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The Capabilities of the GLAST LAT for Studies of Blazar Variability

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Abstract. One of the more notable features of the Large Area Telescope (LAT) on GLAST is its extremely large field of view, which covers more than 20% of the sky at any instant. In survey mode the LAT will be rocked about the orbital plane to provide coverage of the entire γ-ray sky above 20 MeV every three hours. This will be the default observing mode for the first year of operations and is likely to be the dominant observing mode throughout the rest of the mission. Thus the LAT will provide long, evenly sampled, γ-ray lightcurves for a large number of sources. In this paper we describe the nature and quality of the data that will be provided by the LAT and use simulated lightcurves to illustrate some of the scientific questions that can be addressed with LAT observations.

1. Introduction

One of the surprises in AGN astrophysics over the past 15 years has been the detection of blazars at both GeV and TeV energies (see Thompson (2005) and Krawczynski (2005) for more details). One of the unexpected features of γ-ray AGN catalogs is the paucity of overlap between the GeV and TeV catalogs. The brightest GeV blazars were not seen at TeV energies, and TeV blazars are either weak GeV sources, or were not detected at GeV energies at all. This suggests that there will be lots to be learned from observations in the unexplored energy range between 30 GeV and 300 GeV that existed between the previous generation of high energy γ-ray telescopes.

Blazars are highly variable at all wavelengths. An understanding of the nature and underlying cause of the variability provides an useful insight for studying the fundamental properties of AGN. Broadband observations of flares provides an important probe into the physical conditions of the emission regions. Observations at (or close to) the highest energies are particularly important, as these allow constraints on the underlying particle energies and thus the means of acceleration.

The LAT will contribute to AGN science in many ways. The LAT has sensitivity over a broader energy range than any previous satellite based γ-ray telescope. This will allow observations in the hereto unobserved 30 GeV to 300 GeV band allowing us to better understand the differences between GeV and TeV blazars. The much greater sensitivity of the LAT with respect to previous instruments will result in a large increase in the GeV AGN catalog. In this paper we focus on the contributions the LAT will be able to make to variability studies of AGN with its wide field of view and good sensitivity.

2. The Large Area Telescope (LAT)

The LAT is a pair-conversion telescope designed to make observations of the γ-ray sky from 20 MeV to above 300 GeV. It consists of a tracker, a calorimeter, and an anticoincidence shield which work together to measure the energies and directions of incident gamma rays as illustrated in Figure 1.

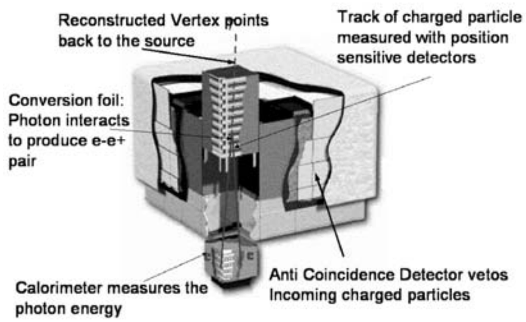

Figure 1. An illustration of the GLAST LAT showing how the various instrument subsystems work together to detect incident gamma rays

The LAT tracker consists of 36 planes of silicon strip detectors for tracking charged particles produced when incident gamma rays convert in one of 16 tungsten foils. The silicon strip detectors have a very fine pitch (228μm) which provides superb position resolution, resulting in good angular resolution particularly at high energies. The calorimeter consists of 1536 CsI crystals. The segmentation allows a measurement of the profile of the energy deposition, enabling corrections for energy leakage. Covering the tracker and calorimeter, the anticoincidence detector consists of 89 plastic scintillator tiles. The segmented design minimizes self-vetos (where secondary particles produced in the calorimeter trigger the ACD) which limited EGRET at high energies. Many of the design choices for the LAT optimise the response at high energies. The LAT will have a much broader energy range than any previous pair conversion telescope with sensitivity from 20 MeV to over 300 GeV with a peak sensitivity at a few GeV. The LAT has a larger physical area and greater detection efficiency than EGRET which results in a greatly increased effective area. Finally, the LAT has a large aspect ratio and is self-triggering resulting in a very large field of view ($>$2.5 sr).

3. The LAT as an all-sky monitor

EGRET made inertially pointed observations (i.e. staring at the same point on the celestial sphere for the entire observing period); this had the drawback of a loss in observing efficiency because of occultation of the field of view by the Earth, and meant that on any given day the behaviour of most of the GeV γ-ray sky was unknown. In contrast, the default mode of operation of the GLAST will be a sky survey, currently designed to tilt the LAT 35 degrees north of the orbit plane for one orbit and 35 degrees south of the orbit plane for the next. In this mode, the LAT will observe the entire sky every two orbits ($\sim$190 minutes).

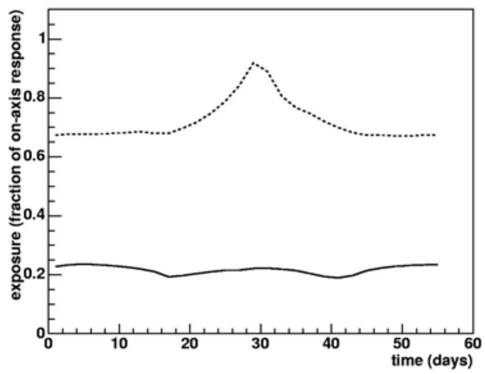

Figure 2. The exposure as a function of time for a 55 day observation of Mrk421. Each point on the curve corresponds to the exposure integrated over a day. The dotted curve is exposure for a pointed observation and the solid curve is exposure for a survey mode observation.

The effective area of the LAT varies as a function of angle from the center of the field of view. Thus the sensitivity of the LAT for a particular source over any given time interval depends both on how long the source has been within the LAT field of view, and on the track of the source across the field of view. We can describe the temporal coverage of the LAT by considering exposure (which has units of area×time) as a function of time. The details will depend on the location in the sky. In order to illustrate the LAT performance we consider the location of Mrk421. Figure 2 shows the exposure for 55 days integrated in one day intervals. On this timescale there is continuous coverage in both survey and pointed observation modes, i.e. Mrk421 is observed every day. The exposure in survey mode is relatively uniform for this source (and in fact for any location on the sky). A pointed observation generally gains about three times the exposure (a factor of 1.7 in sensitivity), with a few days when Mrk421 is continuously visible. However, we note that a pointed observation of any given source comes at the price of reduced and non-uniform exposure over the rest of the sky.

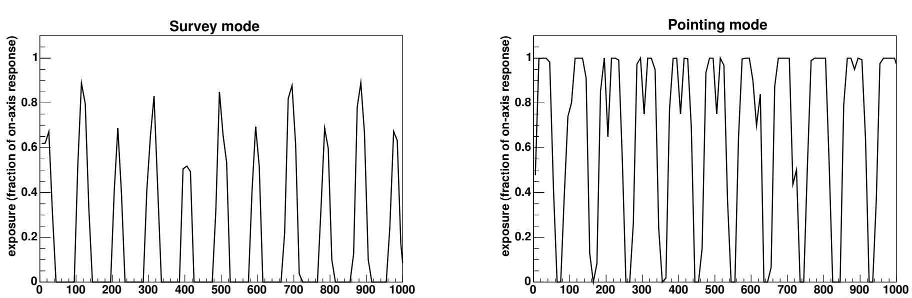

Figure 3. The exposure for Mrk421 as a function of time in 10 minute integrations to illustrate the sampling pattern of the LAT on short timescales: in survey mode (left) and pointed mode (right)

For extremely bright sources it will be possible to resolve lightcurves on much shorter timescales, Figure 3 shows the exposure (binned in 10 minute intervals) as a function of time at the location of Mrk421. The panel on the left is for survey mode observations. While all regions of the sky are guaranteed to be observed every second orbit, some regions are covered every orbit. The plot on the right shows exposure for a pointed observation. It is not possible to have an uninterupted observation for an extended period of time due to occultation of the source by the Earth and downtime during passages through the SAA.

Survey mode will provide very uniformly sampled lightcurves over long periods of time. This is illustrated in Figure 4(a) which shows LAT observations of a 5 year simulated lightcurve (the average γ-ray flux was the same as for 0528). The greater effective area of the LAT will allow lightcurves to be resolved on much shorter timescales than has previously been possible at GeV energies. Figure 4(b) shows EGRET observations of a rapid GeV flare from PKS 1622-297 in 1995 Mattox et al., (1997), the black line is a lightcurve consistent with the EGRET observations and the simulated LAT survey mode observations. The LAT, in survey mode, could see a flare like this from any region of the sky. This is extremely important, as blazars are highly variable, and it is anticipated that some objects will only be detectable during flares.

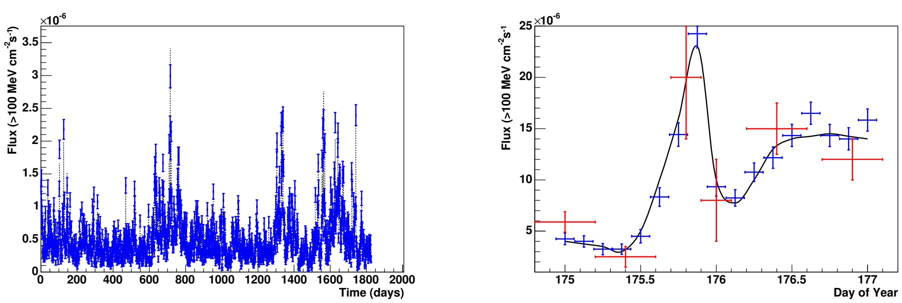

Figure 4. (a) the left hand plot shows a 5 year LAT observation of a simulated lightcurve, (b) the right hand plot shows EGRET (open gray circles) and simulated LAT (solid black squares) observations of an intraday flare seen in 1995 from PKS 1622-297

4. Summary

The Large Area Telescope will greatly contribute to studies of blazar variability. It will provide much more sensitive observations, and can thus resolve weaker and shorter flares. It will have all-sky coverage and thus will continuously monitor all sources over long time periods.

References

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Mattox, J.R. 1997, ApJ, 476, 692
Thompson, D.J., these proceedings