THE AGILE GAMMA-RAY ASTRONOMY MISSION

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ABSTRACT

We describe the AGILE satellite: 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 phenomena, complemented by simultaneous monitoring in the hard X-ray band (10-40 keV).

Key words: Gamma-ray satellites; Instrumentation.

1. INTRODUCTION

The AGILE satellite was proposed in June 1997 to the Program for Small Scientific Missions of the Italian Space Agency (ASI). AGILE (*Astro-rivelatore Gamma a Immagini LEggero*) is a mission devoted to γ-ray (30 MeV–50 GeV) astrophysics during the years 2003-2006 (Tavani et al. 1999, Mereghetti et al. 2000). After the initial ASI selection in December 1997, and a Phase A study done in 1998, AGILE was finally selected in June 1999 as the first ASI Small Scientific Mission. The launch is foreseen in 2003.

The AGILE γ-ray detector is based on the state-of-the-art and reliably developed technology of solid state silicon detectors (Barbiellini et al. 1995). This allows to obtain excellent performances with a very small payload ($\sim$ 65 kg in a volume of $\sim$60$\times$60$\times$54 cm^3), compared to previous satellites operating at these energies. The instrument is designed to achieve an optimal angular resolution (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 using an imaging coded mask system to simultaneously monitor in the 10-40 keV range the sources observed in the central part of the γ-ray field of view.

Despite its simplicity and moderate cost, AGILE is ideal to perform a large number of tasks: monitoring active galactic nuclei, detecting γ-ray bursts with high efficiency, mapping the diffuse galactic and extragalactic emission, studying pulsed γ-ray emission from radio pulsars, monitoring the many unidentified sources and contributing to their unveiling, detecting energetic solar flares. Today it is clear that successful investigations of γ-ray sources rely on coordinated space and ground-based observations. The AGILE scientific program will be focused on a prompt response to γ-ray transients and alerts for follow-up multiwavelength observations.

2. INSTRUMENT OVERVIEW

The AGILE scientific payload (Figure 1) includes three main detectors: a silicon/tungsten Tracker, a cesium iodide Mini-calorimeter, and a coded mask hard X-ray Imaging Detector (Super-AGILE). These elements are integrated in a single structure, covered on the top and lateral sides with a segmented anticoincidence made of plastic scintillator. The detected signals are processed by a Data Handling system, that allows a reduction of the telemetry data rate by

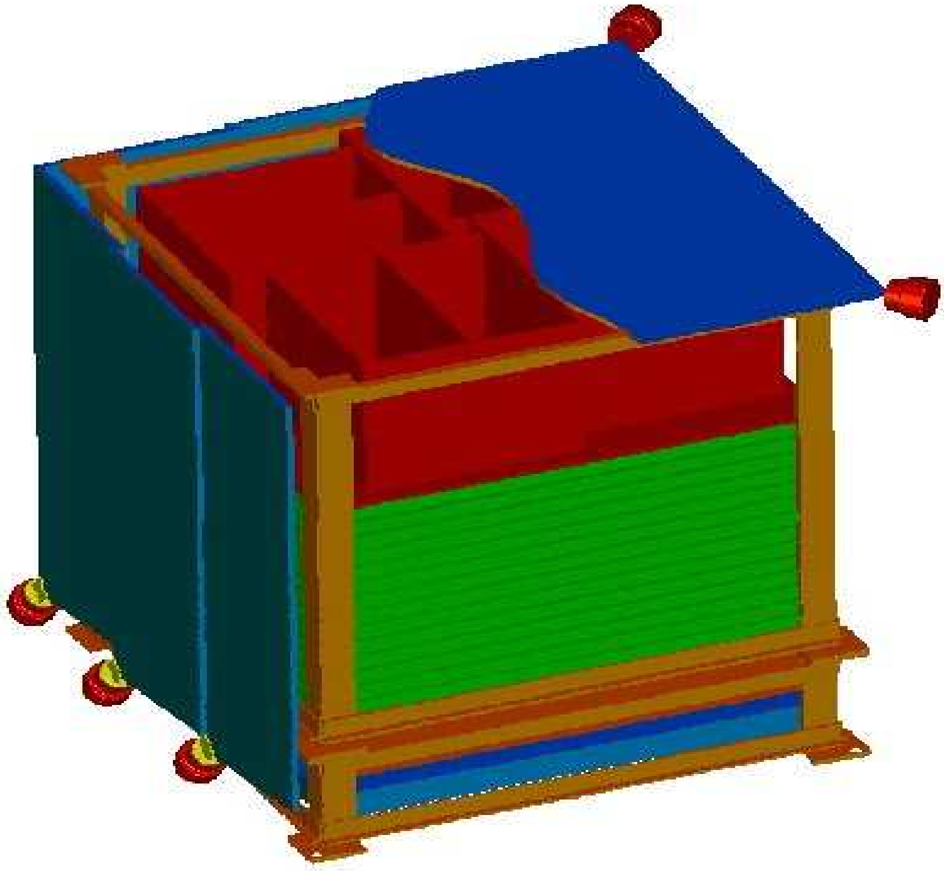

Figure 1. The AGILE payload. Starting from the top, the following subsystems are visible: top Anticoincidence panel, SuperAGILE collimator (the SuperAGILE coded mask is not shown), 14 Silicon Tracker trays, Mini-calorimeter. The whole payload is surrounded by the lateral anticoincidence panels (not shown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

performing a first rejection of background events due to charged particles and is also effective in quickly reacting to the occurrence of γ-ray bursts.

The Tracker, consisting of 14 planes of Si strip detectors, will provide the unambiguous identification of incident γ-rays by recording the characteristic track signature of the e^--e^+ that result from pair creation from the incident photons in thin layers of converting material. The distance between planes has been fixed to 1.6 cm on the basis of extensive optimizations by Montecarlo simulations. 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 coordinates of the particle tracks. The tungsten layer is absent in the last two planes, since the readout trigger requires a signal in at least three consecutive Si planes to be activated. The Tracker has an on-axis total radiation length larger than 0.84 X_0. The resulting effective area is shown in Figure 2.

The fundamental unit for the silicon planes is a module of area 9.5×9.5 cm^2, and pitch (distance between strips) equal to 121 μm. Each plane consists of 4×4 modules. The strips will be read out with a pitch of 242 μm, i.e. 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 readout strips through capacitive coupling. In this way, more than one strip has signal, thus enabling to use an interpolation algorithm to improve the spatial resolution. Appropriate algorithms applied on ground will allow an optimal reconstruction of the photon incidence angle.

The Mini-calorimeter, consisting of 1.5 X_0 of Cesium Iodide (CsI), will allow to determine the energy of the incident photons imaged by the Tracker. In addition, the Mini-calorimeter will also be used to study γ-ray bursts and other transient phenomena in the $\sim$250 keV - 100 MeV energy range. The Mini-calorimeter is located below the Tracker and consists of two planes of CsI(Tl) bars. Each bar has dimensions of $2.3\times1.5\times40$ cm^3. The two planes have

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 $\gtrsim$ 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	$107^\circ\times68^\circ$	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	

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. Note that the problem of particle backscattering for this configuration is much less severe than in the case of EGRET, thus allowing a relatively efficient detection of photons up to 10 GeV.

The hard X-ray detector (Super-AGILE) is based on the 9.5x9.5 cm^2 silicon tiles that are used for the Tracker. 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 at a distance of $\sim$14 cm (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 monodimensional sky images along two orthogonal directions. The mask will be supported by an ultra-light structure in carbon fiber that will also serve as a collimator to reduce the background, which is dominated by the cosmic diffuse radiation.

The Anticoincidence system, aimed at both charged particle background rejection and preliminary photon direction reconstruction, completely surrounds the top and lateral sides of the Super-AGILE, Tracker and Mini-calorimeter. The top panel is a single slab of plastic scintillator with thickness 5 mm. The scintillation light is collected by optical fibers glued on the four sides and directed to four photomultiplier tubes at the corners. Each lateral face is segmented with three partially overlapping panels (6 mm thick) connected with photomultipliers placed at the bottom.

3. PERFORMANCES

The expected scientific performances of AGILE are summarized in Table 1. One of the main characteristics of the AGILE γ-ray detector is its very large field of view. 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.

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 γ-ray bursts, which, scaling the EGRET rate to the 5 times larger field of view of AGILE, are expected at a rate of $\sim$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.

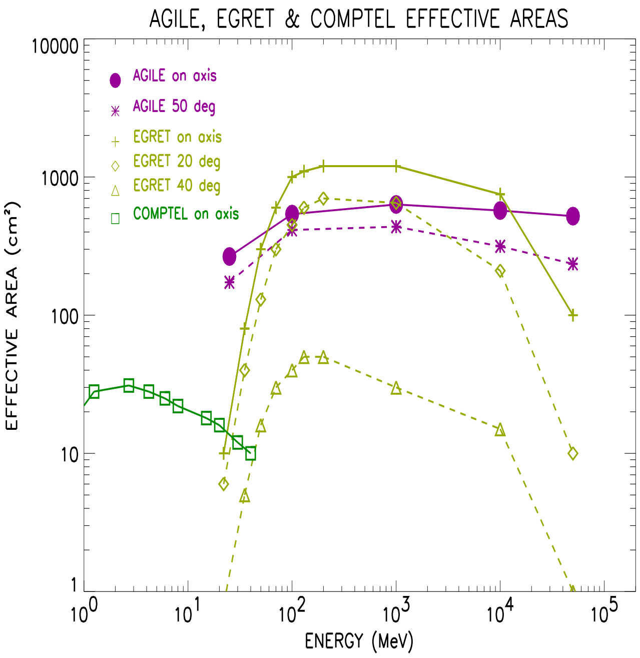

Figure 2. Comparison of the effective area of AGILE with those of previous instruments on CGRO. Note the small decrease at 50° off-axis for the AGILE effective area.

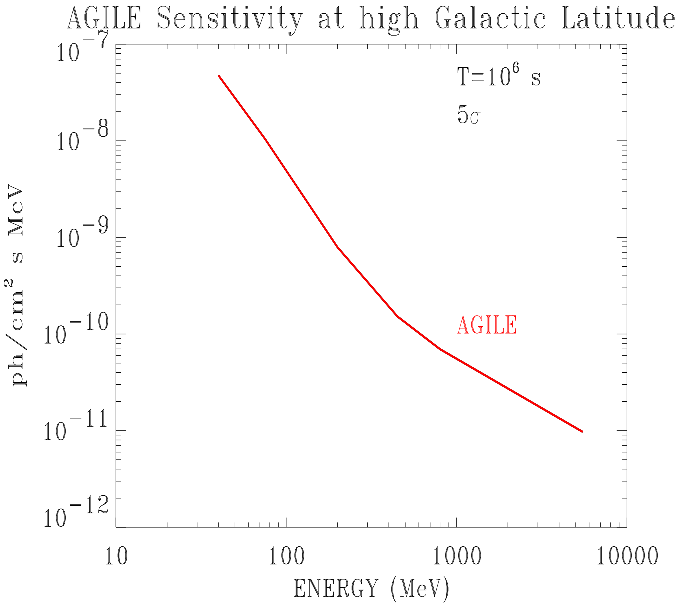

Figure 3. Expected sensitivity for the AGILE γ-ray instrument.

The extension in the hard X–ray range of a γ-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 instrument will be carried in an equatorial (inclination $<5°$), circular orbit (altitude $\sim$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°. An attitude reconstruction at the arcmin level will be obtained a posteriori, 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 instruments 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.

No other γ-ray mission dedicated to the $\sim$30 MeV - 50 GeV energy is planned before GLAST (which will most likely be operational after 2005). Thus AGILE will provide an effective complement to the INTEGRAL satellite, extending the observations to high energies and providing important information on a wide range of astrophysical sources.

REFERENCES

Barbiellini G. et al., 1995, *SPIE* **2478**, 239.

Mereghetti S., et al. 1999, *Mem.S.A.It.* **70**, 229.

Mereghetti S., et al. 2000, *Proc. GeV-TeV Gamma-ray Astrophysics Workshop,* AIP **515**, 467.

Tavani M., et al. 1999, *Mem.S.A.It.* **70**, 201.