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GAMMA-RAY ASTROPHYSICS AND THE AGILE MISSION

Marco Tavani
Istituto Fisica Cosmica, CNR, via Bassini 15, I-20233 Milano (Italy)

ABSTRACT

Gamma-rays of cosmic origin above nuclear transition energies (larger than 10 MeV) are a manifestation of remarkable energetic acceleration and radiative processes. Diffuse gamma-ray radiation from our Galaxy and about three hundred sources reveal a very active Universe in the energy range 30 MeV – 20 GeV. Seven pulsars and about sixty-five Active Galactic Nuclei are currently identified with gamma-ray sources, and five gamma-ray bursts were clearly detected above a few tens of MeV. However, many more sources ($\sim$ 200) are still unidentified, and their origin and underlying physical processes are a challenge to theoretical models. We briefly review the main astrophysics issues (both theoretical and observational) to be addressed in the following years, and how the planned AGILE mission will contribute to resolve many open issues.

1 Introduction

Observational gamma-ray astronomy is a relatively young branch of astrophysics. The first certain satellite detection of photons above 50 MeV (from the Galactic disk) was made by the third Orbiting Solar Observatory (OSO-3) in the late Sixties [25], together with high-altitude balloon experiments' detections of the Crab pulsar [8], and diffuse gamma-ray radiation from the Galaxy [23]. Improved instrumentation on board of the SAS-2 satellite (Nov. 1972 – July 1973) provided a first sky map of the Galaxy and detection of several sources [15]. The European Cosmic-Ray Satellite (COS-B, August 1975 – April 1982) concentrated in observing the Galactic plane with only a few pointings at high Galactic latitudes. About 20 gamma-ray sources could be clearly detected near the plane, together with the first extragalactic source (3C273) [7, 32]. A great advance came with the results of the EGRET instrument [16, 37] on board of the Gamma-Ray Observatory (GRO) (April 1991 – June 2000). About 300 gamma-ray sources above 30 MeV were detected including about 60 extragalactic ones [20, 38, 39, 40]. Currently, seven isolated pulsars are identified as sources of pulsed gamma-ray emission [40], and the big surprise of EGRET, without any doubt, came from the discovery of strongly variable gamma-ray emission from blazars (a special class of Active Galactic Nuclei [19]). In addition, important results were obtained on the cosmic-ray origin [30], diffuse Galactic [21] and extragalactic [31] emissions, and gamma-ray burst detections [12, 22].

The inheritance of past space missions capable of detecting cosmic radiation above 30 MeV is then remarkable. The sky shines in gamma-rays in ways that could not be anticipated before observations and challenging theoretical models. In the following, we briefly outline the main open questions with a perspective about the future.

2 Open Issues

Gamma-rays above 30 MeV provide a crucial diagnostic for a variety of fundamental topics dealing with the most energetic processes in our Universe, including the origin of cosmic-rays, the emission from magnetized neutron stars and black holes, the behavior and jet processes of Active Galactic Nuclei and GRB sources.

2.1 Acceleration processes

A crucial, if not *the* crucial, topic of high-energy astrophysics is particle acceleration. Particle energy distribution functions are usually assumed to be power-laws. However, we need to understand in more detail the fundamental processes of acceleration for a broad variety of environments and boundary conditions. Diffusive Fermi-like acceleration [13, 14] by hydromagnetic turbulence or parallel-shocks has important applications in cosmic-ray acceleration in supernova-remnants and possibly AGN jets. Also resonant scattering and acceleration by magneto-hydrodynamical and plasma effects can also have relevant applications especially when parallel-shock conditions do no apply [41, 42]. Alternately, strong electric fields in plasmas locally avoiding strong e^+/e^- creation are relevant for pulsar magnetospheres, and possibly jets and relativistic ejecta from compact objects.

Gamma-ray observations challenge theoretical models in a variety of ways: particle composition, acceleration processes and timescales, efficiencies, and the competition with gyro-synchrotron and inverse Compton cooling are under discussion for both Galactic and extragalactic sources. Despite a large number of models, no consensus is reached on a variety of fundamental topics. In order to resolve the *empasse*, we need higher statistics and time resolution for photon detection together with a refinement of theoretical models.

2.2 Cosmic rays and diffuse Galactic gamma-ray emission

Diffuse gamma-ray emission from the Galaxy dominate the detected flux. These diffuse photons are a manifestation of cosmic-ray propagation and bombardment in gaseous environments, and are also produced by synchrotron and inverse Compton processes [21]. Gamma-rays reflect the spiral and local geometry of the Galaxy depending on the number density of cosmic-rays (that may vary across the Galaxy because of source localization) and the gas distribution. Photons above 30 MeV are therefore a crucial diagnostic for cosmic-ray processes.

EGRET contributed in an important way to the issue of the Galactic or extragalactic origin of cosmic rays. The lack of detection from the Small Magellanic Cloud at the level below what expected for an extragalactic origin (upper limit of $0.5 \times 10^{-7}\,\mathrm{ph.\,cm^{-2}\,s^{-1}}$ above 100 MeV) suggests that cosmic-rays originate in our Galaxy [29]. Acceleration of hadronic cosmic-rays in supernova ejecta might produce a detectable flux of gamma-rays in nearby supernova remnants (SNRs), but at the moment we are still missing the smoking gun. TeV emission from the Crab [11] and SN1006 [24] indicate the existence of relativistic leptonic populations emitting by inverse Compton scattering. However, there is no proof yet of the association of a SNR and high energy emission originating from accelerated hadrons. Despite several interesting candidates, no Galactic supernova remnant could be unambiguously associated with a unidentified EGRET source because of limited spatial resolution. This issue will definitely be resolved by next generation gamma-ray detectors in space, providing a substantially better localization compared to that of EGRET.

2.3 Pulsar physics

Seven isolated pulsars were detected by EGRET providing a remarkable set of data [40]. Precise timing of gamma-rays is difficult because of a limited statistics and pulsar (micro) glitches that limit the phase coherence reconstruction. Searches of pulsed gamma-ray signals in the EGRET database is therefore difficult without hints from other wavelengths (e.g., radio, X-rays).

The future is promising. Radio monitoring together with gamma-ray larger exposures on fields containing unidentified gamma-ray sources, improved spatial resolution, and better gamma-ray timing properties should lead to new pulsar discoveries. The current debate is on competing pulsar emission models (polar cap vs. outer gap), the existence of a radio-less population of Geminga-like gamma-ray pulsars, whether millisecond pulsars are detectable in gamma-rays, and time-resolved spectral and light curve features. New radio data from the multi-beam Parkes survey [9] led to the discovery of about 30 new young pulsars (age less than 10^5 years). Some of them are apparently coincident with unidentified EGRET sources [10]. Clearly, these young pulsars with characteristics similar to known gamma-ray pulsars are ideal candidates for pulsed gamma-ray detection by future instruments.

2.4 Active Galactic Nuclei: engines and jets

EGRET remarkable discovery of strongly variable gamma-ray emission from blazars started a new way of investigating black holes and jets. Different "states" of core emission and X-ray/gamma-ray/TeV jet emission were detected for a variety of blazars by combining multifrequency observations. Gamma-ray flaring activity appears to be unpredictable, and apparently lasting days-weeks in our observer's frame. Practically all blazars detected by EGRET are strongly variable. In a few occasions, several high-states above 100 MeV were detected from the same source (e.g., 3C279) for an apparent duty cycle of a few years for large flares. The understanding of particle acceleration and evolution in the jet is still preliminary, and certainly we need more exposure, photon statistics, and a larger sample of detected AGNs to study in detail the fundamental processes. What is the ultimate origin of gamma-ray flares ? Is there any relation with the emission of relativistic radio plasmoids ? What is the blazar gamma-ray duty cycle ? What are the particle acceleration and cooling processes in the jet ? What is the physical difference between blazars emitting in the GeV energy range from those emitting in the TeV range ? Is the extragalactic diffuse gamma-ray background resolvable only in terms of AGNs ? These are only a few questions that can be addressed by future investigations of the AGN population.

2.5 Gamma-ray bursts

Relativistic dynamics and acceleration/cooling processed in jets can have important applications for the interpretation of gamma-ray bursts (GRBs) high-energy emission. EGRET observations of GRB emission above 30 MeV provide a challenge to theoretical models. Impulsive prompt emission of gamma-ray photons within instrumental deadtimes (100 ms), absence of a spectral cut-off up to 10 GeV, durations substantially longer than those at lower energies indicating the clear existence of "delayed (afterglow) gamma-ray emission", spectral variability and re-acceleration in multiple pulse events all demonstrate the complexity of the engine, and the realization of remarkable particle acceleration and radiative efficiencies in GRBs. Only 5 GRBs were detected by the EGRET spark chamber in approximately 5 years of operations [12]. Clearly, we need more.

3 Needs

OSO-3, SAS-2, COS-B, and EGRET were remarkable instruments, each contributing an important piece of the puzzle that we are trying to compose. However, if we want to make progress, we need a substantial improvement of the scientific performance of gamma-ray instruments. Based on the accumulated evidence and the technical development of gamma-ray detectors, we are in desperate needs of:

- **better angular resolution and larger fields of view** (an apparently contradictory request !), improving EGRET error boxes by a factor of at least 4 in sky area, and making the FOV larger by a factor of 4-5;
- **better timing**, reaching a few microsecond for photon tagging and a deadtime for gamma-ray detection below 1 ms;
- **capability of simultaneous X-ray and gamma-ray detection by the same instrument**, to improve the physical information on processes involving broad-band emission, and to provide error boxes of order of 2-3 arcmin.

In the following, we will discuss the first of future gamma-ray missions with these capabilities.

4 The AGILE Mission

The space program AGILE (*Astro-rivelatore Gamma a Immagini LEggero*) is planned to be the first of the ASI Scientific Small Missions [34, 35]. AGILE will be the only Mission entirely dedicated to gamma-ray astrophysics (30 MeV–50 GeV) during the period 2003-2006. AGILE is currently in Phase C [4]. The AGILE scientific instrument is based on the state-of-the-art and reliably developed technology of solid state Silicon detectors developed by the Italian INFN laboratories [1, 2, 3, 18]. The instrument is relatively light ($\sim$ 100 kg) and effective in detecting and monitoring gamma-ray sources within a large field of view.

AGILE's philosophy is to have one integrated instrument made of three detectors with broad-band detection and imaging capabilities. The Gamma-Ray Imaging Detector (GRID) is sensitive in the energy range $\sim$ 30 MeV–50 GeV. It will be characterized by the smallest ever obtained deadtime for gamma-ray detection ($\lesssim$100 μs) and by a trigger based exclusively on Silicon plane detectors. The 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 (~ 3 sr), and a sensitivity comparable to that of EGRET for on-axis (and substantially better for off-axis) point sources.

AGILE will also have detection and imaging capabilities in the hard X-ray range provided by the Super-AGILE detector. It consists of an additional plane of four Silicon square detectors positioned on top of the GRID Tracker plus an ultra-light coded mask structure whose 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 burst 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 a very innovative instrument, with an optimal expected performance for transients (GRBs, stellar 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 [36] with durations comparable with the dynamical timescale of $\sim 1\,M_{\odot}$ compact objects.

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 operational during the first decade of the new Millenium (INTEGRAL, XMM, CHANDRA, SWIFT, and others). Furthermore, it can support ground-based investigations in the radio, optical, and TeV bands. No other mission entirely dedicated to

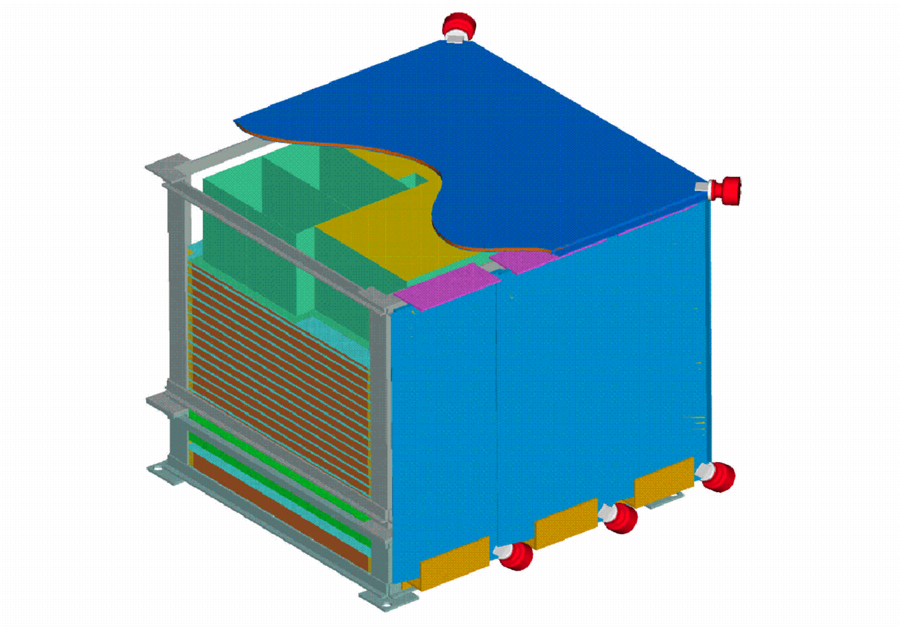

Figure 1: *Schematic view of the AGILE instrument (AC System partially displayed). The GRID is made of a Silicon Tracker (14 Tungsten and Silicon planes) and a Mini-Calorimeter placed at the bottom of the istrument. Super-AGILE has its 4 Si-detectors placed at the top of the first GRID tray, and an ultra-light coded mask system (CMS) positioned on top (the figure shows the CMS partition configuration). The instrument size is* $\sim 63 \times 63 \times 58.5\,\mathrm{cm}^3$, *including Super-AGILE and the AC System for a total weight of* ~ 100 *kg.*

gamma-ray astrophysics above 30 MeV is being planned before GLAST. The technological and scientific development of AGILE is also strongly integrated towards GLAST. 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.

5 Science with AGILE

5.1 Gamma-Ray Astrophysics with the GRID

The GRID has been designed to obtain:

- **excellent imaging capability in the energy range 100 MeV-50 GeV**, improving the EGRET angular resolution by a factor of 2 (see Fig. 2);
- **a very large field-of-view**, allowing simultaneous coverage of $\sim 1/4$ of the entire sky per each pointing (FOV larger by a factor of ~6 than that of EGRET);
- **excellent timing capability**, with absolute time tagging of uncertainty near $1\,\mu$s and very small deadtimes ($\sim 100\,\mu$s for the Si-Tracker and $\sim 20\,\mu$s for each of the individual CsI bars);
- **a good sensitivity for point sources**, comparable to that of EGRET for *on-axis* sources, and substantially better for *off-axis* sources;
- **excellent sensitivity to photons in the energy range ~30-100 MeV**, with an effective area above 200 cm^2 at 30 MeV;
- **a very rapid response to gamma-ray transients and gamma-ray bursts**, obtained by a special quicklook analysis program and coordinated ground-based and space observations.

5.1.1 Large FOV monitoring of gamma-ray sources

Fig. 3 show a typical AGILE pointing. Relatively bright AGNs and Galactic sources flaring with fluxes larger than $10^{-6}\,\mathrm{ph\,cm^{-2}\,s^{-1}}$ (above 100 MeV) can be detected within a few days by the AGILE quicklook analysis. We conservatively estimate that for a 3-year mission AGILE is potentially able to detect a number of gamma-ray flaring AGNs larger by a factor of several compared to that obtained by EGRET during its 6-year mission. Furthermore, the large FOV will favor the detection of fast transients such as gamma-ray bursts. Taking into account the high-energy distribution of GRB emission above 30 MeV, we conservatively estimate that ~1 GRB/month can be detected and imaged in the gamma-ray range by the GRID.

5.1.2 Fast reaction to strong high-energy transients

The existence of a large number of variable gamma-ray sources (extragalactic and near the Galactic plane [33]) makes necessary a reliable program for quick

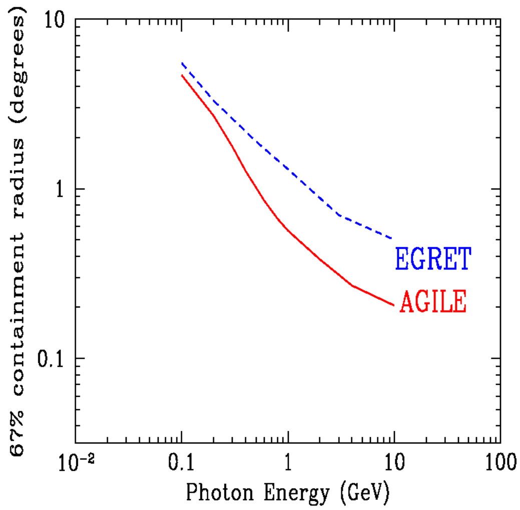

Figure 2: *Three dimensional PSF (67% containment radius) as a function of photon energy for AGILE-GRID and EGRET.*

response to transient gamma-ray emission. Quicklook analysis of gamma-ray data is a crucial task to be carried out by the AGILE Team. Prompt communication of gamma-ray transients (that require typically 2-3 days to be detected with high confidence for sources above $10^{-6}\,\mathrm{ph\,cm^{-2}\,s^{-1}}$) will be ensured. Detection of short timescale (seconds/minutes/hours) transients (GRBs, SGRs, solar flares and other bursting events) is possible in the gamma-ray range. A primary responsibility of the AGILE Team will be to provide positioning of short-timescale transient as accurate as possible, and to alert the community though dedicated channels.

5.1.3 Large exposures for Galactic and extragalactic sky regions

The AGILE average exposure per source will be larger by a factor of ~ 4 for a 1-year sky-survey program compared to the typical exposure obtainable by EGRET for the same time period. After a 1-year all-sky pointing program, AGILE average sensitivity to a generic gamma-ray source above the Galactic plane is expected to be better than EGRET by a factor conservatively given as

~ 2. Deep exposures for selected regions of the sky can be obtained by a proper program with repeated overlapping pointings. For selected regions, AGILE can achieve a sensitivity larger than EGRET by a factor of $\sim 4-5$ at the completion of its program. This can be particularly useful to study selected Galactic and extragalactic sources. For selected sky areas, AGILE can then achieve a flux sensitivity better than 5×10^{-8} ph cm^{-2} s^{-1} at the completion of its scientific program.

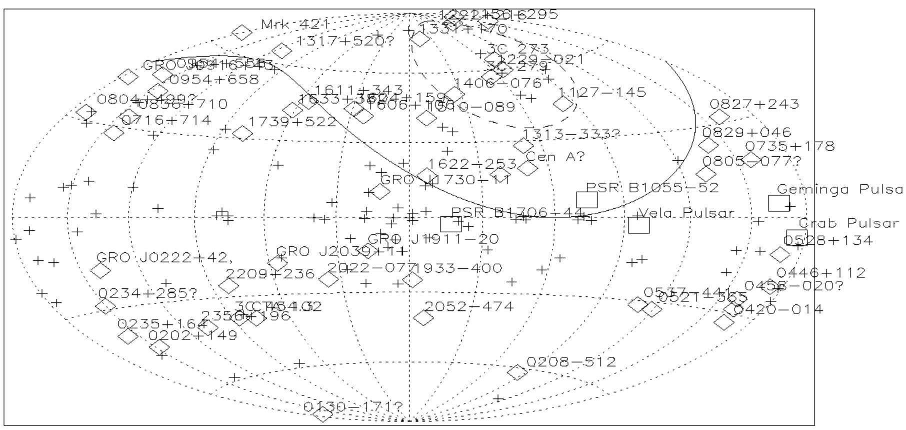

Figure 3: *Comparison between a typical AGILE pointing centered at the blazar 3C 279 (GRID FOV within the solid line circle of radius equal to 60°) and by EGRET (FOV within the dashed line of radius equal to 25°).*

5.1.4 High-Precision Timing

AGILE detectors will have optimal timing capabilities. The on-board GPS system allows to reach an absolute time tagging precision for individual photons near 2 μs. Depending on the detectors hardware and electronics, absolute time tagging can achieve values near $1-2\,\mu$s for the Silicon-tracker, and $3-4\,\mu$s for the individual detecting units of the Mini-Calorimeter and Super-AGILE.

Instrumental deadtimes will be unprecedently small for gamma-ray detection. The GRID deadtime will be of order of 100 μs (improving by three orders of magnitude the performance of previous spark-chamber detectors such as EGRET). The deadtime of MC single CsI bars is near 20 μs, and that of single Super-AGILE readout units is $\sim 5\,\mu$s. Taking into account the segmentation of the electronic readout of MC and Super-AGILE detectors (32 MC elements and 16 Super-AGILE elements) the effective deadtimes will be much less than those for individual units.

Furthermore, the MC events detected during the Si-Tracker readout deadtime will be automatically stored in the GRID event. For these events, precise timing and detection in the $\sim$ 1–200 MeV range can be achieved with temporal resolution well below 100 μs. This is crucial for AGILE high-precision timing investigations.

Fig. 4 show the AGILE deadtime performance compared to other gamma-ray missions. Fast AGILE timing will, for the first time, allow investigations and searches for sub-millisecond transients in the gamma-ray energy range.

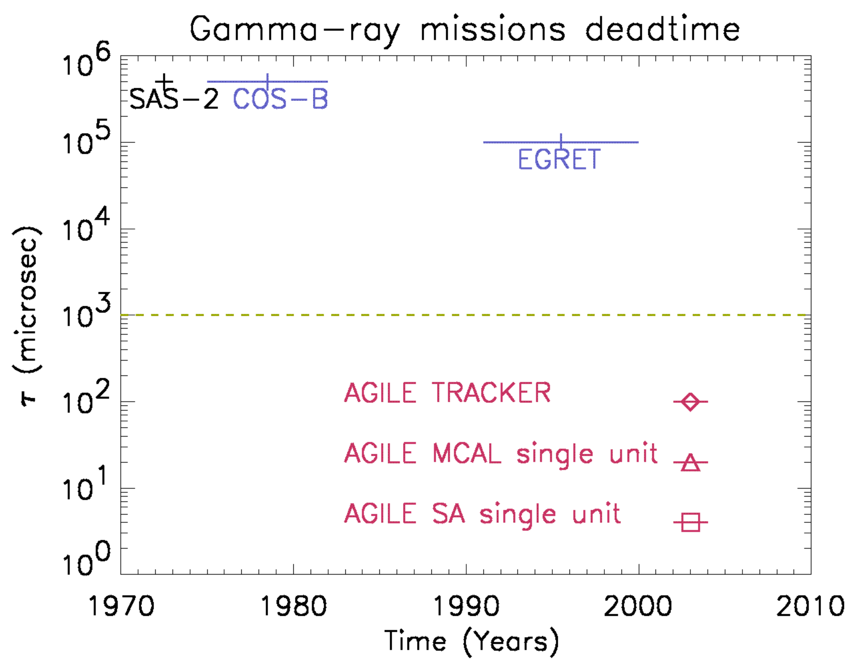

Figure 4: *Instumental deadtimes (τ) for the AGILE detectors and previous gamma-ray instruments.*

5.2 Super-AGILE

An imaging coded mask detector system (Super-AGILE) in addition to the GRID will provide a unique tool for the study of high-energy sources. The Super-AGILE FOV is planned to be ~ 0.8 sr. Super-AGILE can provide important information including:

- **source detection and spectral information in the energy range ~10-40 keV** to be obtained simultaneously with gamma-ray data (5 mCrab sensitivity at 15 keV ($5\,\sigma$) for a 50 ksec integration time);
- **accurate localization (~1-2 arcmins) of GRBs and other transient events** (for typical transient fluxes above ~1 Crab); the expected GRB detection rate is $\sim 1-2$ per month;
- **excellent timing**, with absolute time tagging uncertainty and deadtime near $4\,\mu$s for each of the 16 independent readout units of the Super-AGILE Si-detector;
- **long-timescale monitoring (~2 weeks) of hard X-ray sources**;
- **hard X-ray response to gamma-ray transients detected by the GRID**, obtainable by slight repointings of the AGILE spacecraft (if necessary) to include the gamma-ray flaring source in the Super-AGILE FOV.

The combination of simultaneous hard X-ray and gamma-ray data will provide a formidable combination for the study of high-energy sources. Given the sensitivities of the GRID and Super-AGILE, simultaneous hard X-ray/gamma-ray information is anticipated to be obtainable for: (1) GRBs, (2) blazars with strong X-ray continuum such as 3C 273 and Mk 501, (3) Galactic jet-sources with favorable geometries, (4) unidentified variable gamma-ray sources. Figs. 5,6,7 show the expected scientific performance of Super-AGILE.

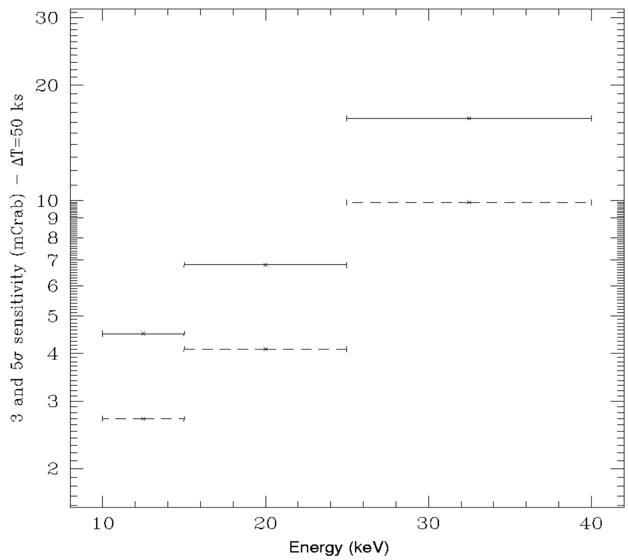

Figure 5: ***Super-AGILE simulated sensitivity (solid data points: 5σ, dashed data points: 3σ) for a 50 ksec integration in mCrab units.***

5.3 Scientific Objectives

We summarize here the main AGILE's scientific objectives (listed without any meaning to the ordering, Table 3 provides a schematic summary).

• **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; (4) hard X-ray/gamma-ray correlations. A program for joint AGILE and ground-based

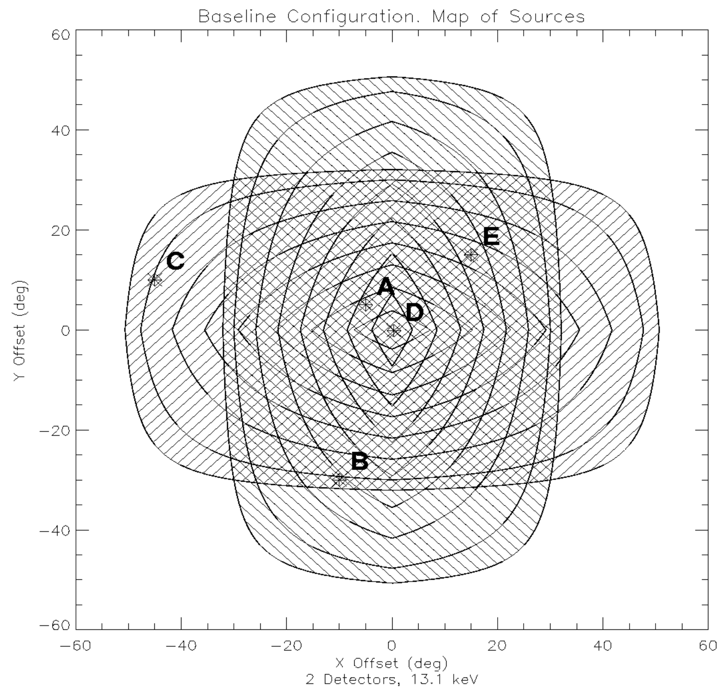

Figure 6: *The Super-AGILE field of view, showing the overlap between sky regions covered by the orthogonal one-dimensional coded mask units.*

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 were detected by the EGRET spark chamber during $\sim$ 7 years of operations [27)]. This number was limited by the EGRET FOV and sensitivity and not by the GRB emission mechanism. GRB detection rate by the GRID is expected to be at least a factor of $\sim$ 5 larger than that of EGRET, i.e., $\geq$5–10 events/year). The small GRID deadtime ($\sim$ 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

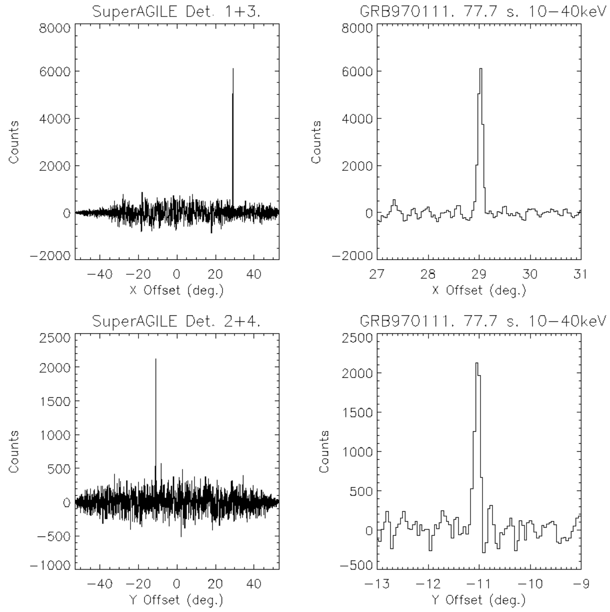

Figure 7: *Simulated detection of GRB 970111 by Super-Agile.*

inadequate). The remarkable discovery of 'delayed' gamma-ray emission up to $\sim$ 20 GeV from GRB 940217 [22] 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 backsplashing. 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. Special emphasis is given to fast timing allowing the detection of sub-millisecond GRB pulses independently detectable by the Si-Tracker, MC and Super-AGILE.

• **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; (2) detecting possible secular fluctuations of the gamma-ray

Table 1: **AGILE Scientific Performance**

Gamma-ray Imaging Detector (GRID)	
Energy Range	30 MeV – 50 GeV
Field of view	~ 3 sr
Sensitivity at 100 MeV (ph cm^{-2} s^{-1} MeV^{-1}, 5σ in 10^6 s)	6×10^{-9}
Sensitivity at 1 GeV (ph cm^{-2} s^{-1} MeV^{-1}, 5σ in 10^6 s)	4×10^{-11}
Angular Resolution at 1 GeV (68% cont. radius)	36 arcmin
Source Location Accuracy (S/N$\sim$10)	$\sim$5–20 arcmin
Energy Resolution (at 300 MeV)	$\Delta E/E\sim1$
Absolute Time Resolution	$\sim 1\,\mu s$
Deadtime	$\sim 100\,\mu s$
Hard X–ray Imaging Detector (Super-AGILE)	
Energy Range	10 – 40 keV
Field of view (FW at Zero Sens.)	$107°\times68°$
Sensitivity (at 15 keV, 5σ in 1 day)	$\sim$5 mCrab
Angular Resolution (pixel size)	$\sim$ 6 arcmin
Source Location Accuracy (S/N$\sim$10)	$\sim$2-3 arcmin
Energy Resolution	$\Delta E<4$ keV
Absolute Time Resolution	$\sim 4\,\mu s$
Deadtime (for each of the 16 readout units)	$\sim 4\,\mu s$
Mini-Calorimeter	
Energy Range	0.3 – 200 MeV
Energy Resolution (above 1 MeV)	$\sim$ 1 MeV
Absolute Time Resolution	$\sim 3\,\mu s$
Deadtime (for each of the 32 CsI bars)	$\sim 20\,\mu s$

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.

• **Search for non-blazar gamma-ray variable sources in the Galactic plane**, currently a new class of unidentified gamma-ray sources such as GRO J1838-04 [33].

• **Galactic sources, new transients**. A large number of gamma-ray sources near the Galactic plane are unidentified, and sources such as 2CG 135+1 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*.

• **Fundamental Physics: Quantum Gravity**. The existence of sub-millisecond GRB pulses lasting hundreds of microseconds [6] opens the way to study QG delay propagation effects by AGILE detectors [36]. Particularly important is the AGILE Mini-Calorimeter with the independent readout for each of the 32 CsI bars of small deadtime ($\sim 20\,\mu$s) and absolute timing resolution ($\sim 3\,\mu$s). Energy dependent time delays near $\sim 100\,\mu$s for ultra-short GRB pulses in the energy range 0.3–3 MeV can be detected (requiring the detection of a minimum of ~ 5 photons). If these GRB ultra-short pulses originate at cosmological distances, sensitivity to the Planck's mass can be reached [36].

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