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The Gamma Large Area Space Telescope: GLAST

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Abstract The GLAST mission is a high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy band extending from 20 MeV to 300 GeV. Our understanding of the Universe has experienced a revolution in the last several years with breakthrough observations of many new phenomena that have changed our view of the high energy Universe and raised many new questions. The GLAST mission stands poised to open enormous opportunities for answering these questions and advancing knowledge in astrophysics and particle physics.

Key words: gamma-rays — dark matter — gamma-rays experiment

1 INTRODUCTION

The energy domain between 10 MeV and hundreds of GeV is an essential one for the multifrequency study of extreme astrophysical sources. The understanding of spectra of detected gamma rays is necessary for developing models for acceleration, emission, absorption and propagation of very high energy particles at their sources and in space. After the end of EGRET on board the Compton Gamma Ray Observatory this energy region is not covered by any other experiment, at least up to 50 GeV where ground Cerenkov telescopes are beginning to take data. Here we will review the status of the space experiment GLAST that will fill this energy region from March 2006 with particular emphasis at the connection with all the other ground and space planned experiments and at the contribution of GLAST to particle physics.

GLAST (Atwood et al. (1994), J. Mattox et al. (1996), A. Morselli (1997)) is a next generation high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy band extending from 20 MeV to more than 300 GeV. The principal instrument of the GLAST mission is the Large Area Telescope (LAT) that is being developed jointly by NASA and the US Dept. of Energy (DOE) as a mission involving an international collaboration of particle physics and astrophysics communities from 26 institutions in the United States, Italy, Japan, France and Germany. The main scientific objects are the study of all gamma ray sources such as blazars, gamma-ray bursts, supernova remnants, pulsars, diffuse radiation,

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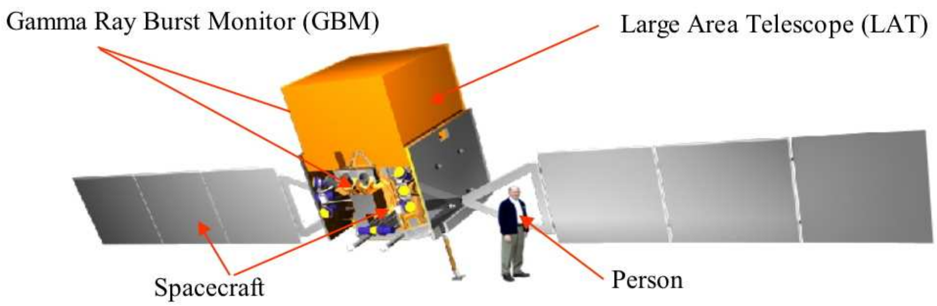

Fig. 1 The GLAST payload.

Table 1 Main GLAST Mission parameters

Launch Vehicle	Delta II 2920-10H
Launch Location	Kennedy Space Center
Orbit Altitude	575 km
Orbit Inclination	28.5 degrees
Orbit Period	95 minutes
Orientation	+X to the Sun
Launch Date	September 2006

and unidentified high-energy sources. Many years of refinement has led to the configuration of the apparatus shown in Figs. 1 and 2, where one can see the 4×4 array of identical towers each formed by: • Si-strip Tracker Detectors and converters arranged in 18 XY tracking planes for the measurement of the photon direction. • Segmented array of CsI(Tl) crystals for the measurement the photon energy. • Segmented Anticoincidence Detector (ACD). In Fig. 3 there is a sample of photon track reconstructed in GLAST.

The pair-converted positron and electron of the gamma, are tracked through the silicon and tungsten of the tracker with the goal of find the best one or two trajectories, depending on the incident energy. Multiple scattering is key to this analysis, in that it is the dominant error contribution below a few GeV. A Kalman filter technique is used in the tracker to account for this effect. It basically follows trajectories, accounting for energy-dependent error introduced by material in the tracker and predicting a cone in which to look for hits to associate in the next layer. At present, energy in the calorimeter is lumped together into a single cluster from whose moments are derived the energy and direction. The energy is used to seed the track finding, since the multiple scattering errors are energy dependent. The calorimeter is not thick enough to contain all the shower energy above few GeV. Corrections are required to estimate the leakage energy. This has been done in two ways: correlating the total energy with the energy measured in the last layer; and by fitting the expected shape of the shower against a standard function. Tracks are extrapolated back to the anti-coincidence device to help distinguish background events.

The data, filtered by onboard software triggers, are streamed to the spacecraft for data storage and subsequent transmittal to groundbased analysis centers. The Tracker provides the

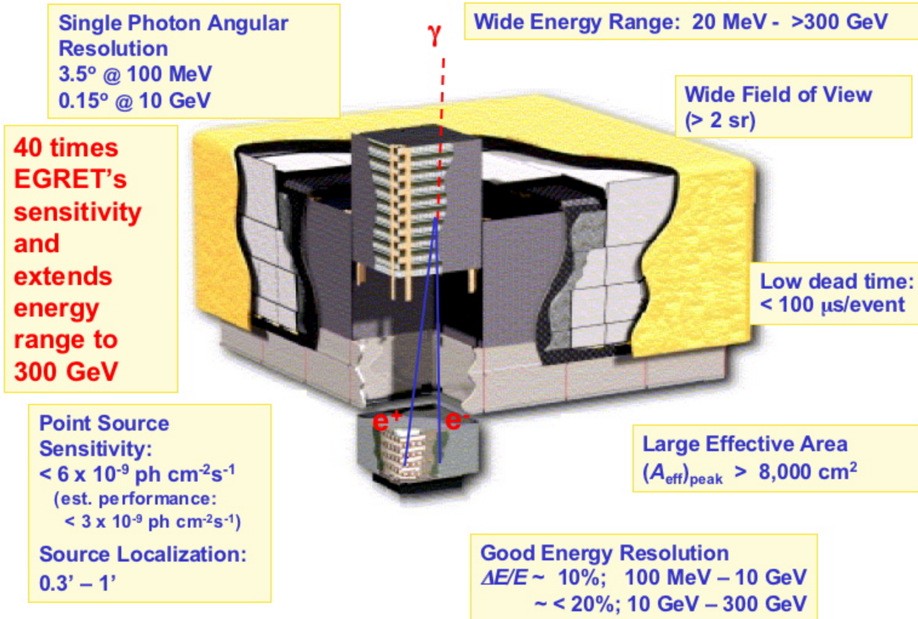

Fig. 2 The GLAST instrument.

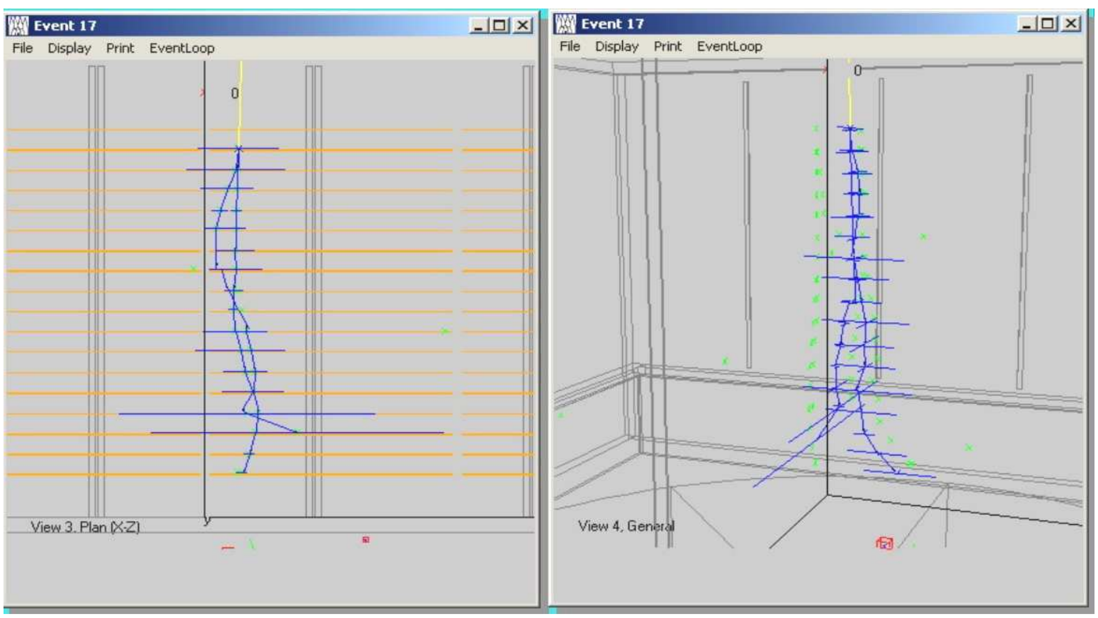

Fig. 3 100 MeV gamma tracked in the GLAST-LAT.

principal trigger for the LAT, converts the gamma rays into electron-positron pairs, and measures the direction of the incident gamma ray from the charged-particle tracks. It is crucial in the first levels of background rejection for providing track information to extrapolate cosmic-ray tracks to the ACD scintillator tiles, and it is important for further levels of background analysis due to its capability to provide highly detailed track patterns in each event.

The main characteristics of the detector, extensively studied with Monte Carlo and beam tests, are an energy range between 20 MeV and 300 GeV, a field of view of ~ 3 sr, an energy resolution of $\sim 5\%$ at 1 GeV, a point source sensitivity of 2×10^{-9} (ph cm^{-2} s^{-1}) at 0.1 GeV, an event deadtime of 20 μs and a peak effective area of 10000 cm^2, for a required power of 600 W and a payload weight of 3000 kg. The main parameters listed in Table 1. A more detailed description of the main GLAST parameters can be found in Morselli et al. (2002).

GLAST will dramatically extend the number of observed Active Galactic Nuclei (AGN), as well as the energy range over which they can be observed. Indeed, GLAST might be called the "Hubble Telescope" of gamma-ray astronomy as it will be able to observe AGN sources up to $z \sim 4$ and beyond, if such objects actually existed at such early times in the universe. Extrapolation from EGRET AGN detections shows that about 5,000 AGN sources will be detected in a 2 years cumulative scanning mode observation by GLAST, as compared to the 85 that have been observed by EGRET in a similar time interval. This large number of AGN's covering a redshift range from $z \sim 0.03$ up to $z \sim 4$ will allow to disantangle an intrinsic cutoff effect, i.e., intrinsic to the source, from a cut-off derived from the interaction with the extra galactic background light, or EBL. Only by observing many examples of AGN, and over a wide range of redshifts, one can hope to untangle these two possible sources of cutoff. Determination of the EBL can provide unique information on the formation of galaxies at early epochs, and will test models for structure formation in the Universe.

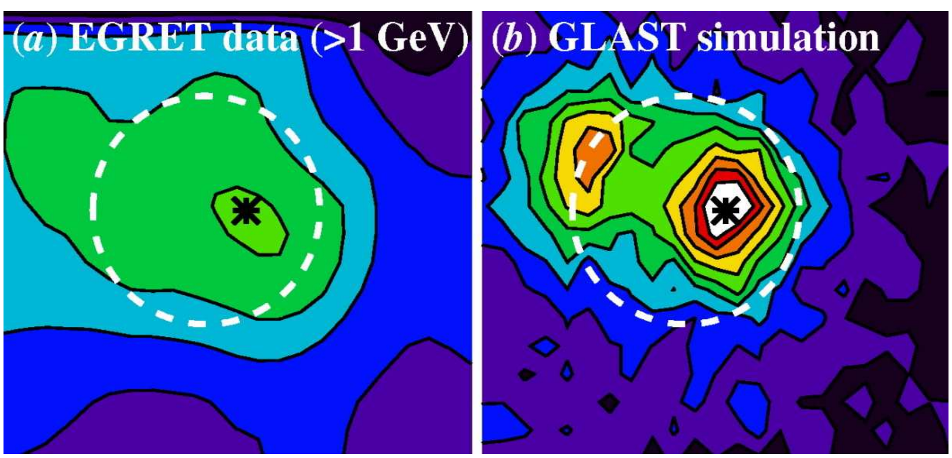

Fig. 4 (a) Observed (EGRET) and (b) simulated GLAST-LAT (1-yr sky survey) intensity in the vicinity of γ-Cygni for energies > 1 GeV. The coordinates and scale are the same as in the images of γ-Cygni in the box at left. The dashed circle indicates the radio position of the shell and the asterisk of a possible pulsar candidate.

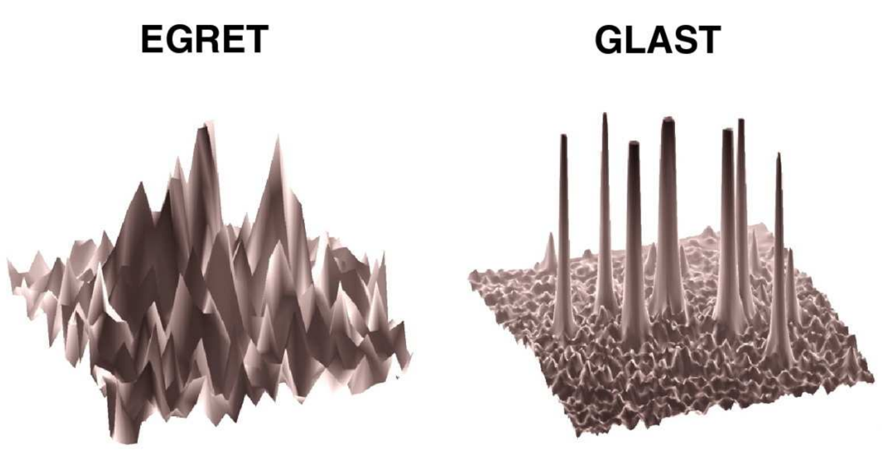

Fig. 5 Comparison of EGRET and GLAST simulated observations of the Cygnus region E> 1 GeV ($15^\circ \times 15^\circ$ box)

GLAST will discover many gamma-ray pulsars, potentially 50 or more, and will provide definitive spectral measurements that will distinguish between the two primary models proposed to explain particle acceleration and gamma-ray generation: the outer gap and polar cap models. Because the gamma-ray beams of pulsars are apparently broader than their radio beams, many radio-quiet, Geminga-like pulsars likely remain to be discovered.

As an example of the improvement of GLAST in respect to EGRET, for Super Novae Remnants (SNR) candidates, the GLAST-LAT sensitivity and resolution will allow mapping to separate extended emission from the SNR from possible pulsar components (see Fig. 4). Energy spectra for the two emission components may also differ. Resolved images will allow observations at other wavelengths to concentrate on promising directions. In Fig. 5 is shown the comparison of EGRET and GLAST simulated observations of the Cygnus region E> 1 GeV ($15^\circ \times 15^\circ$ box).

Another example is in the search for Dark Matter candidates. In Morselli et al. (2002), Morselli et al. (2003), Cesarini et. al. (2003) it is shown how GLAST offers good possibilities to perform the search for a signature in the gamma-ray spectrum due to the annihilation of supersymmetric dark matter particles in the Milky Way halo and how this search will explore a significant portion of the Minimal Supersymmetric Standard Model parameter space.

GLAST is now in the transition phase from design to flight hardware fabrication (for details on the tracker contruction see Bellazzini et al., 2002). The GLAST-LAT Instrument had completed its Critical Design Review for approval to begin flight hardware construction. It is expected to take some 18 months, with integration into the 16 tower LAT beginning in mid 2004, handoff to the spacecraft for integration into the Observatory in late 2005 and the launch scheduled for fall 2006.

In summary:

• GLAST will be an important step in gamma ray astronomy ($\sim$10 000 sources compared to $\sim$200 of EGRET).

• It is a partnership between High Energy Physics and γ-Astrophysics.

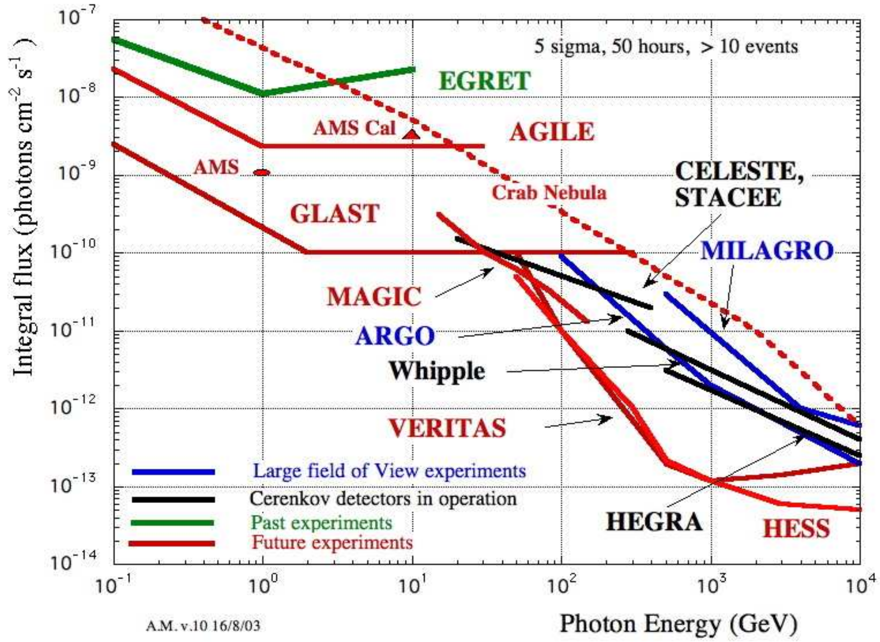

Fig. 6 *Sensitivity of present and future detectors in the gamma-ray astrophysics.*

- Beam tests and software development well on the way.
- It will bring a wide range of possible answers/discoveries.
- It will be a gold era for multiwavelenght studies.

In Fig. 6 the sensitivities of present and future detectors in the gamma-ray astrophysics are shown. The predicted sensitivity of a number of operational and proposed Cherenkov telescopes, CELESTE, STACEE, VERITAS, Whipple is for a 50 hour exposure on a single source. EGRET, GLAST, MILAGRO, ARGO, AMS and AGILE sensitivity is shown for one year of all sky survey. For AMS only the extimate for two points exist (Lamanna et al., 2002). The first, at 1 GeV, is for the AMS-conversion mode and the second, at 10 GeV, is for the calorimeter mode (see Lamanna et al., 2002) for details. The diffuse background assumed is 2×10^{-5} photons cm^{-2} s^{-1} sr^{-1} (100 MeV/E)$^{1.1}$, typical of the background seen by EGRET at high galactic latitudes. The source differential photon number spectrum is assumed to have a power law index of –2, typical of many of the sources observed by EGRET and the sensitivity is based on the requirement that the number of source photons detected is at least 5 sigma above the background. Note that on ground only MILAGRO and ARGO will observe more than one source simultaneously. The Home Pages of the various instruments are at *http://www-hfm.mpi-hd.mpg.de/CosmicRay/CosmicRaySites.html*.

The last calculation of the ARGO-YBJ sensitivity to γ-ray emission from the CRAB Nebula shows that ARGO-YBJ will need three months to see the CRAB at the five σ level, but situation can improve with a proper γ-hadron discrimination, that is still in progress (Vernetto et al., 2003). So the ARGO-YBJ sensitivity in the figure can be optimistic if the γ-hadron discrimination will not give the expected results.

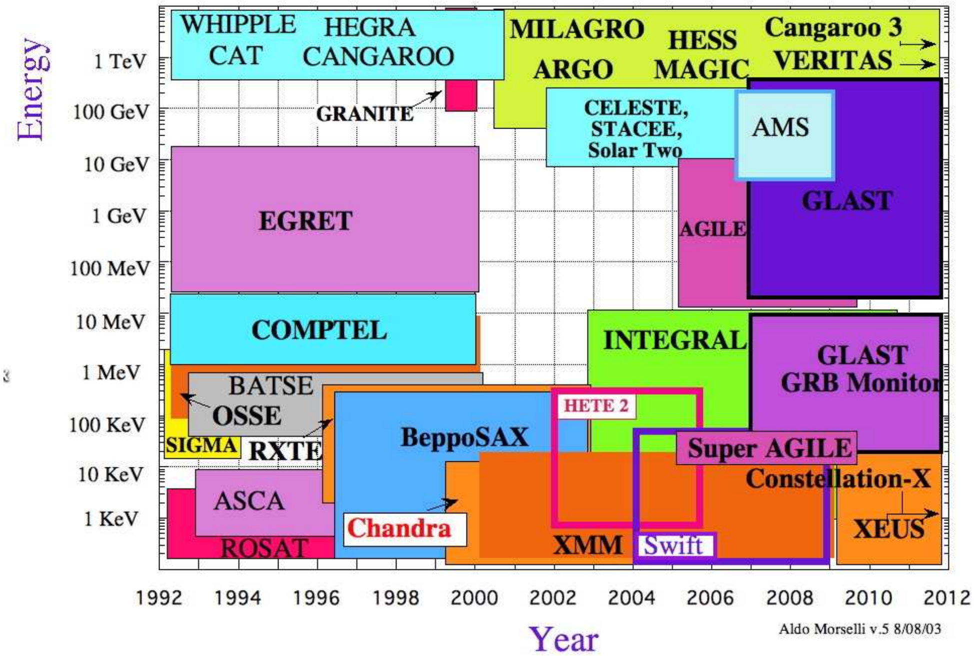

Fig. 7 *Timeline schedule versus the energy range covered by present and future detectors in X and gamma-ray astrophysics.*

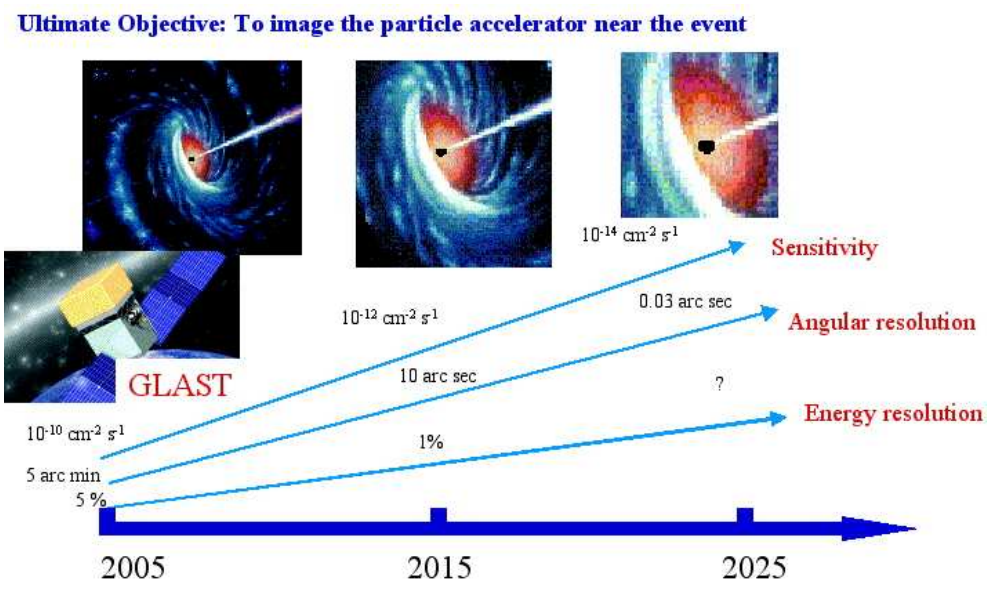

Fig. 8 *Gamma-Ray Astronomy Long Term Plan.*

In Fig. 7 it is shown the time of operation and energy range of space X-ray satellite and gamma-ray experiments . Note that AGILE and GLAST will cover an interval not covered by any other experiments. Note also the number of other experiments in other frequencies that will allow extensive multifrequency studies. The angular resolution and energy resolution achievable in gamma ray astrophysics is still lower to what is desirable and achievable in other band; so a long term plan like the one sketch in Fig. 8 is needed and can bring spectacular results.

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