

LAT Report

Judy Racusin (LAT Deputy Analysis Coordinator)

On behalf of Peter Michelson (LAT PI),
Gulli Johannesson (LAT Analysis Coordinator),
for the LAT Collaboration

11 year skymap
Pass 8 (P8_P305)
Source class
 $E > 1 \text{ GeV}$

Fermi Users Group Meeting - Oct 3, 2019

4FGL

- 8 year source catalogs

- 5065 sources
- Source list: `gll_psc_v20.fit`

- Paper submitted to ApJS,
arXiv:1902.10045

- Improvements relative to 3FGL

- Pass 8 data
- New Galactic Diffuse model (`gll_iem_v07.fits`)
- Weighted maximum likelihood analysis
- Tested all sources with three spectral models (power law, log normal and power law with subexponential cutoff)
- Modeled 75 sources as extended emission regions
- Light curves and variability in one year and two months time bins
- Updated counterpart catalogs

- https://fermi.gsfc.nasa.gov/ssc/data/access/lat/8yr_catalog/

Table 1. Previous *Fermi*-LAT catalogs

Acronym	IRFs/Diffuse model	Energy range/Duration	Sources	Analysis/Reference
1FGL	P6_V3_DIFFUSE	0.1 – 100 GeV	1451 (P)	Unbinned, F/B
	glliem.v02	11 months		Abdo et al. (2010a)
2FGL	P7SOURCE.V6	0.1 – 100 GeV	1873 (P)	Binned, F/B
	gal_2yearp7v6.v0	2 years		Nolan et al. (2012)
3FGL	P7REP_SOURCE.V15	0.1 – 300 GeV	3033 (P)	Binned, F/B
	glliem.v06	4 years		Acero et al. (2015)
FGES	P8R2.SOURCE.V6	10 GeV – 2 TeV	46 (E)	Binned, PSF, $ b < 7^\circ$
	glliem.v06	6 years		Ackermann et al. (2017b)
3FHL	P8R2.SOURCE.V6	10 GeV – 2 TeV	1556 (P)	Unbinned, PSF
	glliem.v06	7 years		Ajello et al. (2017)
FHES	P8R2.SOURCE.V6	1 GeV – 1 TeV	24 (E)	Binned, PSF, $ b > 5^\circ$
	glliem.v06	7.5 years		Ackermann et al. (2018)
4FGL	P8R3.SOURCE.V2	0.05 GeV – 1 TeV	5065 (P)	Binned, PSF
	glliem.v07 (§ 2.4.1)	8 years		this work

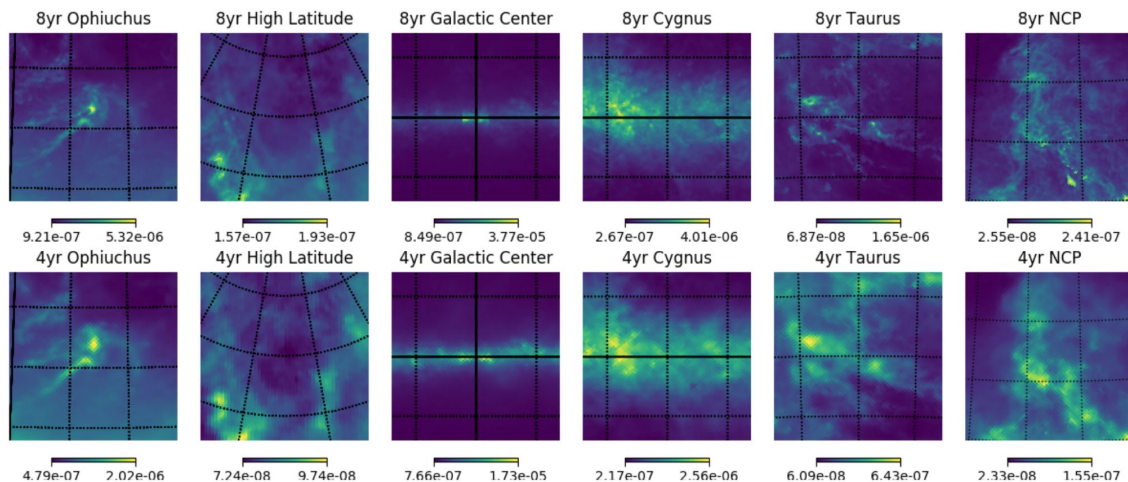
New Diffuse Model (gll_iem_v07.fits)

- Updates/Changes

- New H I survey
- New rotation curve
- New spectral line profile fitting
- New interpolation across the GC and anticenter regions

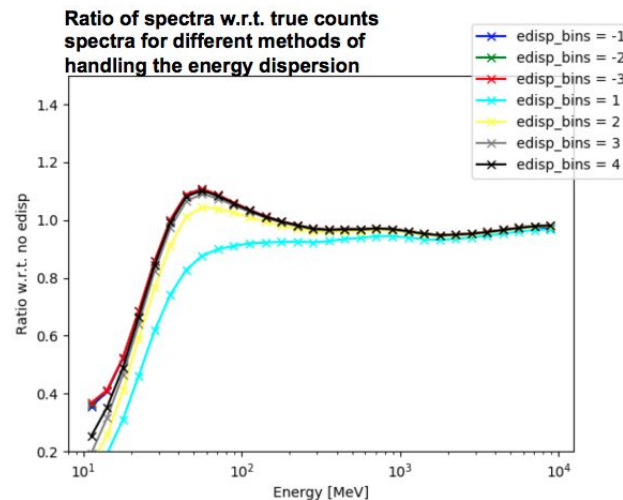
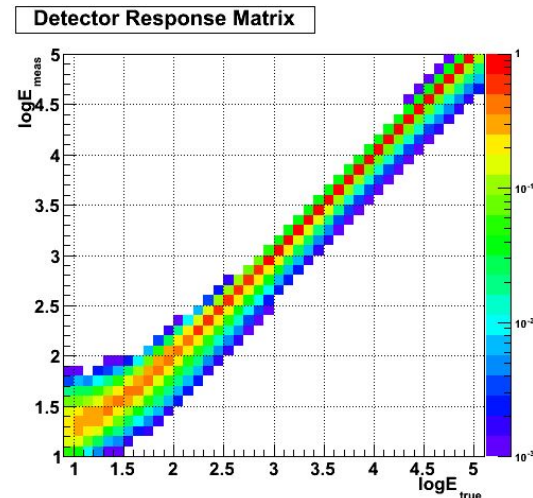
- Details:

[https://fermi.gsfc.nasa.gov/ssc/data/analysis/software/aux/4fgl/Galactic_Diffuse Emission_Model_for_the_4FGL_Catalog_Analysis.pdf](https://fermi.gsfc.nasa.gov/ssc/data/analysis/software/aux/4fgl/Galactic_Diffuse_Emission_Model_for_the_4FGL_Catalog_Analysis.pdf)



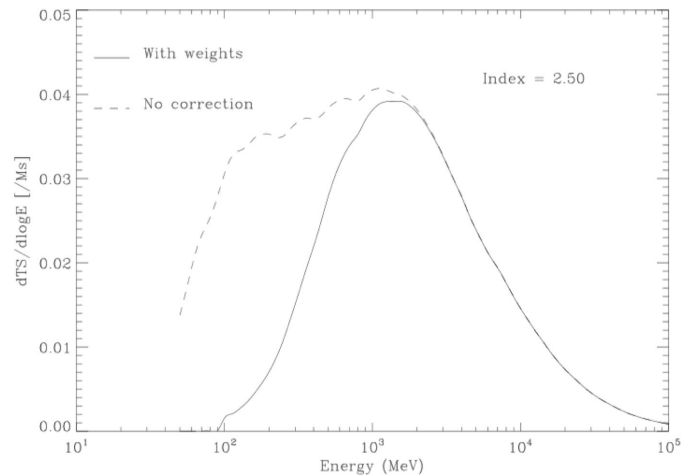
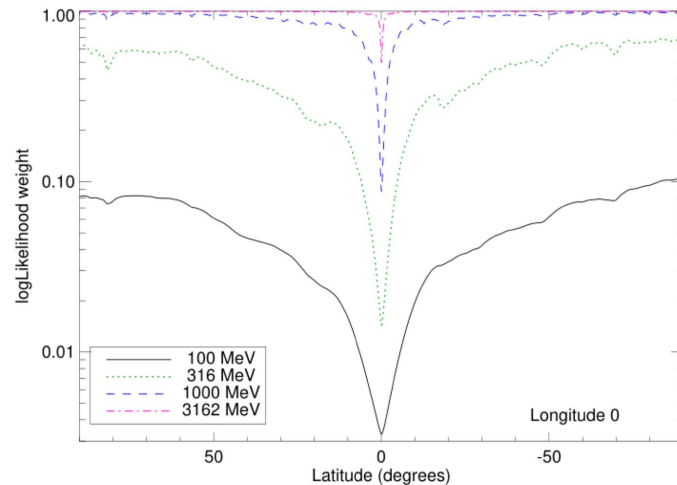
LAT Software

- New version of FermiTools (1.1.7) released Oct 1, includes new energy dispersion handling
- Analyses using the new diffuse model and 4FGL must take into account energy dispersion
 - Especially important < 300 MeV and ~2-3 GeV
- Documentation:
https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Pass8_edisp_usage_future.html



Fermitools/Fermipy (in collaboration with FSSC)

- Recent updates
 - Adding PLSuperExpCutoff2 spectral model
 - Energy dispersion
 - Weighted likelihood (especially important in Galactic Plane < 1 GeV)
 - Bug fixes
- Possible upcoming additions to fermipy
 - Support for using different pixelizations in fermipy
 - Batch farm processing support (for large scale parallel processing, e.g., light curves or spectra)
 - Generic stacking analysis framework



Figs 22 & 23 from 4FGL

Spacecraft File Reprocessing

- Adding velocity vector columns - beneficial for pulsar analyses
 - Allows for complete spacecraft position solution from spacecraft file
 - Validation studies complete
- Modified altitude correction - improves calculation of Geodetic Lat/Lon
 - Completing validation
- Reprocessing starts soon
 - Takes ~1 month

Multimessenger: Gravitational Wave Follow-up

● LIGO-Virgo

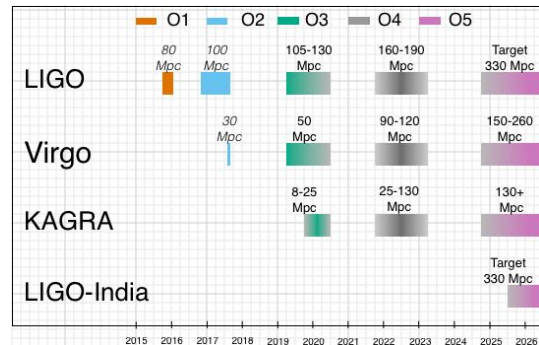
- O3a (3rd LIGO-Virgo Observing Run) - April 1 - October 1, 2019
- O3b - November 1, 2019 - April 30, 2020
- 33 candidate detections (21 BBH, 4 BNS, 2 MassGap, 4 NSBH, 2 Terrestrial)
- <https://gracedb.ligo.org/superevents/public/O3/>

● LAT analysis run on every GW Sky Map

- No significant counterparts detected
- Two independent LAT pipelines - make slightly different analysis choices, run on separate systems
- GCN Circulars put on on every event

● Plan to create public facing GW follow-up FSSC table

- Contain summary of observations, upper limit maps, links to GCNs



GLAST LAT Science Groups / ... / Rapid Response to GW alerts
Internal table of follow-up results for GW events

Created by Magnus Axelsson, last modified by Lorenz - Boston on Sep 05, 2019

Please fill out the table for each GW event, adding the latest at the top.

- BA tool for GW events
- GWFUP pipeline

GW event (with link to gracedb)	Confluence page	LIGO GCN	Type of event	Instant coverage	Time to max coverage	In SAA?	Lowest UL	Highest UL	New source detected?	Comments
S190901ap	S190901ap	GCN 25606	BNS	37%	5 ks (98%)	No	5e-8	3e-7	No	Analysis performed on the updated sky map
S190828i	S190828i	GCN 25503	BBH	22%	5.1 ks	No	1.2e-10	6.7e-10	No	
S190828j	S190828j	GCN 25497	BBH	0%	10 ks (52%)	No	4.3e-10	8.5e-8	No	
S190814dv	S190814dv	GCN 25324	NSBH	100%	-	No	3.1e-10	8.5e-10	No	Analysis performed on the updated sky map
S190728q	S190728q	GCN 25187	MassGap (52%) BBH (34%)	58%	5.8 ks (95%)	No	2.3e-10	2.7e-8	No	Updated sky map released after this analysis. Reached >99% of max coverage at about 2.1 ks.
S190727h	S190727h	GCN 25164	BBH	61%	2.1 ks (100%)	No	1.6e-10	1.3e-09	No	GCN sent on July 27. Current analysis corresponds to LIGO/Virgo map updated on August 1.
S190720a	S190720a	GCN 25115	BBH	45%	4 ks (100%)	No	1.4e-10	3.9e-09	No	
S190718y	S190718y	GCN 25087	Terrestrial (BNS 2%)	30%	4 ks (98%)	No	9.8e-11	1.1e-07	No	LVC performed additional analysis, and maintained the status as a binary merger candidate.
S190707q	S190707q	GCN 25012	BBH	35%	6.6 ks (100%)	No	2.3e-10	6.8e-09	No	Updated sky map released after this analysis.

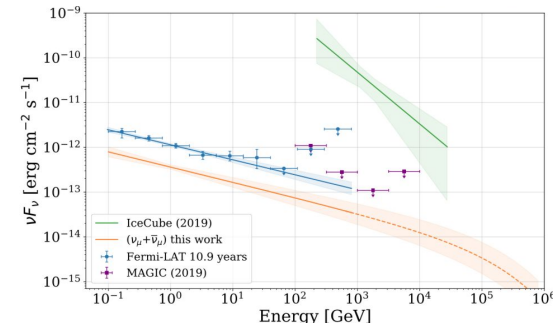
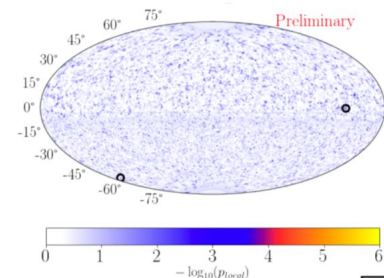
Multimessenger: Neutrino Follow-up

- LAT-IceCube Studies

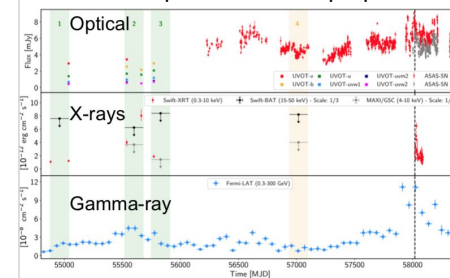
- 10 Year neutrino point source searches - Extragalactic sources from 3FGL, weighted with IceCube sensitivity
- NGC 1068 in a p-p dominated scenario (Seyfert 2 @12.5 Mpc, possible signal hard to explain physically or background source)
- Time dependent neutrino emission from 3LAC
- Multi-wavelength studies of neutrino source candidates
- Source population study
- Multi-epoch modeling of TXS0506+056 and predictions for its long-term neutrino emission

- Realtime Follow-up

- LAT Source searches for each HESE, Gold, Bronze event
- ATels + MWL follow-up observations



Petropoulou et al. in-prep



Catalogs

- Recently Published
 - 2nd LAT GRB Catalog
- Submitted
 - 4FGL
- In-progress
 - Solar Flare Catalog
 - Dark Matter Catalog
 - Flaring sources
 - 3PC (Pulsars)
 - 4LAC (AGN) - source list (ArXiv:1905.10771)
- Proposed
 - Incremental 4FGL every 2(?) years
 - Same diffuse/pipeline as 4FGL
 - Rerun for new sources and associations
 - Should produce ~500 new sources every 2 years
 - 5FGL?

Light Curve Repository

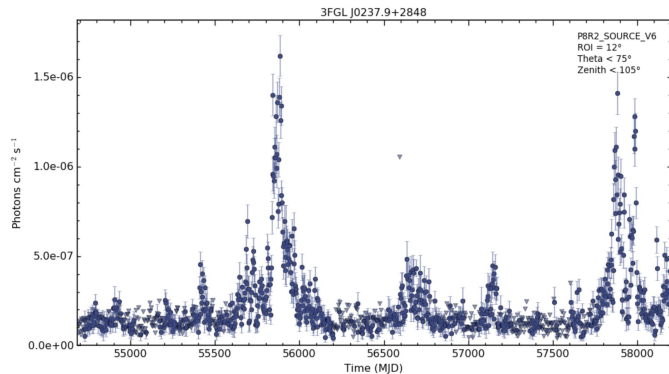
- Proposed in 2019 Senior Review
 - Aid in neutrino counterpart identification
- Implementation Plan
 - Based upon FAVA infrastructure (7-day photometric binned transient variability search, automatically triggers follow-up likelihood analysis)
 - Distributed likelihood tool developed for GW counterpart searches is starting point
 - Maintain light curves of 4FGL sources on timescales of days, weeks, months???

- Concerns

- How to add new sources?
- Crowded regions
- Computationally expensive

- Prototype page

- Comments/Suggestions?



Fermi LAT Light Curve Repository

Available Catalogs

4-year Point Source Catalog (3FGL)
Monthly likelihood light curves - 3034 sources

8-year Point Source Catalog (4FGL)
Monthly likelihood light curves - 5033 sources

2nd FAVA Catalog (2FAV)
Weekly photometric light curves - 518 sources

Optically Selected Blazar Sample
3, 7, 10, 30 day likelihood light curves - 178 sources

Source Catalogs

Source ID	RA	Dec	Gal l	Gal b	Association	Classification
FLR9 J0000.4-7353	0.106	-73.8956	307.716	-42.7555		
FLR9 J0001.2-4740	0.3104	-47.6791	114.247	-14.3444	CRATES J000119-474202	bcu
FLR9 J0001.2-0747	0.3148	-7.7871	89.045	-67.2962	PMN J0001-0746	bl
FLR9 J0001.4+2112	0.365	21.2055	107.626	-40.1762	TXS 2358+209	fsrq
FLR9 J0001.5-4156	0.397	-41.9444	334.259	-72.018	1RXS J000135.5-415519	bcu
FLR9 J0001.7-3503	0.4367	35.0508	111.561	-26.7213		
FLR9 J0002.1+7503	0.5493	75.0545	119.703	12.4923	CRATES J000233+745945	bcu
FLR9 J0002.1-6728	0.5468	-67.4719	310.083	-48.9666	SUMSS J000215-672653	bcu
FLR9 J0002.9+6216	0.7305	62.2793	117.323	-0.029432	PSR J0002+6216	PSR
FLR9 J0003.1+2208	0.7839	22.1444	108.417	-39.3621		
FLR9 J0003.1-5248	0.7768	-52.8098	318.993	-62.7853	RBS 0006	bcu
FLR9 J0003.2+2511	0.8113	25.1953	109.36	-36.4031		
FLR9 J0003.3-0718	0.8364	7.3024	102.529	-53.6534		
FLR9 J0003.3-5905	0.8333	-59.0941	314.253	-56.9643	AT20G J000313-590547	bcu
FLR9 J0003.4-1927	0.851	-19.4639	65.2121	-76.5821	WISE J000318.67-192722.3	
FLR9 J0003.6+3059	0.9036	30.9842	111.002	-30.7773		
FLR9 J0004.0+0840	1.0062	8.6724	103.493	-52.4007	RFC J0003+0841	bcu
FLR9 J0004.0+5714	1.0177	57.2489	116.533	-5.0332		
FLR9 J0004.0-1149	1.0105	-11.8172	84.6388	-71.0751	PMN J0004-1148	bcu
FLR9 J0004.0-4004	1.0144	-40.07	337.103	-73.7594		
FLR9 J0004.4-4738	1.1194	-47.6347	323.956	-67.5311	PKS 0002-478	fsrq
FLR9 J0004.8+6623	1.2199	66.398	118.288	3.94699		
FLR9 J0005.8+3823	1.4614	38.398	113.2	-23.6107	S4 0003+38	bl
FLR9 J0006.3-0620	1.5937	-6.3453	93.6386	-66.6196	VCS J0006-0623	bcu

Source Demographics

4FGL Classification Distribution