Super-AGILE: The X-ray Monitor on-board of AGILE

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Abstract. Super-AGILE is the hard X-ray imaging detector of the AGILE gamma-ray mission. It is devoted to monitor X-ray (10-40 keV) sources with an on-axis sensitivity near 5 mCrab in one observing day and to detect X-ray transients in a field of view of 107 deg x 68 deg. Super-AGILE is well matched with the Gamma-Ray Imaging Detector (GRID), and potentially provides source arc-minute positioning depending on intensity, spectrum and background conditions.

Super-AGILE detects hard X-rays with one additional layer of four Silicon micro-strip detectors, for 1444 cm^2 total geometrical area. It will be placed on top of the AGILE Tracker and equipped with a system of four mutually orthogonal one-dimentional coded masks to encode the X-ray sky. Low-noise electronics based on ASICs technology is the front-end read out. We present here the instrumental and astrophysical performance of Super-AGILE as derived by Monte Carlo simulations and experimental tests.

DESCRIPTION OF SUPERAGILE

Super-AGILE is basically composed by a Detection Plane (DP), a Collimator equipped with a Coded Mask, Front-End Electronics and an Interface Electronics (SAIE). Table 1 summarizes the main instrument characteristics and Figure 1 shows the Detector layout (see also [5] for an extensive description of Super-AGILE). The DP is composed of 4 detection units (DUs), placed on the same Al honeycomb plane support, so that two of them sample the X-direction and the other two are devoted to the Y-direction. Each DU is composed by 4 Si microstrip tiles, bonded in pairs so that the effective length of each strip is approximately 19 cm. They are read-out through a set of IDE AS-XAA1 chips, based on ASIC technology, 12 for each of the DUs. The collimator is mounted on the same tray supporting the DP, and in turn supports the 4 orthogonal, one-dimensional coded masks. The coded masks have a 50% covering factor. They will be manufactured either of Gold or Tungsten. The SAIE is in charge of interfacing Super-AGILE with the

CP587, *GAMMA 2001: Gamma-Ray Astrophysics 2001,* edited by S. Ritz et al.

TABLE 1. The Basic Characteristics of Super-AGILE

Detector Type	Silicon Strip
Basic Detection Unit	4 Si Tiles, 19cm x 19cm
Total Geometric Area	1444 cm^2
On-Axis Effective Area	320 cm^2 (13keV)
Detector Strip Size	121 μm
Detector Thickness	400 μm
Energy Resolution (FWHM)	$\sim$ 3-4 keV
Timing Accuracy	$\sim$ 5 μs
Collimator Materials	75 μm Tungsten-Coated Carbon Fiber
Mask Size	1444 cm^2
Mask-Detector Distance	14 cm
Mask Transparency	50%
Mask Material	Tungsten
Mask Thickness	100 μm
Mask Element Size	242 μm
Field of View (FWZR)	107° x 68°
On-Axis Angular Resolution	5.9 arcmin
Source Location Accuracy	$\sim$ 2 arcmin for bright sources
Point Source Sensitivity	5 mCrab on axis

AGILE Data Handling System, allowing an event-by-event transmission with better than 5 μs timing resolution. The energy information will be provided in the extended energy range between 1 and 64 keV, with 64 channels, to allow a finer threshold calibration at low energies, and exploit for calibration purposes the Tungsten fluorescences at $\sim$58 keV. The combined capabilities of the SAIE and the AGILE Data Handling (see also [4]) allows the transmission to the ground of a relatively large set of scientific housekeeping data, including ratemeters and detector images. In particular, the AGILE Data Handling will be able to perform a continuous automatic search for transient events (e.g. gamma-ray bursts) on timescales from 1 ms to 100 s. Once a transient event is triggered onboard, the Data Handling will be able to provide attitude-corrected sky images for it, determining the location of the transient source on the sky (see Figure 2 for illustration). The possibility to distribute in almost real time the coordinates of the transient event through a fast link (e.g., TDRSS or similar) is currently under study.

SENSITIVITY AND EFFECTIVE AREA

We studied the sensitivity and expected astrophysical performances by means of analytical calculations and Monte Carlo simulations. In Figure 3 we show the combined effective area of four Super-AGILE DUs over the field of view (FOV) in the 10-50 keV energy band. The central 60°x60° area contains the overlapping FOVs of orthogonal detectors, providing an effective bi-dimensional source location capability. The outer regions of the FOV enable one-dimensional localization of sources. This effective area is sufficient to detect on-axis sources as weak as 5 mCrab for an integration time of 50

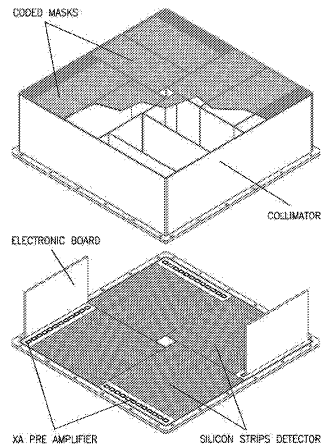

FIGURE 1. Schematic view of the Super-AGILE structure.

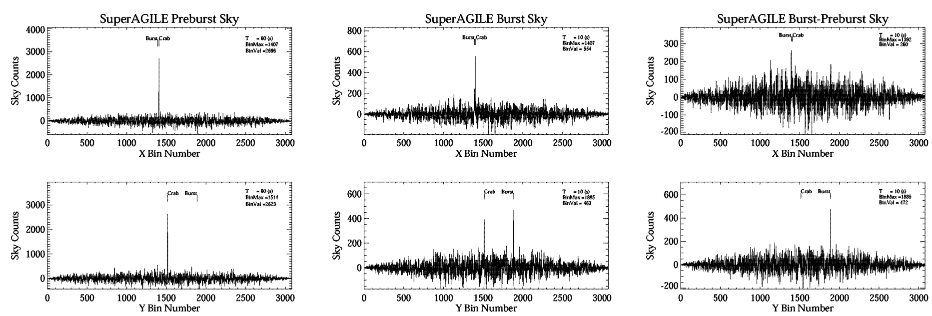

FIGURE 2. Illustration of possible on-board burst localizations by the Data Handling system. *Left:* X and Y sky images, integrated during the last 60 seconds before the burst trigger. The Crab pulsar is visible near the center of the field of view. *Center:* X and Y sky images obtained during 10 seconds of the burst. *Right*: The Data Handling system will be capable of normalizing the pre-burst data and subtracting it from the burst images, with consecutive determination of the burst position.

ks (with four detectors). The right plot in Figure 3 shows the sensitivity of one Super-AGILE detector over the field of view in two orthogonal directions. The plot with Y=0 corresponds to a coding direction.

SOURCE LOCALIZATION

From the Super-AGILE mask/collimator/detector geometry one can derive the angular resolution of the detector to be 5.9 arcmin. However, its source location accuracy should normally be better than that. We anticipate, that Super-AGILE will be able to locate bright sources within a 2 arcmin error box thanks to the fact that the detector bin size

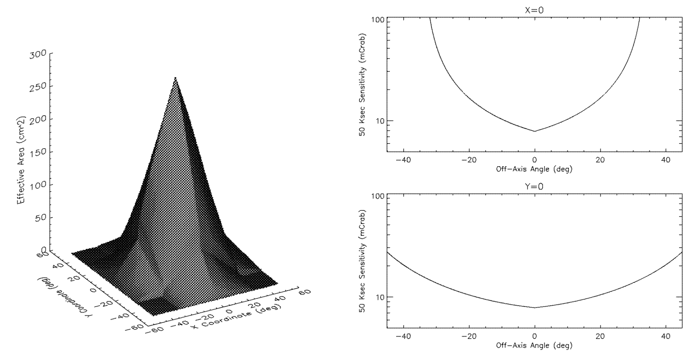

FIGURE 3. *Left Panel:* Effective area of 4 Super-AGILE detector units over the FOV. *Right Panel:* 5σ sensitivity of one Super-AGILE detector over the FOV for a 50 ksec observation

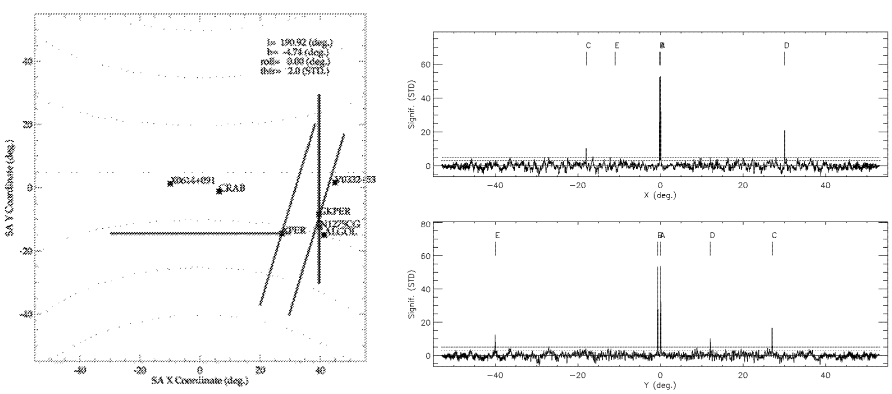

FIGURE 4. *Left Panel:* Simulated observation of a field near the Crab source. See the main text for the explanations. *Right Panel:* Super-AGILE sky images of a sample field with 5 sources. Each image, which is a combination of two detectors was attitude corrected for spacecraft pointing errors.

being half of the mask element size.

For the central 60°x60° region of the FOV we will normally have two one-dimensional positions of the source with an error 2-6 arcmin, depending on the source brightness. The outer regions of the FOV will enable detecting and locating sources in either of 2 orthogonal directions, thus making the source location error box to be 2 arcmin x 60° . For this case a better localization of a new discovered source can be derived using Earth occultation techniques, data from other operating spacecraft or a different AGILE satellite pointing. Figure 4 (Left Panel) presents two simulated Super-AGILE observations of a field around the Crab pulsar. The pointing in both observations remains the same, while the roll angle being different by 16 degrees. Both sources in the central part of the FOV were detected in both orthogonal directions, thus the location error box being within 6 arcmin. Some sources on the outer part on the FOV were detected by only one of two orthogonal detector units, hence their error boxes are extended in one direction. However, the second observation with a different roll angle can locate even these sources by intersecting error boxes. The AGILE spacecraft pointing stability is expected to be within a circle of 1 degree radius. This leads to the necessity of correcting the coordinates of events based on the data provided by star sensors. Without such correction images will be blurred and the sensitivity of the instrument will decrease. Figure 4 (Right Panel) shows the result of correcting of Super-AGILE data. The attitude correction has a positive effect on the quality of Super-AGILE images, although it cannot improve the experiment's sensitivity compared to the "ideal" pointing case. The software attitude correction procedure, designed for Super-AGILE, enables to suppress to some extent the coding noise from bright sources in the field of view, and to make more prominent fainter sources. This is possible by the large Super-AGILE FOV and by the fact that the pixel size expressed in angular units is strongly variable over the FOV. As a result, while reconstructing some part of the sky, we still have shadows cast by other sources blurred strongly enough not to produce hight coding noise peaks. The positive result of such procedure can be clearly seen in Figure 4 (Right Panel).

EXPECTED SCIENTIFIC PERFORMANCE

Super-AGILE will study a variety of X-ray sources of different types including Galactic and some bright extragalactic sources. We note that as a result of the long AGILE pointings ($\sim$2 weeks), Super-AGILE will monitor the same sky region for a long time. This pointing strategy will provide accurate energy spectra and flux monitoring, looking for short timescale variations. Super-AGILE is therefore well suited for studying the activity of fast X-ray transients. For example, it will be able to provide energy spectra of events similar to short recurring bursts from Soft Gamma-ray Repeaters (e.g., [1]). Furthermore, the giant flares from these sources (e.g., [3]) are very good candidates for emission of rapid and intense flashes of gamma-rays, and Super-AGILE can provide to the GRID accurate positions of possible new soft gamma-ray repeater events. A more detailed description of Super-AGILE and its scientific capabilities can be found elsewhere (see also [2, 5, 6]).

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