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e-ASTROGAM: a space mission for MeV-GeV gamma-ray astrophysics

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Abstract.
e-ASTROGAM is an observatory space mission dedicated to the study of the gamma radiation in the range from 0.3 MeV to 3 GeV. The detector is composed by a Silicon tracker, a calorimeter, and an anticoincidence system. The mission is based on an advanced space-proven detector technology, with unprecedented sensitivity, angular and energy resolution, combined with polarimetric capability. Thanks to its performance in the MeV-GeV domain, substantially improving its predecessors, e-ASTROGAM will open a new window on the non-thermal Universe. In particular it will determine the origin of key isotopes fundamental for the understanding of supernova explosions and the chemical evolution of our Galaxy. It will also shed light on the processes behind the acceleration of cosmic rays in our Galaxy.

1. The scientific objectives

e-ASTROGAM [1] is a concept for a gamma-ray space observatory operating in the energy range from 0.3 MeV to 3 GeV, aiming to provide gamma-ray data to a broad astronomical community in a decade of powerful observatories for multiwavelength astronomy and for the detection of gravitational waves, neutrinos and ultra-high-energy cosmic rays (UHECRs). The expected scientific return for such an observatory is substantial [2]. In particular, e-ASTROGAM will address the outstanding issue of the origin and propagation of cosmic rays. It will measure cosmic-ray diffusion in interstellar clouds and their impact on gas dynamics and state, thus providing crucial diagnostics about the impact of cosmic rays on star formation, structures of the interstellar medium, galactic winds and outflows. The improved sensitivity and angular resolution will be

‡ See http://eastrogam.iaps.inaf.it

e-ASTROGAM

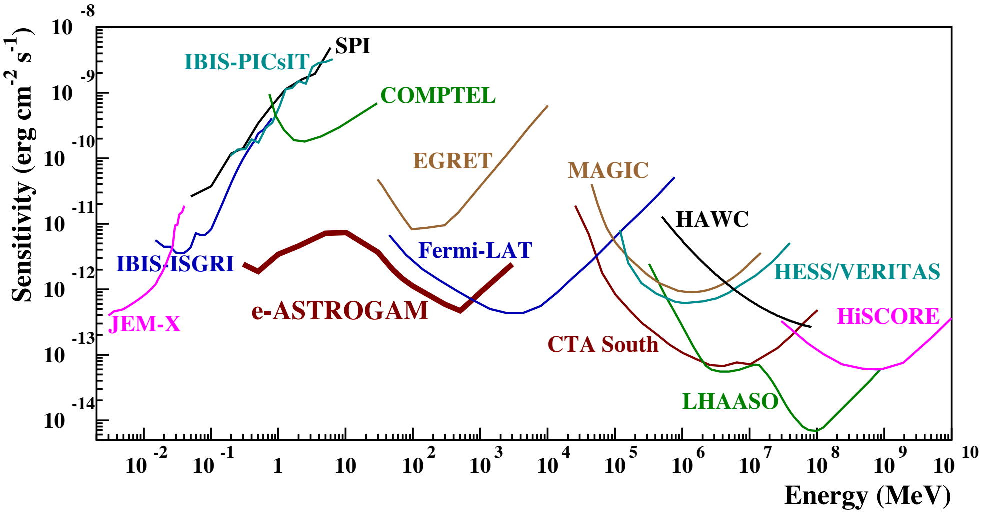

Figure 1. Point source continuum differential sensitivity of different X- and γ-ray instruments, from [2]

crucial to probe the interplay between cosmic rays and the turbulent medium of star forming regions (e.g. the Cygnus Cocoon) during the early steps of their Galactic voyage. Sensitive e-ASTROGAM observations of a set of cosmic-ray sources, such as young supernova remnants, will allow for the first time to distinguish the emission produced by the interactions of cosmic-ray nuclei with the ambient gas and the non-thermal emission from cosmic-ray electrons, helping in the discrimination among models of hadronic and leptonic production.

2. The instrument

The e-ASTROGAM instrument operates over more than four orders of magnitude in energy (from about 150 keV to 3 GeV) by detecting photons in both the Compton (0.15 – 30 MeV) and pair-production (> 10 MeV) regimes. The telescope is made up of three detection systems: a silicon tracker, a scintillator calorimeter and an anti-coincidence system, for a mass of 1.2 tons.

The Si tracker comprises 5600 double-sided strip detectors (DSSDs) arranged in 56 layers, divided in four units of 5×5 DSSDs. Each DSSD has a geometric area of 9.5×9.5 cm^2, a thickness of 500 μm, and a strip pitch of 240 μm. Stacking relatively thin detectors enables efficient tracking of the electrons and positrons produced by pair conversion, and of the recoil electrons produced by Compton scattering. The DSSD signals are read out by 860,160 independent, ultra low-noise and low-power electronics channels with self-triggering capability.

The calorimeter is a pixelated detector made of 33,856 Thallium-activated Cesium Iodide bars of 8 cm length and 5×5 mm^2 cross section. Each element is read out by silicon drift detectors (SDDs) at both ends, the depth of interaction along each

e-ASTROGAM

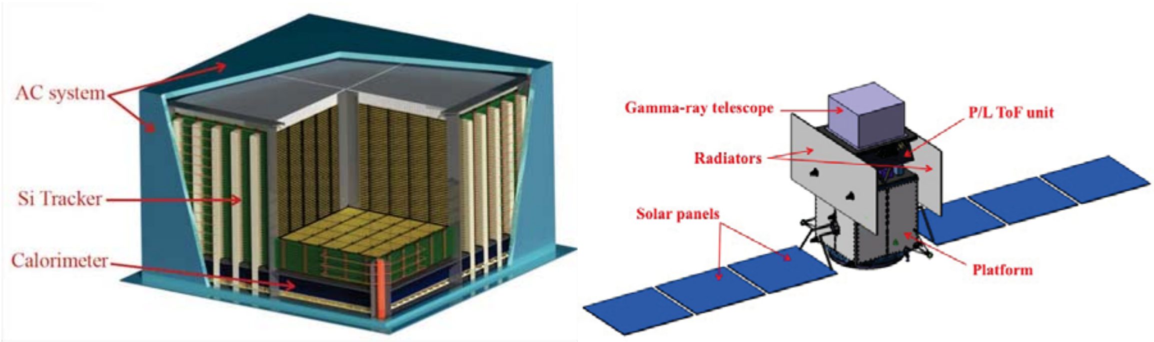

Figure 2. *Left panel* – overview of the scientific intrument. *Right panel* – the scientific intrument on top of the platform. From [1].

crystal is measured from the different light amount collected at both ends. The accurate measurement of the 3D position and deposited energy of each interaction is essential for a proper reconstruction of the Compton events. The total thickness – 4.3 radiation lengths – guarantees an 88% absorption probability for a 1-MeV photon on-axis.

The anti-coincidence system is composed of two parts: a standard anti-coincidence detector (Upper-AC), made of segmented panels of plastic scintillators covering the top and four lateral sides of the instrument, and a time-of-flight system (ToF) placed on the bottom of the instrument, to reject the particle background produced by the mass in the platform. The Upper-AC detector is segmented in 33 plastic tiles (6 tiles per lateral side and 9 tiles for the top) coupled to silicon photomultipliers (SiPM) by optical fibers, the ToF unit is composed of two plastic scintillator layers separated by 50 cm, read out by SiPMs with a timing resolution of 300 ps.

3. Performance

e-ASTROGAM is to be launched into a quasi-equatorial (inclination $i < 2.5°$) low Earth orbit at a typical altitude of 550 – 600 km. Extensive simulations based on the mass model of the satellite and on the model of the background environment [3, 4] have demonstrated the performance of the instrument [1]:

- broad energy coverage ($\sim$0.15 MeV to 3 GeV), with nearly two orders of magnitude improvement of the continuum sensitivity in the range 0.15 – 100 MeV compared to previous missions (Figure 1);
- excellent sensitivity for the detection of key gamma-ray lines e.g. sensitivity for the 847 keV line from thermonuclear supernovae 70 times better than that of the *INTEGRAL* spectrometer (SPI);
- unprecedented angular resolution, improving not only on the angular resolution of CGRO-COMPTEL in the MeV regime, but also on that of *Fermi*-LAT in the GeV regime (68% containment radius at 1 GeV is 9').

e-ASTROGAM

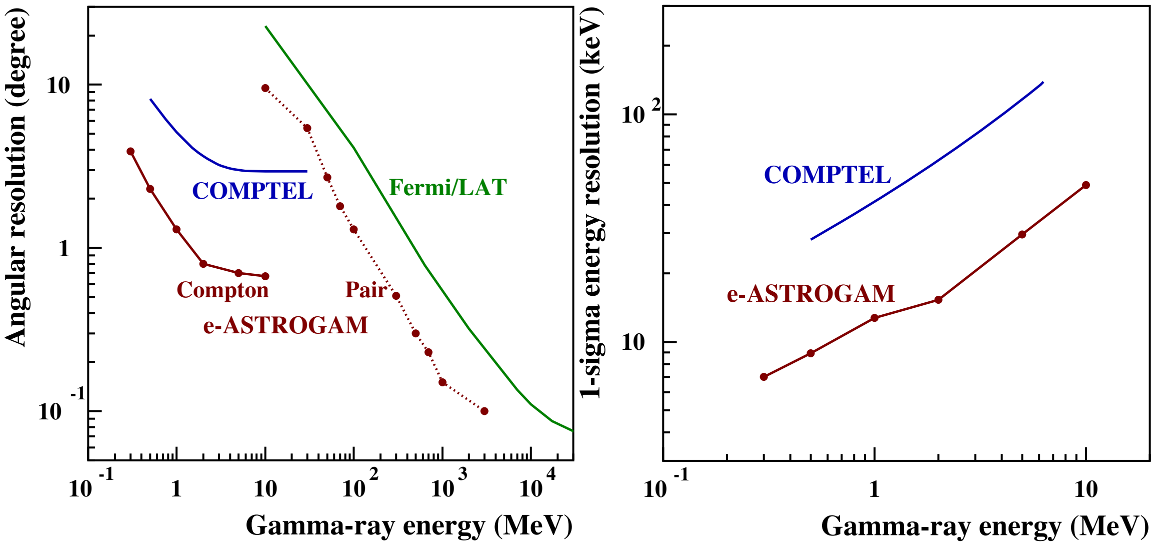

Figure 3. *Left panel* – e-ASTROGAM on-axis angular resolution compared to that of COMPTEL and *Fermi*/LAT. *Right panel* – 1σ energy resolution of COMPTEL and e-ASTROGAM in the Compton domain. From [1].

- large field of view (> 2.5 sr), ideal to detect transient Galactic and extragalactic sources, such as X-ray binaries and GRBs;
- timing accuracy of 1 μs (at 3σ), ideal to study the physics of magnetars and rotation-powered pulsars, as well as the properties of terrestrial gamma-ray flashes;
- pioneering polarimetric capability for both steady and transient sources.

References

[1] De Angelis A, Tatischeff V, Tavani M et al. 2017 *Exp. Astr.* **44** 25–82
[2] De Angelis A, Tatischeff V, Grenier I A et al. submitted to *J. High Energy Phys.* arXiv:1711.01265
[3] Zoglauer A, Andritschke R and Schopper F 2006 *New Astr. Rev.* **50**, 629–632
[4] Bulgarelli A, Fioretti V, Malaguti P, Trifoglio M and Gianotti F 2012 *Proc. SPIE* **8453** 845335