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Scientific Goals and Instrument Performance of the Gamma-Ray Imaging Detector AGILE

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AGILE is a project of the Italian Space Agency (ASI) Scientific Program dedicated to γ-ray astrophysics. It will simultaneously detect and image photons in the 30 MeV - 50 GeV and in the 10-40 keV energy ranges. It is planned to be operational during the second half of 2005 and it will be the only Mission entirely dedicated to γ-ray astrophysics above 30 MeV during the period 2005-2007. We discuss the expected performance of the AGILE space detector, which scientific program emphasizes a quick response to γ-ray transients and multiwavelength studies of γ-ray sources.

1. Introduction

The AGILE scientific instrument, described in detail in ref. [1], consists of three detectors with broad band detection capabilities, see Fig. 1: the AGILE Gamma-Ray Imaging Detector (**GRID**), sensitive in the 30 MeV - 50 GeV energy range; the Super-AGILE detector (**SA**) which provides the additional hard X-ray detection capability in the 10–40 keV energy band, and the CsI Mini-Calorimeter (**MCAL**) which is part of the GRID but will also provide spectral and accurate timing information on transient events independently of the GRID. The GRID consists of a Si-Tracker, based on the state-of-the-art technology developed by the Italian INFN laboratories, with a very good spatial resolution, of order of $\sim 40\mu m$, ref. [2], plus the MCAL and a segmented Anticoincidence System.

AGILE will have, among other features, an unprecedently large field of view (FOV) of ~ 3 sr, larger than previous γ-ray experiments by a factor ~ 4 and excellent timing capabilities: absolute timing of ~ 2 μs and deadtimes of ~ 100 μs for the GRID and of ~ 5 μs for SA and the MCAL. The AGILE Science Program will be focused on prompt response to γ-ray transients and alert for follow up multiwavelenth observations.

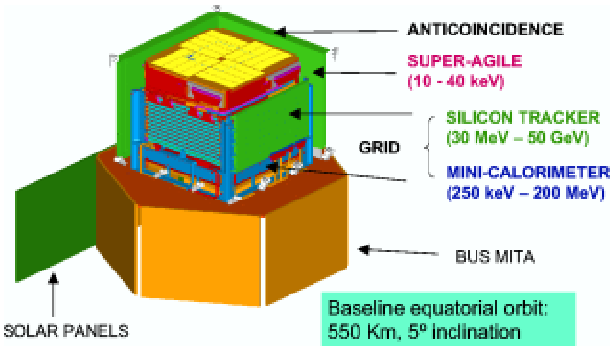

Figure 1. The AGILE instrument size is $\sim 63 \times 63 \times 58$ cm^3 for a total payload weight of ~ 130 kg.

2. Main AGILE scientific objectives

Our present knowledge of high energy γ-ray astrophysics is based mainly on the remarkable results obtained by EGRET [3]. Nearly 300 γ-ray sources above 30 MeV were detected by EGRET, however a big fraction is still unidentified, $\sim 70\%$. Many sources are variable or transient on short timescales and our understanding of many high energy phenomena is still preliminary. We summarize here the main AGILE science topics.

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Active Galactic Nuclei. For the first time, simultaneous monitoring of a large number of AGNs per pointing will be possible. Several issues concerning the mechanism of AGN γ-ray production and activity can be addressed by AGILE. A program for joint AGILE and ground-based monitoring observations is being planned. We conservatively estimate that for a 3-year program AGILE will detect a number of AGNs $\sim$ 3 times larger than that of EGRET. Super-AGILE will monitor, for the first time, simultaneous AGN emission in the γ-ray and hard X-ray ranges.

Gamma-Ray Bursts. The GRID detection rate of GRBs is expected to be a factor of $\sim$ 5 larger than that of EGRET, i.e., $\sim$ 5 - 10 events/year. The small GRID deadtime allows a better study of the initial phase of GRB pulses. Super-AGILE will be able to locate GRBs within a few arcminutes, and will systematically study the interplay between hard X-ray and γ-ray emissions. Special emphasis is given to fast timing allowing the detection of sub-millisecond GRB pulses independently detectable by the Si-Tracker, MCAL and Super-AGILE.

Diffuse Galactic 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 Galactic γ-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: searching for pulsed γ-ray emission from the $\sim$ 30 new young pulsars recently discovered in the Galactic plane; improving photon statistics for γ-ray period searches; detecting possible secular fluctuations of the γ-ray emission from neutron star magnetospheres; studying unpulsed γ-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. AGILE will contribute to the investigation of a new class of unidentified non-blazar γ-ray variable sources in the Galactic plane, such as the mysterious GRO J1838-04 and the variable 2CG 135+1. A large number of γ-ray sources near the Galactic plane are unidentified and can be monitored on timescales of months/years. Also Galactic X-ray sources can produce detectable γ-ray emission for favorable source states and geometries, and a TOO program is planned to follow-up new discoveries of micro-quasars.

Fundamental Physics: Quantum Gravity. AGILE detectors are suited for Quantum Gravity studies. The existence of sub-millisecond GRB pulses lasting hundreds of microseconds opens the way to study QG delay propagation effects with the AGILE detectors. If these ultra-short GRB pulses originate at cosmological distances, sensitivity to the Planck's mass can be reached.

3. SCIENTIFIC PERFORMANCE OF THE AGILE INSTRUMENT

Effective Area. AGILE effective area is characterized by an excellent performance off-axis, being smaller by only a factor of 2 than EGRET for on-axis events, despite the much smaller geometric area. The comparison between AGILE and EGRET effective areas, for fixed directions as a function of photon energy is shown in Fig. 2.

Angular Resolution. The AGILE Point Spread Function (PSF) is obtained by applying the AGILE REconstruction Method (AREM), integrated with Kalman filter algorithms for track identification, ref. [4]. AREM is a 3-Dimensional γ-ray direction reconstruction method applicable to high resolution Si-Tracker detectors. As shown in Fig. 3, the AGILE 3-D PSF on-axis is better than that of EGRET by a factor of $\sim$ 2 above 400 MeV .

Energy Resolution. In order to minimize cost and weight, the Mini-Calorimeter is made of only two planes of 15 CsI bars each, for a total on-axis radiation legth of about $1.5X_0$. However, thank to the excellent spatial resolution, the AGILE Si-Tracker can provide a good estimate of the incident energy from the multiple scattering undergone by the tracks. The AGILE Tracker Energy Reconstruction (ATER) method, see ref.[5], consists in the application of the following three

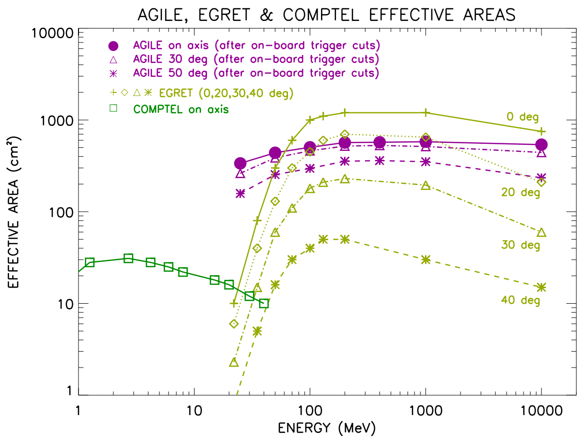

Figure 2. AGILE effective area as a function of energy for several off-axis angles.

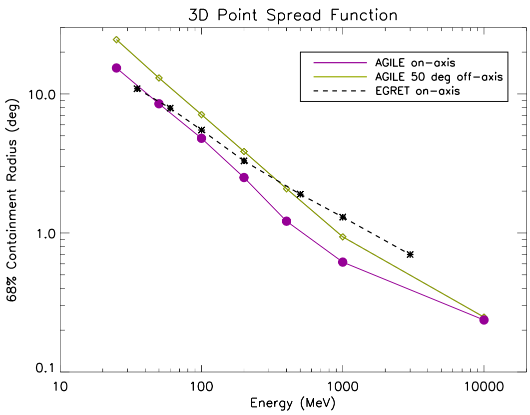

Figure 3. AGILE 3D Point Spread Function.

steps: 1) standard Kalman Filter 2D track reconstruction in each view with iterative input energy; 2) track association and 3D reconstruction; 3) modified Kalman Filter for track energy estimate. The crucial idea of our algorithm is to evaluate in the last step the χ^2 of the reconstructed 3D tracks and derive the track energy estimate by imposing $\chi^2 = 1$. To test the spectral capabilities of the ATER method, we simulate an observation of a point source for 10^6 sec at 30^o off-axis with background induced by mid-latitude diffuse emission. The input source

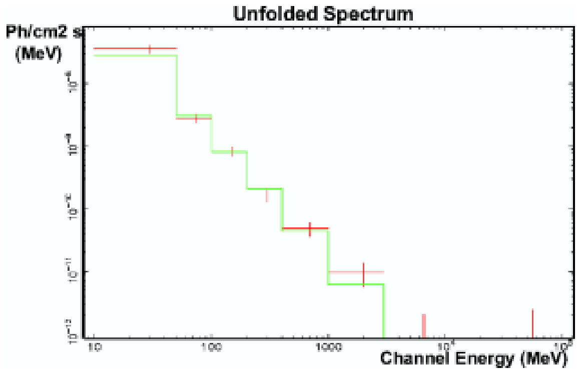

Figure 4. AGILE spectral deconvolution for the simulated observation of a point source for 10^6 sec at 30 degree off-axis, ref.[5].

spectrum is a power law with photon index 2 and flux $1.5 \times 10^7 \mathrm{ph/cm^2 s}$ for $E > 100$ MeV . Fig. 4 shows the preliminary results obtained for the spectral resolution obtained by the Tracker-only information. A measure of multiple scattering provides an energy estimation independently from the Mini-Calorimeter. A full integration between Tracker and Mini-Calorimeter information is in progress, ref.[6].

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