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Eight Years 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 about 900 events which have been confirmed as either soft gamma repeaters or cosmic gamma-ray bursts by other instruments in the IPN. It has also observed over 160 events which are unconfirmed, but which are almost certainly 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, and one or two extragalactic giant magnetar flares.

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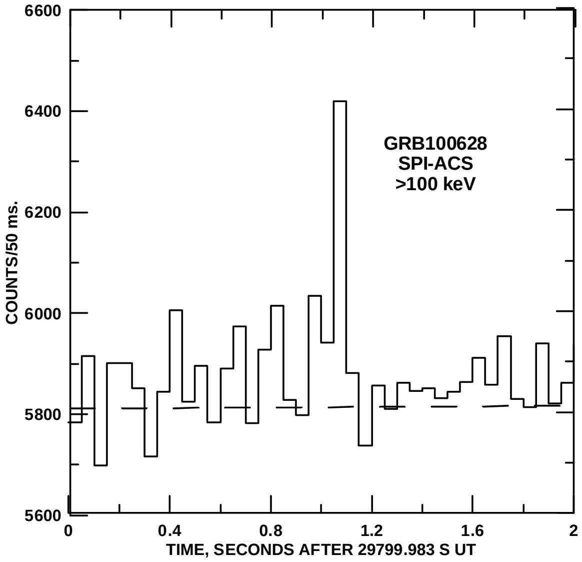
1. Introduction

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 effective 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 has a superior response above 100 keV. Its effective 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. When triggered, it produces 105 s long GRB time histories with 50 ms resolution in a single energy channel which ranges from ~100 keV to 10 MeV. It does not record energy spectra, nor does it have an independent GRB localization capability.

2. The Score So Far

The SPI-ACS has now detected about 875 confirmed cosmic gamma-ray bursts (or about 1 every 3 days); these are events which have been observed by at least one other experiment in the interplanetary network (IPN). The weakest event is GRB100628, with a fluence of 2.5 x 10^{-8} erg cm^{-2}, confirmed by the Swift BAT. Its time history is shown in figure 1. Although 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. 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; 160 have been detected so far. The SPI ACS has detected about 45 short bursts and one giant flare from the magnetar SGR1806-20 [2], one short burst from SGR1900+14, and about 220 bursts from the magnetar 1E1547.0-5408 = SGR J1550-5418.

Figure 1. The weakest confirmed cosmic event observed by SPI-ACS. This burst, which resembles many of the weak unconfirmed events, was also detected by Swift, which reported a 15-150 keV fluence of 2.5x10^{-8} erg cm^{-2}.



3. Science With The SPI-ACS Data

The science which can be done with the SPI-ACS data falls into three broad categories:

1. detailed light curve studies which take advantage of the excellent statistics and high energy sensitivity of the ACS,
2. Obtaining precise burst localizations with the IPN, and searching for electromagnetic counterparts, and
3. Searching for gravitational radiation, neutrino emission, and very high energy gamma-ray emission from bursts, more or less independently of the rapidity and accuracy of the localizations.

We discuss each of these in turn.

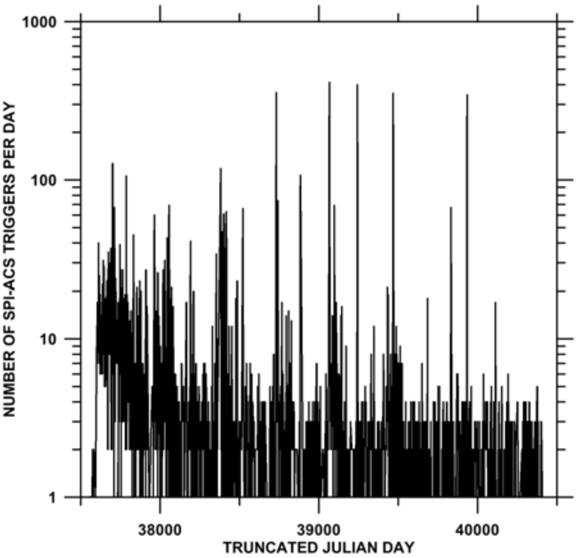


Figure 2. The SPI-ACS trigger rate over the mission so far. The average rate is 4.6/day, which is over an order of magnitude greater than the GRB detection rate. See Section 2 for details.

3.1 Light Curve Studies

Figure 3 shows the light curve of GRB021206. With a fluence of 1.6 x 10^{-4} erg cm^{-2}, this remains one of the most intense events observed by the ACS. The statistics are excellent: up to 60,000 counts are recorded in a single 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, when they are observed with excellent statistics. Gamma-ray afterglows following intense GRBs have been observed by other instruments prior to GRB021206. However, the observation by the SPI-ACS of a gamma-ray afterglow following the giant flare from SGR1806-20 was completely unexpected [2]. This phenomenon, which was confirmed by RHESSI and Konus, lasted about one hour, and its spectrum extended to at least 1 MeV.

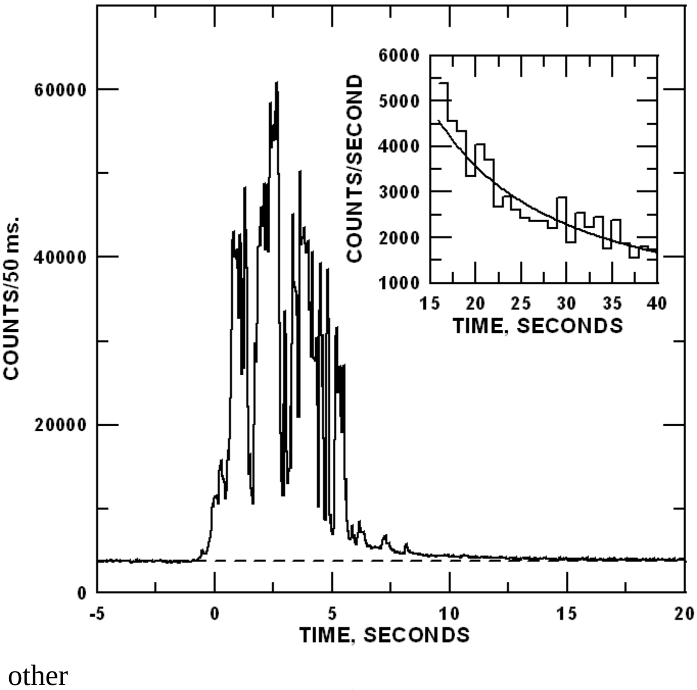


Figure 3. The main figure shows the light curve of GRB021206, with the background indicated by a dashed line. The inset shows the later part of the light curve after background subtraction. A gamma-ray afterglow is evident, which can be fit with a power law of index ~-1.1.

Radio data starting 7 days after the event provide evidence for an expanding outflow from the magnetar [13], 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. Finally, MESSENGER, on its way to Mercury, and Mars Odyssey, in orbit around Mars, provide the interplanetary baselines. The configuration of the network is shown in figure 4. 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 340 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.

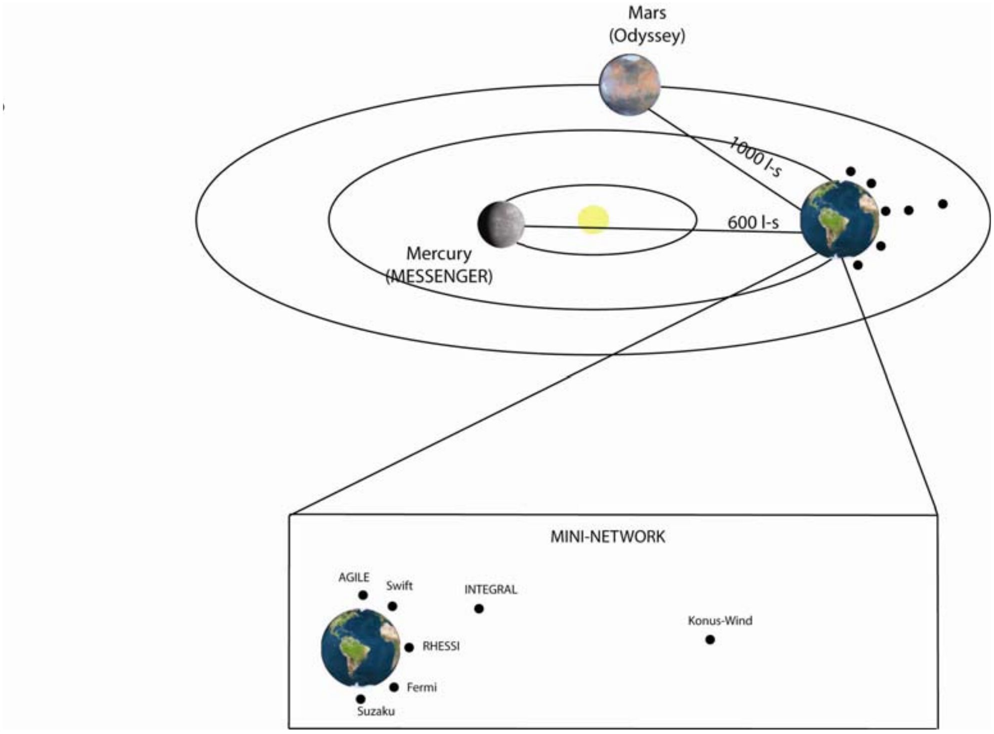


Figure 4. The current configuration of the interplanetary network. The Odyssey spacecraft is presently in orbit around Mars; the MESSENGER spacecraft will start to orbit Mercury in March 2011. Around the Earth, there is a mini-network, consisting of 5 spacecraft in low-Earth orbit, INTEGRAL, with an apogee of about 0.5 light-seconds, and Konus-Wind, which remains around 5 light-seconds from Earth. Even in the absence of a detection by a distant spacecraft, a GRB can often be localized to several degree accuracy by the mini-network.

Two interesting events which were detected by the ACS are bursts on November 3 2005 and February 1 2007. Their light curves are shown in figure 5. Because their error boxes overlap with bright galaxies, and because of their light curves and energy spectra, these bursts are quite likely to be extragalactic giant magnetar flares from M81 and M31 respectively [3,4,12]. If so, their isotropic gamma-ray energies were 7 x 10^{46} and 1.5 x 10^{45} erg, respectively.

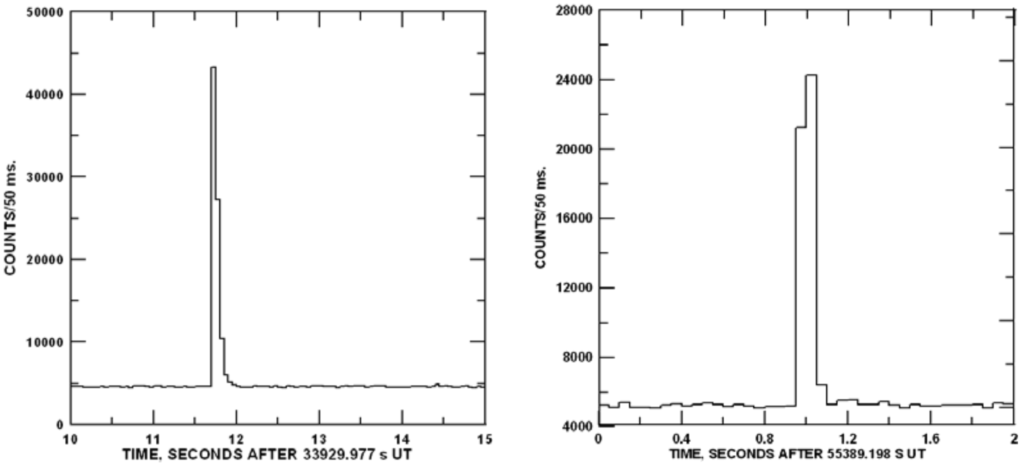


Figure 5. The SPI-ACS light curves of the November 3 2005 (left) and February 1 2007 (right) events.

3.3 Searches for Exotic Counterparts

All-sky experiments, and experiments which view a large fraction of the sky, and record their data, often do not require fast or precise GRB localizations to determine whether an event can be correlated with a GRB. The trigger time alone is often sufficient to search for more exotic radiation, such as gravitational and neutrino radiation, and very high energy gamma-ray emission. LIGO and VIRGO [6,8,9] AMANDA and IceCube [5,10], ARGO-YBJ [11], and Milagro [7] are in this category. These experiments benefit from having a large number of bright (and presumably nearby), isotropically distributed GRBs to study. So far, they are all upper limits, but the LIGO result is particularly interesting, since it demonstrates that the 070201 event could not have been caused by a binary merger in M31. LIGO and VIRGO searches for gravitational radiation coincident with a large sample of SGR and cosmic bursts are currently underway.

4. Summary

The INTEGRAL SPI-ACS is a sensitive monitor of fast gamma-ray transients in the fluence range 2.5 x 10^{-8} erg cm^{-2} and above. Using these data, over 175 GCN Circulars have been issued, and GCN Notices have been issued starting around October 2008. About 90 of the bursts detected by the ACS have radio, optical, and/or X-ray counterparts, and for 38 events, a spectroscopic or photometric redshift has been determined; the redshifts lie in the range 0.105 to 3.35. Both the ACS light curve data, as well as the IPN data, are made publicly available at ftp://isdcarc.unige.ch/arc/FTP/ibas/spiacs/ and ssl.berkeley.edu/ipn3/index.html, respectively.

Acknowledgments

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