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THE AGILE GAMMA-RAY MISSION

M. Tavani [a,b,c]

[a] *IASF-CNR, via Fosso del Cavaliere 100, I-00133 Roma, Italy*

[b] *Dipartimento di Fisica, Universitá Tor Vergata, Roma, Italy*

[c] *Consorzio Interuniversitario Fisica Spaziale (CIFS)*

Abstract

The AGILE Mission is dedicated to gamma-ray astrophysics above 30 MeV during the period 2005-2007 and beyond. The main features of AGILE are: (1) excellent imaging and monitoring capabilities simultaneously in the γ-ray (30 MeV – 30 GeV) and hard X-ray (15-45 keV) energy ranges (reaching 1-3 arcminute source positioning for intense sources); (2) large fields of view for the gamma-ray imager (2.5 sr) and hard X-ray imager (0.8 sr); (3) very good timing (improving by almost three orders of magnitude the instrumental deadtime for γ-ray detection compared to EGRET); and (4) optimal imaging and triggering capability for GRBs and other high-energy transients. The AGILE scientific program is being developed emphasizing a quick response to gamma-ray/hard X-ray variable sources and multiwavelength studies of Galactic snf extragalactic objects.

1 Introduction

Gamma-ray astrophysics is in an exciting discovery phase. Detection of gamma-rays above 30 MeV from space is made possible by the development and operation of particle detectors under extreme conditions. The current knowledge of the gamma-ray sky above 30 MeV is based on the scientific results of important missions: SAS-2, COS-B, and EGRET on board of the Compton Gamma-Ray Observatory. More than 300 gamma-ray sources are known today, with many surprises, puzzles, and open questions.

Making further progress require a substantial improvement in detecting performance of gamma-ray instruments. Three are the areas of improvement that need to be addressed by future gamma-ray missions:

- **optimal angular resolution and a large field of view (FOV)** for gamma-ray detection above 30 MeV (apparently contradictory requests !), improving EGRET error boxes and FOV at least by a factor of 4;

- **microsecond-level timing** for photon tagging, and deadtimes for gamma-ray detection substantially below 1 ms;

- **simultaneous X-ray and gamma-ray detection, and on-board triggering and alert capability for fast X-ray transients**.

The space missions AGILE [1, 2, 3] and GLAST [4] are the next space projects to meet the challenge. It turns out that AGILE and GLAST instrument configurations are very differently optimized. The large area of the GLAST gamma-ray imaging detector (LAT) with a full-size calorimeter, and the operations foreseen for a decade will lead to a large exposures of the whole sky and the detection of very faint and persistent sources with good spectroscopic data. The science goals of a Small Mission such as AGILE are differently focussed as discussed here. It is important to note that the gamma-ray imagers of AGILE and GLAST (both based on solid state technology of Silicon microstrip detectors) are expected to produce equivalent Point-Spread Functions between 100 MeV and 1 GeV, with similar capabilities for the positioning of *γ-ray transients lasting a few days* during phases of the GLAST sky-scanning mode Both missions can then be considered *complementary for the detection of transient sources* and aimed at reaching an **"arcminute gamma-ray astrophysics"** with different methods: by the combined X-gamma-ray imaging in case of AGILE, and by a large effective area at gamma-ray energies in case of GLAST. It will be exciting to see both missions developing and reaching their scientific goals during the next years.

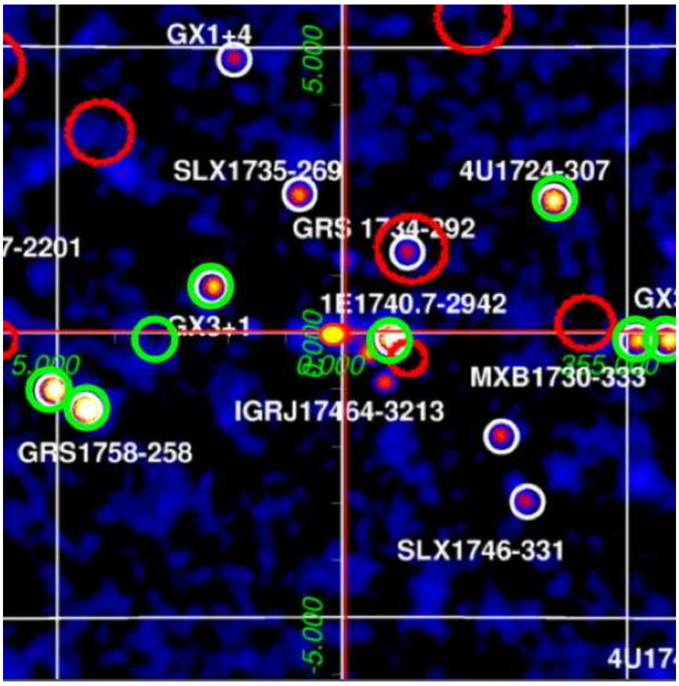

Figure 1: Example of simultaneous hard X-ray and gamma-ray detection and monitoring of high-energy sources to be performed by AGILE. The image shows the *Integral* source map (18-60 keV) of the Galactic Center ($\sim 10^o \times 10^o$) [5, 6] superimposed with the positions of known gamma-ray sources (red ellipses representing their error boxes) of the 3rd EGRET Catalog [7]. The position of the EGRET gamma-ray source near the Sgr A* position is marked in filled yellow color. Hard X-ray sources detectable by Super-AGILE above 20 mCrab at 20 keV are marked in green.

2 The AGILE Mission

AGILE is currently in Phase D. The mission space and ground segments are being developed and are in the final construction stage. Launch is planned by the PSLV rocket during the fourth quarter of 2005.

The AGILE scientific instrument is mostly based on the state-of-the-art and reliably developed technology of solid-state silicon detectors developed by the Italian INFN laboratories. The instrument is light (~ 130 kg) and effective in detecting and monitoring gamma-ray sources within a large field of view ($\sim 1/5$ of the whole sky). The philosophy we adopted is to develop one integrated instrument made of three detectors with broad-band detection and imaging capabilities.

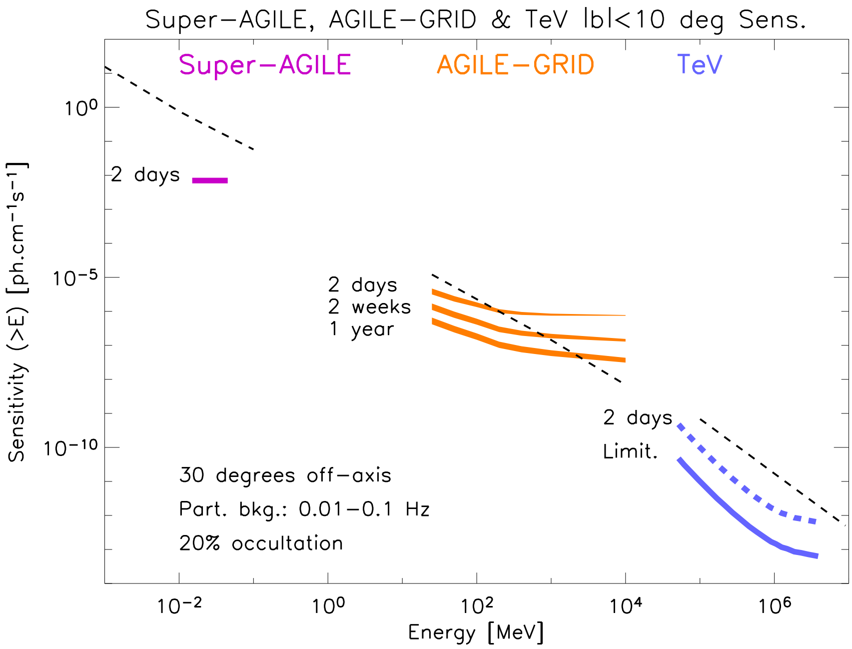

Figure 2: Source integral sensitivity of the AGILE imaging detectors in the hard X-ray energy band (15-45 keV, Super-AGILE) and in the gamma-ray band (30 MeV - 30 GeV, GRID) for different observation timescales (from [8]). The short time-scale (thick dashed curve) and limiting sensitivity of the new generation of TeV telescopes (e.g., H.E.S.S., [9]) is also shown. The light black dashed curve is the integral flux of the Crab Nebula.

The AGILE **Gamma-Ray Imaging Detector (GRID)** is sensitive in the energy range $\sim$ 30 MeV–50 GeV. It is characterized by an optimal spatial resolution and by the smallest ever obtained deadtime for gamma-ray detection ($\lesssim$200 μs). GRID consists of a Silicon-Tungsten Tracker, a Cesium Iodide Mini-Calorimeter, an Anticoincidence system made of segmented plastic scintillators, and fast readout electronics and processing units. The GRID is designed to achieve an optimal angular resolution (source location accuracy $\sim 5' - 20'$ for intense sources), an unprecedently 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 be greatly enhanced by its detection and imaging capabilities in the hard X-ray range (15-45 keV). The **Super-AGILE** detector consists of an additional plane of four Silicon square units positioned on top of the GRID Tracker plus an ultra-light coded mask structure with a top absorbing mask at the distance of 14 cm from the Silicon detectors. The main goals of Super-AGILE are the simultaneous gamma-ray and hard X-ray detection of astrophysical sources (unprecedented for gamma-ray instruments), optimal source positioning (1-3 arcmins, depending on intensity), fast gamma-ray burst and transient alert and on-board trigger capability.

The CsI **Mini-Calorimeter** (MC) will also detect and collect events independently of the GRID. The energy range for this non-imaging detector is 0.3–200 MeV, and it can be very useful to provide spectral and accurate timing information of transient events. The content of a cyclic MC event buffer will be transmitted to the ground for impulsive events (solar flares, GRBs, other transients).

AGILE with its combination of GRID, MC, and Super-AGILE is an innovative instrument, with an optimal expected performance for transients (gamma-ray bursts, solar flares, unidentified gamma-ray sources, AGNs) and steady sources (e.g., pulsars). The fast AGILE electronic readout and data processing (resulting in very small detectors' deadtimes) allow for the first time the systematic search for sub-millisecond gamma-ray transients [2].

The AGILE Team currently includes scientists from the CNR Istituto di Astrofisica Spaziale and Fisica Cosmica (IASF), INFN laboratories, and the Universities of Trieste, Roma-Tor Vergata, and Roma-La Sapienza. The instrument development and scientific operations will take advantage of the work of the **AGILE Multiwavelength Group** composed of scientists from the international community interested in correlated observations and theoretical investigations related with AGILE results.

Despite its simplicity, moderate weight and cost, AGILE is ideal to perform a large number of scientific investigations:

- detecting and monitoring Active Galactic Nuclei (AGNs),
- detecting and imaging gamma-ray bursts (GRBs) with high efficiency in the energy ranges 15 keV - 30 GeV,
- mapping the diffuse Galactic emission with a substantial improvement of the model,
- studying pulsed gamma-ray emission from radiopulsars;
- identifying many of the currently mysterious EGRET unidentified gamma-ray sources;
- carrying out high-precision timing and Quantum Gravity tests.

The new twist of AGILE is certainly the combination of simultaneous hard X-ray and gamma-ray imaging together with very accurate timing.

It is clear today that successful investigations of gamma-ray sources rely on coordinated space and ground-based observations. The AGILE Science Program will be focused on a prompt response to gamma-ray transients and alert for follow-up multiwavelength observations. AGILE will provide crucial information complementary to the many space missions that will be simultaneously operational (INTEGRAL, NEWTON, CHANDRA, SWIFT, ASTRO-E2). Furthermore, it can support ground-based investigations in the radio, optical, and TeV bands (H.E.S.S, MAGIC, VERITAS). Part of the AGILE Science Program will be open for Guest Investigations on a competitive basis. Quicklook data analysis and fast communication of new transients will be implemented as an essential part of the AGILE Science Program.

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