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Gamma-ray Astrophysics with the Space Detector AGILE

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Abstract AGILE is a Scientific Mission of the Italian Space Agency (ASI) with INFN, IASF/INAF e CIFS participation devoted to γ-ray astrophysics. It is a first and unique combination of a γ-ray and an X-ray imager, and it will simultaneously detect and image photons in the 30 MeV −30 GeV and in the 15–45 keV energy ranges. The launch is planned at the beginning of 2006 with the Indian launcher PSLV, and it will be the only space mission entirely dedicated to γ-ray astrophysics above 30 MeV during the period 2006–2007. Primary scientific goals include the study of AGNs, GRBs, pulsars, galactic sources, unidentified γ-ray sources, diffuse galactic and extragalactic emission, high-precision timing studies, and fundamental physics. The AGILE Science Program will be focused on a prompt response to γ-ray transients and alert for follow-up multiwavelength observations. Part of the AGILE Science Program will be open for Guest Investigations on a competitive basis.

Key words: gamma rays: observations — gamma rays: theory — instrumentation: detectors

1 INTRODUCTION

AGILE (Astro-rivelatore Gamma a Immagini LEggero) consists of three detectors with broad band detection capabilities: the Gamma-Ray Imaging Detector (**GRID**), sensitive in the 30 MeV – 30 GeV energy range; the Super-AGILE detector (**SA**) which provides the additional hard X-ray detection capability in the 15–45 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 state-of-the-art technology Si-Tracker, developed by the Italian INFN laboratories, which has a very good spatial resolution, of order of $\sim 40\ \mu$m (Barbiellini et al. 2002), plus the MCAL and a segmented Anticoincidence System. The AGILE scientific instrument depicted in Figure 1, is described in detail in Tavani et al. (2004).

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 $\sim 2\,\mu$s and deadtime of $\sim 100\,\mu$s for the GRID and of $\sim 5\,\mu$s for SA and the MCAL. Quicklook data analysis and fast communication of new transients will be implemented as an essential part of the AGILE Science Program for follow up multiwavelenth observations.

2 STATUS OF THE AGILE MISSION

The AGILE Mission is currently in Phase D and the launch is planned in 2006. An Indian rocket PSLV will launch the satellite in an equatorial orbit with an altitude of 550 km and inclination of $\sim$ 0–6 degrees. This is an optimal orbit from the point of view of the expected particle background and for the GRID characteristics. The AGILE satellite has a dedicated on-board receiver providing GPS timing information, and a special on-board transceiver connected with the constellation of ORBCOMM communication satellites which is able to

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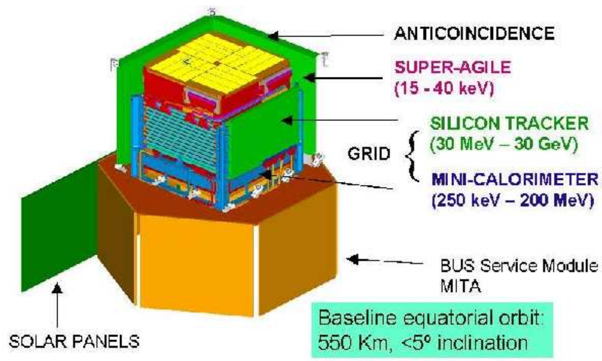

Fig. 1 The AGILE instrument is light (total payload weight of $\sim 130\,\mathrm{kg}$) with a size of $\sim 63\times63\times58\,\mathrm{cm}^3$.

communicate GRB essential data such as time, coordinates and flux within a few seconds since the transient event. Satellite and science data will be down-linked every orbit, every ca 95 min, at the ASI ground station at Malindi (Kenya). AGILE data are then sent from Malindi to the AGILE Operations and Control Center (AOCC) at Telespazio Fucino through ASINET. Scientific and auxiliary data are subsequently transferred to the ASI Science Data Center (ASDC) c/o ESA-ESRIN in Frascati for processing, Quicklook analysis, archiving and data distributing, according to the AGILE data rights policy. AGILE is a small Scientific Mission with a Guest Observers Program (GOP). GOP data will be allocated through the Data Allocation Committe by means of yearly Announcements of Opportunity (AO's). Both for AGILE Team Projects and for AGILE Guest Observer Program, there will be a one year proprietary period at the end of which the data will be moved to the AGILE public archive and will therefore be available to the Science Community.

3 SCIENCE WITH AGILE: 3 EXAMPLES

3.1 AGN's with AGILE

The unprecedently large AGILE field of view will permit for the first time, simultaneous monitoring of a large number of Active Galactic Nuclei (AGN's) per pointing. 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 and a dozen sources per pointing can be considered a typical number for such kind of multiwavelength studies, see Figure 2 from Vercellone et al. (2003).

We conservatively estimate that for a 3-year program AGILE will detect a number of AGN's ~ 3 times larger than that of EGRET, that is ~ 100 new AGN's. Super-AGILE will monitor, for the first time, simultaneous AGN emission in the γ-ray and hard X-ray ranges.

We estimate from simulations that the GRID source location (95% c.r.) for a ~ 30 degrees off-axis AGN with a flux $F_{\mathsf{E}>100\ \mathrm{MeV}} \sim 30 \times 10^{-8}\mathrm{ph\ cm^{-2}\ s^{-1}}$, observed for a typical AGILE exposure time of about 2 weeks, is $r \sim 20$ arcmin, i.e. about a factor of two better than EGRET. The error box radius would be further reduced at the level of few arcmin if the source would be detectable also with Super-AGILE, see Figure 3.

AGILE will achieve deep exposures of AGN's by monitoring at different epochs the low-level emission as well as detecting flares, substantially improving our knowledge of AGN γ-ray duty cycle. Blazar flares detected by AGILE could produce QuickLook alerts in a timescale of $\sim$2 or 3 days.

3.2 GRB's with AGILE

About ten GRBs were detected by EGRET, which was operational between 1991 and 1999, and this number was limited by the EGRET FOV and sensitivity. The AGILE GRID detection rate of GRBs is expected to be a factor of ~ 5 larger than that of EGRET, thus we expect to detect $\sim$5–10 events year^{-1}. The small GRID deadtime, 1000 times smaller than that of EGRET, allows a better study of the initial phase of GRB

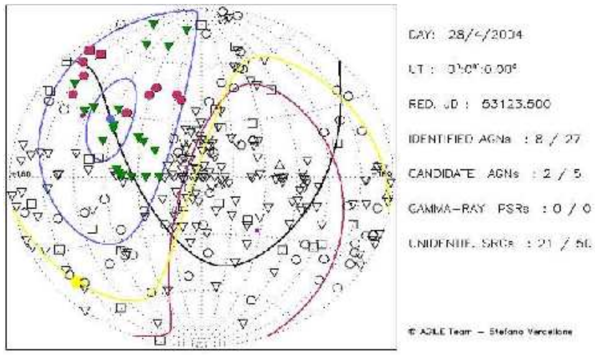

Fig. 2 The figure shows an example on a particular day of a possible simultaneous γ-ray and hard X-ray monitoring of AGNs by AGILE.

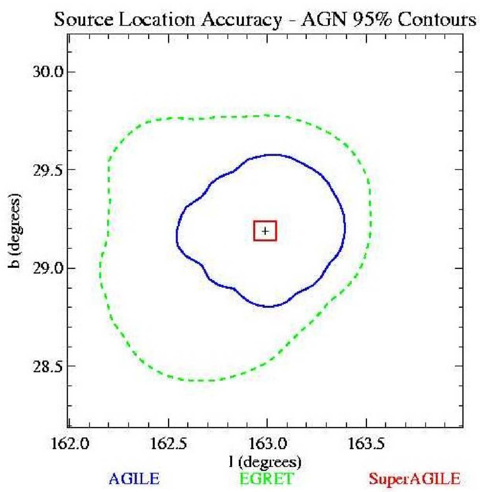

Fig. 3 AGILE GRID and SA Source Location Accuracy compared with EGRET for a dim off-axis AGN.

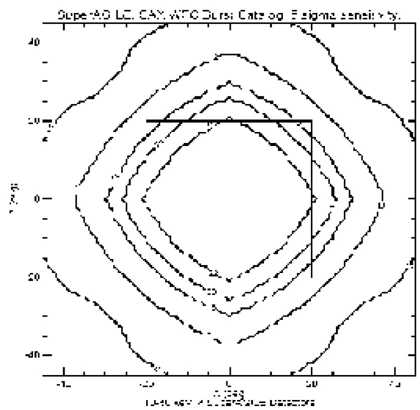

Fig. 4 Out of 23 GRBs in the SAX/WFC burst catalogue at 5σ sensitivity, the numbers in the figure indicate the ones detectable by Super-AGILE as a function of off-axis angle, with the FOV of SAX/WFC indicated by the square.

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. Figure 4 shows the number of GRB that would be detectable by Super-AGILE as a function of off-axis angle out of the 23 GRBs detected by SAX/WFC. The FOV of SAX/WFC is indicated by the square.

Special emphasis is given to fast timing allowing the detection of sub-millisecond GRB pulses independently detectable by the GRID, MCAL and Super-AGILE.

3.3 Diffuse Cosmic Radiation with AGILE

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. In Figure 5 we show the AGILE emission model for the first Galactic quadrant, from Giuliani et al. (2003). New data from HI and CO radio

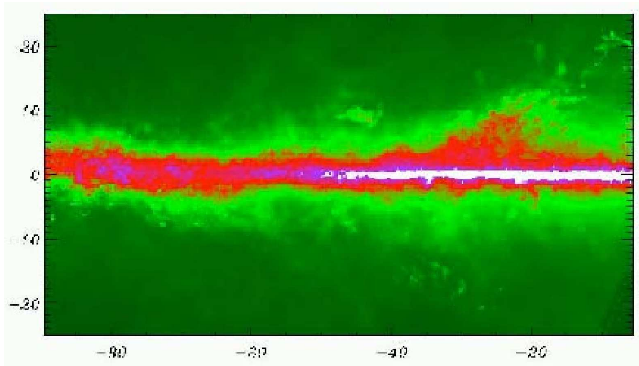

Fig. 5 AGILE emission model for the first Galactic quadrant.

surveys and new models of the Galactic cosmic ray distribution allowed us to create an updated AGILE map of diffuse Galactic gamma-ray emission, both for use in point source analysis and in detailed observations of molecular cloud regions.

References

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DISCUSSION

ALAN MARSCHER: What are the pointing constraints of AGILE relative to the sun?

PITTORI CARLOTTA: AGILE solar panels must always be pointed toward the sun, hence there is one degree of freedom left for choosing the Payload ponting.

JIM BEALL's Comment: A comment about the GLAST launch: it may be further delayed, so AGILE is very important from the point of view of time coverage.