IL NUOVO CIMENTO Vol. 28 C, N. 4-5 Luglio-Ottobre 2005
DOI 10.1393/ncc/i2005-10170-9

Gamma-ray burst detection and localization capabilities of the IBIS/INTEGRAL(*) telescope Compton mode(**)

R. Marcinkowski(1), Ph. Laurent(2)(3), M. Denis(1), P. Goldoni(2)(3)
T. Bulik(4) and A. Rau(5)

(1) *CBK - Bartycka 18a, PL-00-716 Warsaw, Poland*
(2) *SAp CEA - Saclay, 91191 Gif sur Yvette, France*
(3) *APC, UMR 7164 - 11 Place M. Berthelot, 75231 Paris, France*
(4) *CAMK - Bartycka 18, PL-00-716 Warsaw, Poland*
(5) *MPE - Giessenbachstrasse, 85748 Garching, Germany*

(ricevuto il 23 Maggio 2005; pubblicato online il 28 Ottobre 2005)

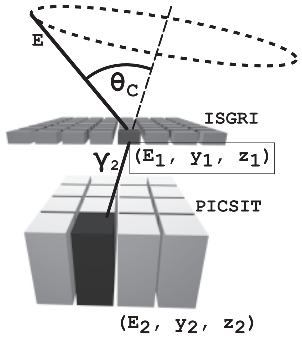
Summary. — We present the capabilities of the IBIS/INTEGRAL Compton mode for the detection and localization of GRBs. Based on the example of GRB030406 we demonstrate that the IBIS Compton mode is able to detect a GRB and (if it is strong enough) localize it with an accuracy of a few degrees. Energetic spectra extraction is also possible in the range from a few hundred keV to a few MeV.

PACS 95.55.Ka – X- and γ-ray telescopes and instrumentation.
PACS 98.70.Rz – γ-ray sources; γ-ray bursts.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

The IBIS telescope is the coded mask, imaging instrument on-board the INTEGRAL satellite [1,3]. The detector plane consists of two layers: ISGRI and PICsIT. ISGRI is an array (128×128) of pixels made of semiconductive CdTe, sensitive to photons between 15 keV and ~1 MeV. PICsIT, having the same detection area as ISGRI, is an array (64×64) of CsI scintillators, sensitive between ~170 keV and 15 MeV. The distance between the two layers is about 94 mm.

(*) Based on observations with INTEGRAL, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), Czech Republic and Poland, and with the participation of Russia and the USA
(**) Paper presented at the “4th Workshop on Gamma-Ray Burst in the Afterglow Era”, Rome, October 18-22, 2004.



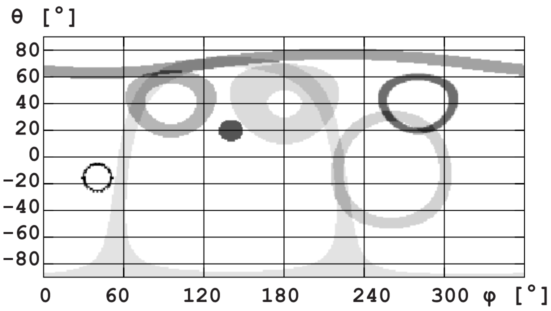


Fig. 1. – A Compton event in IBIS: the photon is scattered in an ISGRI pixel and absorbed in a PICsIT crystal (left panel). Examples of eight Compton rings on the all sky map — Cartesian projection — each ring corresponds to one Compton event (right panel).

2. – Compton mode

The Compton mode makes use of photons with energies mainly between a few hundreds of keV and a few MeV. About 2–5% of them are Compton scattered in one layer and absorbed in the other (fig. 1, left panel). Coincidences within an appropriate time window (1–5 μs) are detected on board and the energies and positions of both interactions are recorded. The use of Compton kinematics allows the determination of the Compton scattering angle θ_C, the energy of the primary photon $E_0 = E_1 + E_2$ and the direction of the scattered photon(γ_2).

3. – Compton maps

The direction of the scattered photon and the Compton angle (θ_C) define a cone. The intersection of this cone with the celestial sphere is a circle shown as a dashed ellipse in the left panel of fig. 1. The circles are converted to annuli with the width reflecting uncertainties in the measured energies and positions: E_1, E_2, y_1, z_1, y_2 and z_2. The right panel of fig. 1 shows examples of such rings with typical widths. The summation of many such Compton rings produces a Compton map. In the case of a strong source (like a GRB), a significant excess will appear at the source position on the Compton map.

4. – GRB030406

The SPI ACS [4, 6] triggers, identifying the GRB, were used for the selection of time intervals for the Compton mode analysis. We have analyzed the data collected over a period of 3 months and found a few cases where the Compton mode count rate increased significantly. At first we focused on GRB030320, whose position has been well measured by ISGRI and SPI as it was inside the FOV [5].

Here we present the analysis of the most interesting case: GRB030406 (36° off axis, out of the IBIS coded field of view). Figure 2 shows the light curve of the burst obtained with ~ 200 selected Compton photons. The selection made use of Compton kinematics, *i.e.,* only events for which Compton rings were compatible with the source position were selected. The events in the background estimation which was subsequently subtracted underwent the same selection. The signal-to-noise ratio reached $\sim 11\sigma$ in the peak.

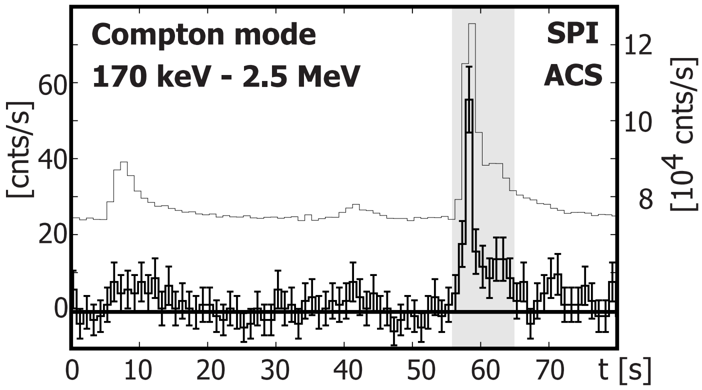


Fig. 2. – GRB030406 light curve from Compton mode (histogram with errors, left scale) and count rate in SPI ACS (bright histogram, right scale). The time interval denoted in grey has been used in the construction of the Compton map and spectral analysis.

The sky map (fig. 3) comprises information from about 1200 photons corresponding to the time interval marked on fig. 2 (but without selection previously described) and takes into account about 30 minutes of independent acquisition for the background estimation. Photons with energy between 200 keV and 950 keV have been used. We have assumed that the order of photons interactions was: ISGRI-first and PICsIT-next.

The data from the same time interval as for the map has been used for the best fit of the GRB spectrum (fig. 4). The fit was performed using the XSpec software package. Using Monte-Carlo simulations with the IBIS Mass Model [2] in Geant (3.21) we derived the specific Compton mode response matrix for GRB030406.

Additional simulations of the GRB030406-like burst combined with experimental background showed that the 1σ error of the position estimation is $\sim 3.5°$.

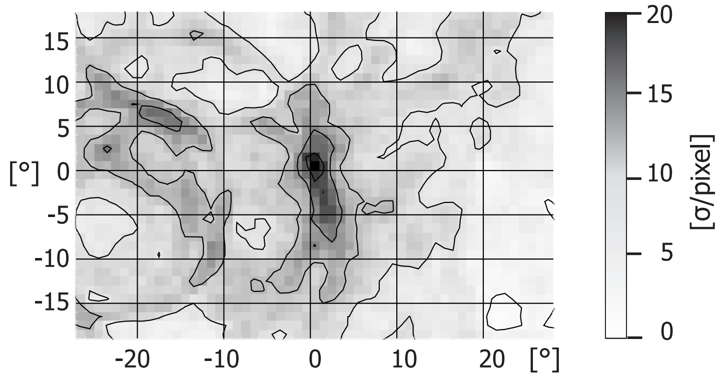


Fig. 3. – Compton mode significance map of the burst region centered on the IPN [7] reconstructed position of GRB030406 Ra $= 285.43°$ Dec $= -68.08°$. IPN's 3σ position uncertainty was about $9' \times 9'$ (not shown).

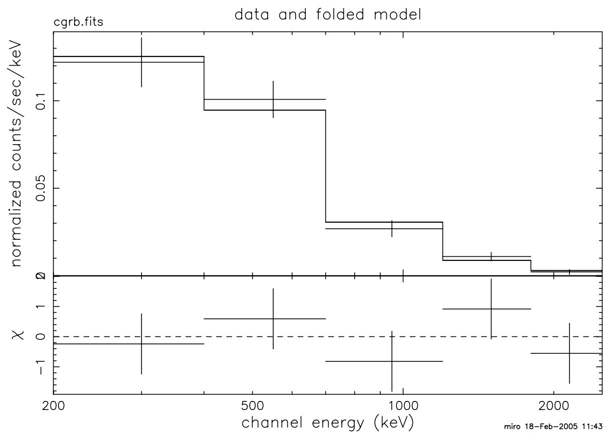


Fig. 4. – 200 keV–2.5 MeV spectrum of GRB030406. We show experimental data points and the best fit power law $\sim E^{-1.48\pm0.16}$ with residuals. The reduced χ^2 is equal 0.74 for 3 degrees of freedom and the normalization is arbitrary.

5. – Conclusion

The principal advantages of the IBIS Compton mode are:

- wide field of view, theoretically reaches 2π steradians;
- energy range 200 keV-6 MeV.

The IBIS Compton mode is able to:

- detect GRBs in the raw count rate (almost in real time),
- localize GRBs with up to a few degrees error box,
- provide photon spectra,
- complement INTEGRAL GRB detection and localization capabilities.

* * *

This research has been supported by the KBN grants 2 P03D 001 25, and PBZ-KBN-054/P03/2001.

REFERENCES

[1] Ubertini P. *et al.*, *A&A*, **411** (2003) 131.
[2] Laurent Ph. *et al.*, *A&A*, **411** (2003) 185.
[3] Goldwurm A. *et al.*, *A&A*, **411** (2003) 223.
[4] von Kienlin A. *et al.*, *A&A*, **411** (2003) 299.
[5] von Kienlin A. *et al.*, *A&A*, **411** (2003) 321.
[6] Rau A. *et al.*, astro-ph 0504357 (2005).
[7] Hurley K. *et al.*, `http://gcn.gsfc.nasa.gov/gcn3/2127.gcn3`, 2127 (2003).