The fermi lat Light Curve Repository





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* Starting from August 15th 2023





ea Light Curve Repository



Fermi Light Curve Repository



- LAT sources deemed variable in the 4FGL
- monitor interesting LAT sources and alerting them of new gamma-ray flares

• A public library of publication ready light curves on time scales of days, weeks, and months for all

• Hosted at the FSSC, this library will serve as a general purpose repository for light curve data • Consist of a full likelihood modeling of the source and surrounding region • Provides flux and spectral index history over the lifetime of the Fermi mission

• Serves as a resource to the time-domain and multi-messenger communities by helping scientists

Motivation

The long-baseline monitoring of the gamma-ray sky provided by the LAT has been critical to <u>time-domain and multi-messenger</u> discoveries

- The TXS 0506+056 association suggested that astrophysical neutrinos detected by IceCube could be attributed to high fluence AGN that undergo intense flaring activity [Abbasi et al. 2022]
- Study AGN variability
 - e.g. Lags in 3C 279 [Hayashida et al. 2012, 2015]
 - quasi-periodic variations in PG 1553+113 [Ackermann et al. 2015]
 - constraints on the rate of orphan flares [Liodakis et al. 2019]





Sample Selection

- - <1% chance of being a steady source







Monitor variable gamma-ray sources















Date (UTC)	Julian Date	MET	τs	Photon Flux [0.1-100 GeV] (photons cm ⁻² s ⁻¹)	Photon Flux Error (photons cm ⁻² s ⁻¹)	Photon Index	Photon Index Error	Sun Distance	Fit Tolerance	MINUIT Return Code
Aug 08 2008	2454687	239889601	3	< 5.83e-8	-	-	-	98.45	1e-8	0
Aug 15 2008	2454694	240494401	15.37	8.44e-8	3.45e-8	-2.62	0.39	104.61	1e-8	0
Aug 22 2008	2454701	241099201	1.91	< 6.87e-8	-	-	-	110.50	1e-8	0
Sep 05 2008	2454715	242308801	1.71	< 7.61e-8	-	-	-	121.34	1e-8	0
Sep 12 2008	2454722	242913601	27.88	1.22e-7	3.65e-8	-2.58	0.33	126.22	1e-8	0
Sep 19 2008	2454729	243518401	45.79	1.26e-7	3.44e-8	-2.28	0.22	130.69	1e-8	0
Sep 26 2008	2454736	244123201	11.38	5.36e-8	3.14e-8	-2.34	0.41	134.72	1e-8	0
Oct 03 2008	2454743	244728001	20.89	7.44e-8	3.12e-8	-2.17	0.31	138.24	1e-8	0
Oct 10 2008	2454750	245332801	45.4	1.35 e- 7	3.68 e -8	-2.33	0.26	141.19	1e-8	0
Oct 10 2008	2454750	245332801	45.4	1.35e-7	3.68e-8	-2.33	0.26	14 1.19	Associations	0
Oct 03 2008	2454743	244728001	20.89	7.44e-8	3.12e-8	-2.17	0.31	13 8.24	Classification:	0
Sep 26 2008	2454736	244123201	11.38	5.36e-8	3.14e-8	-2.34	0.41	13 4.72	Association:	0
Sep 15 2008								130.69	Association (FGL	.): ⁰ 3FGI

Data Overlays

LAT Point Source Catalog (4FGL) Abdollahi et al. 2020 - 5523 Sources

FAVA Flare Catalog (2FAV) Abdollahi et al. 2017 - 4309 Flares

2nd LAT GRB Catalog (2FLGC) Ajello 2019/GCN - 207 Detections

IceCube Neutrino Alerts GCN/AMON Notices - 68 Events

3rd LAT Pulsar Catalog (3PC) Smith et al. 2023 - 294 Pulsars

National Aeronautics and Space Administration Goddard Space Flight Center

arch	Catalog Map
Dec: Radius:	+
Clear	20
ıs	
Galactic -	0° 170° 160° 150°
Aitoff -	
al V Ecliptic	
afo ☑ Grid Lines ations Milky Way Moon er Label:	30°
me Association soc Classification	
r Color: -Variable Sources	RA:, Dec:
e r Size: / Index Significance olved Significance (3 day)	54683 10 -
ays	0 – – 54683
ource Catalog (4FGL) 2020 - 5523 Sources	Date: 573
B Catalog (2FLGC) B/GCN - 186 Detections	
atrino Alerts	4FGL

Future Work

• Automated secondary analysis of light curve data • Flare identification via Bayesian block analysis

- Quiescent background estimation
- Variability characterization

• GCN notifications

 Finding new computational resources to carry out the LCR analysis • The SLAC computer cluster has many users who can be impacted by heavy use • Moving to a more dedicated or commercial solution could give us more flexibility

• Allow users to subscribe to GCN alerts for flaring episodes of individual sources

Please feel free to reach out if you would like to contribute!

Backup

Michela Negro

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The Fermi Large Area Telescope Light Curve Repository

Analysis Logistics

- A major challenge of producing likelihood light curves is the computational expensive
- The computational overhead is tackled by parallelizing the full unbinned likelihood analysis with a computer cluster at SLAC National Accelerator Laboratory using a distributed likelihood analysis code developed for LIGO followup • Each sky bin is analyzed on a separate node, same can be done for individual time bins
- The 3-day distributed unbinned likelihood light curves can then be generated in ~ 15 minutes

Current Status

- The light curves for all 1525 sources in the repository are up to date • Data will be continually updated as new data arrives
- The data portal is up and running at the FSSC • <u>https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository</u>
- The data portal's front end code is up on GitHub • <u>https://github.com/dankocevski/LightCurveRepository</u>
- A python API package is also available to allow for direct access to the LCR database • <u>https://github.com/dankocevski/pyLCR</u>

4FGL J0237.8+2848

- I 50 sources within I 2 deg • 15 variable sources
- Example of a source where the existing FAVA light curves would be of little use to characterize the region
- A variable 4FGL source has on average 16 other variables sources within 12 deg
- Requires a full likelihood analysis that takes into account the variability of all nearby sources

4FGL J0237.8+2848

Data Selection & Model Generation

Data Selection

- Energy Range: 100 MeV to 100 GeV
- Event Selection: P8R3 SOURCE
- Instrument response function: P8R3 SOURCE V3
- Acceptance cone (ROI): 2 deg
- Zenith angle cut (zmax): 90 deg

Model Generation

- Galactic interstellar emission model: gll iem v07.fits
- Isotropic spectral template: iso P8R3 SOURCE V3 v1
- Catalog: 4FGL-DR2 catalog (gll_psc_v27.fit)

Likelihood Fitting Strategy

- Use pylikelihood to perform unbinned analysis using MINUIT
- Perform a nested fixed and free spectral index fit • First fit: only normalization set free and spectral index is fixed to catalog value • Second fit: both normalization and spectral index are set free
- Iterative likelihood fit using increasingly tighter fit tolerances • Perform multiple fits using fit tolerances ranging from [1, 1-e4, 1e-8] Implemented to minimize fit non-convergence
- Flux extraction occurs for both fixed and free index fits • Flux is extracted for all fits that yield TS > I • 95% Bayesian upper limits are also calculated whenever TS < 4 (~2 sigma) • Users can then choose the minimum TS level for flux estimation

Number of Variable Sources In Each ROI

• Number of variable sources within 12 deg of each source in the sample

