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The sample of INTEGRAL SPI-ACS gamma-ray bursts(*)

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Summary. — The anti-coincidence system of the spectrometer on board *INTEGRAL* is operated as a nearly omnidirectional gamma-ray burst detector above $\sim 75\,\mathrm{keV}$. During the elapsed mission time 324 burst candidates were detected. As part of the 3rd Interplanetary Network of gamma-ray detectors the cosmic origin of 115 burst was confirmed. Here we present a preliminary analysis of the SPI-ACS gamma-ray burst sample. In particular we discuss the origin of a significant population of short events (duration $< 0.2\,\mathrm{s}$) and a possible method for a flux calibration of the data.

PACS `95.85.Pw` – γ-ray.
PACS `98.70.Rz` – γ-ray sources; γ-ray bursts.
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The detection and investigation of cosmic gamma-ray bursts is an important scientific objective of ESA's *INTEGRAL* mission. For bursts in the fields of view of the spectrometer SPI and imager IBIS, *INTEGRAL* offers accurate positions for rapid ground and space-based observations. In addition high-energy spectra in the range of 20 keV to 8 MeV can be provided [1, 2]. The anti-coincidence system (ACS) of SPI acts as an omnidirectional GRB detector and produces time profiles with a time resolution of 50 ms.

1. – Instrument and data

The SPI-ACS consists of 91 $Bi_4Ge_3O_{12}$ (BGO) crystals and provides a large ($\sim 0.5\,\mathrm{m}^2$) effective area for the detection of gamma-ray bursts. Unfortunately, the energy range is not exactly known, as the thresholds of the individual Front End Electronics are different due to differences in the light yields of the individual BGO crystals. Thus, the lower energy limit can only be estimated to $\sim 75\,\mathrm{keV}$. The upper end of the energy range is less well defined, but definitely $> 10\,\mathrm{MeV}$. The detector surrounds the Ge-detectors of

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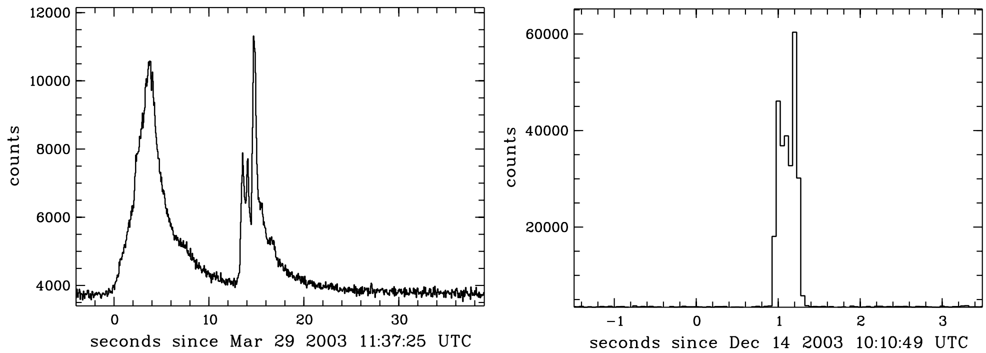

Fig. 1. – SPI-ACS light curves of two bright GRBs. *Left:* the long duration event GRB 030329 detected by *HETE-2* [5]. *Right:* a short GRB from Dec 14 2003 triangulated by the IPN [6].

the spectrometer nearly completely, thus offering a quasi-omnidirectional field of view. As only the overall detector count rate in 50 ms time bins is recorded no spatial or energy resolution is provided. SPI-ACS is part of the INTEGRAL Burst Alert System [3]. A software trigger algorithm searches for an excess in the overall count rate with respect to a running average background. For each trigger an ASCII light curve (5 s pre-trigger to 100 s post-trigger, fig. 1) and the spacecraft ephemeris are stored and made publicly available([1]). Shortly after the launch of *INTEGRAL* SPI-ACS was incorporated into the 3rd Interplanetary Network (IPN) of gamma-ray detectors [4]. The IPN provides burst localizations using the triangulation method and allows to compensate at least partly the lack of spatial resolution of SPI-ACS. Furthermore, the IPN played an important role for the timing calibration of the instrument.

2. – The SPI-ACS GRB sample

Using the selection criteria described in [7,8] 324 GRB candidates were detected during the first 23 months (Nov 11, 2002 - Oct 11, 2004) of the mission. From these, a total of 115 candidates have been confirmed by detections with other gamma-ray burst instruments until May 2004. A surprisingly prominent short event population was detected (fig. 2) but most of these events are certainly not of GRB origin. This is supported by the fact that only less than 8 % of the short-duration candidates were detected by other gamma-ray instruments while $\sim 60\,\%$ of the long-duration bursts were confirmed. A possible explanation is given below.

The existence of this contamination of the short burst requires a conservative cut of the sample at short durations for durations for a sophisticated analysis. Considering all burst candidates with $T_{90} > 0.2\,\mathrm{s}$ SPI-ACS observed an event rate of ~ 0.3 per day (~ 100 per year).

Unfortunately, SPI-ACS does not provide spectral information. Thus, the analysis of physical sample properties (*e.g.*, peak flux, fluence) requires a cross-calibration with data from other gamma-ray instruments for individual burst. A first attempt was carried out using the Ulysses fluences and peak fluxes for bursts observed in both instruments

([1]) `http://isdarc.unige.ch/arc/FTP/ibas/spiacs`

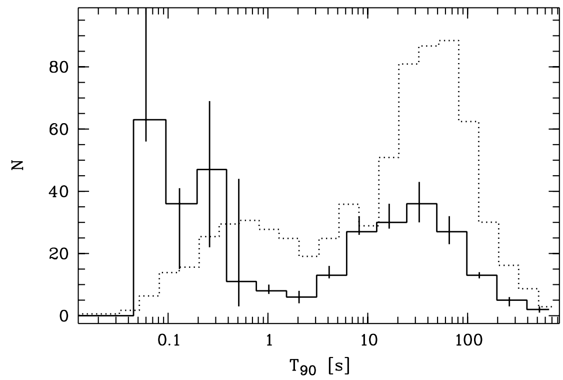

Fig. 2. – T_{90} distribution for the sample of SPI-ACS GRB candidates (solid) and for 1234 GRBs from the 4th BATSE GRB catalogue [9] (dashed) scaled to the elapsed *INTEGRAL* mission time (23 months). Note, the very large fraction of short events in the SPI-ACS sample.

(fig. 3). It appears obvious that such a "pseudo-calibration" has to be considered with caution. The different energy ranges of the instruments together with the variety of burst spectral properties, *e.g.* peak energy and spectral slope, produce significant uncertainties in the calibration. Additionally, the effective area of the detector is a function of energy and incident angle of the event and thus varies for individual bursts.

3. – The origin of the short events population

A significant fraction of the short events is accompanied by the simultaneous saturation of one or several Ge-detectors of SPI. Such a saturation event occurs approximately every 4 hours and nearly all of these events have a simultaneous rate increase in SPI-ACS. The reverse approach of an independent search for short events in the SPI-ACS

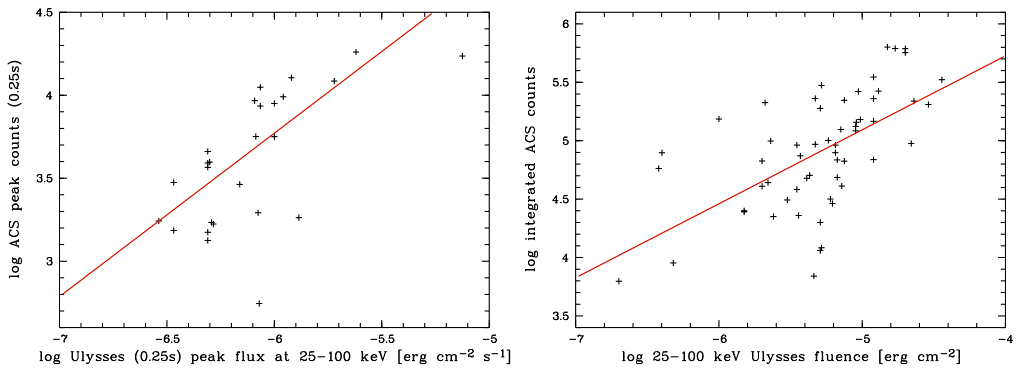

Fig. 3. – *Left:* Background subtracted SPI-ACS peak counts (0.25 s) *vs.* Ulysses peak flux from 25–100 keV for bursts observed with both instruments. The significant scatter is produced by the different energy ranges in conjunction with the individual spectral properties, *e.g.* peak energy, spectral slope, of the bursts. The solid line shows the best linear fit. *Right:* T_{90} Integrated SPI-ACS counts *vs.* Ulysses 25–100 keV fluence.

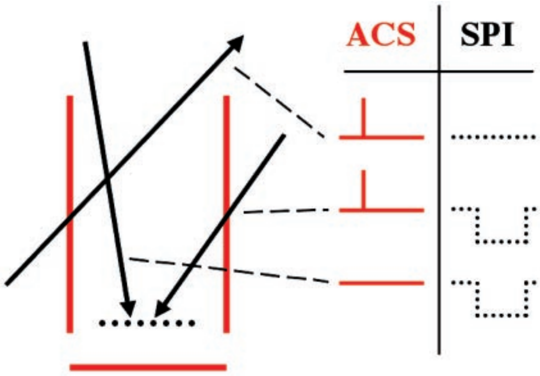

Fig. 4. – Schematic view of the instrument and of the flight directions of interacting cosmic-ray particles (black arrows) together with the corresponding together with the corresponding count rate increases in SPI-ACS (gray) and saturations ind SPI (dotted).

overall count rate found 15 events per hour at a $4.5\,\sigma$ level. Considering these two results, approximately every 60th short SPI-ACS event coincides with a saturation in the Ge-detectors (the probability of a chance coincidence is $3{\times}10^{-8}$). A scenario emerges: a very energetic cosmic-ray particle hits a BGO crystal and deposits part of its energy, thus producing the short count rate increase (fig. 4). Depending on the flight direction, the particle can further hit one or several Ge-detectors and deposits enough energy to cause the saturation. Geometric considerations show that every 40th particle hitting SPI-ACS also reaches the Ge-detectors. This is in rough agreement with the observed rate of short events with simultaneous saturations. The SPI-ACS count rate increase can be produced by recurrent triggering on the inner-crystal afterglow of BGO (0.005% at $3\,\mu$s). The typical observed overall count rate together with the total light yield for BGO and the integration of the electronics gives a rough estimate of the initial excitation energy of $\sim$1.6 GeV (for details see [7, 8]).

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