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A Decade of Bursts With The SPI-ACS

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The anticoincidence system of the INTEGRAL spectrometer has been an essential component of the interplanetary network since launch. It has observed over 1100 gamma-ray bursts and over 100 soft gamma repeater bursts, which have been confirmed by other instruments in the IPN. It has also observed over 200 events which are unconfirmed; probably half or more of them are weak bursts below the thresholds of the other IPN experiments. We review the highlights of these observations, which include gamma-ray bursts, soft gamma repeaters, three possible extragalactic giant magnetar flares, and a handful of "mystery" bursts.

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1. Introduction

The SPI anticoincidence system (SPI-ACS) was first proposed as a gamma-ray burst (GRB) detector at the 2nd INTEGRAL workshop in St. Malo in 1996 [1]. Its BGO shield, which surrounds the spectrometer on the bottom and sides, has a maximum geometric area of up to 5250 cm^2 at 100 keV, and a thickness of 1.6 to 5 cm. For comparison, a BATSE module had 4000 cm^2, the Swift BAT has 5240 cm^2, and the Fermi Burst Monitor has ~200 cm^2. The SPI-ACS area is a function of azimuthal and zenithal angles, and drops to about 500 cm^2 on-axis. One consequence of this is that many of the weak bursts which are imaged by IBIS are not detected by the SPI-ACS. Because of its thickness, and the fact that it is composed of BGO, the SPI-ACS has excellent response above 100 keV, and its effective area actually increases above the pair-production threshold. SPI-ACS data consist of time histories with 50 ms resolution in a single energy channel which ranges from ~100 keV to 10 MeV. Energy spectra are not recorded, nor does it have an independent GRB localization capability.

2. Some statistics

As of August 2012, the SPI-ACS has detected 1139 confirmed cosmic gamma-ray bursts (or about 1 every 3.3 days); these are events which have been observed by at least one other experiment in the interplanetary network (IPN). The weakest event is GRB 100628, with a 15 – 150 keV fluence of 2.5 x 10^{-8} erg cm^{-2}, confirmed by the Swift BAT (figure 1). Although the redshifts are not known for most SPI-ACS bursts, an estimate of their redshifts can be made by considering the subset of events that are detected by Swift and whose redshifts have been measured. The range is 0.105 to 4.1745.

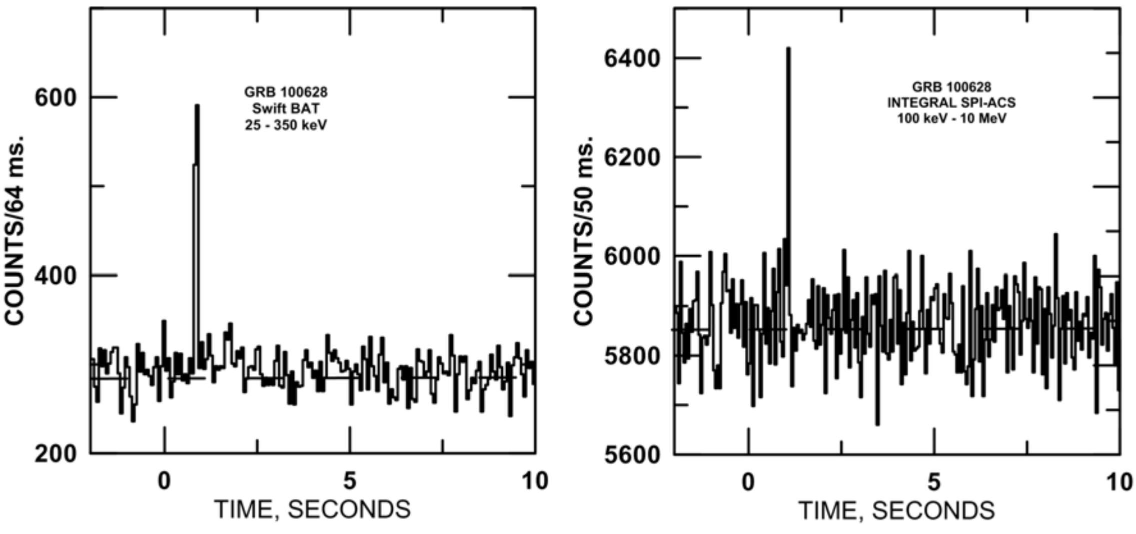

Figure 1. Swift BAT and INTEGRAL SPI-ACS time histories of GRB 100628, the weakest confirmed burst detected by the SPI-ACS. The fluence, as measured by the Swift BAT in the 15-150 keV energy range, is 2.5 x 10^{-8} erg cm^{-2}. The redshift of this burst is unknown. Since many SPI-ACS unconfirmed bursts have time histories similar to this one (i.e. an increase in a single bin), it is likely that some fraction of them are in fact real GRBs.

While the total trigger rate is extremely variable, ranging from one to several hundred triggers per day (figure 2), many triggers are spurious and have a well-determined cause [18]. For example, high voltage changes made while the trigger software was active result in very high trigger rates. Solar activity caused numerous triggers in the early phases of the mission. Finally, some triggers are random fluctuations, noise, or particles. However, there are also almost certainly weak gamma-ray bursts which are unconfirmed simply because they are below the thresholds of the other IPN experiments; 222 have been detected so far, and their time histories often resemble that of GRB 100628, i.e. a single spike. Considering its high energy threshold, it is interesting that the SPI ACS has also detected about 45 short bursts and one giant flare from the magnetar SGR1806-20 [2], one short burst from SGR1900+14, about 84 bursts from the magnetar 1E1547.0-5408 = SGR J1550-5418 [3], and one burst from the magnetar 1E1841-045.

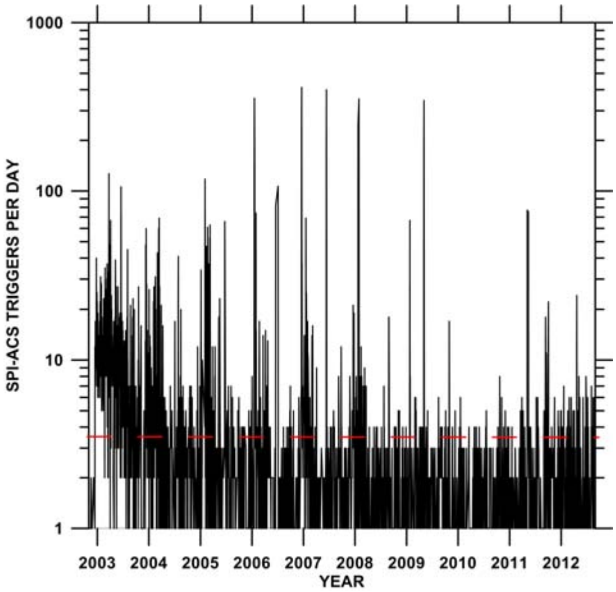

Figure 2. The SPI-ACS daily trigger rate over the mission so far. The average rate is 3.8/day, which is over an order of magnitude greater than the confirmed GRB detection rate. See Section 2 for details.

3. Four examples of science with the SPI-ACS

3.1 Light curve studies

Figure 3 shows the light curve of GRB 021206. With a fluence of 1.6 x 10^{-4} erg cm^{-2}, this re-

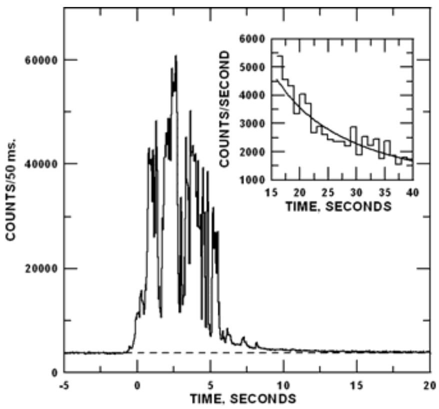

Figure 3. Main figure: the light curve of GRB021206, with the background indicated by a dashed line. Inset: gamma-ray afterglow in the later part of the light curve after background subtraction, with a power law fit,. index ~-1.1.

mains one of the most intense events observed by the ACS. The statistics are excellent: up to

60,000 counts/50 ms time bin (saturation corresponds to ~10^5 counts/50 ms). A gamma-ray afterglow is evident in this light curve; these are only detected in the strongest bursts, and only when they are observed with excellent statistics. Gamma-ray afterglows have been observed by other instruments prior to GRB 021206. However, the observation by the SPI-ACS of a gamma-ray afterglow following the giant flare from SGR1806-20 was completely unexpected [2]. Radio data starting 7 days after the event provide evidence for an expanding outflow from the magnetar [4], and the gamma-ray afterglow may be the first manifestation of it.

3.2 SPI-ACS in the 3rd Interplanetary Network.

The SPI-ACS is one of nine instruments in the IPN. The others are RHESSI, the Suzaku WAM, AGILE (Super-AGILE and the mini-calorimeter), Fermi GBM, and the Swift BAT, all in low Earth orbit. Konus-Wind is at about 5 light-seconds from Earth, and MESSENGER and Mars Odyssey, in orbit around Mercury and Mars, respectively, provide the interplanetary baselines. The INTEGRAL spacecraft occupies a unique position in the network: it is far enough from Earth to provide a statistically independent vertex for GRB localization. About 325 bursts per year are now detected by the IPN, and in general, they are not the same ones that imaging instruments such as IBIS, SuperAGILE, MAXI, and the Swift BAT observe. They are the more intense events, with fluences >10^{-6} erg cm^{-2}, and/or peak fluxes >0.4 photon cm^{-2}. Because INTEGRAL, Wind, and MESSENGER have fields of view that are unocculted by planetary bodies, the IPN constitutes an all-sky monitor, and it is in continuous operation, when the duty cycles of all its instruments are considered.

Three interesting events which were localized by the IPN with the help of the ACS are GRB 051103, 070201, and 110406, shown in figure 4. Because their error boxes overlap with bright galaxies, and because of their short time histories and hard energy spectra, these bursts are quite likely to be extragalactic giant magnetar flares from M81, M31, and NGC 404 respectively [5,6,7,8,9]. If so, their isotropic gamma-ray energies were 7 x 10^{46}, 1.5 x 10^{45}, and 6x10^{46} erg, respectively.

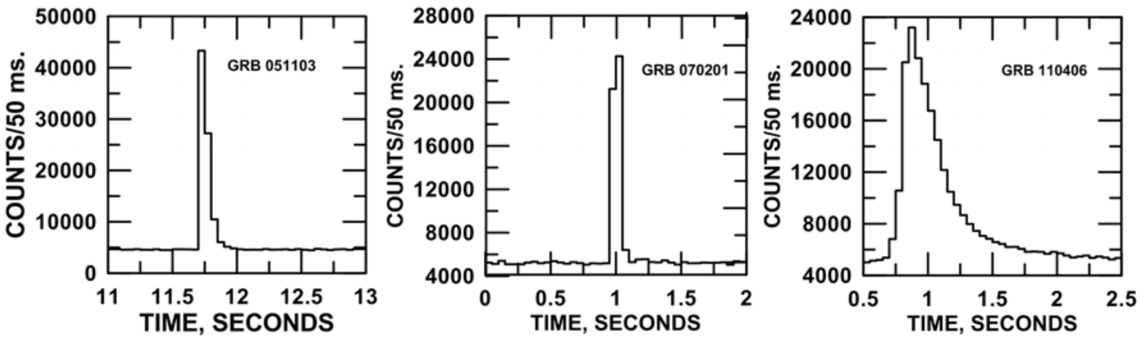

Figure 4. The SPI-ACS light curves of GRB 051103, 070201, and 110406. The time resolution is 50 ms, and the energy range is ~100 keV – 10 MeV. These bursts, which were localized with the help of INTEGRAL, have error boxes which include the nearby galaxies M81, M31, and NGC 404, respectively. They are thought to be giant magnetar flares.

3.3 Searches for Non-electromagnetic GRB Counterparts.

LIGO, VIRGO [10,11,12,13], AMANDA, and IceCube [14,15,16] benefit from having a large number of bright, relatively close, isotropically distributed GRBs to study. The LIGO results are particularly interesting, since they demonstrate that the 070201 and 051103 events could not have been caused by binary mergers in M31 and M81. The IceCube results have begun to constrain models of GRBs which accelerate ultra-high energy cosmic rays. LIGO, VIRGO, and IceCube searches with large samples of bursts are currently underway..

3.4 Mystery Events.

When an experiment like INTEGRAL remains in orbit for 10 years, it almost inevitably records events which seem to defy any good explanation. GRB060306C (figure 5) is one such event. Its intensity suggests that it could be Galactic, possibly a magnetar burst. However, while its localization is consistent with this idea, its error box is too large to exclude an extragalactic origin.

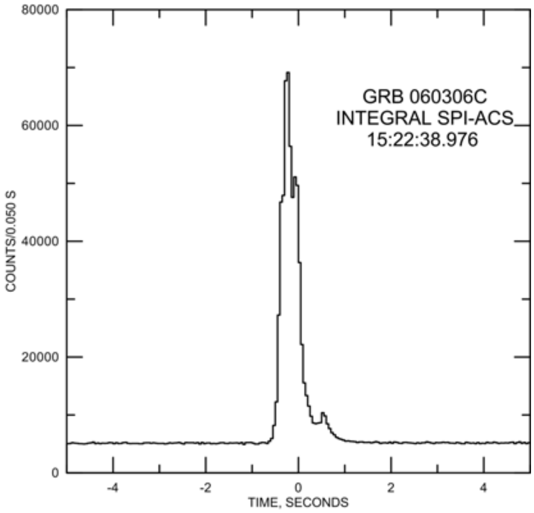

Figure 5. The light curve of GRB 060306C. Note the intensity, which is close to saturation. This burst has an error box which crosses the Galactic plane, but it is too large to exclude an extragalactic origin.

Other examples are clusters of very short events which could be weak magnetar bursts, but are too weak to be detected by other IPN spacecraft [17].

4 Summary

Ten years after launch, the SPI-ACS remains as relevant as ever to gamma-ray burst and magnetar studies. About 300 GCN Circulars have been issued for the more than 1100 bursts that it has detected. The light curve data are public, and can be found at ftp://isdcarc.unige.ch/arc/FTP/ibas/spiacs/. IPN data are available at http://ssl.berkeley.edu/ipn3/index.html.

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