The INTEGRAL Burst Alert System

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Abstract. We describe the INTEGRAL Burst Alert System (IBAS): the automatic software developed at the INTEGRAL Science Data Center to allow the rapid distribution of the coordinates of the Gamma-Ray Bursts detected by INTEGRAL.

More than one GRB per month is expected in the field of view of the main INTEGRAL instruments. Positions with an accuracy of a few arcminutes will be distributed to the community for follow-up observations within a few tens of seconds of the event.

1 Introduction

The INTEGRAL gamma-ray astronomy satellite (Winkler 1999) carries two main imaging instruments operating in the $\sim$20 keV – 10 MeV energy range (SPI and IBIS) complemented by an X–ray (JEM-X) and an optical (OMC) monitor. The launch is scheduled in April 2002. The coded mask instruments on board INTEGRAL have large fields of view and offer the possibility of rapidly obtaining accurate positions of GRB's.

No on-board GRB triggering system is present on the INTEGRAL satellite. Since the data are continuously transmitted to the ground, the search for GRB's will be performed by means of a near real time analysis software running at the INTEGRAL Science Data Center (ISDC, Courvoisier et al. 1999). Here the relevant data packets will be extracted from the telemetry stream and fed into a dedicated software system (Mereghetti et al. 1999). The first step of the GRB search will be based on a simple monitoring of the IBIS and SPI count rates, without resorting to more complex image analysis. This will be done by looking for significant excesses with respect to a running average, in a way similar to traditional on-board triggering algorithms. The search will be simultaneously performed in different time scales and energy ranges, to optimize the sensitivity to GRB's with different characteristics. When a candidate event is detected, a process of image analysis shall start to verify the origin of the count rate variation and to ensure that the event was not caused by an instrumental malfunctioning or by a background variation. Images shall be accumulated for different time intervals, deconvolved with very fast algorithms, and compared to the pre-burst reference images in order to detect the appearance of the GRB as a new source. If the event is genuine, the satellite attitude information will be applied to derive a sky position that is then automatically transmitted to all the subscribed users. In addition, if the GRB is located in the sky region covered by the OMC, an appropriate telecommand will be sent to the satellite to reconfigure its observing parameters in order to optimize the possible detection of optical emission.

Because full event validation and localization might require a longer time, we foresee different levels of alert messages providing increasingly accurate and reliable information. These messages will be configured in such a way to allow an easy filtering by the users in order to react only to the situations that best fit their needs.

2 Number of expected GRB's

A simple estimate of the number of GRB's expected within the field of view of the INTEGRAL instruments can be done by scaling the total rate of events measured by BATSE ($\sim$666 GRB year^{-1}, Paciesas et al. 1999). For the field of view of IBIS ($\sim 30° \times 30°$), this yields 666 $\times$ (0.23 sterad / 4π) $\sim$ 12 GRB year^{-1}.

A more accurate estimate must take into account the varying sensitivity within the IBIS field of view and the different energy range of the BATSE detectors. This can be done by convolving the IBIS sensitivity and solid angle as a function of off-axis angle with the BATSE LogN-LogP relations, converted to the appropriate energy range assuming an average GRB spectral shape. Such computations do not significantly change the above rough result. In fact we obtain expected rates of $\sim$13, 10 and 8 GRB year^{-1}, within the IBIS field of view, adopting respectively the LogN-LogP corresponding to BATSE trigger times ΔT of 1 s, 256 ms and 64 ms. The major uncertainty on the derived GRB rates is related to the extrapolation of the BATSE LogN-LogP curves down to the IBIS sensitivity ($\sim$0.1 ph cm^{-2} s^{-1}, 50-300 keV peak flux for ΔT=1 s). Such an extrapolation depends on the poorly known spectral shape of the faintest GRB's.

These estimates do not take into account the possible existence of GRB's with different characteristics than those observed by BATSE. BATSE had a limited sensitivity for events shorter than 64 ms, as well as a strong bias against the detection of long, slowly rising GRB's. It is therefore very likely that the figures reported above are underestimated, and that a few events per month will be available through IBAS for rapid multi-wavelength follow-up observations.

3 IBAS Performances

3.1 Location Accuracy

The source location accuracy (SLA) of coded mask imaging systems depends on the signal to noise ratio of the source. For sources detected with a high statistical significance the SLA can be a small fraction of the angular resolution. Theoretical evaluations, confirmed by several independent simulations, have shown that for IBIS a SLA smaller than $30''$ (90% confidence level) can be obtained for a signal to noise ratio of 30. For most of the time (i.e. except during satellite slews) the INTEGRAL attitude accuracy will be $\lesssim 30''$. Actually, most of the detected GRB's will have relatively small signal to noise ratios, resulting in typical uncertainties, dominated by the photon statistics, of the order of $\sim$2-3$'$.

3.2 Time Delay

Using simulated telemetry data, we have obtained the following performance figures for the current prototype version of IBAS running on a SUN ULTRA 10 workstation (440 MHz clock, 256 Mbytes RAM - the final version will run on a faster workstation exclusively dedicated to the IBAS system).

The first IBAS steps (telemetry receipt, extraction and sorting of the relevant data packets, photon binning for the trigger search) require less than 0.1 s. The speed of the triggering algorithm depends on the duration of the smallest time interval considered and on the number of timescales. For example, sampling on bins of 1, 4, 16, 64 and 256 ms, with a resolution of 1 ms it is possible to process the telemetry at a speed twice faster than that of the real-time incoming data. The most time consuming tasks are those related to the image analysis. For this reason, the first part of imaging after a trigger is based on a detection algorithm able to discover new sources by only considering (ghost) peaks in the fully coded field of view. This can be done within $\sim$200 ms, allowing to discriminate between false triggers and true events. Only when a likely point source is detected, a more thorough analysis will be done to determine its position. The deconvolution of the whole (totally plus partially coded) field of view and localization of the true source peak currently requires $\sim$5 s. Thus it should be possible to send the first GRB alert within a few seconds after the trigger time. The delay between the trigger time and the GRB onset is of course dependent on the intensity and time profile of the event, but the IBAS simultaneous sampling in different timescales should ensure a minimum delay in most cases. To this time budget one has to add the time required for the telemetry transmission from the satellite to the ISDC, that under normal circumstances should be smaller than $\sim$30 s. Thus, in many cases, we foresee to be able to generate *first level* alerts while the GRB is still ongoing.

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