Automated Science Processing for GLAST LAT Data

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Abstract

Automated Science Processing (ASP) will be performed by the GLAST Large Area Telescope (LAT) Instrument Science Operations Center (ISOC) on data from the satellite as soon as the Level 1 data are available in the ground processing pipeline. ASP will consist of time-critical science analyses that will facilitate follow-up and multi-wavelength observations of transient sources. These analyses include refinement of gamma-ray burst (GRB) positions, timing, flux and spectral properties, off-line searches for untriggered GRBs and gamma-ray afterglows, longer time scale monitoring of a standard set of sources (AGNs, X-ray binaries), and searches for previously unknown flaring sources in the LAT band. We describe the design of ASP and its scientific products; and we show results of a prototype implementation, driven by the standard LAT data processing pipeline, as applied to simulated LAT and GBM data.

Automated Science Processing

ASP comprises automated processing of Level 1 (L1) LAT data for time-critical science analyses. Level 1 data are the event and spacecraft data that have passed through standard event reconstruction, classification, and filtering. These data are packaged as FITS files for delivery to the astronomical community and can be analyzed using the LAT suite of ScienceTools. Figure 1 illustrates the data flow in the LAT ISOC pipeline, starting with the Level 0 (L0) data received from the Mission Operations Center (MOC), through the L1 processing, and then finally through the Level 2 (L2) processing, which includes ASP.

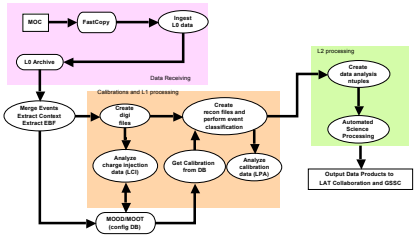

Figure 1: Schematic of LAT ISOC data flow

In the L2 processing, "time-critical science" entails the monitoring of transient behavior from astrophysical sources. If such behavior is observed at an appropriate level of significance, it triggers a call for follow-up observations at other wavelengths, or by the LAT itself. Although other automated tasks will be routinely performed on the L1 data by the ISOC, since these tasks will either emphasize monitoring of instrument performance or will not require time sensitive follow-up observations, these activities are not included in ASP.

The ASP tasks fall into two broad categories: GRB detection and follow-up, and flaring source monitoring and detection. Table 1 lists the specific tasks in these categories, the data products that will be publicly available, delivery methods, and the proposed latencies associated with each task. Note that the latencies are referred to the availability of the L1 data needed for the specific analysis. The content of the deliverables and their latencies are defined in the LAT Data Release Plan (DRP).

Table 1: ASP Tasks and Data Products

Task	Products	Delivery Method	Proposed Latency
1. GRB position refinement using LAT data	GRB position and error, date, time-of-day, and fluences or upper limits in 3 bands	GCN Notice; Web site	15 minutes
2. Blind search for GRBs in L1 data	GRB position and error, date, time-of-day, and fluences or upper limits in 3 bands	GCN Notice; Web site	15 minutes
3. GRB afterglow detection and analysis	Flux estimates on various time scales, hardness or spectral index estimates; refined position and errors	GCN Circular; Web site	1 hour
4. Monitoring of DRP "Sources-of-Interest"	FITS files and plots of flux on 1 day and 1 week intervals in 3 bands; photon index for E > 100 MeV; 1 sigma unc. or 2 sigma U.L.s	Web site	Weekly updates
5. Flare detection of new DRP sources	Coordinates, ID, flare onset and duration (if known), plots of light curve in 3 bands	Email notification; Web site	12 hours; Weekly updates

GRB Analysis

ASP analyses of GRBs can be triggered in two ways: by the arrival of L1 data with each TDRSS downlink (every ~3 hours); or by notification of a burst detection by the GBM, on-board by the LAT, or via a GCN Notice that would be issued for detection by other instruments (Figure 2). In the latter cases, the GRB position estimate and trigger time are used by the GRB position refinement task in querying the L1 database for the appropriate event and spacecraft data that will be needed for the subsequent position, light curve, and spectral analyses. In the blind search case, the position and timing estimates obtained from the blind search analysis are sent to these sub-tasks.

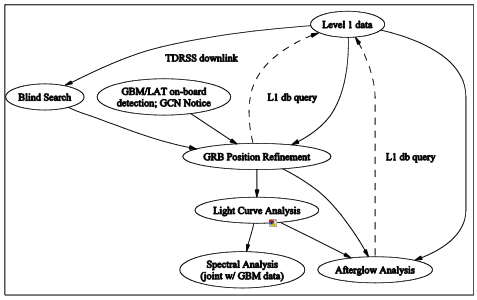

Figure 2: GRB Analysis Flow

Figure 3 shows some example output of the ASP GRB tasks as applied to data from a full Monte Carlo simulation of a GRB in the GBM and the LAT. The upper left plot shows the GBM measured location and error circle, and the pixels show a sky map of the counts per bin detected by the LAT. The upper right plot shows the light curve of the raw LAT events with the yellow region indicating the burst interval determined from the LAT data via a Bayesian Blocks analysis (Jackson, Scargle, et al. 2005). The lower left plot shows the results from the position-refinement analysis. The black cross is the true position of the burst, and the red cross is the fitted position. The contours indicate the 68.3, 90, and 95.4% CL regions. The lower right plot is the counts spectrum fit to the LAT data. The fitted spectral index is -2.02 ± 0.08 while the input index was -1.94.

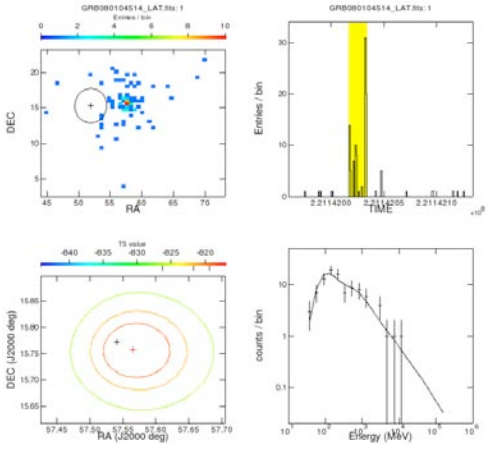

Figure 3: GRB Analysis Results

Flaring Source Monitoring

The LAT DRP specifies "sources-of-interest" that will be monitored on daily and weekly time scales. In the current proposal, these sources consist of the 18 objects listed in Table 2. The content of this list is under review, and the revised list will be posted at http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Monitored_Sources.html. Presently, eleven of these objects are blazars that have been detected by EGRET at a significance greater than 5σ. The remaining 6 blazars (indicated with an asterisk) have marginal (<5σ) or non-detections by EGRET but are known emitters at TeV energies. The final source is LSI +61 303, a high mass X-ray binary with a strongly suspected EGRET association. Figure 4 shows the location of the DRP sources-of-interest plotted on an EGRET All-Sky map in Galactic coordinates.

Table 2: DRP Sources-of-Interest

Source Name	3EG Flux (10^{-8} cm^{-2} s^{-1})	Source Name	3EG Flux (10^{-8} cm^{-2} s^{-1})
0208−512	85.5 ± 4.5	1730−130	36.1 ± 3.4
PKS 0528+134	93.5 ± 3.6	3C 454.3	53.7 ± 4.0
0827+243	24.9 ± 3.9	W Comae *	11.5 ± 1.8
Mrk 421	13.9 ± 1.8	PKS 2155−304 *	30.4 ± 7.7
3C 273	15.4 ± 1.8	Mrk 501 *	
3C 279	74.2 ± 2.8	1ES 1959+650 *	
1406−076	27.4 ± 2.8	1ES 2344+514 *	
PKS B 1633−382	47.4 ± 3.7	H 1426+428 *	
1633−382	58.4 ± 5.2	LSI +61 303	69.3 ± 6.1

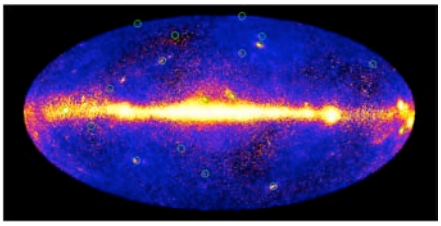

Figure 4: EGRET All-Sky Map and DRP Sources-of-Interest

In addition to these sources, ASP will search for any other source that flares in the LAT band on 1 day or 1 week time scales. Sources which flare with fluxes greater than 2×10^{-6} cm^{-2} s^{-1} (E > 100MeV) will also have their daily and weekly fluxes reported on a weekly basis until the flux of the source returns below 2×10^{-7} cm^{-2} s^{-1}.

Figure 5 shows an example daily light curve analysis applied to a full LAT simulation of 3C 279 during a relatively moderate flare for this object. The simulation includes nearby point sources and Galactic and extragalactic diffuse components. The red curve in the main panel is the input model light curve, and the blue data points show the daily flux estimates and 1σ uncertainties. The dashed horizontal line shows the lower limit given in the DRP for reporting fluxes from sources not in the predefined list. The inset shows the hardness ratios obtained for a single power-law fit to the daily values above and below 1 GeV versus the hardness ratios computed from the Monte Carlo (MC) truth.

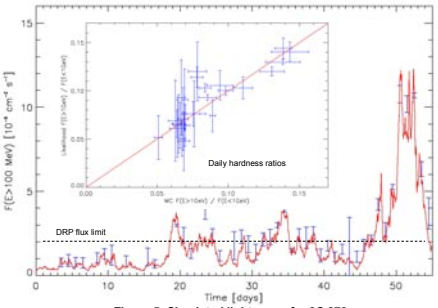

Figure 5: Simulated light curve for 3C 279