Fermi Large Area Telescope

Status and requests for 2011

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on behalf of the INFN-Pisa Fermi LAT team

INFN-Pisa, July 23, 2010

Just turned 2!

Happy Birthday, Fermi Telescope

by Kelen Tuttle

(Image courtesy NASA and Kelen Tuttle.)

Today marks the start of the Fermi Gamma-ray Space Telescope's third year in space. Since the spacecraft launched on June 11, 2008, it has completed 10,990 orbits of the Earth at an average altitude of 554 kilometers, for a total of 298 million miles traveled. The Large Area Telescope, the main instrument on the Fermi mission, was managed at SLAC, which also led the development of the electronics and flight software.

The LAT has been up and running more than 99 percent of the time since science operations began on August 4, 2008. The LAT has so far recorded more than 22 billion total events, sending more than 11,383 gigabytes of heavily compressed data to Earth for detailed processing at SLAC. These processed data occupy more than 550 terabytes on disk.

Numerology

- 10,990 orbits of the Earth
- 298 million miles traveled
- $>$ 99% uptime on average
- 533 CPU years for ground data processing/analysis
- Over 10,000 public data retrievals

The spacecraft carrying the telescope launched from Cape Canaveral June 11, 2008. (Photo courtesy of NASA.)

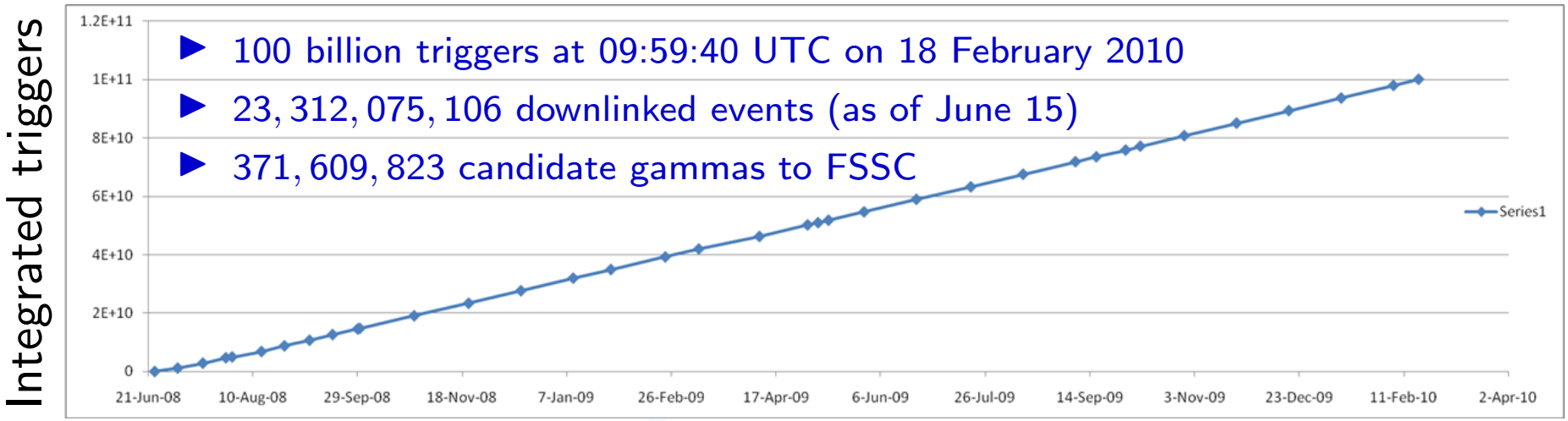
So far, the LAT collaboration has used more than 533 CPU years processing and analyzing Fermi data. (A CPU year is the amount of processing work a single, modern central processing unit performs during one year of constant operation.) On average, it takes only a few hours for data to be collected onboard the LAT, transmitted to SLAC, processed, and sent on to the Fermi Science Support Center at NASA's Goddard Space Flight Center. The FSSC, which makes these data public, has served over 10,000 retrievals of Fermi data since August 2009.

All these data have allowed the LAT collaboration to publish 77 papers (with another 24 papers submitted but not yet published), including five of the top 50 most-cited papers in astronomy, astrophysics and physics in 2009.

Happy birthday, Fermi Gamma-ray Space Telescope! Here's to many more.

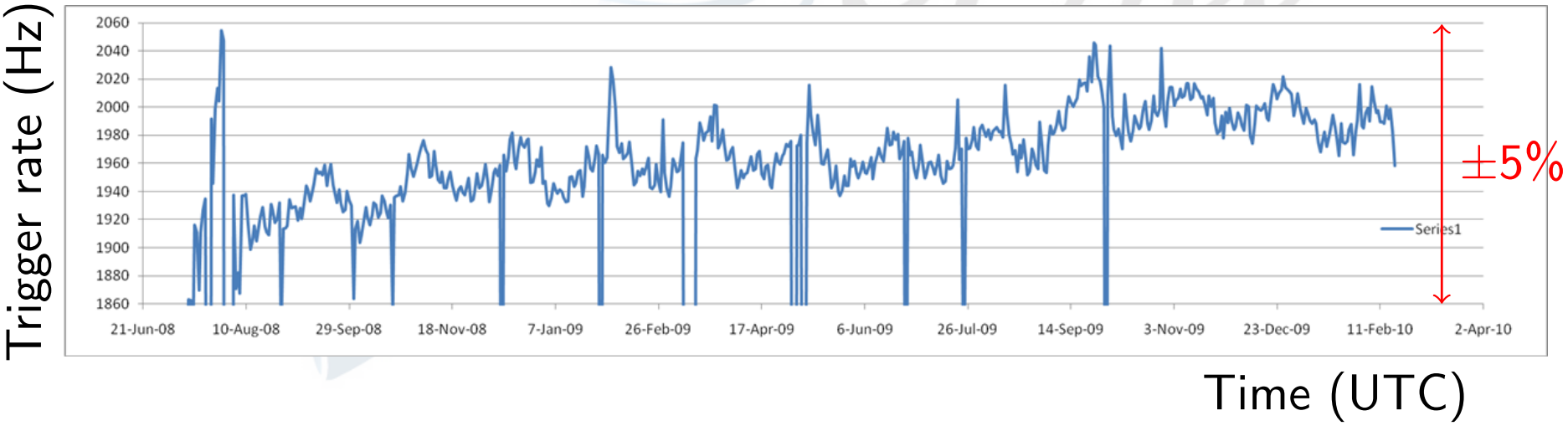
http://today.slac.stanford.edu/a/2010/06-11.htm

Basic operation statistics



- 100 billion triggers at 09:59:40 UTC on 18 February 2010
- 23, 312, 075, 106 downlinked events (as of June 15)
- 371, 609, 823 candidate gammas to FSSC

- Some 130 h downtime—SIU reboots (110 h), calibrations (14 h), FSW updates (6 h); uptime essentially 100% since last October.



Time-line overview

Launch
Jun 11, 2008

Science ops start
Aug 04, 2008

Data go public
Aug 13, 2009

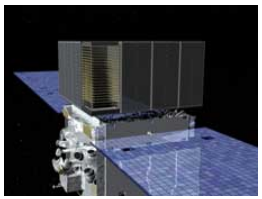
100 B triggers
Feb 18, 2010

TOO on 3C 454.3 (200 ks)
Apr 5, 2010

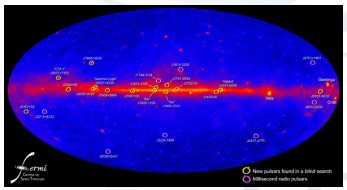
2008 | 2009 | 2010

C | Science operation year 1 | Science operation year 2

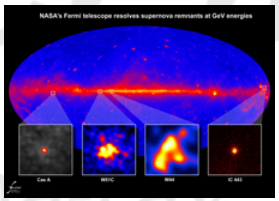
CREs
PRL, 102, 181101 (2009)



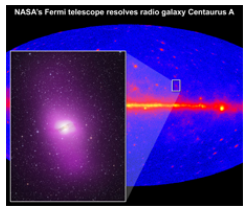
Pulsars
Science, 325, 840 (2009)



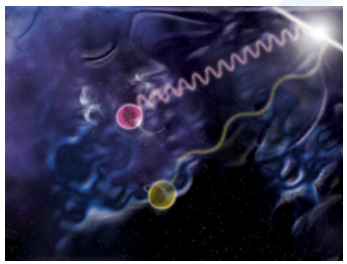
SNRs
Science, 327, 1103 (2010)



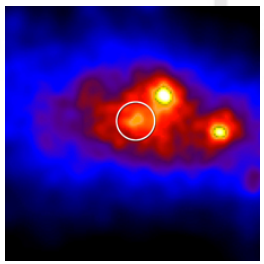
Centaurus A
Science, 328, 725 (2010)



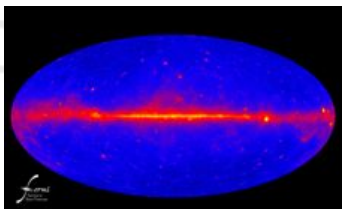
GRB 090510
Nature, 462, 331 (2009)



Cygnus X-3
Science, 326, 1512 (2009)

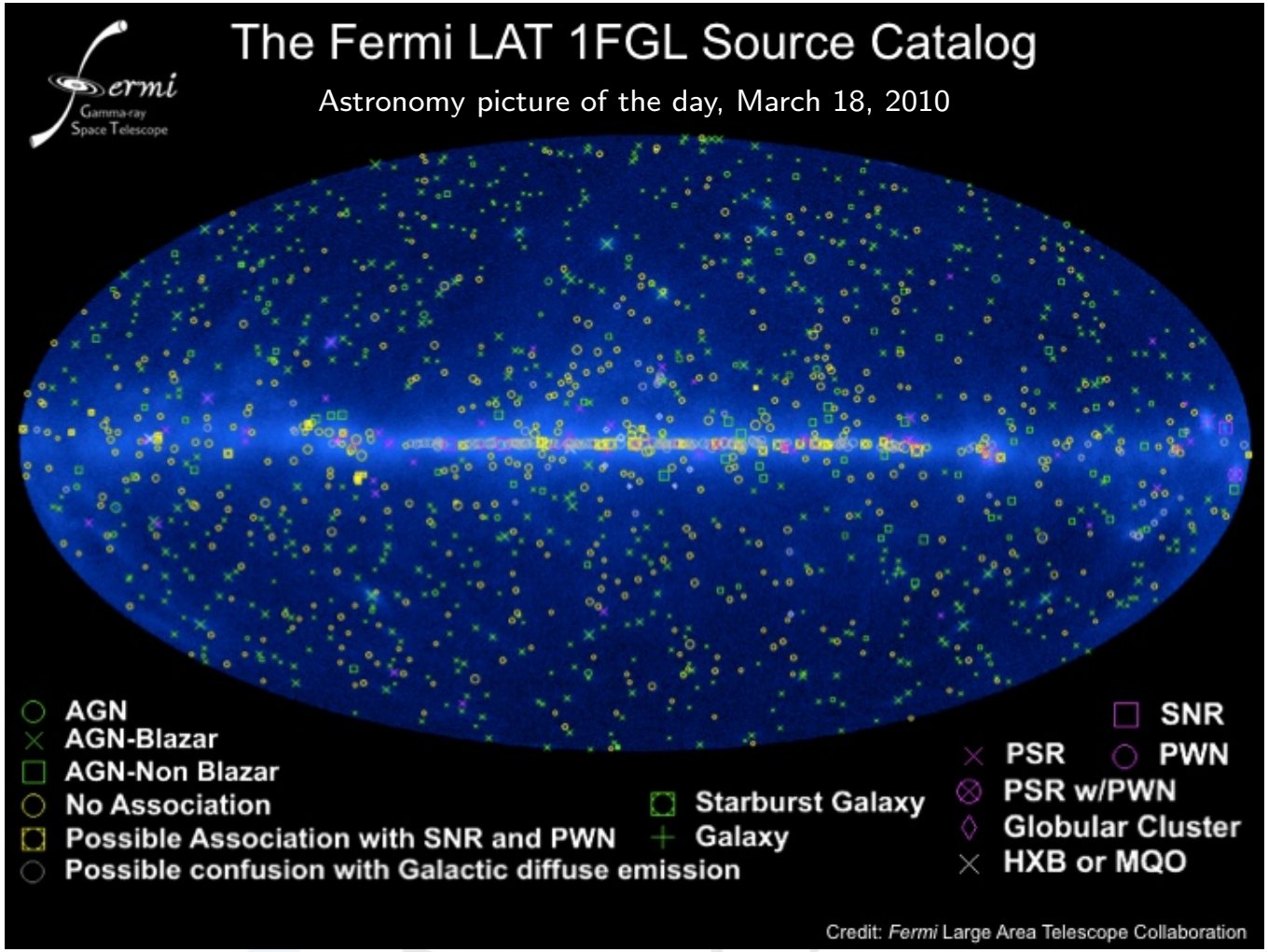


Isotropic diffuse γ
PRL, 104, 101101 (2010)



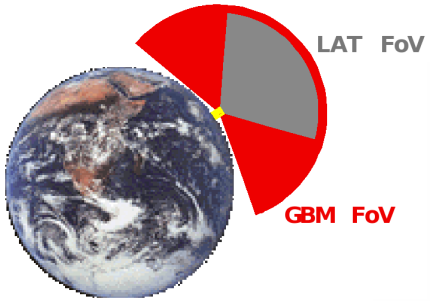
http://fermi.gsfc.nasa.gov/news/

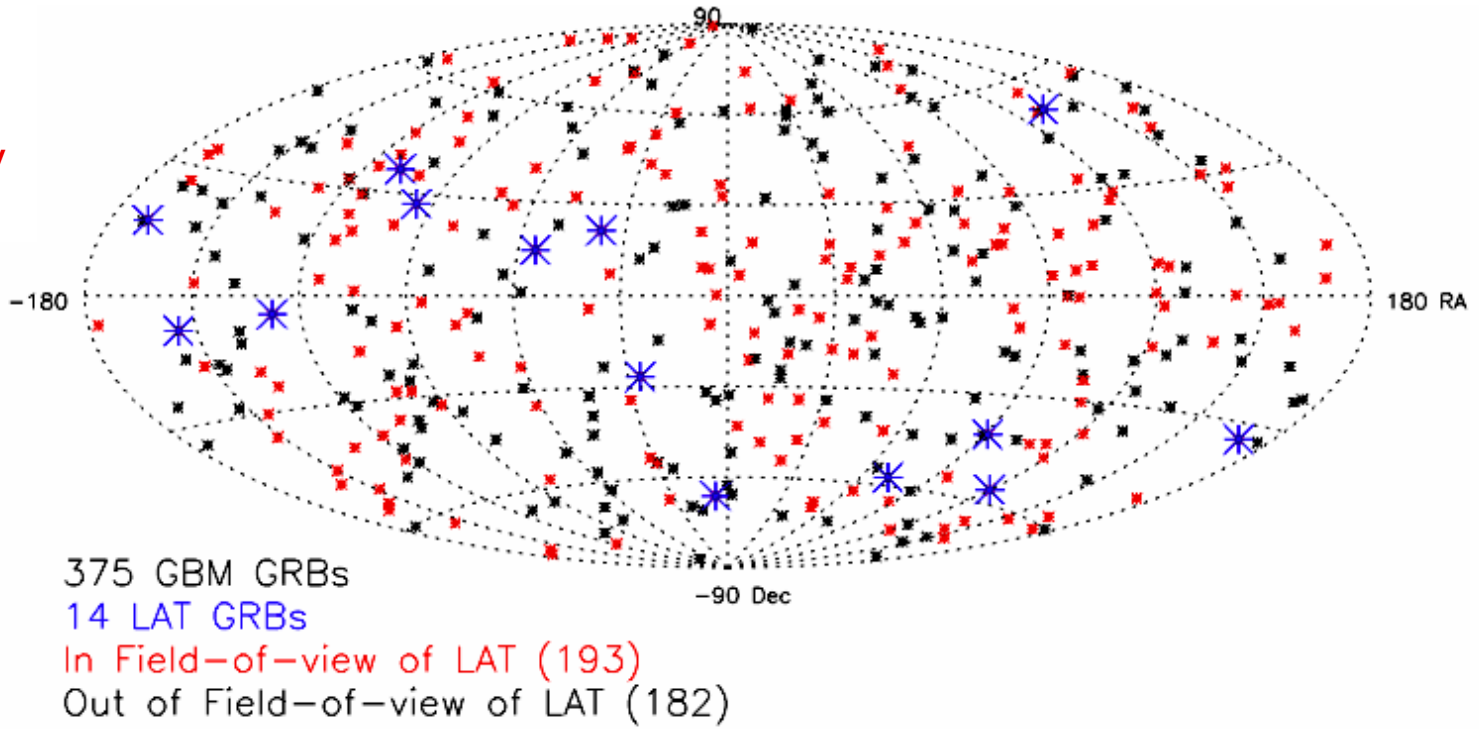
1 FGL catalog



- 1FGL catalog submitted to ApJs (arXiv:1002.2280)
  - 1451 sources (100 MeV–100GeV, TS $>$ 25), 630 unassociated
- 1LAC catalog (AGN only) submitted to ApJ

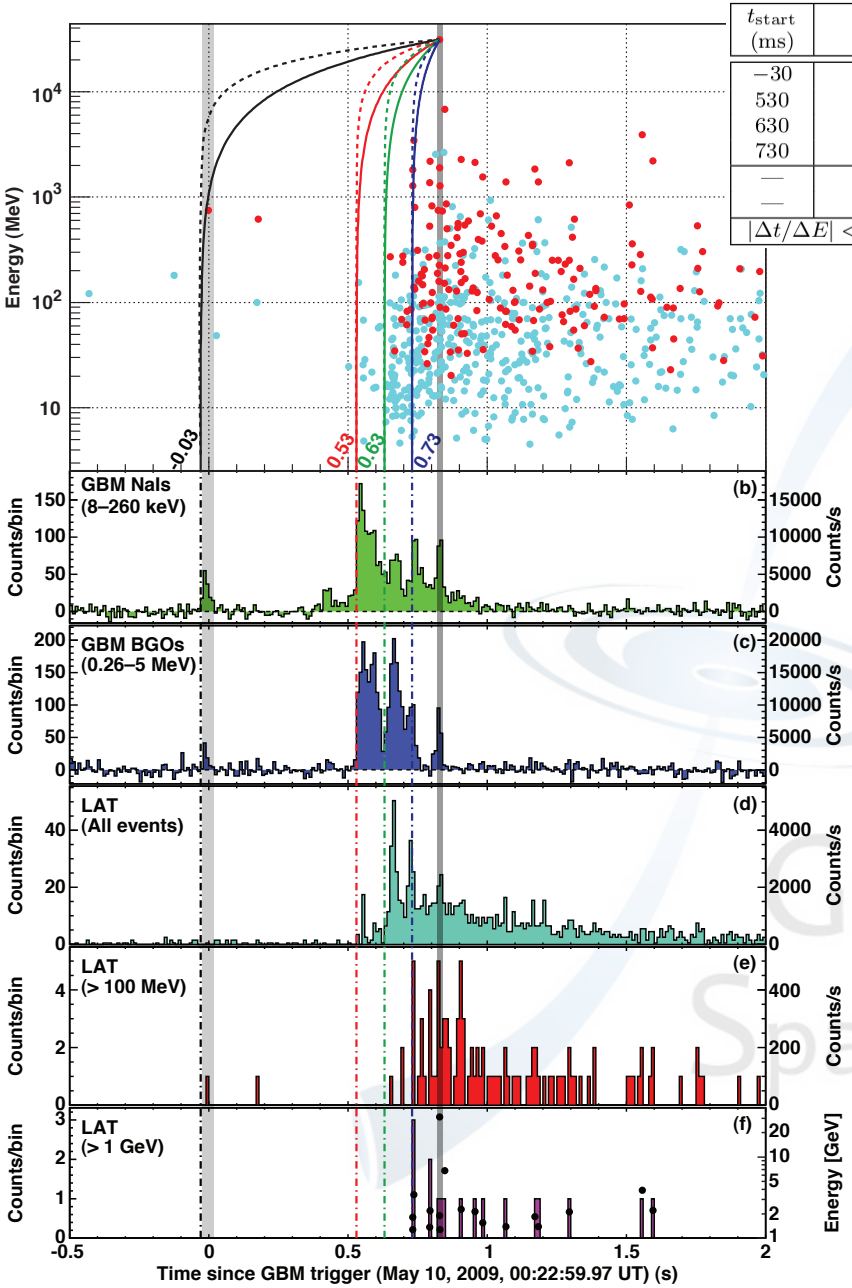
Fermi GRB catalog





- The GBM detects $\approx$ 250 bursts per year
  - $\approx$ 50% of which are in the LAT field of view
- The LAT detects $\approx$ 10% of the GBM bursts ($\approx$ 10 per year)
  - 17 detected so far, LAT GRB catalog in preparation.

Photons and time: GRBs



$t_{\rm start}$ (ms)	limit on $\lvert\Delta t\rvert$ (ms)	Reason for choice of $t_{\rm start}$ or limit on Δt	E_l (MeV)	valid for s_n	lower limit on $M_{\rm QG,1}/M_{\rm Planck}$	limit on $M_{\rm QG,2}$ in 10^{10} GeV/c^2
-30	< 859	start of any observed emission	0.1	1	$> \mathbf{1.19}$	> 2.99
530	< 299	start of main < 1 MeV emission	0.1	1	$> \mathbf{3.42}$	> 5.06
630	< 199	start of > 100 MeV emission	100	1	$> \mathbf{5.12}$	> 6.20
730	< 99	start of > 1 GeV emission	1000	1	$> \mathbf{10.0}$	> 8.79
—	< 10	association with < 1 MeV spike	0.1	± 1	$> \mathbf{102}$	> 27.7
—	< 19	if 0.75 GeV γ is from 1$^{\rm st}$ spike	0.1	-1	$> \mathbf{1.33}$	> 0.54
$\lvert\Delta t/\Delta E\rvert < 30$ ms/GeV		lag analysis of all LAT events	—	± 1	$> \mathbf{1.22}$	—

GRB science

- Can study the time structure above 100 MeV for the first time (tens of photons above 1 GeV for the brightest bursts)
- High-energy onset delayed in the vast majority of the bursts (spectral evolution)
- Synergy with other space/ground-based observatories (fast follow-up, measurement of the redshift)
- If the redshift is known, can place limits on possible Lorentz invariance violations.
- GRB 090510, 31 GeV photon after ≈ 0.9 s: models with linear LIV ruled out (mass scale $M_{QG,1} > M_{\rm Planck}$).

Pulsars

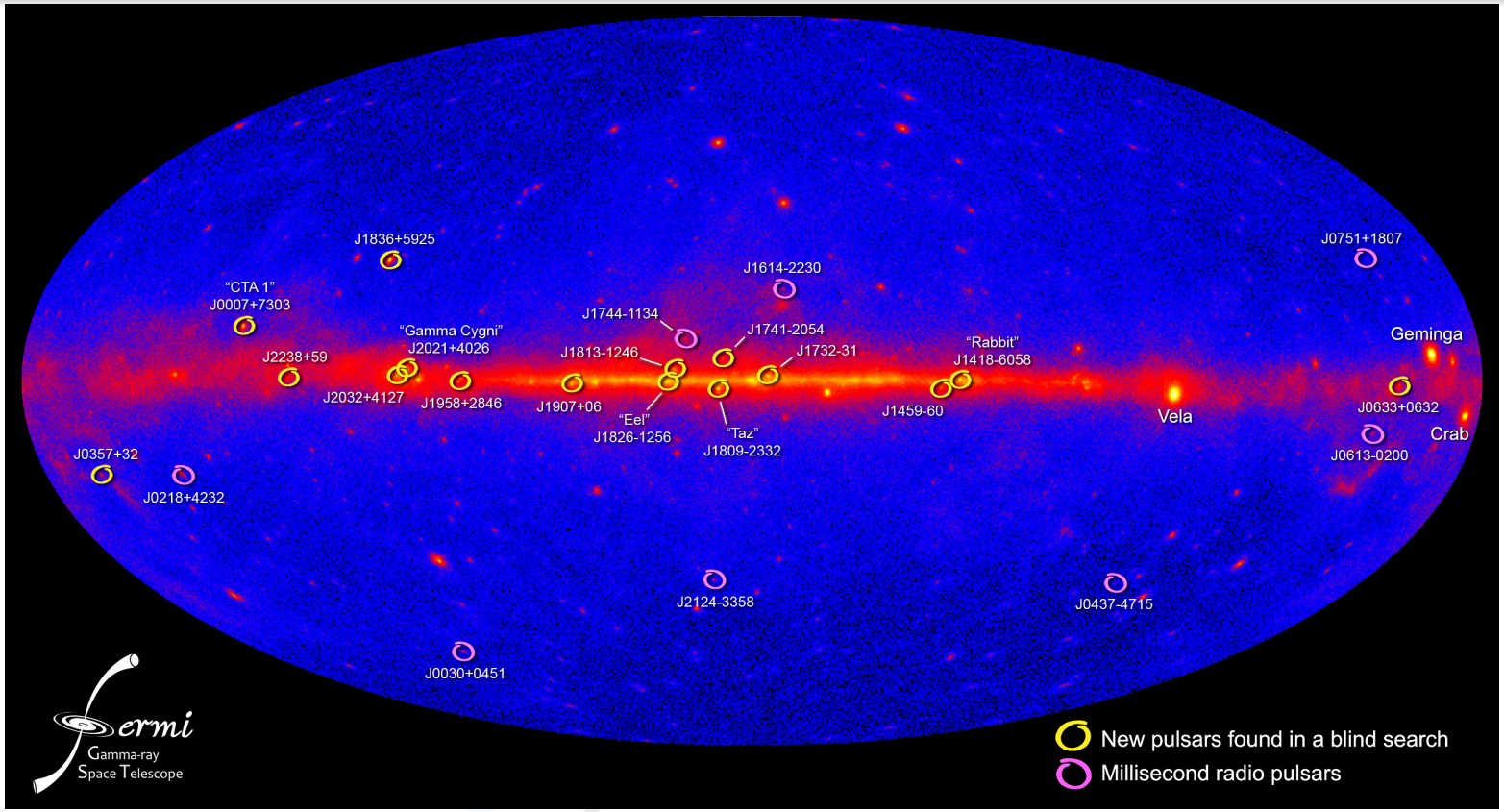
A Population of Gamma-Ray Millisecond Pulsars Seen with the Fermi Large Area Telescope
Abdo, A. A. et al. 2009, Science, 325, 848.

Discovery of high-energy gamma-ray emission from the globular cluster 47 Tucanae with Fermi
Abdo, A. A. et al. 2009, Science, 325, 845.

Detection of 16 Gamma-Ray Pulsars Through Blind Frequency Searches Using the Fermi LAT
Abdo, A. A. et al. 2009, Science, 325, 840.

Rated by Science as the 2^{nd} most significant discovery of 2009

Pulsar population studies/emission models



- # young radio-loud $\approx$ # young γ-selected $\approx$ # ms pulsars
  - $\approx 1/3$ of all ms pulsars are γ-ray pulsars
  - $\approx 1/3$ of all γ-ray pulsars are ms pulsars
- Pulsar catalog accepted by ApJS last Feb (arXiv:0910.1608)
- Near-surface emission models ruled out (no super-exp cutoff)

Cosmic-ray electron spectrum

Selected for a Viewpoint in *Physics*
PRL **102,** 181101 (2009) PHYSICAL REVIEW LETTERS week ending 8 MAY 2009

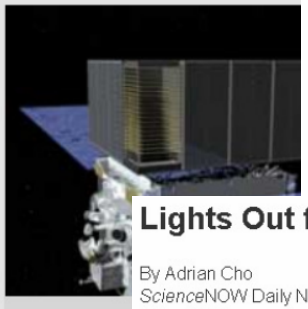
Measurement of the Cosmic Ray $e^+ + e^-$ Spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope

A. A. Abdo,[1,2] M. Ackermann,[3] M. Ajello,[3] W. B. Atwood,[4] M. Axelsson,[5,6] L. Baldini,[7] J. Ballet,[8] G. Barbiellini,[9,10] D. Bastieri,[11,12] M. Battelino,[5,13] B. M. Baughman,[14] K. Bechtol,[3] R. Bellazzini,[7] B. Berenji,[3] R. D. Blandford,[3] E. D. Bloom,[3] G. Bogaert,[15] E. Bonamente,[16,17] A. W. Borgland,[3] J. Bregeon,[7] A. Brez,[7] M. Brigida,[18,19] P. Bruel,[15] T. H. Burnett,[20] G. A. Caliandro,[18,19] R. A. Cameron,[3] P. A. Caraveo,[2]

NASA's Fermi Explores High-energy "Space Invaders" 05.04.09

Since its launch last June, NASA's Fermi Gamma-ray Space Telescope has discovered a new class of pulsars, probed gamma-ray bursts and watched flaring jets in galaxies billions of light-years away. Today at the American Physical Society meeting in Denver, Colo., Fermi scientists revealed new details about high-energy particles implicated in a nearby cosmic mystery.

"Fermi's Large Area Telescope is a state-of-the-art gamma-ray detector, but it's also a terrific tool for investigating the high-energy electrons in cosmic rays," said Alexander Moiseev, who presented the findings. Moiseev is an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md.



SLAC today

High-energy Electrons Could Come from Pulsars—or Dark Matter

by Michael Wall

Something in our

Lights Out for Dark Matter Claim?

By Adrian Cho
*Science*NOW Daily News
2 May 2009

Enlarge Image

er, data from a balloon-borne particle detector circling the South dramatic excess of high-energy particles from space--a dark matter, the mysterious substance whose gravity seems to together. But satellite data reported today stick a pin in that ers working with NASA's orbiting Fermi Gamma-ray Space

***Physics:* Cosmic light matter probes heavy dark matter**

May 4, 2009

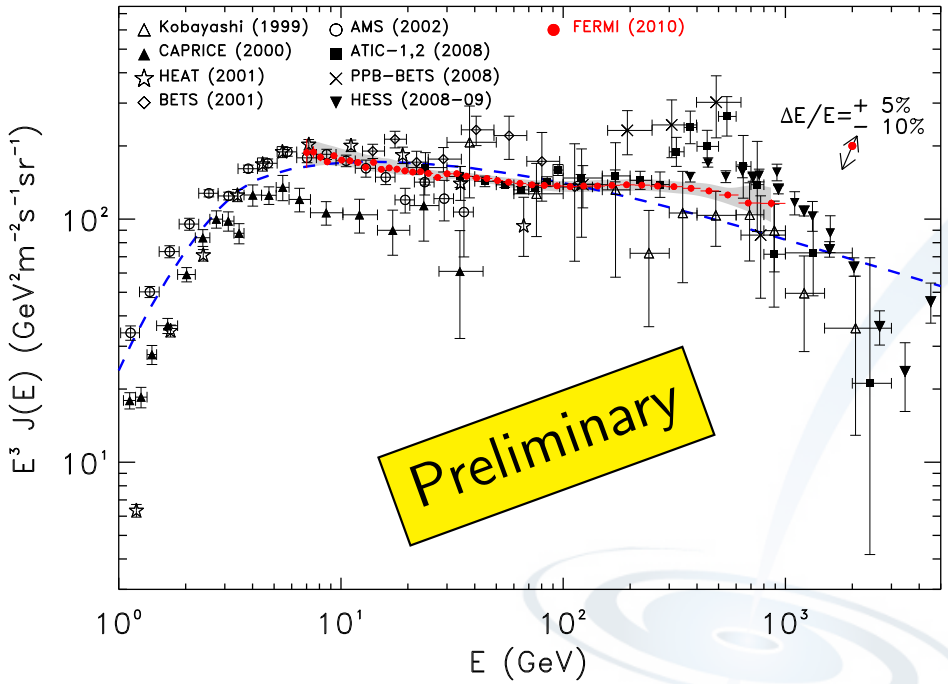
New results from the Fermi Gamma-Ray Space Telescope the most precise to date in the energy range 20 GeV to 1 TeV, should help resolve whether cosmic rays composed of the lightest charged particles, i.e., electrons and positrons, come from dark matter or some other astrophysical source.
[Viewpoint on Phys. Rev. Lett. **102,** 181101 (2009)]

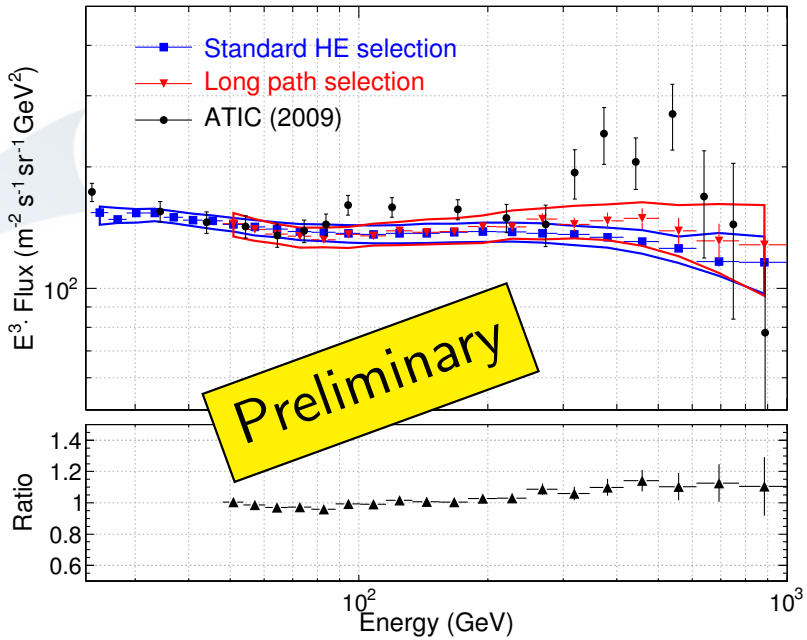
(Fermi LAT Colla

PRL, 102, 181101 (2009)

- PRL viewpoint ($\approx 0.5\%$ of the papers published by the APS)
- The most cited LAT paper, so far.
- 306 citation (194 refereed) as of yesterday

Cosmic-ray electron spectrum





- Extension to lower energies
  - 7 GeV is the lowest accessible energy for primary electrons in the Fermi orbit
- Dedicated analysis optimized for energy resolution
  - Select events with long path in the calorimeter
  - Acceptance reduced to 5% of the std analysis, $\Delta E/E < 5\%$
- Paper submitted to Physical Review D

Event reconstruction/background rejection

- Pre-launch instrument response functions served year 1 science
- Incremental improvements to the reconstruction/background rejection over the last two years
  - Based on the knowledge of the operative environment acquired in the first year of operation...
  - ...but we're not exploiting all the capabilities of the instrument
- Long term (1–2 years) for a substantial restructuring of the reconstruction and background rejection
  - Clustering/topology analysis in the calorimeter
  - New pattern recognition in the tracker
  - New ACD reconstruction
- Huge potential scientific return
  - Increase effective area, improve signal to noise
  - Open new windows (i.e. γ-ray polarization)
  - Dedicated team of ≈ 15 people (4–5 in Pisa)

Summary of Fermi LAT science publications[1]

Journal	Published	Accepted	Total
Astronomy and Astrophysics	1+1=2	-	2
Astroparticle Physics	1+2=3	-	3
Astrophysical Journal	33+3=36	5	41
Astrophysical Journal Letters	15+2=17	2	19
Astrophysical Journal Supplement	3+0=3	-	3
Journal of Cosmology and Astroparticle Physics	2+2=4	-	4
Nature	2+0=2	-	2
Physical Review D	1+0=1	-	1
Physical Review Letters	4+0=4	-	4
Science	8+0=8	-	8
Total	70+10=80	7	87

Papers submitted to journals: 15
Near submission: 2

Astronomers' telegrams: 88

GCN circulars: 25

10 with corresponding authors from Pisa

- Cosmic-ray electrons (3)
- Gamma-ray bursts (3)
- Pulsars (4)

[1] As of June 21, 2010

Attività a Pisa per il 2010/2011

- Collaboration management
  - SSAC, Speakers Bureau
- Instrument calibration and performance
  - Validation of simulations
  - Upgrade of the background model
  - Post-launch performance updates
  - (Major) upgrade of the reconstruction strategy
  - Background rejection
- Instrument operations
  - Data processing pipeline operation
  - Data monitoring infrastructure maintenance and upgrade
  - Data monitoring shifts

Attività a Pisa per il 2010/2011

- Cosmic-ray electron analysis
  - Group coordination (meetings, papers)
  - Search for anisotropies in the arrival directions
  - Measurement of the positron fraction
- Gamma-ray burst
  - Burst advocate shifts
  - Temporal/spectral analysis
- Pulsars
  - Pulsar catalog
  - Blind search
- Diffuse gamma emission
  - High-energy (> 100 GeV) extragalactic diffuse emission
  - Correlation with the Cosmic-ray electron measurements

Gruppo Fermi INFN-Pisa

Nome	Affiliazione	Percentuale
R. Bellazzini	INFN (Project Manager Fermi-Italia)	100%
A. Brez	INFN	100%
G. Spandre	INFN	100%
M. Kuss	INFN	100%
F. Angelini	Università di Pisa	60%
M. M. Massai	Università di Pisa	100%
E. Pian	SISSA (on leave SNS)	50%
S. Shore	Università di Pisa	50%
L. Baldini	INFN (assegnista INFN)	100%
N. Omodei	currently at SLAC	0%
J. Bregeon	INFN (borsista INFN)	100%
D. Grasso	INFN (art. 2222)	50%
L. Latronico	INFN (art. 23)	100%
C. Sgrò	INFN (art. 23)	100%
M. Razzano	INFN (assegnista per il 2011)	100%
M. Pesce-Rollins	INFN (assegnista per il 2011)	100%
D. Gaggero	Università di Pisa (dottorando)	100%
	Totale FTE	14.1
M. Ceccanti	Tecnico alte tecnologie	
M. Minuti	Tecnico elettronico	
M. Pinchera	Ingegnere meccanico	
A. Burato	Ingegnere elettronico	

Richieste finanziarie anno 2011

Capitolo	Voci specifiche	Subtotale	Totale[2]
Apparati	Operating Common Funds	140	140
Materiale inventariabile	Storage, espansioni memoria, licenze software	10	23
	Worker nodes farm di Pisa	10	
	Server analisi di gruppo	3	
Consumo	Metabolismo e manteinance strumentazione e camera pulita	30	30
Missioni estero	Viaggi e missioni Project Manager	20	193
	5 mu a SLAC per turni ISOC	41	
	3 collaboration meeting per 8 persone per 1 settimana	50	
	10 mu per missioni per SWG (analisi, coordinamento simulazioni)	82	
Missioni Italia	Riunioni collaborazione Italiana	20	35
	Riunioni di lavoro per analisi e coordinamento	15	
Totale			421

[2] Richieste finanziarie in keuro, profilo di spesa costante per i prossimi 3 anni

Richieste personale sezione anno 2011

Descrizione	Attività	Lavoro
Centro di calcolo	Setup e manutenzione macchine per simulazione/ricostruzione (5 worker nodes GRID)	5% farm[3] (CPU+storage)
	Setup e manutenzione server di analisi e storage centralizzato (10 TB)	

[3] 0.15 FTE, 2 mu per 3 FTE