THE BURST ALERT TELESCOPE (BAT) ON THE SWIFT MIDEX MISSION

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Abstract. The burst alert telescope (BAT) is one of three instruments on the Swift MIDEX spacecraft to study gamma-ray bursts (GRBs). The BAT first detects the GRB and localizes the burst direction to an accuracy of 1–4 arcmin within 20 s after the start of the event. The GRB trigger initiates an autonomous spacecraft slew to point the two narrow field-of-view (FOV) instruments at the burst location within 20–70 s so to make follow-up X-ray and optical observations. The BAT is a wide-FOV, coded-aperture instrument with a CdZnTe detector plane. The detector plane is composed of 32,768 pieces of CdZnTe (4 × 4 × 2 mm), and the coded-aperture mask is composed of ∼52,000 pieces of lead (5 × 5 × 1 mm) with a 1-m separation between mask and detector plane. The BAT operates over the 15–150 keV energy range with ∼7 keV resolution, a sensitivity of ∼10−8 erg s−1 cm−2, and a 1.4 sr (half-coded) FOV. We expect to detect >100 GRBs/year for a 2-year mission. The BAT also performs an all-sky hard X-ray survey with a sensitivity of ∼2 m Crab (systematic limit) and it serves as a hard X-ray transient monitor.

Keywords: gamma-ray, GRB, hard X-ray, survey, burst, afterglow, CZT, coded aperture, astrophysics, cosmology

1. Introduction

1.1. SWIFT MISSION OVERVIEW

From the discoveries by BeppoSAX (Costa et al., 1997) and the subsequent ground-based follow-ups (Van Paradijs et al., 1997; Frail et al., 1999), we now know that gamma-ray bursts (GRB) are cosmological (red-shifts range from 0.0085 to ∼4.5). As of September 2004, there are 34 GRBs and two X-ray flashes with firm redshift measurements. Swift will add greatly to this number, and by studying the...
frequency histogram distribution with redshift, it will become possible to distinguish between a simple model in which GRBs simply trace the comoving volume of the Universe, and more detailed models that trace, for example, star formation. Historically, the difficulties involved with operations and scheduling constrain the time delay between the burst and when the small error-box positions are available, and therefore when the follow-up observations can begin, to be typically in the range of 3 to 8 h. These delays hold for all but two of the ∼100 GRBs that have follow-up observations – GRB990123 was observed in the optical during the burst itself (Akerlof et al., 1999). These time delays are rather limiting to the study of GRB engines. To constrain GRB theories in a meaningful way, a much shorter response time is required.

*Swift* will eliminate these delays and fill in the hole in the afterglow observations by using in a single spacecraft instrument to detect the burst, provide a position within a several seconds, incorporate on-board autonomy to execute a spacecraft slew without ground-based intervention, and point X-ray and UV/optical telescopes at the burst position to make follow-up observations within as little as 20–70 s after the start of the burst. For ∼10% of the bursts, the X-ray and UV/optical follow-up observations will begin while the GRB is still bursting in the gamma-ray bandpass. UV observations are not possible from ground-based instruments. It is this rapid-response, plus panchromatic approach, that will provide the next step in our understanding of GRBs. The *Swift* compliment of instruments also provides a powerful observatory for the follow-up of other hard X-ray transients detected by BAT.

1.1.1. The *Swift* Science

There are several key questions which the *Swift* mission will address: What are the sites and nature of the GRB progenitors? Are there multiple classes of GRBs? What are the local environments around the progenitors? What can GRBs tell us about the early universe? For a more complete discussion of these questions and a description of the science objectives by *Swift*, see Gehrels et al. (2004).

1.1.2. The *Swift* Instruments

The burst alert telescope (BAT) is a highly sensitive, large FOV, coded-aperture telescope designed to monitor a large fraction of the sky for the occurrences of GRBs. The BAT provides the burst trigger and the 1–4 arcmin accurate position, that is then used to slew the spacecraft to point the two narrow-FOV instruments (the X-ray telescope – XRT, and the ultraviolet and optical telescope – UVOT) for follow-up observations. While observing bursts, BAT simultaneously and automatically accumulates an all-sky hard X-ray survey. The BAT consists of a 5200 cm$^2$ array of $4 \times 4$ mm$^2$ CdZnTe elements located 1 meter behind a 2.7 m$^2$ coded-aperture mask of $5 \times 5$ mm$^2$ elements, with a point spread function (PSF) of 17 arcmin. The BAT coded-aperture mask, and hence its FOV, is limited by the Delta rocket fairing.