HIGH ENERGY GAMMA PHYSICS WITH GLAST

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The Gamma-ray Large Area Space Telescope (GLAST) is a space mission that will detect photons from the sky in the energy range between 10 keV and 300 GeV, scheduled for launch by NASA in 2007. Compared to previous missions, GLAST will have greatly improved sensitivity and ability to resolve γ-ray point sources. This report describes the detector design and performance and presents an overview of the physics goals of the GLAST observatory.

1. Introduction

Our understanding of the GeV γ-ray sky was greatly improved since the launch of the Energetic Gamma-Ray Experiment Telescope (EGRET) [1] on the Compton Gamma-Ray Observatory in 1991. The number of known GeV γ-ray sources increased from few to 271, listed in the 3rd EGRET Catalog [2]. The most of them, however, remain unidentified as a direct association to known sources was not possible. The GLAST mission [3] will use detectors exploiting long-standing technologies developed for particle physics experiments, resulting in an overall improvement in sensitivity with respect to EGRET of more than one order of magnitude.

2. Instrument design

GLAST is an international space mission to explore the high energy γ-ray Universe. There are two instruments on board. The Large Area Telescope (LAT), the main instrument, will measure energy and direction of the photons at energies from 20 MeV to 300 GeV. The very good angular resolution of the instrument, together with its large field of view and minimum detection dead time, results in a sensitivity a factor more than 30 times better than previous instruments. The second instrument, the GLAST Burst Monitor (GBM), will have a field of view several times larger than the LAT and will provide spectral coverage for γ-rays in the range from 10 keV to 25 MeV.

2.1. *The Large Area Telescope (LAT)*

A schematic view of the LAT is shown in Figure 1.

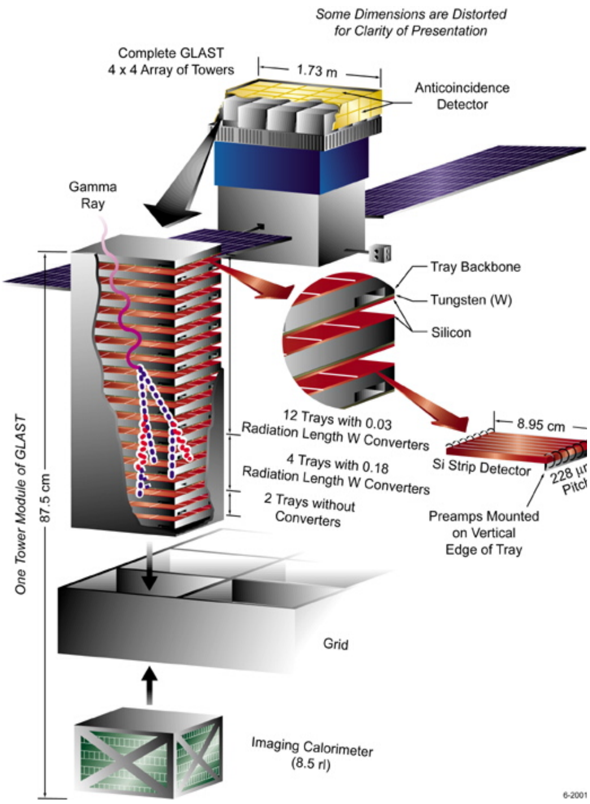

Figure 1. The GLAST LAT Detector

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composed of an array of 4 x 4 identical towers, each equipped with a high resolution silicon tracker/converter, an imaging CsI calorimeter and a custom read-out electronics module. It is surrounded by a segmented anticoincidence detector (ACD) for charged particle background rejection. The payload weight is 3000 kg for a total power consumption of 650 W.

2.1.1. *The LAT tracker/converter*

The LAT tracker [4] is the largest silicon tracker ever built for space applications, with an overall area of ~80 m^2 and approximately 10^6 channels. Each tracker tower consists of 18 pairs of X-Y detection planes, equipped with tungsten (W) converter and single-sided 228 μm pitch silicon strip detectors (SSD). The W thickness varies across the tower: the first 12 pairs, the front section, have 3% radiation length (r.l.) thick converter planes, while the following 4 (back section) have converters 18% r.l. thick and the final planes have no converter. Including structural material the converter is 1.485 r.l. thick in total. Photons converting in the front section are measured with better angular resolution, while the back section assures high overall photon detection efficiency. The LAT towers are self-triggered when a signal is detected in any three consecutive X-Y plane pairs; further trigger selection is applied using events from all 16 towers and ACD data, in order to reduce the raw trigger rate from few kHz to few Hz.

2.1.2. *The CsI calorimeter*

The hodoscopic calorimeter consists of a segmented array of 1536 CsI (Tl) crystals in 8 layers, for a total of 8.5 r.l. and approximately $6 \cdot 10^5$ channels, giving both longitudinal and transverse information about the energy deposition.

2.1.3. *The ACD detector*

The AntiCoincidence Detector provides most of the rejection for charged particles background (10^5 the expected γ-ray flux). It consists of 89 plastic scintillator tiles, read out by wave-shifting fibers, surrounding the towers. Each tile has a charged particle detection efficiency of 0.9997, while the fine segmentation prevents the loss of effective area at high energy due to self-veto effects.

2.2. ***Instrument capabilities***

The LAT performance are compared to EGRET in Table 1.

Table 1. LAT properties compared to EGRET

	EGRET	LAT
Energy range	20 MeV–30 GeV	20 MeV–300 GeV
Energy resolution	10 %	9 %
Effective Area	1500 cm^2	10000 cm^2
Angular resolution	5.8° - 0.3°	3.4° - 0.09°
Field of View	0.5 sr	2.4 sr
Flux Sensitivity (E > 100 MeV)	10^{-7} cm^{-2} s^{-1}	$2 \cdot 10^{-9}$ cm^{-2} s^{-1}
Dead Time	100 ms	25 μs

The improvement in resolution will result in a much improved ability to localize sources, while the increase in effective area will enhance source identification via their temporal signature. The short dead time gives better efficiency for closely spaced in time events during intense phases of gamma ray bursts and solar flares. The extended energy range will provide complete spectral coverage from MeV to hundreds GeV energies for the first time, resulting in a significant overlap with the next generation of ground bases telescopes, as shown in Figure 2, where integral sensitivities for past, current and future high energy γ-ray instruments are compared.

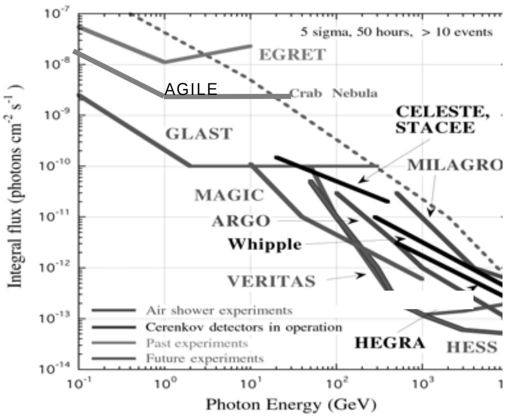

Figure 2. Sensitivities of past, current and future high energy γ-ray detectors

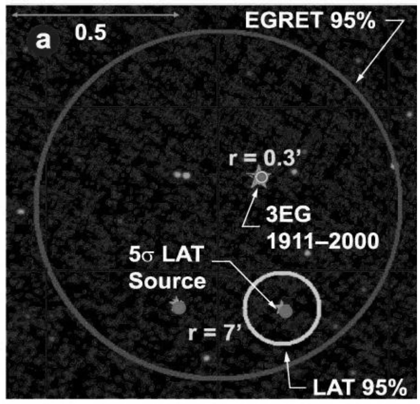

Figure 3. Comparison of GLAST and EGRET 95% C.L. radius on a 5σ source

3. GLAST Science Program

GLAST has a wide range of scientific objectives, ranging from γ-astrophysics to fundamental physics. In the following a brief description of GLAST capabilities on selected items will be given, while a report on GLAST potentiality in search for supersymmetric dark matter can be found in the contribution by A. Morselli to these proceedings.

3.1. *Sky map and unidentified sources*

Most of the γ-ray sky, as we currently understand it, consists of unidentified objects: the reason why most of the 271 sources in the 3rd EGRET catalog are unidentified is that the large error boxes in the localization (about 1 sq degree) did not allow unambiguous association to known objects in the optical, radio or X-ray bands. A full-sky survey with the LAT is planned for the first year of the GLAST mission: the excellent angular resolution and sensitivity will provide high quality data with large statistics for detailed sky mapping at the level of arc-minutes. Figure 3 shows a comparison of the relative sizes of EGRET and GLAST 95% confidence contours on a portion of the 1.4 GHz NRAO VLA Sky Survey (Condon at al, 1996), illustrating the dramatic improvement in source identification that will be possible with the LAT.

3.2. *Active Galactic Nuclei*

A large fraction of the known high energy sources is represented by Active Galactic Nuclei (AGN), most of them belonging to the blazar class. Blazars are flat radio spectrum AGN, whose members include BL Lac objects and highly polarized and optically variable quasars, often emitting more in γ-ray than at any other frequency. GLAST will dramatically extend the number of observed AGNs, as well as the energy range over which they will be observed. Extrapolation from the log N-log S relation [5] for AGNs suggests that the number of blazars detected by the LAT will range from ~2500 to ~10000. The high sensitivity and the large effective area of the LAT will allow testing different models proposed for the blazar central engine: detailed spectral studies should allow to distinguish between pure leptonic and hadronic particle acceleration mechanisms. This large number of AGNs, covering a redshift range from z ~0.03 to z ~4, will allow to study the redshift dependence of the cutoff in the γ-ray spectra at large z, to disentangle intrinsic effects from interaction with extragalactic background light (EBL).

3.3. *Gamma-Ray Bursts*

Gamma-ray bursts (GRB) are the most intense but short-lived sources of γ-rays. Observations are generally made of two phases of a burst: the prompt phase (milliseconds to thousands seconds) is a period of very intense γ-ray emission, while the afterglow phase observed at radio, optical, X-ray and γ-ray wavebands, has timescales of hours to days. EGRET detected few bursts at energies greater than 50 MeV and could not perform temporal studies due to its large dead time comparable to the γ-ray pulse width. The unprecedentely short dead time combined with the large effective area, will allow the LAT to detect bursts to much lower intensities and will greatly advance GRB study at high energies. GRB energy and timing properties will be much better studied by combining data from the LAT and GBM, measuring energy spectra from a few keV to hundreds GeV. GLAST will also alert other observers in the context of multiwavelength afterglow observations.

3.4. *Pulsars*

GLAST will discover ~200 new γ-ray pulsars and will provide definitive spectral measurements to distinguish between the two primary models (*outer gap* and *polar cap*) of γ-ray production for rotation powered pulsars. The good time resolution and detection efficiency of the LAT will allow direct pulsation search in the γ-ray band and, since the γ-ray beams of pulsars are apparently broader than their radio beams, the identification of many sources with X or radio-quiet Geminga-like pulsars is expected.

3.5. *Cosmic Rays*

One of the long-standing problems in astrophysics is the origin of cosmic rays (CR). EGRET observations have shown that CR are likely to be Galactic in origin. GLAST has the potential to be the first instrument to detect the production sites of CR nuclei, widely believed to be supernova remnants (SNR). The conclusive signature of CR nuclear acceleration by a SNR would be the π^0 bump from CR nucleons interacting in an interstellar medium at the shell of the SNR. The LAT should be able to resolve SNR sources of γ-rays, as well as measuring the spectral signature of π^0 decay on top of electron bremsstrahlung and inverse Compton emission from CR electrons associated with SNRs. Through observations of diffuse γ-ray emission produced by interactions of CR with interstellar gas and photons, GLAST will also be a powerful mission to study the distribution of CR within the Milky Way and in external galaxies.

4. Conclusions

GLAST originates from a partnership of the HEP and Astrophysics communities sharing scientific objectives and technology expertise. It has been designed to use very performant particle detectors, resulting in more than one order of magnitude inprovement in sensitivity and resolution with respect to previous missions. With the launch of GLAST it will be possible to explore the sky in the 10 keV–300 GeV energy range (where many astrophysical objects like AGN, GRB, pulsars and SNR radiate) giving an answer to many of the exciting questions raised by the EGRET observatory.

References

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