LAT Report

FUG Meeting
July 20, 2012

S. Ritz

see http://www-glast.stanford.edu/
and links therein

Previous FUG Meeting…

Summary

Peter Michelson - LAT Status
16 June 2011 FUG Meeting

- LAT continues to operate well
- 2FGL catalog release on track for the end of June
- Pass 7 and new diffuse model release at the end of July
- Work underway on Pass 8 – major revision/update to all aspects of LAT event analysis

…and this FUG Meeting

Summary

Peter Michelson - LAT Status
16 June 2011 FUG Meeting

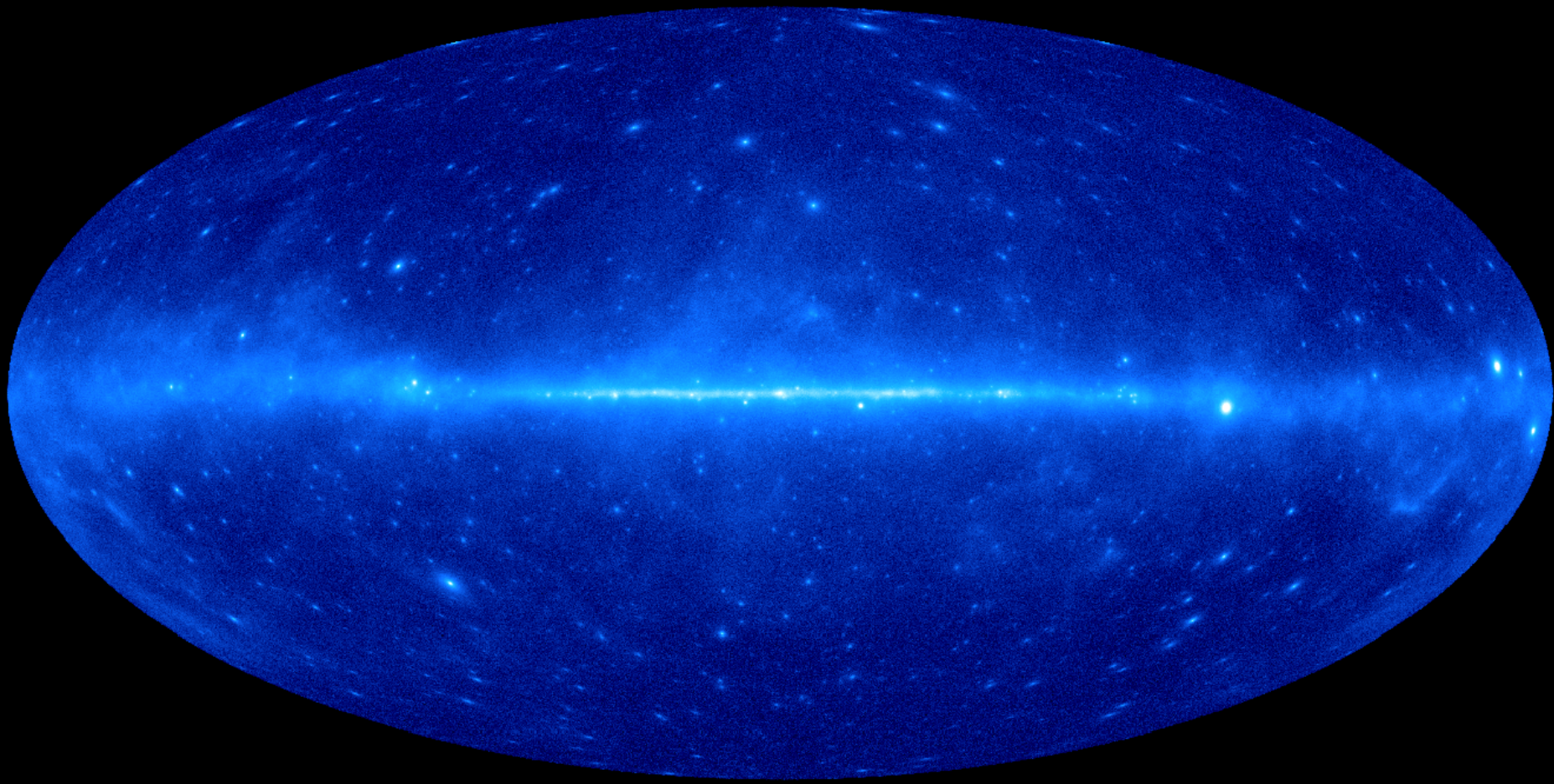
- LAT continues to operate well ✔
- 2FGL catalog release on track for the end of June ✔
- Pass 7 and new diffuse model release at the end of July ✔+…
- Work underway on Pass 8 – major revision/update to all aspects of LAT event analysis Continuing

- **PLUS large amount of work in support of senior review**

Fermi Large Area Telescope Second Source Catalog
Nolan, P. L. et al., ApJS **199**, 31

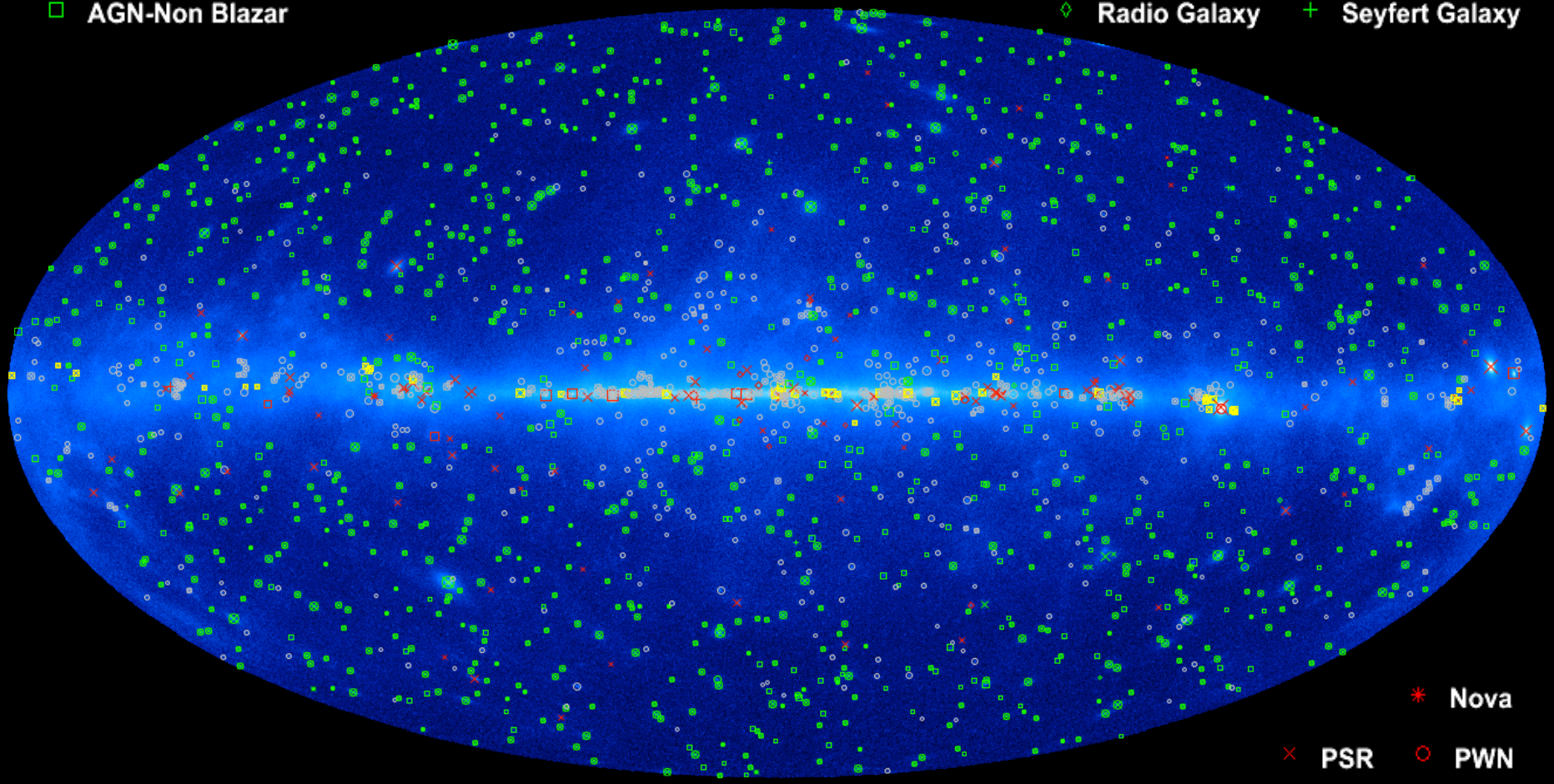
26

Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration

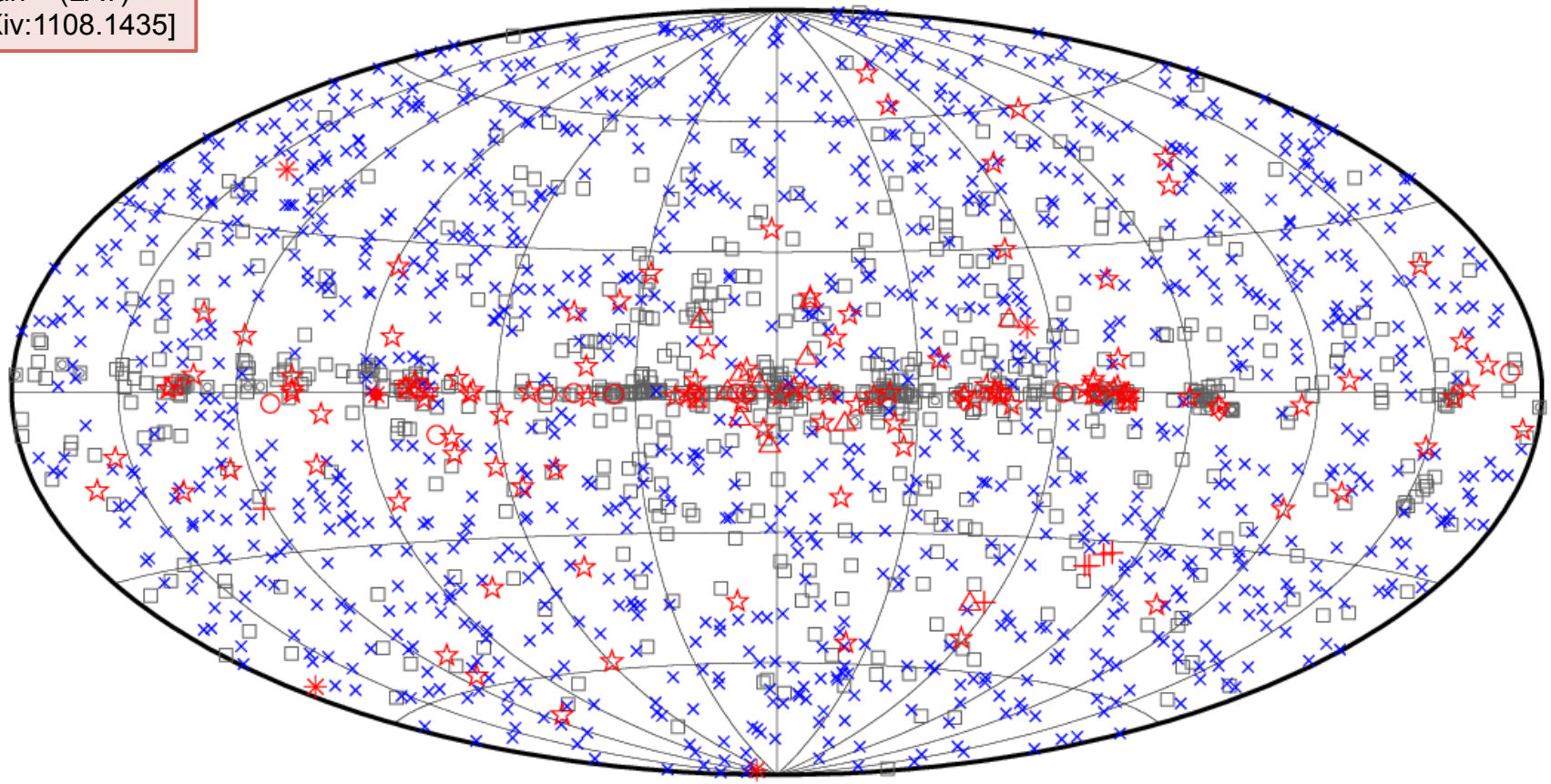
Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration

The Second Fermi-LAT Source Catalog

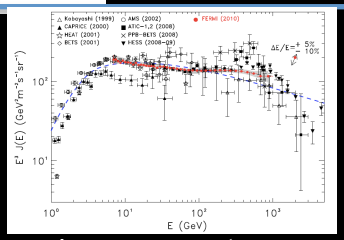
Nolan+ (LAT)
[arXiv:1108.1435]



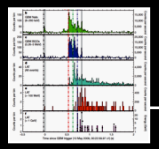
No association	Possible association with SNR or PWN	
AGN	Pulsar	Globular cluster
Starburst Gal	PWN	HMB
Galaxy	SNR	Nova

Expanding Classes of Fermi-LAT Sources

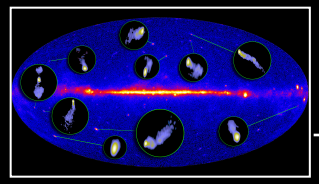
Fermi Gamma-ray Space Telescope



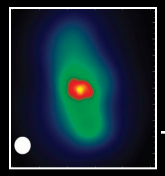
e^+e^- spectrum



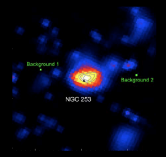
GRBs



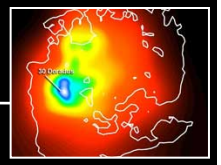
Blazars (782)



Radio Galaxies (12)

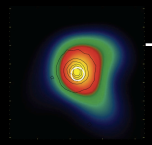


Starburst Galaxies (4)



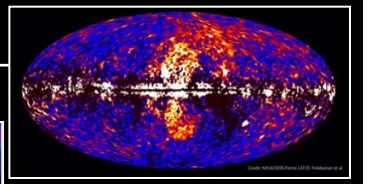
LMC & SMC

Extragalactic

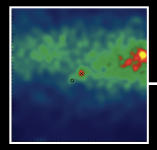


Globular Clusters (11)

Fermi Bubbles

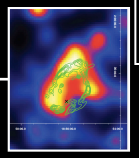


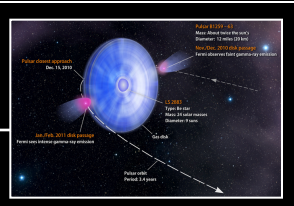
Galactic



Nova (1)

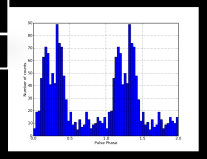
SNR & PWN (68)





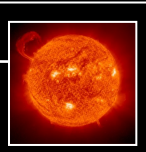
γ-ray binaries (6)

Pulsars: young & millisecond (MSP) (117+)

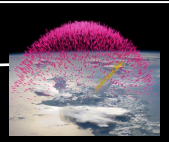


Local

Sun: flares & CR interactions

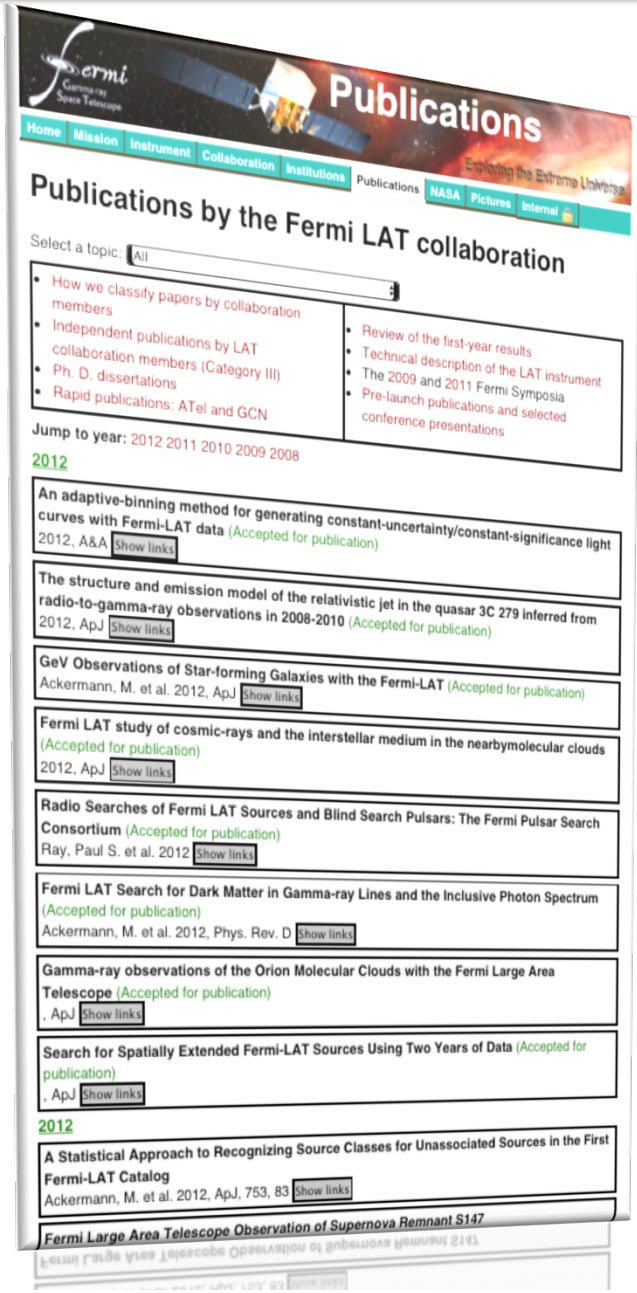


Terrestrial Gamma-ray Flashes

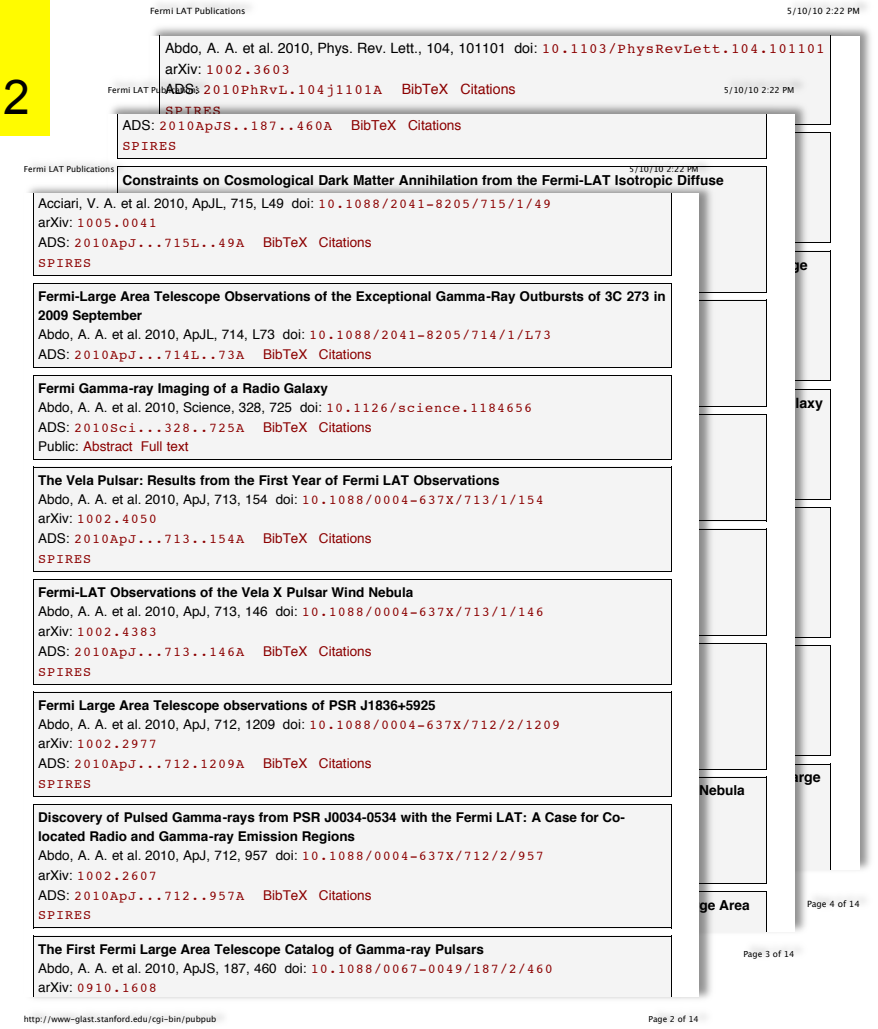


Unidentified Sources (~600)

>200 LAT Team papers out…



~50 papers
so far in 2012



…with many more in the pipeline…and many hundreds more using public LAT data.

http://www-glast.stanford.edu/cgi-bin/pubpub

Some LAT Highlights

- Discovery and study of 117 gamma-ray pulsars, 36 of which are seen to pulse only in gamma rays. 40 are ms pulsars.
  - 43 new ms radio pulsars discovered thanks to LAT data!
- Remarkable high-energy emission from gamma-ray bursts
  - Starting to see what was missing
  - w/GBM, provides interesting limits on photon velocity dispersion
- Very high statistics measurement of the cosmic e+e- flux to 1 TeV
- Nailing down the diffuse galactic GeV emission
- LAT determination of the isotropic diffuse flux
- Searches for Dark Matter signatures in different kinds of sources
- Many new results on supermassive black hole systems (AGN), including sources never seen in the GeV range
- More cosmic accelerators: Galactic X-ray binaries, supernova remnants, PWNe. Probing the cosmic-ray distributions in other galaxies; LMC and SMC.
- Extragalactic Background Light measurements
- New limits on large extra dimensions
- Crab short *flares*
- 2nd catalog: 1873 sources

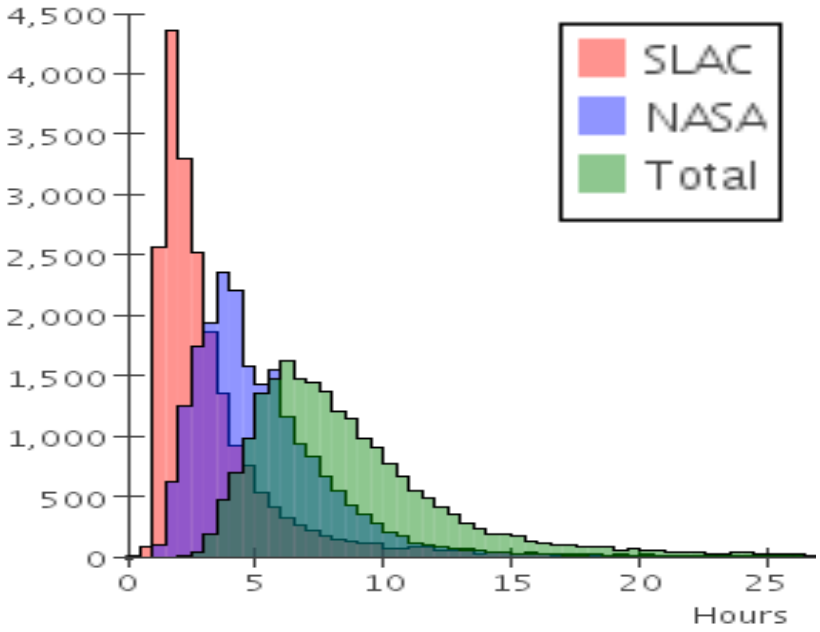
LAT Flight Operations

- **ISOC has maintained high efficiency for LAT data production**
  - **99.6% Uptime for Physics since the start of the Science Mission**
- **15 Flight Software updates since launch**
- **Only 1 FSW update in the past year**
  - **2011 Oct 11: FSW B2-3-2, to change LAT delay for GRB repoint requests**
- **3 Instrument configuration updates in the past year**
  - **Updating masks for noisy Tracker Si channels in the LAT**
  - **Further Tracker channel masking likely for 1 noisy Si ladder (of 2304)**
- **Other events interrupting or disturbing routine LAT data-taking**
  - **Infrequent high-radiation upsets to LAT electronics (SEFIs, SEUs)**
  - **Infrequent spacecraft events**
    - Collision Avoidance Maneuver for *Fermi* (April 2012)
    - *Fermi* entered Sunpoint returning from Nadir pointing (October 2011)
  - **Infrequent engineering or diagnostic tests**
    - Attempted diagnosis of TKR noisy ladder
  - **Errors:** In 2012, a total of 3 orbits of LAT data were not taken due to planning/operator errors, which are being addressed.
  - **Routine on-orbit detector charge injection calibrations (3 per year)**

ISOC Science Data Processing

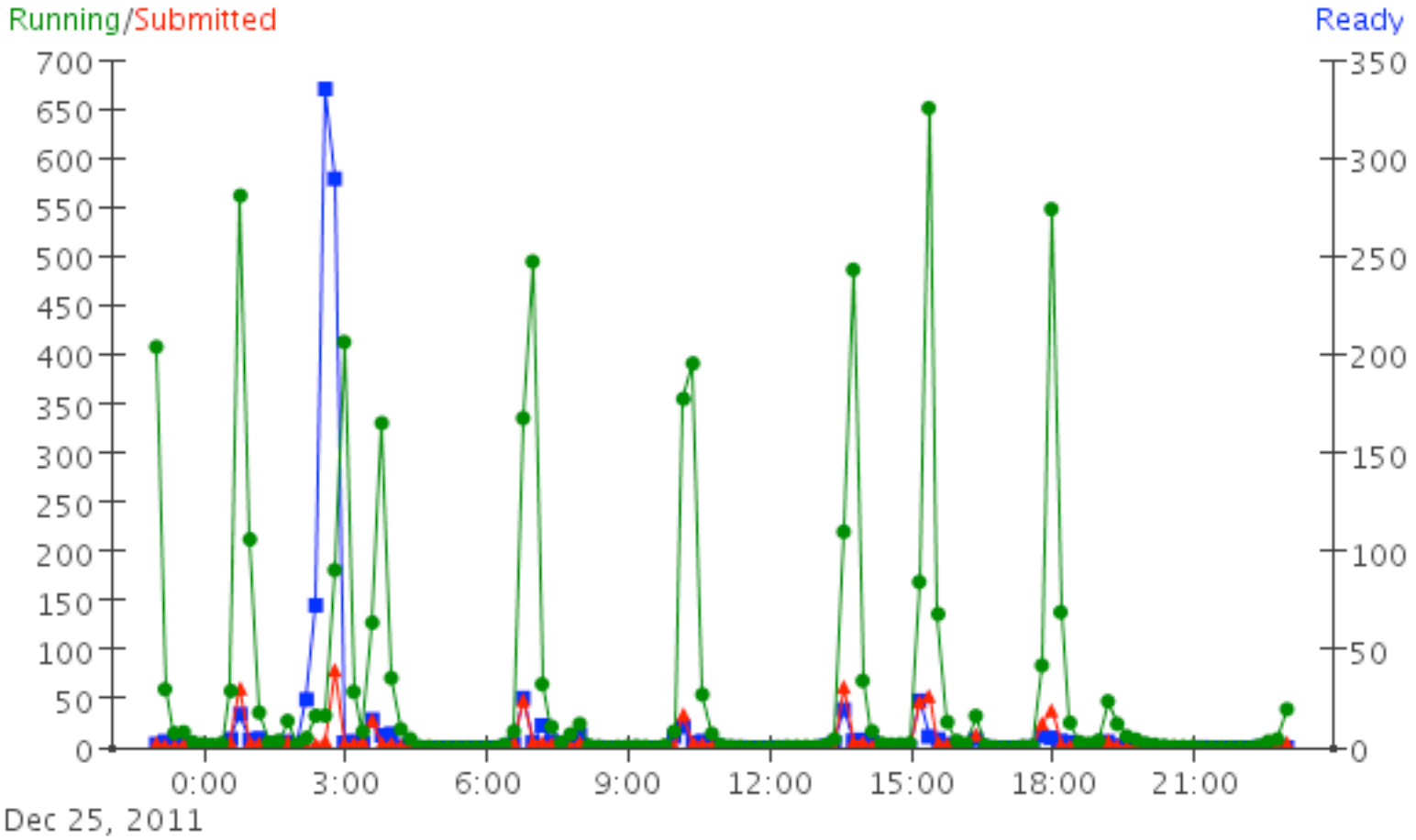
- **Since the start of the science mission**
  - 240 billion triggers of the LAT
  - 48 billion event readouts down-linked to the ISOC
    - 1.37 billion events classified as photons in Level1 processing and delivered to the Fermi Science Support Center for public release
    - 460 CPU-years of Level 1 processing at SLAC (10 CPU-yrs/month)
    - 1.1 PB of output data files
    - Data reprocessed multiple times
- **Science Data Monitoring**
  - 120,000 quantities monitored
  - 4238 quantities with alarm limits
- **Automated science processing (ASP) results regularly sent to FSSC.**
  - Blind searches for flaring sources, flux/spectral monitoring, search for prompt/afterglow emission from all GRB triggers within LAT FoV, transients searches,…
  - Also supports Collaboration's Flare Advocate and Burst Advocate tasks

Data Processing Times at NASA and SLAC



Compute Farm Usage at SLAC

- Current resources: 1600 cores at SLAC + 600 cores at Lyon (for Monte Carlo)
- Level 1 processing uses ~10 CPU-years/month
- Increases in usage rate for Pass 6 and 7 reprocessing + Monte-Carlo runs

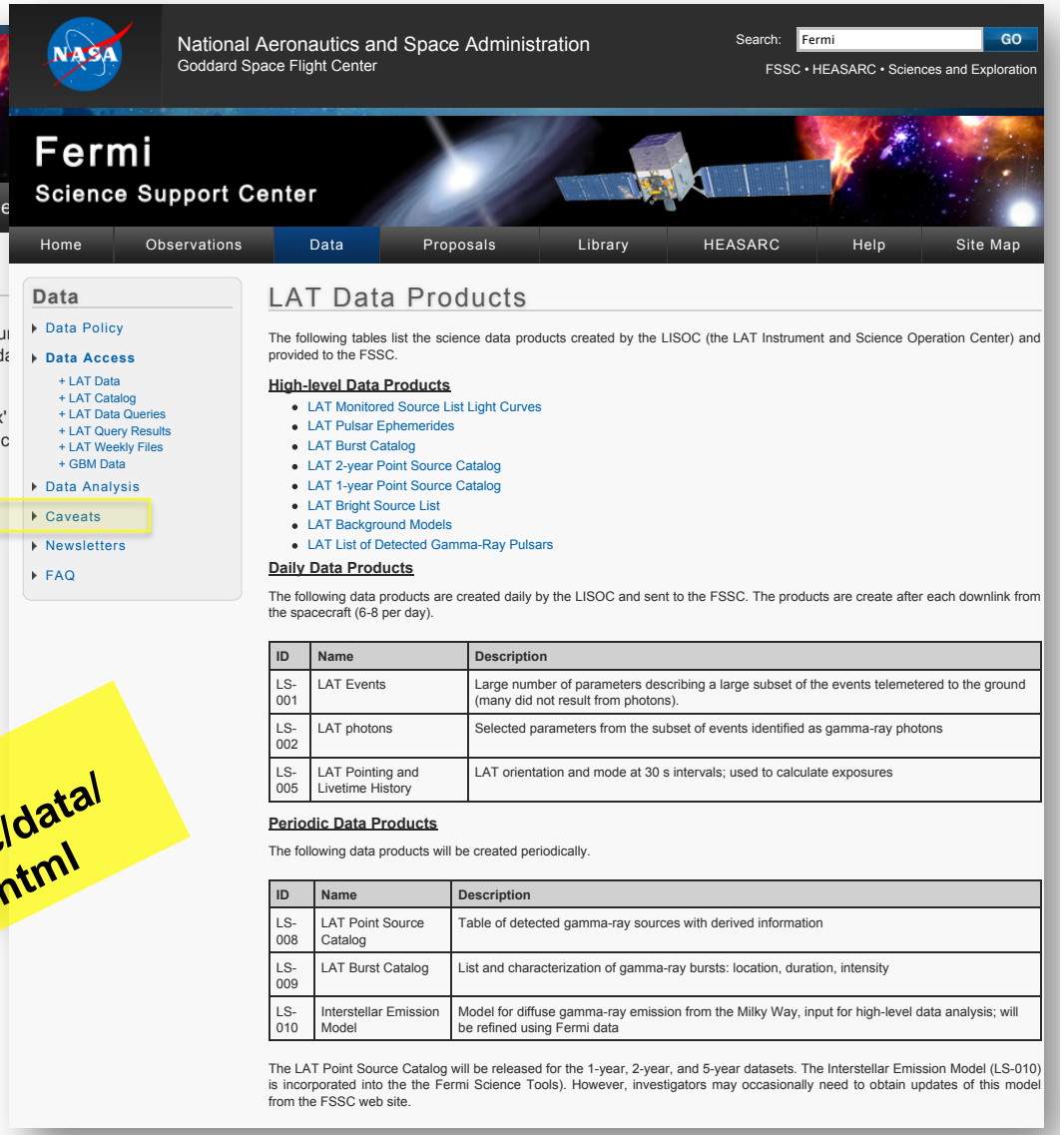


ISOC Plans

- On-going mission support and data processing activities, plus….
- Transition to using new "Trunc64" TKR readout buffering is being studied
  - Removal of TKR layer readout buffer limits, to improve the LAT PSF, bkgd rejection, and possibly Aeff
  - On-board limits can be replicated in offline processing, if needed
- At least 3 FSW updates are in work or being planned
  - B3-0-0: Upgrade to FSW build environment for future maintenance, plus simplified offline use of FSW photon, MIP and ion filters
  - B3-1-0: data compression fix, before using "Trunc64" configuration
  - B3-1-1: fix 4 known remaining minor bugs
  - (B3-2-0: Background filter for improved real-time GRB detection)
- Pass 8 development, implementation and transition
  - Test processing
  - Then reprocess and redeliver entire mission dataset with Pass 8
  - Both Pass 7 and Pass 8 processing for some time
  - Expecting the transition to general LAT Collaboration validation in 2013-14 timeframe

LAT Data Products @ FSSC

http://fermi.gsfc.nasa.gov/ssc/data/access/lat/



PLEASE SEE http://fermi.gsfc.nasa.gov/ssc/data/analysis/LAT_caveats.html

LAT Photon Data

http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_LAT_IRFs/IRF_overview.html

direction of each event, and calculating myriad quantities with are used by the selection algorithms to separate photons from cosmic ray backgrounds. This is a much longer term project and will eventually be released as "Pass 8" of the event selection.

The main features of P7 IRFs are:

- Improved effective area and/or lower background contamination relative to P6. As the "Pass 7" analysis was designed using flight data, the instrument team was able to improve the photon/cosmic ray separation. In general the selections were tuned to give roughly the same background contamination rates as for "Pass 6" analysis while gaining in effective area, particularly at lower energies (below 300 MeV).
- Inclusion of second order effects released in P6_V11: azimuthal- and livetime-dependence of effective area are also included in "Pass 7"
- As in the P6_V11 IRFs the point spread function derived by fitting the width of bright point sources. This was done because the point spread function derived from Monte Carlo was observed to be an incorrect description of the LAT performance at high energies.
- The Pass 7 event selections are based only on quantities that have been shown to be well modeled in the Monte Carlo simulations. Therefore the associated IRFs do not require any flight based correction of the type that was applied in making the P6_V11_DIFFUSE IRFs.

Recommendations for the appropriate selection and IRF set to be used within an analysis are provided in the data preparation section of the Cicerone. The tables below give the association between the Pass 7 IRF sets and the photon properties as provided in the LAT photon data.

P7 IRF name	Event Class (evclass)	Conversion Type	Description
P7ULTRACLEAN_V6	4	0+1	Highest quality and lowest background selection - somewhat overconservative, this entails a significant loss of effective area. Recommneded mainly to use as a cross check that observed features are not due to cosmic-ray contamination
P7ULTRACLEAN_V6::FRONT	4	0	Front converting events
P7ULTRACLEAN_V6::BACK	4	1	Back converting events
P7CLEAN_V6	3	0+1	Very high quality and low background selection - recommended for analyses that integrate large regions of the sky. Reduces non-photon spectral features to very low levels.
P7CLEAN_V6::FRONT	3	0	Front converting events
P7CLEAN_V6::BACK	3	1	Back converting events
P7SOURCE_V6	2	0+1	High quality selection - recommended for most analysis
P7SOURCE_V6::FRONT	2	0	Front converting events
P7SOURCE_V6::BACK	2	1	Back converting events
P7SOURCE_V6MC	2	0+1	Monte Carlo PSF - for studies of short term (<1 month) variability
P7SOURCE_V6MC::FRONT	2	0	Front converting events
P7SOURCE_V6MC::BACK	2	1	Back converting events
P7TRANSIENT_V6	0	0+1	Lower quality selection - used for certain transient or timing analysis
P7TRANSIENT_V6::FRONT	0	0	Front converting events
P7TRANSIENT_V6::BACK	0	1	Back converting events

Additional Information

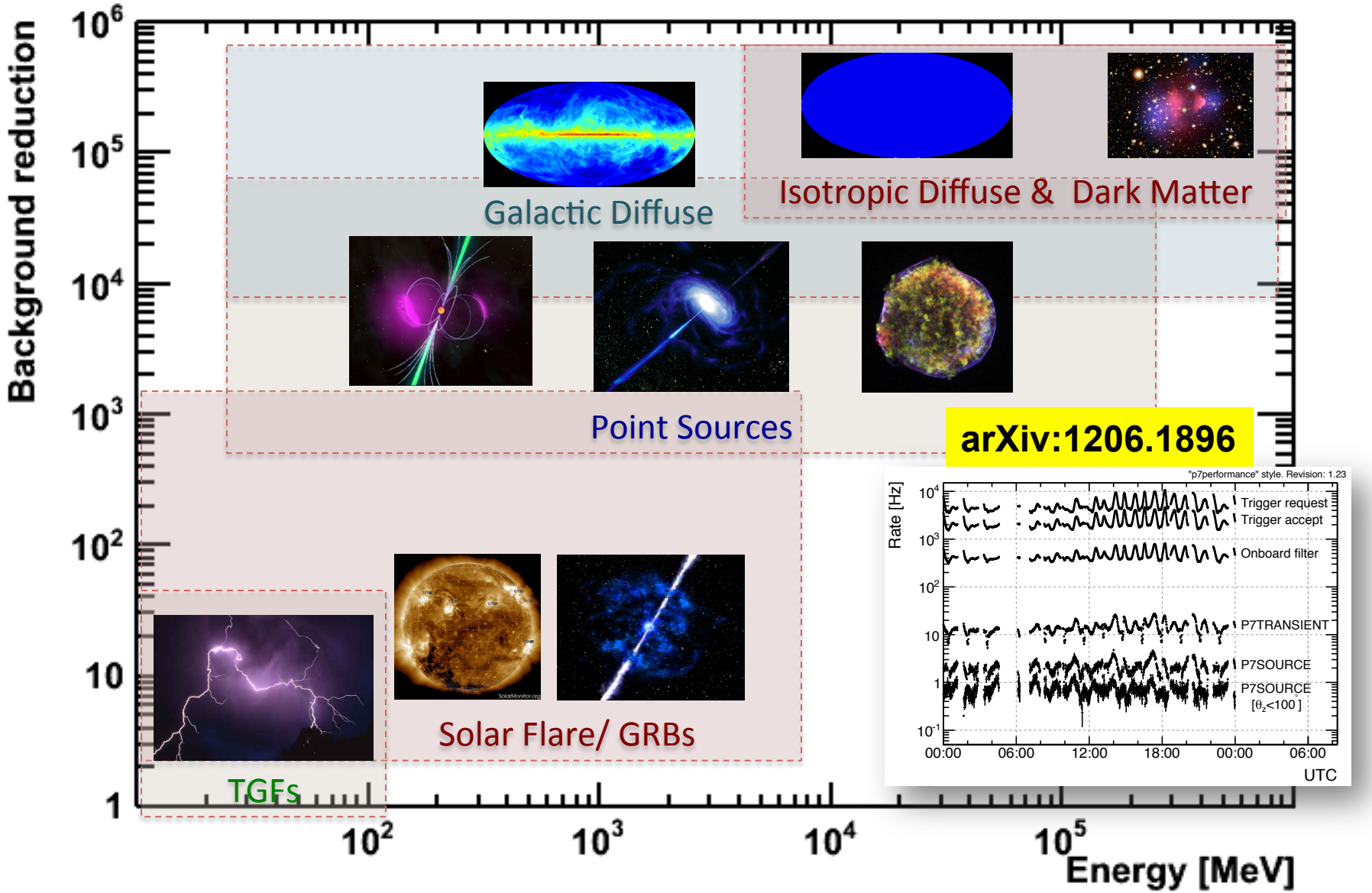
Detailed descriptions of the LAT instrument, event analysis, and performance can be found in the following:

- LAT Performance Page: http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm.
- Pass 7 Performance Paper: The Fermi Large Area Telescope On Orbit: Event Classification, Instrument Response Functions, and Calibration, Ackermann, M. et al., 2012, ArXiV e-print: 1206.1896.
- The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission, Atwood, W. B. et. al., ApJ, 2009, 695, 1071.
- The on-orbit calibration of the Fermi Large Area Telescope, Abdo, A. A., et al. 2009, Astroparticle Physics, 32, 193

The IRFs shown here are based on updated simulations of the instrument that take into account effects measured in flight that were not considered in pre-launch performance estimates. Recent information regarding the results of post-launch testing which led to this formulation can be found in the following documentation:

- Post-launch performance of the Fermi Large Area Telescope, R. Rando, 31st ICRC Conference Proceedings, Lodz, Poland, 2009.

Huge Dynamic Ranges

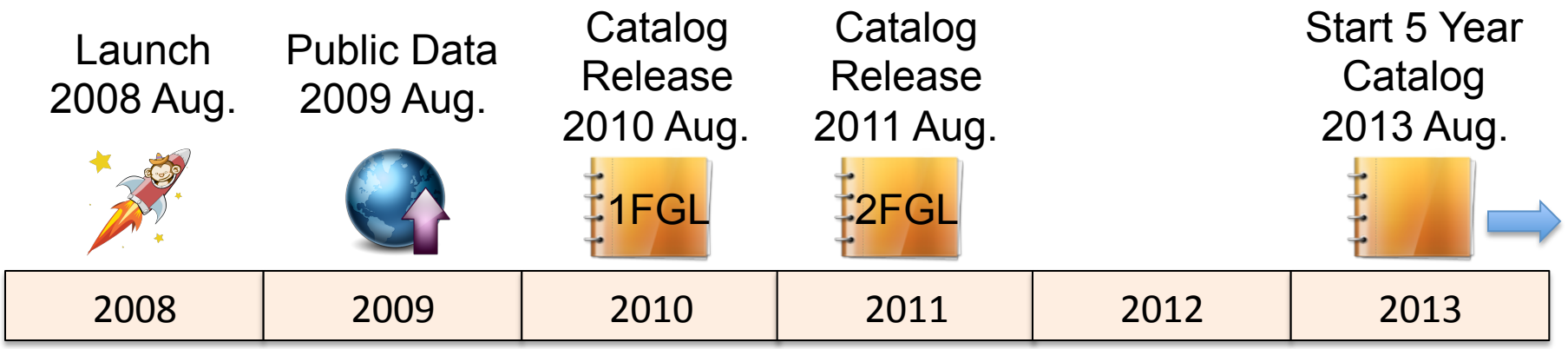


Evolution, Improvements

- Event reconstruction and choices of event selection "knobs" all determine instrument performance. For stability, standard event class definitions established with IRFs.
- Data were released with Pass 6.
  - Some known issues, described in Caveats on FSSC site and in LAT papers, addressed with patch to IRFs.
  - Pass 7 and Pass 8 address the remaining issues.
- Pass 7 released
    - Improved standard photon classes. **Used in 2nd Catalog.**
    - Event analysis taking into account "ghost" events
  - Ongoing: reprocessing Pass 7 using updated calibrations. Main improvement: PSF @ high energies.
- Exciting progress on Pass 8, expected to be the ultimate version.

LAT Data Releases

…PLUS tools, diffuse models, transients/monitored sources,…



L1 Data Pipeline: Pass 6 | Pass 7 | Pass 7R

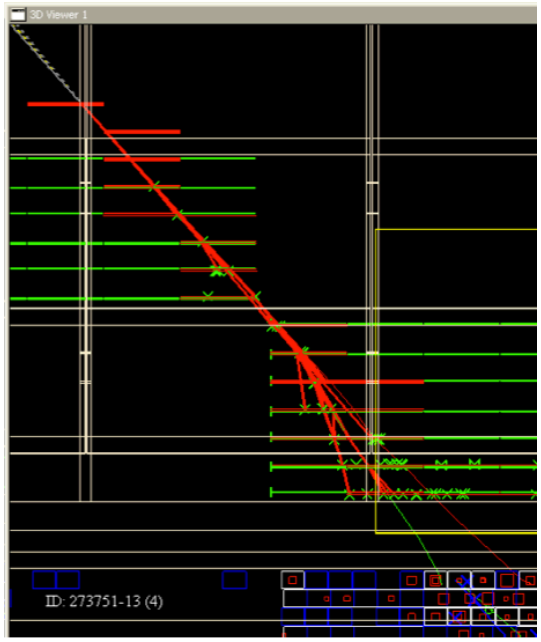
Development: Pass 7; Pass 8

Reprocessing & Validation: Pass 7 | Pass 7R | Pass 8

Pass 6: Pre-launch Event Reconstruction and Classification
Pass 7: Event Classification Re-optimized Using Flight Data
Pass 7R: Pass 7 Reprocessed with Improved Calibrations
Pass 8: Event Reconstruction and Classification Major Upgrades

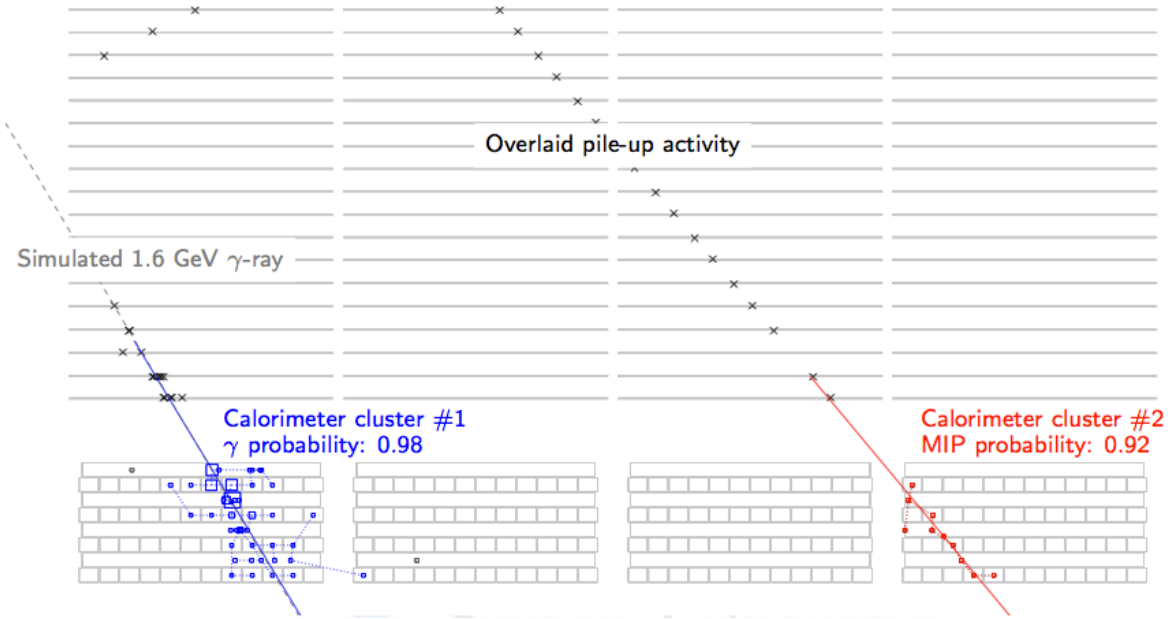
Pass 8 Synopsis

The two really MAJOR changes



Tree-based Tracking

(better model for EM shower)

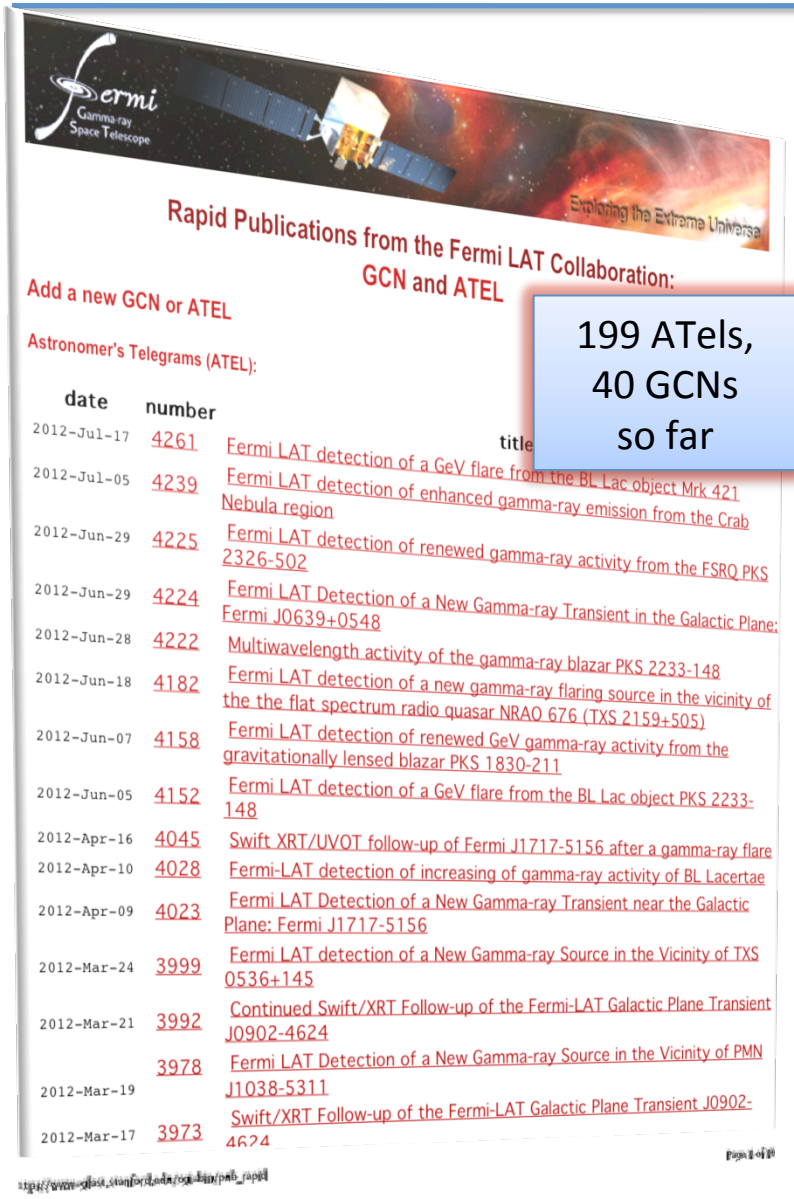


Calorimeter Cluster & Cluster Classification

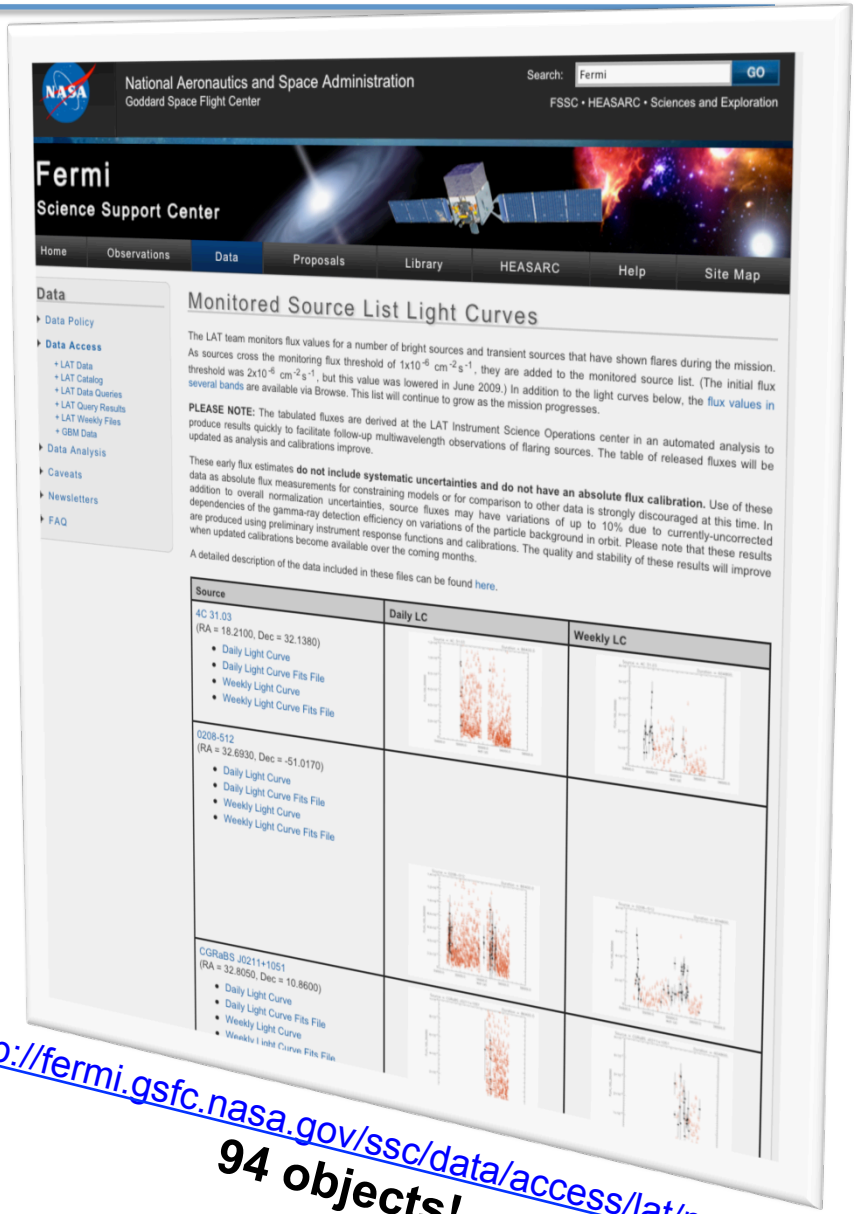
Also: cosmic ray track finder, handling of buffer overflows, improved cluster errors, removing ghost hits, improved track-fitting, vertex energy weighting, TKR-CAL matching, error projection to ACD, CAL cluster projection to ACD, improved GEANT modeling, updated simulation of CAL light yield, development of validation samples

Science analyses developed *along with* Pass8 => there may be some interim results. Main goal: release Pass8 data with 5-year catalog (w/updated diffuse model) based on Pass8.

Transients & Flaring Sources



199 ATels,
40 GCNs
so far



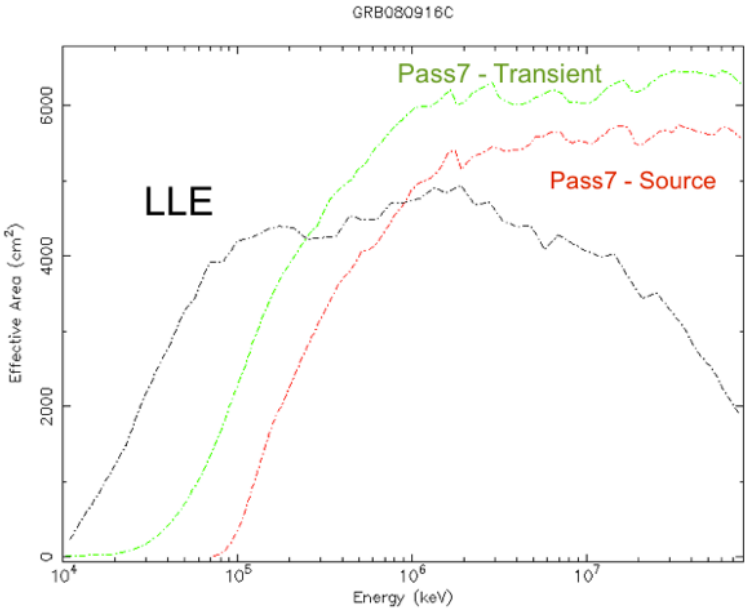
http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/

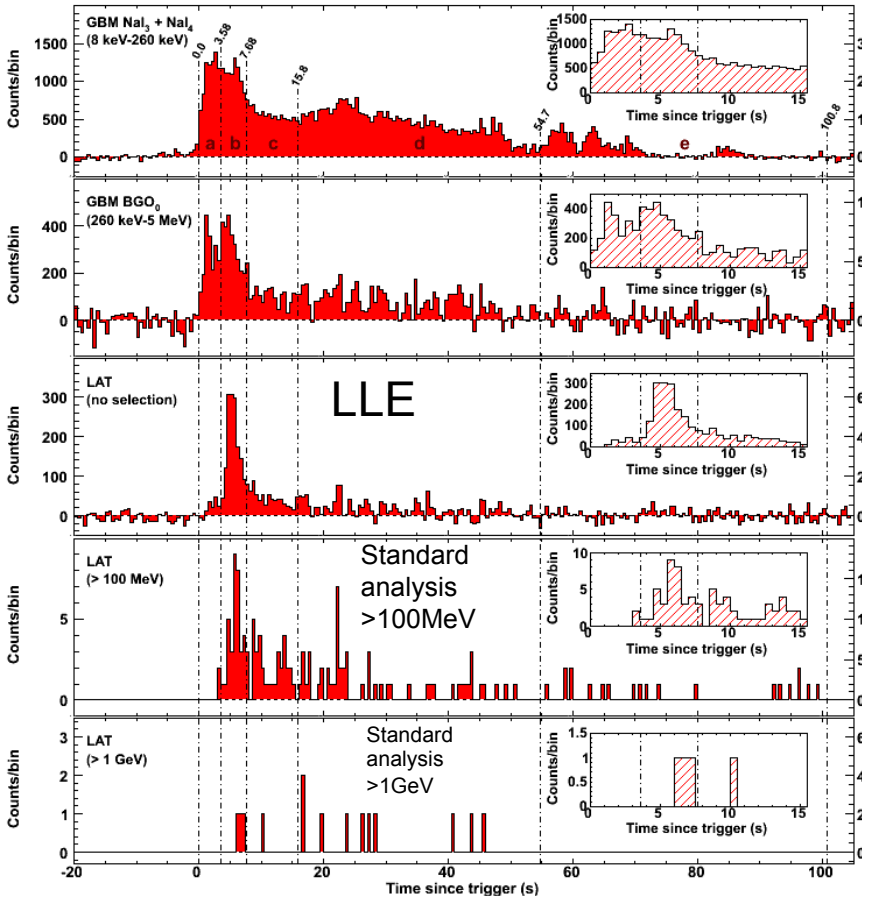
94 objects!

Also see http://fermisky.blogspot.com/

LAT Low Energy (LLE) analysis

- Purpose
  - In the standard analysis background rejection on "event by event" basis, using classification trees to reduce the particle contamination, classify the event, improve the quality of the signal (PSF, energy dispersion,…).
  - LLE Analysis: For GRBs, Solar Flares (rapid transients) we can also use the temporal profile to reduce the background. This information can be used to relax the "standard cuts" and open the effective area at low energy by an enormous amount.





LLE analysis makes accessible a new energy range.

At high energy Standard analysis more efficient.

Delivery of LLE data products
Major -non scheduled- improvement!

- New data products will be delivered by the LAT team to the FSSC
- The new data products are delivered for every GRBs and Solar Flare detected in LLE data! (*to date: 23 GRBs and 5 Solar Flares*)
  - LLE events: un-binned event file, suitable for temporal studies (high resolution light curve >30 MeV)
  - LLE spectrum files (PHAII,PHAI and RSP): ready-to-use burst products in rmfit and XSPEC
  - Quick look files (png images)

Usage Notes and Caveats

a) The LLE data selection and response depend on the input localization of the GRB. Although the procedure to obtain LLE data and response is fully automatic, the update of the GBM trigger catalog is not, and this might introduce a latency in the delivery of the data products with the optimized location.

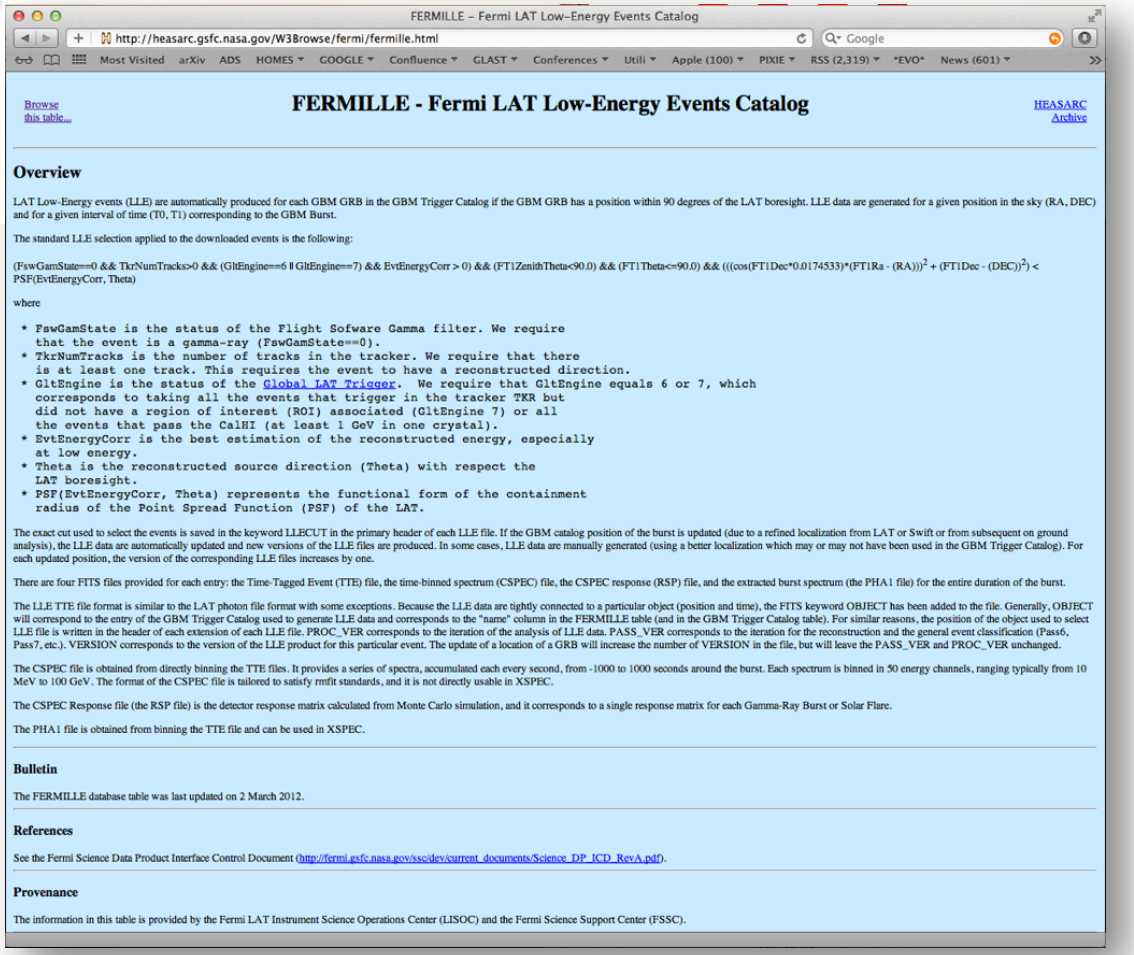
b) The Monte Carlo used to generate the response covers an energy range between 10 MeV and 100 GeV. At low energy (<100 MeV) the effect of the energy dispersion can be significant, and, with the current analysis, we discourage any spectral analysis below 30 MeV.

c) Above few hundred MeV (depending on the off axis angle of the event) the signal-to-noise ratio for standard data (TRANSIENT, SOURCE and cleaner event classes) is higher than for LLE data. In case of bright events with emission above few hundred MeV we suggest using standard LAT event data at high energy and LLE data at low energy.

d) The background in LLE is mainly driven by residual particle events and soft gamma-ray events in particular coming from the bright limb of the Earth. During Autonomous Repoint Requests (ARR), a significant fraction of the Earth limb enters the LAT field of view and an increase of the event rate is clearly visible in LLE data. We urge users to exercise care in the treatment of the Earth limb.

e) Data and response are, by construction, related to each other. In case of updates, we recommend updating both the response and the data, making sure that the version number is the same.

Serving the community: The LLE data portal @ FSSC



FERMILLE – Fermi LAT Low-Energy Events Catalog

http://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermille.html

Most Visited arXiv ADS HOMES GOOGLE Confluence GLAST Conferences Utili Apple (100) PIXIE RSS (2,319) *EVO* News (601)

Browse this table...

FERMILLE - Fermi LAT Low-Energy Events Catalog

HEASARC Archive

Overview

LAT Low-Energy events (LLE) are automatically produced for each GBM GRB in the GBM Trigger Catalog if the GBM GRB has a position within 90 degrees of the LAT boresight. LLE data are generated for a given position in the sky (RA, DEC) and for a given interval of time (T0, T1) corresponding to the GBM Burst.

The standard LLE selection applied to the downloaded events is the following:

(FswGamState==0 && TkrNumTracks>0 && (GltEngine==6 || GltEngine==7) && EvtEnergyCorr > 0) && (FT1ZenithTheta<90.0) && (FT1Theta<=90.0) && (((cos(FT1Dec*0.0174533)*(FT1Ra - (RA)))^2 + (FT1Dec - (DEC))^2) < PSF(EvtEnergyCorr, Theta)

where

* FswGamState is the status of the Flight Sofware Gamma filter. We require that the event is a gamma-ray (FswGamState==0).
* TkrNumTracks is the number of tracks in the tracker. We require that there is at least one track. This requires the event to have a reconstructed direction.
* GltEngine is the status of the Global LAT Trigger. We require that GltEngine equals 6 or 7, which corresponds to taking all the events that trigger in the tracker TKR but did not have a region of interest (ROI) associated (GltEngine 7) or all the events that pass the CalHI (at least 1 GeV in one crystal).
* EvtEnergyCorr is the best estimation of the reconstructed energy, especially at low energy.
* Theta is the reconstructed source direction (Theta) with respect the LAT boresight.
* PSF(EvtEnergyCorr, Theta) represents the functional form of the containment radius of the Point Spread Function (PSF) of the LAT.

The exact cut used to select the events is saved in the keyword LLECUT in the primary header of each LLE file. If the GBM catalog position of the burst is updated (due to a refined localization from LAT or Swift or from subsequent on ground analysis), the LLE data are automatically updated and new versions of the LLE files are produced. In some cases, LLE data are manually generated (using a better localization which may or may not have been used in the GBM Trigger Catalog). For each updated position, the version of the corresponding LLE files increases by one.

There are four FITS files provided for each entry: the Time-Tagged Event (TTE) file, the time-binned spectrum (CSPEC) file, the CSPEC response (RSP) file, and the extracted burst spectrum (the PHA1 file) for the entire duration of the burst.

The LLE TTE file format is similar to the LAT photon file format with some exceptions. Because the LLE data are tightly connected to a particular object (position and time), the FITS keyword OBJECT has been added to the file. Generally, OBJECT will correspond to the entry of the GBM Trigger Catalog used to generate LLE data and corresponds to the "name" column in the FERMILLE table (and in the GBM Trigger Catalog table). For similar reasons, the position of the object used to select LLE file is written in the header of each extension of each LLE file. PROC_VER corresponds to the iteration of the analysis of LLE data. PASS_VER corresponds to the iteration for the reconstruction and the general event classification (Pass6, Pass7, etc.). VERSION corresponds to the version of the LLE product for this particular event. The update of a location of a GRB will increase the number of VERSION in the file, but will leave the PASS_VER and PROC_VER unchanged.

The CSPEC file is obtained from directly binning the TTE files. It provides a series of spectra, accumulated each every second, from -1000 to 1000 seconds around the burst. Each spectrum is binned in 50 energy channels, ranging typically from 10 MeV to 100 GeV. The format of the CSPEC file is tailored to satisfy rmfit standards, and it is not directly usable in XSPEC.

The CSPEC Response file (the RSP file) is the detector response matrix calculated from Monte Carlo simulation, and it corresponds to a single response matrix for each Gamma-Ray Burst or Solar Flare.

The PHA1 file is obtained from binning the TTE file and can be used in XSPEC.

Bulletin

The FERMILLE database table was last updated on 2 March 2012.

References

See the Fermi Science Data Product Interface Control Document (http://fermi.gsfc.nasa.gov/ssc/dev/current_documents/Science_DP_ICD_RevA.pdf).

Provenance

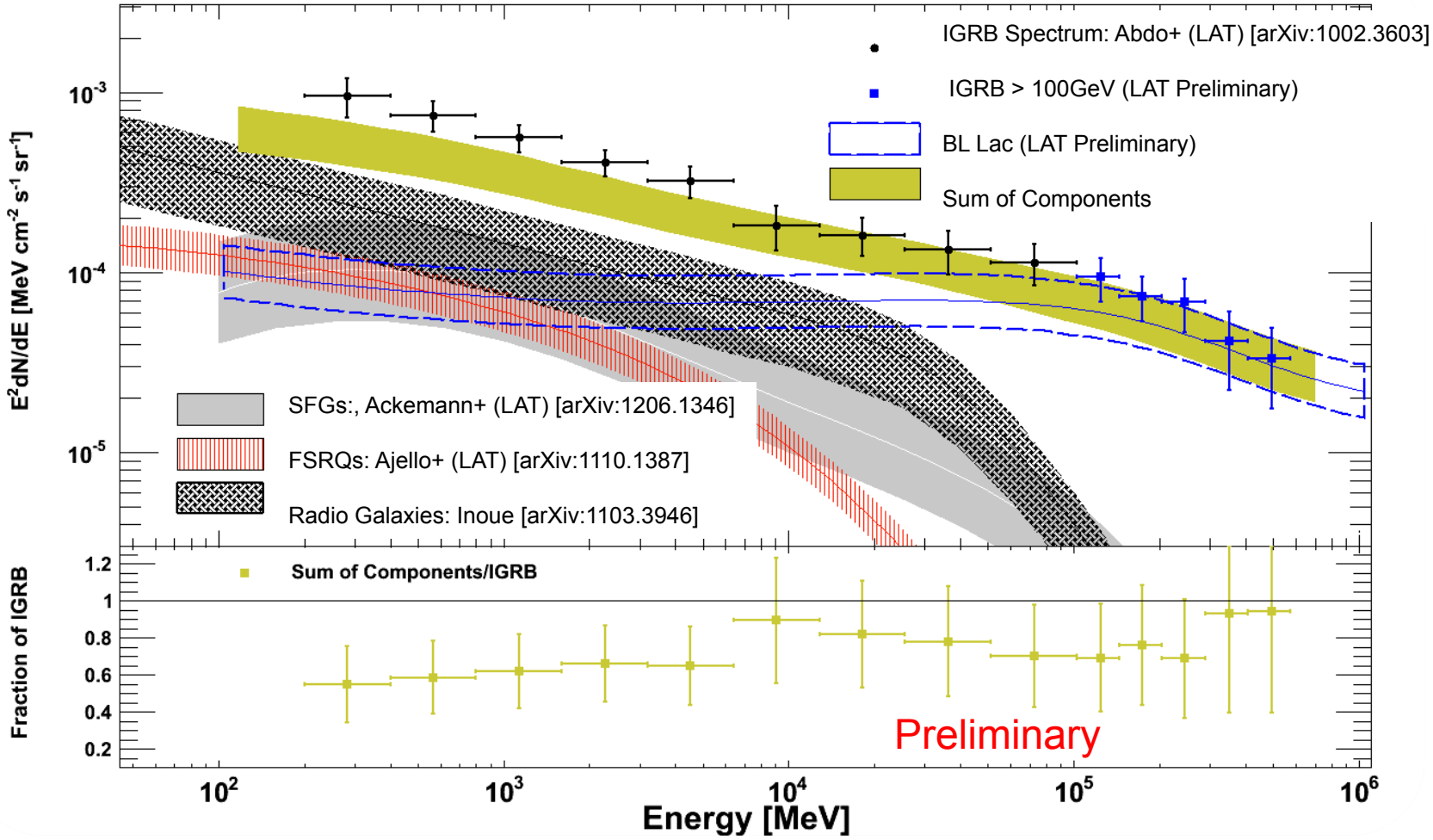
The information in this table is provided by the Fermi LAT Instrument Science Operations Center (LISOC) and the Fermi Science Support Center (FSSC).

- All the LLE data products as well as usage notes, caveats, data description will be uploaded to the FSSC
- Expect a latency of LLE data ~ 48 hours (+ updates)

The High Energy Frontier

- Now obtaining sufficient statistics above ~100 GeV
  - like a new experiment turning on!
- Three interesting examples:
  - Isotropic flux
  - EBL attenuation
  - Dark matter

Update: What Produces the Isotropic Flux?



See other studies by: Stecker&Salomon+96, Pavlidou&Fields+02, Narumoto&Totani06,Dermer07, Bhattacharya+09, Inoue&Totani09, Fields+10, Makiya+10, Inoue+11,Abazajian+10, Ghirlanda+11,Stecker&Venters11,Malyshev&Hogg11

What's Next?

- What is producing the unaccounted flux?
- What will higher precision above 100 GeV reveal?
  - will we see attenuation due to the extragalactic background light (EBL)?
  - what else is contributing at the highest energies?
- More statistics, with detailed understanding of energy reconstruction and backgrounds at the highest energies.

EBL!

Analysis Procedure

- We define 3 redshift bins with 50 members each: z= 0-0.2, 0.2-0.5, 0.5 -1.6
- All BL Lacs are modeled with a *LogParabola* spectrum
- 3 Steps Procedure:
  1. fit each ROI (1-500 GeV) to optimize all components
  2. re-fit only up to the energy for which EBL absorption is negligible (we call this E_{crit})
     1. This step is needed to determine the properties of the intrinsic spectrum
  3. Combine the likelihoods of each ROI (for a z-bin) and fit "b"
- We evaluate 2 cases: $F(E)_{absorbed} = F(E)_{\text{int}\,rinsic} \cdot e^{-b\cdot\tau_{\text{mod}\,el}}$
  1. Null hypothesis b=0 : there is no EBL
  2. Null hypothesis b=1 : the model prediction are correct

only $e^{-\tau}$ of the original source flux reaches us

Photons with E>10 GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL)

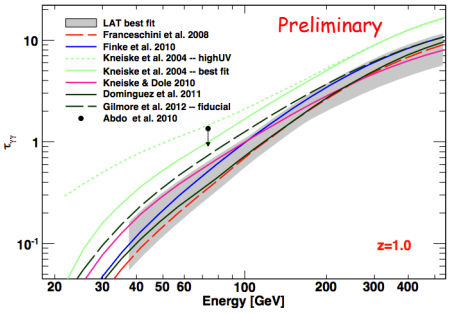
Composite Likelihood Results: 2

A significant steepening in the blazars' spectra is detected

This is consistent with that expected by a 'minimal' EBL:

- i.e. EBL at the level of galaxy counts
- 4 models rejected above 3sigma

- All the non-rejected models yield a significance of detection of 5.6-5.9 σ
- The level of EBL is 3-4 times lower than our previous UL (Abdo+10, ApJ 723, 1082)

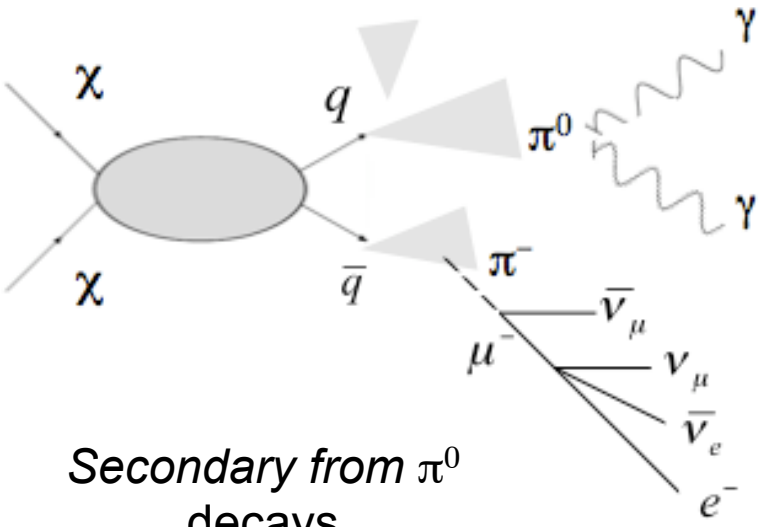


EBL Detection Significance ↓ | Model Rejection Significance ↓

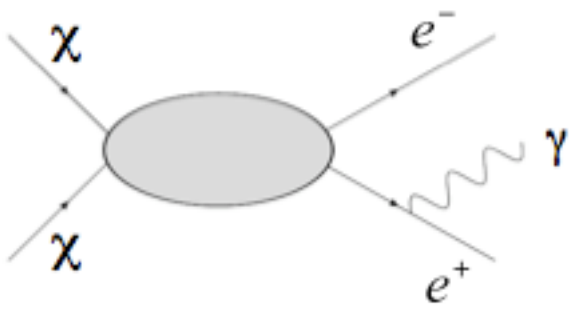
Model[a]	Significance of b=0 Rejection[b]	b^c	Significance of b=1 Rejection[d]
Stecker et al. (2006) – fast evolution	4.6	0.10±0.02	17.1
Stecker et al. (2006) – baseline	4.6	0.12±0.03	15.1
Kneiske et al. (2004) – high UV	5.1	0.37±0.08	5.9
Kneiske et al. (2004) – best fit	5.8	0.53±0.12	3.2
Gilmore et al. (2012) – fiducial	5.6	0.67±0.14	1.9
Primack et al. (2005)	5.5	0.77±0.15	1.2
Dominguez et al. (2011)	5.9	1.02±0.23	1.1
Finke et al. (2010) – model C	5.8	0.86±0.23	1.0
Franceschini et al. (2008)	5.9	1.02±0.23	0.9
Gilmore et al. (2009)	5.8	0.97±0.22	0.9
Gilmore et al. (2012) – fixed	5.8	1.02±0.22	0.7
Kneiske & Dole (2010)	5.7	0.90±0.19	0.6
Gilmore et al. (2009)	5.8	0.99±0.22	0.6

Preliminary

Gamma rays from Dark Matter annihilation



Secondary from π^0 decays



Prompt lepton pair production

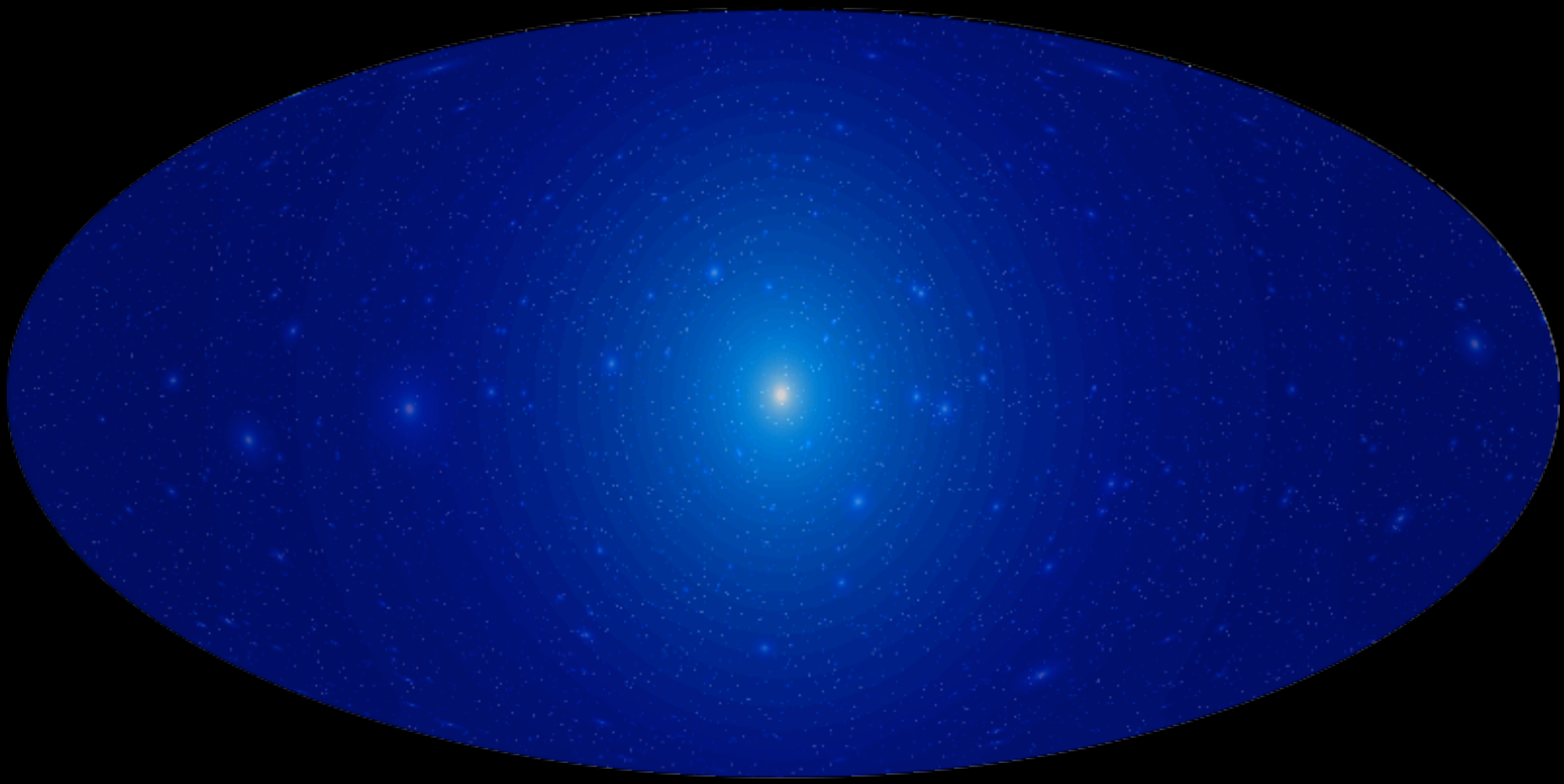
$$\Phi_{WIMP}(E,\Psi) = J(\Psi) \times \Phi^{PP}(E)$$

Astrophysical factor

$$J(\Psi) = \int_{l.o.s} dl(\Psi)\,\rho^2(l)$$

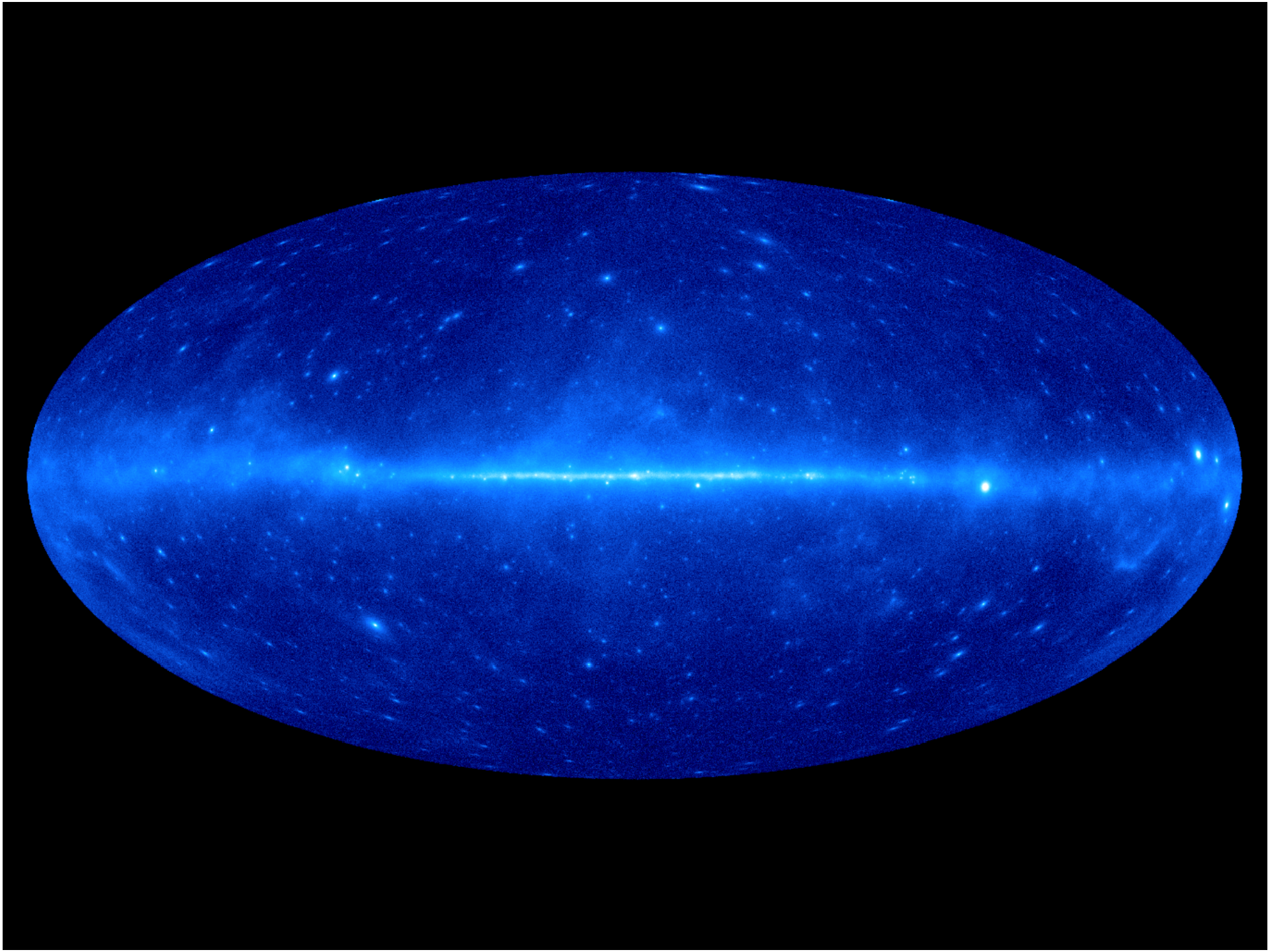
Particle physics factor

$$\Phi^{PP}(E) = \frac{1}{2}\frac{\langle \sigma v \rangle}{m^2_{WIMP}} \sum_f \frac{dN_f}{dE} B_f$$

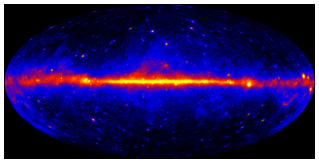


Gamma rays expected from Dark Matter Annihilation

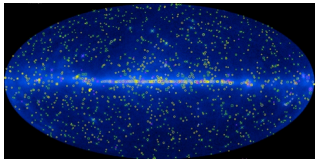
Gamma rays from dark matter annihilation



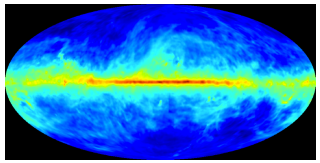
Understanding the Gamma-ray Sky


data

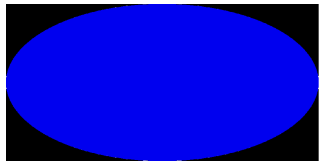
=


sources

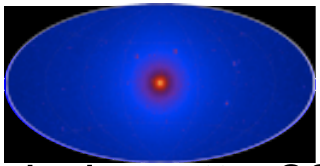
+


galactic diffuse

+


isotropic diffuse

+


dark matter??

+ ??

Bootstrapped, iterative process

Dark Matter: Many Places to Look!

Galactic Center

Good Statistics but source confusion/diffuse background

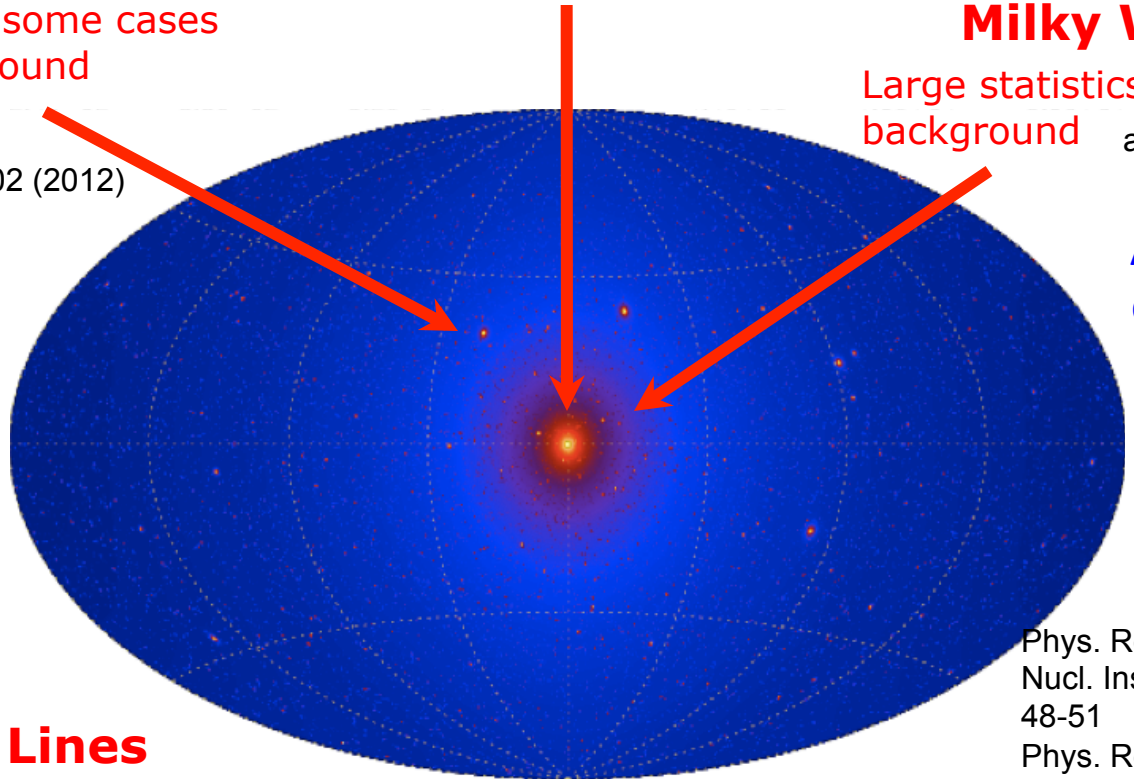
Satellites

Low background and good source id, but low statistics, in some cases astrophysical background

JCAP 1204 (2012) 016
ApJ 747, 121 (2012)
Phys. Rev. Lett. 107, 241302 (2012)
ApJ 712, 147 (2010)
JCAP 01 (2010) 031
ApJ 718, 899 (2010)

Milky Way Halo

Large statistics but diffuse background arXiv:1205.6474



All-sky map of gamma rays from DM annihilation arXiv:0908.0195 (based on Via Lactea II simulation)

And anomalous charged cosmic rays (little/no directional information, trapping times, etc.)

Phys. Rev. D84, 032007 (2011)
Nucl. Instrum. Meth. A630 (2011) 48-51
Phys. Rev. D82, 092003 (2010)

Spectral Lines

No astrophysical uncertainties, good source id, but low sensitivity because of expected small BR

Phys. Rev. D, In press (2012)
Phys. Rev. Lett. 104, 091302 (2010)

Extragalactic

Large statistics, but astrophysics, galactic diffuse background JCAP 04 (2010) 014

Galaxy Clusters

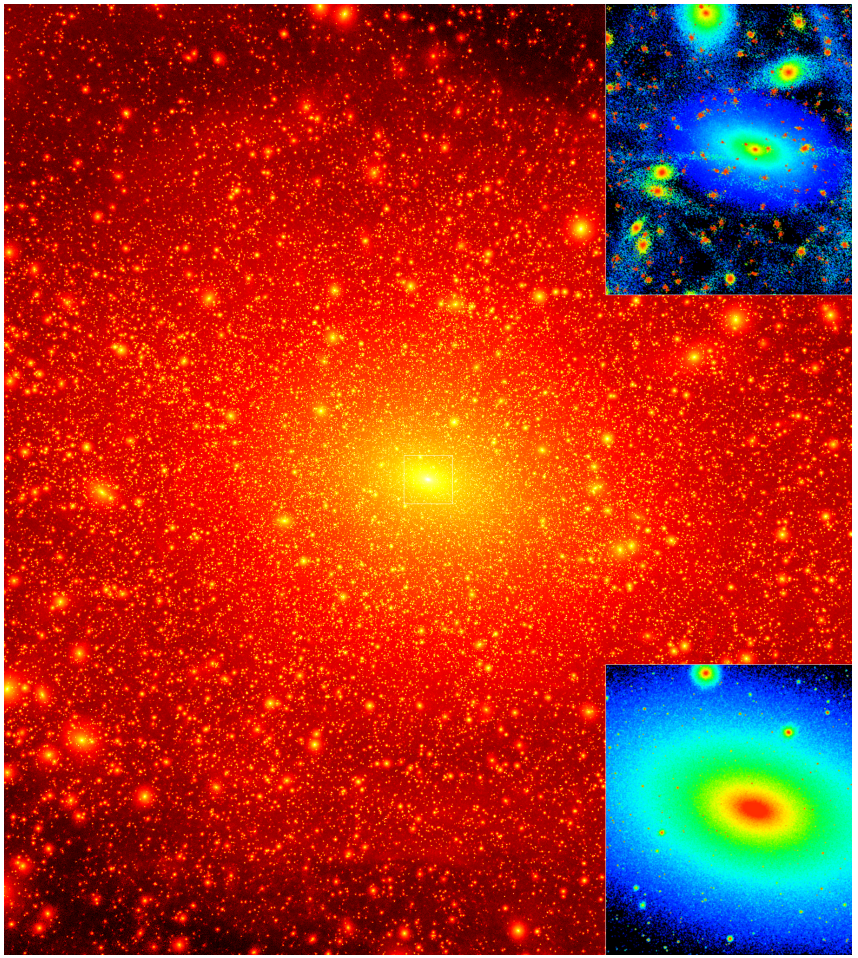
Low background, but low statistics

JCAP 05 (2010) 025

Dwarf Spheriodal (dSph) Galaxies

- Largest galactic substructures predicted (in ΛCDM)
- DM-dominated: mass-to-light ratios O(100-1000)
- Very low astrophysical backgrounds
  - no detected gas, low recent star formation activity
- SDSS discovery of many more ultrafaint Milkyway satellites
  - more are welcome!

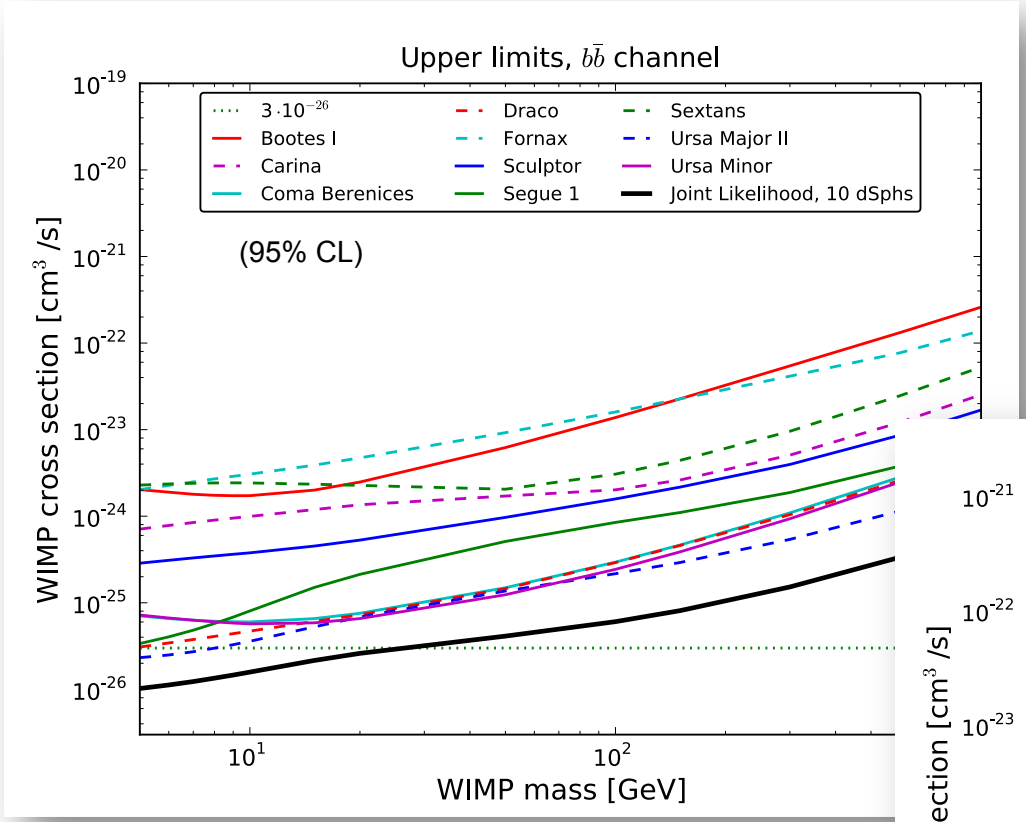
- Great opportunity for indirect DM signal searches!

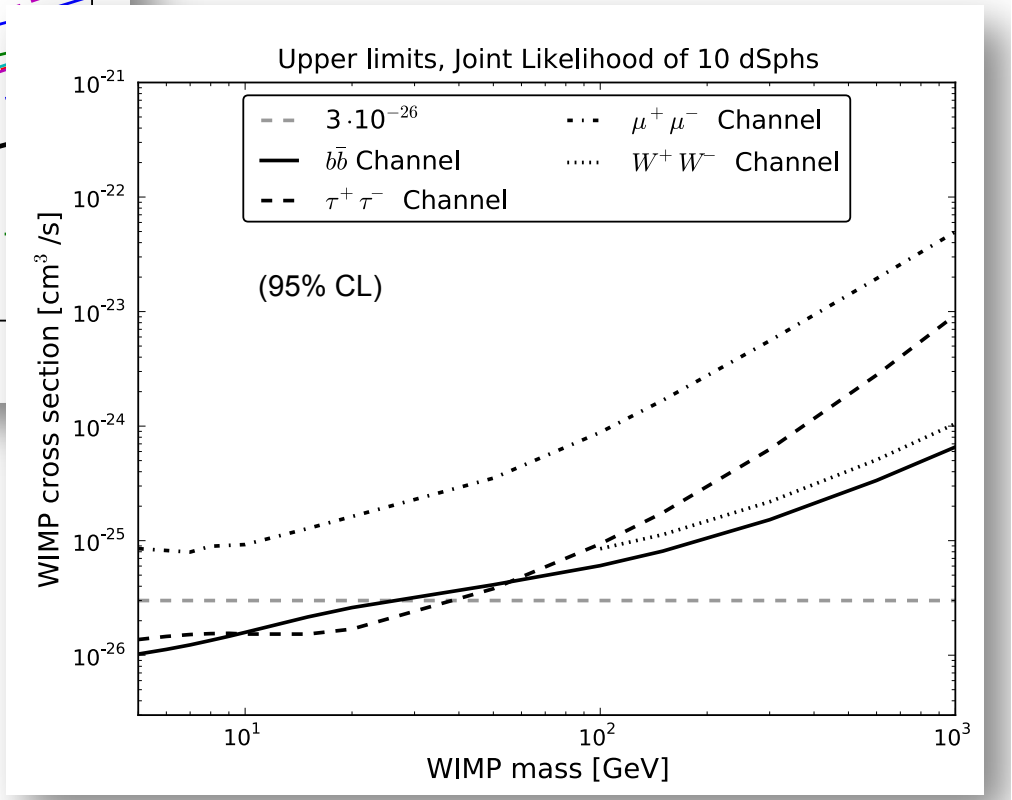


Via Lactea II simulation

Combining dSph Limits

arXiv:1108.3546v2





Now getting to very interesting sensitivity ranges!

APS Spotlight

Physics

Synopsis: Gamma Rays Carry No Trace of Dark Matter

NASA/General Dynamics

Constraining Dark Matter Models from a Combined Analysis of Milky Way Satellites with the Fermi Large Area Telescope

M. Ackermann et al. (The Fermi-LAT Collaboration)

Phys. Rev. Lett. **107**, 241302 (2011)
Published December 8, 2011

Exclusion of Canonical Weakly Interacting Massive Particles by Joint Analysis of Milky Way Dwarf Galaxies with Data from the Fermi Gamma-Ray Space Telescope

Alex Geringer-Sameth and Savvas M. Koushiappas

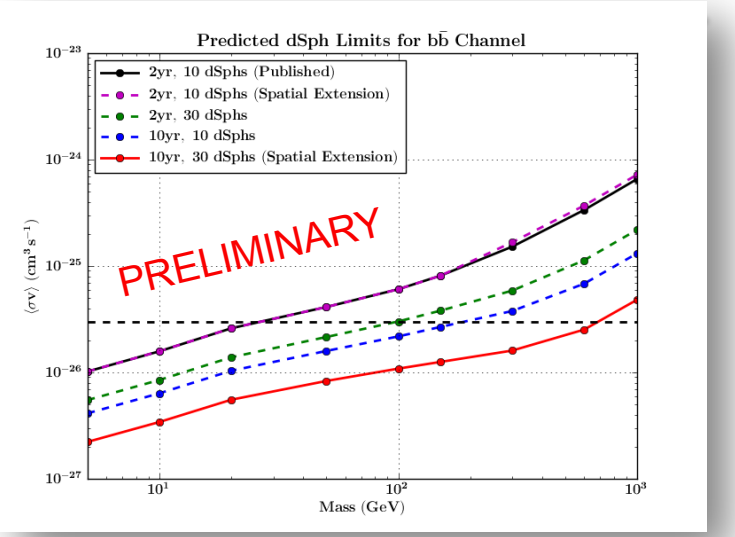
Phys. Rev. Lett. **107**, 241303 (2011)
Published December 8, 2011

Dark matter is thought to make up 25% of the mass of the universe, but clear evidence of what constitutes it has not yet been obtained. A number of major experimental efforts are currently devoted to unfolding this mystery. An indirect approach is to look for gamma rays that could result from the annihilation of dark matter particles colliding with their antiparticles. The dwarf spheroidal galaxies, small galaxies near the Milky Way, are ideal regions in which to look for this radiation: they contain a high ratio of dark matter to normal matter and the background gamma radiation from baryonic processes is expected to be low.

In 2010, the Fermi Large Area Telescope (LAT) collaboration reported limits on dark matter particles obtained from their observations of the dwarf galaxies. Now the same collaboration reports in *Physical Review Letters* a new study based on an updated data set, which includes data from more galaxies, involves a

A Look Forward

- Much more to do in all areas:
  - future DM limits from dSph projected to improve due to increased observation time, discovery of new dwarfs
  - Lines: more data, improved analysis of high-energy events, optimization of regions, **checks!**
  - Halo: more detailed accounting of uncertainties in limits
  - Galactic Center
- Additional results:
  - Anisotropy analyses
  - Clusters
  - …

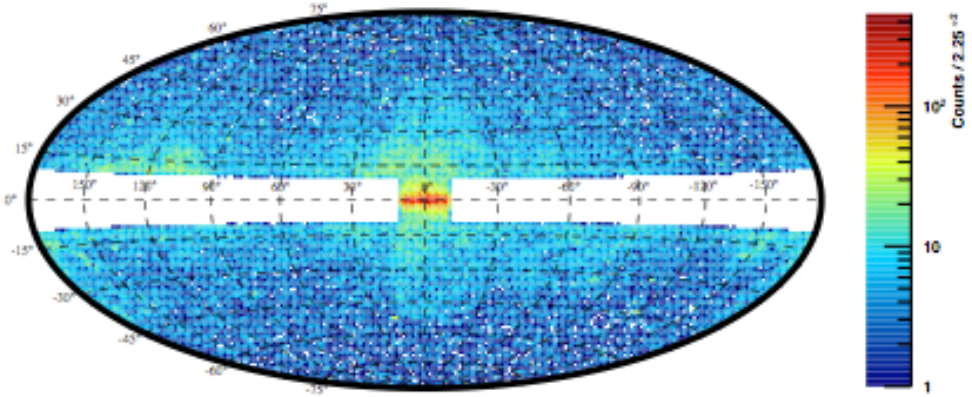


see also: Geringer-Sameth & Koushiappas, PRL 107, 241303 (2011); Cholis & Salucci, arXiv:1203.2954

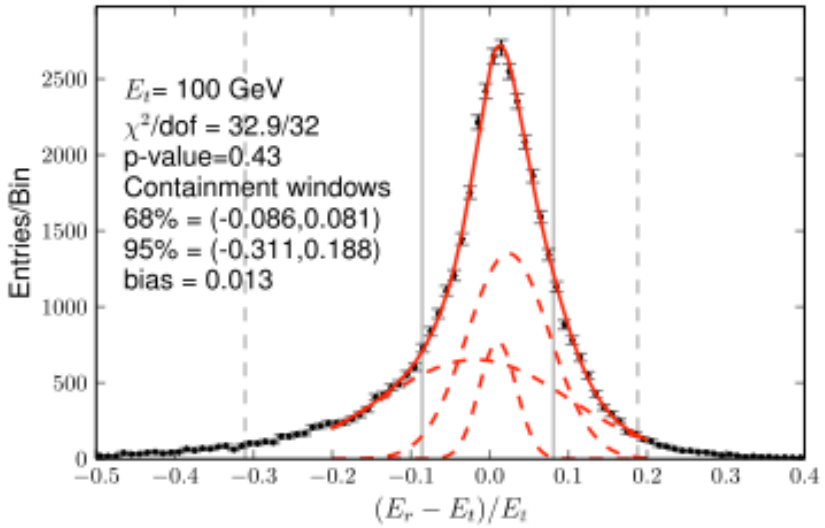
Search for spectral lines

arXiv:1205.2739

Region-of-interest for line search



LAT energy response to 100 GeV line

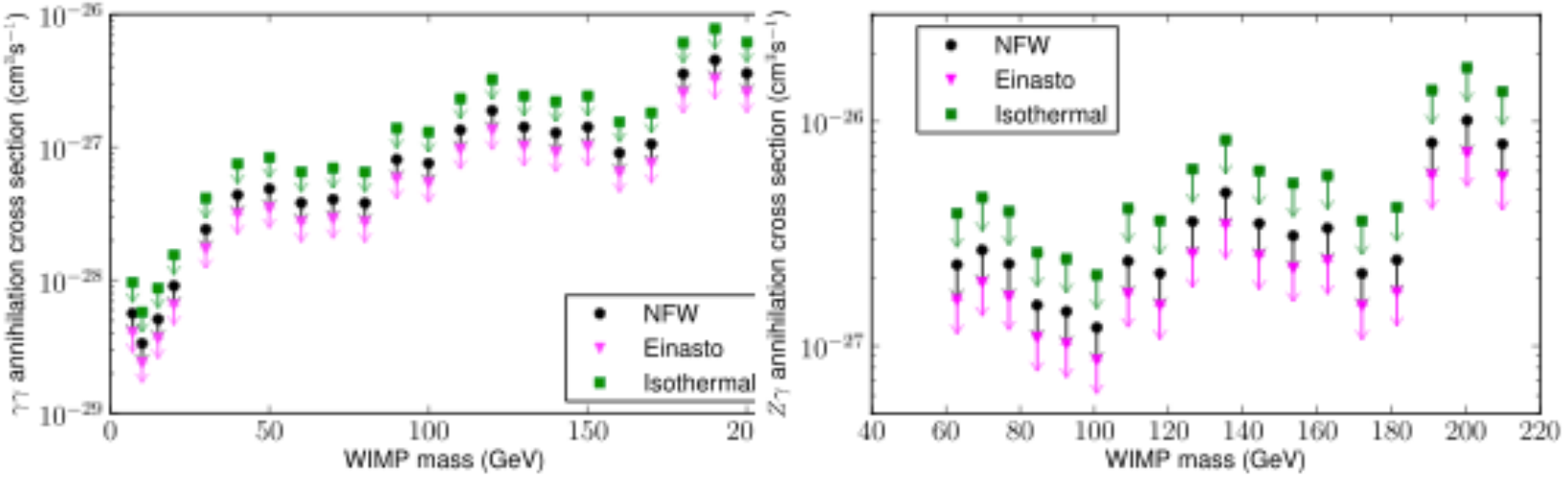


- search for line emission from dark matter annihilation or decay ($\gamma\gamma$ and $Z\gamma$ channels)
- exclude Galactic plane and 1FGL sources
- assume power-law background (spectral index free to vary) in each energy window

Constraints from line search

arXiv:1205.2739

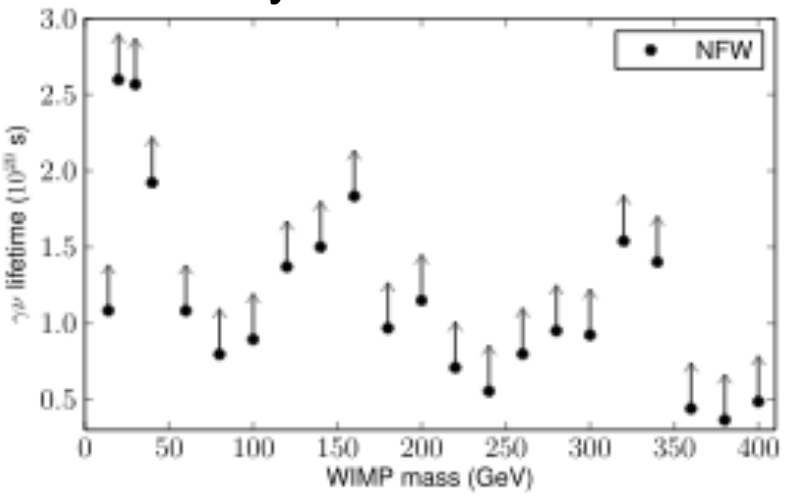
Annihilation cross-section constraints



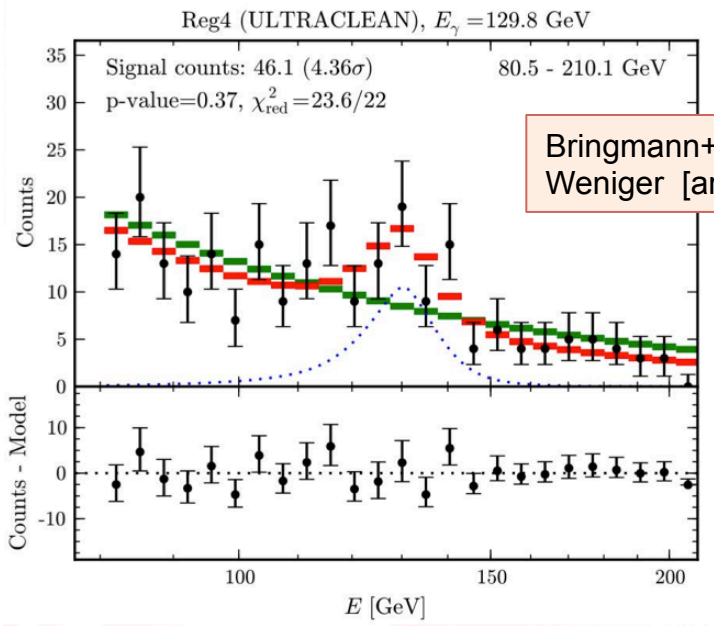
Ackermann et al. [Fermi LAT Collaboration], submitted to PRD

- non-detection places limits on annihilation cross section or decay lifetime to $\gamma\gamma$ and $Z\gamma$
- **recent papers in the arXiv suggest lines or hard spectral features consistent with DM predictions – <u>much more to do!</u>**

Decay lifetime constraints



Things Going Bump



Bringmann+ [arXiv:1203.1312]
Weniger [arXiv:12.2797]

Interpretations and follow up analyses:
Tempel+ [arXiv:1205.1045]
Kyae & Park [arXiv:1205.4151]
Dudas+ [arXiv:1205.1520]
Lee+ [arXiv:1205.4700]
Acharya+ [arXiv:1205.5789]
Buckley & Hooper [arXiv:1205.6811]
Su & Finkbeiner [arXiv:1206.1616]
Chu,Hambye + [arXiv:1206.2279]
& many others

Astrophysical Interpretations:
Boyarsky+ [arXiv:1205.4700]
Aharonian+ [arXiv: 1207.0458]

Associated with Inner Galaxy and also possibly the Earth.

Many DM models, but also models of spectra features from astrophysics such as Pulsar Wind Nebulae (PWNe)

Much work to do! Also improving "albedo" statistics ASAP.

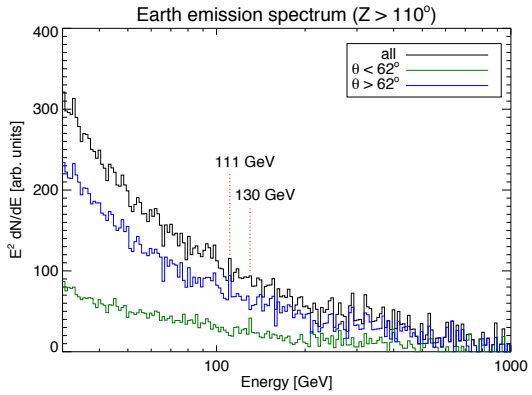
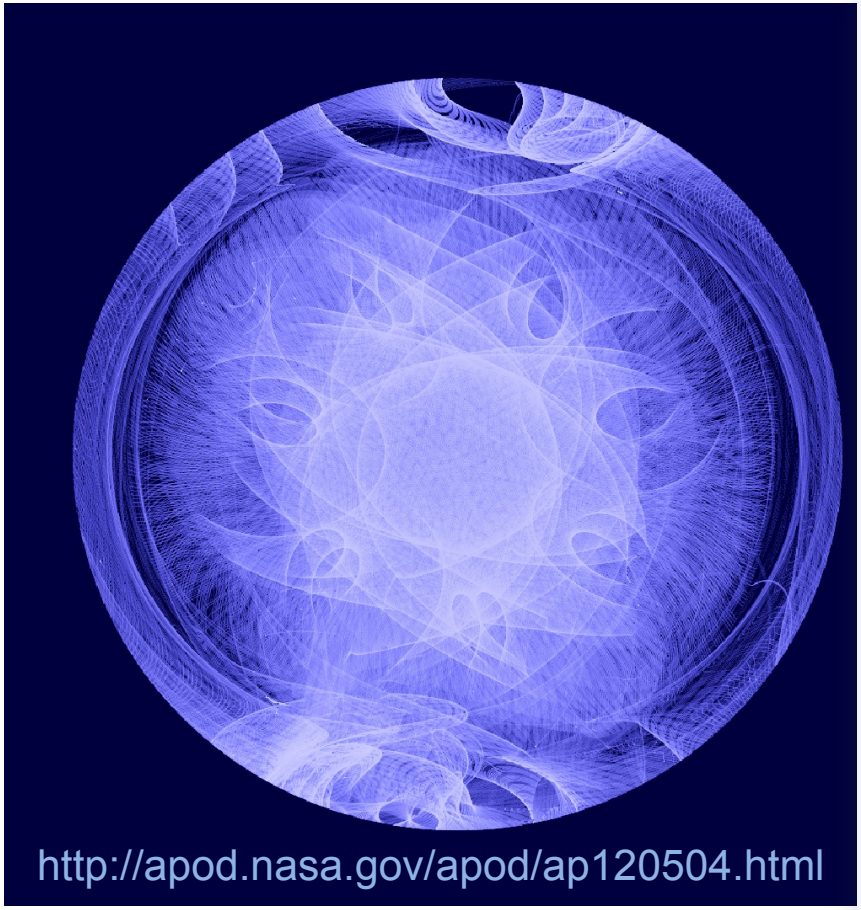


FIG. 21.— Photons from cascades in the Earth's atmosphere (sometimes incorrectly called "albedo" photons), and with 10° of the GC, show a slight excess at 111 and 130 GeV also. Because these photons arrive at high zenith angle ($Z > 110°$), they tend to have a high incidence angle (median $\theta = 63.2°$). The low-θ photons show a small bump at 130 GeV, and the high-θ photons show a small bump at 111 GeV. The cuts were chosen to maximize these features, so interpretation of this plot requires a modest trials factor.

Su & Finkbeiner

arxiv 1206.1616v2

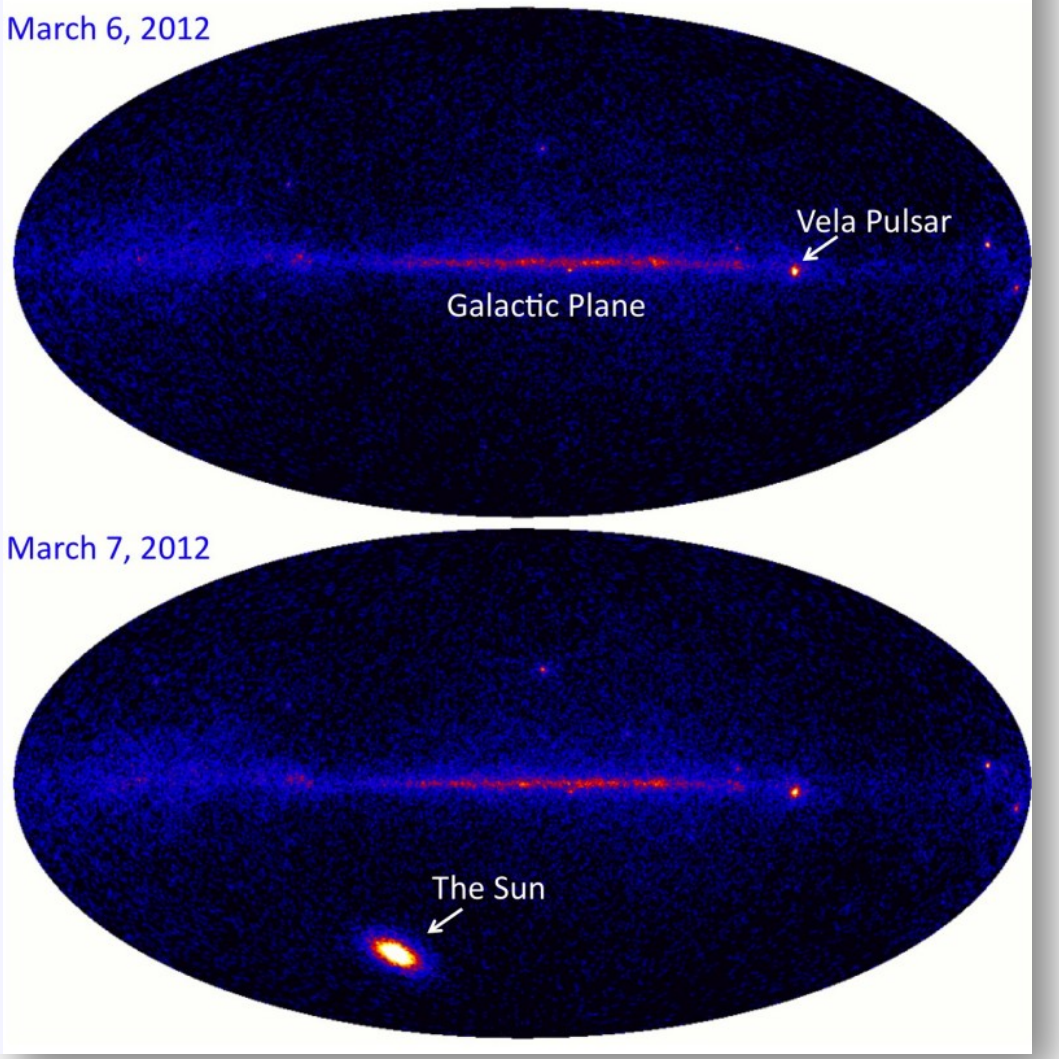
Recent APODs



Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2012 March 15



Exceptional Awards

- The 2012 W.K.H. Panofsky Prize in Experimental Particle Physics awarded to Bill Atwood
  - "*For his leading work on the design, construction, and use of the Large Area Telescope on the Fermi Gamma-Ray Satellite, enabling numerous new results in gamma-ray astrophysics and fundamental physics.*"
- The 2011 Rossi Prize
  - *"…awarded to Bill Atwood, Peter Michelson, and the Fermi Gamma Ray Space Telescope LAT team for enabling, through the development of the Large Area Telescope, new insights into neutron stars, supernova remnants, cosmic rays, binary systems, active galactic nuclei, and gamma-ray bursts."*

LAT Collaboration

- France
  - CNRS/IN2P3, CEA/Saclay
- Italy
  - INFN, ASI, INAF
- Japan
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- Sweden
  - Royal Institute of Technology (KTH)
  - Stockholm University
- United States
  - Stanford University (SLAC and HEPL/Physics)
  - University of California, Santa Cruz - Santa Cruz Institute for Particle Physics
  - Goddard Space Flight Center
  - Naval Research Laboratory
  - Sonoma State University
  - The Ohio State University
  - University of Washington

PI: Peter Michelson
(Stanford)

~400 Scientific Members (including 97 Affiliated Scientists, plus 71 Postdocs and 123 Students)

Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

Project managed at SLAC.

Happy Birthday, Fermi!
(and many happy
returns)

Discussion