AGILE: A GAMMA-RAY MISSION FOR A LIGHT IMAGING DETECTOR

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ABSTRACT. AGILE is an innovative, cost-effective gamma-ray mission proposed to the ASI Program of Small Scientific Missions. It is planned to detect gamma-rays in the 30 MeV–50 GeV energy band and operate as an Observatory open to the international community. Primary scientific goals include the study of AGNs, gamma-ray bursts, Galactic sources, unidentified gamma-ray sources, solar flares, and diffuse gamma-ray emission. AGILE is planned to be operational during the year 2001 for a 3-year mission. It will ideally ‘fill the gap’ between EGRET and GLAST, and support ground-based multiwavelength studies of high-energy sources.

1. Introduction

The gamma-ray mission AGILE (Astro-rivelatore Gamma a Immagini LEggero) is currently in a study phase for the Italian Space Agency (ASI) program of Small Scientific Missions. AGILE ideally conforms to the faster, cheaper, better philosophy adopted by space agencies for scientific missions. Gamma-ray detection by AGILE is based on silicon tracking detectors developed for space missions by INFN and Italian University laboratories during the past years (Barbiellini et al., 1995; Morselli et al., 1995). AGILE is both very light (∼ 60 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 (∼ 1/5 of the whole sky) because of state-of-the-art readout electronics and segmented anticoincidence system. AGILE was selected by ASI (1997 December) for a phase A study to be completed within the end of 1998. 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 ∼ 60°). Planned to be operational during the year 2001 for a 3-year mission, AGILE will ideally ‘fill the vacuum’ between the end of EGRET operations and GLAST. AGILE’s data will provide crucial support for ground-based observations and several space missions including AXAF, INTEGRAL, XMM, ASTRO-E, SPECTRUM-X.

(*) Adapted from a paper presented at the Conference Dal nano- al Tera-eV: tutti i colori degli AGN, Rome 18-21 May 1998, to be published by the Memorie della Società Astronomica Italiana.
Fig. 1 (left panel) shows the baseline instrument layout. We refer to a companion paper for more details on the instrument (Morselli et al., 1998). Spectral information ($\Delta E/E \sim 1$) will be obtained by multiple scattering of created pairs in tungsten-silicon planes (for energies less than $\sim 500$ MeV) and by the use of a mini-calorimeter. We are also studying the possibility of adding an ultra-light coded mask imaging system sensitive in the energy band $\sim 10-40$ keV on top of AGILE. Super-AGILE is an innovative concept, combining silicon technology to simultaneously detect gamma-rays and hard X-rays with accurate imaging.

2. Scientific Objectives

Table 1 summarizes the expected performance of AGILE vs. that of EGRET. Because of the large field of view ($\sim 0.8 \pi$ 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. Fig. 1 (right panel) shows the off-axis response to gamma-ray detection of AGILE and EGRET. We summarize here AGILE’s scientific objectives.

- **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. A companion paper presents the impact of AGILE on the study of AGNs (Mereghetti et al., 1998). Super-AGILE will monitor, for the first time, simultaneous AGN emission in the gamma-ray and hard X-ray ranges.

- **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 impulsed 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 (de Jager et al., 1996).

- **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 (e.g.,

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1 Developed in collaboration with E. Costa, M. Feroci, L. Piro and P. Soffitta
|                      | EGRET | AGILE |
|----------------------|-------|-------|
| Mass (kg)            | 1830  | 60    |
| Energy band          | 30 MeV – 30 GeV | 30 MeV – 50 GeV |
| Field of view (sr)   | 0.15 π | 0.8 π |
| Angular resolution*  | ~ 1°   | ~ 0.5° |
| Sensitivity for pointlike sources† | 8 × 10^{-7} ($\oplus$ 0.1 GeV) | 6 × 10^{-7} ($\oplus$ 1 GeV) |
| (ph cm^{-2} s^{-1} MeV^{-1}) | 1 × 10^{-10} | 4 × 10^{-11} ($\oplus$ 1 GeV) |
| (ph cm^{-2} s^{-1} MeV^{-1}) | 1 × 10^{-11} | 3 × 10^{-12} ($\oplus$ 10 GeV) |
| Required pointing reconstruction | ~10 arcmin | ~1-2 arcmin |

(*) FWHM of the point spread function ($E > 100$ MeV) calculated for an incidence angle less than 20° and a photon spectrum $\sim E^{-2})$. (†) Obtained for a typical exposure time near 2 weeks at high galactic latitude for both AGILE and EGRET.

GRO J1838-04) 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.

- **Gamma-ray bursts.** About ten GRBs have been detected by EGRET’s spark chamber during $\sim$ 7 years of operations (Schneid et al., 1996a). This number appears to be limited by the EGRET FOV and sensitivity and not by the GRB emission mechanism. GRB detection rate by AGILE is expected to be a factor of $\sim$ 5 larger than that of EGRET, i.e., $\sim$5–10 events/year). The small AGILE deadtime ($\sim$ 100 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 by EGRET of ‘delayed’ gamma-ray emission up to $\sim$ 20 GeV from GRB 940217 (Hurley et al., 1994) is of great importance to model burst acceleration processes. 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.

- **Solar flares.** During the last solar maximum, solar flares were discovered to produce prolonged high-intensity gamma-ray outbursts (e.g., Schneid et al., 1996b). AGILE will be operational during part of the next solar maximum and several solar flares may be detected. Particularly important for analysis will be the flares simultaneously detected by AGILE and HESSI (sensitive in the band 20 keV–20 MeV).

### 3. Mission

AGILE is planned to be integrated with a spacecraft of the MITA class currently being developed by Gavazzi Space with the support of ASI. AGILE’s pointing is obtained by a three-axis stabilization system with an accuracy near 0.5–1 degree. Pointing reconstruction reaching an accuracy of 1–2 arcmin is obtained by star trackers. The downlink telemetry rate is planned to be $\sim$ 500 kbit s$^{-1}$, and is adequate for AGILE and Super-AGILE for a single contact per orbit. The ideal orbit is equatorial (550 – 650 km).
Fig. 1. Left panel: Lateral view of the AGILE baseline instrument. The anticoincidence system of plastic scintillator panels (not shown) surrounds the detector made of 10 W-Si planes (0.7 $X_0$) plus 2 more Si-only planes and a CsI mini-calorimeter (1.5 $X_0$). The baseline payload size is $\sim 53 \times 53 \times 35$ cm$^3$, and $\sim 53 \times 53 \times 44$ cm$^3$ for Super-AGILE. Right panel: Effective area at 1 GeV as a function of photon incidence angle for EGRET (Thompson et al., 1993) and AGILE. The segmented AC system and AGILE’s trigger electronics allows detection of gamma-rays at large incidence angles.

The AGILE mission is being planned as an **Observatory** open to the international scientific community. Planning of pointed observations, quicklook and standard data analysis results will be available to the community through a Guest Observer Program. The AGILE mission emphasizes a rapid response to the detection of gamma-ray transients. The AGILE Science Support Group will help coordinating multiwavelength observations of gamma-ray sources, and will stimulate investigations of observational and theoretical nature on gamma-ray sources detected by AGILE.

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