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The BATSE Experiment on the Compton Gamma Ray Observatory: Status and Some Early Results

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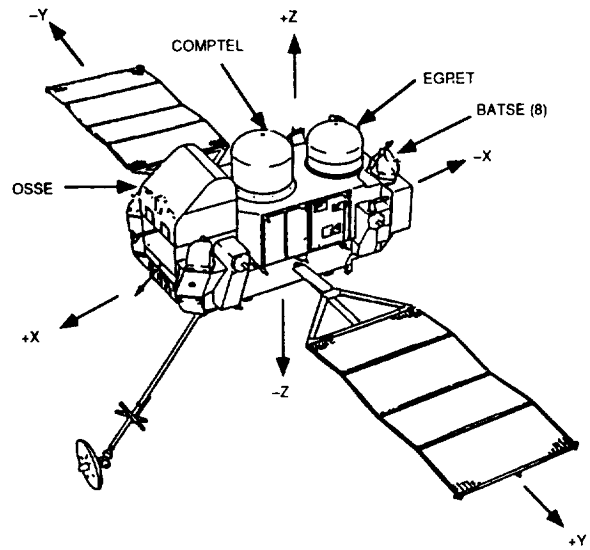
Abstract

The Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory is a sensitive all-sky detector system. It consists of eight uncollimated detectors at the corners of the spacecraft which have a total energy range of 15 keV to 100 Mev. The primary objective of BATSE is the detection, location and study of gamma-ray bursts and other transient sources. The instrument also has considerable capability for the study of pulsars, solar flares and other discrete high energy sources.

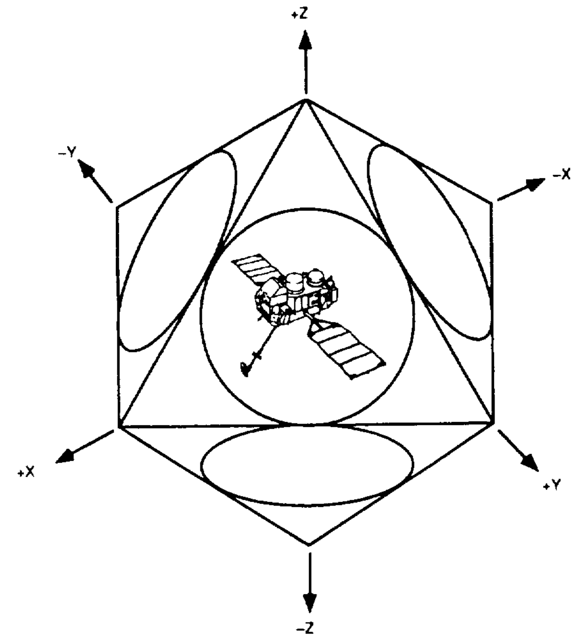
The experiment is now in full operation, detecting about one gamma-ray burst per day. A brief description of the on-orbit performance of BATSE is presented, along with examples of early results from some of the gamma-ray bursts observed.

Description and Scientific Objectives

The Burst and Transient Source Experiment (BATSE) consists of eight uncollimated detector modules arranged on the corners of the Compton Gamma Ray Observatory to provide the maximum unobstructed view of the celestial sphere. Each detector module contains a large-area detector (LAD), optimized for sensitivity and directional response, and a spectroscopy detector (SD) optimized for broad energy coverage and energy resolution. The eight planes of the large-area detectors are parallel to the faces of a regular octahedron. The three primary axes of the octahedron are parallel to the three principal axes of the spacecraft, as shown in figure 1. This provides nearly uniform sky coverage and produces an inherent symmetry in various aspects of the data analysis.



GAMMA RAY OBSERVATORY



BATSE DETECTOR ASPECT

Figure 1. The location and aspect of the eight BATSE detectors on the Compton Gamma Ray Observatory.

Table 1

	BATSE DETECTORS	
	LARGE AREA	SPECTROSCOPY
Material:	NaI(Tℓ)	NaI(Tℓ)
Frontal Area:	2,025 cm^2	127 cm^2
Thickness:	1.27 cm	7.62 cm
Energy Range:	30 – 1900 keV	15 keV – 110 MeV*
Energy Resol.:	27% @ 88 keV typ.	7.2% @ 662 keV typ.
		*Detector gain dependent

The basic characteristics of the two types of detectors are given in Table 1. A more comprehensive description of the instrument is given in several papers included in the first GRO Science Workshop (Fishman et al 1989a,b; Paciesas et al 1989; Pendleton et al 1989), and in a recent report (Horack 1991). A detailed paper on instrumentation and calibration is currently in preparation (Fishman et al 1992). The BATSE data system is a versatile and complex system. Data from the detectors are sorted on-board into 14 data types with different temporal and spectral resolution. Some data types are continuously transmitted according to a preprogrammed schedule, while other, higher time resolution data are accumulated from on-board triggered gamma-ray bursts. The data recorded from a burst require the duration of the following orbit, about 93 minutes, to unload the experiment burst memory. A summary of the characteristics of the data types are contained in the references above.

BATSE is expected to provide the most sensitive observations of gamma-ray bursts yet obtained. The more significant features of BATSE include: the ability to obtain the locations of weak bursts; the ability to detect spectral features and rapid spectral variations in many bursts, and the ability to provide burst locations to the scientific community quicker than previously possible. The celestial distribution and intensity distribution of hundreds of weak gamma-ray bursts, unobtainable with previous instrumentation, may finally provide the distance scale for gamma-ray bursts. BATSE will also be able to provide long-term and frequent monitoring of hard x-ray and low energy gamma-ray emission from the stronger sources, including transients, pulsating sources and solar flares.

On-Orbit Performance

All eight detector modules have been operating well since the experiment high voltage was turned on April 24, 1991. Considerable progress has been made in the determination of the on-orbit energy calibration, atmospheric scattering contributions and the detector response matrices (Pendleton et al, 1992; these proceedings). The background in the large area detectors above 30 keV varies between approximately 3000 and 6000 counts/s per detector during most portions of the orbit. Often, usually above geographic latitudes of about 24 degrees, the spacecraft encounters regions of enhanced background radiation due to precipitating electrons. During these times, bremsstrahlung from these electrons increases the background considerably and many times produces false burst triggers (Horack and Fishman 1991). The BATSE operations team has been successful in eliminating many of these false triggers by pre-determining the regions of high background and disabling the on-board burst trigger system at the appropriate times. Other sources of false burst triggers include solar flares and large increases in background radiation around the region of the South Atlantic Anomaly, especially during periods when the magnetosphere is disturbed.

During undisturbed times, the background radiation at energies between 30 keV and 100 keV is dominated by the diffuse x-ray background and discrete sources. Thus, the detector background is sensitive to the ratio of the earth/sky in the field of view, as well as which sources are in the field of view. At energies above 100 keV, the primary source of background is due to cosmic ray secondaries and is closely coupled to the geomagnetic latitude. The background shows an increase of approximately a factor of three twice per orbit at the high latitudes compared to that near the equator. At these energies, the counting rate is relatively insensitive to the detector aspect with respect to the earth.

Gamma-ray Burst Observations

The criteria for the on-board trigger of a gamma-ray burst are given in Table 2. During undisturbed times, the rate of gamma-ray bursts has averaged about one per day. The rate of false triggers increases to as much as six or eight per day during times of high solar activity or when the earth's magnetosphere is disturbed. During these times the apparent rate of real gamma-ray bursts decreases due to the reduction of the trigger efficiency, since the trigger threshold is increased until the burst data are read out over the next orbit.

Table 2

BATSE — Burst Trigger Criteria

- Trigger energy range : 60-300 keV
- 3 timescales tested : 64, 256, 1024 ms
- 5.5 σ increase above 17s background rate
- 2 or more detectors required to trigger

A few examples of the variety of gamma-ray bursts observed since launch are shown in Figures 2,3, and 4, and discussed in the captions. Detailed temporal and spectral analyses of gamma-ray bursts are underway. The results of these analyses will be presented in publications and presentations in the coming months.

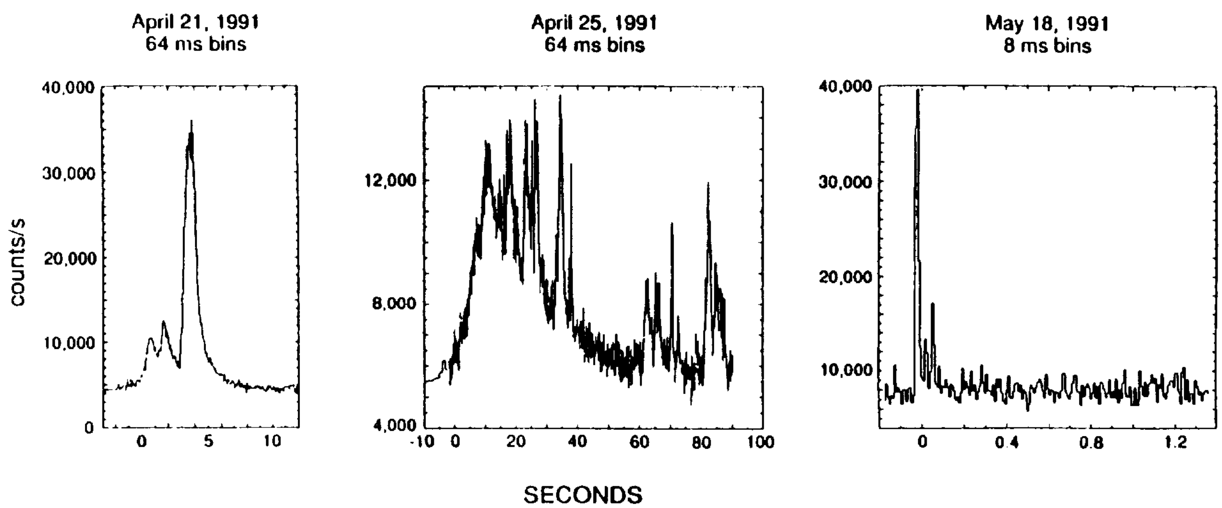


Figure 2. A sample of the wide variety of time profiles observed by BATSE. Burst durations have ranged from 8 ms to over 500 s. This figure illustrates three of the many types of time profiles that have been seen. The energy range of counts in these plots is 60 keV to 300 keV.

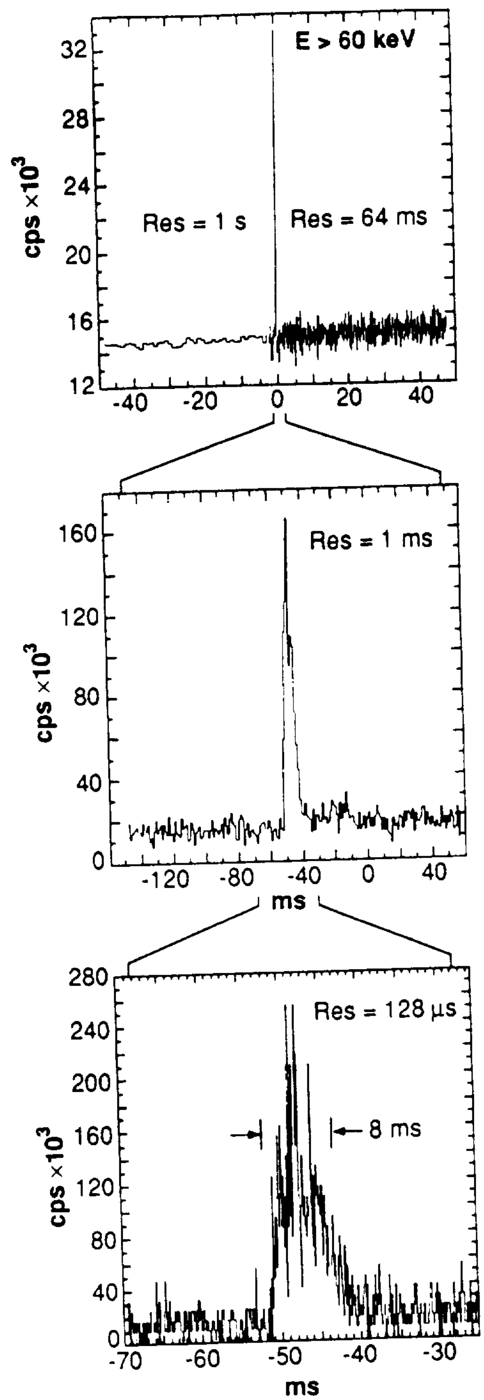


Figure 3. The shortest gamma-ray burst seen thus far (GRB 910711). The FWHM is 8 ms in this energy range. The burst is shown on three different time scales, with the time resolution indicated.

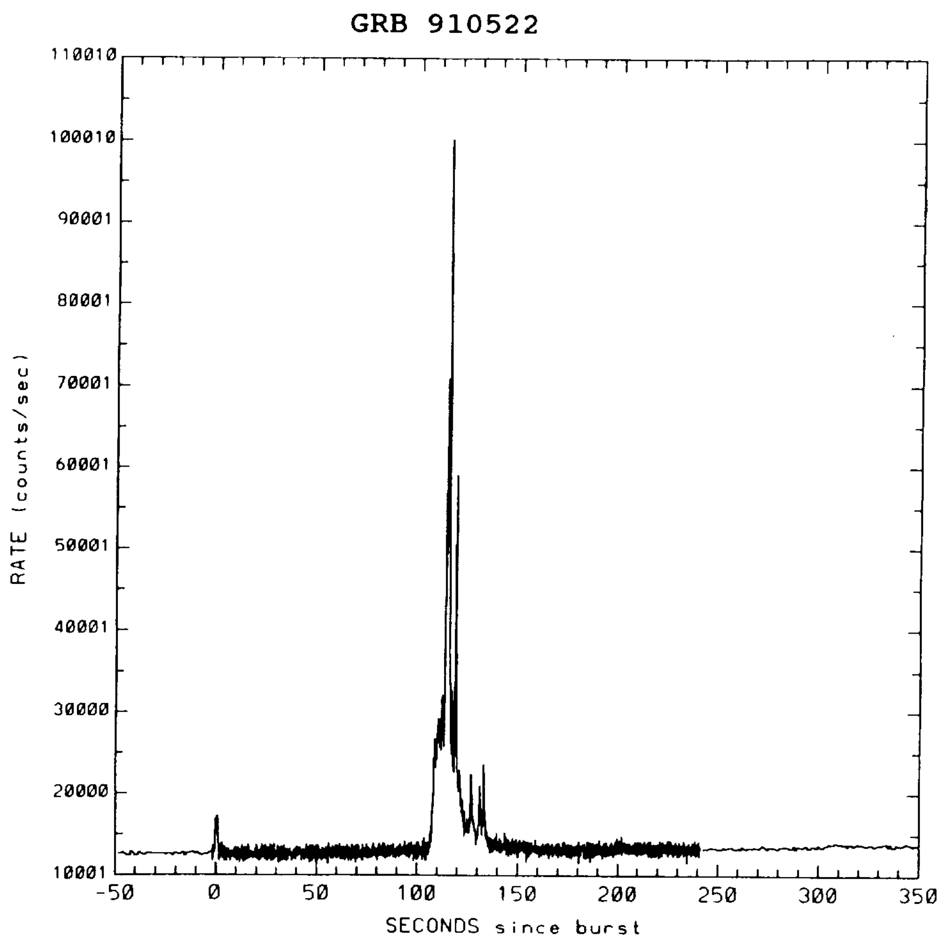


Figure 4. An unusual gamma-ray burst with a weak precursor occurring 110 s before the main part of the burst emission. Previous burst experiments would have missed this precursor or could not have determined that it was from the same location as the main part of the burst.

Perhaps the most dramatic and unexpected observation made by BATSE thus far is the isotropy of the distribution of gamma-ray bursts. From recent burst experiments on other spacecraft, as well as from the initial BATSE measurements of the frequency of gamma-ray bursts verses their intensity, it is apparent that the sources of gamma-ray bursts are spatially confined. The most widely assumed source of the confinement was thought to be the Galactic plane. The observed isotropy indicates that the gamma-ray bursts are not confined to the Galactic plane, and in fact, may not be due to Galactic objects. The explanation of this observation is not presently known and is currently the subject of intense speculation. Two exciting possibilities are that: 1) The gamma-ray bursts are coming from objects, probably neutron stars, in an extremely large, and previously undetected, spherical Galactic halo, or 2) They are coming from some unknown objects at cosmological distances. These observations were reported in an IAU Circular (Meegan et al 1991), and at a gamma-ray burst Workshop in Huntsville in October. They will also be published soon in Nature (Meegan et al 1991).

Other Early Results

The analysis of early BATSE observations of hard x-ray pulsars, other discrete sources, and solar flares is proceeding well. The high sensitivity and all-sky viewing of the BATSE detectors is expected to provide new data on many of these objects. These GRO Workshop Proceedings contain a sample of some of these early results. The reader is referred to BATSE papers in these proceedings with the following lead authors: R.B. Wilson, B.A. Harmon, M. Finger, C. Kouveliotou, and R.A. Schwartz.

The BATSE experiment supports an active Guest Investigator Program. Several of the GRO Phase One Guest Investigators have been heavily involved with various aspects of BATSE data analysis. We look forward to continued collaborations with guest investigators in succeeding phases of the Compton Gamma Ray Observatory Guest Investigator Program.

References

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