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Observing GRB's with INTEGRAL

Christoph Winkler[1]

Astrophysics Division, Space Science Department, ESA-ESTEC
2200 AG Noordwijk, The Netherlands

Abstract. The International Gamma-Ray Astrophysics Laboratory INTEGRAL is dedicated to the fine spectroscopy and fine imaging of celestial gamma-ray sources in the energy range 15 keV to 10 MeV. This paper summarises the GRB detection and observation capabilities of the INTEGRAL instruments and describes the dissemination of INTEGRAL GRB alerts to the science community to enable rapid follow-up observations of GRB error boxes for counterpart searches and subsequent investigations.

INTRODUCTION

INTEGRAL [16] is ESA's next major 15 keV - 10 MeV gamma-ray mission in collaboration with Russia (PROTON launcher) and NASA (ground stations). The observatory is scheduled for launch in 2001 with a lifetime of two years to up to five years. The scientific objectives focus around high-energy resolution spectroscopy and fine imaging/location of gamma-ray sources and include: study of compact objects (black holes, neutron stars); explosive and hydrostatic nucleosynthesis (supernovae and novae, WR stars); high energy transients and GRB's; mapping of the Galactic structure (Galactic Centre) and ISM; normal galaxies and clusters; AGN, Blazars and Seyferts; cosmic diffuse background and identification of high energy sources. The payload consists of a Germanium spectrometer (SPI) optimised to perform high-resolution spectroscopy of gamma-ray lines and observations of the large scale diffuse emission, a CdTe/CsI imager (IBIS) optimised to provide fine point source images with accurate locations and sensitive studies of broad lines, and two

[1] This paper is written on behalf of the INTEGRAL Science Working Team consisting of: T. Courvoisier, N. Gehrels, A. Gimenez, S. Grebenev, W. Hermsen, F. Lebrun, N. Lund, G. Palumbo, J. Paul, R. Sunyaev, B. Teegarden, P. Ubertini, V. Schönfelder, G. Vedrenne, C. Winkler

monitors in the X-ray (JEM-X) and optical energy range (OMC) which identify and monitor high energy sources at the low end of the INTEGRAL energy band. All instruments onboard INTEGRAL are co-aligned with overlapping FOV's and they operate simultaneously. The three high energy instruments utilize coded aperture masks. A particle radiation monitor complements the payload. The key features of the instruments are shown in Table 1. As a baseline, INTEGRAL[2] will be launched by a Russian PROTON launcher into a High Earth Orbit (48^h period, 46000 km perigee, 51.6° inclination) allowing to operate the science instruments entirely outside the Earth's trapped proton belt, and largely outside the electron belts. The entire orbit can be used for real-time scientific observations (downlink data-rate = 86 kbps).

GRB DETECTIONS AND OBSERVATIONS

From the scientific objectives and the instrument characteristics in Table 1 it follows that GRB's are one important scientific objective for INTEGRAL, but the payload is not specifically designed to support primarily a GRB mission. However, INTEGRAL is well suited to provide important new observational data on the GRB phenomenon. In particular, INTEGRAL will provide GRB locations to arcminute accuracy or better, spectral coverage from 3 keV (JEM-X) up to 10 MeV (IBIS, SPI) with concurrent optical monitoring and high resolution spectroscopy (3 keV FWHM @ 1.33 MeV). Recent discoveries of optical, X-ray and radio counterparts, as discussed during this Symposium, show, as expected, that major progress in understanding the GRB phenomenon comes from accurate locations, broad band coverage and rapid response. SPI [7], IBIS [14] and JEM-X [15] would detect GRB's in their nominal operational modes (on–ground, photon–by–photon events). In addition it its foreseen that IBIS will provide an on–board trigger to OMC [4] which subsequently switches into a burst trigger mode. The implementation of that trigger mechanism and the impact of false trigger events is currently under investigation by the instrument teams. The expected number of GRB's per year detected within the fully coded field of view has been estimated to 13 (SPI), 6 to 24 (IBIS) – where the lower and upper limits are given by the BATSE detection rate and extrapolation of the BATSE lgN/lgP distribution [13] – and 2 to 6 (JEM-X). IBIS will be able to locate GRB's with its upper CdTe detector area (2621 cm^2) to $< 30''$ (Table 1). A simulation of an IBIS GRB detection [12] is shown in Figures 1 and 2. Upon receipt of an IBIS trigger, the OMC [8] would accumulate a sequence of binned CCD images and compares them to the reference image accumlated at trigger time. The image is being searched and areas of significant flux variations are being identified and transmitted to ground.

[2] Further details on INTEGRAL can be found in [16] and references therein as well as on the WWW using URL http://www.rssd.esa.int/SA-general/Projects/Integral/integral.html

TABLE 1. Key performance parameters of the INTEGRAL payload.

	SPI	IBIS	JEM-X	OMC
Detection area	500 cm^2	2621 cm^2 (CdTe)	1000 cm^2	1k $\times$ 1k CCD
Energy range	20 keV – 8 MeV	15 keV – 10 MeV	3 – 35 keV	550 nm (V)
ΔE (FWHM)	3 keV @ 1.33 MeV	7 keV @ 100 keV	1.5 keV @ 10 keV	n/a
FCFOV[a]	16°	9×9°	4.8°	5×5°
PCFOV[b]	35°	29×29°	13.2°	n/a
Angular resol.	2°	12′	3′	17.6″/pixel
10σ source location	$< 15'$	$< 30''$	$< 20''$	8″
S_c[c]	7×10^{-8}	4×10^{-7}	9×10^{-6}	19.7^{m_v} (10^3 s)
S_l[d]	5×10^{-6}	1×10^{-5}	1.7×10^{-5}	–
Timing	100 μs	100 μs – 1000 s	100 μs	> 1 s

[a] Fully Coded Field of View
[b] Partially Coded Field of View (Zero Response)
[c] Cont. sensitivity (3σ, 10^6 s), at 1 MeV (SPI), 100 keV (IBIS), 6 keV (JEM-X), units = ph cm^{-2} s^{-1} keV^{-1}
[d] Line sensitivity (3σ, 10^6 s), at 1 MeV (SPI), 100 keV (IBIS), 6 keV (JEM-X), units = ph cm^{-2} s^{-1}

Routine observations (pointings of up to typically 14 days) allow in principle the observation of pre- and post-GRB emission in γ-, X-ray and optical domains. Due to specific requirements by the SPI instrument to improve its coded mask imaging, the spacecraft will perform, during many pointings, a number (7 – 25) of small (2°) dithering steps around the nominal target position along a hexagonal or rectangular pattern. This increases the effective sky area viewed by the instruments considerably. Quiescent or afterglow counterparts can principally be captured during nominal target pointings. Al-

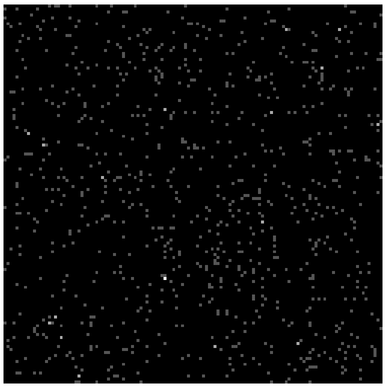

FIGURE 1. Simulation of 10σ GRB (600 background events, 250 source events) within IBIS 9×9° detection plane.

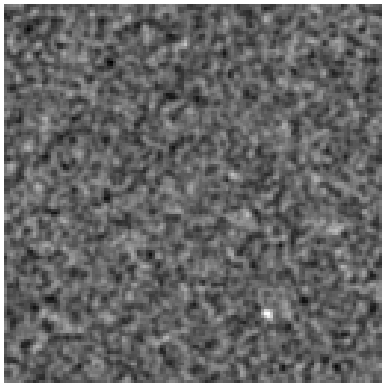

FIGURE 2. Deconvoled image (pixel size = 5′). The GRB is in the lower right corner.

ternatively the spacecraft can react to GRB's outside it's FOV through the standard Target of Opportunity mechanism which allows a re-scheduling of the observing programme and re-pointing of the spacecraft on average within $\sim$30 hours. It is noted that INTEGRAL will perform, as part of its Core Programme [5], weekly scans of a b = $\pm$ 20° wide strip along the entire Galactic plane to detect high energy transients (e.g. GRS 1915+105 etc.), and GRB's would be covered due to their spatial and temporal serendipity. We have estimated whether INTEGRAL would have detected the afterglow of GRB 970228, which may or may not be "typical" for GRB afterglow emission processes. The 55 s burst itself – as observed by SAX – can be fit at high energies (13 keV – 700 keV) by a -1.95 power law [3]. An observation of 5515 s duration by SAX/LECS of the fading counterpart (1.5 – 10 keV), 8 hours after the event, resulted in a -1.9 power law spectrum [11]. During this integration time, JEM-X would have possibly detected at 3σ the counterpart at $<$ 10 keV and marginally at 30 keV. At higher energies the afterglow is too soft to be detected. On shorter timescales, the prospects for observing the fading counterpart are more promising: X-ray afterglow data for 4 GRB counterparts in 1997 indicate a generic $t^{-1.1}$ decay curve up to 10^6 s after the event. IBIS and JEM-X would have sufficient sensitivity to discover afterglow emission on $\sim$ mCrab level at around one hour after the event.

INTEGRAL GRB ALERTS AND THE SCIENTIFIC COMMUNITY

Following the successful utilisation of the BACODINE/GCN network [1] and the BATSE/COMPTEL/NMSU rapid response system [9], it is planned to install a similar GRB alert system for INTEGRAL [12]. Its purpose is to faciliate rapid follow-up observations. Based on INTEGRAL detections, a largely automatic system at the INTEGRAL Science Data Centre (ISDC) in Geneva monitors the real–time telemetry in order to detect, localize and validate an event before an alert is distributed via TCP/IP sockets or e-mail to the community. Once the spacecraft has achieved stable pointing after a slew, the predicted attitude is known to few arcminutes accuracy. A snapshot of the actual (refined) spacecraft attitude is available 5 – 10 minutes into stable pointing (absolute pointing error $< 1'$) and will be sent from ESA to the ISDC in real-time. Various steps from detection, via ground station links to on-ground processing steps like deconvolution, validation, localization and alert release will result in a delay (i.e. time difference between dissemination of GRB alert message and GRB trigger time) of about 14 s (best case) to 344 s (worst case) [12], where the main delay (of the order of 300 s worst case) at present is associated with the ground station performances (delay of science telemetry at NASA ground stations). For the best case scenario it is noted that a significant number of GRB's, as deduced from the BATSE 3B distribution of durations [10], has durations longer than 14 s.

INTEGRAL, THE 4TH IPN AND BATSE

Following [6], the 4th Interplanetary Network (IPN) could consist of 3 interplanetary missions (Mars surveyor, Pluto express and Ulysses) while INTEGRAL, and possibly CGRO would provide large detectors in near Earth orbits. It is planned to use parts of the SPI anticoincidence subsystem to provide simple time histories (50 ms binning) for apx 300 GRB's/year above 4×10^{-7} erg/cm^2. A GRB event of moderate strength would produce a typcial annulus width of $\sim 7''$, assuming Ulysses at a distance of 4.3 AU. After the succesful reboost of the CGRO in 1997 into a higher Low Earth Orbit, the prospects of operating CGRO during the next decade are high. The BATSE instrument onboard CGRO could be of great value to support, as an all-sky monitor, the INTEGRAL mission. In particular the following GRB related areas would be of importance [2]: (i) During the Core Programme, INTEGRAL will perfom weekly scans of the Galactic plane (b $\sim \pm 20°$) while BATSE would cover the high-latitude range, i.e. $|b| > 20°$; (ii) BATSE would provide ancillary time history and spectral evolution data for those GRB's which are inside the INTEGRAL FOV.

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