The Fermi Gamma-ray Space Telescope

Hiromitsu Takahashi（高橋弘充）
Hiroshima University（広島大学）
hirotaka@hep01.hepl.hiroshima-u.ac.jp
for the LAT Collaboration

2008 June 11th

Contents

- Gamma-ray observation and detectors onboard Fermi
- First results
- Data archive etc…

Fermi LAT Collaboration

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Stanford University (SLAC and HEPL/Physics)
- University of Washington
- Washington University, St. Louis

France
- IN2P3, CEA/Saclay

Italy
- INFN, ASI

Japanese GLAST Collaboration
- Hiroshima University
- ISAS/JAXA, RIKEN
- Tokyo Inst of Technology

Spain
- ICREA and Inst de Ciencies de l'Espi

Swedish GLAST Collaboration
- Kalmar University
- Royal Institute of Technology (KTH)
- Stockholm University

PI: Peter Michelson (Stanford & SLAC)

~270 Members (including ~90 Affiliated Scientists, plus 37 Postdocs, and 48 Graduate Students)

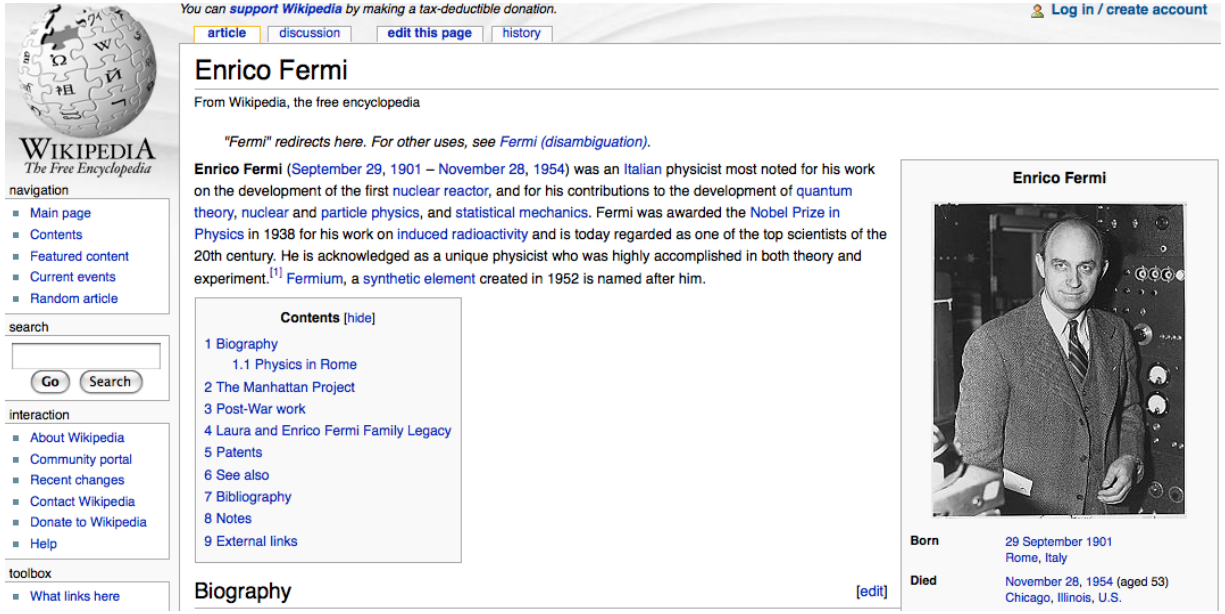
Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

Managed at Stanford Linear Accelerator Center (SLAC).

GLAST was renamed to Fermi

on Aug 26

Fermi
Gamma-ray
Space Telescope



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Enrico Fermi

From Wikipedia, the free encyclopedia

"Fermi" redirects here. For other uses, see Fermi (disambiguation).

Enrico Fermi (September 29, 1901 – November 28, 1954) was an Italian physicist most noted for his work on the development of the first nuclear reactor, and for his contributions to the development of quantum theory, nuclear and particle physics, and statistical mechanics. Fermi was awarded the Nobel Prize in Physics in 1938 for his work on induced radioactivity and is today regarded as one of the top scientists of the 20th century. He is acknowledged as a unique physicist who was highly accomplished in both theory and experiment.[1] Fermium, a synthetic element created in 1952 is named after him.

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4 Laura and Enrico Fermi Family Legacy
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Enrico Fermi

Born 29 September 1901 Rome, Italy

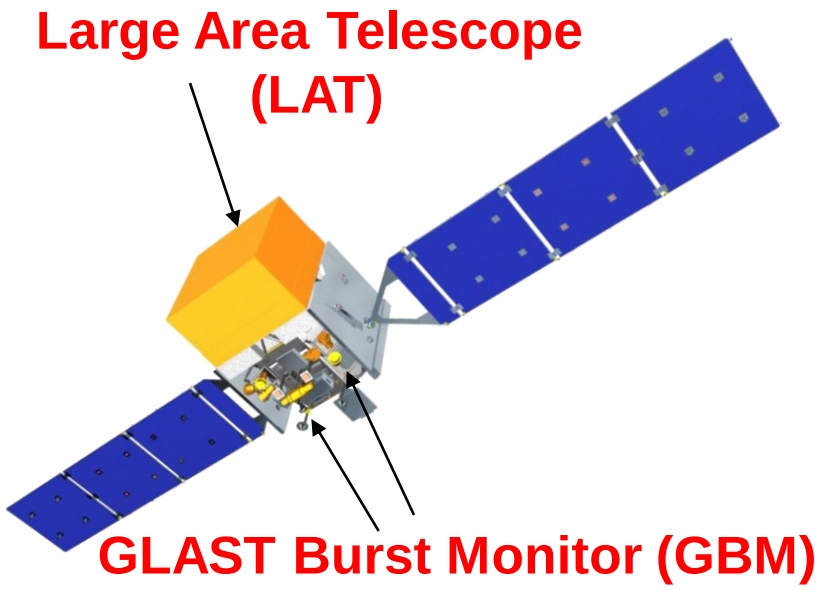
Died November 28, 1954 (aged 53) Chicago, Illinois, U.S.

Biography [edit]

Fermi Key Features

Compared to EGRET:
- **> 100 MeV, 1 yr sensitivity x25**
- **localization x10^2**
- **field of view x5**
- **observing efficiency x2**
- **deadtime x10^{-3}**

- Two gamma-ray instruments:
  - LAT:
    - high energy (20 MeV – >300 GeV)
  - GBM:
    - low energy (8 keV – 30 MeV)



- Huge field of view with good angular resolution
  - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.

- Wide energy range, including largely unexplored band 10 GeV - 100 GeV

Fermi Science Targets

- Super-massive black holes (Active Galactic Nuclei)
- Gamma-ray bursts (GRBs)
- Pulsars, Pulsar wind nebulae (PWNe)
- Galactic binaries
- Supernova remnants (SNRs),
- Galactic diffuse emission
- Solar physics

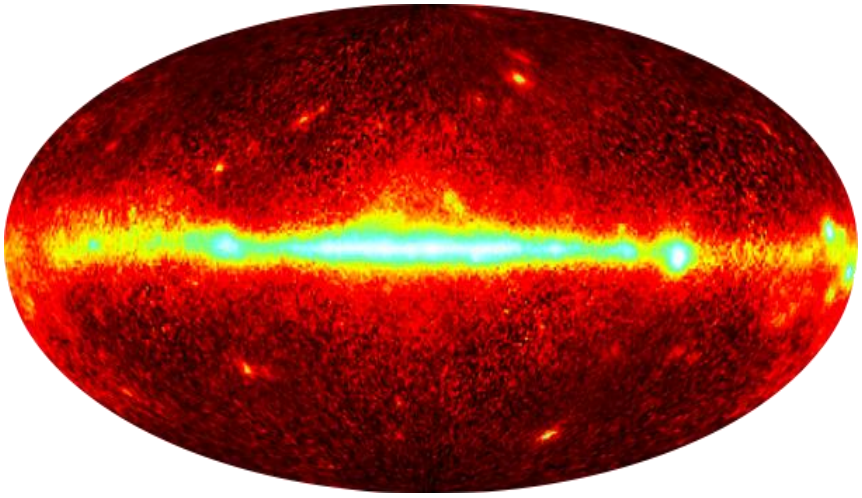
Physics of high-energy emission
Origin of cosmic-rays

- Optical-UV background light

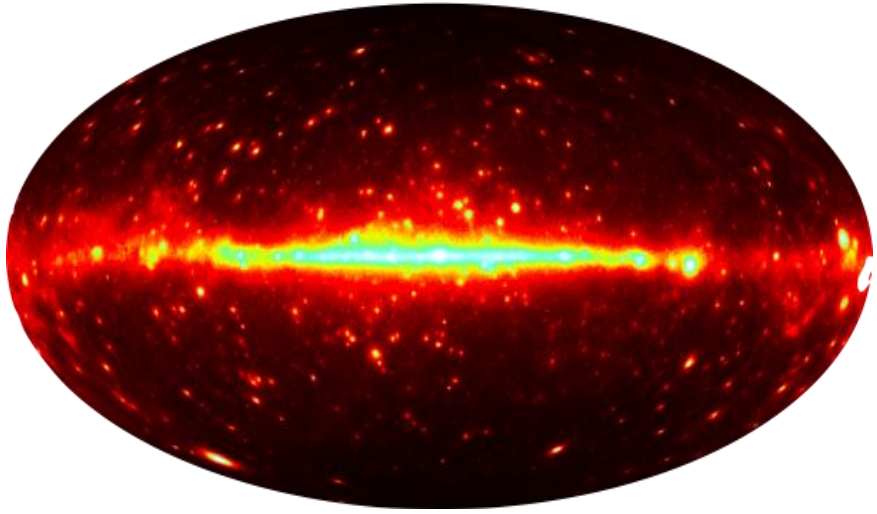
Probing the era of galaxy formation

- High-energy unidentified sources
- Dark Matter

Discovery and new sciences



5 yrs EGRET

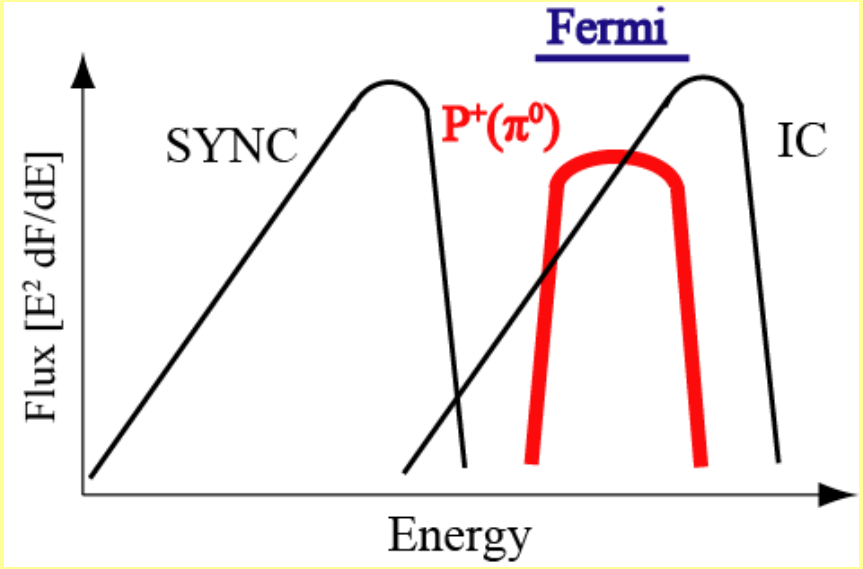


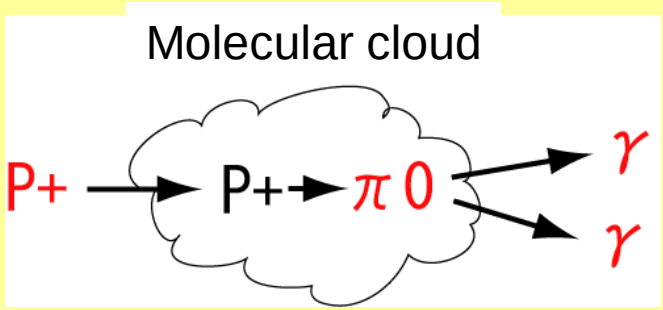
1 yr (sim) Fermi

Detected sources : ~270 (Unidentified : ~170)

Origin of Cosmic-Rays

- Where do protons come ? Cosmic-rays are dominated by protons.
- Photons keep the information of the original source position (complementary to measuring charged particles which are effected by magnetic field)
- We need to detect hadronic interaction, since the emission from leptonic interaction (synchrotron and inverse-Compton) is mainly from electrons.



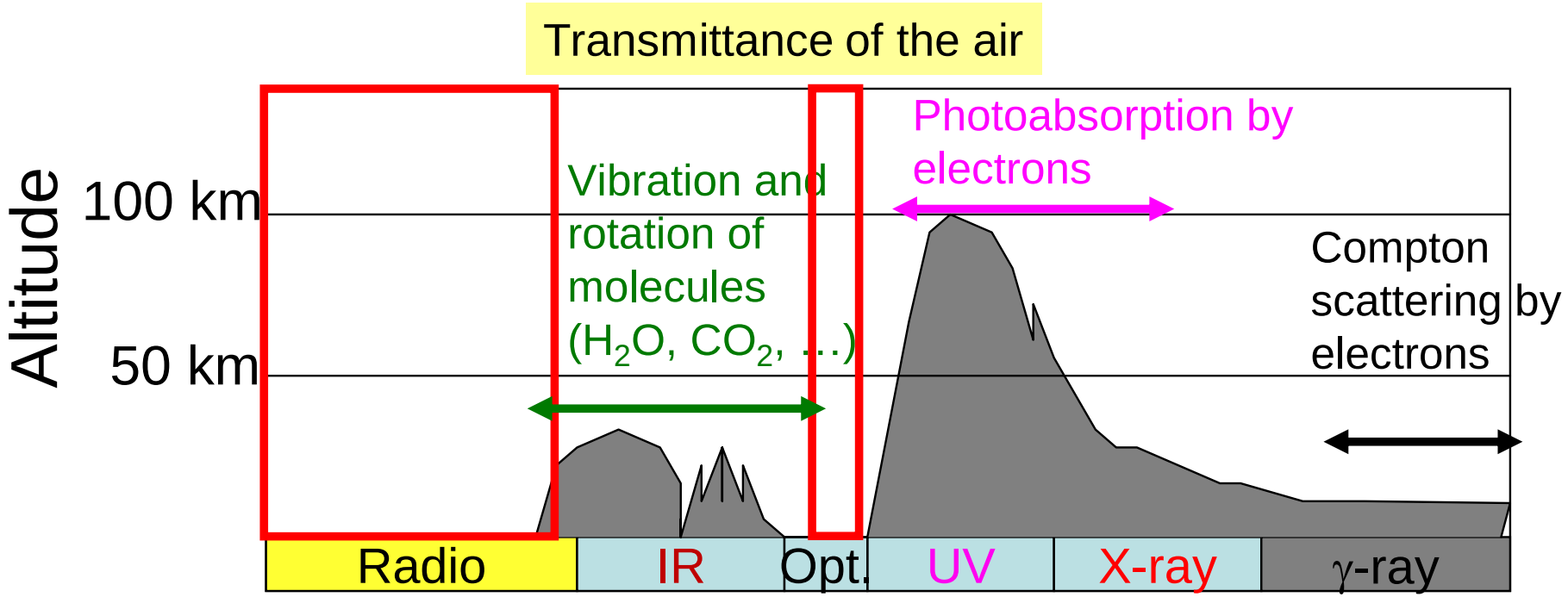


Around SNRs, PWNe, …

MeV gamma-rays are very important to reveal accelerated protons directly.

Why Satellites ?

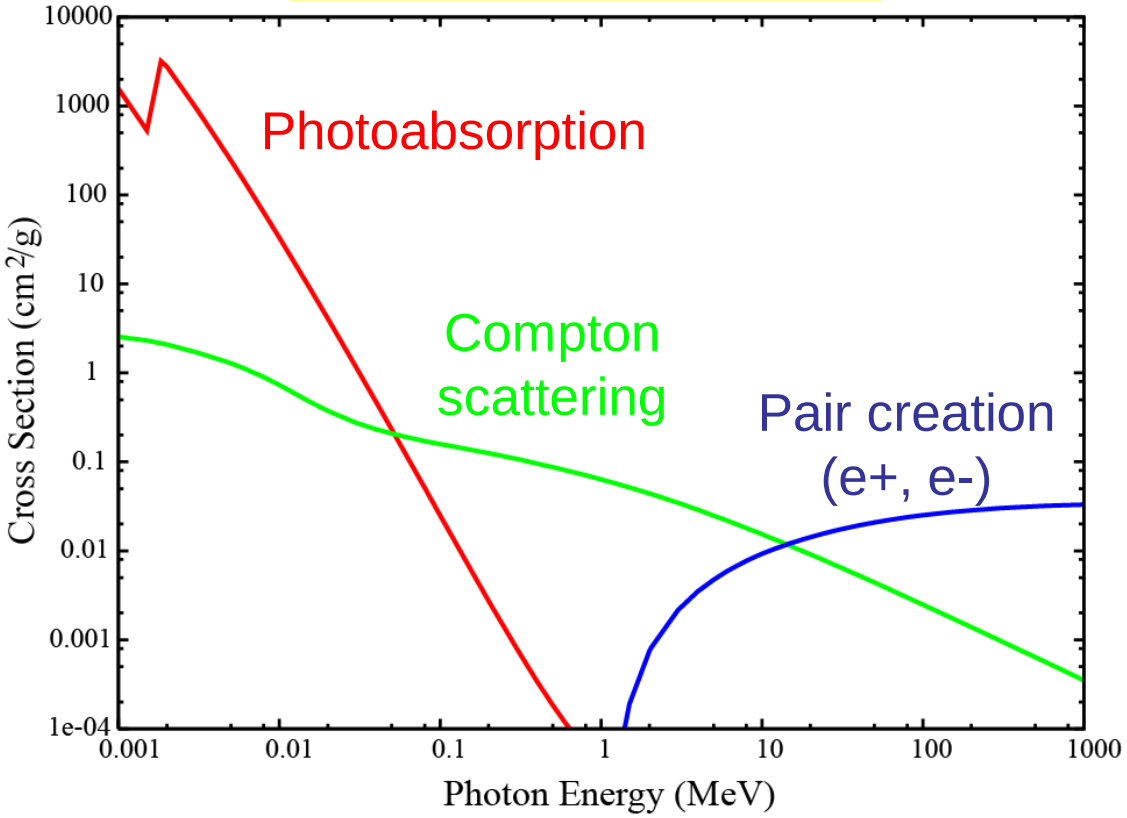
- Only optical and radio emission can reach the ground.
- Then, we need satellites or balloons to observe other wavelengths.



Interaction of Gamma-Rays

- Photoabsorption
- Compton scattering
- Pair creation (e+, e-)

Cross section of Silicon



MeV-GeV photons are detected through the pair-creation interaction.

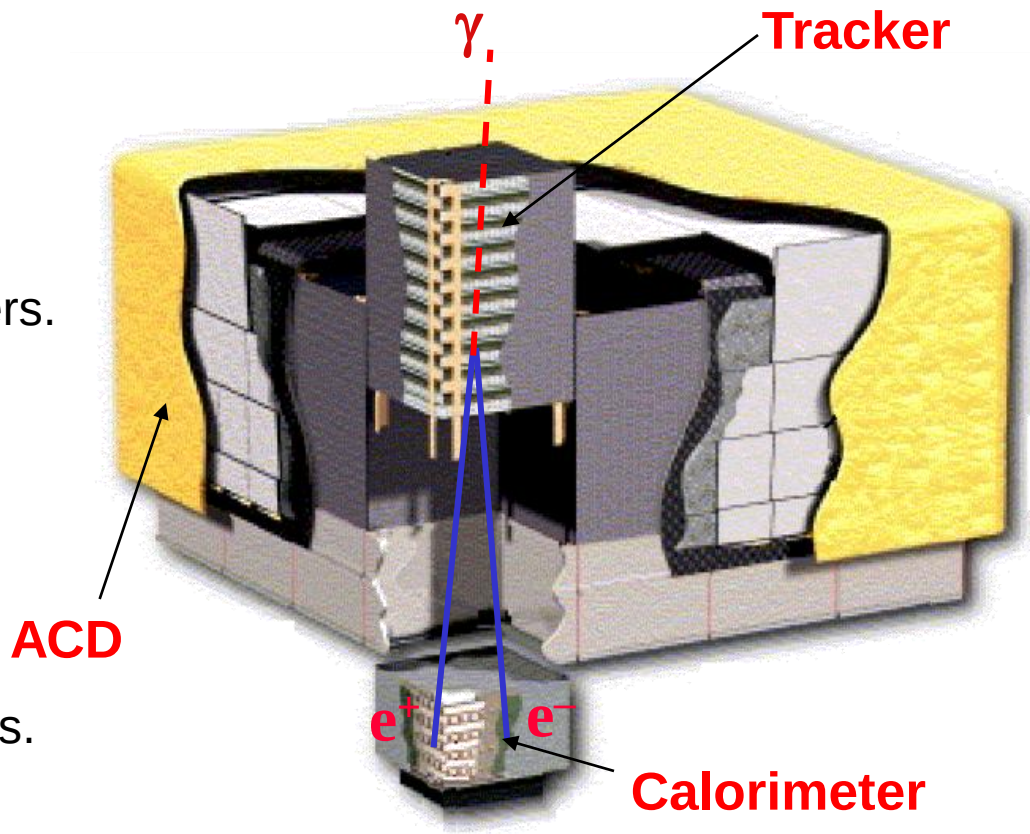
Large Area Telescope (LAT)

Compared to EGRET:
- **> 100 MeV, 1 yr sensitivity x25**
- **localization x10^2**
- **field of view x5**
- **observing efficiency x2**
- **deadtime x10^{-3}**

- Precision Si-strip Tracker (TKR)
  -18 XY tracking planes.
  - 1 plane consists of single-sided silicon strip detectors (228 μm pitch) and tungsten converter.
  - Measure the photon direction.

- Hodoscopic CsI Calorimeter(CAL)
  - Array of 1536 CsI(Tl) crystals in 8 layers.
  - Measure the photon energy

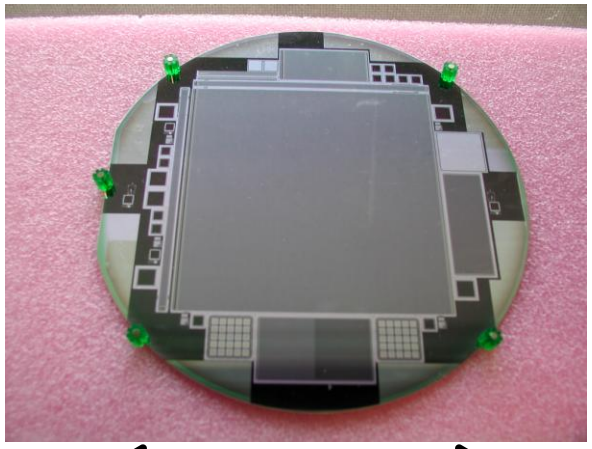
- Segmented Anticoincidence Detector (ACD)
  - 89 plastic scintillator tiles.
  - Reject background of charged particles.



Systems work together to identify and measure the flux of cosmic gamma-rays with energy 20 MeV - >300 GeV.

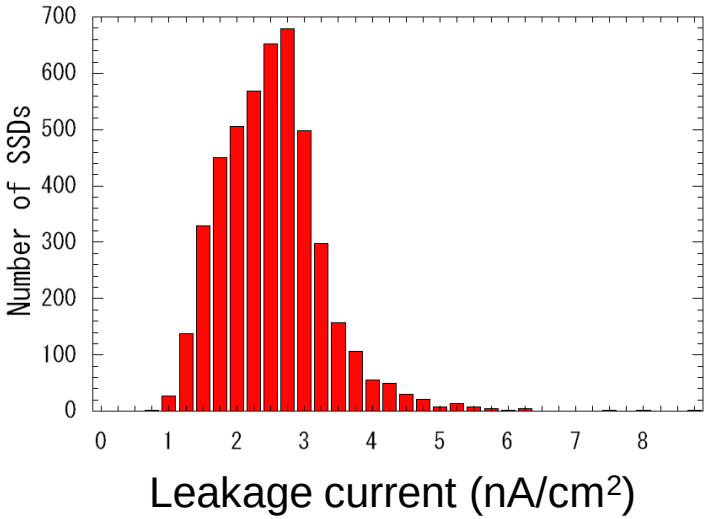
Si-Strip Detector (SSD)

SSD was developed by Hiroshima Univ. and Hamamatsu Photonics in Japan.



High Quality

- Fraction of Dead strips: < 0.01%
- Very low leakage current; ~2.5 nA cm^{-2}



SSD

- Wafer thickness 400 μm
  - Wafer Area 8.96 x 8.96 cm^2
  - Strip pitch 228 μm

Total

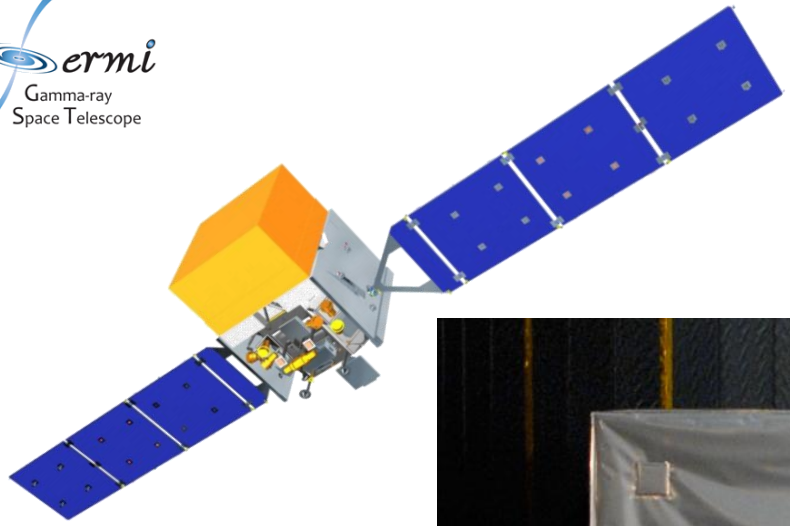
- 11500 SSDs, 1M channels
- 93 m^2 of Si

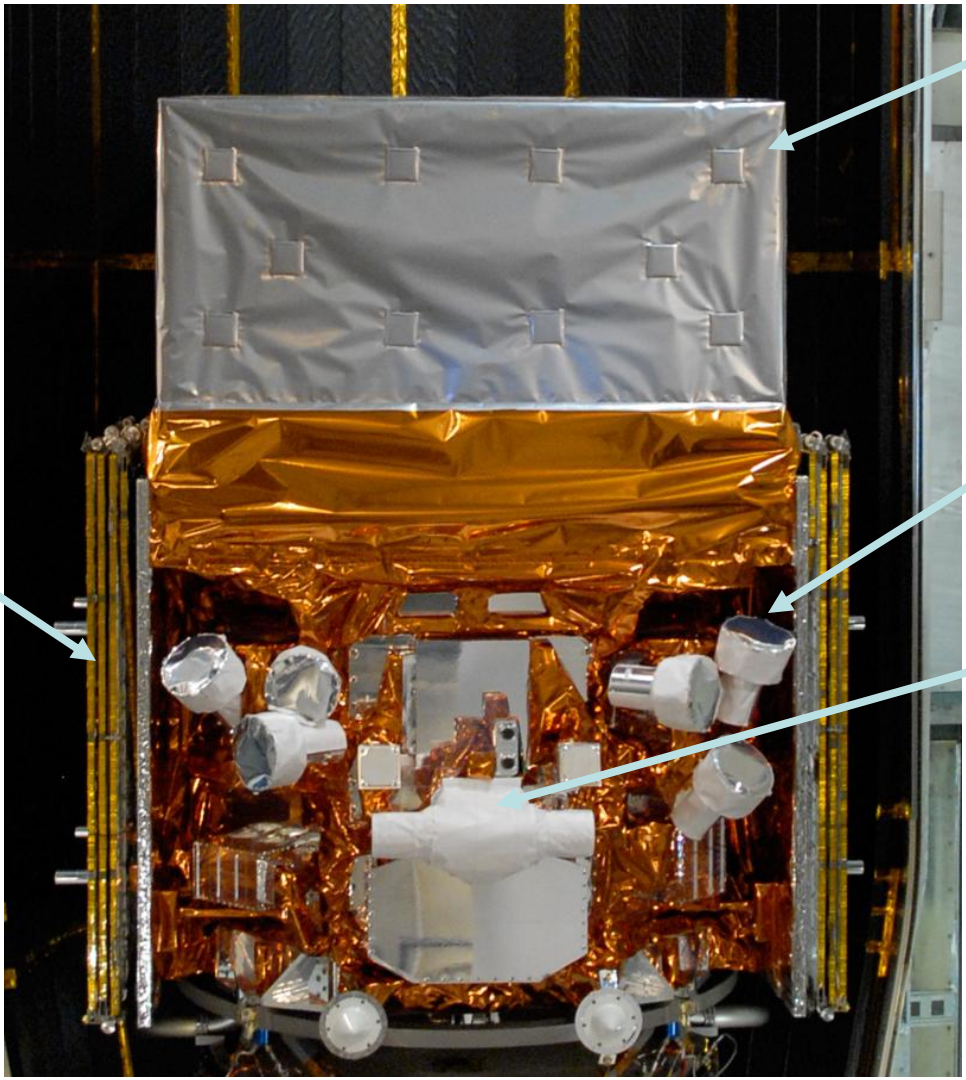
Increasing the angular resolution and FOV

- SSD (Fermi) :~200 μm

⟷ Spark chamber (EGRET) :~1 mm

Fermi
Gamma-ray
Space Telescope





LAT

GBM Sodium Iodide Detector

x 12

Solar panel

GBM Bismuth Germanate Detector

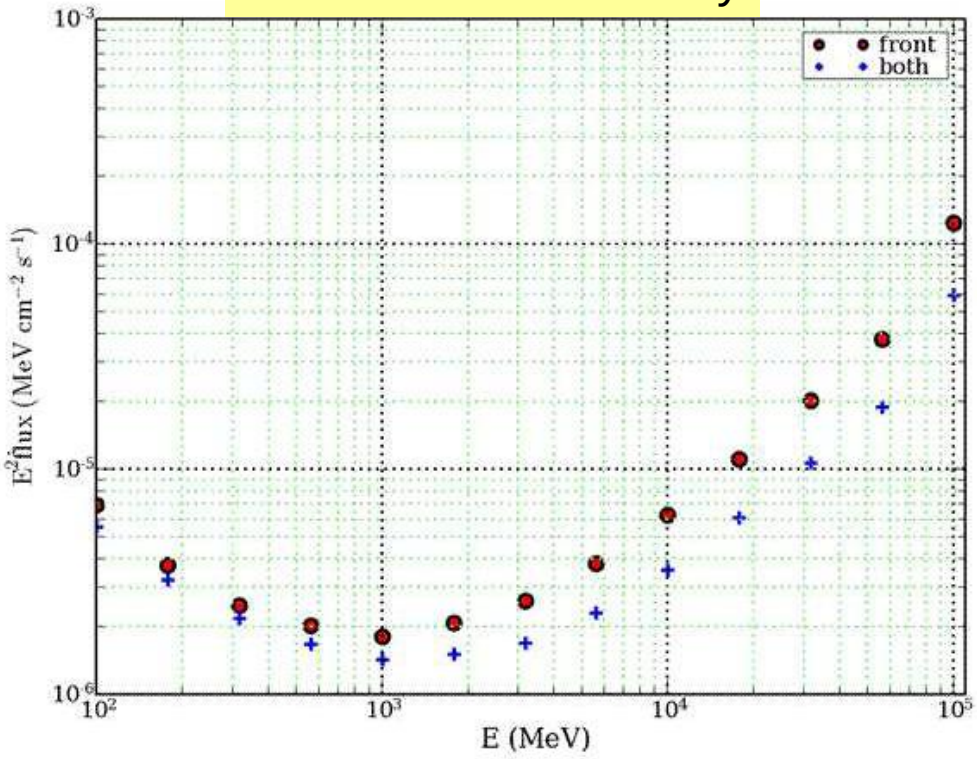
x 2

Fermi LAT Performance

http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm

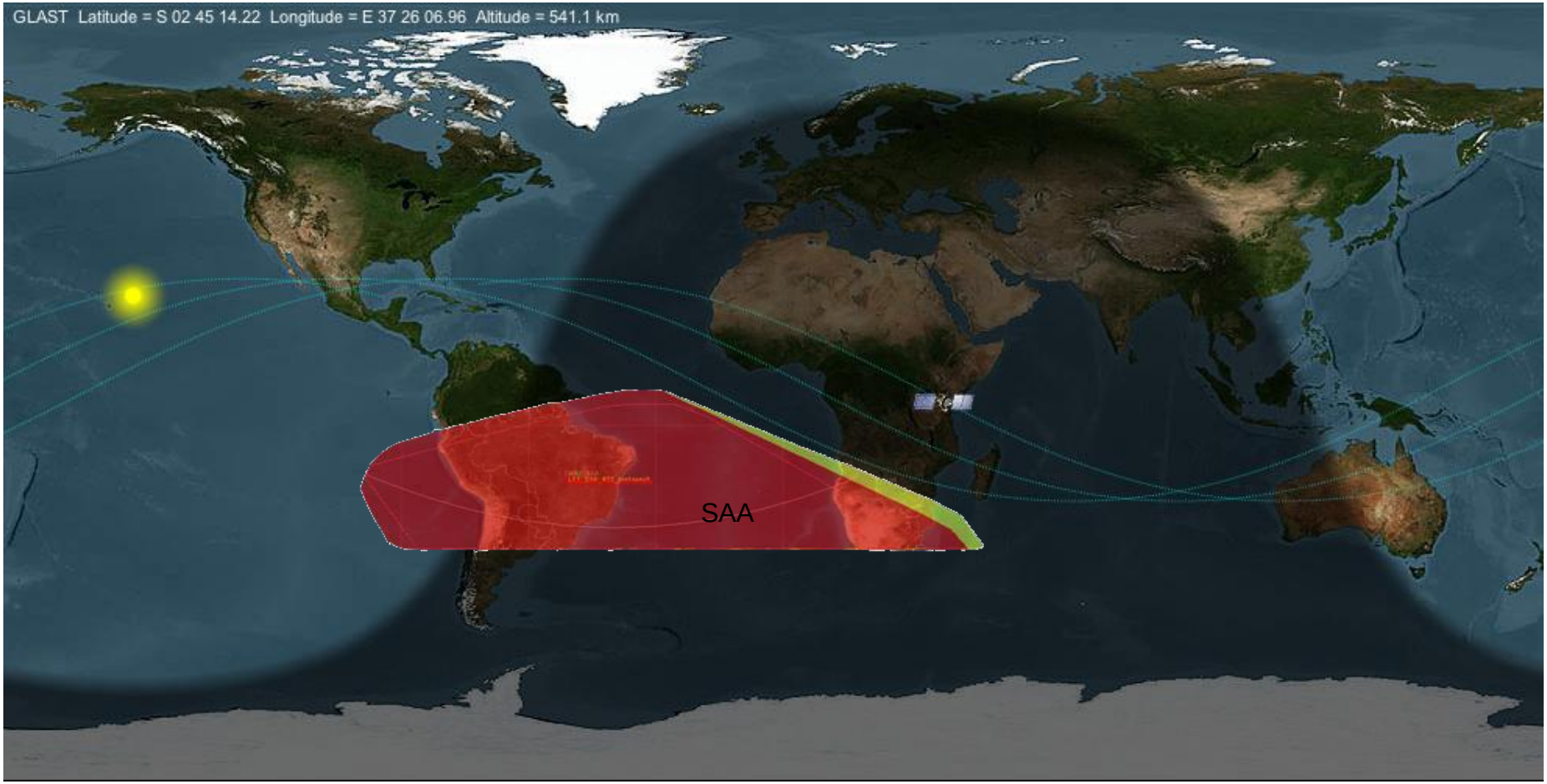
- Energy Resolution: ~10% (~5% off-axis)
- PSF (68%) at 100 MeV ~ 3.5 deg (thin section)
- PSF (68%) at 10 GeV ~ 0.1 deg
- Field Of View: 2.4 str

Point Source sensitivity



- 1 year all-sky survey
- diffuse background flux :
  $1.5 \times 10^{-5}/cm^2/s/str$ (E>100 MeV)
- spectral index : -2.1

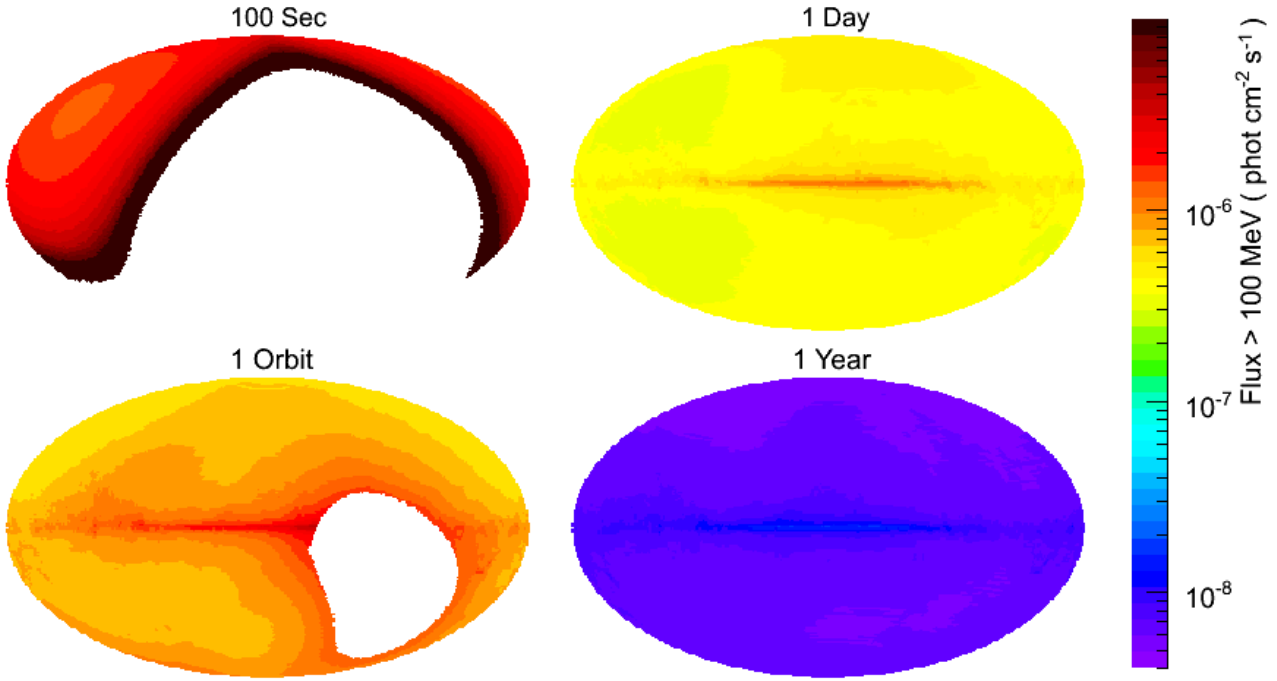
Orbit of the Fermi Satellite



http://observatory.tamu.edu:8080/Trakker/

- Launched from Kennedy Space Center on June 11 2008
- Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination
- There is no observation during South Atlantic Anomaly (SAA).

Operation Mode



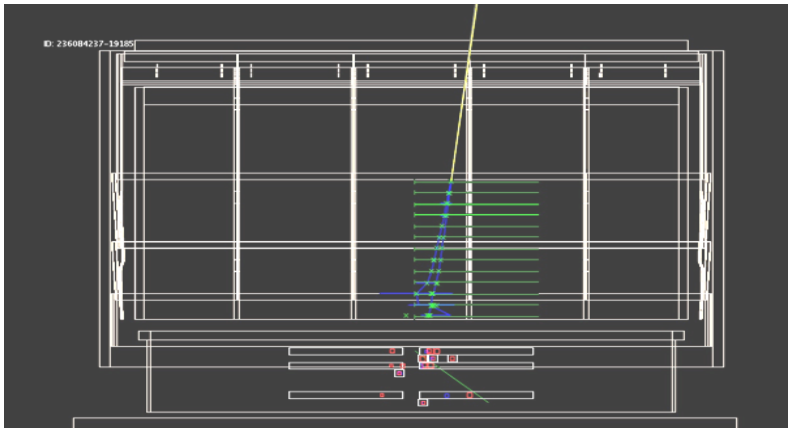
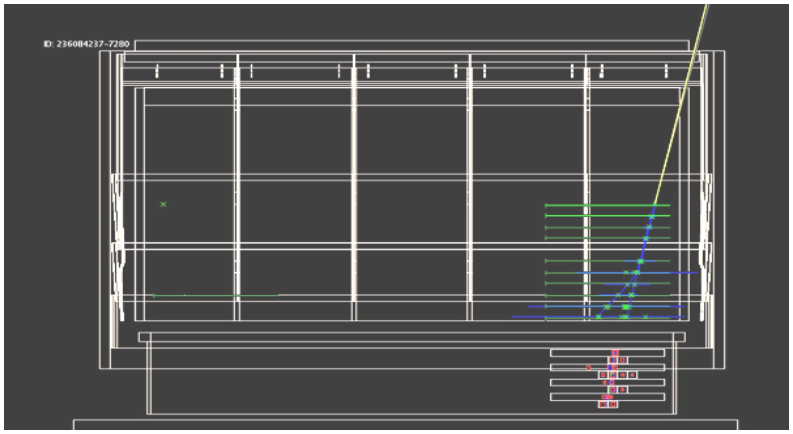
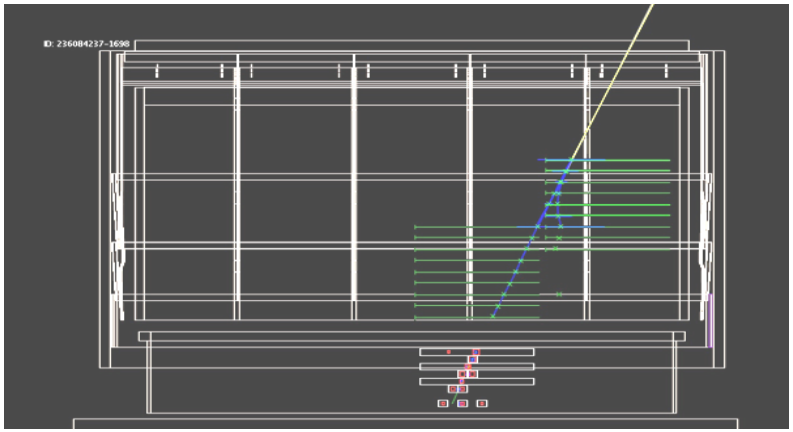
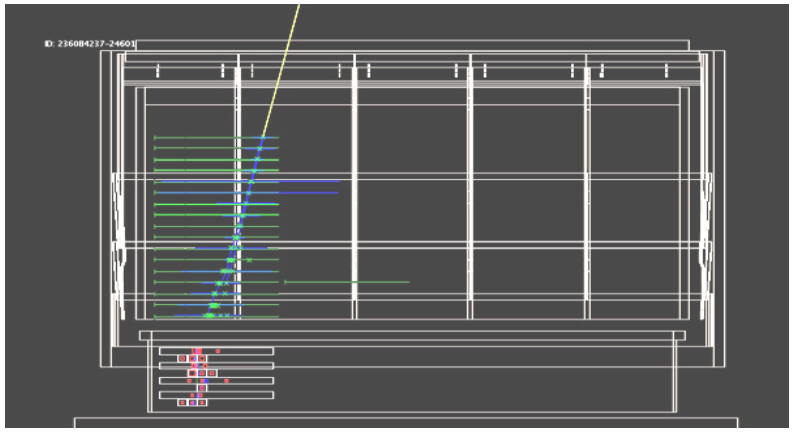
LAT sensitivity on 4 different timescales: 100 s, 1 orbit (96 mins), 1 day and 1 year

- In survey mode, the LAT observes the entire sky every two orbits (~3 hours).
- The LAT can also perform pointed observations of particularly interesting regions of the sky.
- GBM sees entire unocculted sky.

Multiwavelength campaigns with the LAT are always welcome.

Observed Single Gamma-ray Events

~ few Hz

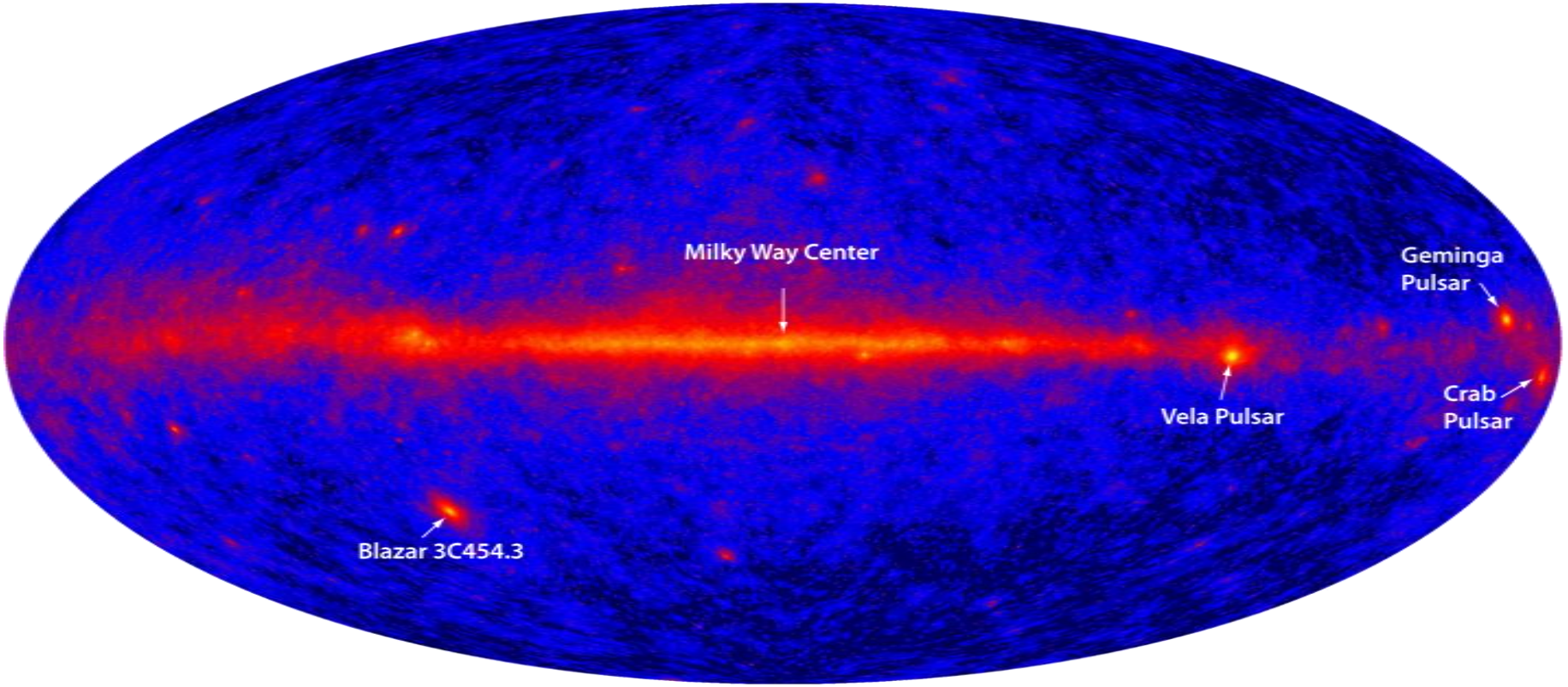
Green : positions of the charged particles, Blue : reconstructed track trajectories

Yellow : estimated direction of gamma-ray, Red : energy depositions in the calorimeter.

Events are efficiently identified as gamma-rays or charged particles.

First-Light Sky Map with 95 hrs (4 days)

Equivalent to EGRET's first year!



- Galactic diffuse emission
- Pulsars
- Blazars

http://www.nasa.gov/mission_pages/GLAST/news/glast_findings_media.html

Vela Pulsar

- Well-known bright pulsar
- (Pulse-on) – (Pulse-off) : background-free analysis
- Good to evaluate the detector response
  (Timing, PSF, Energy, …)

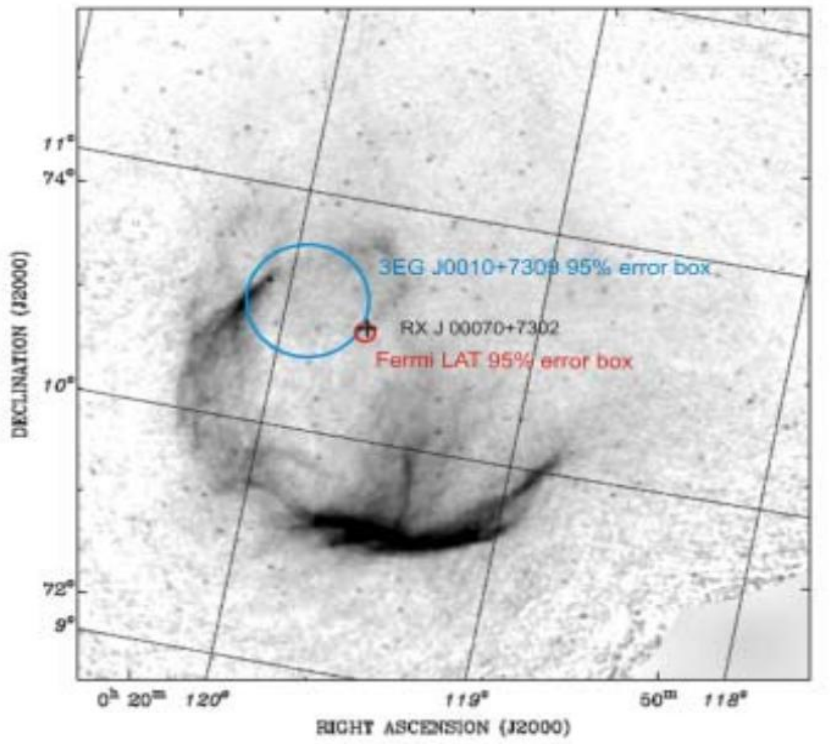
Period = 89 ms

Movie

http://www.nasa.gov/mission_pages/GLAST/news/glast_findings_media.html

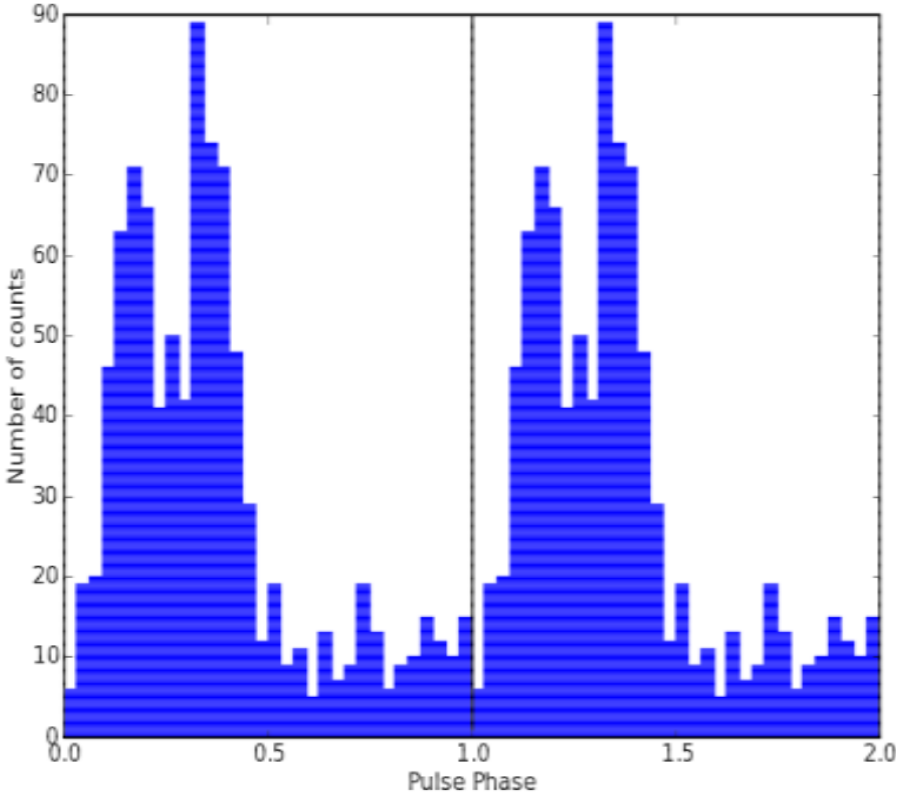
A Radio-Quiet Pulsar in CTA1

Abdo et al. science 2008, October 16



Location of EGRET source 3EG J0010+7309, the Fermi-LAT source, and the central X-ray source RX J0007.0+7303

P ~ 317 ms
Pdot ~ 3.6E-13
Characteristic age ~ 10,000 yrs



- There is X-ray point source, but the pulsation is only detected with gamma-ray (not X-ray or radio).
- Emission mechanism ? Other EGRET unID sources ?

GCN and ATel Reports

- Gamma-ray Burst Coordination Network (GCN)

  There are already 3 GRBs detected by the LAT.

- Astronomer's Telegram (ATel)

  Some of bright Blazars and transients in the Galactic plane.

GLAST-LAT detection of extraordinary gamma-ray activity in 3C 454.3

ATel #1628; *G. Tosti (Univ/INFN-Perugia) , J. Chiang (SLAC), B. Lott (CENBG/Bordeaux), E. do Couto e Silva (SLAC), J. E. Grove (NRL/Washington), J. G. Thayer (SLAC) on behalf of the GLAST Large Area Telescope Collaboration*
on 24 Jul 2008; 14:25 UT
Password Certification: Gino Tosti (tosti@pg.infn.it)

Subjects: Gamma Ray, >GeV, AGN, Quasars

The Large Area Telescope (LAT), one of two instruments on the Gamma-ray Large Area Space Telescope (GLAST) (launched June 11, 2008), which is still in its post-launch commissioning and checkout phase has been monitoring extraordinarily high flux from the gamma-ray blazar 3C 454.3 since June 28, 2008. This confirms the bright state of the source reported by AGILE (see ATel #1592) and by the optical-to-radio observers of the GASP-WEBT Project (ATel #1625).

3C 454.3 has been detected on time scales of hours with high significance (> 5 sigma) by the LAT Automatic Science Processing (ASP) pipeline and the daily light curve (E>100 MeV) indicates that the source flux has increased from the initial measurements on June 28. Although in-flight calibration is still ongoing, preliminary analysis indicates that in the period July 10-21, 2008 the source has been in a very high state with a flux (E>100MeV) that is well above all previously published values reported by both EGRET (Hartman et al. 1999, ApJS, 123,79) and AGILE (see e.g. ATel #1592 and Vercellone et al. 2008, ApJ,676,L13).

Because GLAST will continue with calibration activities, regular monitoring of this source cannot be pursued. Monitoring by the LAT is expected to resume in early August. In consideration of the ongoing activity of this source we strongly encourage multiwavelength observations of 3C 454.3.

The GLAST LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.

Fermi LAT Detection of a New Gamma-ray Transient in the Galactic Plane: J0910-5041

ATel #1788; *C.C. Cheung (NASA/GSFC), L. Reyes (U. Chicago), F. Longo (INFN Trieste), G. Iafrate (INAF/OA Trieste) on behalf of the Fermi Large Area Telescope Collaboration*
on 17 Oct 2008; 20:00 UT
Distributed as an Instant Email Notice (Transients)
Password Certification: Teddy Cheung (ccheung@milkyway.gsfc.nasa.gov)

Subjects: Gamma Ray, >GeV, Transients

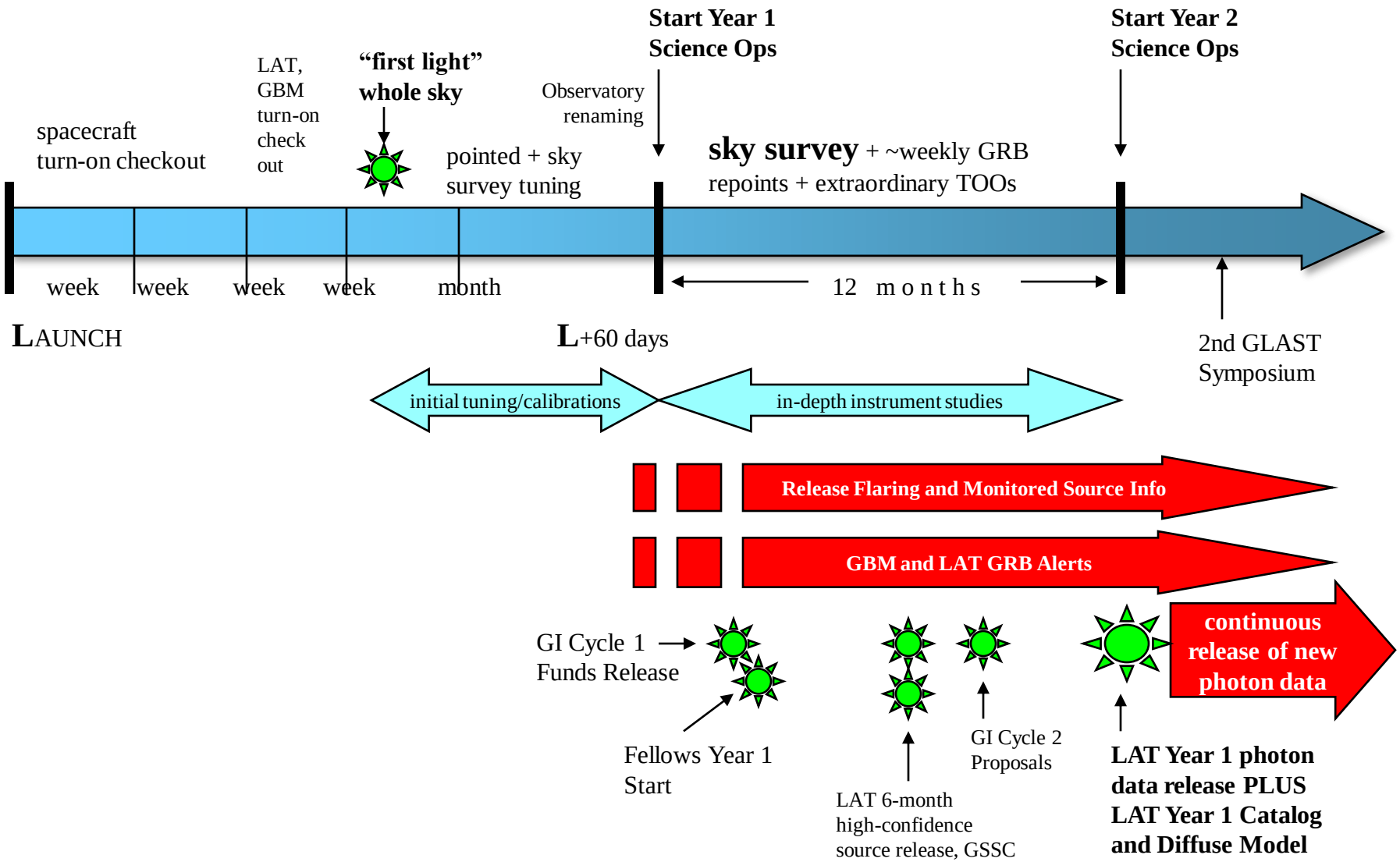
The Large Area Telescope (LAT), one of two instruments on the Fermi Gamma-ray Space Telescope (formerly GLAST, launched June 11, 2008), has detected a transient gamma-ray source in the Galactic Plane starting on October 15, 2008. The preliminary LAT position is (J2000.0): RA, Dec = 137.69 deg, -50.74 deg (l, b = 271.62 deg, -1.80 deg) with a 68% confidence error circle radius 0.07 deg (statistical). The systematic error on the location is smaller than the statistical error.

Preliminary analysis of the Oct 15 data shows a high-significance source (10 sigma), with a gamma-ray flux (E>100MeV) = (1.4 +/- 0.3) x 10-6 photons cm-2 s-1 with an additional 30% systematic uncertainty. The source was not detected previously by the LAT and there is no previously reported EGRET gamma-ray detection at this location. Furthermore, there is no obvious lower-energy counterpart.

Because Fermi operates in an all-sky scanning mode, regular gamma-ray monitoring of this source will continue. In consideration of the activity of this source we strongly encourage multiwavelength observations. For this source the Fermi LAT contact person is C.C. Cheung (e-mail: Teddy.Cheung@nasa.gov).

The Fermi LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.

Year 1 Science Operations Timeline Overview



Data Release plan and operations

- **First Year observations - Sky Survey**
  - **After initial on-orbit checkout (60 days), the first year of observations will be a sky survey.**
  - **Repoints for bright bursts and burst alerts will be enabled**
  - **Extraordinary ToOs will be supported.**
  - **First year data will be used for detailed instrument characterization and key projects (catalog, background models etc).**
- **First Year Data release**
  - **All GBM data**
  - **Information on all LAT detected GRB (flux, spectra, location)**
  - **High level LAT data (time resolved flux/spectra) on ~20 selected sources and on all sources which flare above $2x10^{-6}$, continued until the source flux drops below $2x10^{-7}$ (rate ~ 1-4 such objects per month).**
  - **The LAT team will produce a preliminary source list after ~6 months on a best effort basis**
- **Subsequent years: Observing plan driven by guest observer proposal selections by peer review. Default is sky survey mode.**
  - **All data publicly released within 72 hours through the Science Support Center (GSSC).**
- **See http://glast.gsfc.nasa.gov/ssc/data/policy/ for more details**

LAT First Year Source Monitoring List

- Data are provided for daily and weekly integrations for all sources.
- A “quicklook” analysis, priority is to get the results out as quickly as possible.
- You can download the data from http://heasarc.gsfc.nasa.gov/cgi-bin//W3Browse/w3table.pl?Action=Detailed%20Mission&Observatory=fermi

Source Type	Source Name	EGRET Name	Average or Min. Flux (10^{-8} Y $cm^{-2}s^{-1}$)	Galactic Lattitude	Redshift	TeV Source
Blazar	0208-512	3EGJ0210-5055	85.5 ± 4.5	-61.9	1.003	
	0235+164	3EGJ0237+1635	65.1 ± 8.8	-39.1	0.94	
	PKS 0528+134	3EGJ0530+1323	93.5 ± 3.6	-11.1	2.060	
	PKS 0716+714	3EGJ0721+7120	17.8 ± 2.0	28	0.3	
	0827+243	3EGJ0829+2413	24.9 ± 3.9	31.7	0.939	
	OJ 287	3EGJ0853+1941	10.6 ± 3.0	35.8	0.306	
	Mrk 421	3EGJ1104+3809	13.9 ± 1.8	65.0	0.031	Yes
	W Com 1219+285	3EGJ1222+2841	11.5 ± 1.8	83.5	0.102	
	3C 273	3EGJ1229+0210	15.4 ± 1.8	64.5	0.158	
	3C 279	3EGJ1255-0549	74.2 ± 2.8	57.0	0.538	
	1406-076	3EGJ1409-0745	27.4 ± 2.8	50.3	1.494	
	H 1426+428	NA		64.9	0.129	Yes
	1510-089	3EGJ1512-0849	18.0 ± 3.8	40.1	0.36	
	PKS 1622-297	3EGJ1625-2955	47.4 ± 3.7	13.4	0.815	
	1633+383	3EGJ1635+3813	58.4 ± 5.2	42.3	1.814	
	Mrk 501	NA		38.9	0.033	Yes
	1730-130 NRAO 530	3EGJ1733-1313	36.1 ± 3.4	10.6	0.902	
	1ES 1959+650	NA		17.7	0.048	Yes
	PKS 2155-304	3EG2158-3023	13.2 ± 3.2	-52.2	0.116	Yes
	BL_Lacertae (2200+420)	3EGJ2202+4217	39.9 ± 11.6	-10.4	0.069	Yes
	3C 454.3	3EGJ2254+1601	53.7 ± 4.0	-38.3	0.859	
	1ES 2344+514	NA		-9.9	0.044	Yes
HMXB	LSI+61 303 2CG135+01	3EGJ0241+6103	69.3 ± 6.1	1.0		Yes

Activities at Hiroshima University

- Multiwavelength observations
  - Optical/Infrared telescope “Kanata”
  - X-ray satellite “Suzaku”

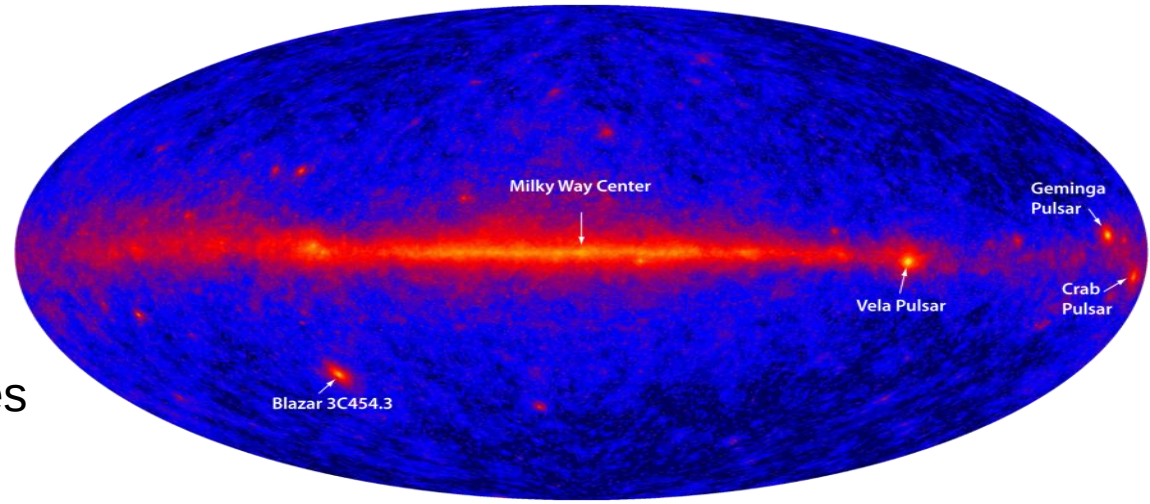
- Monitoring the condition of the LAT detector
- Searching transient or Gamma-ray burst events

Conclusions

- Fermi was launched on June 11 2008, and all the instruments were turned on successfully and are working without any problems.
- Some of data release has been already started.
- More results from the first year data are coming soon.

- Super-massive black holes (Active Galactic Nuclei)
- Gamma-ray bursts
- Pulsars, Pulsar wind nebulae
- Galactic binaries
- Supernova remnants
- Galactic diffuse emission
- Solar physics
- Optical-UV background light
- High-energy unidentified sources
- Dark Matter

…



Fermi First-Light Sky Map (95 hrs)