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Exploring the violent and high-energy frontier of the Universe with GLAST

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Abstract. The Gamma-ray Large Area Space Telescope (successfully launched in June 11, 2008) is opening the violent, restless and high-energy frontier of the Universe to exploration. This unique experiment and mission (bringing together the astrophysics and high-energy particle physics communities and knowledge), teamed up NASA and the US Department of Energy joined with Government Agencies and Institutions in France, Germany, Japan, Italy and Sweden, while General Dynamics built the spacecraft.

Key words. gamma rays: bursts, pulsars, AGNs, blazars, SNRs, diffuse, dark matter, sun — gamma rays: observations — radiation mechanisms: non-thermal — telescopes

1. Introduction

The Gamma-ray Large Area Space Telescope[1] [2] (GLAST) mission (Ritz 2007) is an international effort bringing together the astrophysics and high-energy particle physics communities and expertise. This mission is funded and realized with the collaboration of NASA and the US Department of Energy, and the participation of Government Agencies and Institutions in France, Germany, Italy, Japan, and Sweden. General Dynamics built the spacecraft, and the satellite was successfully launched in June 11, 2008, at 12:05 p.m. EDT (16:05 UTC), on board of a United Launch Alliance Delta II rocket from the Cape Canaveral Air Force Station, USA (Fig. 3).

GLAST has two instruments (and collaborations): the Large Area Telescope[3] (LAT), a pair tracker-converter telescope allowing to observe the sky at γ-ray energies between 20 MeV and 300 GeV, and the Burst Monitor[4] devoted to correlative GRB and transient observations in the energy range between about 8 keV - 30 MeV. GLAST (following in the footsteps of the successful CGRO-EGRET mission) has a nominal five-year mission, and a goal for an extension of further five years.

2. LAT instrument and capabilities

The LAT instrument (Fig. 1) construction was managed by the Stanford Linear Accelerator Center (SLAC). This primary instrument is composed of a modular array of 16 towers,

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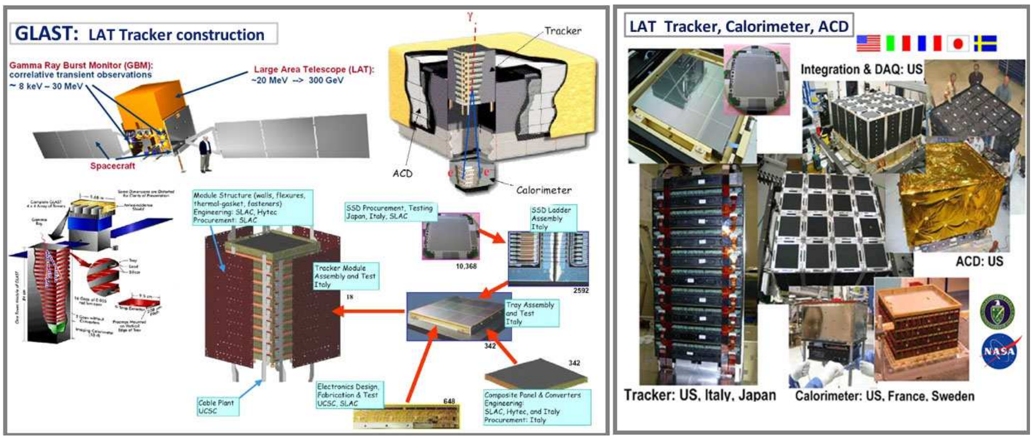

Fig. 1. Scheme and pictures of LAT GLAST, an instrument project managed by SLAC, (PI and Spokesperson: P.F. Michelson), with important contributions from Institutes and Agencies in US, France, Italy, Japan and Sweden. The LAT consists of four main components: precision tracker, calorimeter, DAQ, and ACD. The LAT is composed by an array of 16 identical "tower" modules each with a tracker-converter (silicon micro-strip detectors), a calorimeter (CsI with PIN diode readout), and DAQ module. The array is surrounded by finely segmented ACD (plastic scintillator with PMT readout). To be noted that a relevant amount of silicon microstrip detectors were used for the tracker subsystem, equivalent to a total surface of about $83\mathrm{m}^2$ of silicon detectors (11500 SSDs), being second only to CMS at the Large Hadron Collider of CERN (Bellazzini et al. 2002; Michelson 2003, 2007; Atwood et al. 2007, 2008).

each with a tracker-converter based on silicon micro-strip detector technology and a calorimeter. The whole array is surrounded by an Anti-Coincidence Detector (ACD) and provided of a Data Acquisition System (DAQ).

In particular, the Italian collaboration has contributed in the construction and test of the towers of the precision tracker-converter subsystem, mainly through the participation of INFN (Bellazzini et al. 2002). Each module of this subsystem has 18 planes of high-Z material in which gamma-rays incident on the LAT can convert to an e^+e^- pair, interleaved with position-sensitive silicon micro-strip detectors (SSDs) recording the passage of charged particles. The measure of the particles tracks is used to reconstruct the directions of the incident cosmic gamma-ray photons.

The calorimeter measures the energy deposition and images the shower development profile. Each calorimeter module has 96 CsI(Tl) crystals (arranged horizontally in 8 layers of 12 crystals each), and its layer is aligned 90° with respect to its neighbors, forming an x, y (hodoscopic) array, providing a total vertical depth of 8.6 radiation lengths (total calorimeter depth of 10.1 radiation lengths). The ACD provides charged-particle background rejection, through plastic scintillator tiles that are segmented to suppress the backsplash (self-veto) effect created by the calorimeter mass at high energies. The DAQ collects data from the other subsystems, implements the multi-level event trigger, supplies on-board event processing to run filter algorithms to reduce the number of downlinked events, and provides an on-board science analysis platform to rapidly search for transients. Information on the LAT can be found, for example, in Bellazzini et al. (2002), Michelson (2003, 2007), and Atwood et al. (2007, 2008).

The resulting performance of the LAT[5] are governed primarily by the hardware design, event reconstruction algorithms, background and event quality selections. At the time I am writing, some of the calculated pre-launch performances are the following: 1) Energy range:

[5] updated GLAST LAT performance here: www-glast.stanford.edu

Fig. 2. The GLAST LAT and GBM during spacecraft integration at General Dynamics, in December 2006. (Credit: NASA/General Dynamics Advanced Information Systems).

Fig. 3. The first moments of the heart-palpitating GLAST spacecraft liftoff on board of a United Launch Alliance Delta II rocket from the Cape Canaveral Air Force Station, Florida, USA. (Credit: Carleton Bailie for United Launch Alliance).

20 MeV - 300 GeV. 2) Effective area at normal incidence: around 9000 cm^2. 3) 1σ energy resolution: $\leq$10% (at 100 MeV - 10 GeV, on axis); $\leq$20% (at 10 GeV - 300 GeV, on-axis); $\leq$6% (at >10 GeV, >60° incidence). 4) Single photon angular resolution (on-axis, 68% containment radius): $\leq$0.15° at > 10 GeV, 0.5° at 1 GeV, 3.5° at 100 MeV. 5) Field of view (FOV): 2.4 steradians. 6) Timing accuracy: <10 μsec. 7) Event readout time (dead time): 26.5 μsec (see Atwood et al. 2008). These performances are translated in an unprecedented FOV, broadband energy passband, and point spread function for γ-rays, and a factor >30 of sensitivity improvement, with respect to EGRET.

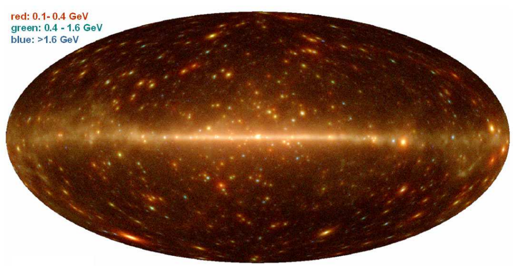

Fig. 4. Simulation of the whole sky seen by the GLAST LAT after 1-year of all-sky survey. The LAT (as an all-sky hunter and surveyor for high-energy transients, flares and source variability) is expected to detect few thousands γ-ray sources, during the GLAST mission.

3. Objectives

The very large FOV of the LAT allows to observe about 20% of the gamma-ray celestial sphere (2.4 sr) at any instant, and the entire sky every 2 orbits (about 3 hours) in survey mode. Therefore the starting and main science operating mode is a continuous all-sky scanning survey. In this way each point on the celestial sphere receives about 30min exposure during the two all-sky orbits, making GLAST a natural all-sky observer, monitor, and hunter for cosmic γ-ray bursts, transients, flares, and source variability, capturing the essence of the restless, transient, variable and violent high-energy Universe. These LAT capabilities allow also to record long and well-sampled light curves, for many bright γ-ray sources, like blazars (McEnery 2006; Lott et al. 2007). Multifrequency observing campaigns joined with GLAST, will be limited only by the ability to coordinate to other ground-based and space-borne observations in other wavebands[6] (Thompson 2007; Tosti 2007).

[6] glast.gsfc.nasa.gov/science/multi/

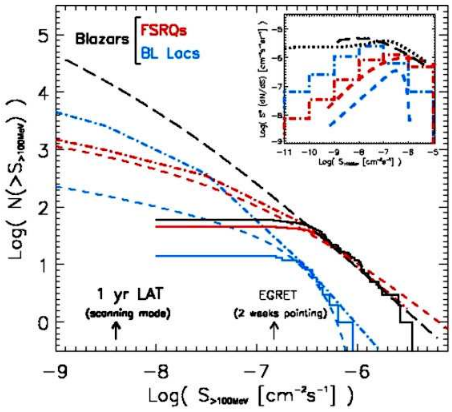

Fig. 5. LogN-LogS plot with 3 model predictions of the cumulative number of γ-ray blazars will be seen by GLAST (FSRQs: blue curves, BL Lacs: red curves; Atwood et al. 2008).

GLAST allows a full frontier science research (Ritz 2007; Atwood et al. 2008). 1) The dynamic range and temporal-evolution frontier (the all-sky aperture for transients and variability monitoring of sources, and the dynamic range of emission). 2) The depth frontier (deepening the exposure over the whole mission lifetime). 3) The energy frontier (discovering energy budgets and characteristics of wide variety of cosmic accelerator systems on different scales, the unknown 10-100 GeV sky, the connection with Cherenkov TeV telescopes, and the 7 decades of LAT+GBM energy coverage for GRBs). 4) The spatial frontier (subarcmin γ-ray point-source localizations, making easier the identification, and allowing to resolve spatially >0.5° features). 5) The timing frontier (transient and periodic pulse profiles searches). 6) The measurement frontier (rich data set to mine, touching many areas of modern science). 7) The unknown frontier (known γ-ray emitting sources and those awaiting discovery). 8) The multiwavelength and multimessenger frontier (GLAST, with its continuous all sky survey, is the ideal and necessary companion of even greater multiwavelength/multimessenger future observing campaigns and opportunities).

Finally, GLAST has a very broad menu of targets and objectives, and only some examples are listed here. Resolve the γ-ray sky, associate and understand the nature of EGRET unidentified sources and the origins of the diffuse emissions. Investigate the interstellar emission from our Galaxy, nearby galaxies, and galaxy clusters, and study the extragalactic diffuse emission. Understand the mechanisms of particle acceleration in celestial sources and the origin of cosmic rays. Study the extreme physics of systems driven by accreting supermassive black holes (active galactic nuclei: blazars, radiogalaxies, starburst and luminous IR galaxies), and understand the nature of jets and their emission processes. Study galactic sources like microquasars, pulsars, pulsar wind nebulae, supernova remnants, plerions, and host supernova remnants. Study the high energy behavior of the mysterious GRBs and other transients. Understand the high-energy radiation from the Sun and solar flares physics. Probe the nature of dark matter, search for possible relics from the Big Bang, and further fundamental physics checks (as the Lorenz invariance violation). Use high-energy γ-rays to probe the galaxy formation era, trough the absorption by the optical-UV extragalactic background light.

All these scenarios and questions, and many other surprises and undiscovered frontiers are expected in the next years, thanks to this unique and exciting mission.

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