AGILE: a Gamma-Ray Mission

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Abstract. AGILE is an innovative, cost-effective gamma-ray mission selected by the Italian Space Agency for a Program of Small Scientific Missions. The AGILE gamma-ray imaging detector (GRID, made of a Silicon tracker and CsI Mini-Calorimeter) is designed to detect and image photons in the 30 MeV–50 GeV energy band with good sensitivity and very large field of view (FOV $\sim$ 3 sr). The X-ray detector, Super-AGILE, sensitive in the 10–40 keV band and integrated on top of the GRID gamma-ray tracker will provide imaging (1–3 arcmin) and moderate spectroscopy.

For selected sky areas, AGILE might achieve a flux sensitivity (above 100 MeV) better than 5×10^{-8} ph cm^2 s^{-1} at the completion of its scientific program. AGILE will operate as an Observatory open to the international community and is planned to be operational during the year 2002 for a nominal 2-year mission. It will be an ideal 'bridge' between EGRET and GLAST, and the only mission entirely dedicated to high-energy astrophysics above 30 MeV during that period.

INTRODUCTION

AGILE (*Astro-rivelatore Gamma a Immagini LEggero*) is a gamma-ray mission [7] selected by the Italian Space Agency (ASI) as the first project for the Program of Small Scientific Missions. AGILE ideally conforms to the *faster, cheaper, better* philosophy for a scientific mission. Gamma-ray detection by AGILE is based on silicon tracking detectors developed for space missions by INFN and Italian University laboratories during the past ten years [1]. AGILE is both very light ($\sim$ 70 kg) and highly efficient in detecting and monitoring gamma-ray sources in the energy range 30 MeV–50 GeV. The accessible field of view is unprecedently large ($\sim$ 1/4

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of the whole sky) because of state-of-the-art readout electronics and a segmented anticoincidence system. The goal is to achieve an on-axis sensitivity comparable to that of EGRET on board of CGRO (a smaller background resulting from an improved angular resolution more than compensates the loss due to a smaller effective area) and a better sensitivity for large off-axis angles (up to $\sim 60°$). We refer to a companion paper for more details on the instrument (Barbiellini et al., these Proceedings). Table 1 shows the expected scientific performance of the baseline AGILE GRID and Super-AGILE detectors. The AGILE scientific program is optimized for three main goals.

(1) Optimal imaging capabilities, reaching $1' - 3'$ resolution by the combined gamma-ray/hard X-ray detection.

(2) Excellent timing capabilities (absolute time resolution $\lesssim 10\,\mu$s, deadtime $\sim 10\,\mu$s for the Mini-Calorimeter and Super-AGILE detectors and $\lesssim 100\,\mu$s for the GRID).

(3) Fast reaction to transients, with dissemination of consolidated quicklook results to allow multiwavelength observations.

SCIENTIFIC OBJECTIVES

Because of the large field of view ($\sim$ 3 sr) AGILE will discover a large number of gamma-ray transients, monitor known sources, and allow rapid multiwavelength follow-up observations because of a dedicated data analysis and alert program. We summarize here some of AGILE's scientific objectives (listed without any meaning to the ordering).

• **Active Galactic Nuclei**. For the first time, simultaneous monitoring of a large number of AGNs per pointing will be possible. Several outstanding issues concerning the mechanism of AGN gamma-ray production and activity can be addressed by AGILE including: (1) the study of transient vs. low-level gamma-ray emission and duty-cycles; (2) the relationship between the gamma-ray variability and the radio-optical-X-ray-TeV emission; (3) the correlation between relativistic radio plasmoid ejections and gamma-ray flares. A program for joint AGILE and ground-based monitoring observations is being planned. On the average, AGILE will achieve deep exposures of AGNs and substantially improve our knowledge on the low-level emission as well as detecting flares. We conservatively estimate that for a 3-year program AGILE will detect a number of AGNs 2–3 times larger than that of EGRET. Super-AGILE will monitor, for the first time, simultaneous AGN emission in the gamma-ray and hard X-ray ranges.

• **Gamma-ray bursts**. About ten GRBs have been detected by EGRET spark chambers during $\sim$ 7 years of operations [4]. This number is limited by the EGRET FOV and sensitivity and apparently not by the GRB emission mechanism. GRB detection rate by the AGILE-GRID is expected to be at least a factor of ~ 5 larger than that of EGRET, i.e., $\gtrsim$ 5–10 events/year). The small AGILE deadtime ($\leq$ 1000 times smaller than that of EGRET) allows a better study of the initial phase of GRB pulses (for which EGRET response was in many cases inadequate). The remarkable discovery of 'delayed' gamma-ray emission up to $\sim$ 20 GeV from GRB 940217 [3] is of great importance to model burst acceleration processes. AGILE is expected to be highly efficient in detecting photons above 10 GeV because of limited backscattering. Super-AGILE will be able to locate GRBs within a few arcminutes, and will systematically study the interplay between hard X-ray and gamma-ray emissions above 30 MeV. AGILE fast timing allows the study of ultra-short GRB pulses of duration $\sim 100\,\mu$s [2].

• **Diffuse Galactic and extragalactic emission**. The AGILE good angular resolution and large average exposure will further improve our knowledge of cosmic ray origin, propagation, interaction and emission processes. We also note that a joint study of gamma-ray emission from MeV to TeV energies is possible by special programs involving AGILE and new-generation TeV observatories of improved angular resolution.

• **Gamma-ray pulsars**. AGILE will contribute to the study of gamma-ray pulsars in several ways: (1) improving photon statistics for gamma-ray period searches by dedicated observing programs with long observation times of 1-2 months per source; (2) detecting possible secular fluctuations of the gamma-ray emission from neutron star magnetospheres; (3) studying unpulsed gamma-ray emission from plerions in supernova remnants and searching for time variability of pulsar wind/nebula interactions, e.g., as in the Crab nebula.

• **Galactic sources, new transients**. A large number of gamma-ray sources near the Galactic plane are unidentified, and sources such as 2CG 135+1 or transients suggesting the existence of a new class of gamma-ray sources (e.g., GRO J1838-04) [6] can be monitored on timescales of months/years. Also Galactic X-ray jet sources (such as Cyg X-3, GRS 1915+10, GRO J1655-40 and others) can produce detectable gamma-ray emission for favorable jet geometries, and a TOO program is planned to follow-up new discoveries of *micro-quasars*.

• **Solar flares**. During the last solar maximum, solar flares were discovered to produce prolonged high-intensity gamma-ray outbursts [5]. AGILE will be operational during part of the next solar maximum and several solar flares may be detected by the Mini-Calorimeter and by the Si-Tracker for favorable pointings. Particularly important for analysis will be the flares simultaneously detected by AGILE and HESSI (sensitive in the band 20 keV–20 MeV).

• **Fundamental Physics: Quantum Gravity**. AGILE detectors are suited for Quantum Gravity studies [8]. The existence of GRB micro-pulses lasting hundreds of microseconds [2] opens the way to study QG delay propagation effects with AGILE detectors. Particularly important is AGILE's Mini-Calorimeter with its independent readout for each of the 32 CsI bars with small deadtime and absolute timing accuracy ($10-20\,\mu$s). Energy dependent time delays near $\sim 100\,\mu$s for GRB micro-pulses in the energy range 0.3–3 MeV can be detected (requiring the detection of a minimum of 5-10 photons). If GRB micro-pulses originate at cosmological distances, sensitivity to the Planck's mass can be reached [8].

AGILE Scientific Performances

	Gamma-Ray Imaging Detector	
Energy Range	30 MeV – 50 GeV	
Field of View	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% contain. radius)
Source Location Accuracy	~5-20 arcmin	for S/N $\gtrsim$ 10
Energy Resolution	ΔE/E~1	at 400 MeV
Absolute Timing Accuracy	$\lesssim 10\,\mu$s	
	Super-AGILE	
Energy Range	10-40 keV	
Field of View	$107^\circ\times68^\circ$	Full Width Zero Sens.
Sensitivity	5–10 milliCrab	(5σ in 1 day)
Angular Resolution (Pixel Size)	6 arcmin	
Source Location Accuracy	~1-3 arcmin	for S/N~10
Energy Resolution	ΔE<4 keV	
Absolute Timing Accuracy	$\lesssim 10\,\mu$s	

MISSION

The ideal orbit for AGILE is a low-background orbit of 550-650 km. The AGILE satellite weight is 200-220 kg, and its pointing will be obtained by a three-axis stabilization system with an accuracy near 0.5–1 degree. Pointing reconstruction reaching an accuracy of $\lesssim$ 1 arcmin will be obtained by two star sensors. The total downlink telemetry rate of science data is 500 kbit s^{-1}. The AGILE mission is being planned as an Observatory open to the Italian and international scientific community. The AGILE mission emphasizes a rapid response to the detection of gamma-ray transients. AGILE will ideally 'fill the vacuum' between the upcoming end of EGRET operations and the beginning of the GLAST mission.

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