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The First GRB Survey of the IBIS/PICsIT Archive

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We investigate the capabilities offered to the study of GRBs by the IBIS/PICsIT (0.2-10 MeV) instrument on board the INTEGRAL satellite. We search for transient episodes in the PICsIT light curves archive covering the time period from May 2006 to August 2009, using stringent criteria optimized for the detection of long events. PICsIT successfully observes GRBs in the 260 – 2600 keV energy range, with incoming direction spread over half sky for the brightest events. We compile a list of 39 bursts, most being confirmed GRBs or simultaneous to triggers from other satellites/instruments. The good time resolution provided by PICsIT data allows us to produce light curves and hardness ratios in three energy bands. For all events we derived fluences and peak fluxes in instrumental units. Since an adequate response matrix is not yet available for the PICsIT burst sample, we obtain a calibration coefficient by comparing instrumental counts with physical fluences inferred from observations with different satellites.

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1. Introduction

PICsIT [2], the high-energy detector of the IBIS imager [4] on-board the INTEGRAL satellite [5], consists of a 64×64 pixels array of CsI(Tl) scintillators, operating in the nominal energy band 175 keV-10 MeV. Due to the tight telemetry rate available, PICsIT scientific data are pre-processed on-board and organized in Spectral Imaging (SI) and Spectral Timing (ST) histograms before they are sent to the ground. Spectral imaging histograms preserve the full spatial information but they are integrated over the whole duration of each pointing (typically a few thousand seconds) and are in general useless for GRBs. ST data provide the total rate of events on the detector plane with a configurable time binning down to 1 ms resolved in up to eight energy channels, but the spatial information is not preserved. We here summarize the results of the search for GRBs in the ST light curves archive. A detailed discussion on method and sample properties can be found in [1].

2. PICsIT Data and Method

We analyzed the ST public archive restricted to May 2006 – August 2009 (revolutions 440–834), when the time resolution was set to 16 ms and the energy range 208-2600 keV was sampled in the 8 channels reported in Table 1. We defined a burst candidate as an excess in the light curve: $C_i > B + N\sigma$, where C_i is the number of counts in the i-th time bin, the background B is defined as the average of counts, N is the threshold in units of standard deviation σ. The search for GRB candidates is first performed on the raw data of each observation (Science Window – ScW) rebinned at 10 s resolution and using N=8. Thus we are mostly sensitive to long GRBs. The search is performed in the $260 - 312$ keV energy band, which maximizes the signal to noise ratio (SNR) for typical GRB spectra. The first energy bin is neglected, since affected by a systematic non-Poissonian background component. ScWs with GRB candidates are processed by `osa v.7.0`. The trigger time of bursts is cross-checked with solar flares or high activity to exclude particle events and then compared with GCNs and GRB/trigger catalogs available from other instruments.

3. Burst Sample

The PICsIT burst sample consists of 39 events (Table 2): 23 bursts have been detected and localized by other satellites confirming their GRB nature; most of the remaining events are simultaneous to triggers from other observatories and only 4 are detected exclusively by PICsIT. Sixteen bursts are hard events detected up to the highest energy channel, 26 reach the 780-1196 keV band, and 2 are not visible above 468 keV. The fine time and energy sampling allow us to produce light curves and hardness ratio for each event (Fig. 1). A simple χ^2 test applied to the hardness ratio curves identifies 9 events with significant spectral variability (with probability $> 90\%$) without a common evolution, as observed for different energy regimes, by other instruments [3] .

Channel	1	2	3	4	5	6	7	8
keV	208-260	260-312	312-364	364-468	468-572	572-780	780-1196	1196-2600

Table 1: Energy bands for ST data since May 2006.

Burst	UT (hh:mm:ss)	T_{90} (s)	Fluence (ct)	Peak Flux (ct/s)	Energy range (keV)	Instrument	GCN #
060805B	14:27:15	4.7± 0.4	6315±186	3600±208	260-2600	IA, K, R	5407
060819	18:28:13	14 ± 2	12228±305	2394±195	260-2600	IA, K	
060901	18:43:56	8 ± 1	2199±182	1671±186	260-780	II, K	5491
060905	14:48:51	239 ± 47	25055±849	1918±188	260-572		
060928	01:20:06	31 ± 4	38936±462	4966±220	260-2600	B, IA, K, R, S	5684
061031	12:19:47	34 ± 3	4707±329	1367±186	260-572	K	
061122	07:56:52	>1.50	>2196	> 3212	260-780	II, K	5834
061222A	03:30:15	10.5± 1.5	3509±236	1871±191	260-1196	B, K	5954
070207	21:00:48	10.0± 0.5	6178±255	3700±210	260-2600	B, IA, K, S	6089
070227B	21:39:23	32± 13	3341±316	672±179	260-572	IA, R	
070326	00:45:26	26.2± 0.7	3080±302	1466±189	260-468	IA	
070329	14:59:48	40± 3	8720±495	1048±185	260-2600	IA, K	
070403	12:40:28	47± 3	5788±347	701±181	260-468		
070418	17:16:19	31± 2	5471±369	1461±192	260-780	K	
070429	02:40:28	20.50±0.4	3081±326	1634±192	260-2600		
070829	20:08:36	73± 1	9766±618	1762±194	260-1196	IA, K	
070917	04:41:24	7± 2	2946±202	1119±95	260-780	IA, K	
071003	07:40:54	12.0± 0.3	16175±302	4013±218	260-2600	B, K, II	6837
071006	06:42:08	47± 8	3332±401	940±188	260-572	B, K, IA	6858
071108	21:40:29	20.0± 0.5	9976±372	5072±229	260-2600	IA, K, A	
080122	18:32:43	105± 4	10796±743	2112±199	260-1196	IA, K, S, A, B	7211
080204	13:56:35	14± 3	9901±312	4254±220	260-2600	K, IA, S, A, B	7256
080303	21:34:45	29.2± 1.5	31507±461	8283±254	260-2600	IA	
080319B	06:12:50	42± 1	29392±536	1905±198	260-2600	B, K	7427
080328	08:03:12	33± 2	6593±419	2243±200	260-1196	B, K, S, IA	7525
080408	10:23:25	40± 1	6355±424	1464±194	260-780		
080514B	09:55:58	6± 1	5611±195	3495±214	260-2600	A, K, S,IA	7715
080607	06:07:27	10± 1	4748±195	2225±201	260-2600	B, A, K, IA	7847
080613B	11:12:40	31.7± 0.5	5181±417	1712±197	260-1196	B, K, IA	7877
080615	04:07:33	9.5± 0.3	6769±239	2768±206	260-1196	K, R	
080721	10:25:14	16.0± 0.3	14627±340	4888±227	260-2600	B, K, IA, R	7988
080723B	13:22:34	45± 2	>9936	>3030	260-780	II, A, K	8002
080817A	03:52:16	42± 2	10461±528	1509±196	260-1196	F, K, IA	8108
080918	09:44:37	2.5± 0.3	3986±147	3916±220	260-2600	K, IA	
090528B	12:22:57	81 ± 7	6665±622	1141±199	260-780	F, S, K, IA	9447
090618A	08:29:26	15± 7	3032±301	865±198	260-1196	B,A,F,K,S,IA	9512
090623	02:34:30	40± 2	6517±489	1540±204	260-1196	F, S, K, IA	9566
090626A	04:32:11	42± 1	13167±545	3577±221	260-2600	F, S, K, IA, B	9579
090809B	23:28:17	9± 1	3399±257	1501±203	260-1196	F, K IA	9760

Table 2: Observables of the PICsIT burst sample: Burst name and trigger time; T_{90}, Fluence in units of counts integrated over T_{90} and Energy range; Peak flux in the same energy band; telescope/instruments that observed the event (A = AGILE, B= Swift/BAT, F = Fermi/GBM, II = *INTEGRAL*/ISGRI, IA = *INTEGRAL*/SPI-ACS, K= Wind/Konus, R = RHESSI, S = Suzaku/WAM); GCN number of confirmed GRBs.

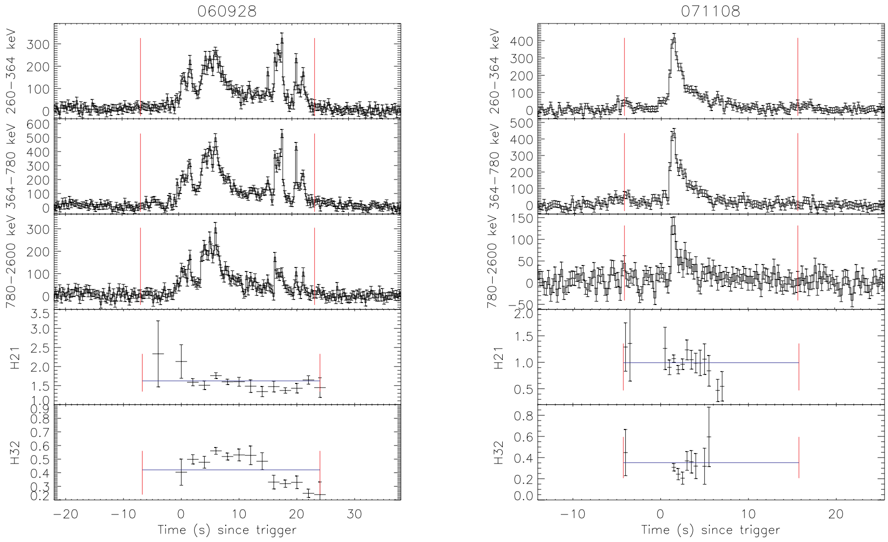

Figure 1: Light curve and hardness ratio for GRB 060928 (*left panel*) and Burst 071108 (*right panel*).

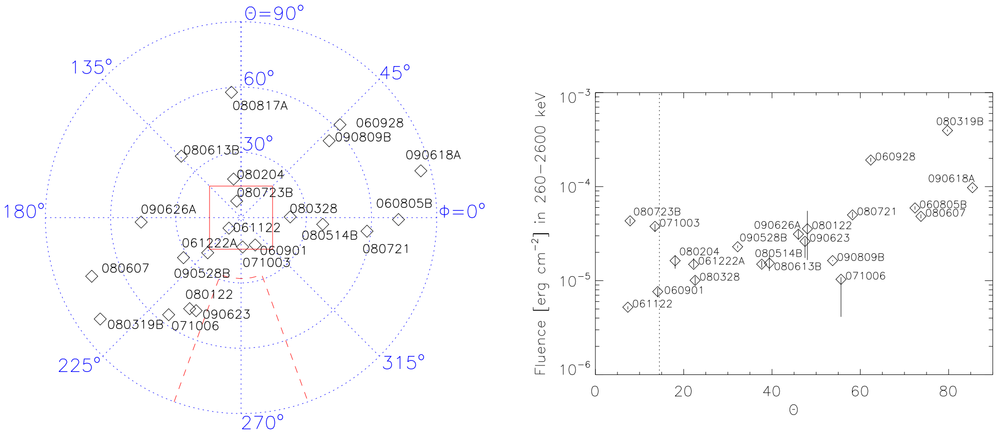

Figure 2: *Left panel*: GRBs spatial distribution in the (Θ, ϕ) plane, where Θ is the off-axis angle and $\phi =$ the azimuth (sun direction: $\phi = 90°$). The approximate PICsIT FoV (red square) and the region shielded by the spectrometer SPI (dashed line) are also shown. *Right panel*: Fluence in 260-2600 keV as a function of the off-axis angle. Fluences are converted to the PICsIT energy range from spectral parameters reported in literature for each single GRB.

3.1 Spatial Distribution and Spectral Characterization

Although not provided by the ST data, the event arrival direction in instrumental coordinates can be derived for the GRBs which have been localized by other satellites. The spatial distribution in instrumental coordinates (left panel of Fig. 2) shows that most bursts arrive from large off-axis direction, i.e. out of the PICsIT imaging field of view (FoV), where an instrument response matrix is not available.

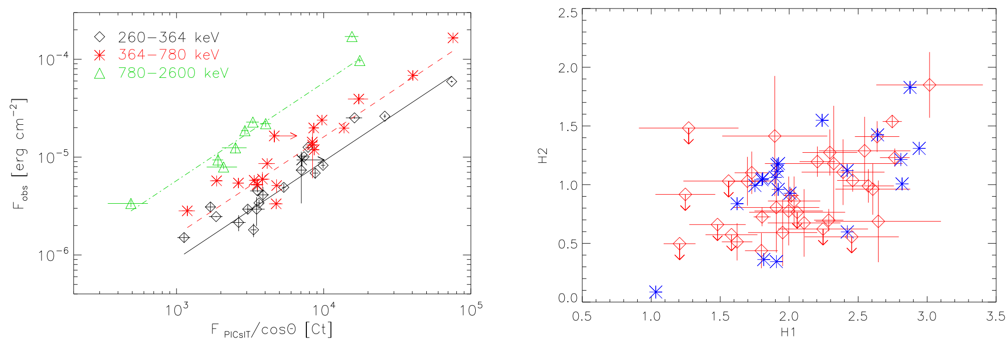

Figure 3: Spectral Characterization. *Left panel*: Correlation between fluences derived from observations with other instruments and PICsIT measured counts. The residual dispersion is due to a more complicated energy- and direction-dependent instrumental response as well as to the spectral parameters assumed for each single GRB. *Right panel*: Color plot. $H1 = F2/F1$ and $H2 = F3/F2$ are derived from $F1 =$ fluences in 260-364 keV, $F2$ in 364-780 keV, $F3$ in 780-2600 keV. Diamonds refer to PICsIT instrumental quantities, and stars are obtained from documented spectral parameters.

Energy	K	σ
(keV)	(10^{-9} erg cm^{-2} ct^{-1})	
260-364	0.9	0.3
364-780	1.6	0.6
780-2600	5.7	2.0

Table 3: Conversion coefficient from PICsIT counts to physical units in three energy bands.

When spectral parameters are available in literature, fluences can be converted to the PICsIT energy range (Fig. 2- right panel). Four bursts within the PICsIT FoV ($\Theta < 15°$) span ~ 1 order of magnitude, while brighter events are detected at larger off-axis angles.

We compare the observed fluences from other instruments with PICsIT measured fluences in the energy bands: 260-364 keV, 364-780 keV, 780-2600 keV. When corrected for the geometrical projection effect on the detector, the correlation between physical (F) and instrumental (F_{PICsIT}) fluences (Fig. 3 - left panel) is described by a simple conversion coefficient:

$$F(\Delta E) = k(\Delta E) \times \frac{F_{PICsIT}(\Delta E)}{\cos\Theta}, \tag{3.1}$$

and the derived values for k are given in Table 3.

We defined the hardness ratios $H1 = F2/F1$ and $H2 = F3/F2$, where $F1$, $F2$, and $F3$ are the fluences observed by PICsIT in the three selected energy bands, multiplied by the conversion coefficients in Table 3. Right panel of Fig. 3 shows the spectral colors of a typical burst observed by PICsIT. For those spectra described by a Band function we found no correlation between PICsIT spectral colors and the Band function parameters.

4. Conclusions

PICsIT successfully detects GRBs with energy extending up to ∼3 MeV. The PICsIT sample for the time period May 2006 – August 2009 is composed by 39 bursts, with incoming direction spread over half the sky for the brightest events. Since an adequate response matrix is not yet available for the burst sample, we derived a rough conversion factor of instrumental counts to physical fluence, for GRBs with known arrival direction. The fine time and energy sampling provided by the ST data allows a spectral and temporal characterization of the observed bursts. More details on this work can be found in reference [1].

Acknowledgments

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