GLAST Science Analysis Software Modules

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Tools & Utilities

Module	Inputs	Outputs	Functions	Utilities Required
'SkyUtil'	Coordinates, source names, dates	Generally, sources detected by GLAST near a given direction	Primarily searches the source catalog, date & coordinate conversions	Catalog database (and perhaps exposure database)
Event getter/item getter	Event identifier (probably some kind of sequence number)	The specified event or item within that event	Accesses event database to retrieve specified event or just a specified item within the event	Event database
Event display	Event identifier	Display like Glastsim's GUI	Accesses event and displays it graphically	Event getter, Event database
Exposure maps	Time, energy, angle ranges, region of sky, gridding, coordinate projection	Exposure map, or more generally, multi-dimensional exposure arrays	Accesses the exposure history/livetime database to construct exposure matrix	Exposure history/livetime database
Map utilities	A 2-d map or file with 2 coordinate dimensions, reprojection, regridding, or smoothing parameters	Reprojected, regridded, or smoothed version of the input file	Resample, smooth, reproject	
'SkyView'	Image file	Display (or hardcopy) of the image	Interactive display of an image (e.g., intensity map) with optional overlays	[May be able to use SkyView service?]

Observation simulator	Source coordinates, estimated spectrum, GLAST observing mode	Estimate of detectability for different observation durations	Generates simulated exposure, estimates detectability (w/ diffuse model and pt. source catalog)	

Extended Emission

Module	Inputs	Outputs	Functions	Utilities Required
Likelihood analysis generalized	Model for region with potentially extended emission, time range, region of the sky	Maximum likelihood values of the parameters, significance of extended emission (if one set of parameters corresponds to the point source case)	Likelihood analysis as for other applications, with a flexible interface for user-defined models	Photon retrieval, exposure calculation
Source-subtracted sky map	Time range (perhaps limited to some standard ranges)	Sky map (with standard energy ranges) of the observed gamma-ray intensity, with point sources subtracted	Accesses or creates all-sky intensity maps, subtracts sources using their avg. fluxes for the specified time range	Source catalog

Gamma-Ray Bursts

Module	Inputs	Outputs	Functions	Utilities Required
Detection (i.e., trigger)	Time range, info from other S/C. Inflight will need real-time rates or photon times from ACD, GBM, LAT	Times, directions, and direction uncertainties of bursts, perhaps tentative assignments of photons to bursts	Spatial & temporal 'trigger' for detection, TBD for determination of confidence regions	Photon retrieval (for ground-based search)
Pulse profiles	Photons, times, energies assigned to a specific burst	Parametric and non-parametric pulse descriptions	Decomposes bursts into pulses using max. likelihood Bayes approach, optionally fits parametric model	Photon retrival, exposure calculation
Spectroscopy	Photons, times, energies assigned to a specific burst	Spectrum, or spectral fit (like from Spectral)	Perhaps has an interface to Spectral	Photon retrival, exposure calculation

Point Sources

Module	Inputs	Outputs	Functions	Utilities Required
Source detection	Generally, a time range and possibly a region of the sky	Entries in a database with detection significance, position, flux, and uncertainties (error ellipses), consistency with pt. source	TBD, likelihood analysis of some kind	Photon retrieval, exposure calc., diffuse em. model
Flux histories (Source catalog & flaring sources)	Database of detections, source assignments*, cutoff significance for association	Generally, sources detected by GLAST near a given direction, with positions, flux histories	TBD, includes flagging flaring sources**	
Source identification	Source catalog, catalogs of potential counterparts, significances, cutoff significance	Table of potential source identifications, with confidence levels	TBD, approach of Mattox et al.***	
Spectral fitting	Measured flux, flux uncertainties for specified bands of energy, spectral model	Coefficients of spectral model, flux estimates for each band	Forward folding of model with instrument response functions	Source analysis (to derive fluxes), calibration files

*The database of detections contains all of the point source detections from all of the sky coverages/time ranges analyzed, with the position, position uncertainty, flux (>100 MeV?), and significance. Source assignments are obtained by correlating the detections with themselves to identify (at some specified level of confidence) the detections that are associated with each other. After the cross correlation, the best position (and position uncertainty) and flux history of the source can be constructed.

**Note that flagging flaring/fading sources is easiest for sources detected previously, for which a baseline flux is estabilsihed. Potentially, most of the flaring sources that are detected will be detected for the first time during a flare, in which case we will need to have a module that can establish upper limits for fluxes at earlier times.

***This will also include evaluation of flux ratios, e.g., F(radio)/F(gamma) or F(X-ray)/F(gamma), for potential counterparts, as well as correlating time histories at other wavelengths, to the extent possible.

Pulsars (Dave Thompson)

Module	Inputs	Outputs	Functions	Utilities Required
Barycentric correction	Photon selection parameters (time, energy, angle ranges)	For each photon, vector to the solar system barycenter	Solar system ephemeris	Photon retrieval
Pulsar phase folding	Pulsar, photons with barycenter vectors, phase bin selection	Histogram of arrival times of photons with pulsar phase, statistical measure of nonuniformity, list of photons with phases	Phase calculation, including calc. of barycenter arrival time, statistical measure of nonuniformity.	Photon retrieval, pulsar ephemeris
Periodicity search	Photon selection parameters, range of sky coordinates, pulsar period, and period derivative	Statistical significances of periodicities investigated (possibly for separate time ranges)	Possibly several; most basically phase folding, also Fourier transforms, Gregary-Laredo method	Photon retrieval
Pulsed spectrum	Photon selection parameters, energy binning, on/off pulse phase ranges, pulsar	On-minus-off pulse phase spectrum, suitable for 'forward folding' analysis	Phase calculation, if phase not already available	Photon retrieval, exposure calc., pulsar ephemeris
Phase resolved maps	Photon selection parameters, including region of the sky, phase range, map gridding, pulsar	Count and intensity maps for the specified range of phase, energy, etc.	Like ordinary map generation, with the selection of photons by phase and the scaling of exposure correspondingly	Photon retrieval, exposure calc., pulsar ephemeris

In-Flight ACD Calibration (Jonathan Ormes, Steve Ritz)

Module	Inputs	Outputs	Functions	Utilities Required
Pulse Height Histograms	Time range, tile number*	Histogram of pulse heights in this tile, possibly corrected for path length using reconstructed direction or special 'straight-through' flag	Accesses cosmic-ray database, as appropriate corrects pulse heights for path length**	Cosmic-ray retrieval

*Note that the readout modes, still being debated, may include reading out two non-triggering ACD tiles with each event, using cyclic sampling. These readouts would be useful for establishing noise/threshold levels and pedestals.

**Some 'lateral' cosmic rays, i.e., those entering normal to the side tiles, will not have a track reconstruction, but will be usefule for calibration of the ACD.

In-Flight Calorimeter Calibration (Eric Grove)

Module	Inputs	Outputs	Functions	Utilities Required
Cosmic-ray selector	Crystal hit, time range, geomagnetic latitude, nuclear charge	List of cosmic rays that satisfy the input criteria, including having good geometry through crystals but having no nuclear interactions.	Identify events with useful trajectories through CsI logs. Establish that no nuclear interactions occurred by evaluating dE profile. Optionally, identify crystals traversed before nuclear interaction occurred.	Cosmic-ray retrieval
Energy deposition	List of cosmic rays and a specific crystal in the calorimeter	Correlation of energy deposition with signal (for the relevant gain ranges), and relation between location of deposition along bar and signals from both ends (pedestals and gains)	Accesses cosmic-ray database, calculates energy deposition from trajectory & dE/dx	Cosmic-ray selector
Pedestals and gains	Energy depositions and signals from the Energy deposition module	Pedestals and gains for the crystal/diode/readout. NOTE: Because the readout is zero-suppressed, pedestal calibration is typically done on board and summary histograms are telemetered. Only through an optional diagnostic mode are the pedestal distributions accumulated on ground.	Likely to be some kind of least squares fitting (parameters TBD)	Energy deposition

Calibration history	Time or time range, optionally a specific crystal	Set of "official" calibration coefficients, or the time history for a specific crystal	Likely accesses a calibration database	Calibration database access

In-Flight Tracker Calibration (Robert Johnson)

Module	Inputs	Outputs	Functions	Utilities Required
Tower & tray alignment	Time range	Set of offsets of trays within a tower, relative orientations of towers**	Access cosmic-ray database, parameters of alignment model TBD	Cosmic-ray database retrieval
Alignment with optical axis	Most likely photons from a pointed observation of a field with =2 bright sources with known positions (like Crab & Geminga)	Offset and rotation of tracker z-axis from z-axis of the spacecraft (i.e., from star tracker)	In addition to routine likelihood analysis for point sources, fit three d.o.f. (inclination, azimith and rotation) to point src offsets	Likelihood analysis or access to database of detections
Dead/noisy strips*	List of cosmic rays and a specific crystal in the calorimeter	Trigger and channel masks	Accumulate hits for ~100,000 random events from event database	Event database retrieval

*Note that evaluation of dead or noisy strips will probably be done onboard the spacecraft. In ground processing, dead strips in particular will be identified only by accumulating the hits for many, many events. Want to use cosmic rays to verify that the DAC threshold levels are low enough to maintain very high efficiency for detecting charged particles. This must be done systematically (DAC chip by DAC chip) and will require some kind of interface to the reconstruction routine (so missing planes can be flagged).

**The expectation is that relative rotations of trays within a tower will be negligible.

In-Flight Monitoring of the PSF

Module	Inputs	Outputs	Functions	Utilities Required
Phase selected maps and radial profiles	Photons, pulsar ephemeris, phase range, map coordinate range, binning, energy range	Image file and radial profile of intensity	Phase selecting photons (barycenter correction), map and profile binning	Photon retrieval, exposure calculation
Expected radial profile	Pulsar spectrum, coordinates, calibration files, energy range	Calculated radial profile of the composite PSF	Numerical integration of PSF weighted by the pulsar spectrum	Calibration files

In-Flight Monitoring of the Effective Area

Module	Inputs	Outputs	Functions	Utilities Required
Intensity variations with angle	Photons, (large) region of sky, time range, energy range	Variation of intensity with inclination and azimuth, relative to the interstellar em. model	Counts and exposure map generation for ranges of inclination, azimuth, energy, and time, map binning	Photon retrieval, exposure calculation, interstellar em. model
Pulsar flux variations	Pulsar, time range	Flux vs. time	Access to flux histories in the source catalog	GLAST source catalog retrieval

Special Analyses (Polarization, WIMP lines, Multi-gamma events)...