelengths may be tied to the fact that no observations have yet been attempted soon after the detection in gamma-rays. The COMPTEL/BATSE rapid response approach to the search for GRB counterparts will allow us to search several COMPTEL GRB localizations per year at other wavelengths within hours of burst onset. The identification or non-identification of GRB counterparts or any lingering effects will provide invaluable new clues about the nature of GRB's. The success of this approach is contingent both upon the refinement of this plan and the active involvement of as many multi-wavelength observatories as possible.

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