

# 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  $5 \times 10^{-8}$  ph cm<sup>2</sup> s<sup>-1</sup> 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 unprecedentedly large ( $\sim 1/4$

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  $\sim 60^\circ$ ). 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  $\lesssim 10 \mu\text{s}$ , deadtime  $\sim 10 \mu\text{s}$  for the Mini-Calorimeter and Super-AGILE detectors and  $\lesssim 100 \mu\text{s}$  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 ( $\sim 3 \text{ sr}$ ) 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  $\sim 5$  larger than that of EGRET, i.e.,  $\gtrsim 5\text{--}10$  events/year). The small AGILE dead-time ( $\leq 1000$  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  $\sim 100 \mu\text{s}$  [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 ( $10 - 20 \mu\text{s}$ ). Energy dependent time delays near  $\sim 100 \mu\text{s}$  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	$6 \times 10^{-9}$ ph cm <sup>-2</sup> s <sup>-1</sup> MeV <sup>-1</sup>	(5 $\sigma$ in 10 <sup>6</sup> s)
Sensitivity at 1 GeV	$4 \times 10^{-11}$ ph cm <sup>-2</sup> s <sup>-1</sup> MeV <sup>-1</sup>	(5 $\sigma$ in 10 <sup>6</sup> s)
Angular Resolution at 1 GeV	36 arcmin	(68% contain. radius)
Source Location Accuracy	~5-20 arcmin	for S/N $\gtrsim$ 10
Energy Resolution	$\Delta E/E \sim 1$	at 400 MeV
Absolute Timing Accuracy	$\lesssim 10 \mu\text{s}$	
Super-AGILE		
Energy Range	10-40 keV	
Field of View	107° × 68°	Full Width Zero Sens.
Sensitivity	5-10 milliCrab	(5 $\sigma$ in 1 day)
Angular Resolution (Pixel Size)	6 arcmin	
Source Location Accuracy	~1-3 arcmin	for S/N ~ 10
Energy Resolution	$\Delta E < 4$ keV	
Absolute Timing Accuracy	$\lesssim 10 \mu\text{s}$	

## 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<sup>-1</sup>. 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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