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GLAST And Suzaku: Study on Cosmic-Ray Acceleration And Interaction in the Cosmos

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The Gamma-Ray Large Area Space Telescope (GLAST) is an international and multi-agency mission scheduled for launch in the fall 2007. The Large Area Telescope (LAT), the primary instrument of the mission, will survey the high energy sky found to be very dynamic and surprisingly diverse by its predecessor the Energetic Gamma Ray Experiment Telescope (EGRET). GLAST-LAT will have a much improved sensitivity when compared with EGRET and extend the higher energy coverage to ~ 300 GeV. The insrument is now mounted on the spacecraft and undergoing a suite of pre-flight tests. Data analysis software has been tried out by collaborators in two rounds of "Data Challenges" using simulated observations including backgrounds. The instrument performance and observational data on selected sources presented here have been obtained through the Data Challenges in the collaborative efforts. There are features in the GLAST-LAT observation possibly unfamiliar to X-ray astronomers: 1) GLAST will operate mostly in the survey mode; 2) the foreground objects (gas, dust, and star-light) become gamma-ray sources; 3) multiple sources will be "confused" because of the wide point-spread-function. The last two features will pose a challenge for analysis on extended Galactic sources such as supernova remnants and pulsar wind nebulae: multi-wavelength study with X-ray instruments like Suzaku and atmospheric Chrenkov telescopes will become essential to dig out the underlying physics.

§1. Introduction

Suzaku-HXD [1], GLAST-LAT [2], HESS [3] and VERITAS [4] have comparable sensitivity to persisitent point sources when normalized by the Crab nebula spectrum and jointly cover about 10 decades of energy except for the 2 decades between 0.5 and 50 MeV as shown in Fig.1. For Suzaku HXD the sensitivity is limited by the knowledge of the instrumental background assumed [5),1] to be 2 %; for GLAST-LAT, it is limited by the photon statistics of the signal (5 σ significance in 1 yr) and the knowledge on the instrumental and extragalactic backgrounds [2]; for HESS and VERITAS, it is determined by statistics of signal (> 10 photons in 50 hrs) and the knowledge on the charged particle background [3] [4].

For gamma-ray bursts and short flares, the effective area gives a measure of the detectable flux with an instrument. Suzaku Wide-Angle-Monitor (WAM) [1], GLAST Burst Monitor (GBM) [6] and GLAST-LAT [2] together cover 7 decades of energy as shown in Fig. 2. The GRB detectability depends on its spectrum. We assume here a sum of a power-law synchrotron with index 2 and an inverse Compton component. The two lines of detectability threshhold in Fig.2 are to give a crude

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[**] See the paper by G. Madejski for GLAST-Suzaku studies on AGNs and Blazars.

guide. The important point is that GLAST-LAT can discover (or constrain) the inverse Compton component as well the pi-zero component. See papers by Böttcher and Dermer [7] and Zhang and Mészaros [8] for details.

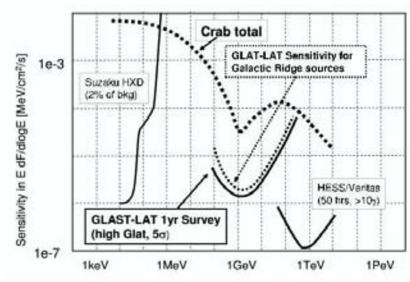


Fig. 1. Point-source sens. for GLAST-LAT, Suzaku-HXD and HESS/Veritas. See text.

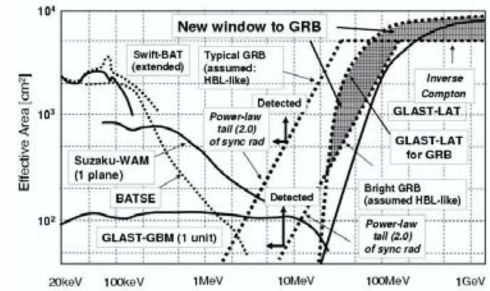


Fig. 2. Eff area for GLAST-LAT/GBM, Suzaku-WAM with detectability thresholds.

§2. Observation with GLAST-LAT

Observation and analysis of gamma-ray sky with GLAST-LAT will be different from that of X-ray sky with Chandra, XMM and Suzaku in several ways. The difference comes from the radiation environment, gamma-ray interaction in the detector and the observation strategy.

- Cosmic-ray-induced background is non-negligible.
- Interstellar gas, dust and photon field produce diffuse gamma-ray emission on and near the Galactic plane.
- Point-spread-function is much larger than that of modern X-ray instruments.
- GLAST-LAT will operate mostly in the survey mode.

2.1. *Instrumental Background*

Charged primary cosmic rays will trigger GLAST-LAT at a few kHz (near the geomagnetic equator) to $\sim$ 5 kHz (at higher geomagnetic latitudes). Albedo electrons, positrons, protons and gamma-rays are expected to nearly double the trigger rate. The extra-terrestrial gamma-rays are expected at a few Hz. Hence the onboard and ground event filtering must reduce the background by 4-5 orders of magnitude. The Anti-Coincidence Detector (ACD) is a prime instrument for this reduction and the hit pattern in the Tracker provides equally important information. Details on the trigger and data processing are given in the GLAST-LAT home page [2].

2.2. *Foreground*

Solar photons [9], dark clouds [10),11], Galactic photons [12], HI clouds [13] and H_2 clouds [14),15] emit gamma-rays via proton interaction or inverse Compton scattering. These foreground emissions partially overlap spatially and spectroscopically, and their modeling will be essential in extracting contributions from sources of interest. Such a modeling has been done for the Galactic inverse Compton emission using a computer program, GALPROP [16] as shown in Fig.3. The foreground emissions will be a challenge for analyses on Galactic extended sources.

One Galactic SNR of interest for GLAST-LAT is RXJ1713.7-3946 (G347.3-0.5).

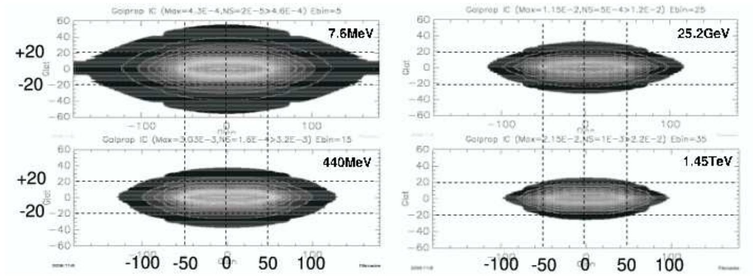
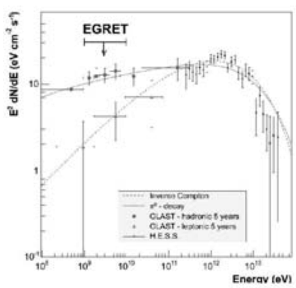


Fig. 3. Inverse Compton emission by Galactic light and electrons [16].

The recent measurement of TeV gamma-ray spectrum from the SNR by HESS suggests possible dominance of the hadronic process [17]. Simultion [19] predicts that GLAST-LAT will determine the underlying process decisively (Fig.4). Note that a recent study [18] on inverse Compton spectrum from SNRs predicts a flattening in the spectrum near the highest energy.



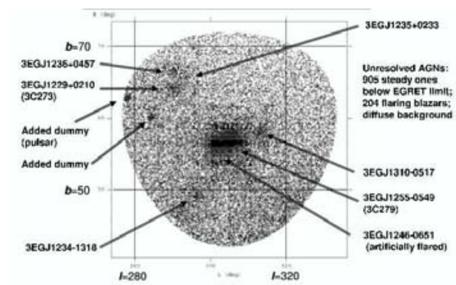


Fig. 4. Simul. LAT spectra (5 yr) of RXJ1713 for hadronic and leptonic processes [19].

Fig. 5. Source confusion in 3C249 region: simulation with added features.

2.3. *Source Confusion*

GLAST-LAT detects cosmic gamma-rays by converting them to electron-positron pairs in the Tracker made of stacks of tungsten foils and silicon strip detectors. The PSF results from combination of the multiple Coulomb scattering in tungsten and the strip width of the silicon detector anode: the PSF is predicted to be 3-3.5 deg. (rms) at 100 MeV and 0.1 deg. (rms) at 10 GeV.

We expect reconstructed gamma-rays from multiple sources overlap even in high Galactic latitude as shown in Fig.5 for $E > 100$ MeV. Note that unresolved Active Galactic Nuclei population, a pulsar and a flare in 3EGJ1246-0651 have been added to the EGRET sources in Fig.5.

2.4. *Constantly Changing Response Function of Survey Mode*

In the survey mode GLAST will cover the full sky every 2 orbits or 3 hours. The exposure will vary by about ± 50 % for one day integration and about ± 20 % for 55 day integration.

Number of gamma-rays detected by GLAST-LAT will depend largely on the purity of signal required for a specific analysis. We expect 130k-150k gamma-rays per year with $E > 100$ MeV and ~ 40k with $E > 1$ GeV from Vela. From RXJ1713.7

we expect $\sim$ 1k/yr ($E > 100$ MeV) and $\sim$ 400/yr (> 1 GeV) for the hadronic model. The Galactic diffuse emission will be $\sim 1k/\text{deg}^2/\text{yr}$ for $E > 100$ MeV.

§3. Simulated Observations

Two other simulated analyses (1yr obs) are given in Figs.6 and 7. The first is the spectrum expected from the jet in M87 assuming the model by Reimer et al. [20] and the second is the diffuse emission ($E > 100$ MeV) from Large Magellanic Cloud [21].

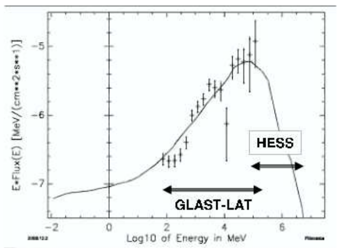


Fig. 6. Spectrum obtained in a simulated GLAST-LAT observation (1yr) of M87 assuming a proton synchrotron model by Reimer et al. [20].

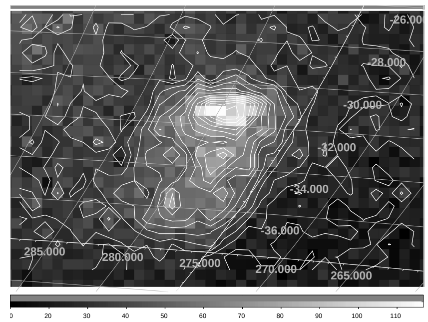


Fig. 7. Simulated LAT observation (1 yr) of LMC above 100 MeV [21].

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