A&A 411, L307–L310 (2003)
DOI: 10.1051/0004-6361:20031155

Astronomy & Astrophysics

Letter to the Editor

GRB 021125: The first GRB imaged by INTEGRAL⋆

G. Malaguti[1], A. Bazzano[2], V. Beckmann[3,4], A. J. Bird[5], M. Del Santo[2], G. Di Cocco[1], L. Foschini[1], P. Goldoni[6], D. Götz[7], S. Mereghetti[7], A. Paizis[3], A. Segreto[8], G. Skinner[9], P. Ubertini[2], and A. von Kienlin[10]

1 Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) del CNR, Sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy
2 Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) del CNR, Sezione di Roma, via Fosso del Cavaliere 100, 00133 Roma, Italy
3 INTEGRAL Science Data Centre, Chemin d'Écogia 16, 1290 Versoix, Switzerland
4 Institut für Astronomie and Astrophysik, Universität Tübingen, Sand 1, 72076 Tübingen, Germany
5 School of Physics and Astronomy, University of Southampton, Highfield, Southampton, SO17 1BJ, UK
6 CEA Saclay, DSM/DAPNIA/SAp, 91191 Gif-sur-Yvette Cedex, France
7 Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) del CNR, Sezione di Milano, via Bassini 15, 20133 Milano, Italy
8 Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) del CNR, Sezione di Palermo, via U. La Malfa 153, 90146 Palermo, Italy
9 Centre d'Étude Spatiale des Rayonnements, 9 avenue du Colonel Roche, 31028 Toulouse Cedex 4, France
10 Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse, 85748 Garching, Germany

Received 14 July 2003 / Accepted 30 July 2003

Abstract. In the late afternoon of November 25th, 2002 a gamma–ray burst (GRB) was detected in the partially coded field of view (about 7.3° from the centre) of the imager IBIS on board the INTEGRAL satellite. The instruments on-board INTEGRAL allowed, for the first time, the observation of the prompt gamma-ray emission over a broad energy band from 15 to 500 keV. GRB 021125 lasted ∼24 s with a mean flux of ∼5.0 photons cm^{-2} s^{-1} in the 20–500 keV energy band, and a fluence of $\sim 4.8 \times 10^{-5}$ erg cm^{-2} in the same energy band. Here we report the analysis of the data from the imager IBIS and the spectrometer SPI.

Key words. gamma rays: burst – gamma rays: observations

1. Introduction

INTEGRAL is the ESA satellite dedicated to the astrophysics in the X– and γ–ray domain, launched on October 17th, 2002 (Winkler et al. 2003). It is composed of two main high–energy telescopes (IBIS, SPI) coupled with two monitors, one in the X–ray energy band (JEM–X, Lund et al. 2003) and the other working at optical wavelengths (OMC, Mas–Hesse et al. 2003). IBIS (Ubertini et al. 2003) has moderate energy resolution, and is optimized for fine imaging, with 12′ angular resolution, and ≤1′ point source location accuracy for ≥30σ detections (Gros et al. 2003) in a 9° × 9° fully coded field of view. IBIS is composed of two layers: ISGRI (Lebrun et al. 2003) working in the energy band 15–1000 keV, and PICsIT (Di Cocco et al. 2003) operating from 175 keV to 10 MeV. The spectrometer SPI provides spectra with high energy resolution (3 keV at 1.7 MeV) in the energy band from 20 keV to 8 MeV (Vedrenne et al. 2003).

Just a few weeks after the launch, the INTEGRAL satellite started the in–orbit calibration observing Cyg X–1. On November 25th, 2002, the satellite was set up for a special observation with the PICsIT layer in the non–standard photon–by–photon mode, a reduced number of channels, and most of the satellite telemetry. This special configuration was required since PICsIT operates in an energy band where the background rate is very high (≈3500 counts/s on the whole detector) and the available telemetry is not sufficient to download all the data (for more details on the PICsIT modes of operation see Di Cocco et al. 2003) in photon-by-photon. So, to perform the calibration of PICsIT photon–by–photon mode it was necessary to limit the operative range at <500 keV and to strongly reduce the telemetry allocation to the other instruments (SPI, JEM–X, OMC were sending only housekeeping data to ground) and to the ISGRI layer of IBIS.

During this test, at 17:58:30 UTC a gamma–ray burst occurred in the partially coded field of view of IBIS (about 7.3°

Send offprint requests to: G. Malaguti,
e-mail: `malaguti@bo.iasf.cnr.it`

⋆ 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, Spain, Switzerland), Czech Republic and Poland, and with the participation of Russia and the USA.

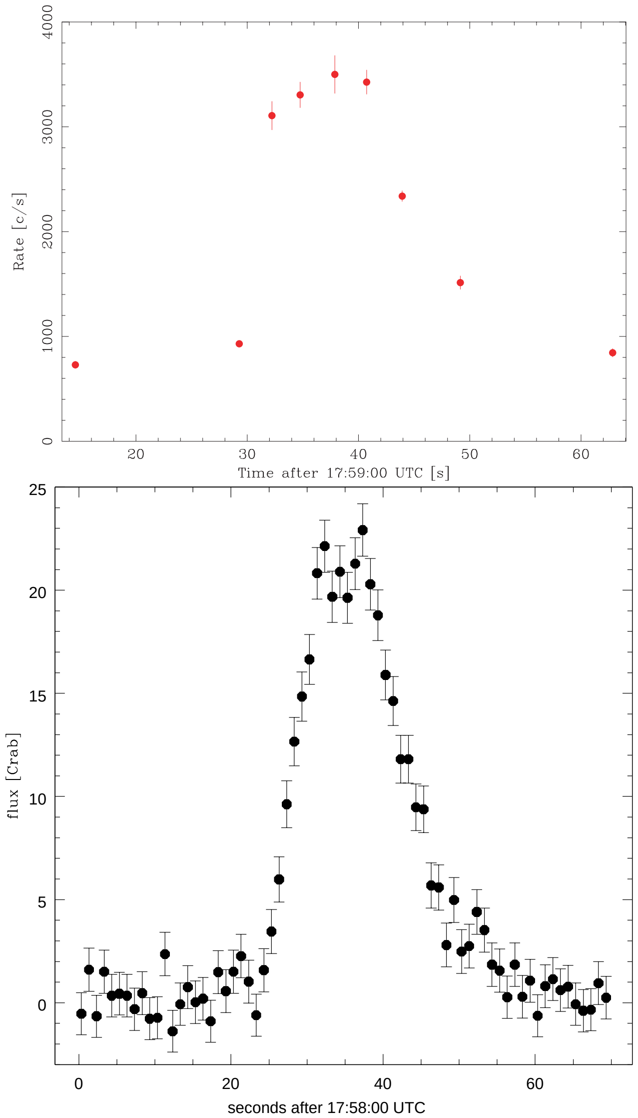

Fig. 1. GRB 021125 lightcurves: (*top*) IBIS/ISGRI lightcurve in the whole energy range, heavily affected by telemetry gaps; time starts from 17:58:00 UT. (*bottom*) SPI lightcurve (in Crab units) obtained from the detector count rates in the energy range 0.02–8 MeV, which are part of the scientific housekeeping data; time starts from 17:58:00 UT.

off–axis), and lasted about 24 s (Bazzano & Paizis 2002). The burst was soon confirmed by the InterPlanetary Network (IPN) composed of the satellites Ulysses, Mars Odyssey–HEND, and RHESSI (Hurley et al. 2002). Here we report on the analysis of the data from the INTEGRAL instruments.

2. Lightcurves

Lightcurves were available from IBIS and SPI instruments. For the former, the ISGRI detector data were strongly affected by telemetry reduction (data were available only for about 10% of time), so that the lightcurve has very few points (Fig. 1). Due to the restricted telemetry mode, SPI transmitted to ground only the science housekeeping data containing the detector's total count rates. In this case, the energy band is 20 keV–8 MeV, with a time resolution of 1 s (Fig. 1). The IBIS/PICsIT layer,

Table 1. Sky coordinates of the GRB 021125 as seen by the different instruments onboard INTEGRAL and by the IPN (3σ).

Instrument	RA (J2000)	Dec (J2000)	Error radius
IBIS/ISGRI	19:47:56	+28:23:28	2′
IBIS/PICsIT	19:47:51	+28:19:16	5′
SPI	19:47:55	+28:23:49	13′
IPN (centre)	19:47:25.93	+28:16:0.45	
IPN (corner 1)	19:46:49.27	+28:09:14.20	
IPN (corner 2)	19:47:47.73	+28:13:09.68	
IPN (corner 3)	19:47:37.78	+28:21:06.43	
IPN (corner 4)	19:48:36.40	+28:25:00.85	

although with a special amount of dedicated telemetry and a reduced number of channels, was influenced by telemetry gaps (about 62% of events were downloaded), clearly visible in Fig. 2. Moreover, only PICsIT single (i.e. events which deposit their energy in one pixel only) events were sent to ground, thus limiting the information for the high energy part of the spectrum.

Considering the duration of the GRB as the time when the count rate is more than 4σ above the background rate, we have that GRB 021125 was 24 s long in the energy range of IBIS/PICsIT, while it is 23 s according to SPI–ACS. For IBIS/ISGRI, because of the telemetry gaps, we have only a lower limit of 21 s.

The IBIS/PICsIT lightcurve (Fig. 2) in different energy bands shows the indication of a possible softening in the second part of the GRB. This is also consistent with the steep spectrum in the PICsIT energy range (see Sect. 4). On the other hand, the absence of detection above 500 keV could be due to the limited PICsIT energy range during this observation.

3. Imaging

The fact that PICsIT was in photon–by–photon mode, allowed the extraction of the events in the time region around the burst and the subsequent deconvolution using the standard software IDAS[1]. The same occurred for IBIS/ISGRI, for which the photon–by–photon mode is already the standard operation mode and the only available. In addition, for ISGRI it was possible also to use the IBAS (INTEGRAL Burst Alert System, Mereghetti et al. 2003) off–line software, even though the special set up for PICsIT strongly reduced the available telemetry for ISGRI. Nevertheless, it was possible to obtain images also for ISGRI and to reconstruct the sky position. Only the scientific housekeeping and on board spectra data were available for SPI, because of the special configuration of INTEGRAL. However, these data allowed to obtain a deconvolved image, although with non–standard techniques.

The GRB coordinates as seen by INTEGRAL instruments and the IPN are shown in Table 1. Figure 3 shows the error boxes for IBIS/ISGRI (Gros & Produit 2002), IPN (Hurley et al. 2002), SPI, and IBIS/PICsIT.

[1] *INTEGRAL Data Analysis System*, available at `http://isdc.unige.ch/index.cgi?Soft+download`. See also Goldwurm et al. (2003).

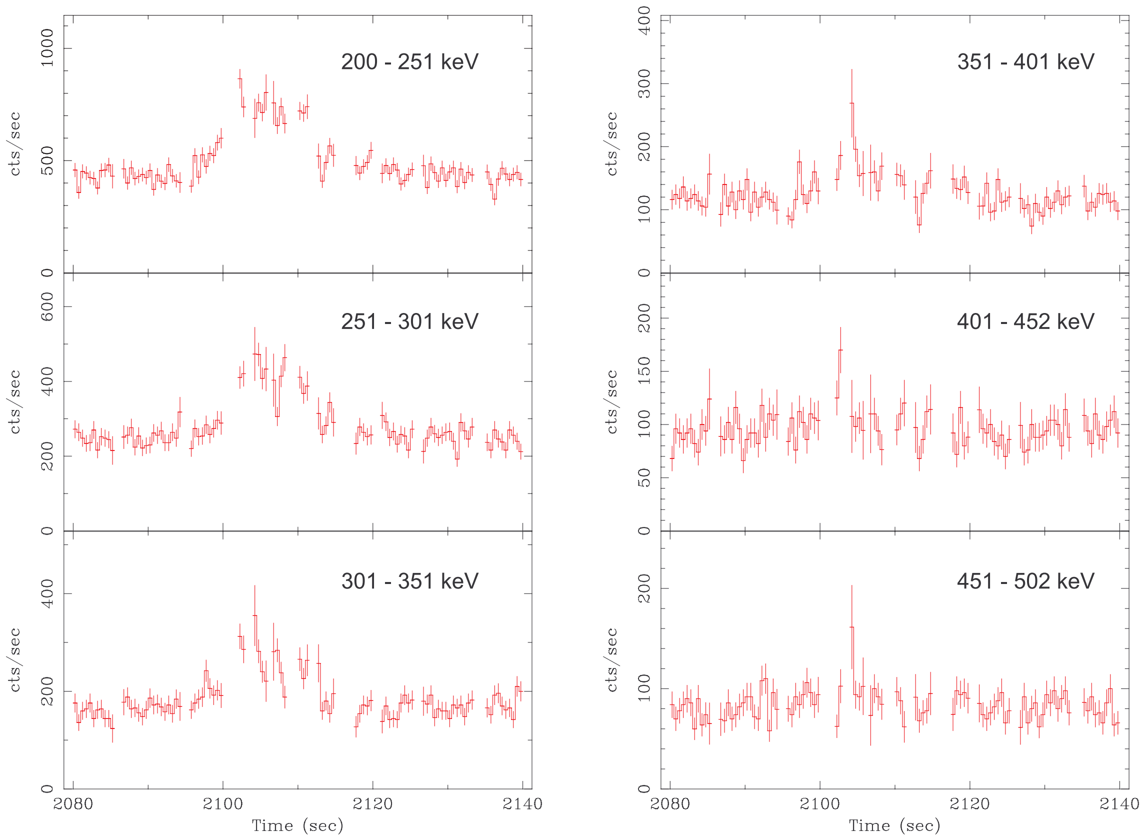

Fig. 2. GRB 021125: IBIS/PICsIT lightcurve for single events in different energy bands. Time starts from 17:23:50 UT.

The non-standard telemetry configuration of the instruments forced the IBAS[2] system to remain in idle mode. This, together with the fact that INTEGRAL was still in the PV phase, caused a delay in the release of the GRB coordinates of about one day, while the refined error box (with 2 arcmin uncertainty) was released only 3.7 days after the GRB. Therefore, the fact that no optical counterpart of GRB 021125 was found, could mean that the afterglow was below the actual sensitivities of ground telescopes.

4. Spectral analysis

IBIS is a coded mask detector and the photons of a single point source are spread all over the detector (e.g. Skinner 2002). The procedure of spectral extraction for ISGRI consists of the modelling of the illuminated mask by a point source of unitary flux, placed in the same sky coordinates of the GRB. Then, the model is fitted to the detected shadowgram in each energy channel to obtain the rate and error for each channel (see Goldwurm et al. 2003 for more details). The count spectra obtained by using this procedure, independently implemented in both ISGRI off–line scientific analysis and IBAS off–line software gave results in very good agreement.

The high PICsIT count rate during the burst (about 50% more than the background level) has allowed the use of a more direct procedure. The count spectrum of the GRB has been extracted by subtracting the background obtained from an empty field observation, and cleaning for the cosmic–rays induced events. This method implemented both in the Ground Support Equipement (GSE) and in the Instrument Specific Software (ISSW), has given results in good agreement.

The 20–500 keV time averaged spectrum from combined data of ISGRI and PICsIT, both corrected for intrinsic

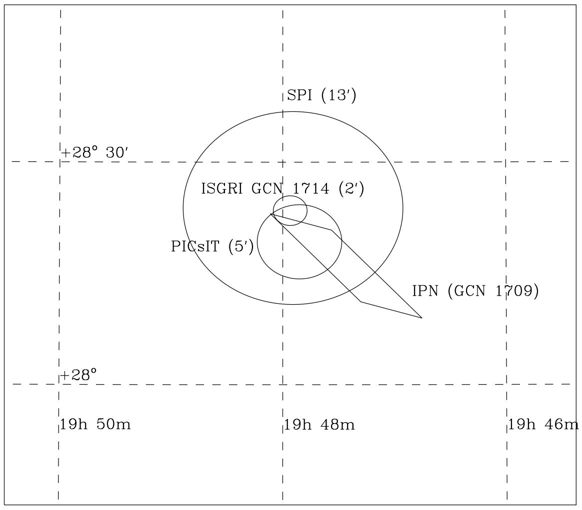

Fig. 3. Localisation uncertainties of the GRB 021125 from IBIS/ISGRI, IBIS/PICsIT, SPI, and the Interplanetary Gamma–Ray Burst Timing Network. For more details see Table 1.

[2] Normally, IBAS is triggered by the ISGRI layer, but in this case the limited data flow received from the detector telemetry did not allow the triggering.

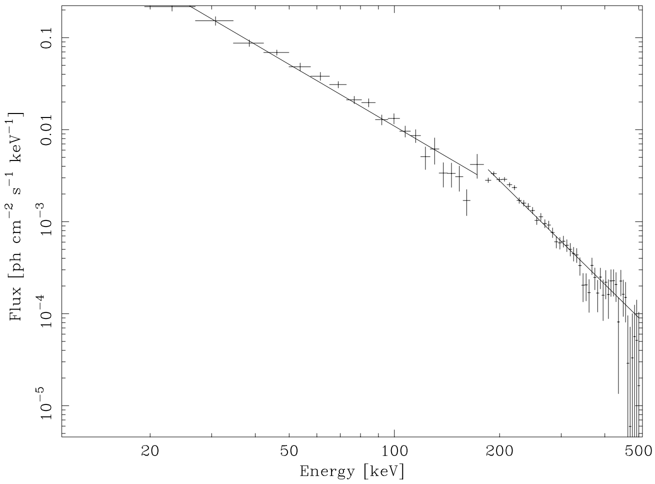

Fig. 4. IBIS photon spectrum of single events in the energy band 20–500 keV, fitted with the two power law models. The boundary between the two layers data is clearly visible.

detector deadtimes and telemetry gaps, is shown in Fig. 4. ISGRI refers to the energy range 20–180 keV, while PICsIT covers the range 175–500 keV. The low energy part of the spectrum (ISGRI) is well fitted with a power law model with $\Gamma \approx 2.2$, while the PICsIT part is fitted with a power law with $\Gamma \approx 3.7$. This difference in spectral indices between ISGRI and PICsIT could be the indication of a spectral break around 200 keV, but given the present uncertainties in the response of the two layers, it is not possible to clearly define the energy of the break. In any case, the estimated value would be in agreement with the statistical distribution of the energy break calculated by Preece et al. (2000) on the basis of about 5500 GRB observed with CGRO/BATSE. The apparent inconsistency between the ISGRI and PICsIT fluxes at 180–200 keV, is to be ascribed to the uncertainty in the ISGRI absolute flux measurement due to the large data loss caused by the 90% dead time during the GRB.

The average fluxes, corrected for intrinsic detector deadtimes and telemetry gaps, are 5.3 ± 0.6 ph cm^{-2} s^{-1}, and 0.25 ± 0.03 ph cm^{-2} s^{-1}, in the ISGRI and PICsIT energy bands, respectively. These correspond to 14 ± 2 Crab for ISGRI and 9 ± 1 Crab for PICsIT. The average flux obtained by SPI in the energy range 0.02–8 MeV is 9 ± 1 Crab, in agreement with IBIS. The fluence is approximately 5.1×10^{-5} erg cm^{-2} in the whole IBIS range.

As observed by Ulysses, the GRB had a duration of approximately 30 seconds, a 25–100 keV fluence of approximately 8.7×10^{-6} erg cm^{-2} and a peak flux of approximately 7.8×10^{-7}erg cm^{-2} over 0.50 seconds (Hurley et al. 2002).

5. Final remarks

GRB 021125 was the first GRB detected by INTEGRAL in the field of view of the IBIS imager. The sky coordinates reconstruction with IBIS and SPI are in agreement with each other, and consistent with the error box of the Interplanetary Network. The spectrum and lightcurve, obtained with independent methods, which gave consistent results, show an indication of a possible softening of the spectrum in the second part of the GRB.

GRB 021125 has shown the capabilities of the instruments on board the INTEGRAL satellite.

Acknowledgements. This work has been partially funded by the Italian Space Agency (ASI). LF acknowledges the hospitality of the INTEGRAL Science Data Centre (ISDC) during part of this work. AJB acknowledges funding by PPARC grant GR/2002/00446.

References

Bazzano, A., & Paizis, A. 2002, GCN 1706

Di Cocco, G., Caroli, E., Celesti, E., et al. 2003, A&A, 411, L189

Goldwurm, A., David, P., Foschini, L., et al. 2003, A&A, 411, L223

Gros, A., & Produit, N. 2002, GCN 1714

Gros, A., Goldwurm, A., Cadolle–Bel, M., et al. 2003, A&A, 411, L179

Hurley, K., Mazets, E., Golenetskiiet, S., et al. 2002, GCN, 1709

Lebrun, F., Leray, J. P., Lavocat, P., et al. 2003, A&A, 411, L141

Lund, N., Brandt, S., Budtz-Jorgensen, C., et al. 2003, A&A, 411, L231

Mas–Hesse, J. M., Giménez, A., Culhane, L., et al. 2003, A&A, 411, L261

Mereghetti, S., Götz, D., Borkowski, J., Walter, R., & Pedersen, H. 2003, A&A, 411, L291

Preece, R. D., Briggs, M. S., Mallozzi, R. S., et al. 2000, ApJS, 126, 19

Skinner, G. K. 2002, in The Gamma-Ray Universe, Proc. of the XXXVII Rencontres de Moriond, ed. A. Goldwurm, D. N. Neumann, & J. Tran Thanh Van (The Gioi Publ.), 423

Ubertini, P., Lebrun, F., Di Cocco, G., et al. 2003, A&A, 411, L131

Vedrenne, G., Roques, J.–P., Schönfelder, V., et al. 2003, A&A, 411, L63

Winkler, C., Courvoisier, T. J. L., Di Cocco, G., et al. 2003, A&A, 411, L1