Routine Science Processing of Fermi/LAT Data for Monitoring X-ray Binary Systems

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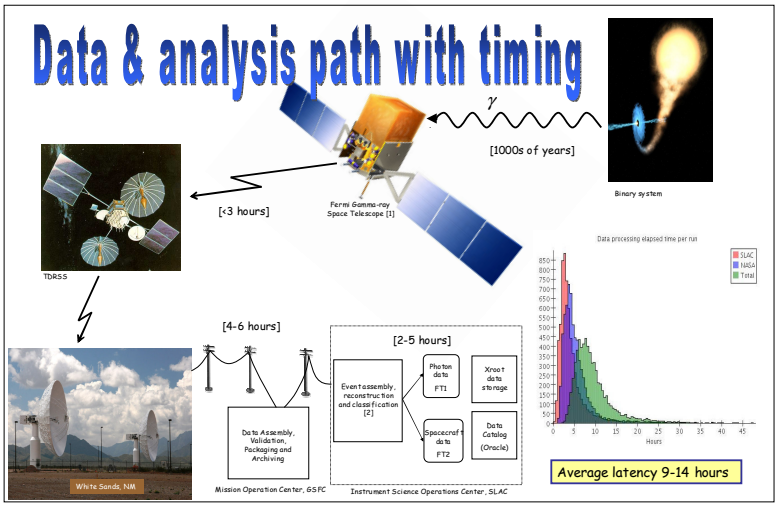
on behalf of the Fermi Large Area Telescope Collaboration

Summary: Part of the FGST routine data analysis includes monitoring of X-ray binary systems. This processing is described with illustrations from the LSI +61 303 system.

Abstract

The Fermi Gamma-ray Space Telescope normally transmits science data to earth every two orbits (~180 minutes); basic event reconstruction is typically complete 24 hours later. An Automated Science Processing (ASP) task then takes a quick look at all data, recording, for example, blazar activity. This is followed by a number of semi-automated Routine Science Processing (RSP) tasks. One such RSP task monitors pulsars. Another RSP task, and the focus of this work, analyzes and monitors X-ray binary systems, including source detection, spectral analysis, and activity trending for each source. The structure and features of this task, plans for future enhancements, and its application to the LSI +61 303 system are described.

Data & analysis path with timing



Routine Science Processing

Objectives:

- Continuously improved detections and fits due to steadily increasing statistics
- Early notification of flares and other activity changes
- Rapid analysis of selected binary systems (leveraging SLAC batch farm to extract ~300 CPU-hours per processing cycle)
- Routine full processing cycles, ~1 per week, automatically and on demand

Analysis Requirements:

- Standard analysis for all sources
- Extensive, custom analysis for better-known sources
- Source detection
- Spectral fitting with flexible source modeling
- Monitor for flaring activity
- Monitor for baseline activity shifts
- Periodicity determination
- Maintain library of web-accessible standard plots
- Maintain tables of web-accessible trending data

Current list of monitored sources

Source	RA	DEC
1A 0535+26	84.72738	26.3.1578
1A 0620-00	95.685	-0.3.4583
1E 1740.7-2942	265.97846	-29.74517
1E 2259+586	345.28456	58.87901
3EG J2033+4118	308.41	41.32
4U 0115+63	19.63292	6.374
4U 0614+091	94.28042	9.13694
4U 1543-47	236.78583	-47.66944
4U 1608-52	243.17917	-52.42306
4U 1630-47	248.50167	-47.39417
4U 1636-536	250.23125	-53.75139
4U 1702-429	256.56081	-43.03575
4U 1705-440	257.22696	-44.10204
4U 1735-444	264.74292	-44.45
4U 1820-303	275.91855	-30.36113
AE Aqr	310.03818	-0.87085
AM Her	274.05554	49.86783
Aql X-1	287.81667	0.585
Cen X-3	170.31575	-60.62297
Cir X-1	230.17031	-57.16674
Cyg X-1	299.59031	35.2016
Cyg X-2	326.17167	38.32167
Cyg X-3	308.10742	40.95725
GRO J0422+32	65.43621	32.91742
GRO J1655-40	253.50058	-39.84581
GRS 1758-258	270.30125	-25.74333
GRS 1915+105	288.79833	10.94556
GS 1124-683	171.61083	-68.67564
GS 2000+251	300.70658	25.23647
GS 2023+338	306.01575	33.86756
GX 13+1	273.63146	-17.15742
GX 17+2	274.00583	-14.03639
GX 3+1	266.98333	-26.56361
GX 304-1	195.32167	-61.60194
GX 339-4	255.70625	-48.78972
GX 340+0	251.44875	-45.61111
GX 349+2	256.43542	-36.42306
GX 354-0	262.98917	-33.83472
GX 5-1	270.28417	-25.07917
GX 9+1	270.38458	-20.52889
GX 9+9	262.93417	-16.96167
H1705-250	257.06083	-25.09139
H1743-322	266.05833	-32.23667
HESS J0632+057	98.24292	5.80556
Her X-1	254.45769	35.34239
IGR J17497-2821	267.40875	-28.35472
LMC X-4	83.20748	-66.3705
LS 5039	276.56274	-14.84841
LSI +61 303	40.131	61.229
PSR 1259-63	195.69857	-63.83574
SAX J0635.2-0533	98.8225	5.55583
SLX 1746-331	267.45208	-33.20508
SMC X-1	19.27144	-73.44334
SS 433	287.9565	4.98267
SWIFT J1753.5-0127	268.36792	-1.4525
Sco X-1	244.97946	-15.64022
Ser X-1	279.98958	5.03583
V4641 Sgr	274.83092	-25.40097
Vela X-1	135.52858	-40.5547
XTE J1118+480	169.5452	48.03694
XTE J1550-564	237.74458	-56.47667
XTE J1650-500	252.50417	-49.9605
XTE J1701-462	255.24358	-46.18572
XTE J1720-318	259.99583	-31.75028
XTE J1748-288	267.02108	-28.47383
XTE J1817-330	274.43142	-33.01883
XTE J1818-245	274.605	-24.54194
XTE J1859-226	284.67325	22.65817
XTE J1908+094	287.22117	9.38469
XTE J2012+381	303.1575	38.18364

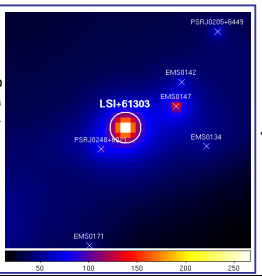
Pipeline Processing

(current) code outline

- Setup
  - Define analysis time period (MET)
  - Extract spacecraft data (FT2)
  - Submit jobs – 1 per source
- mqAnalysis (parallel jobs, one per source)
  - Extract photon data (FT1)
  - Prepare source model
  - (Basic) analysis
    - Count maps, live time cubes, exposure maps, etc.
    - Event selection (e.g., ROI & zenith angle cuts)
    - Spectral fitting
    - Aperture photometry (light curve)
- finishup
  - Register output data in Data Catalog
  - Load trending data
  - Other bookkeeping

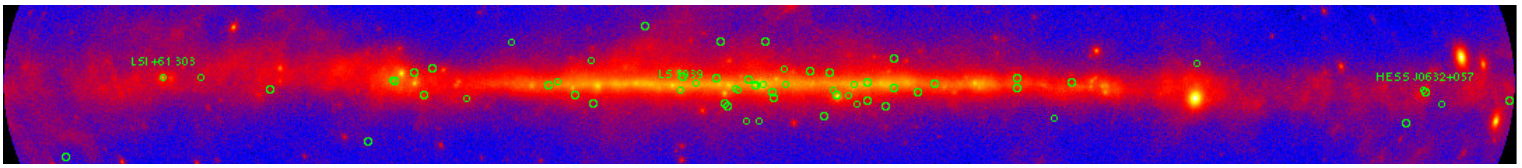
- **Fermi Pipeline** [3,4]: a system to organize and manage a large automated processing task, including an interface to the SLAC and Lyon batch farms, a comprehensive Data Catalog, self-monitoring, and reporting.
- Processing task driven by **python scripts**, including general-purpose **analysis classes**, optimized for automated, parallel pipeline operation.

Source model map constructed from generated source model and fitted parameters.



Source Modeling

- General purpose **python classes** for source model generation, editing, and xml production for use with maximum likelihood tools
- Candidate Sources from special database table (at right)
  - Choice of spectral model behavior (e.g., power law, broken power law, power law with exponential cutoff, etc.)
  - Ad hoc candidates (not in DB table) may be invented dynamically
- Nearby Sources from LAT catalog
  - Select observed nearby sources, e.g., within desired ROI
  - Initial spectral parameters (from LAT catalog) may be fixed or left floating
- After spectral fit, parameters may be adjusted, nearby sources removed, etc. for a refit

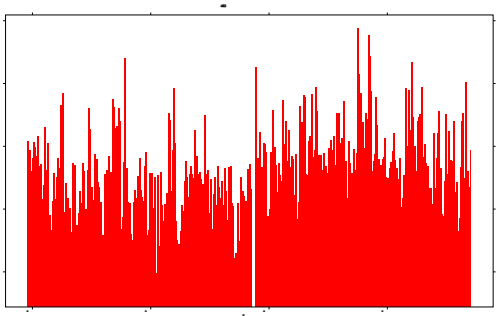


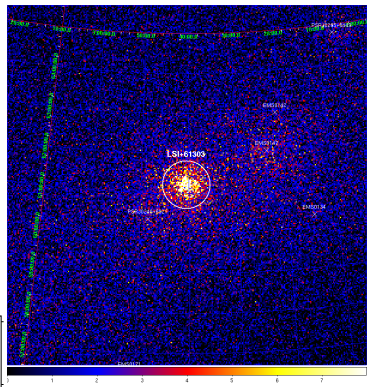
Analysis

All analysis is performed with Fermi ScienceTools [5] and the HEASoft library [6]

Automatically produced data products:

Source model (.xml)
Ancillary files (livetime cubes, exposure maps, etc.)
Counts map (image and FITS)
Fit results: summary (txt) and counts spectra (FITS)
Light curve (image and FITS)



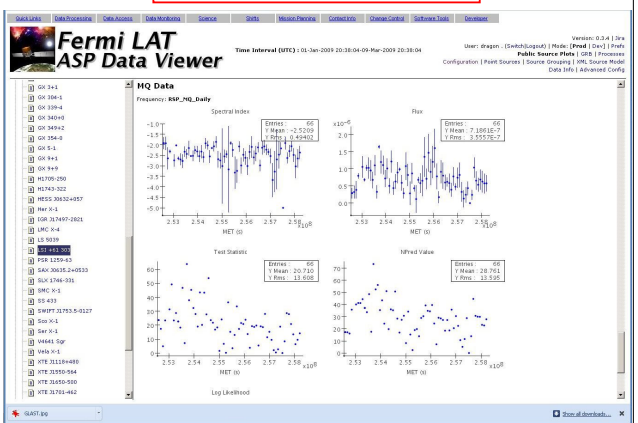


LSI +61 303 [7,8] examples:

- Counts map (actual data in 0.03-deg bins, above)
- Light curve (1-day binning, left)
- Trending database web application (right)

Trending database quantities currently include:

- fitted spectral index (with error)
- flux, test statistic, and other fit parameters



References

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