LAT Status and Plans

Fermi User Group meeting
June 16, 2011

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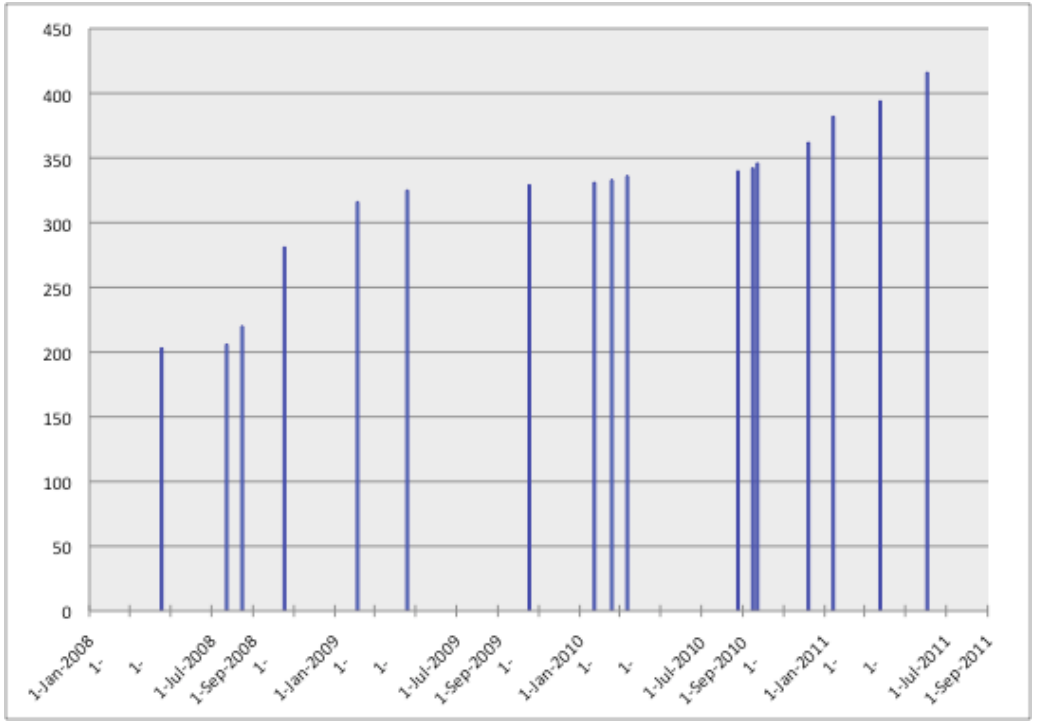
on behalf of the Fermi LAT collaboration

- LAT status
- recent LAT science highlights
- Catalog, diffuse model, and Pass 7 release schedule
- a look ahead – Pass 8

LAT status

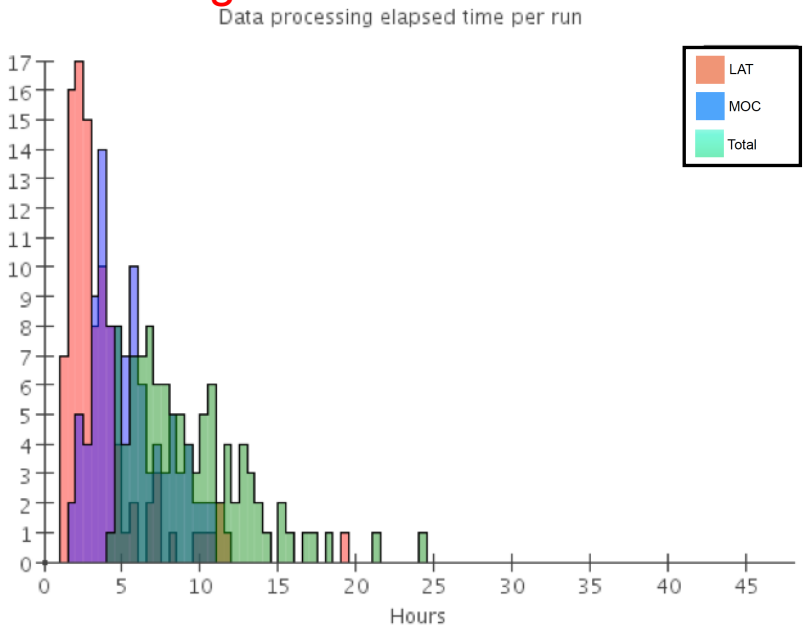
LAT Status

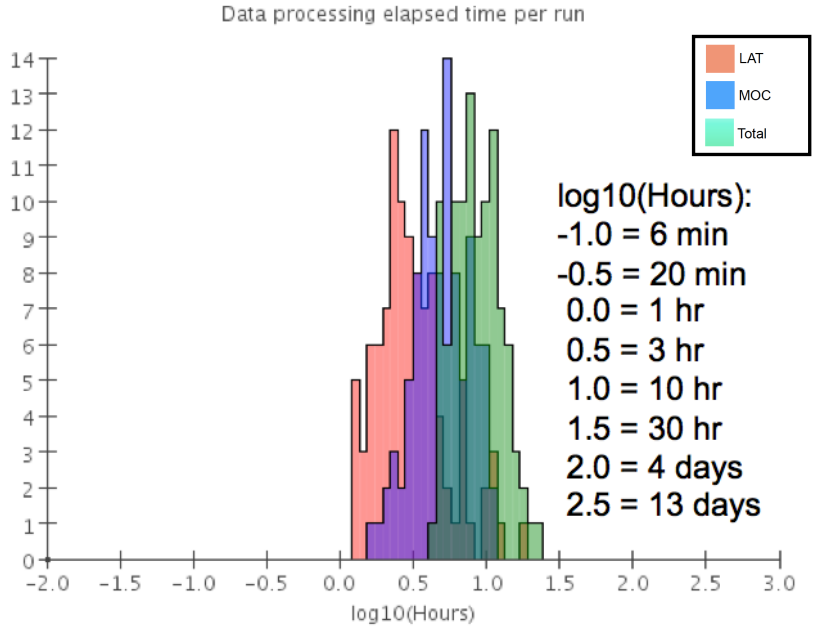
- LAT instrument continues to operate well
- FSW build (B3-0-0) will be loaded to the LAT soon (i.e. July) after completion of ~3 weeks more testing:
- LAT instrument is generally very stable;
  - of 885,000 channels in LAT tracker, 237 masked since launch
- in Feb reported increasing noise seen in Tkr tower 3 in a single Si ladder in Layer 35; impact on performance is tiny
  - 86 strips now masked in this layer



LAT Data Processing

- LAT data processing remains stable, and running like a clock:
  - ~ 900 TB of processed data to date
  - Typical latency from detection of gamma-ray photon to availability in public archive is ~8 hours: requirement < 72 hours
  - 10 CPU-yrs per month – average 125 CPUs doing processing – done by next downlink
  - Less time to process data at ISOC than time to receive it from MOC!
  - Data quality monitoring performed by LAT collaborator volunteers around the world – running short of volunteers; will address at August LAT Collaboration meeting





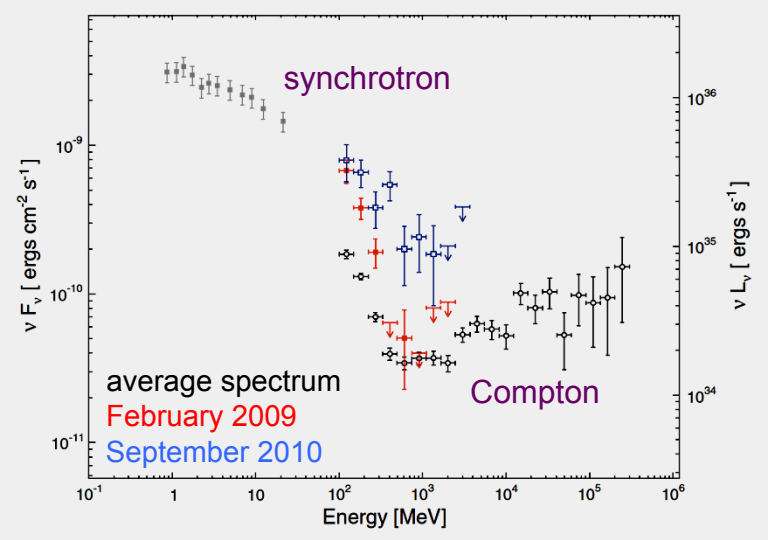
recent LAT science highlights

Gamma-ray flares from the Crab Nebula

Science **331,** 817 (2010); seen by AGILE and Fermi LAT

1st reports of variability of high-energy γ-ray emission from Crab nebula

Spectral energy distribution (25 months)

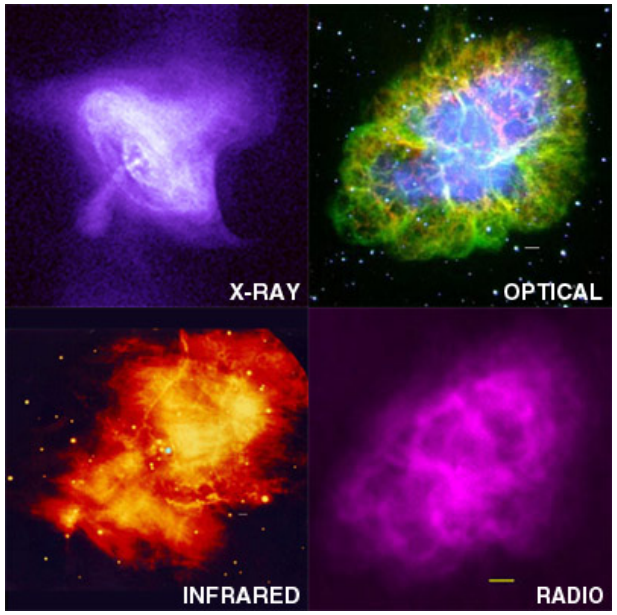


brief flare timescales (4 days) imply compact flaring region:

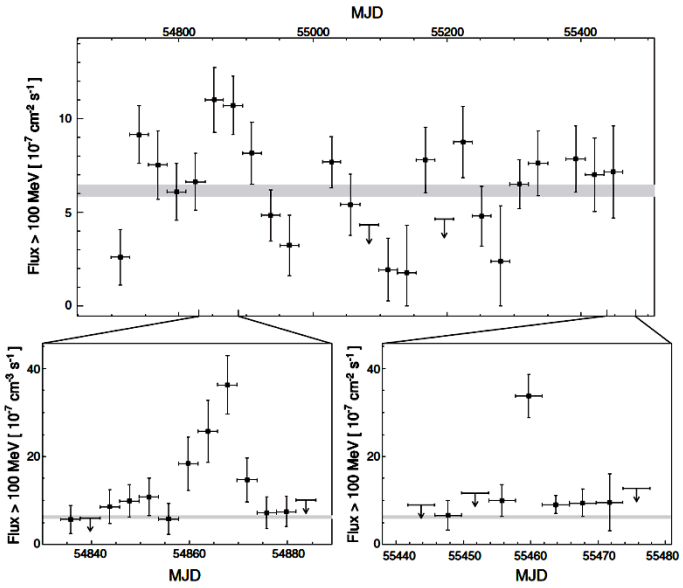
$L < Dct < 1.4 \times 10^{-2}$ pc

(1.5 arcsec)

structures this small only found in inner part of nebula, close to the pulsar wind termination shock, the base of the jet, or the pulsar.



spectrum and short flare time scales imply that **emission is synchrotron radiation** (electron cooling timescales for IC emission & bremsstrahlung ≥ 10^7 yr.)



detection of synchrotron photons up to ≥ 1 GeV implies electrons accelerated to ≥ 1 PeV in the nebula.

efficiency of synchrotron losses requires a strong electric field to compensate; severe difficulties for diffusive shock acceleration mechanism.

Crab nebula: an unexpected "transient" source

- Transient source science requires
  - **Short data pipeline latency (typically < 8 hours),**
  - **GRB and flaring source alerts,**
  - **Bright source monitoring**

LAT scientists examine output from ASP pipeline, perform follow-up analyses, produce ATels, and propose ToOs

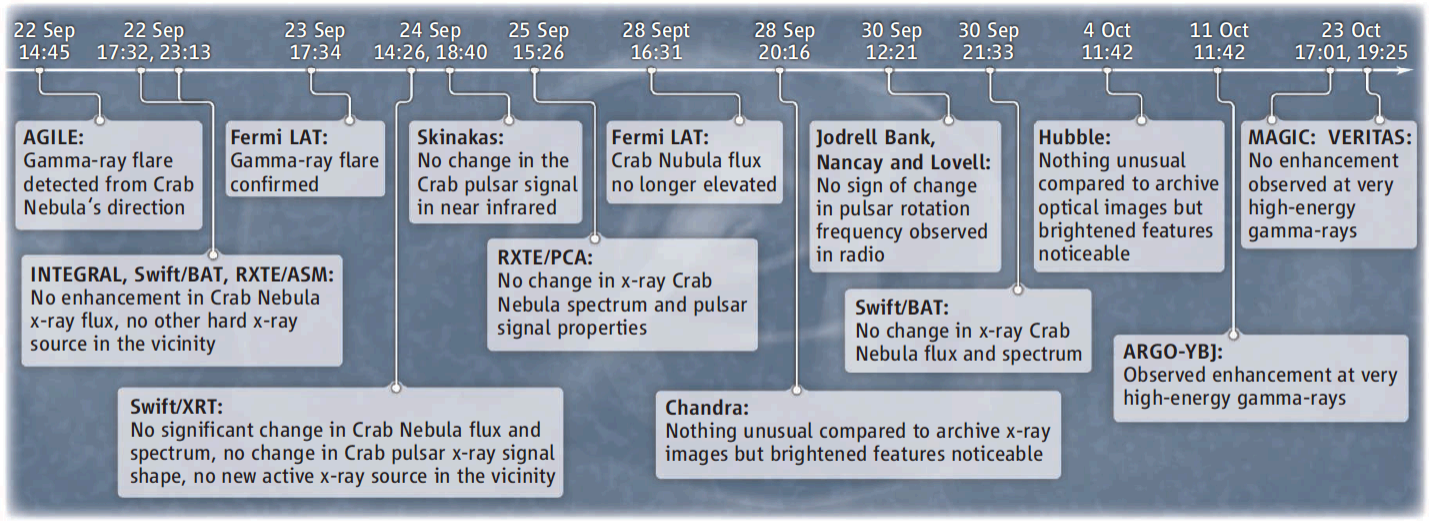
ASTRONOMY

Astronomy in the Time Domain

Elisa Bernardini

Coordination between various instruments provides a real-time aspect to observing transient astrophysical events.

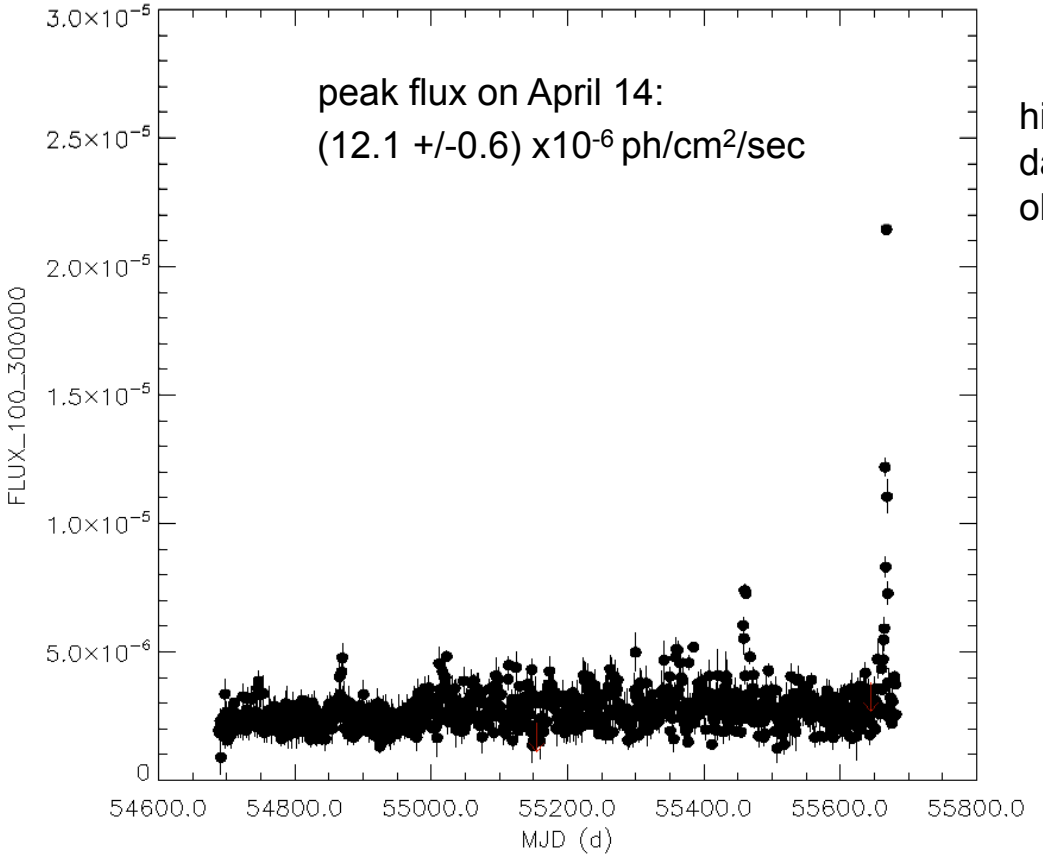
reported in Science, 331, 686 (2011)



A time line of events. Timetable of the *Astronomer's Telegram* releases on the recent Crab Nebula flare in universal time, within 1 month after discovery on 22 September 2010. Corresponding telegram IDs are: 2855, 2856, 2858, 2861, 2866, 2867, 2868, 2872, 2879, 2882, 2889, 2893, 2903, 2921, 2967, 2968.

latest Crab flare

April 2011

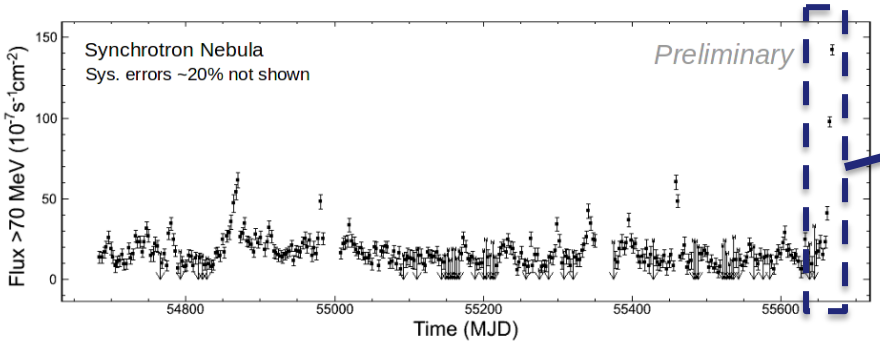


highest gamma-ray flux on daily scales which has been observed from this source

average Crab flux: (2.9 +/- 0.1) x10^{-6} ph/cm^2/sec

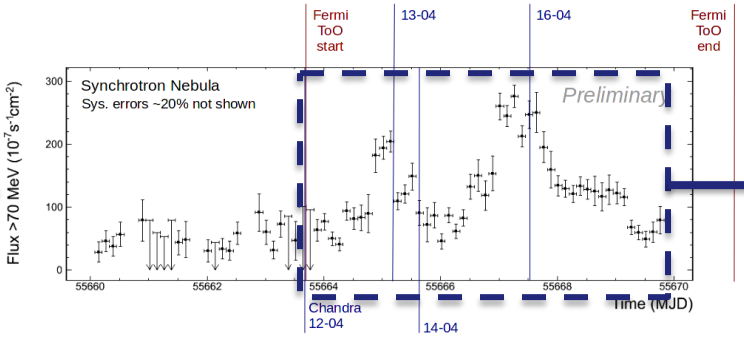
latest Crab Flares

Three day Crab synch. 32 month light curve



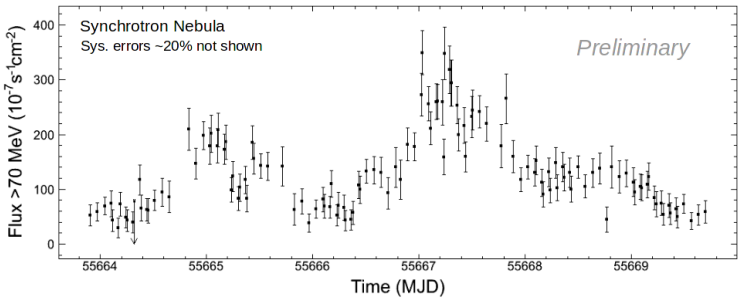
Persistently variable, three flares stick out

3 hours binning – MW time line



Synchrotron nebula increased by factor ~40
Very good Chandra coverage

20 min flare light curve



Fast variability (<1h)

Extremely bright flare has tremendous scientific potential

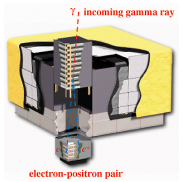
Enough statistics to make light curves with 10-20 minute bins

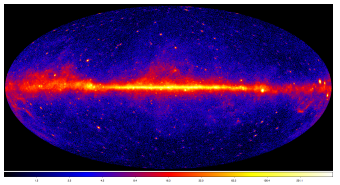
Early detection allows excellent MW observations

Fermi and the Radio Pulsar Community: A Productive Symbiotic Relationship

Radio Pulsar Community

Fermi LAT





Timing models for >700 pulsars → Discovered gamma-ray pulsations from 44 radio pulsars (28 young, 16 MSP)

Radio detection of 3, deep upper limits for rest (really "radio quiet") ← 26 LAT blind search pulsar positions and timing

New MSP in GC NGC 6652 ← Gamma-ray globular cluster detections (indicating that they harbor MSPs)

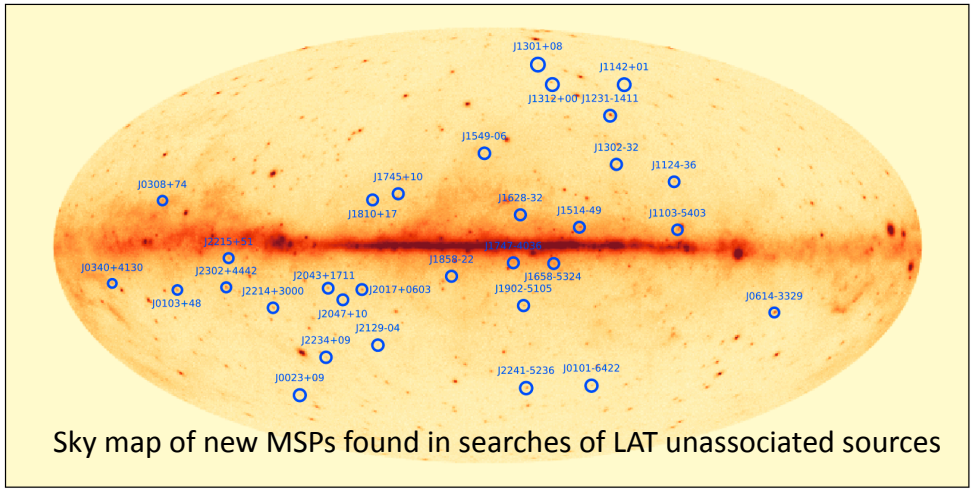
VLBA astrometry for distance measurements → Accurate efficiency and energetics

33 new MSPs discovered! ← UNASSOC source positions

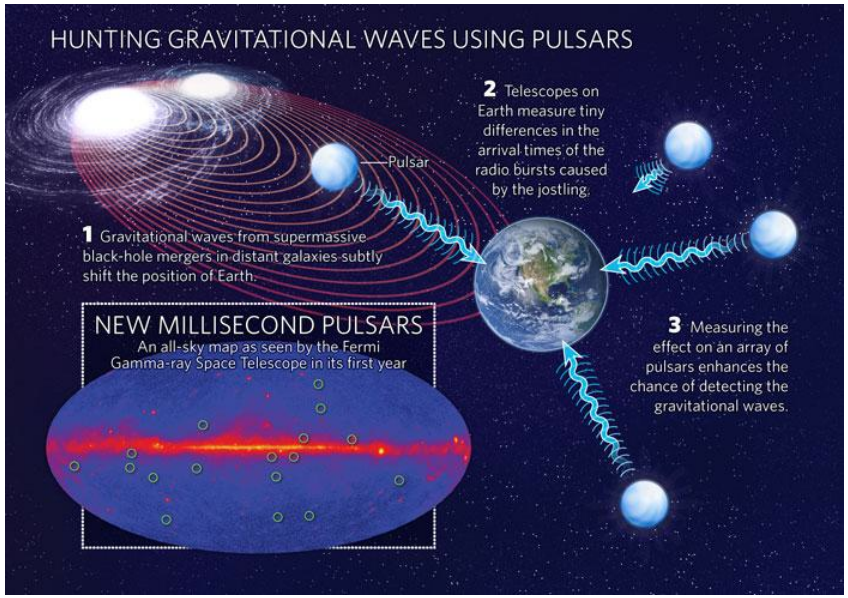
→ LAT pulsations found from 11 so far!

Exciting Results: present and future

- **went from 6 to 88 known gamma-ray pulsars**
  - **Gamma-rays dominate pulsar energy budgets**
  - **Gamma-ray profiles constrain emission region geometry**
- **LAT is an efficient finder of MSPs**
  - **50% increase in number of known MSPs!**
  - **At least 7 new black widow binaries (much larger proportion than in radio surveys… why?) Only ~4 known outside the globular cluster system previously**
- **pulsar timing array search for gravitational radiation**



Sky map of new MSPs found in searches of LAT unassociated sources



Future Promise

- MORE pulsar discoveries – radio fluxes don't correlate with gamma-ray, so new faint LAT sources may point to bright radio pulsars
- Look for shock emission from black widow systems – orbital modulation?
- Population studies will constrain Galactic MSP population
- Pulsar timing arrays could detect nanoHertz gravitational waves

2FGL Catalog, diffuse model, and Pass 7 release schedule

Pass 6 V11 release

Released May 25, 2011

- new IRFs only for the “Diffuse” class of events, the most widely used Pass 6 class. They include:
  - in-flight measured PSF
  - corrected effective area misestimated because of the mismatch between Data and Monte Carlo.
  - rate-dependent inefficiency and phi dependence of effective area.
- new Diffuse Models based on the P6_V3 model rescaled by the ratios of the acceptances between P6_V11 Diffuse and P6_V3 diffuse.
- new data files including diffuse response for the new combination of IRFs and Diffuse models
- new version of the Science Software Tools
- new documentation

2FGL Catalog

- based on:
  - Pass7 “Source” event class
  - 24 months of data
  - P7_V6 IRFs
  - improved model of diffuse gamma-ray emission
- includes:
  - improved source detection and analysis procedures
  - improved spectral source modeling (not only power-law)
  - extended Sources in model of the sky (e.g. LMC, Cen A, W51C)
  - improved association procedure (more catalogs used)

(see D. Thompson report for details)

"Pass 7" event analysis

Pass 7 is first version of event analysis to use knowledge from flight data

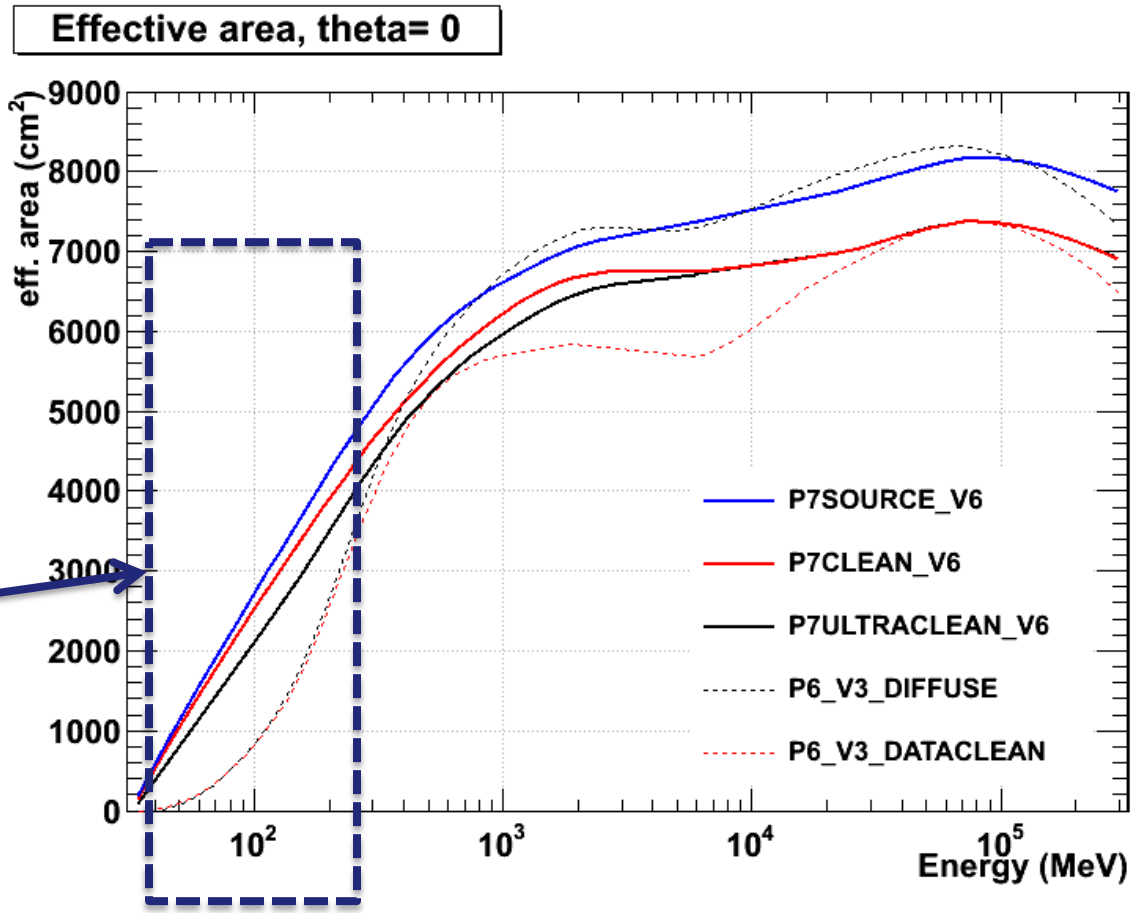
compensates for pile-up in electronics from cosmic-ray backgrounds

many times more A_{eff} below 300 MeV

A_{eff} curve is less steep, better for spectral analysis

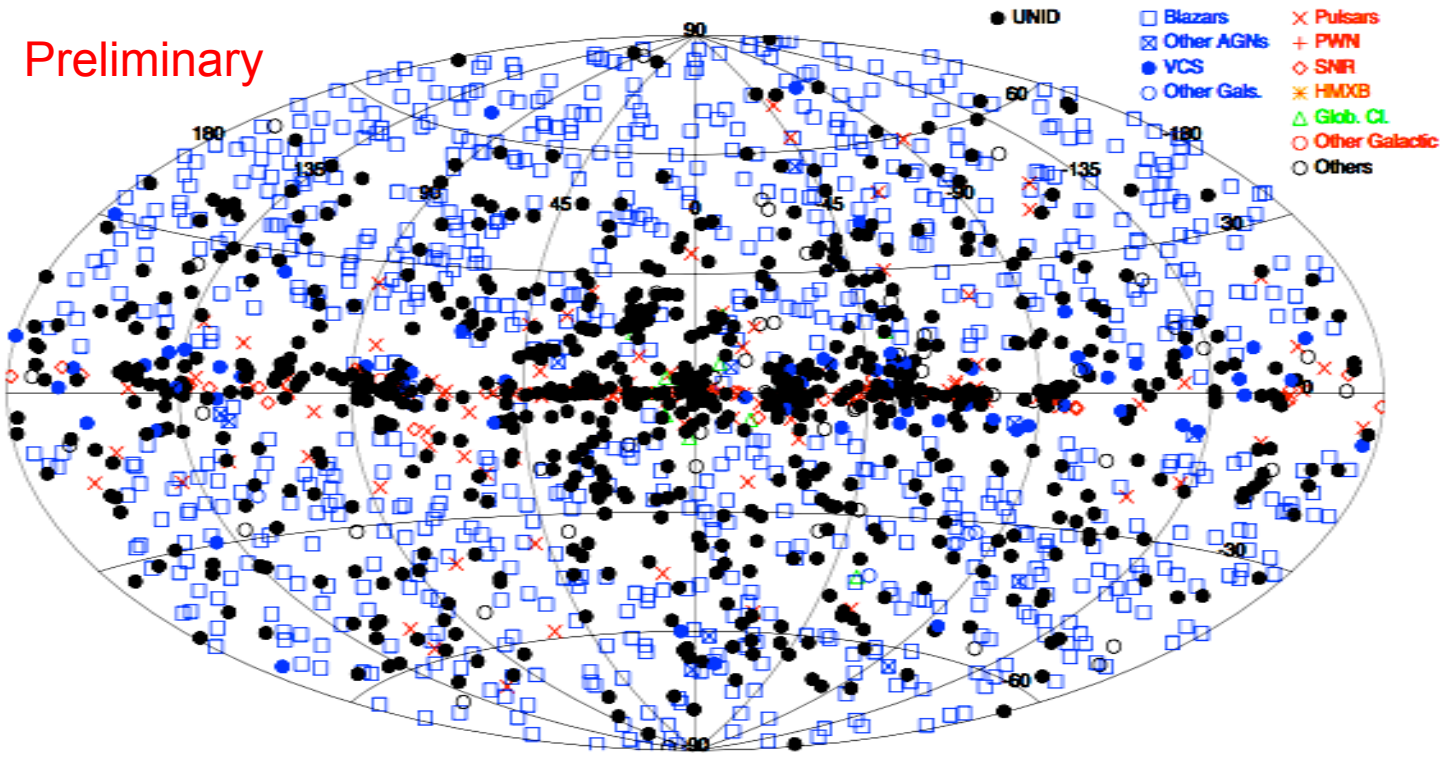
new IRFs for each event class

updated energy estimators



2FGL Catalog

release now planned for 3rd week of June



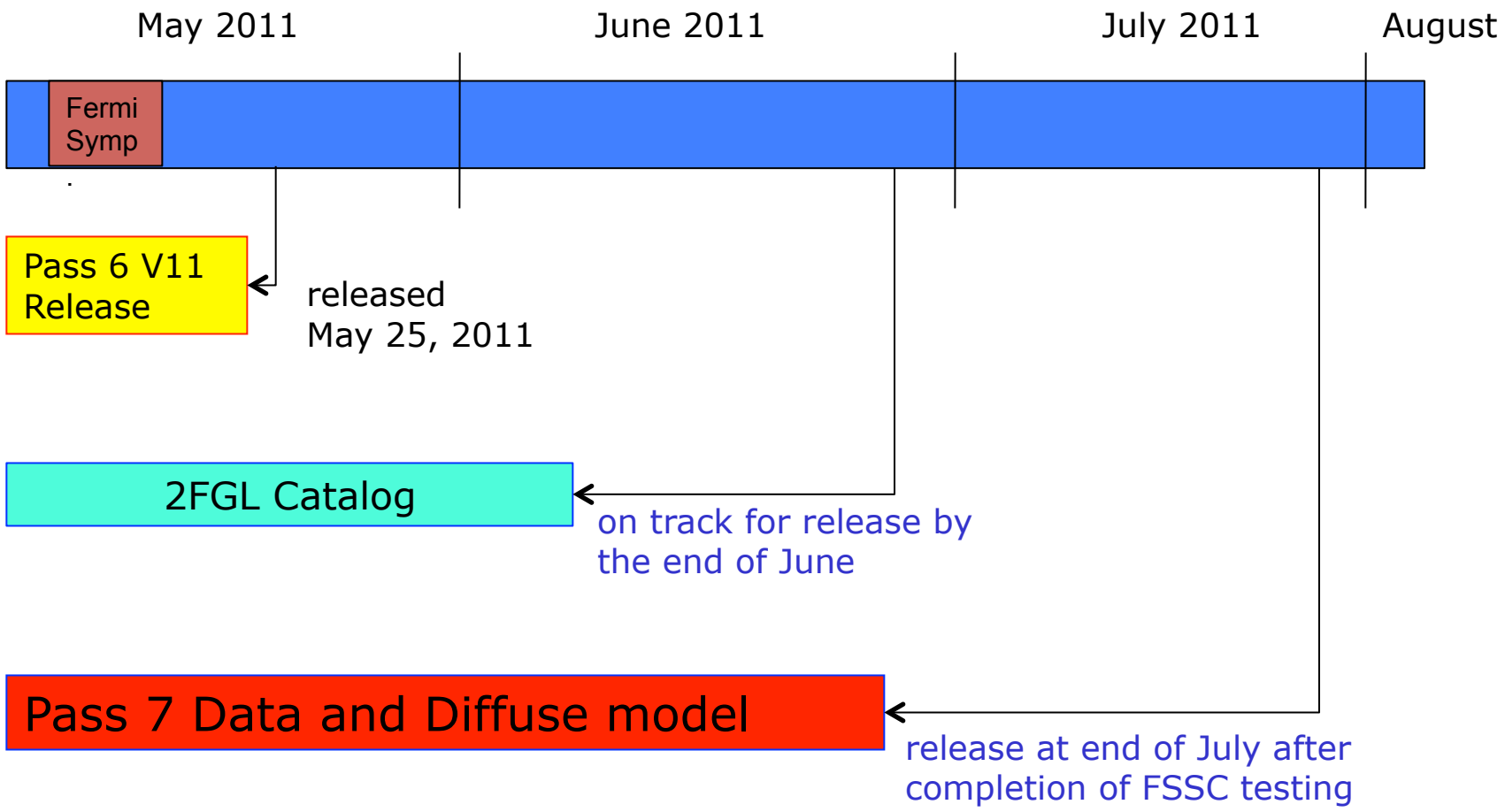
2FGL catalog includes 1,873 sources,
1,451 sources in 1FGL

2FGL Catalog

- About 350 1FGL sources are not in 2FGL.
  - detailed analysis of differences with 1FGL has delayed completion of the catalog.
- The number of unidentified sources is still high
- The number of AGN is still growing: about 830 2FGL sources associated with Blazars
- The number of pulsars and MSPs is growing too
- higher confidence in association of 2FGL sources with SNRs and PWNs.

(see D. Thompson report for details)

timeline


May 2011
June 2011
July 2011
August
Fermi Symp
Pass 6 V11 Release
released May 25, 2011
2FGL Catalog
on track for release by the end of June
Pass 7 Data and Diffuse model
release at end of July after completion of FSSC testing

diffuse model

release mid-July 2011

- improved diffuse model used in the 2FGL catalog developed for point source analysis, not for studying the diffuse emission itself. It was obtained as a linear combination of various templates.

- model includes:
- new HI, CO column density map (no Magellanic stream for example).
- new GALPROP-derived template for IC
- patches for unaccounted excess of photons e.g.:
  - Loop I
  - Fermi “Bubble”
  - 3 regions in the central part of the Galaxy.

diffuse model

- model characteristics
  - grid for model: 0.125°
  - size ~500 Mbyte
  - fitted with 24 months of LAT data in 14 energy bands.
  - based on P7.6 “clean” class; can also be used for “source” class. for the isotropic component there are two separate models for “source” and “clean” classes.

  - Pass 7V6 FT1 files to be released will include the diffuse response columns for the “Source” and “Clean” event class and IRFS.

  - supplementary model of Earth limb built specifically for use in construction of 2FGL catalog; limb model will be also released but should be used only to reproduce the 2FGL catalog results.

a look ahead – Pass 8

Pass 8

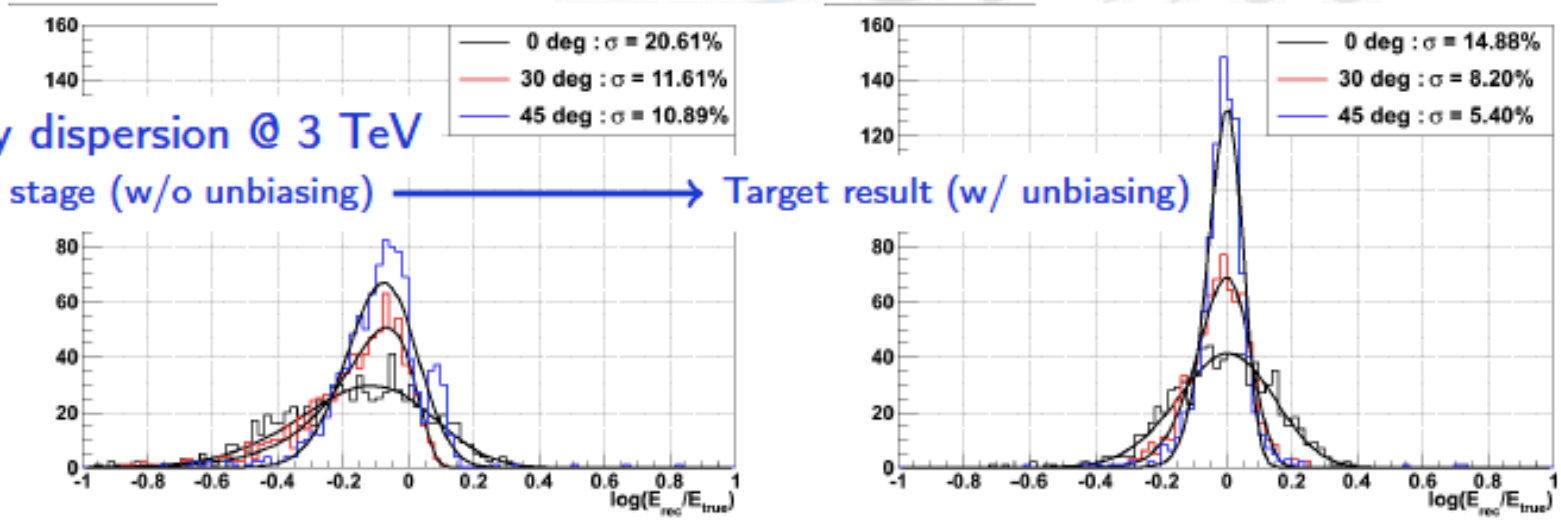
- Current LAT event-level analysis was largely developed before launch using Monte Carlo simulations
  - In a series of iterations that we call Passes (Pass 6 in use now and Pass 7 about to be released)
- Real life experience while on orbit has revealed some neglected and overlooked issues. . .
  - primarily (but not only) the instrumental pile-up (aka Ghost Events)
- . . in addition to the aspects of the simulation and analysis software that couldn't be developed before launch due to time constraints
- Clear improvements with the potential to greatly extend the LAT science capabilities have been identified in all the main areas:
  - Monte Carlo simulation
  - event reconstruction
  - background rejection
- All of them are will be deployed in a systematic and coherent fashion in the context of Pass 8

Pass 8: potential performance improvements

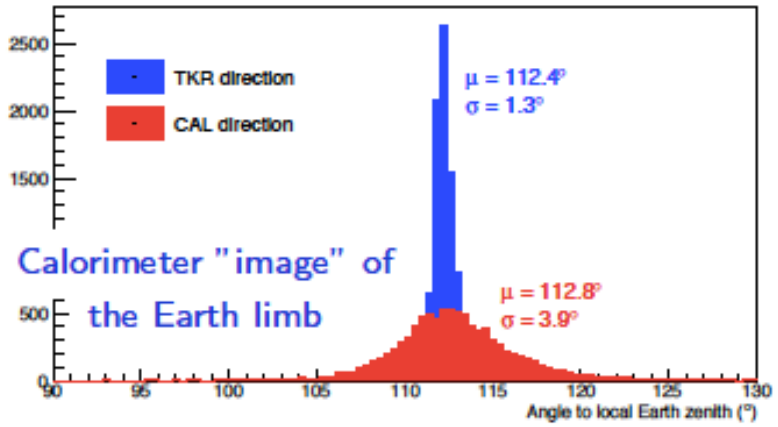
- Lower backgrounds
  - New ACD reconstruction, additional information from the tree-based patrec, standalone cosmic-ray tracking, calorimeter clustering
- Better control over the systematic uncertainties
- Extension of the energy reach
  - Below 100 MeV: better energy resolution thanks to the new tracker reconstruction/analysis, lower background (GRBs science)
  - Above 100 GeV: less tracking confusion in high multiplicity events (diffuse photon spectra)
  - Above 1 TeV: better compensation for crystal saturation (Cosmic-ray electron spectrum)

Energy dispersion @ 3 TeV

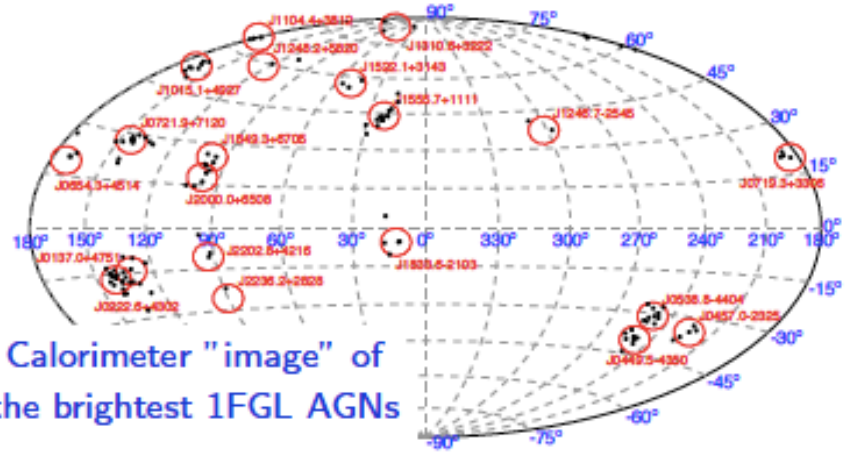
Current stage (w/o unbiasing) → Target result (w/ unbiasing)



Pass 8: potential performance improvements



Calorimeter "image" of the Earth limb



Calorimeter "image" of the brightest 1FGL AGNs

- Recover the CAL-only events for the science analysis
  - Can increase A_{eff} by 50% above $\approx$ 20 GeV (onboard hi-pass)
- Tracker pointing resolution improvement
  - Current high-energy PSF $\times$2 worse than expected (AGN pair halo)
- Multi-photon events
  - Coherent γ-ray production in GRBs and AGNs, BH evaporation
- Identify and flag events converting in the silicon sensors
  - "Gold plated" events: $\approx$ 20% of conversions in front (thin radiators) tracker section with a much better PSF—currently one of the main limitations at low energy
  - Seriously investigate the potential for γ-ray polarimetry

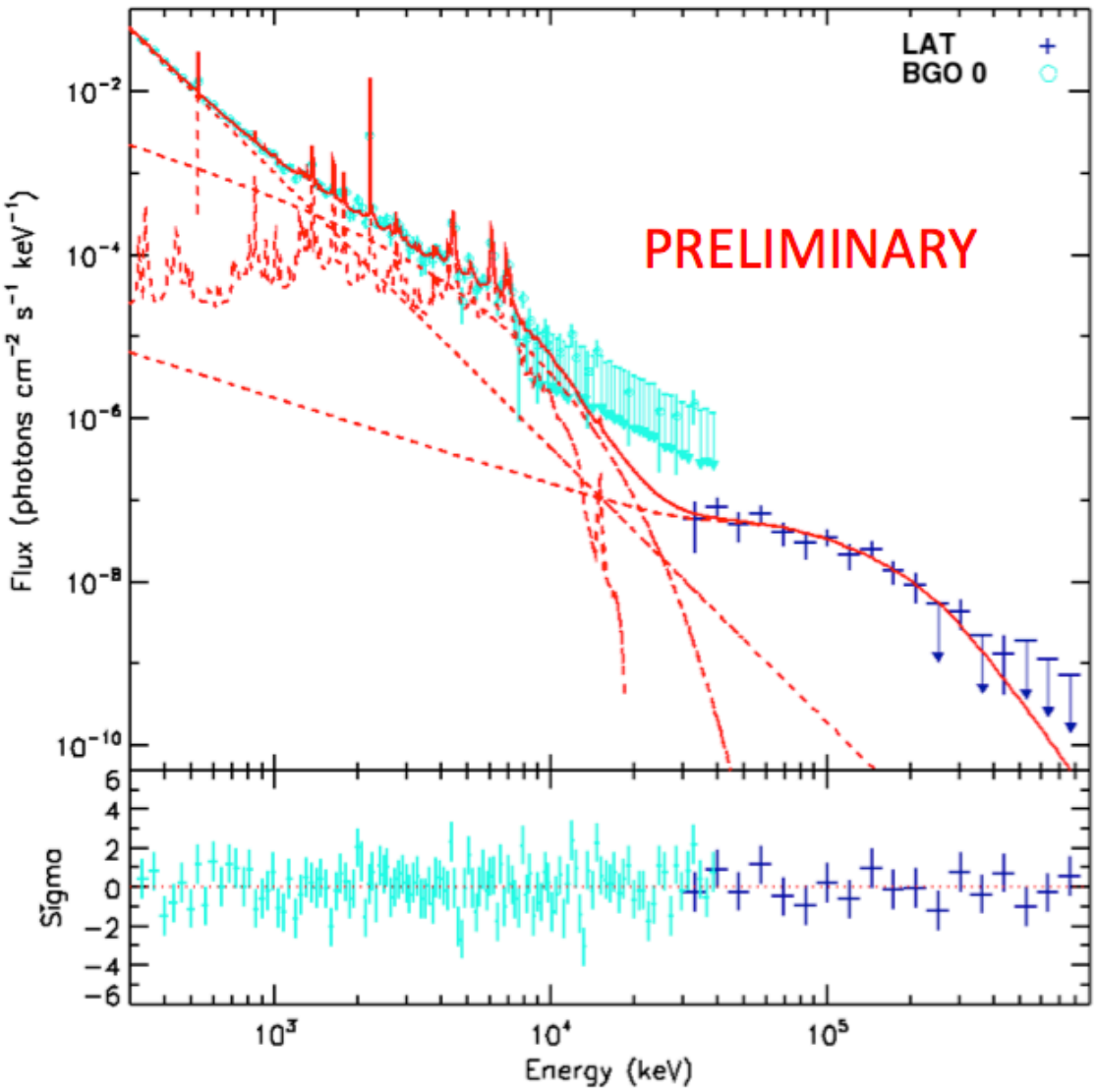
Summary

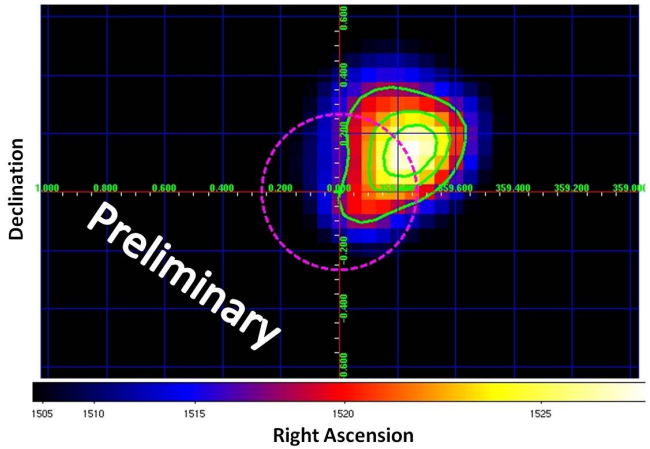
- LAT continues to operate well
- 2FGL catalog release on track for the end of June
- Pass 7 and new diffuse model release at the end of July
- Work underway on Pass 8 – major revision/update to all aspects of LAT event analysis

Fermi Gamma-ray Space Telescope

Backup slides

Solar Flares



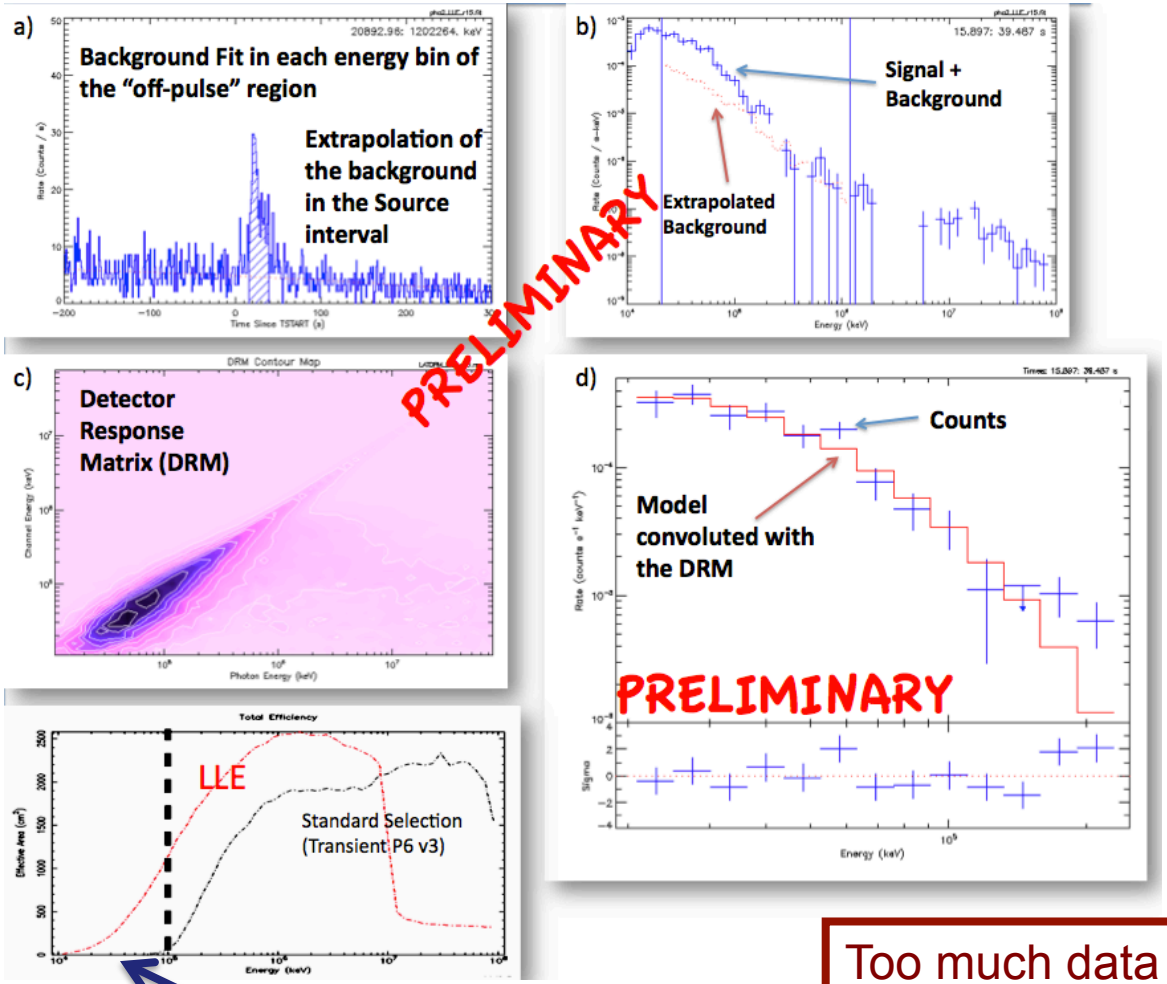


HE Emission localized to Northwest quadrant of solar surface

LLE Analysis gives us spectrum down to 30 MeV (overlap with GBM)

We can resolve π-decay component of the emission

LAT Low Energy (LLE) analysis



The LAT Low Energy (LLE) analysis use an extremely loose event selection (~70% of all downlinked events) and depends on temporal sidebands to perform background subtraction

For bright transients the huge increase in A_{eff} more that compensates for the increased background

Lots of A_{eff} at energies below reach of standard event classes

Too much data to export it via FSSC
LAT team is developing burst data products akin to GBM products to export for LLE
Public release later this year

Improved Diffuse Model

- Diffuse model to be released with Pass 7 will be more accurately extrapolated to lower and higher energies by taking account of the energy dependencies of the various components separately rather than extrapolating the overall model.
- Model will incorporate better spatial resolution [0.25 deg; close to the available CO maps] and E(B-V) artifacts removed.
- We plan to have a publication documenting the preparation and limitations of the model.
- The model should mainly be used for sources detection and identifications. Diffuse and Galactic center studies are not advised with this model**. For that, GALPROP, also developed partly within the LAT collaboration is a good alternative for those studies (WebRun, see **http://galprop.stanford.edu/webrun.php**)

** because the object of this model is to make flat residuals (spatially and spectrally) for studies of discrete sources, and contributions from unresolved point sources have not been considered in developing the model. This is particularly important in the GC region.