THE AGILE GAMMA-RAY ASTRONOMY SATELLITE

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Abstract The AGILE satellite will be a unique tool for high-energy astrophysics in the 30 MeV - 50 GeV range before GLAST. The scientific performances of AGILE are comparable to those of EGRET, despite the much smaller weight and dimensions. The AGILE mission will be optimized for the imaging capabilities above 30 MeV and for the study of transient astrophysical sources.

1. INTRODUCTION

The AGILE satellite will be the next gamma-ray satellite mission operating in the 30 MeV–50 GeV energy range. It will fill the time gap between the end of the EGRET era and the advent of GLAST. AG-

ILE (*Astro-rivelatore Gamma a Immagini LEggero*, Tavani et al. 1999, Mereghetti et al. 2000) is the first satellite of the Program for Small Scientific Missions of the Italian Space Agency (ASI). It is expected to be operative in the years 2003-2006.

The progress achieved in the technology of solid state silicon detectors make it possible now to develop within a very small ($\sim 60 \times 60 \times 54$ cm^3) and light payload ($\sim$ 65 kg) an instrument as powerful as EGRET (actually more powerful than EGRET in a few respects, as described below).

AGILE, being optimized from the point of view of its imaging performances, will give a significant contribution to solve the mystery of the unidentified gamma-ray sources. The AGILE Gamma Ray Imaging Detector (GRID) will cover the 30 MeV - 50 GeV range with a very good angular resolution (allowing a source location accuracy $\sim 5' - 20'$ for intense sources), a very large field of view ($\sim$3 sr), and a sensitivity comparable to that of EGRET for on-axis (and substantially better for off-axis) point sources. AGILE will also carry a hard X–ray detector (Super-AGILE) using an imaging coded mask system to simultaneously monitor in the 10-40 keV range the sources observed in the central part of the GRID field of view. The possibility of simultaneously observing the same part of the sky in the hard X–ray and gamma-ray bands, with a combination of detectors on the same satellite, is an unique capability of AGILE that will also be very useful in the study of unidentified high energy sources.

2. OVERVIEW OF THE AGILE INSTRUMENT

The AGILE scientific payload (Figure 1) can be regarded as a single instrument consisting of three detectors (GRID, MCAL and Super-AGILE) plus two auxiliary systems (Anticoincidence and Data Handling).

2.1. GRID

The heart of the GRID (Gamma Ray Imaging Detector) is a silicon Tracker, consisting of 14 planes of Si strip detectors. This will provide the unambiguous identification of incident gamma-rays by recording the characteristic track signature of the e^--e^+ that result from pair creation in thin layers of converting material. A CsI Mini-calorimeter placed below the tracker will provide energy information with a resolution of the order of $\Delta E/E \sim 1$ at 200 MeV. A better energy resolution can be

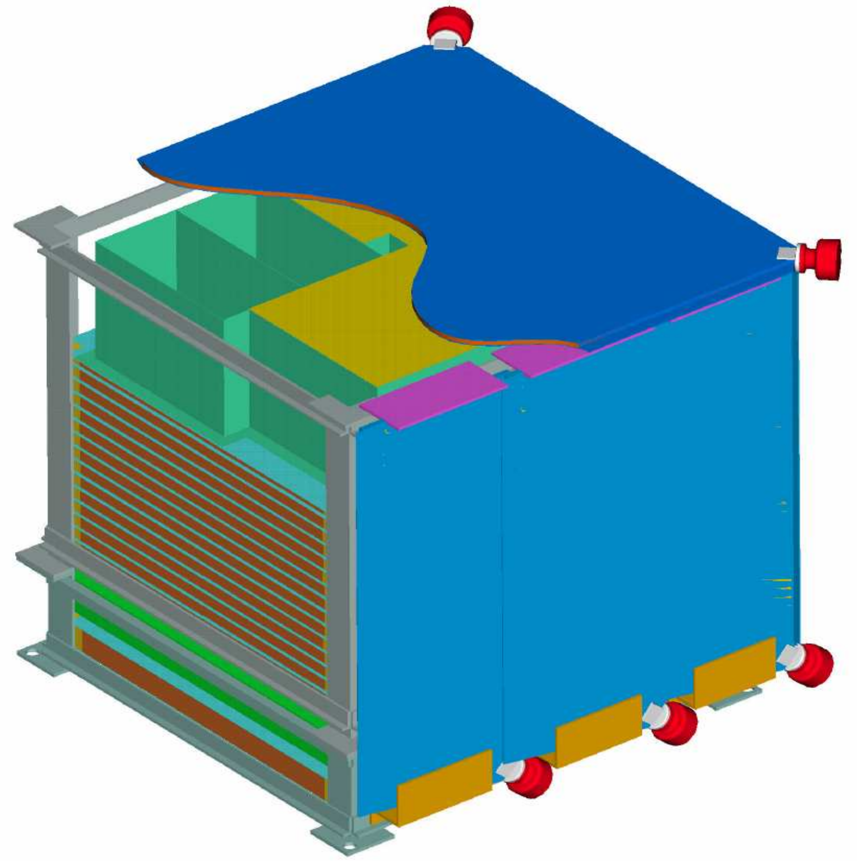

Figure 1 The AGILE payload. Starting from the top, the following subsystems are visible: top Anticoincidence panel, SuperAGILE collimator (the SuperAGILE coded mask is not shown), 14 Silicon Tracker trays, Mini-calorimeter. The whole payload is surrounded by the lateral anticoincidence panels (not shown on two sides for clarity).

achieved at lower energies by the combined use of the Mini-calorimeter and the multiple scattering measured in the Tracker.

Each plane of the Tracker (with the exception of the two at the bottom) is made of three layers: a 245 μm thick photon pair converter in tungsten (0.07 X_0) is followed by two planes of silicon strip detectors (thickness 410 μm) with the strips arranged in orthogonal directions to provide the X and Y coordinates of the particle tracks. The Si detectors have a pitch (distance between strips) of 121 μm, but only half of the strips will be read out, with a floating strip every two strips, yielding a total of $\sim$43,000 channels for the whole Tracker. If a particle crosses a floating strip, charges are induced on the two adjacent read-out strips through capacitive coupling. In this way, more than one strip has signal, thus enabling to use an interpolation algorithm to recover the original spatial resolution.

The Mini-calorimeter consists of two planes of CsI(Tl) bars. Each bar has dimensions of $2.3\times1.5\times40$ cm^3. The two planes have the bars arranged in orthogonal directions to provide the X and Y location of the showers. The scintillation light is collected by photodiodes placed at both ends of each bar.

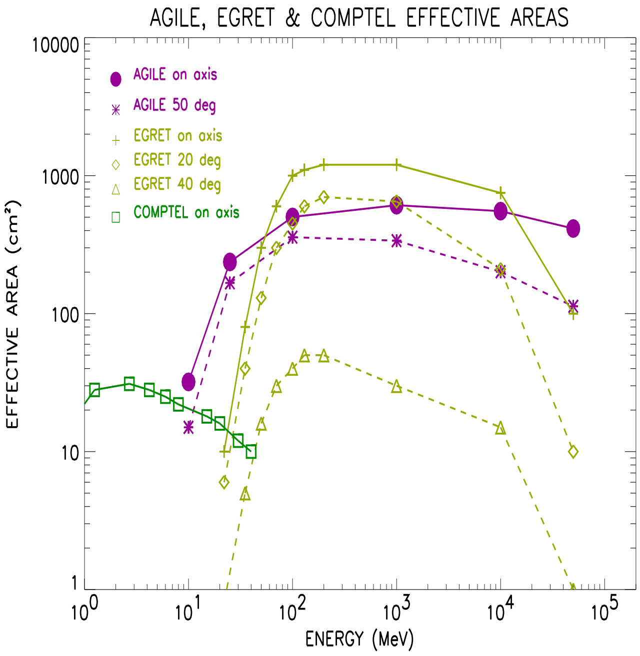

Figure 2 Comparison of the effective area of AGILE with those of previous instruments on CGRO. The curves refer to different off-axis angles. Note the small decrease at 50° off-axis for the AGILE effective area.

The Mini-calorimeter, with a thickness of 1.5 radiation lengths, will allow to determine the energy of the incident photons recorded by the Tracker. In addition, the Mini-calorimeter will be used to study gamma-ray bursts and other transient phenomena in the ~250 keV - 100 MeV energy range (without directional information).

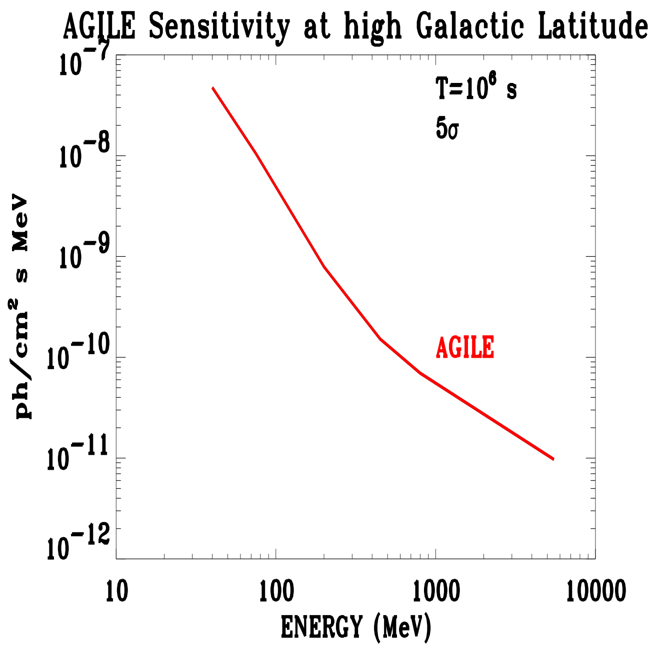

Figure 3 Expected AGILE sensitivity for a gamma-ray point source at high galactic latitude.

2.2. SUPER-AGILE

The hard X-ray detector (Super-AGILE) is based on the same building blocks (9.5×9.5 cm^2 silicon tiles) that are used for the Tracker planes. These will be placed on the top of the Tracker (above the first tungsten layer) to form an additional detection plane sensitive in the 10-40 keV range and used in conjunction with a coded mask to obtain imaging capabilities. The mask will be placed at a distance of ~14 cm from the detectors (below the top anticoincidence). Since the silicon microstrips provide pixels only along one dimension, Super-AGILE will consist of four equal modules arranged in two pairs, giving mono-dimensional sky images along two orthogonal directions. The mask will be supported by an ultra-light carbon fiber structure that will also serve as a collimator to reduce the background, which, at these energies, is dominated by the cosmic diffuse radiation.

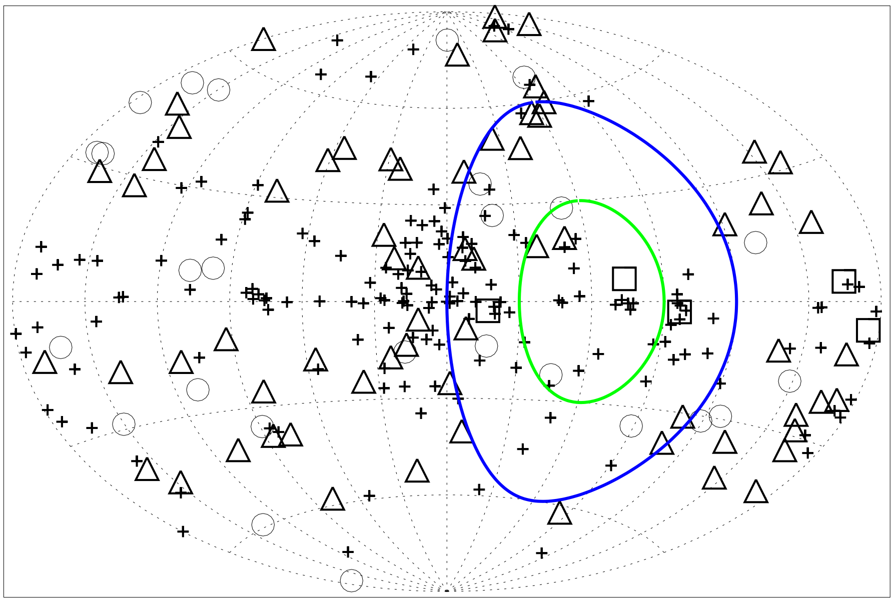

Figure 4 Comparison of the AGILE GRID and EGRET fields of view. The symbols indicate the sources of the 3EG catalog (AGNs: triangles, possible AGNs: circles, Pulsars: squares, Unidentified: crosses)

3. SCIENTIFIC PERFORMANCES

The expected scientific performances of AGILE are summarized in Table 1. One of the main characteristics of the AGILE GRID is its very large field of view (see Figure 4). As shown in Figure 2 the AGILE effective area remains almost constant for large off-axis angles. This will allow to simultaneously monitor a large number of sources in a single pointing and will also result, at the end of the mission, in a large exposure factor for each region of the sky (Mereghetti et al. 1999). The great sky exposure factor, coupled with the good angular resolution, will allow a detailed study of the diffuse Galactic and Extra-Galactic emission and to better locate the unidentified EGRET sources. The expected sensitivity for regions outside the Galactic Plane is shown in Figure 3.

Another important characteristic of the AGILE Tracker is the very small dead time, $\sim$100 μsec (i.e. three orders of magnitude smaller than for EGRET). This will be crucial in the study of the high energy emission of gamma-ray bursts, which are expected in the field of view at a rate of ~5-10 per year. Furthermore, an on-board GPS system will allow to time tag the photons with an absolute accuracy of only a few μsec.

The extension in the hard X–ray range of a gamma-ray mission, made possible by the Super-AGILE detector, is an innovative concept that will allow the study of correlated variability for sources of different classes, ranging from active galactic nuclei and blazars to unidentified galactic transients.

4. THE MISSION

The AGILE payload will be carried in an equatorial (inclination $<5°$), circular orbit (altitude ~550 km), by a spacecraft of the MITA class, developed by Gavazzi Space as prime contractor. The total mass of the satellite will be of the order of 180-200 kg. The satellite will point with a 3-axis attitude stabilization with an accuracy of the order of 1°. A post-facto attitude reconstruction at the arcmin level will be obtained by means of star sensors.

A typical AGILE pointing will last 2-3 weeks. AGILE will also have the possibility to quickly repoint (within 1 day) in order to react to interesting targets of opportunity.

An Operations and Control Center will have the primary responsibility of satellite operations and communications using the ASI ground base at Malindi (Kenya). The equatorial orbit will allow a single contact per orbit at a downlink rate of 500 kbit s^{-1}.

The AGILE Data Center will be devoted to the monitoring of the instrument scientific performance, to the quick look analysis, and to the processing, distribution and archival of scientific data products and the associated calibration data.

Part of the AGILE data will be available to the international astrophysical community through a Guest Observers Program managed by ASI, while a number of long term scientific projects involving the systematic analysis of large amount of data and requiring a deep knowledge of the instrument will be carried out by the AGILE Team. The Super-AGILE detector will also act as a wide field monitor to study the long term variability of bright sources in the 10-40 keV range and to discover new transients. The Super-AGILE data will be routinely analyzed at the AGILE Data Center and the results will be made publicly available as a service to the community, in a way similar to what is currently done with the ASM data on board RossiXTE.

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Table 1 AGILE Scientific Performances

Gamma-ray Imaging Detector (GRID)	
Energy Range	30 MeV – 50 GeV
Field of view	$\sim$3 sr
Sensitivity at 100 MeV	6×10^{-9} ph cm^{-2} s^{-1} MeV^{-1} (5σ in 10^6 s)
Sensitivity at 1 GeV	4×10^{-11} ph cm^{-2} s^{-1} MeV^{-1} (5σ in 10^6 s)
Angular Resolution at 1 GeV	36 arcmin (68% cont. radius)
Source Location Accuracy	$\sim$5-20 arcmin S/N>10
Energy Resolution	ΔE/E$\sim$1 at 300 MeV
Absolute Time Resolution	$\sim$1 μs
Dead time	$\sim$100 μs
Hard X–ray Detector (Super-AGILE)	
Energy Range	10-40 keV
Field of view	$107°\times68°$ FW at Zero Sensitivity
Sensitivity	$\sim$5 milliCrabs (5σ in 1 day)
Angular Resolution	6 arcmin
Source Location Accuracy	$\sim$2-3 arcmin S/N$\sim$10
Energy Resolution	ΔE<4 keV
Absolute Time Resolution	$\sim$4 μs
Dead time (for each of the 16 readout units)	$\sim$4 μs
Mini-Calorimeter	
Energy Range	250 keV - 100 MeV
Energy Resolution	$\sim$1 MeV above 1 MeV
Absolute Time Resolution	$\sim$3 μs
Dead time (for each of the 32 bars)	$\sim$20 μs