Recent Physics Results from *Fermi* LAT

Pheno2012

9 May 2012

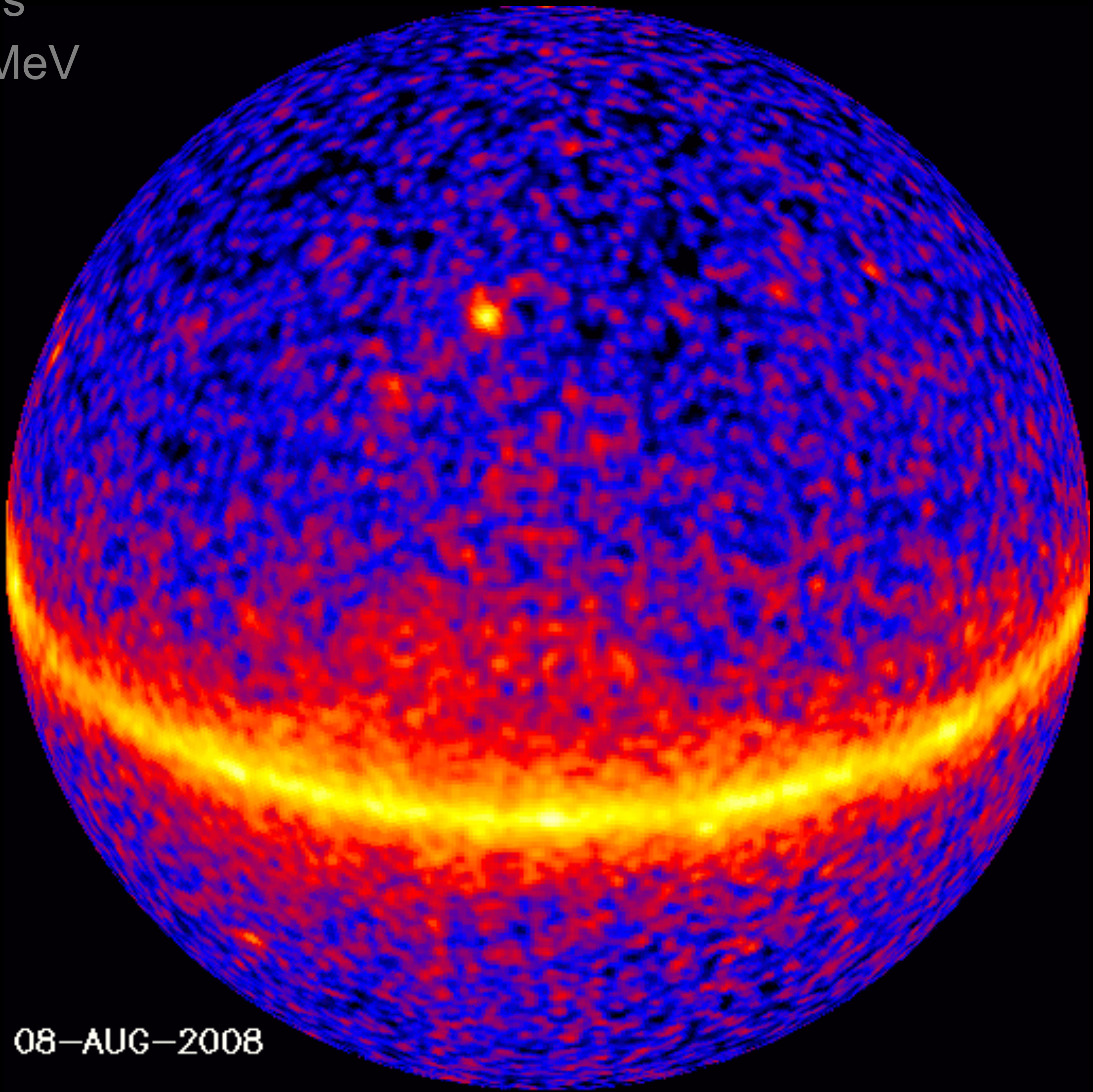
S. Ritz
ritz@scipp.ucsc.edu

on behalf of the Fermi Mission Team

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

The Variable Gamma-ray Sky

36 months
E > 100 MeV

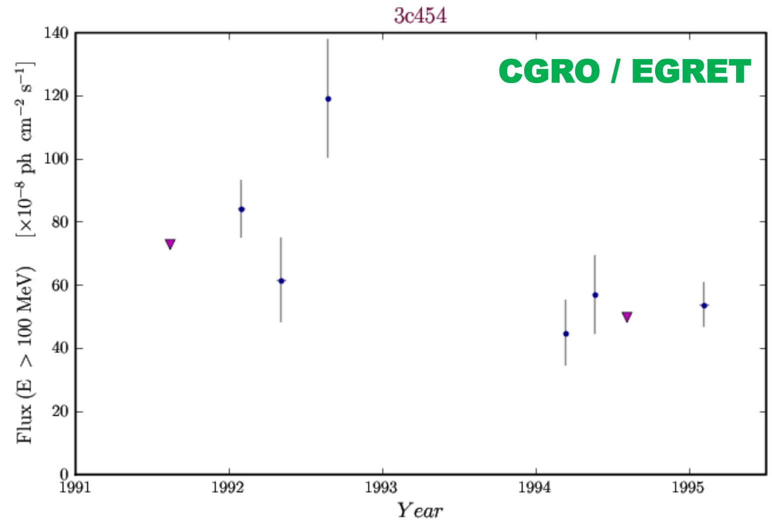


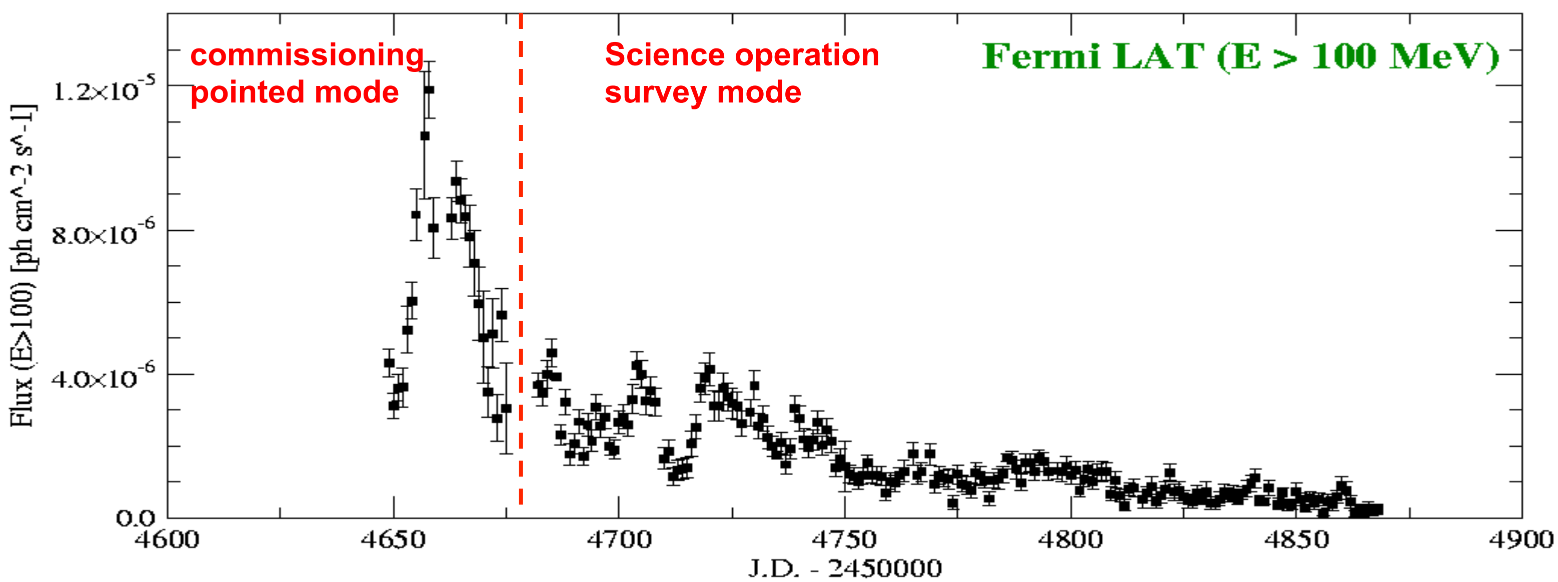
many transients in the γ-ray sky

with time, deeper exposure has revealed many new sources and new source classes

Example of all-sky payoff: 3C454.3

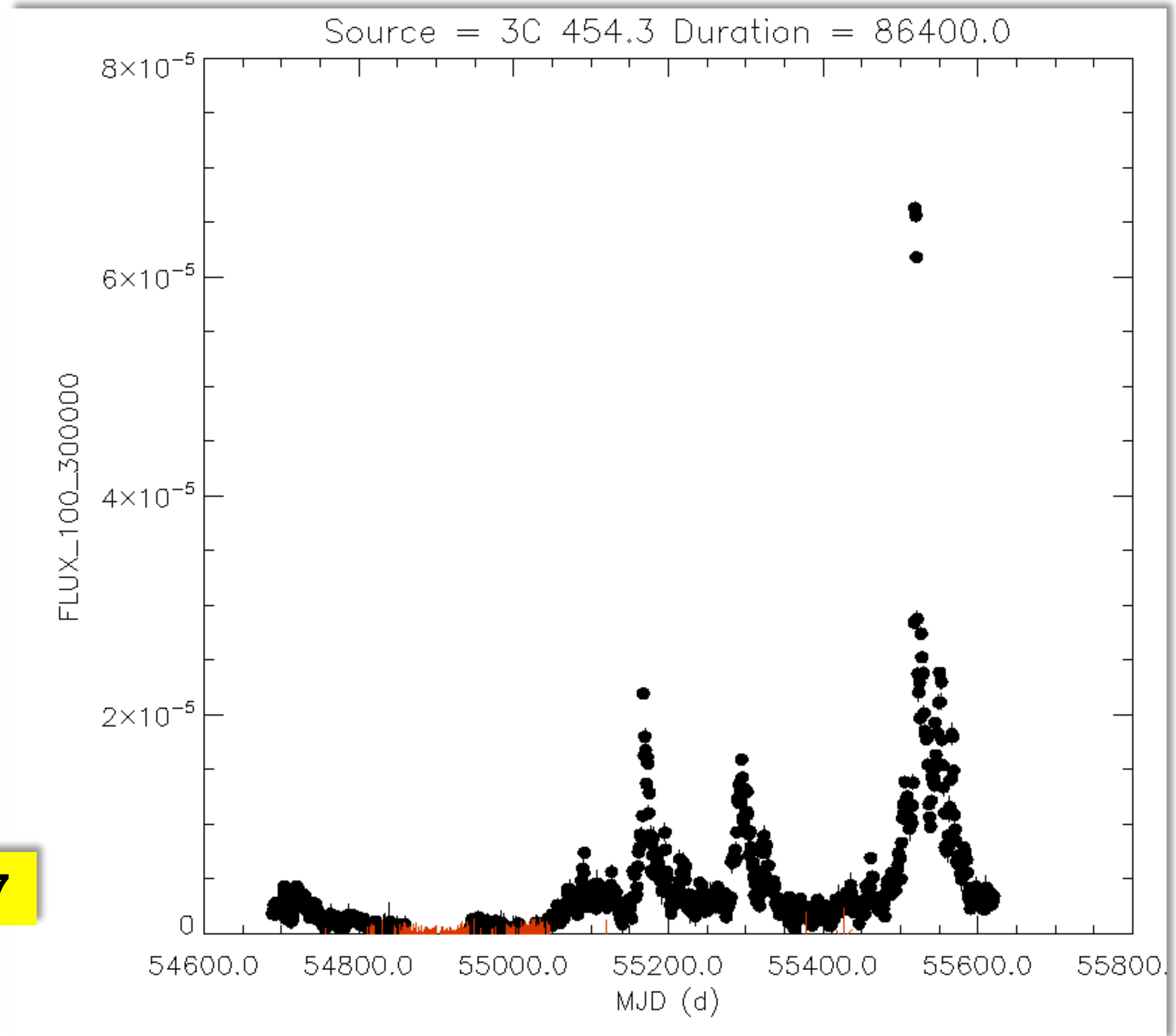
- **Well-known radio source at z = 0.859; also detected by EGRET, AGILE**





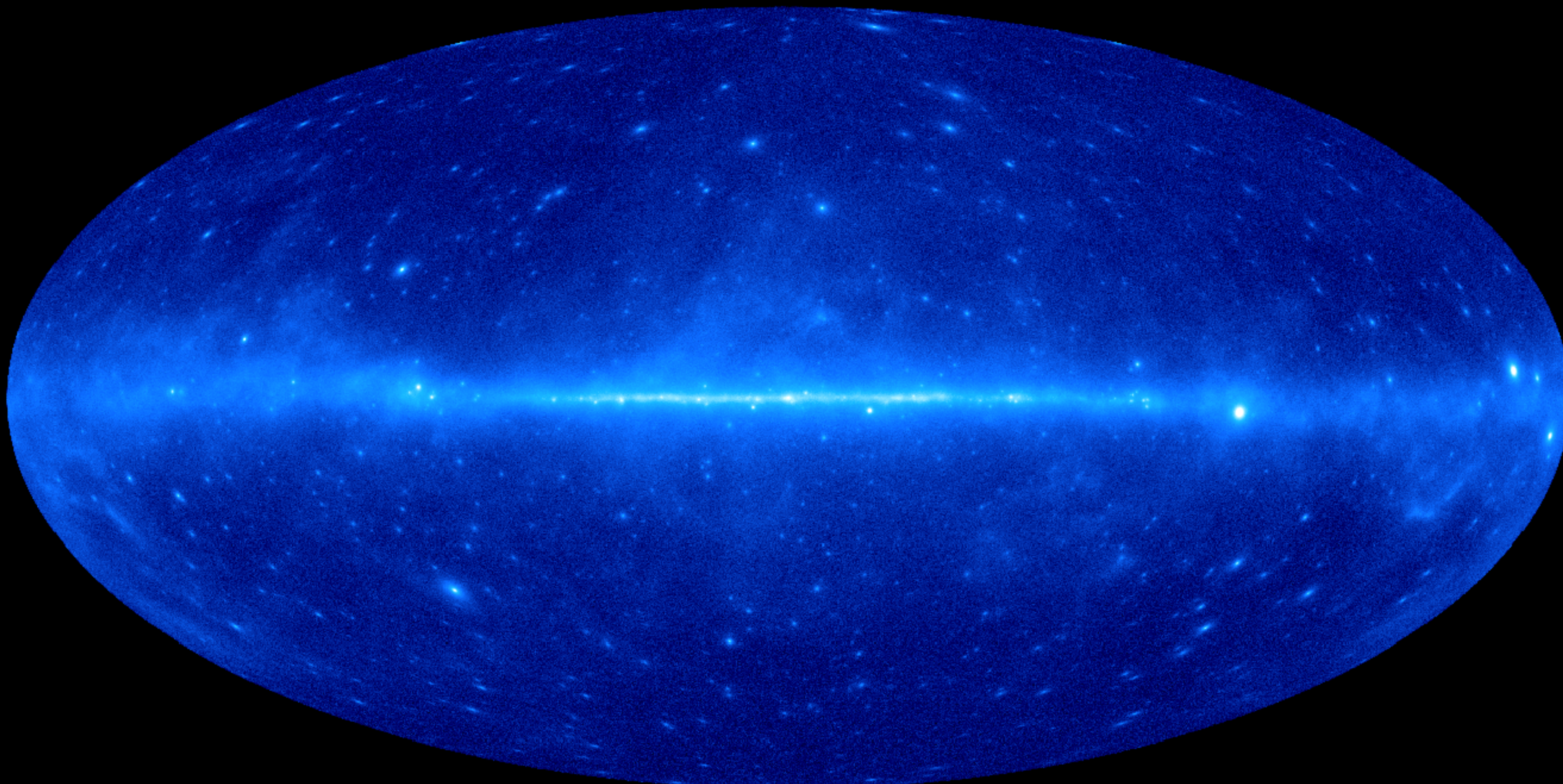
3C454.3

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

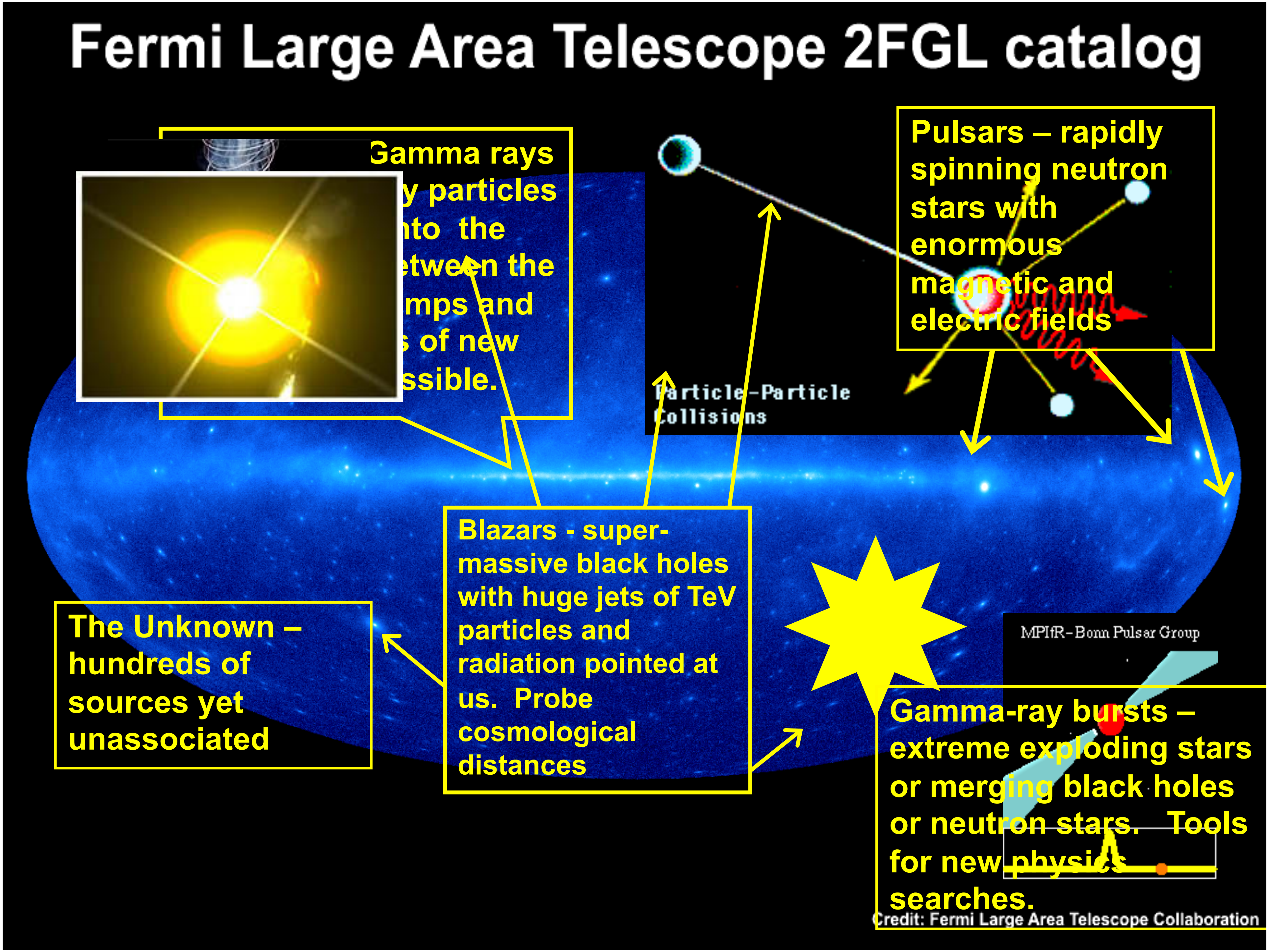


Also see **arXiv:1102.0277**

Fermi Large Area Telescope 2FGL catalog



Credit: Fermi Large Area Telescope Collaboration



Fermi Large Area Telescope 2FGL catalog
Gamma rays
y particles
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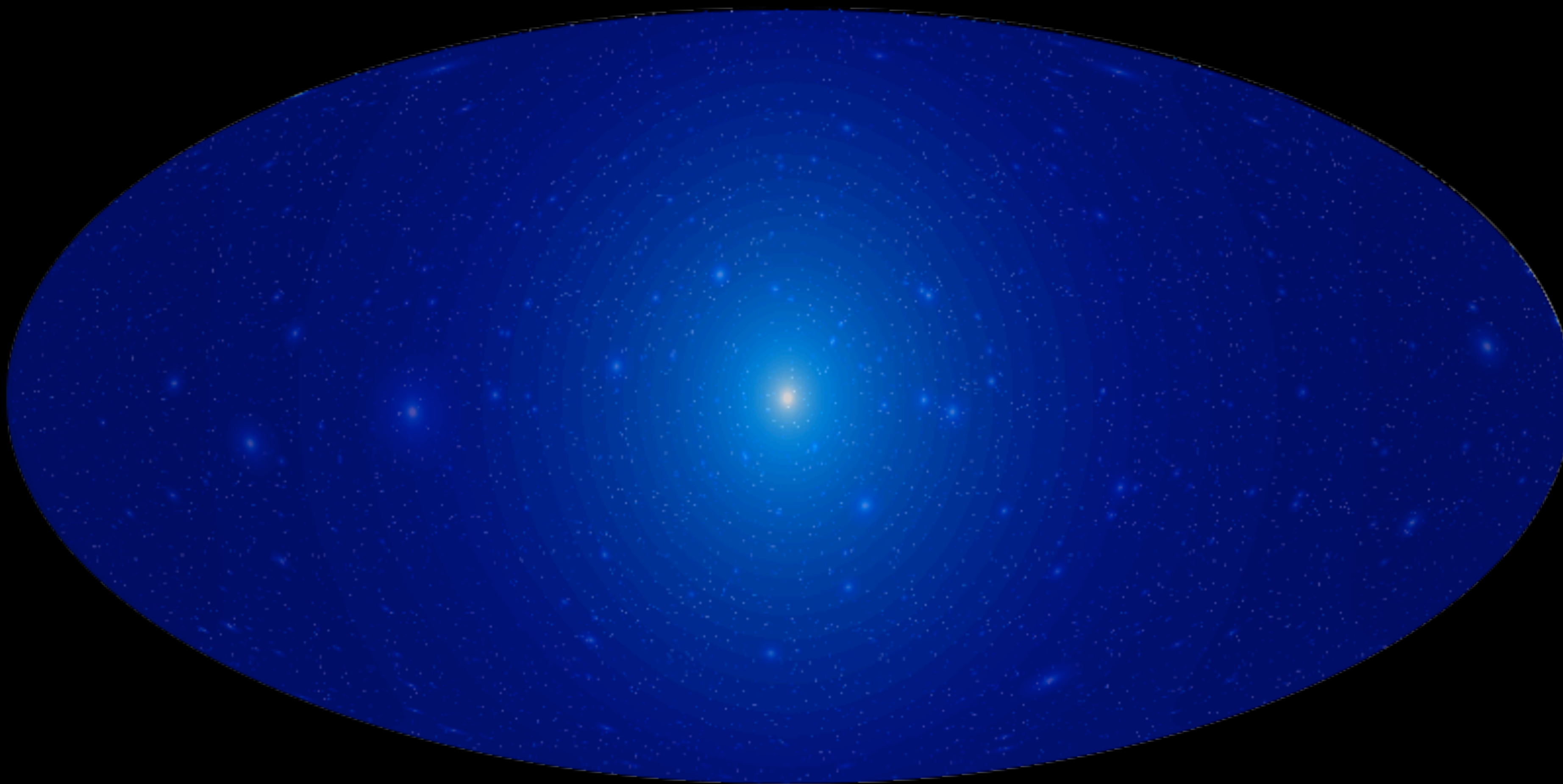
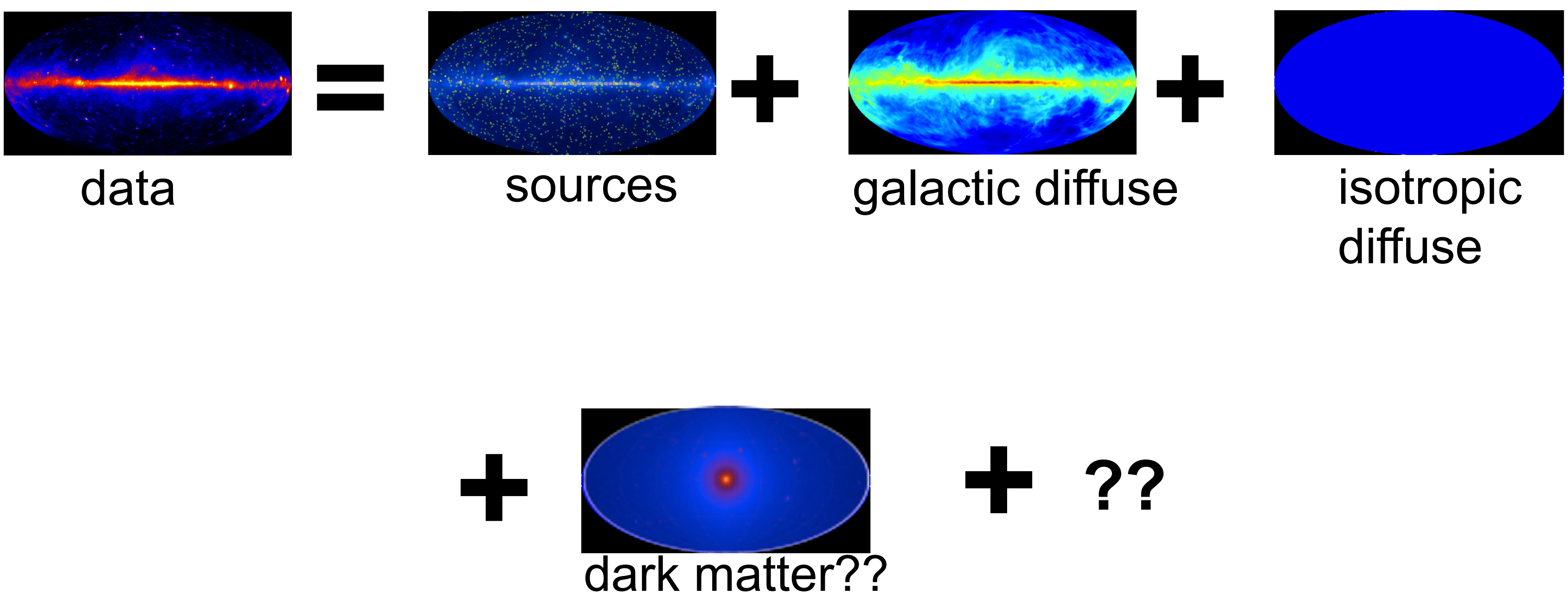
mps and
s of new
ssible.
Particle-Particle Collisions
Pulsars – rapidly spinning neutron stars with enormous magnetic and electric fields
Blazars - super-massive black holes with huge jets of TeV particles and radiation pointed at us. Probe cosmological distances
The Unknown – hundreds of sources yet unassociated
MPIfR-Bonn Pulsar Group
Gamma-ray bursts – extreme exploding stars or merging black holes or neutron stars. Tools for new physics searches.
Credit: Fermi Large Area Telescope Collaboration



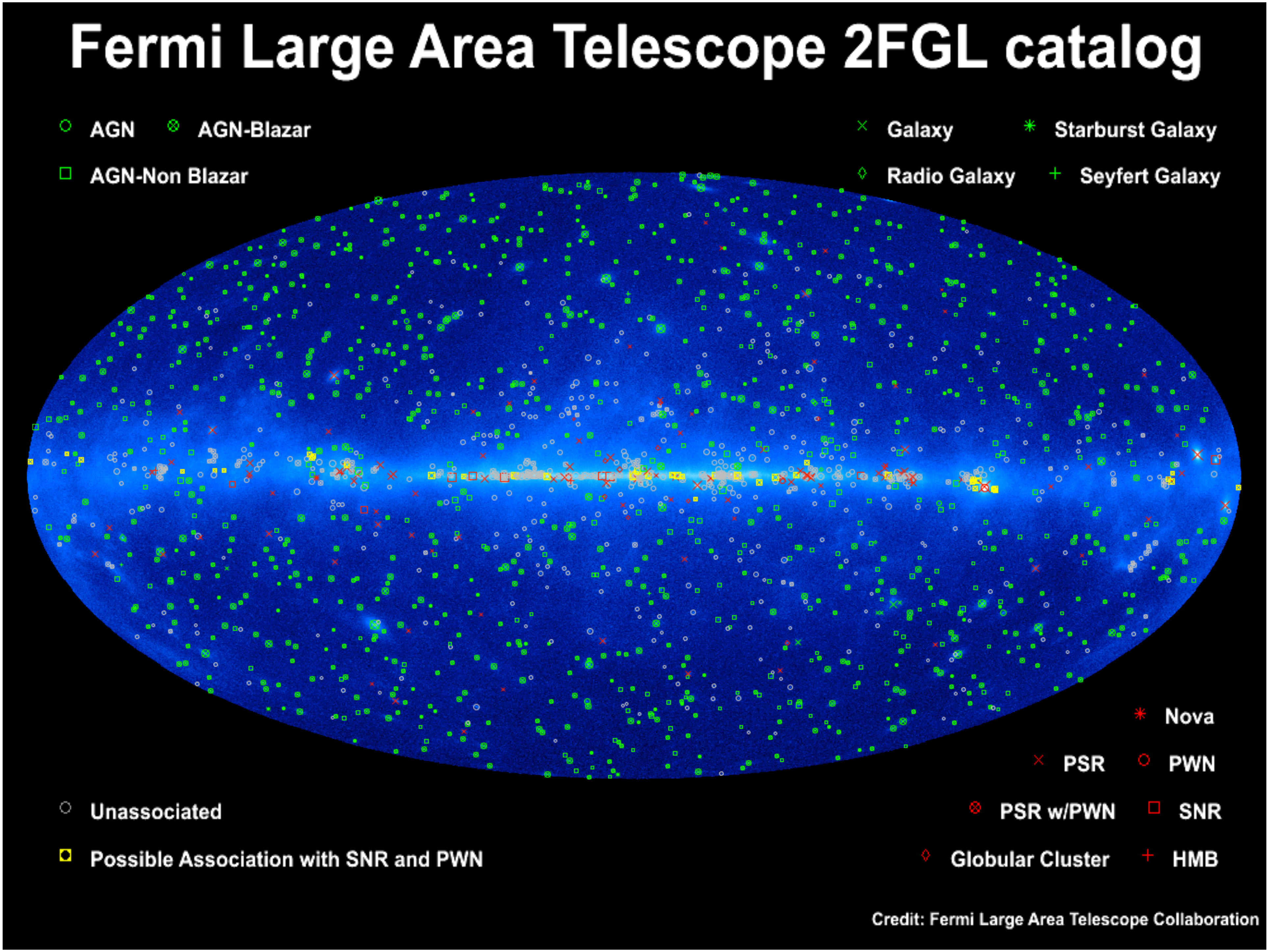
Gamma rays expected from Dark Matter Annihilation

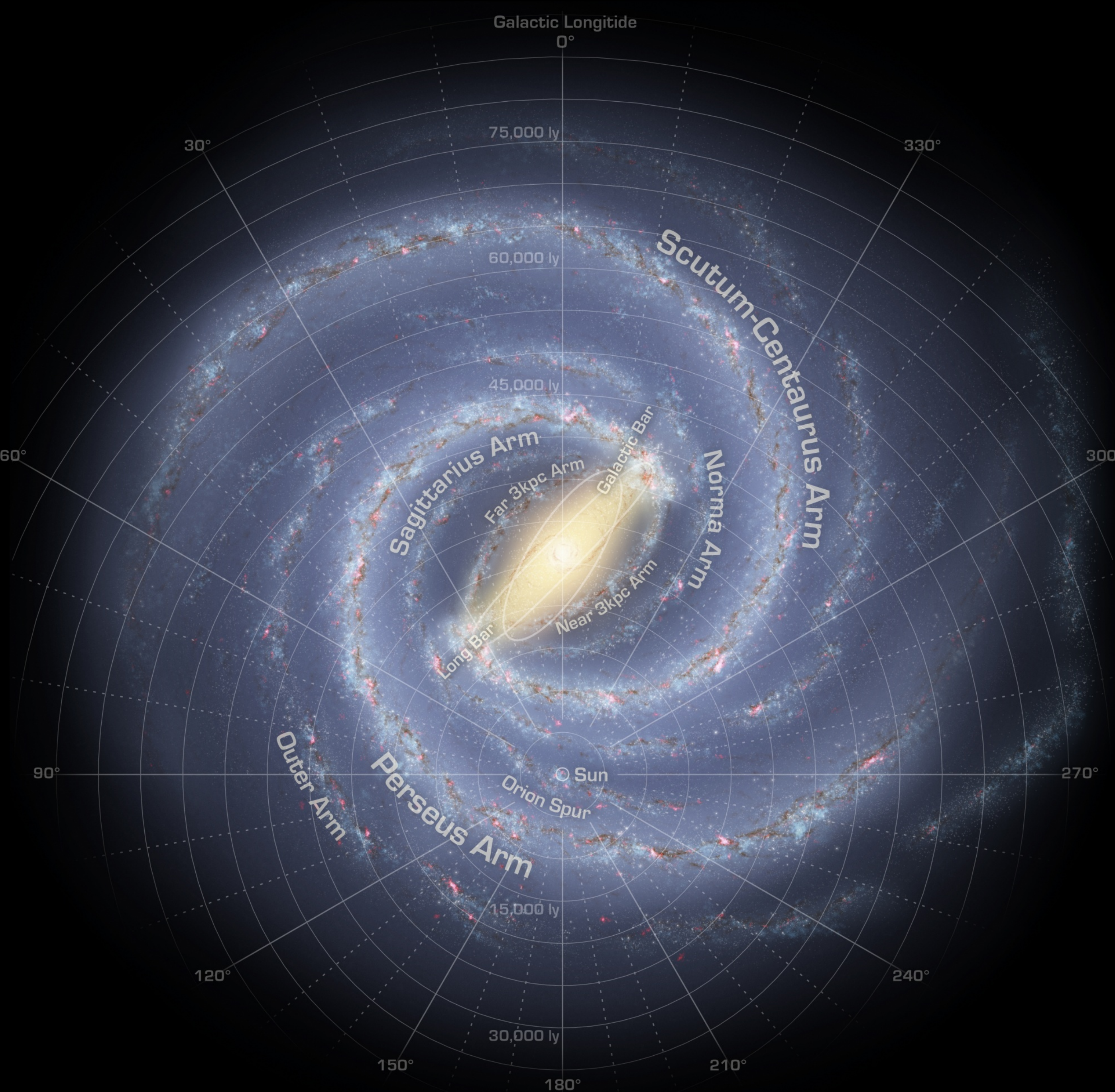
Gamma rays from dark matter annihilation

Understanding the Gamma-ray Sky



Bootstrapped, iterative process

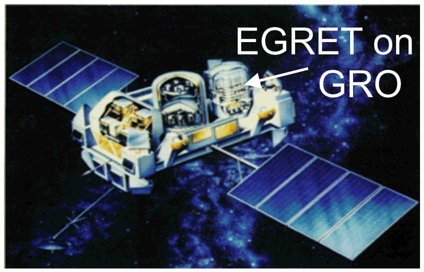

Fermi Large Area Telescope 2FGL catalog
AGN
AGN-Blazar
AGN-Non Blazar
Galaxy
Starburst Galaxy
Radio Galaxy
Seyfert Galaxy
Nova
PSR
PWN
PSR w/PWN
SNR
Globular Cluster
HMB
Unassociated
Possible Association with SNR and PWN
Credit: Fermi Large Area Telescope Collaboration

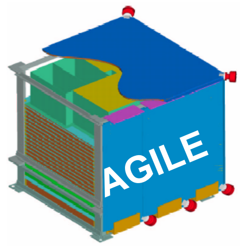


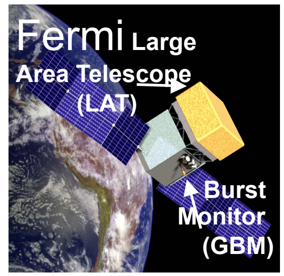
Credit: R. Hurt

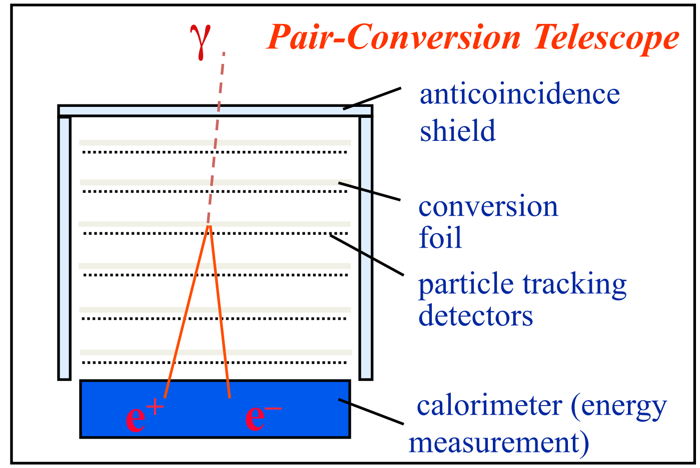
HE Gamma-ray Experiment Techniques

- Space-based:
  - use pair-conversion technique





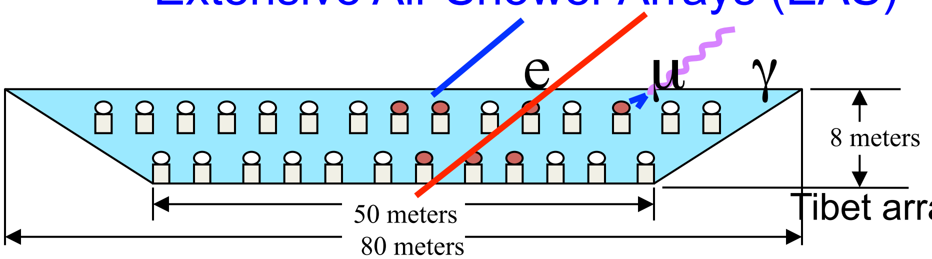




- Ground-Based:
  - Atmospheric Cerenkov Telescopes (ACTs)

image the Cerenkov light from showers induced in the atmosphere. Examples: VERITAS, MAGIC, HESS; CTA.

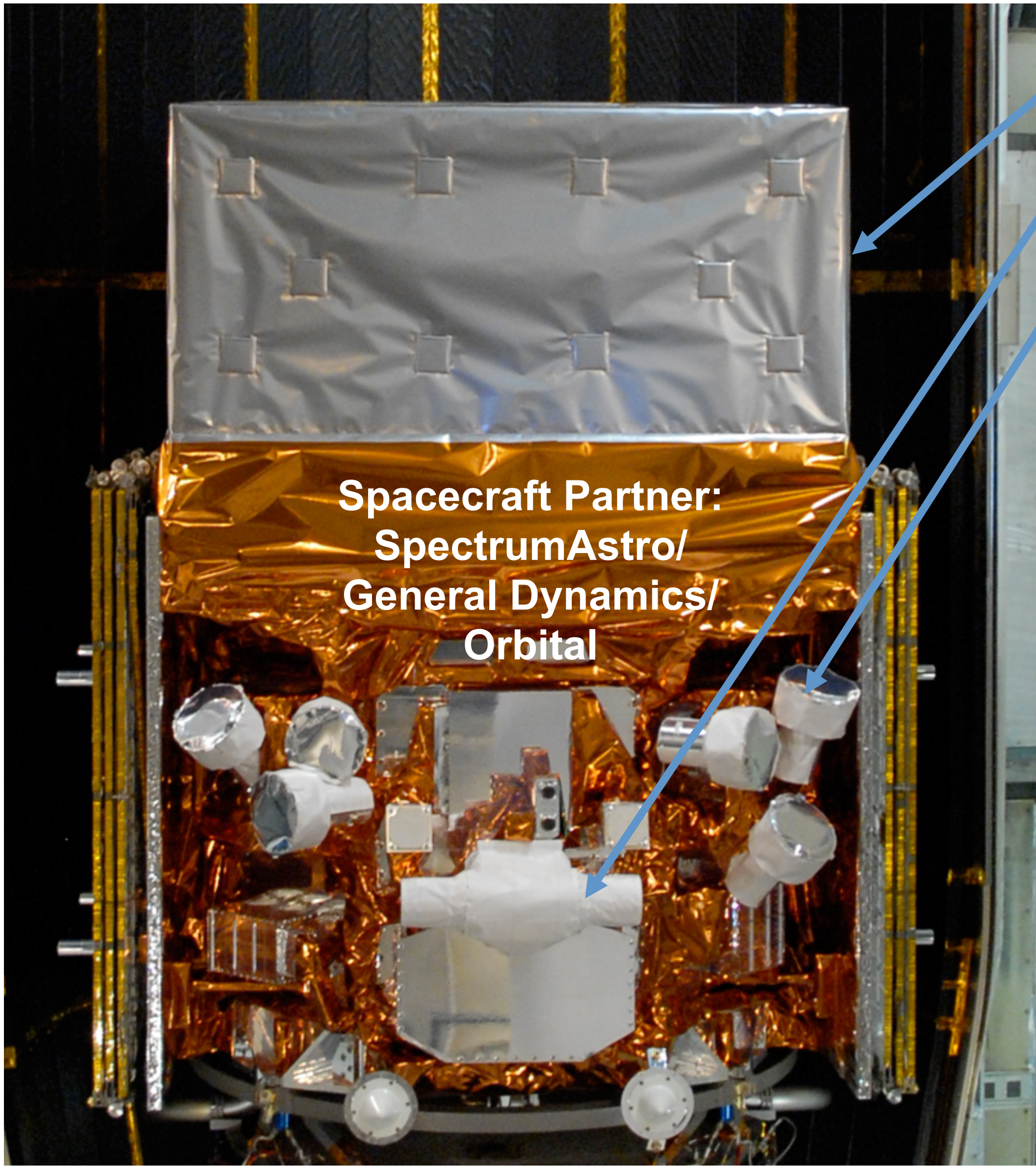
  - Extensive Air Shower Arrays (EAS)



Tibet array

Directly detect particles from the showers induced in the atmosphere. Example: Milagro; HAWC,

The Observatory, Spring 2008



Large AreaTelescope (LAT)
20 MeV - >300 GeV

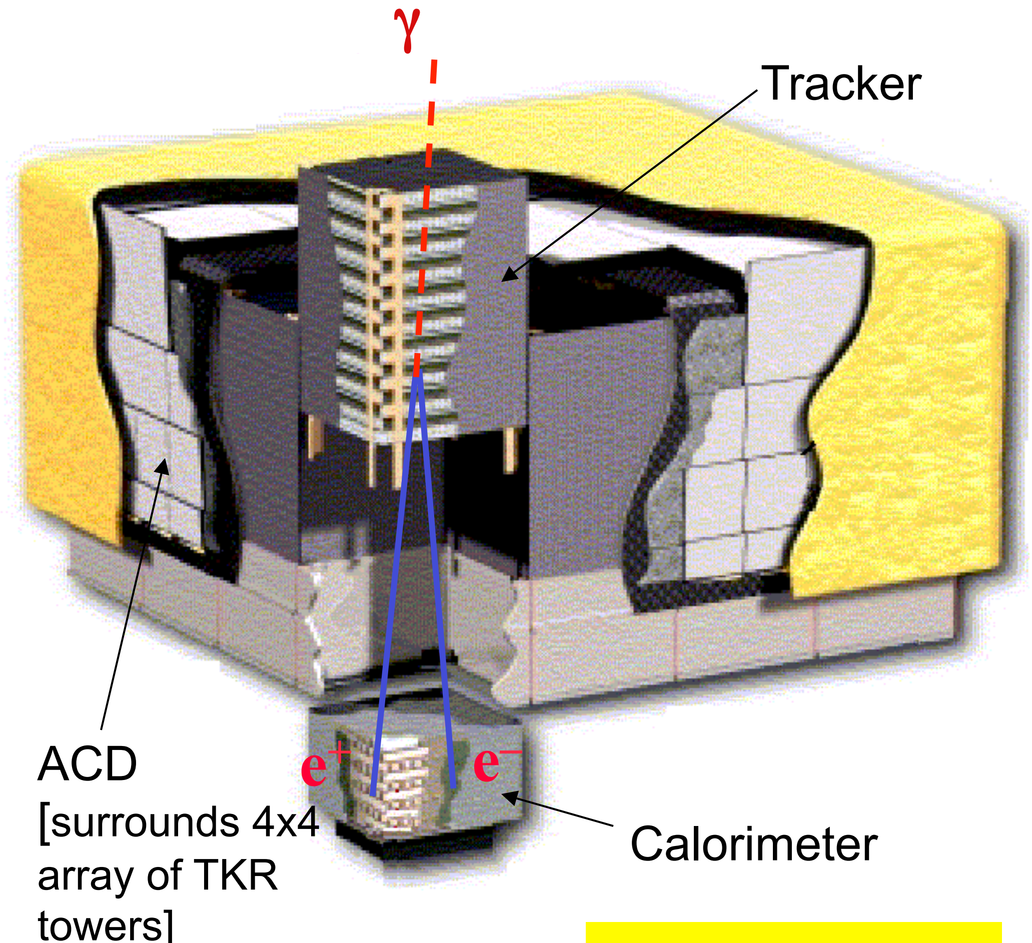
Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

KEY FEATURES

- **Huge field of view**
  - **–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.**
- **Huge energy range, including largely unexplored band 10 GeV - 100 GeV. Total of >7 energy decades!**
- **Large leap in all key capabilities. Great discovery potential.**

LAT Overview

- Precision Si-strip Tracker (TKR) Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter (CAL) Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.

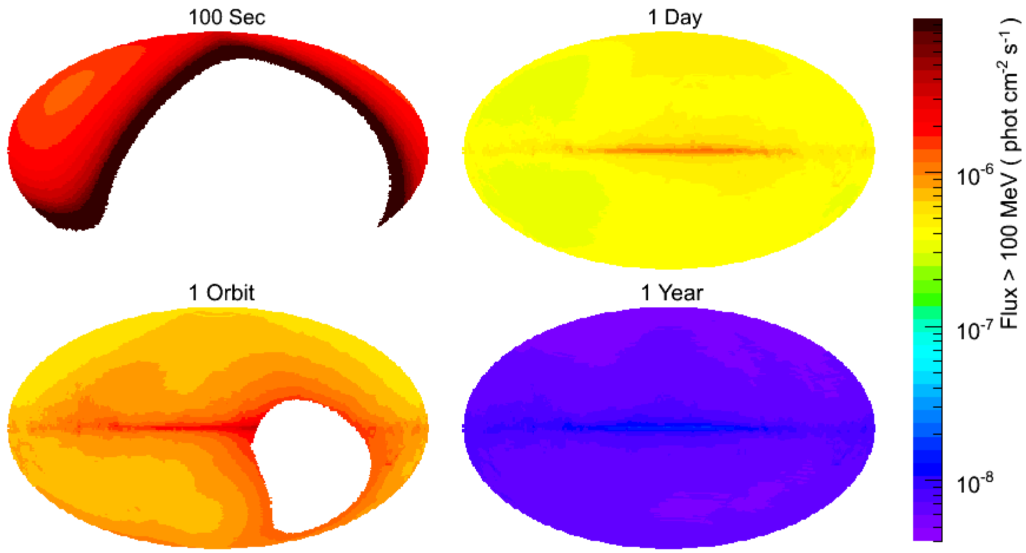


Atwood et al, ApJ

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

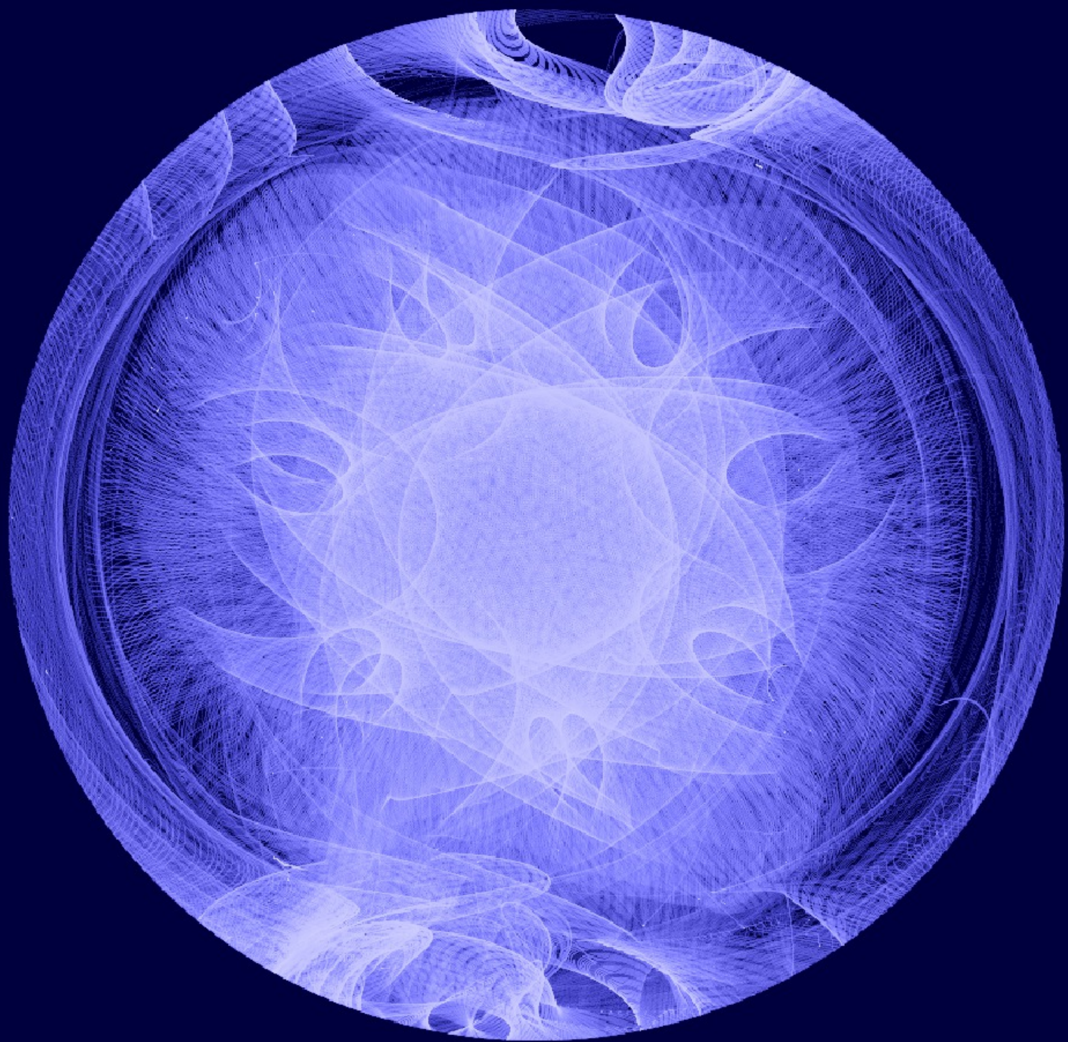
Operating modes

- Primary observing mode is Sky Survey
  - Full sky every 2 orbits (3 hours)
  - Uniform exposure, with each region viewed for ~30 minutes every 2 orbits
  - Best serves majority of science, facilitates multiwavelength observation planning
  - Exposure intervals commensurate with typical instrument integration times for sources
  - EGRET sensitivity reached in days



- **Pointed observations when appropriate (limited fraction, and selected by peer review) with automatic earth avoidance selectable. Target of Opportunity pointing.**
- **Autonomous repoints for onboard GRB detections in any mode.**

Recent APOD



http://apod.nasa.gov/apod/ap120504.html

Non-trivial "Trivia" (circa Fall 2011)

- >200 billion LAT event triggers
- GBM Triggers: >1600 (809 GRB, 214 TGF, >300 other transients and 190 solar flares)
- # Autonomous Repoint Requests (ARR): 75
- Highest-z LAT GRB: 4.35
- Highest-energy photon from a GRB: 33 GeV (at 82s, z=1.82)
- Highest-z LAT AGN: 3.1
- Highest-energy photon candidate event: 4 TeV
- # Gamma-ray pulsars: 101
  - # Young (radio-selected): 38
  - # Millisecond Pulsars (MSPs): 27
  - # Gamma-ray-selected (radio-blind) pulsars: 36
  - # new radio MSPs due to LAT data: 35
- Public data access: >8TB

Some Fermi Highlights

- Discovery and study of >101 gamma-ray pulsars, 36 of which are seen to pulse only in gamma rays. 27 are ms pulsars.
  - 35 new ms radio pulsars discovered thanks to LAT data!
- Remarkable high-energy emission from gamma-ray bursts
  - Starting to see what was missing
  - Also 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
- First Fermi 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 and supernova remnants. Probing the cosmic-ray distributions in other galaxies; LMC and SMC.
- Extragalactic Background Light constraints
- New limits on large extra dimensions
- Crab short *flares*
- 2nd catalog: 1873 sources

>190 LAT papers out…

Fermi LAT Publications 5/10/10 2:22 PM

Publications

Exploring the Extreme Universe

Home | Mission | Instrument | Collaboration | Institutions | Publications | NASA | Pictures | Internal

Fermi LAT collaboration publications

Select a topic: All

Links:

- How we classify papers by collaboration members
- Independent publications by LAT collaboration members (Category III)
- Ph. D. dissertations
- Rapid publications: ATel and GCN
- Proceedings of the 2009 Fermi Symposium
- Pre-launch publications

2010

Gamma-ray Spectral Evolution of NGC 1275 Observed with Fermi LAT
Kataoka, J. et al. 2010, ApJ, 715, 554 doi: 10.1088/0004-637X/715/1/554
arXiv: 1004.2352
ADS: 2010ApJ...715..554K BibTeX Citations
SPIRES

The First Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope
Abdo, A. A. et al. 2010, ApJ, 715, 429 doi: 10.1088/0004-637X/715/1/429
arXiv: 1002.0150
ADS: 2010ApJ...715..429A BibTeX Citations
SPIRES

Detection of the energetic pulsar PSR B1509-58 and its pulsar wind nebula in MSH 15-52 using the Fermi Large Area Telescope
Abdo, A. A. et al. 2010, ApJ, 714, 927 doi: 10.1088/0004-637X/714/1/927
arXiv: 1003.3833
ADS: 2010ApJ...714..927A BibTeX Citations
SPIRES

The discovery of gamma-ray emission from the blazar RGB J0710+591

http://www-glast.stanford.edu/cgi-bin/pubpub Page 1 of 14

Fermi LAT Publications 5/10/10 2:22 PM

Abdo, A. A. et al. 2010, Phys. Rev. Lett., 104, 101101 doi: 10.1103/PhysRevLett.104.101101
arXiv: 1002.3603
ADS: 2010PhRvL.104j1101A BibTeX Citations

ADS: 2010ApJS..187..460A BibTeX Citations
SPIRES

Constraints on Cosmological Dark Matter Annihilation from the Fermi-LAT Isotropic Diffuse

Acciari, V. A. et al. 2010, ApJL, 715, L49 doi: 10.1088/2041-8205/715/1/49
arXiv: 1005.0041
ADS: 2010ApJ...715L..49A BibTeX Citations
SPIRES

Fermi-Large Area Telescope Observations of the Exceptional Gamma-Ray Outbursts of 3C 273 in 2009 September
Abdo, A. A. et al. 2010, ApJL, 714, L73 doi: 10.1088/2041-8205/714/1/L73
ADS: 2010ApJ...714L..73A BibTeX Citations

Fermi Gamma-ray Imaging of a Radio Galaxy
Abdo, A. A. et al. 2010, Science, 328, 725 doi: 10.1126/science.1184656
ADS: 2010Sci...328..725A BibTeX Citations
Public: Abstract Full text

The Vela Pulsar: Results from the First Year of Fermi LAT Observations
Abdo, A. A. et al. 2010, ApJ, 713, 154 doi: 10.1088/0004-637X/713/1/154
arXiv: 1002.4050
ADS: 2010ApJ...713..154A BibTeX Citations
SPIRES

Fermi-LAT Observations of the Vela X Pulsar Wind Nebula
Abdo, A. A. et al. 2010, ApJ, 713, 146 doi: 10.1088/0004-637X/713/1/146
arXiv: 1002.4383
ADS: 2010ApJ...713..146A BibTeX Citations
SPIRES

Fermi Large Area Telescope observations of PSR J1836+5925
Abdo, A. A. et al. 2010, ApJ, 712, 1209 doi: 10.1088/0004-637X/712/2/1209
arXiv: 1002.2977
ADS: 2010ApJ...712.1209A BibTeX Citations
SPIRES

Discovery of Pulsed Gamma-rays from PSR J0034-0534 with the Fermi LAT: A Case for Co-located Radio and Gamma-ray Emission Regions
Abdo, A. A. et al. 2010, ApJ, 712, 957 doi: 10.1088/0004-637X/712/2/957
arXiv: 1002.2607
ADS: 2010ApJ...712..957A BibTeX Citations
SPIRES

The First Fermi Large Area Telescope Catalog of Gamma-ray Pulsars
Abdo, A. A. et al. 2010, ApJS, 187, 460 doi: 10.1088/0067-0049/187/2/460
arXiv: 0910.1608

http://www-glast.stanford.edu/cgi-bin/pubpub Page 2 of 14

Page 3 of 14

Page 4 of 14

…with many more in the pipeline… plus GBM papers..plus many more still using the public data!

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

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)

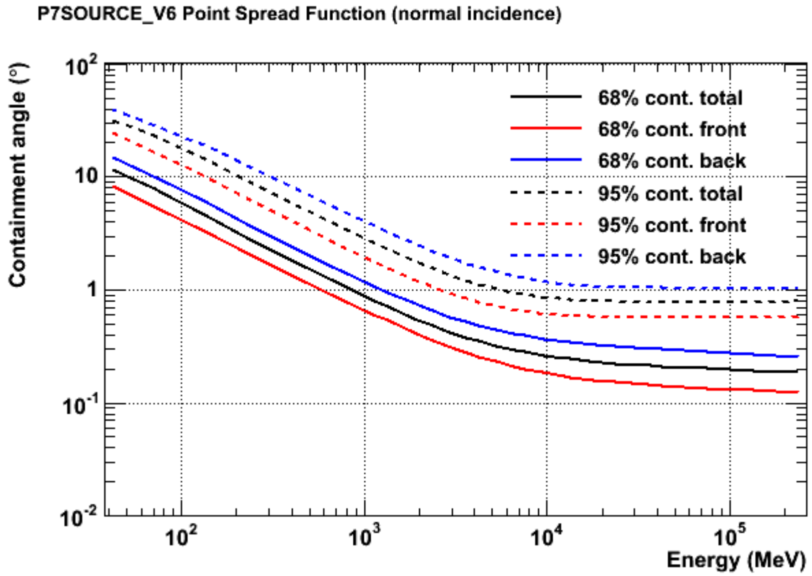
~400 Scientific Members (including 97 Affiliated Scientists, plus 71 Postdocs and 123 Students)

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

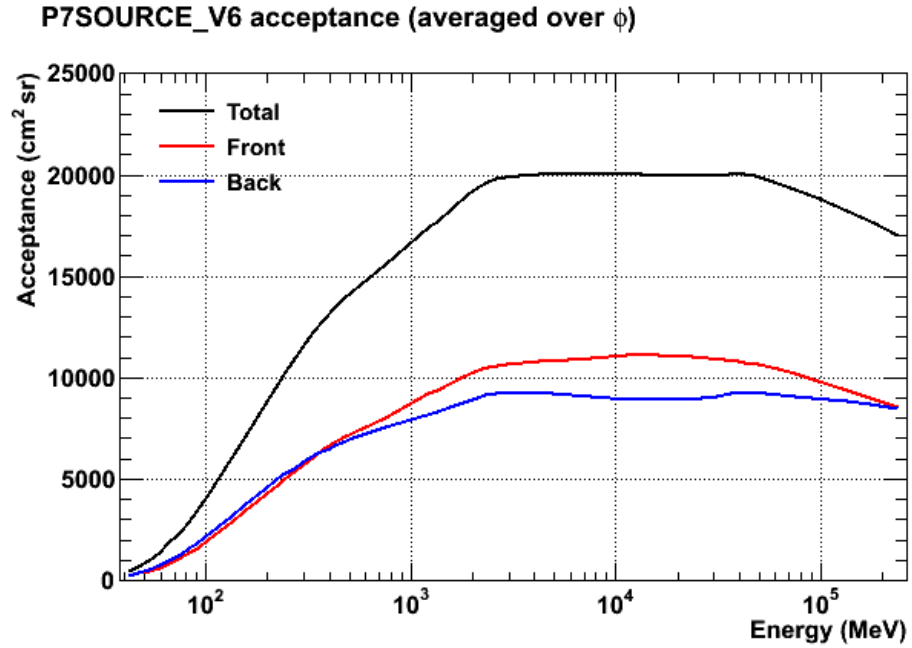
Project managed at SLAC.

LAT Performance

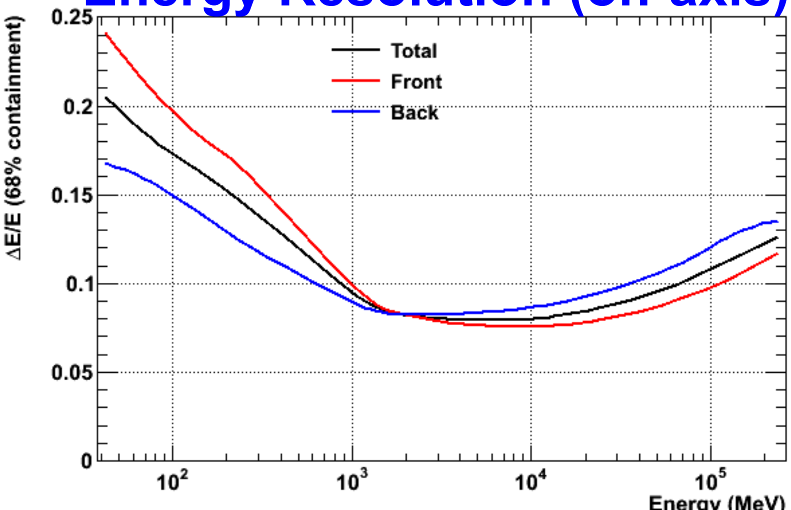
PSF 68% Cont. Radius

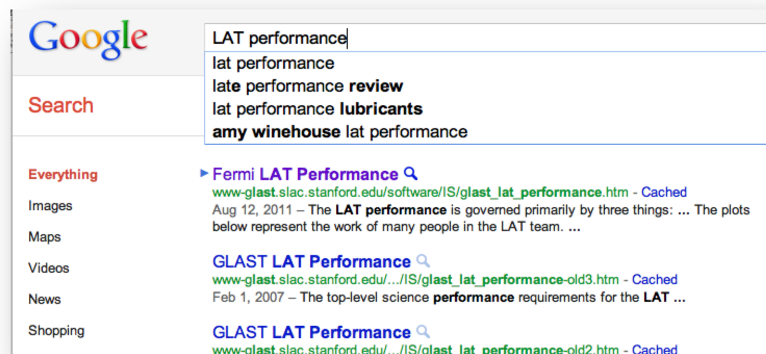


Acceptance



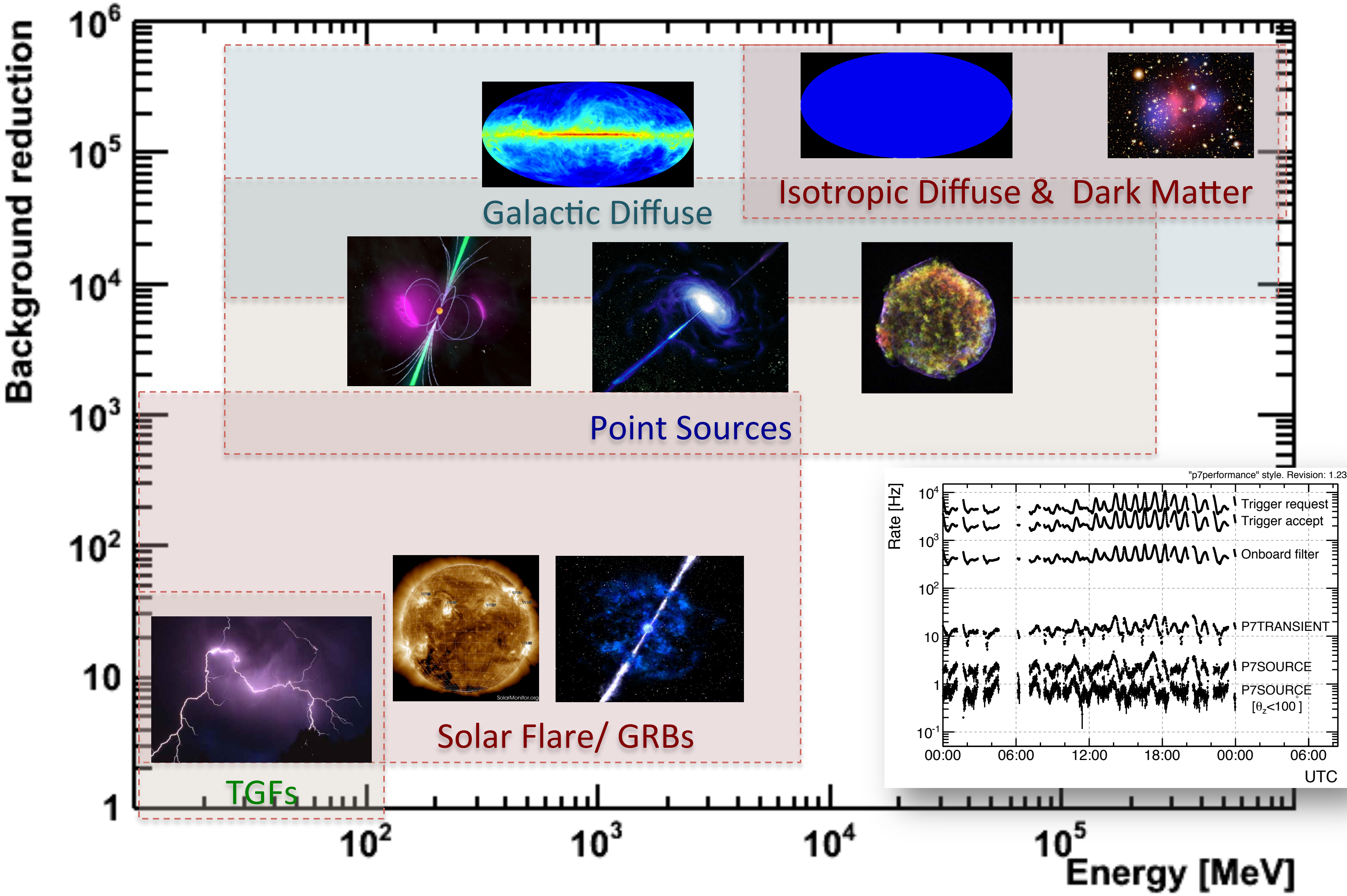
Energy Resolution (on-axis)





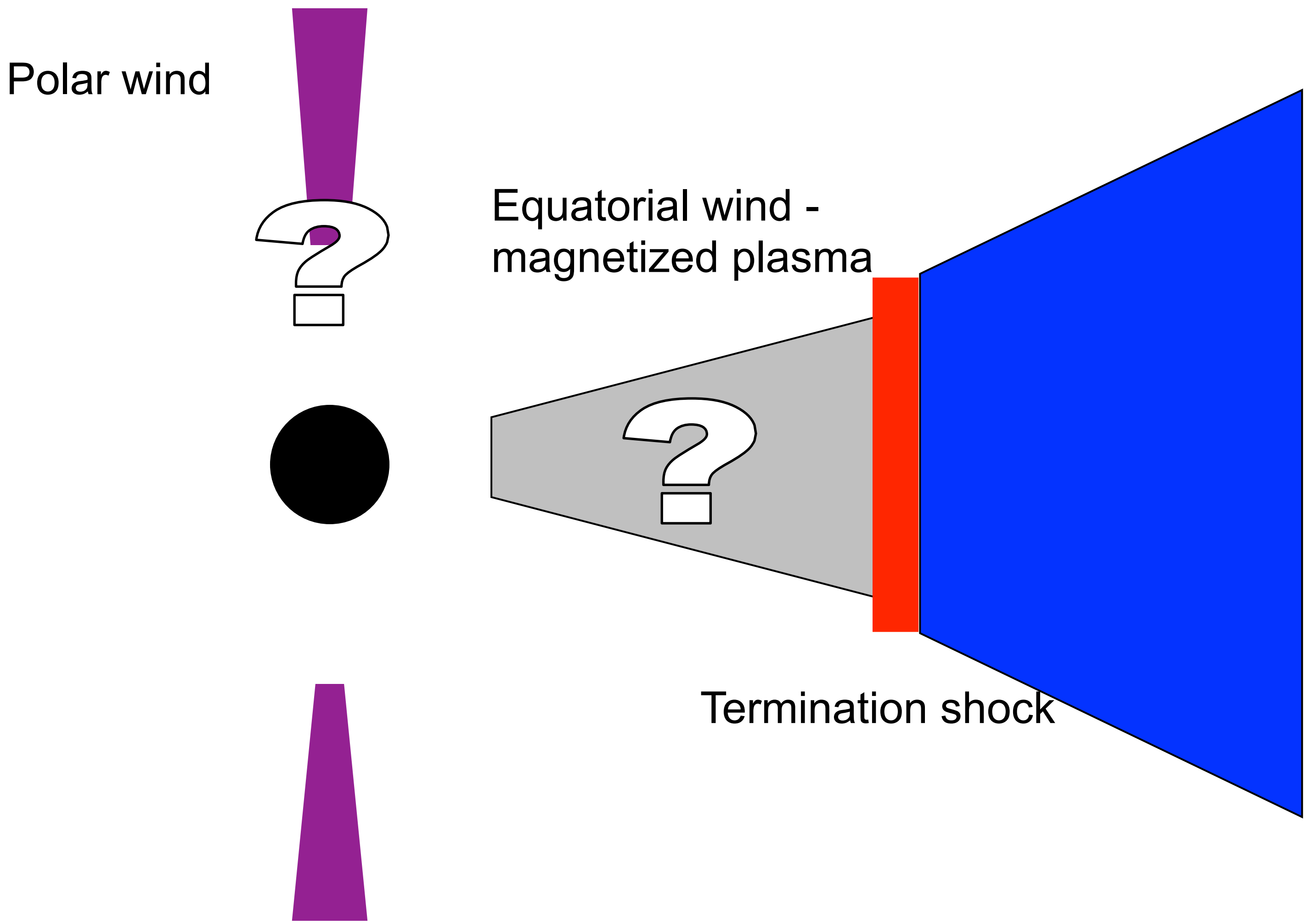
Different event classes trade background rejection and PSF against effective area

Huge Dynamic Range



A Variable Standard

Nebula Structure Cartoon



Basics from Rees and Gunn 1974

High Energy Activity from the Crab

AGILE detection of enhanced gamma-ray emission from the Crab Nebula region

ATel #2855; M. Tavani (INAF/IASF Roma), E. Striani (Univ. Tor Vergata), A. Bulgarelli (INAF/IASF Bologna), F. Gianotti, M. Trifoglio (INAF/IASF Bologna), C. Pittori, F. Verrecchia (ASDC), A. Argan, A. Trois, G. De Paris, V. Vittorini, F. D'Ammando, S. Sabatini, G. Piano, E. Costa, I. Donnarumma, M. Feroci, L. Pacciani, E. Del Monte, F. Lazzarotto, P. Soffitta, Y. Evangelista, I. Lapshov (INAF-IASF-Rm), A. Chen, A. Giuliani(INAF-IASF-Milano), M. Marisaldi, G. Di Cocco, C. Labanti, F. Fuschino,M. Galli (INAF/IASF Bologna), P. Caraveo, S. Mereghetti, F. Perotti (INAF/IASF Milano), G. Pucella, M. Rapisarda (ENEA-Roma), S. Vercellone (IASF-Pa), A. Pellizzoni, M. Pilia (INAF/OA-Cagliari), G. Barbiellini, F. Longo (INFN Trieste), P. Picozza, A. Morselli (INFN and Univ. Tor Vergata), M. Prest (Universita` dell'Insubria), P. Lipari, D. Zanello (INFN Roma-1), P.W. Cattaneo, A. Rappoldi (INFN Pavia), P. Giommi, P. Santolamazza, F. Lucarelli, S. Colafrancesco (ASDC), L. Salotti (ASI)
*on **22 Sep 2010; 14:45 UT***
Distributed as an Instant Email Notice (Transients)
Password Certification: Marco Tavani (tavani@iasf-roma.inaf.it)

Subjects: Pulsars
Referred to by ATel #: 2856, 2858, 2861, 2866, 2867, 2868, 2872

AGILE is detecting an increased gamma-ray flux from a source positionally consistent with the Crab Nebula.

Integrating during the period 2010-09-19 00:10 UT to 2010-09-21 00:10 UT the AGILE-GRID detected enhanced gamma-ray emission above 100 MeV from a source at Galactic coordinates (l,b) = (184.6, -6.0) +/- 0.4 (stat.) +/- 0.1 (syst.) deg, and flux F > 500 e-8 ph/cm2/sec above 100 MeV, corresponding to an excess with significance above 4.4 sigma with respect to the average flux from the Crab nebula (F = (220 +/- 15)e-8 ph/cm^2/sec, Pittori et al., 2009, A&A, 506, 1563).

We strongly encourage multifrequency observations of the Crab Nebula region.

No corresponding flare in X-rays with INTEGRAL (Atel # 2856), Swift (Atel # 2858, 2866), or RXTE (Atel # 2872) or NIR (Atel #2867). No evidence for active AGN near Crab (Swift, Atel # 2868).

Fermi LAT confirmation of enhanced gamma-ray emission from the Crab Nebula region

ATel #2861; R. Buehler (SLAC/KIPAC), F. D'Ammando (INAF-IASF Palermo), E. Hays (NASA/GSFC) on behalf of the Fermi Large Area Telescope Collaboration
*on **23 Sep 2010; 17:34 UT***
Distributed as an Instant Email Notice (Transients)
Password Certification: Rolf Buehler (buehler@slac.stanford.edu)

Subjects: >GeV, Pulsars
Referred to by ATel #: 2866, 2867, 2868, 2872

Following the detection by AGILE of increasing gamma-ray activity from a source positionally consistent with the Crab Nebula occurred from September 19 to 21 (ATel #2855), we report on the analysis of the >100 MeV emission from this region with the Large Area Telescope (LAT), one of the two instruments on the Fermi Gamma-ray Space Telescope.

Preliminary LAT analysis indicates that the gamma-ray emission (E >100 MeV) observed during this time period at the location of the Crab Nebula is (606 +/- 43) x10^-8 ph/cm2/sec, corresponding to an excess with significance >9 sigma with respect to the average flux from the Crab nebula of (286 +/- 2) x10^-8 ph/cm2/sec, estimated over all the Fermi operation period (only statistical errors are given). Ongoing Fermi observations indicate that the flare is continuing.

The flaring component has a spectral index of 2.49 +/- 0.14. Its position, Ra: 83.59 Dec: 22.05 with a 68% error radius of 0.06 deg, is coincident with the Crab Nebula.

Fermi will interrupt its all-sky scanning mode between 2010-09-23 15:49:00 UT and 2010-09-30 15:49:00 UT to observe the Crab Nebula. Afterwards regular gamma-ray monitoring of this source will continue. We strongly encourage further multifrequency observations of that region.

For this source the Fermi LAT contact person is Rolf Buehler (buehler@stanford.edu).

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.

A Variable Standard

arXiv:1011.3855v1

Science, 331, 739

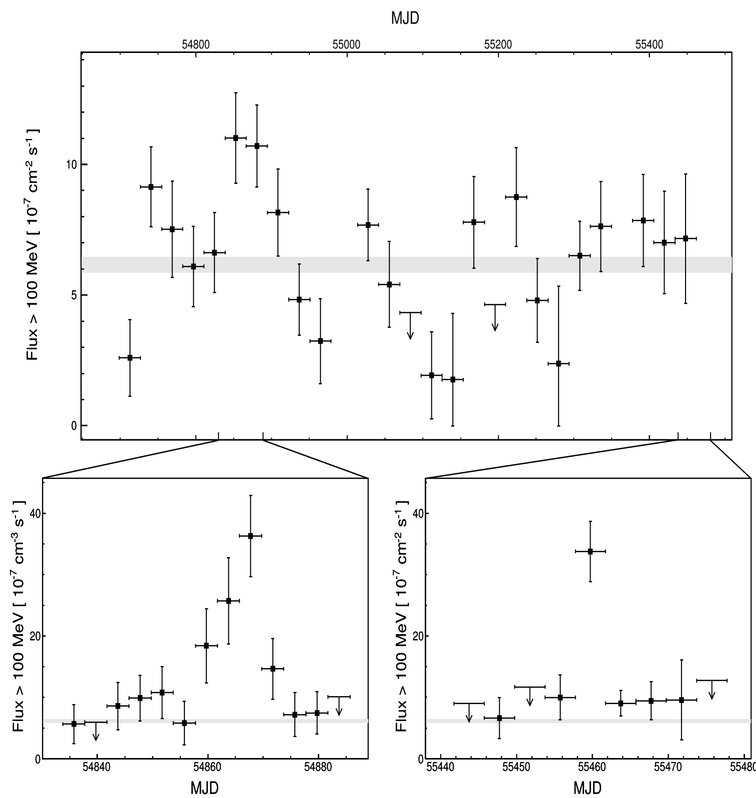
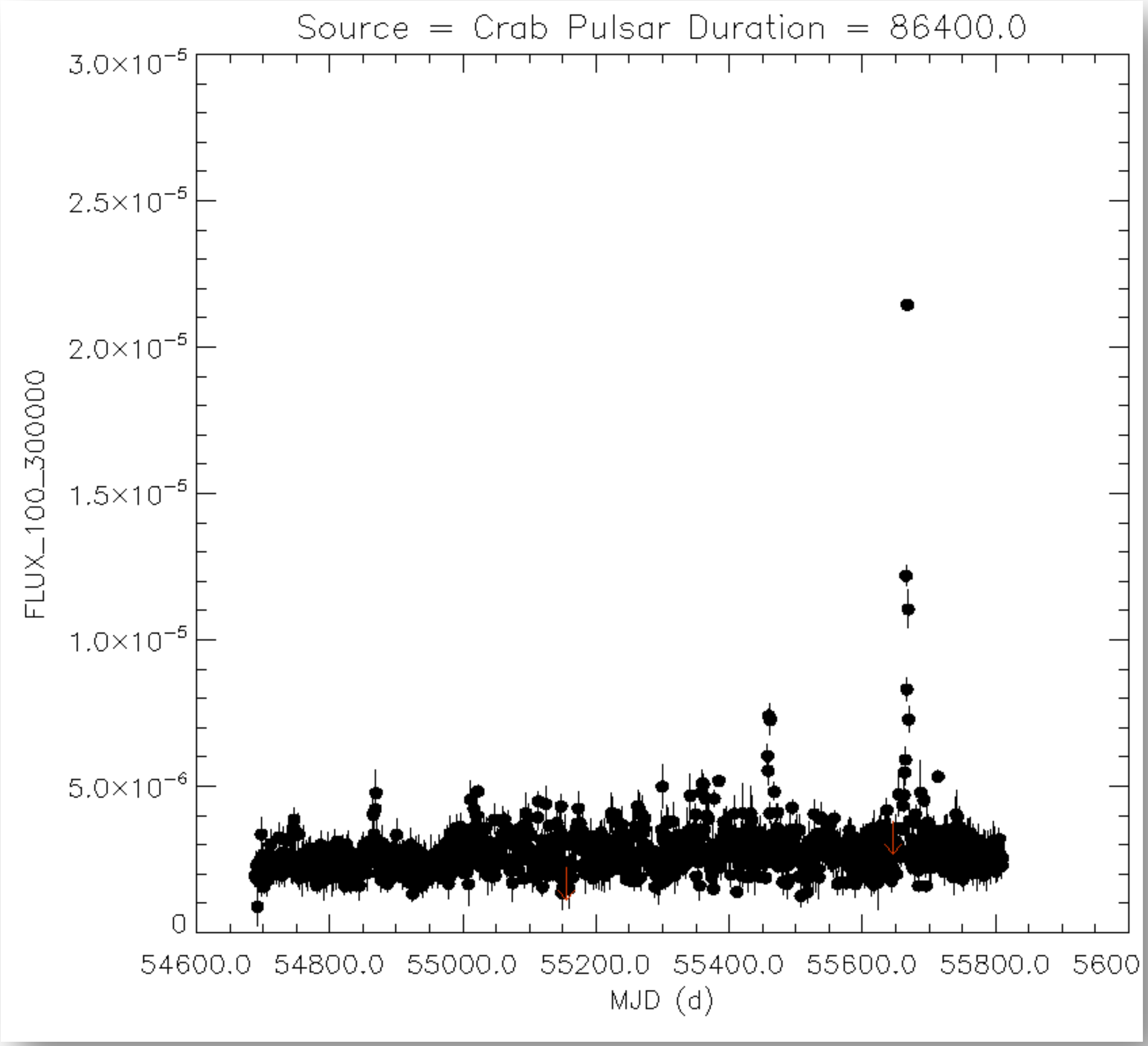


Figure 2: Gamma-ray flux above 100 MeV as a function of time of the synchrotron component of the Crab Nebula. The upper panel shows the flux in four-week intervals for the first 25 month of observations. Data for times when the sun was within 15° of the Crab Nebula have been omitted. The gray band indicates the average flux measured over the entire period. The lower panel shows the flux as a function of time in four-day time bins during the flaring periods in February 2009 and September 2010. Arrows indicate 95% confidence flux limits.

Now added to monitored source list

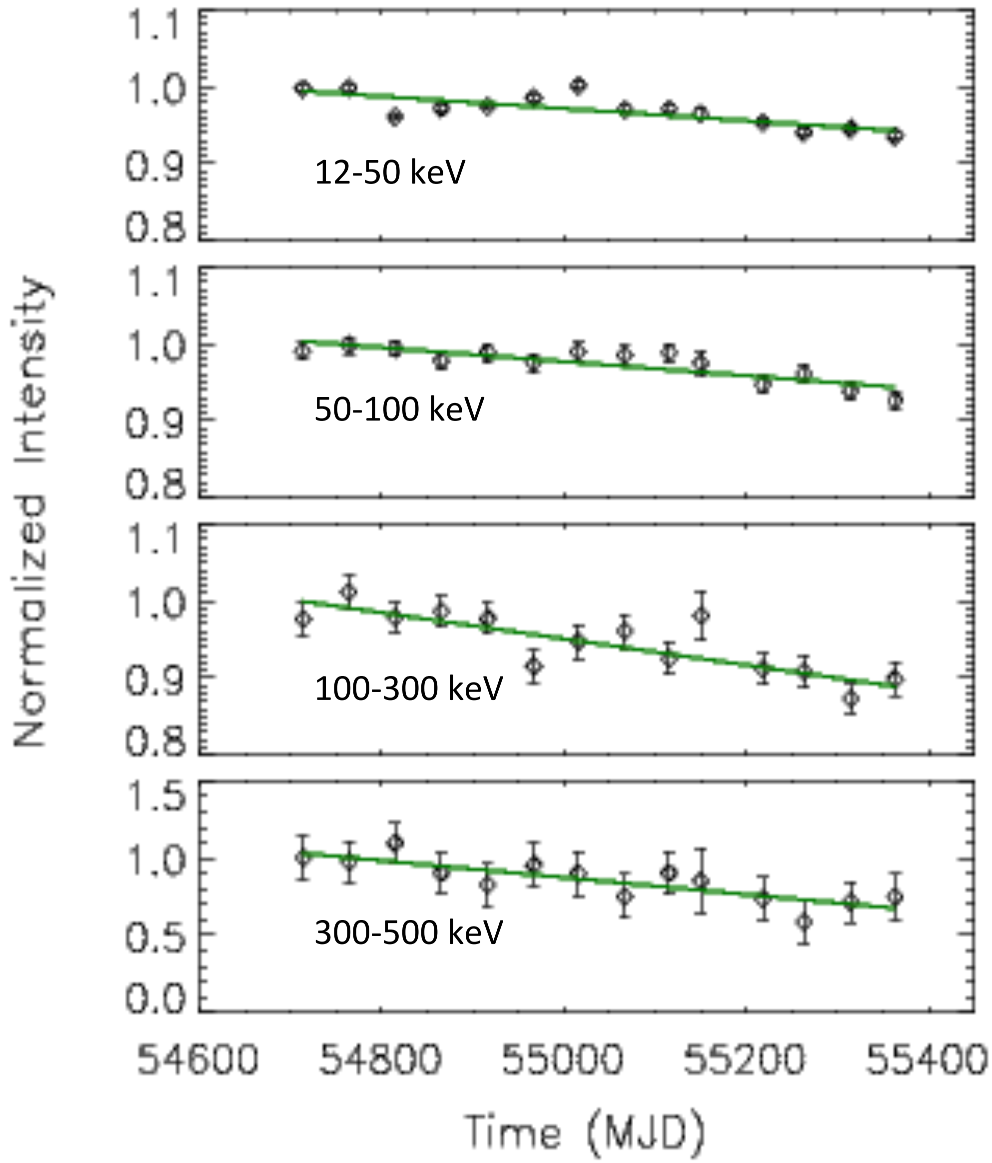
…also see **arXiv:1010.2679**

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



GBM Observations of the Crab Nebula

- **Normalized to long-term average in each band**
- **Decline in Crab flux (MJD 54690-55390)**
- **No changes in GBM response or calibration**



Wilson-Hodge et al 2010

arXiv:1010.2679

Fermi Gamma-ray Space Telescope

"But if the quality of the crab is uncertain…the season hangs in limbo."

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Dungeness crab season opens after short delay

Kelly Zito, Chronicle Staff Writer
Wednesday, November 17, 2010

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Kat Wade / Special to The Chronicle
For this year's Dungeness crab season, neither the captains nor processors would disclose their pricing deal.

0 Tweet | 1467 share

After a brief delay, the first Dungeness crab cakes of the season should be on Bay Area dinner tables by Thursday.

Tests late Monday confirmed that the catch is mature and meaty enough - allowing crab boat owners and processors to finalize a price for the prized crustacean. In the wee morning hours Tuesday, San Francisco crab boats chugged out through the Golden Gate and dropped their traps. The first load arrived at the docks Tuesday evening.

"The crab are going to start coming in - we put 120 pots in this morning," said Larry Collins, captain of the Autumn Gale and president of the Crab Boat Owners Association of San Francisco.

The Dungeness season in the coastal zone between Pacifica and Bodega Bay kicks off on Nov. 15 each year under state statute. But if the quality of the crab is uncertain, or if the crabbers and seafood wholesalers can't agree on a price, the season hangs in limbo.

Late last week, Collins said, his organization's 40 members were trying to negotiate $2

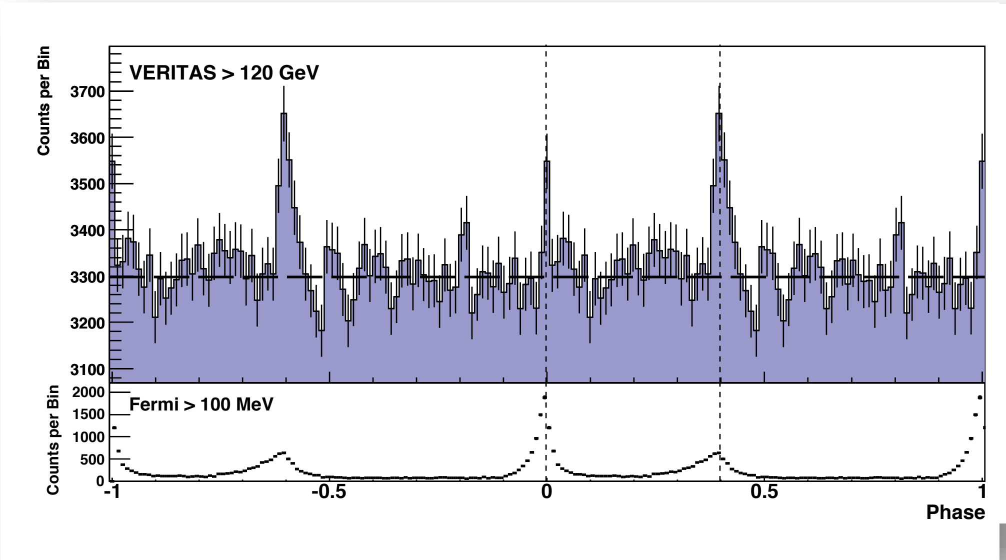
IMAGES

View All Images (31)

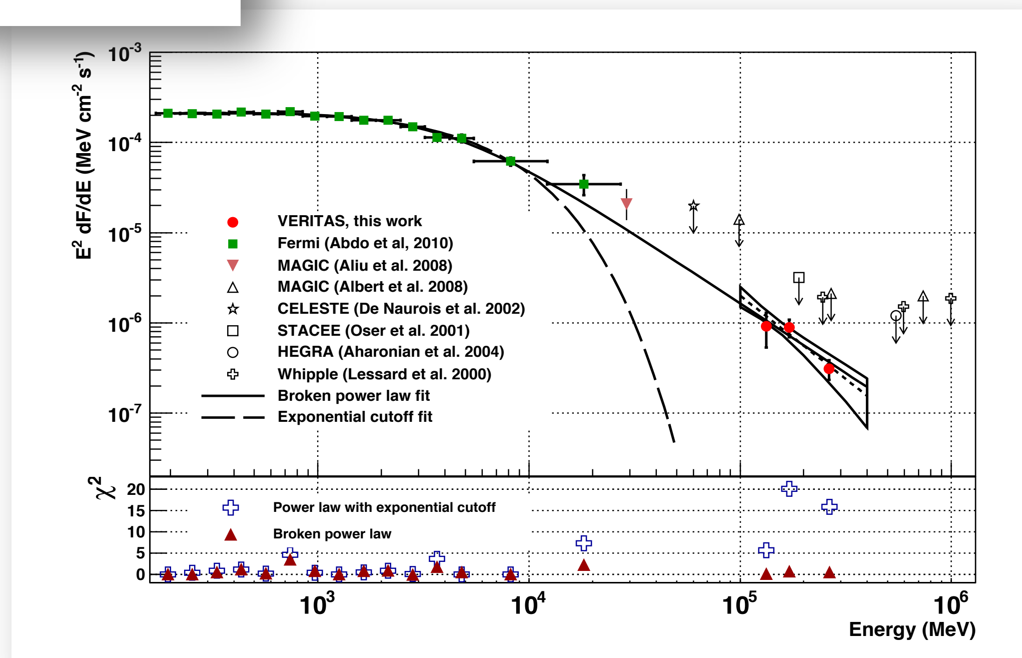
MORE NEWS

- Senate to vote again on military gay ban 11.17.10
- Obama enlists big guns to help save nuclear treaty 11.17.10
- UCSF shuttle bus strikes, kills pedestrian 11.17.10

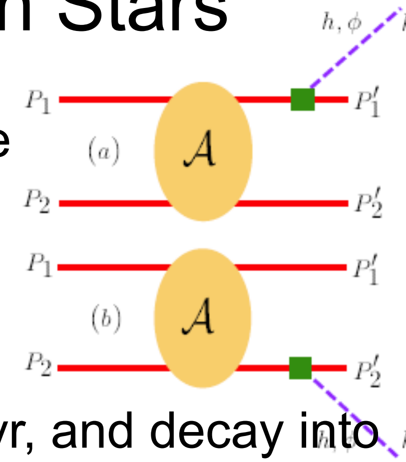
VERITAS Crab Pulsation!



published in Science and arXiv:1108.3797v1



Large Extra Dimensions with Neutron Stars



- In the LED model by ADD, Kaluza-Klein (KK) gravitons (h) are produced via nucleon-nucleon gravi-bremsstrahlung in supernova cores (involves scattering process of nucleons)

$$NN \longrightarrow NNh$$

- These h particles have masses ~ 100 MeV, lifetimes of ~10^9 yr, and decay into photons: $h \rightarrow \gamma\gamma$
- The first astrophysical bounds on LED were placed indirectly from SN1987A
  - based on neutrino signal precluding too much energy loss into KK gravitons' channel
- Restrictive limits on the size of extra dimensions can be placed from neutron star γ−ray emission originating from trapped *h* graviton decay.
  - see for example: Hannestad and Raffelt, 2003, *Phys. Rev. D* **67** 125008
  - More stringent than the limits that can be probed by signatures of extra dimensions at colliders (for n < 5)
- In this model, neutron stars (NS) will shine in ~100 MeV γ-rays.
- Previous results
  - Hannestad and Raffelt (2003): used EGRET point source sensitivity as basis for results
  - Casse et al (2004): averaged over a population of ~10^9 NS in the galactic disk
    - Many assumptions made, such as all NSs having the same EGRET flux, distance.

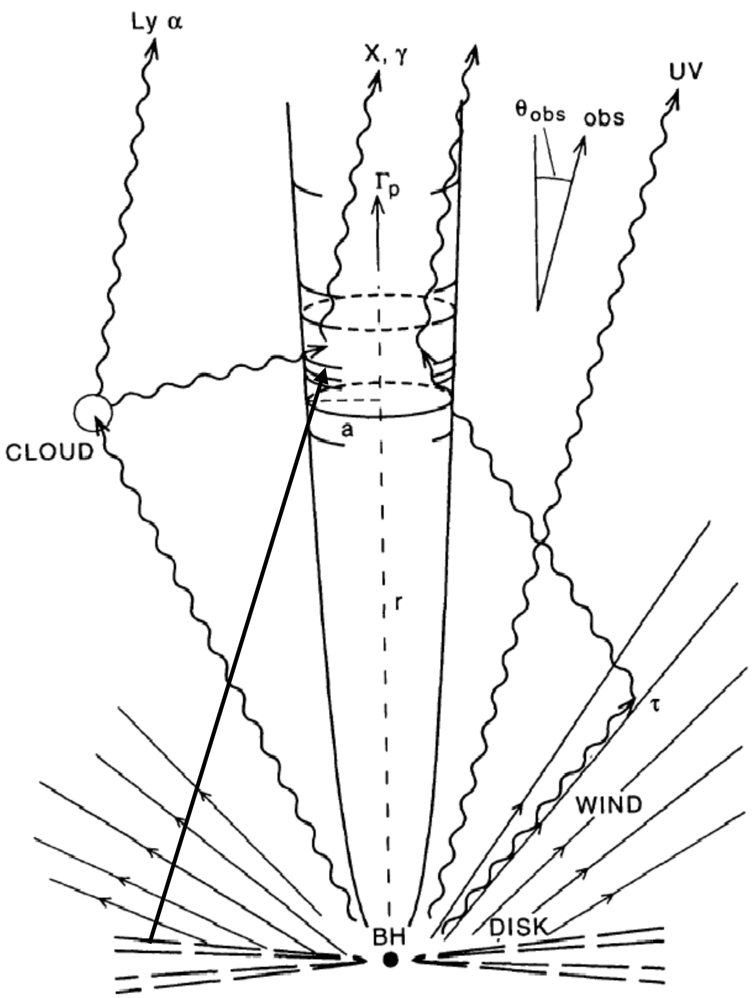
Lower Limits on Unification Scale

- 95% CL Lower Limits on the (n+4)-dimensional Planck Scale (TeV)
- Better than current collider limits for n < 4

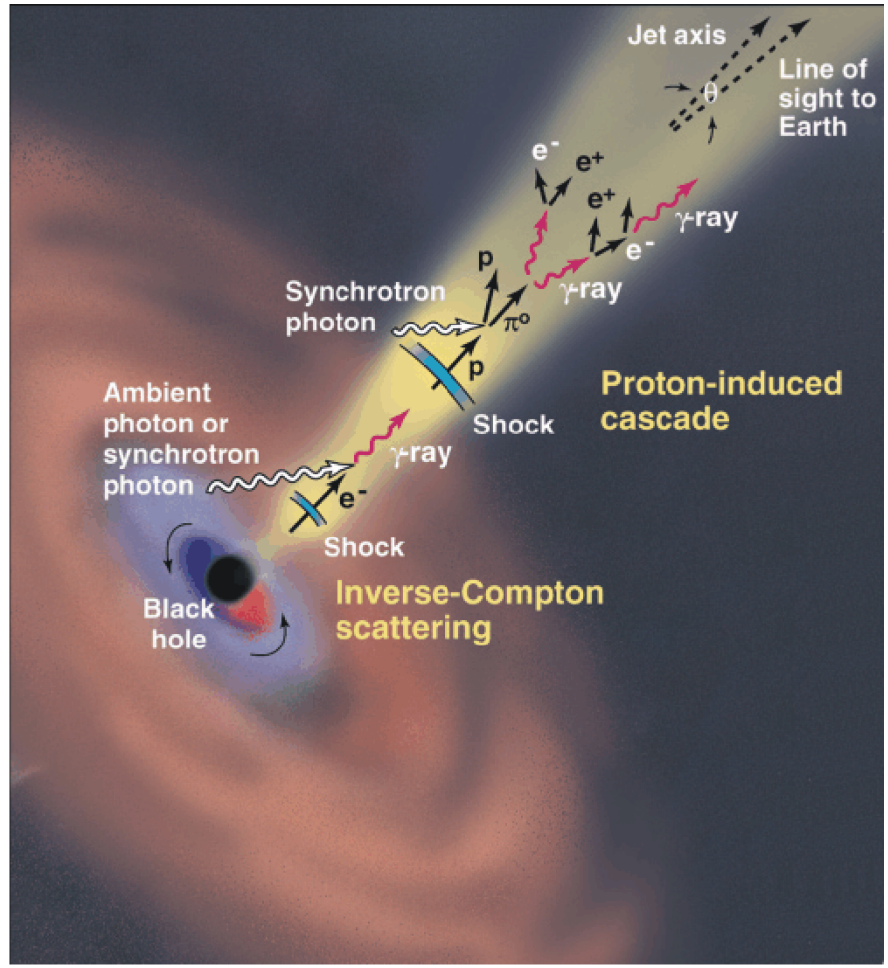
n	Combined	CDF	DØ	LEP	ATLAS	CMS
2	230	2.09	1.40	1.60	1.5	3.2
3	16	1.94	1.15	1.20	1.1	3.3
4	2.5	1.62	1.04	0.94	1.8	3.4
5	0.67	1.46	0.98	0.77	2.0	3.4
6	0.25	1.36	0.94	0.66	2.0	3.4
7	0.11	1.29	-	-	-	-

arXiv:1201.2460

Models of Blazar Gamma-ray Production



(from Sikora, Begelman, and Rees (1994))



(credit:J. Buckley)

Variability and MW keys

LAT Continuous Source Releases

The LAT team continuously releases flux & spectra as a function of time for all sources in a pre-defined list + flaring sources during flares.

- **Modified data release after ~6 months:**
  - **Lowered flux threshold to release information on flaring sources by factor of 2.**
  - **Provided information continuously (not just during flares).**
  - **started with 23 sources, now have >50, with contact people assigned.**

•http://fermisky.blogspot.com

Contact Information for Individual Sources - GLAST LAT Multiwavelength Coordinating Group - SLAC Confluence 5/10/10 2:34 PM

Contact Information for Individual Sources

Added by David J. Thompson, last edited by C. C. Teddy Cheung on May 05, 2010

Please note: This is a public page (for multifrequency purposes).

List of Contacts for Individual Sources

LAT Monitored Source List Light Curves are available for most of these sources

Fermi-LAT Weekly Sky blog and Daily Sky blog

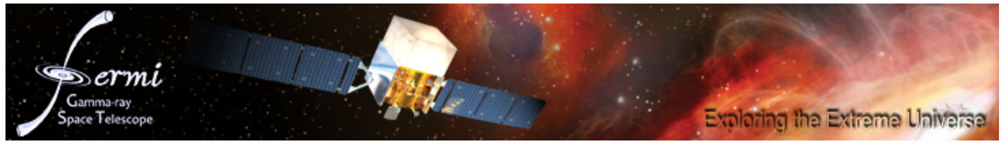
For reference, see all Astronomer's Telegrams from the Fermi-LAT collaboration

Extragalactic sources from ATels, in order of (the First) ATel number, starting with earliest

Source Name(s)	Friend(s) of the Source	ATEL number(s)
3C 454.3	Greg Madejski (madejski at stanford.edu)	1628, 2200, 2328, 2534
PKS 1502+106	Stefano Ciprini (stefano.ciprini at pg.infn.it)	1650, 1905
PKS 1454-354	??	1701
3C273	Jim Chiang (jchiang at slac.stanford.edu), Werner Collmar (wec at mpe.mpg.de)	1707, 2168, 2200
1510-089	Andrea Tramacere (tramacer at slac.stanford.edu)	1743, 1897, 2033
AO 0235+164	Luis C. Reyes (lreyes at kicp.uchicago.edu)	1744, 1784
3C 66A	Luis C. Reyes (lreyes at kicp.uchicago.edu)	1759
PKS 0208-512	Werner Collmar (wec at mpe.mpg.de)	1759
PKS 0537-441	Gino Tosti (tosti at pg.infn.it)	1759, 2124, 2591
3C279	Greg Madejski (madejski at slac.stanford.edu), Werner Collmar (wec at mpe.mpg.de)	1864, 2154
B0133+47	Hiromitsu Takahashi (hirotaka at hep01.hepl.hiroshima-u.ac.jp), Gino Tosti (tosti at pg.infn.it)	1877
J123939+044409	Andrea Tramacere (tramacer at slac.stanford.edu), Nanda Rea (N.Rea at uva.nl)	1888
PKS 1244-255	Andrea Tramacere (tramacer at slac.stanford.edu), Nanda Rea (N.Rea at uva.nl)	1894
PKS 0454-234	Dario Gasparrini (dario.gasparrini at asdc.asi.it)	1898
0917+449	William McConville (wmcconvi at umd.edu)	1902

https://confluence.slac.stanford.edu/display/GLAMCOG/Contact+Information+for+Individual+Sources Page 1 of 4

Fermi Gamma-ray Space Telescope



Rapid Publications from the Fermi LAT Collaboration: GCN and ATEL

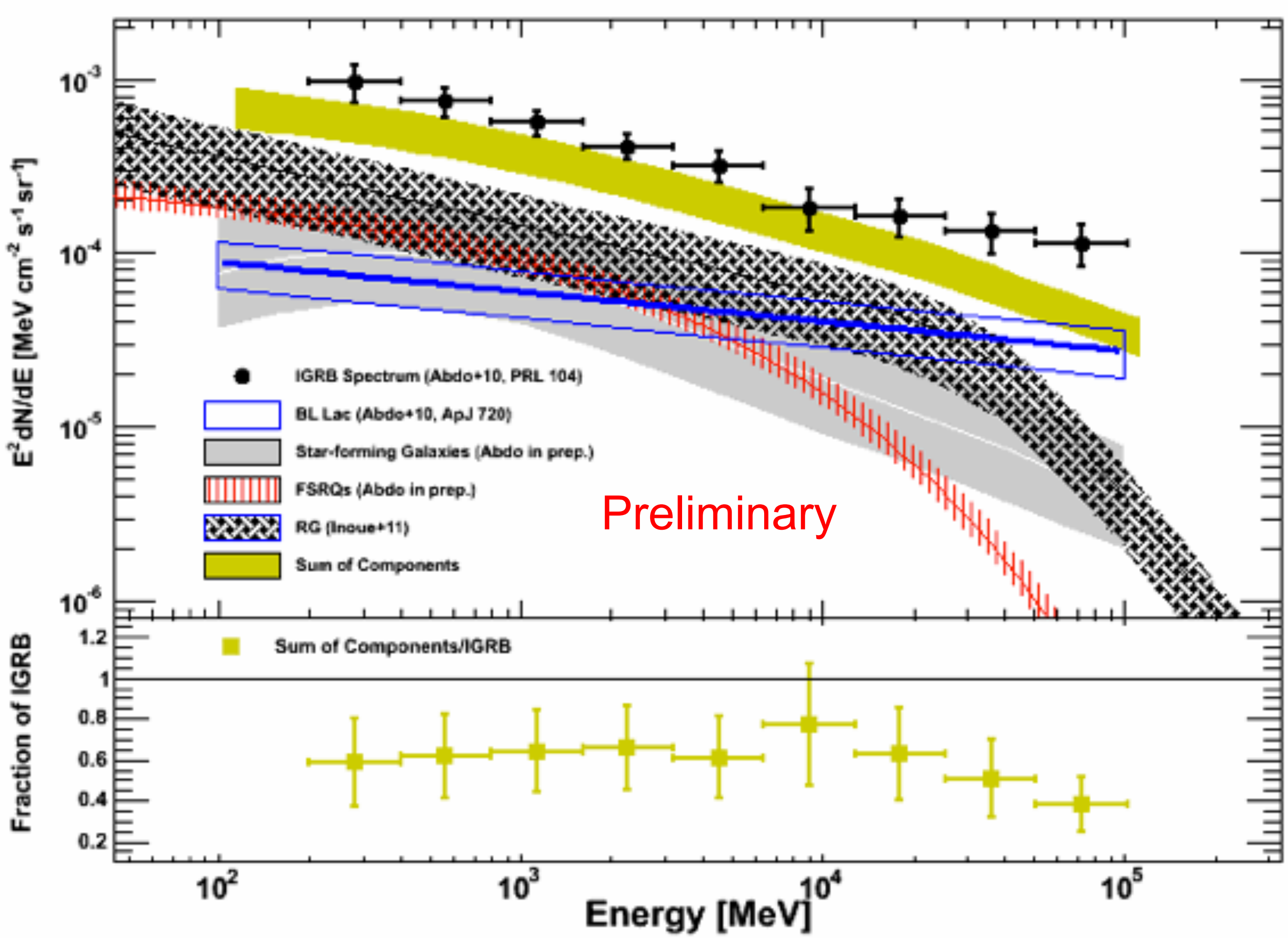
Astronomer's Telegrams (ATEL):

date	number	title
2010-Nov-11	3026	Fermi LAT detection of increasing gamma-ray activity from the FSRQ B3 1708+433
2010-Nov-08	3014	GeV emission from SHBL J001355.9-185406
2010-Nov-03	3002	Fermi LAT detection of increasing gamma-ray activity from the FSRQ PKS 1730-13
2010-Oct-30	2986	Swift follow-up confirms the high flaring state of the blazar PMN J2345-1555
2010-Oct-26	2972	Detection of a simultaneous optical and gamma-ray flare from blazar PMN J2345-1555
2010-Oct-22	2966	Fermi LAT detection of a possible new gamma-ray blazar PMN J1913-3630
2010-Oct-21	2963	Swift follow-up confirms the high activity state of CGRaBS J1848+3219
2010-Oct-19	2954	Fermi LAT detection of a GeV flare from CGRaBS J1848+3219
2010-Oct-15	2944	Fermi LAT observations of enhanced gamma-ray activity of blazar PKS 2155-304
2010-Oct-15	2943	Fermi LAT detection of an intense GeV flare from the high-redshift and gravitationally lensed blazar PKS 1830-211
2010-Oct-05	2907	Fermi-LAT detection of GeV gamma-ray emission from CRATES J0531-4827
2010-Oct-03	2901	Swift follow-up of the gamma-ray flaring blazar PKS 0727-11
2010-Sep-29	2886	Fermi LAT observations of increasing gamma-ray activity of blazar 3C279
2010-Sep-28	2879	Crab flux no longer elevated in Fermi-LAT band
2010-Sep-23	2861	Fermi LAT confirmation of enhanced gamma-ray emission from the Crab Nebula region
2010-Sep-23	2860	Fermi LAT detection of a GeV flare from the FSRQ PKS 0727-11
2010-Sep-18	2848	Flaring blazar B2 0619+33: Swift X-ray and UV/optical observations
2010-Sep-09	2837	PKS 1329-049 revived: new gamma-ray activity observed by Fermi LAT

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

What Produces the Isotropic Flux?

earlier work: arXiv:1002.3603



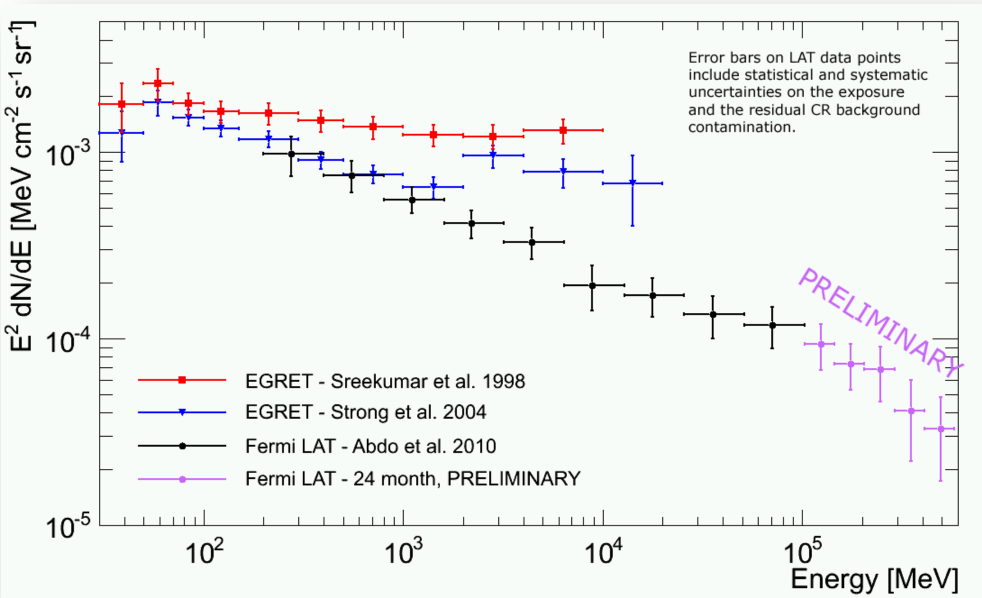
updated

FSRQ
Star-forming Gal.
BL Lac
Radio Galaxies

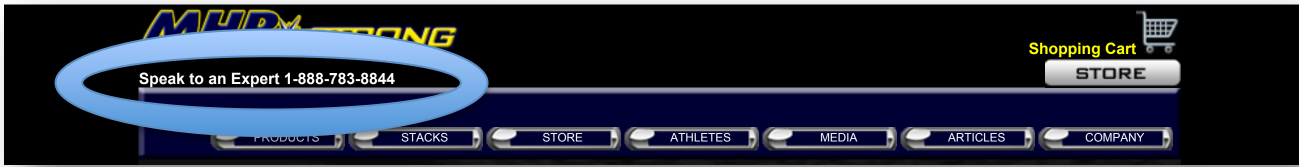
more to explore!

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

Recent Update to 600 GeV

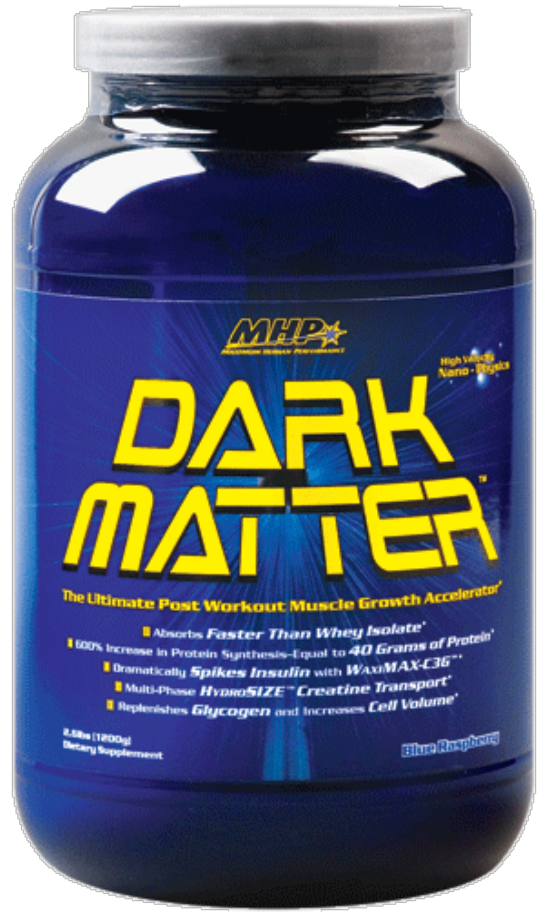


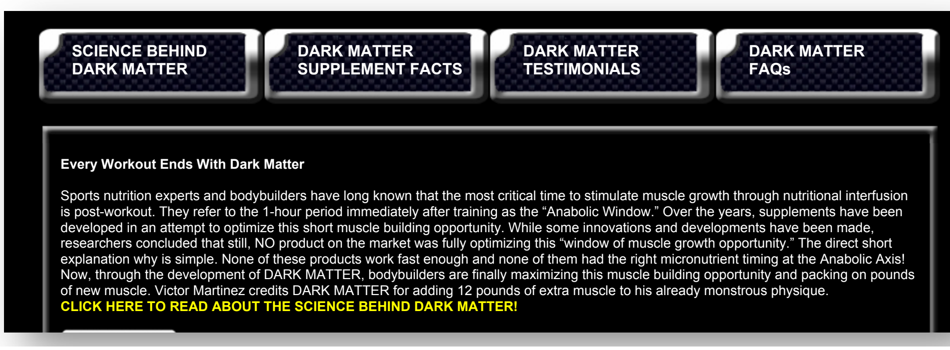
- What's next?
  - What is producing the unaccounted flux?
  - What will higher precision above 100 GeV reveal?
    - will we see attenuation due to the extragalactic background light (EBL)?
    - what else is contributing at the highest energies?
  - More statistics, with detailed understanding of energy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



Dark Matter

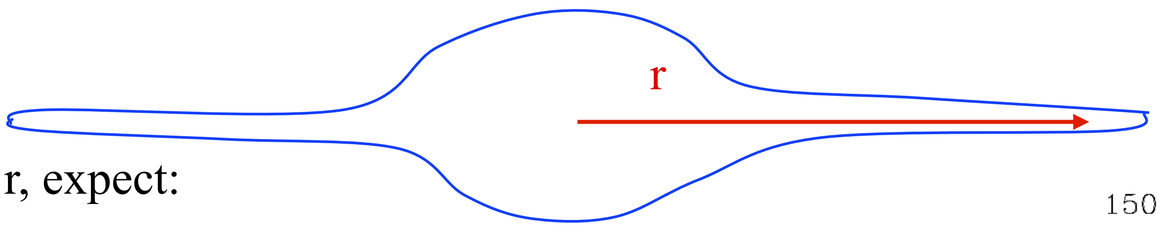
A Quick Tour



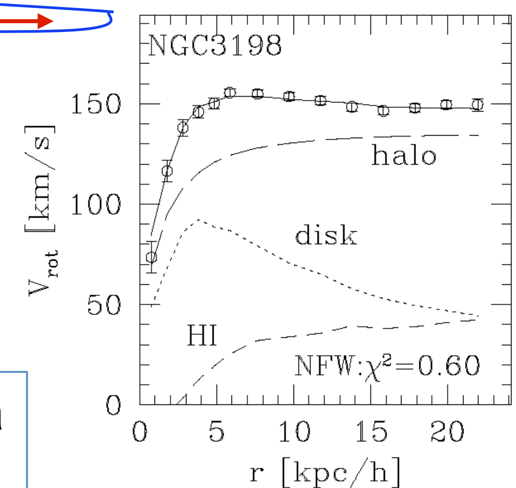


The Dark Matter Problem

Observe rotation curves for galaxies:



Begeman/Navarro

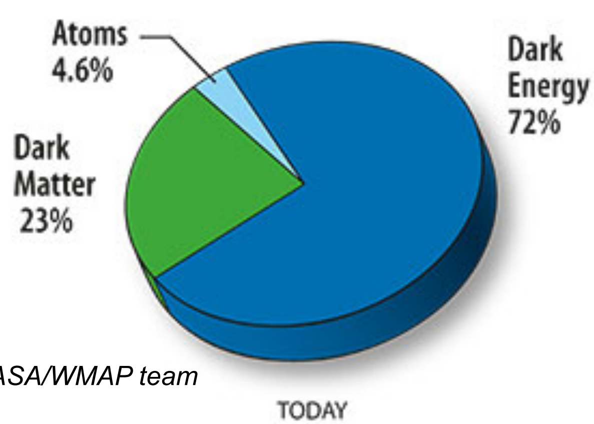


For large r, expect:

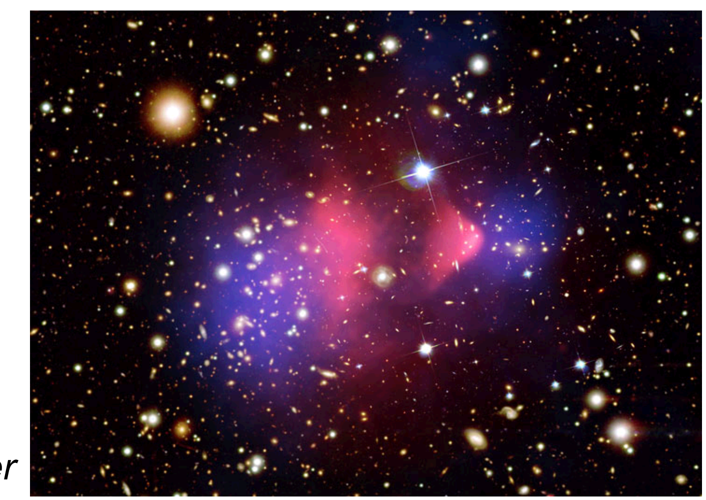
$$G\frac{M}{r^2} = \frac{v^2(r)}{r} \qquad v(r) \sim \frac{1}{\sqrt{r}}$$

see: flat or rising rotation curves

Hypothesized Solution: the visible galaxy is embedded in a much larger halo of dark matter.



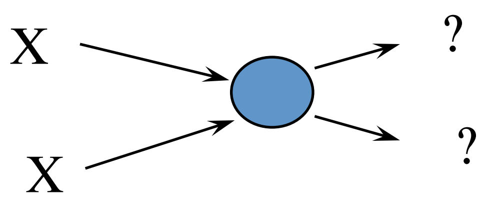
Credit: NASA/WMAP team



Bullet cluster

Dark Matter

Some important models in particle physics could also solve the dark matter problem in astrophysics. If correct, these new particle interactions could produce an anomalous flux of cosmic particles ("indirect detection").



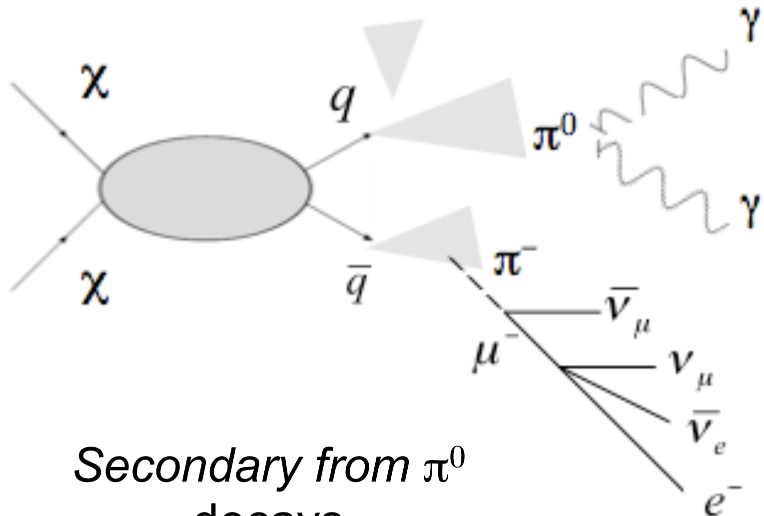
Anomalous gamma ray spectra and/or $\gamma\gamma$ or $Z\gamma$ "lines" and/or anomalous charged cosmic rays and/or neutrinos?

- If particles are stable: rate ~ (DM density)^2
- If particles unstable: rate ~ (DM density)

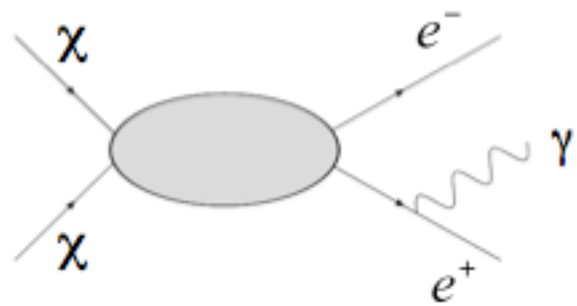
- Key interplay of techniques:
  - colliders (TeVatron, LHC)
  - direct detection experiments underground
  - indirect detection (most straightforward: gamma rays and neutrinos)
    - Full sky coverage look for clumping throughout galactic halo, including off the galactic plane (if found, point the way for ground-based facilities)
    - Intensity highly model-dependent
    - **Challenge is to separate signals from astrophysical backgrounds**

Just an example of what might be waiting for us to find!

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

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

Dark Matter: Many Places to Look!

Satellites

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

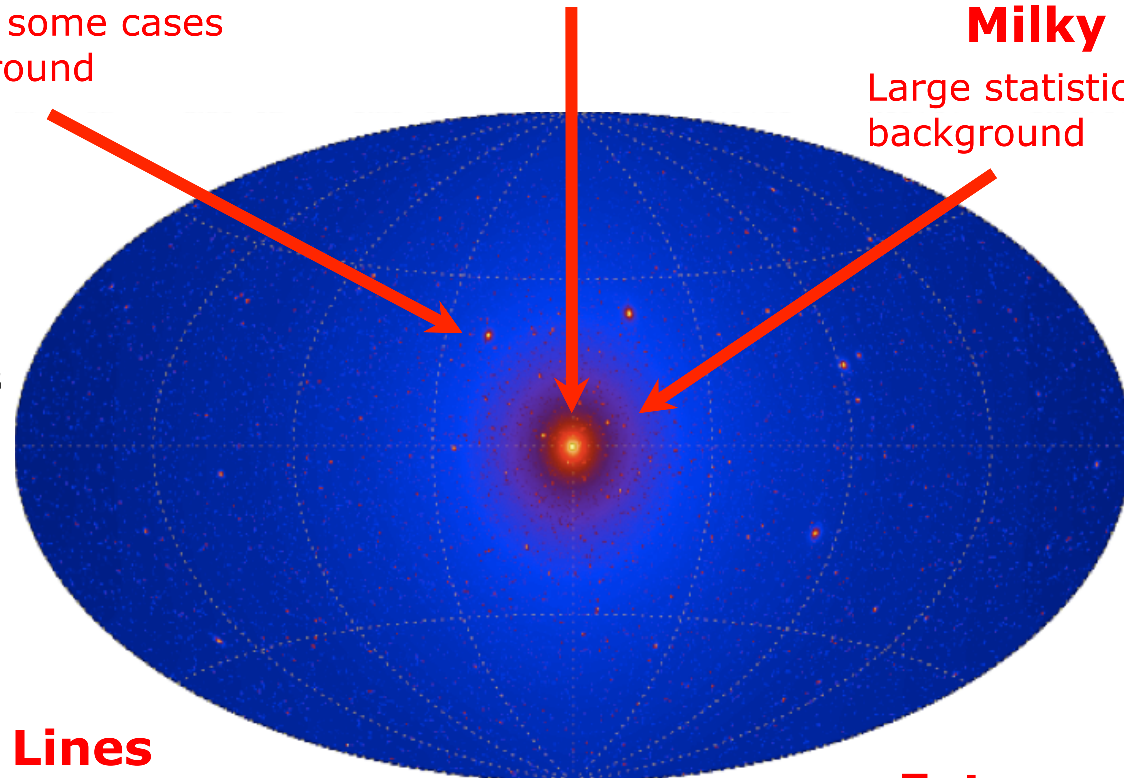
Galactic Center

Good Statistics but source confusion/diffuse background

Milky Way Halo

Large statistics but diffuse background

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.)

Spectral Lines

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

Extra-galactic

Large statistics, but astrophysics, galactic diffuse background

Galaxy Clusters

Low background, but low statistics

They Play Together!

Direct Detection
Relic scattering RIGHT HERE at low energy. Push to larger target mass, lower backgrounds, directional sensitivity?

Accelerators
Direct production. Push to higher energy

Observations
Push toward finding and studying galactic halo objects and large scale structure.

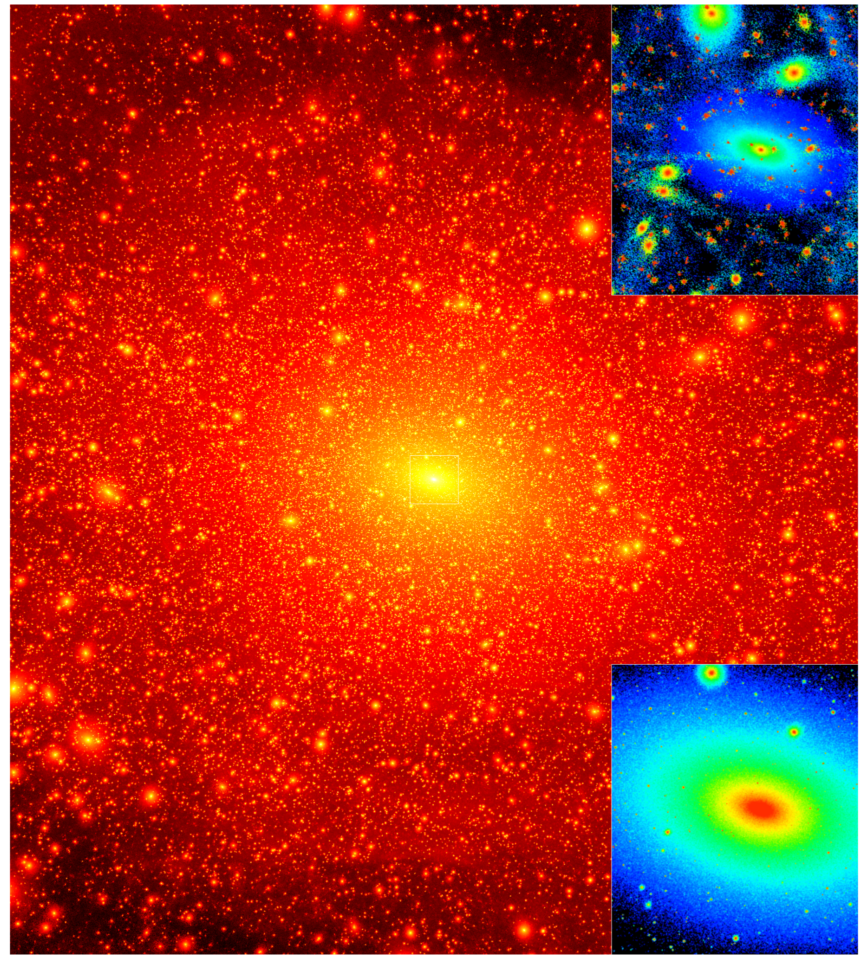
Indirect Detection
Relic interactions (annihilations, decays) Understand the astrophysical backgrounds in signal-rich regions. Reveal the detailed astrophysical distribution of dark matter.

Simulations
Large scale structure formation. Push toward larger simulations, finer details.

Dwarf Spheriodal (dSph) Galaxies

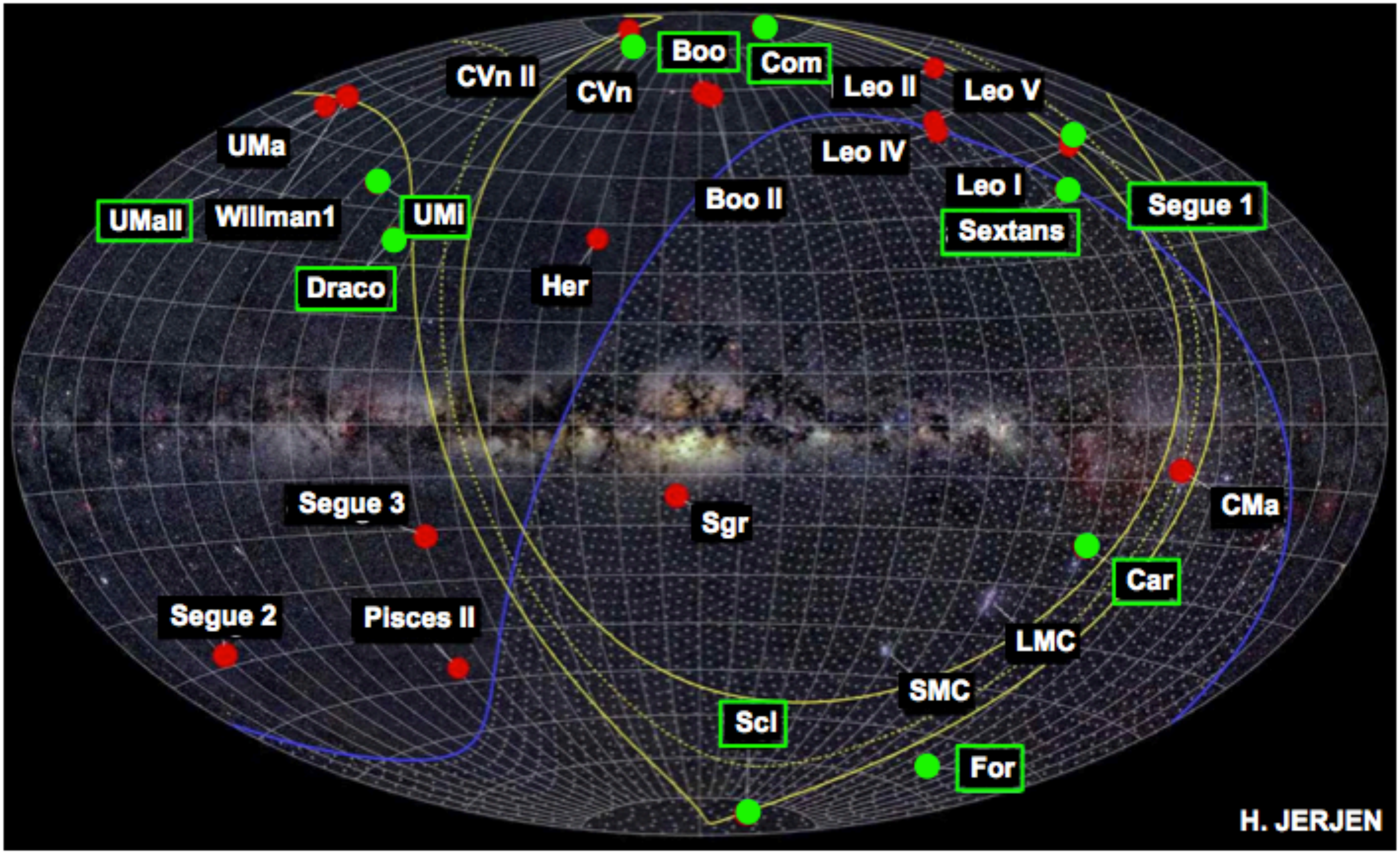
- Largest galactic substructures predicted (in ΛCDM)
- DM-dominated: mass-to-light ratios O(100-1000)
- Very low astrophysical backgrounds
  - no detected gas, low recent star formation activity
- SDSS discovery of many more ultrafaint Milkyway satellites
  - more are welcome!

- Great opportunity for indirect DM signal searches!



Via Lactea II simulation

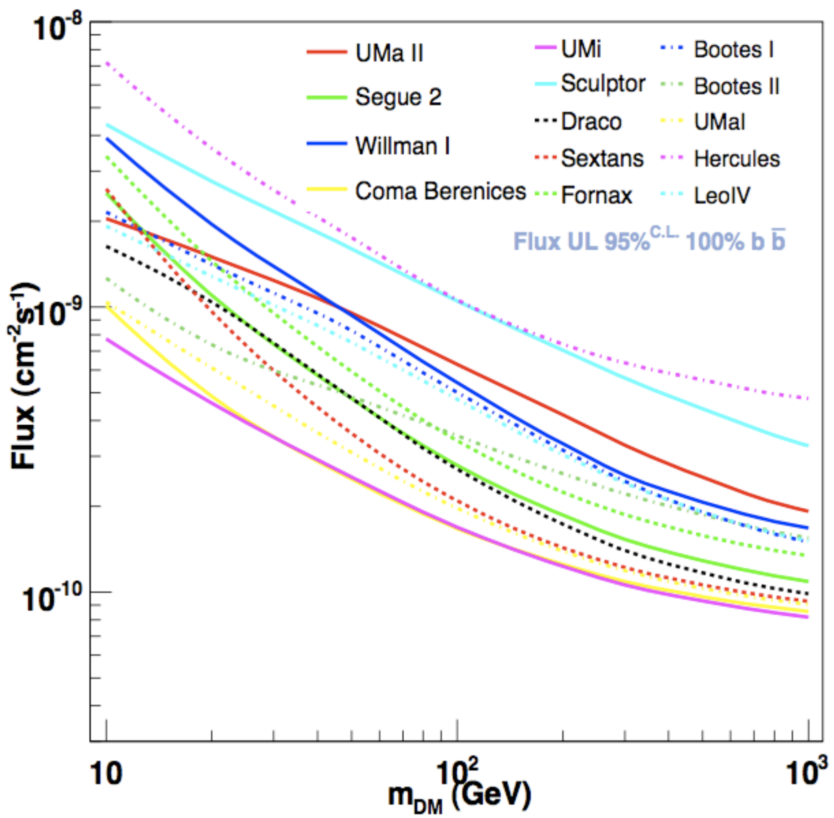
Search for gamma rays from dwarf galaxies

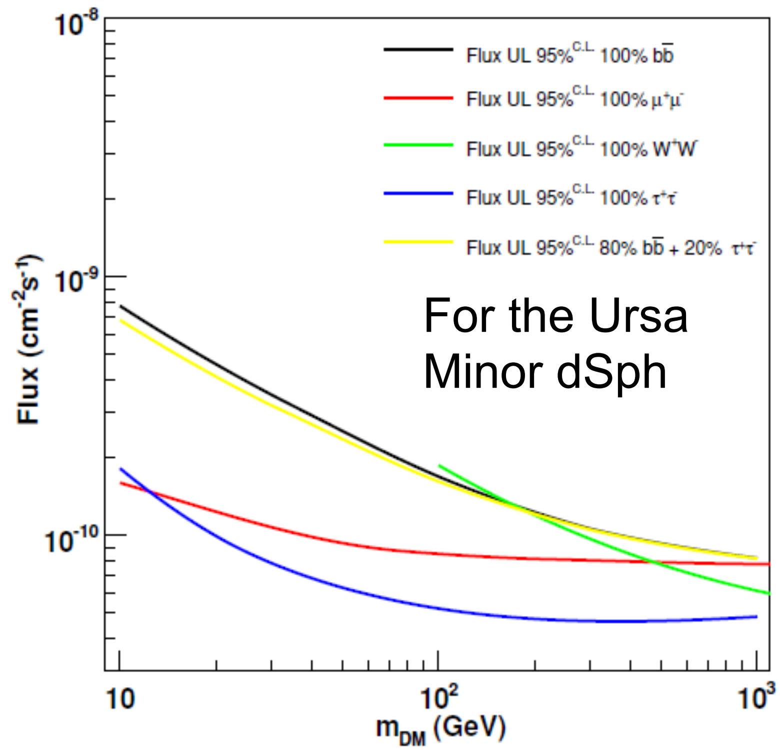


Search for DM in dSph

A.A. Abdo et al., ApJ 712 (2010) 147.

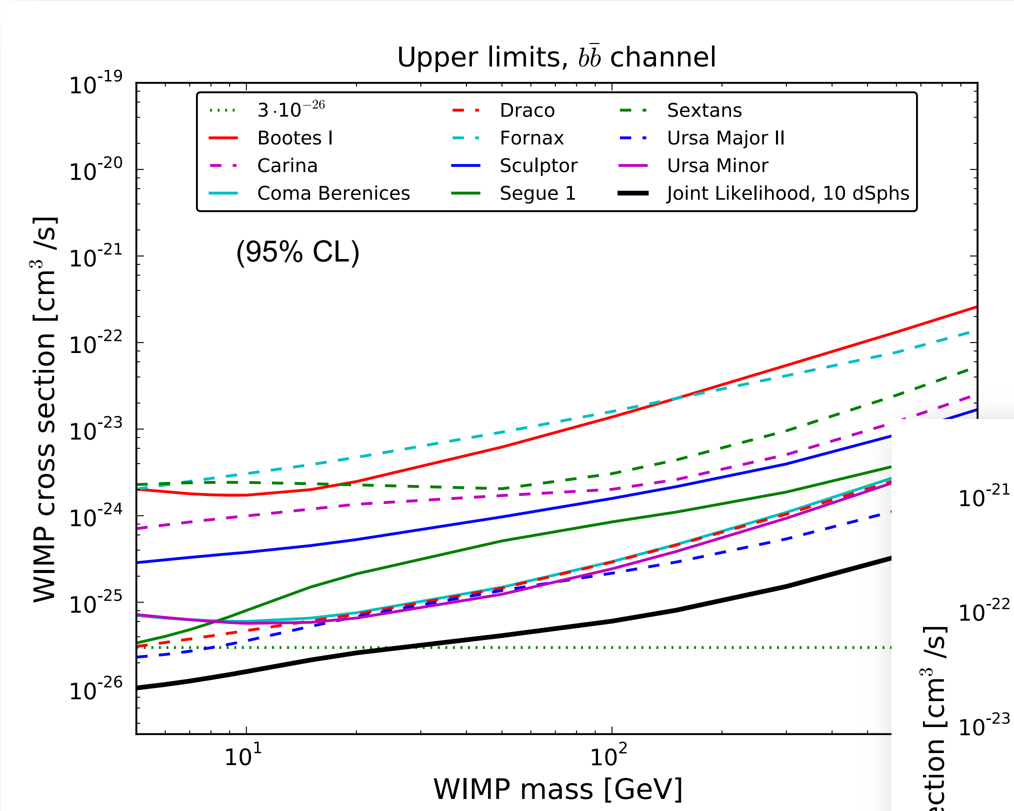
No detection by Fermi (100 MeV – 50 GeV) with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

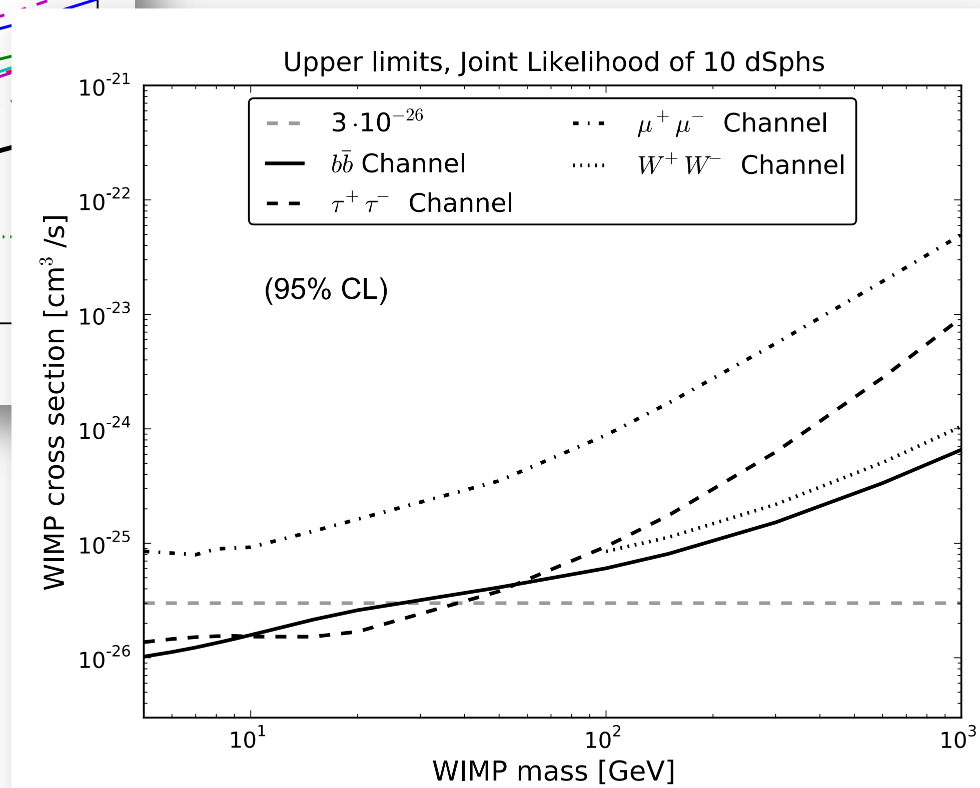




Combining dSph Limits

arXiv:1108.3546v2

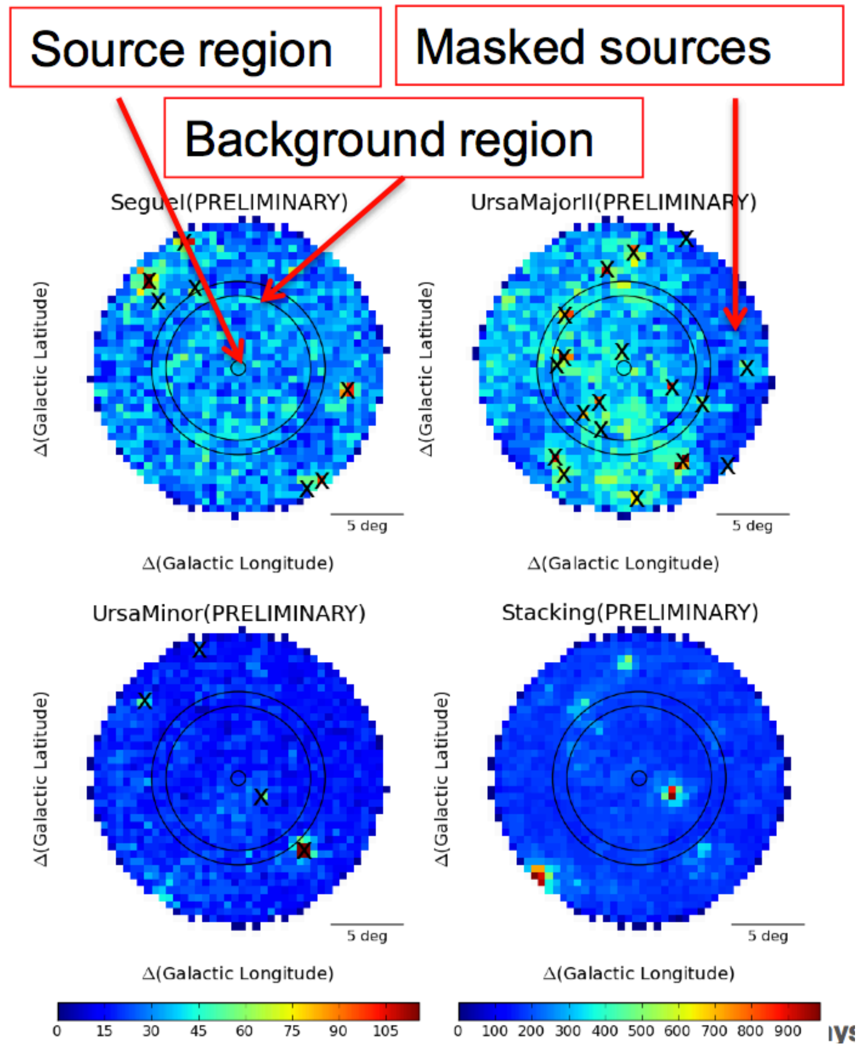




Now getting to very interesting sensitivity ranges!

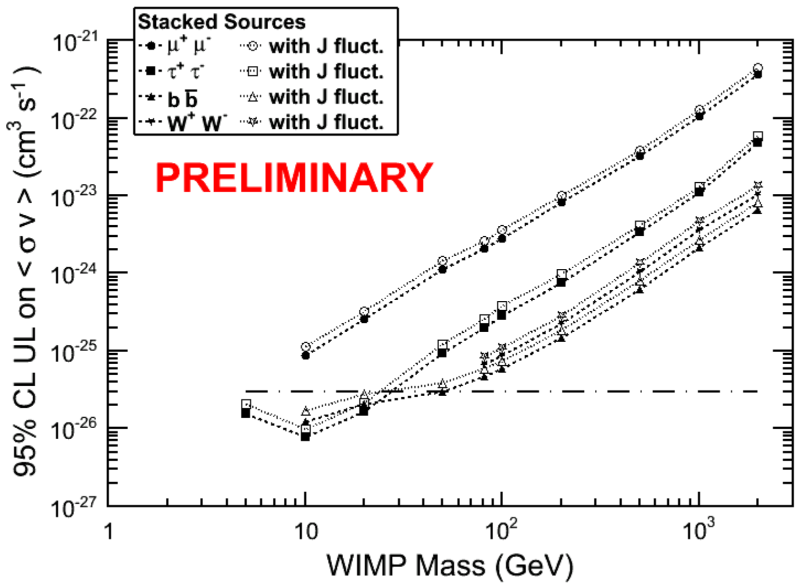
Model-independent dwarf analysis

- data set: 3 years of SOURCE_P7V6 data, 2FGL sources masked
- the background is evaluated in an annulus around each source (the diffuse model is not used)
- the expected gamma-ray flux from the DM was evaluated using the DMFIT package



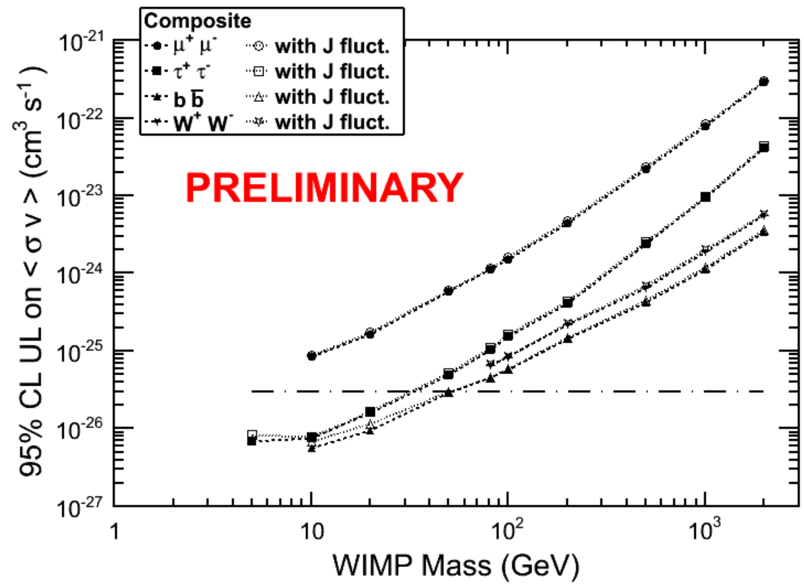
Model-independent limits from dwarfs

STACKING METHOD



- all 10 dSphs are stacked and the stacked J factor is determined by averaging weighting by the individual exposures
- standard Bayesian method for UL evaluation with a flat prior is used

COMPOSITE LIKELIHOOD



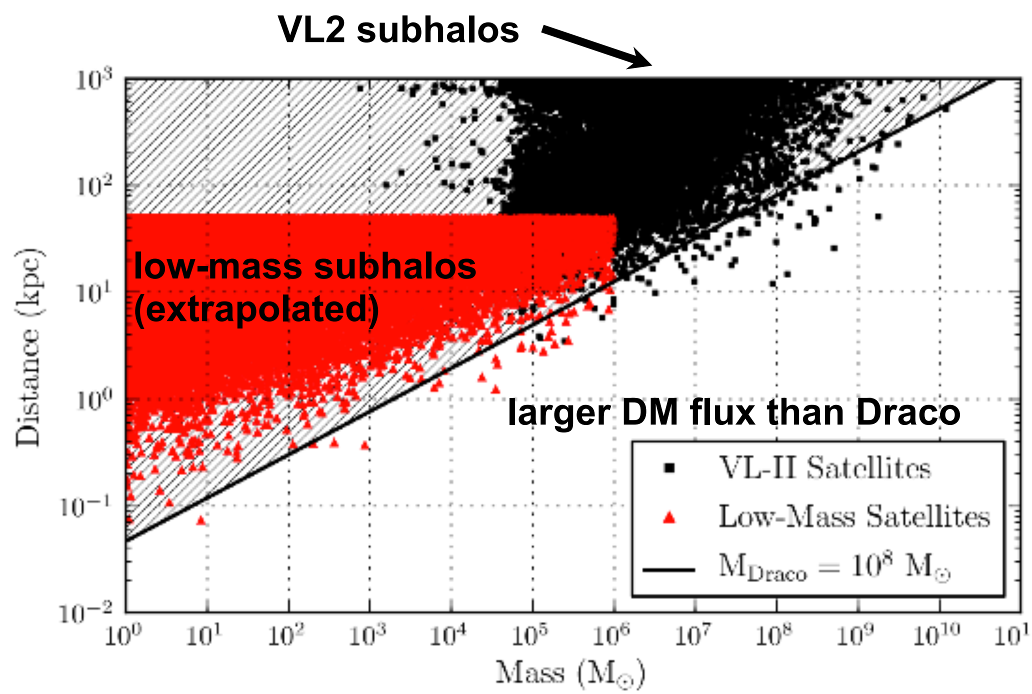
- weight dSph with different J values differently
- each posterior pdf is combined and the upper limit is evaluated

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

Unassociated source analysis

- **dark matter satellites:**
  - **hard γ-ray spectra**
  - **finite angular extent**
  - **lack of counterparts at other wavelengths**

no viable DM satellite candidates found in unassociated LAT sources using 1 year of data



Ackermann et al. [Fermi LAT Collaboration], ApJ 747 (2012)121

arXiv:1201.2691v1

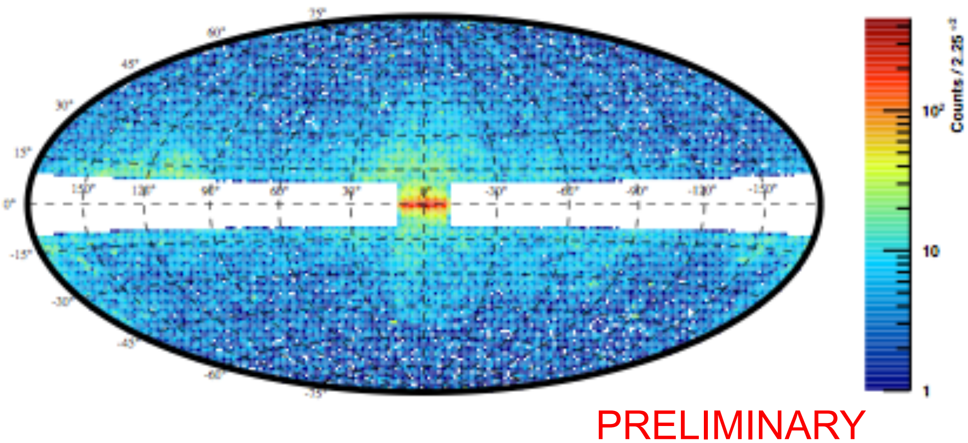
- **used N-body simulations to determine probability of not detecting viable sources to place constraints on annihilation cross-section:**

$\langle\sigma v\rangle \lesssim 2 \times 10^{-24}$ cm^3 s^{-1}

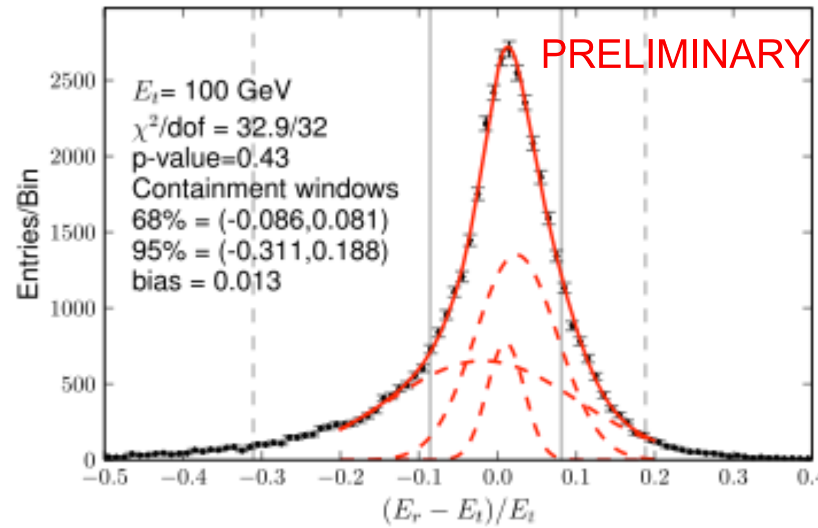
(100 GeV WIMP, $b\bar{b}$ channel)

Search for spectral lines

Region-of-interest for line search



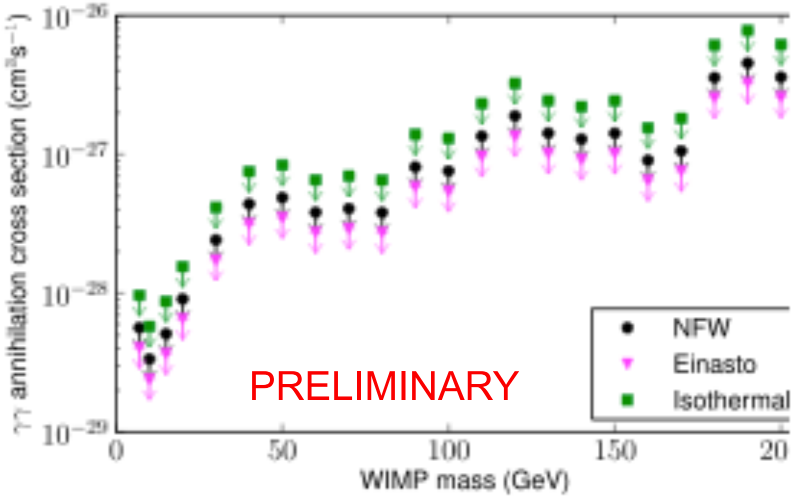
LAT energy response to 100 GeV line

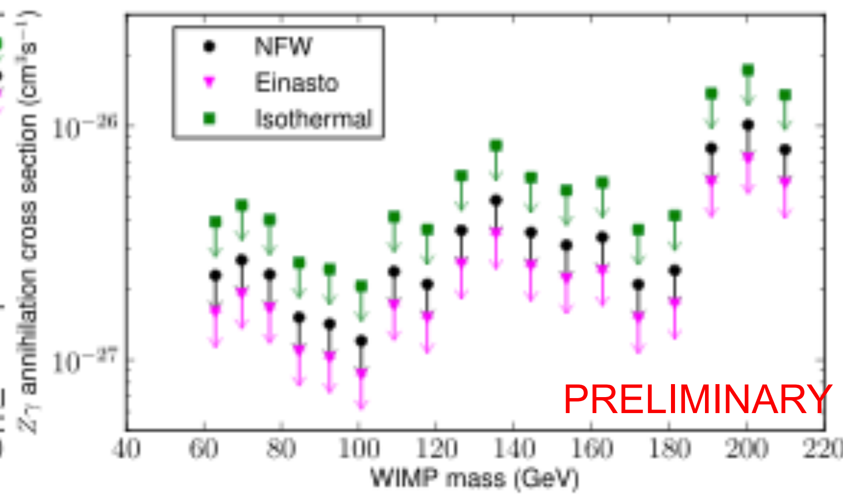


- search for line emission from dark matter annihilation or decay ($\gamma\gamma$ and $Z\gamma$ channels)
- exclude Galactic plane and 1FGL sources
- assume power-law background (spectral index free to vary) in each energy window

Constraints from line search

Annihilation cross-section constraints

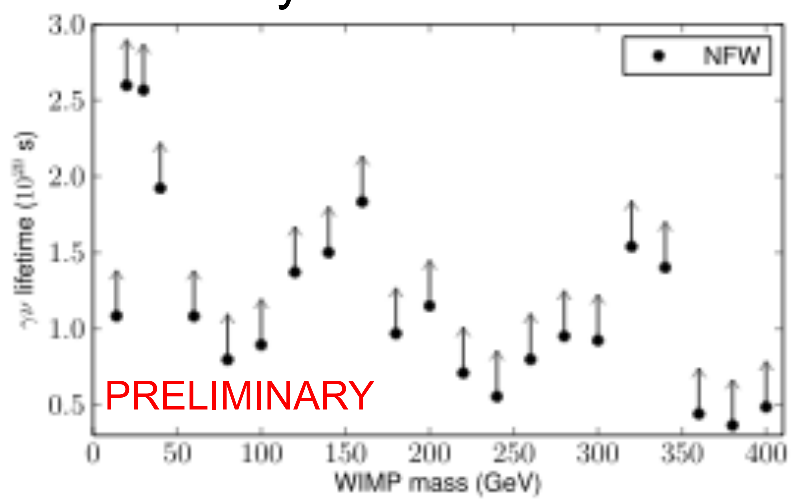




Ackermann et al. [Fermi LAT Collaboration], submitted to PRD

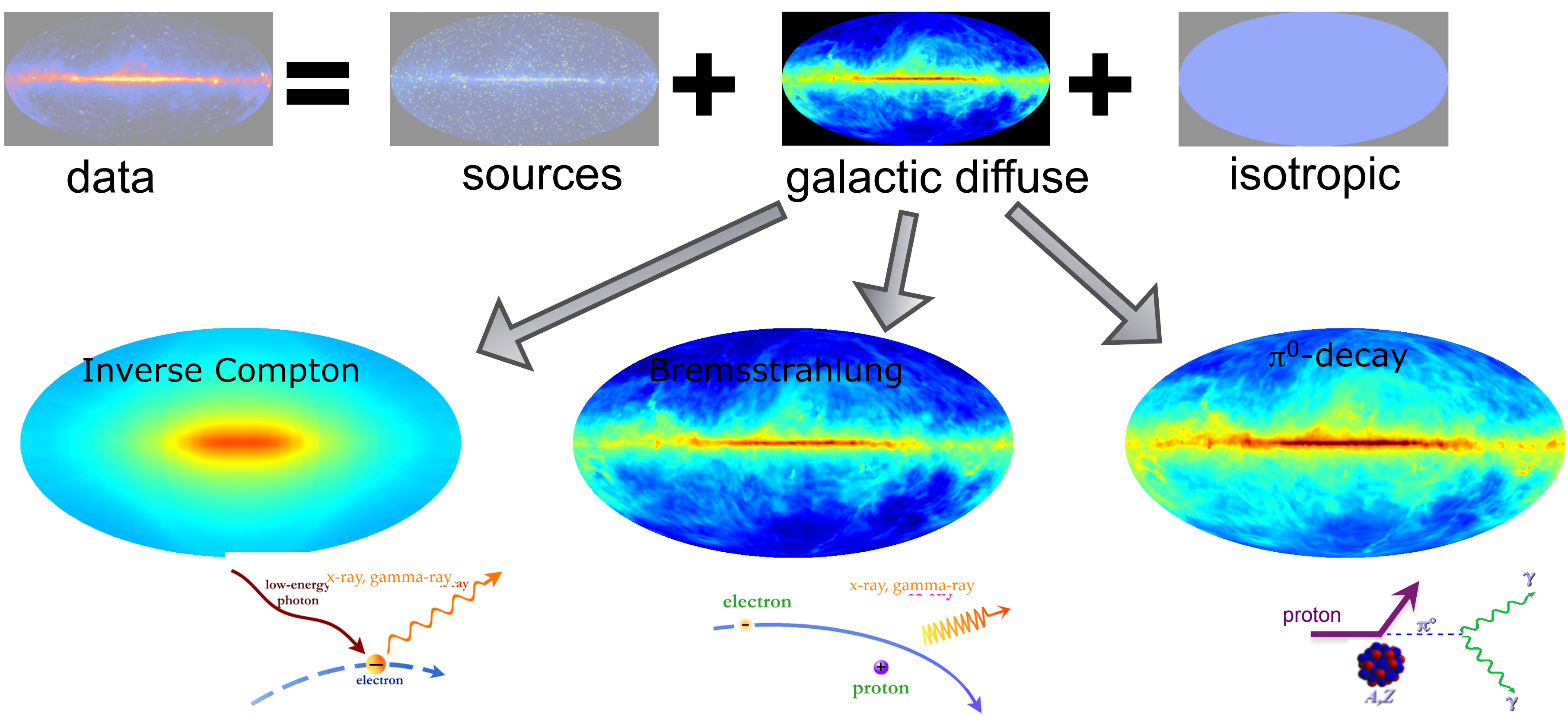
- non-detection places limits on annihilation cross section or decay lifetime to $\gamma\gamma$ and $Z\gamma$
- **recent papers in the arXiv suggest lines or hard spectral features consistent with DM predictions – much more to do!**

Decay lifetime constraints



Galactic Diffuse Emission

The diffuse gamma-ray emission from the Milky Way is produced by cosmic rays interacting with the interstellar gas and radiation field and carries important information on the acceleration, distribution, and propagation of cosmic rays.



All-sky modeling

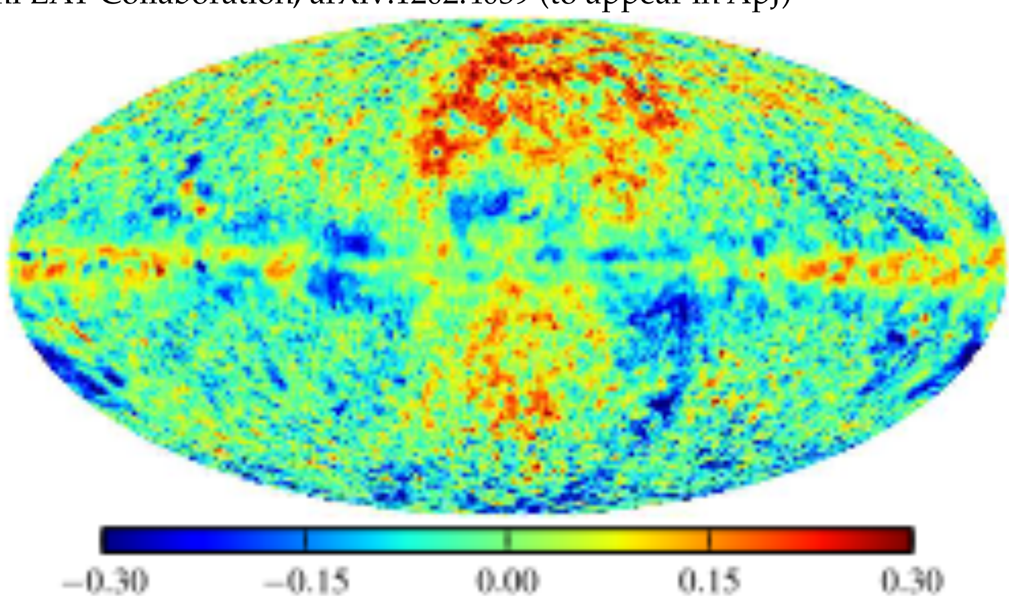
- Cosmic ray origin, propagation, and properties of the interstellar medium can be constrained by comparing the data to predictions.
- Generate models (in agreement with CR data) varying CR source distribution, CR halo size, gas distribution (GALPROP, http://galprop.stanford.edu) and compare with Fermi LAT data (21 months, 200 MeV to 100 GeV, P6 DATACLEAN)

On a large scale the agreement between data and prediction is overall good, however some extended excesses stand out.

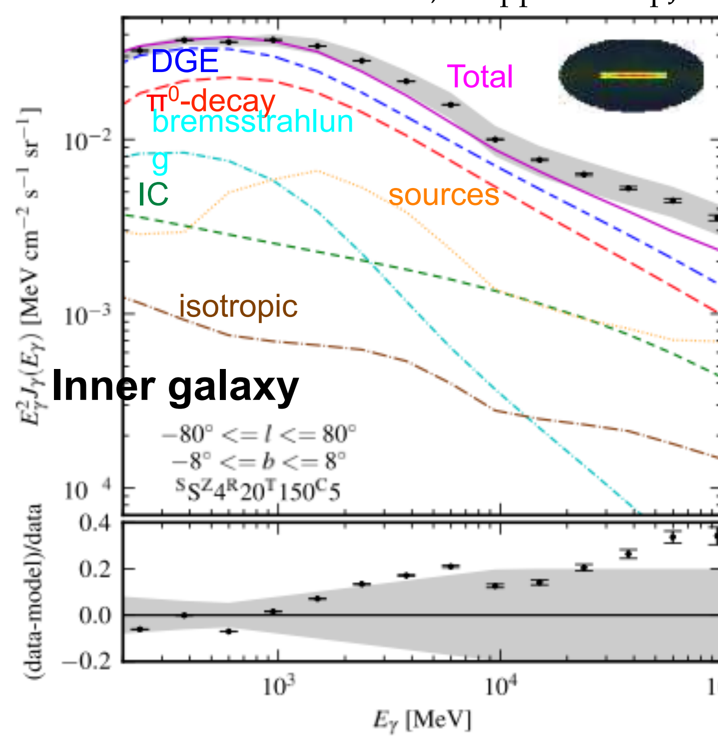
<u>Example model:</u>
CR source distribution: SNRs
CR confinement region: 20 kpc radius, 4 kpc height

(data - prediction)/prediction) for example model

Fermi LAT Collaboration, arXiv:1202.4039 (to appear in ApJ)



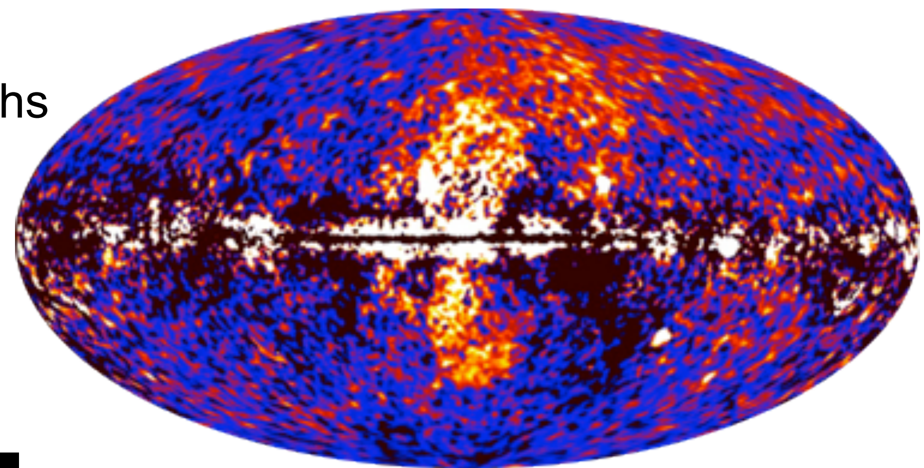
Fermi LAT Collaboration, to appear in ApJ

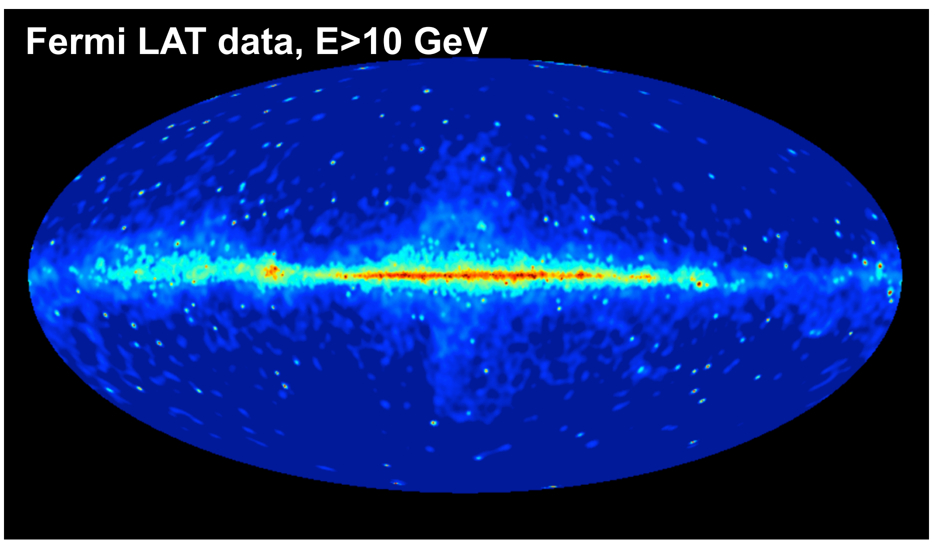


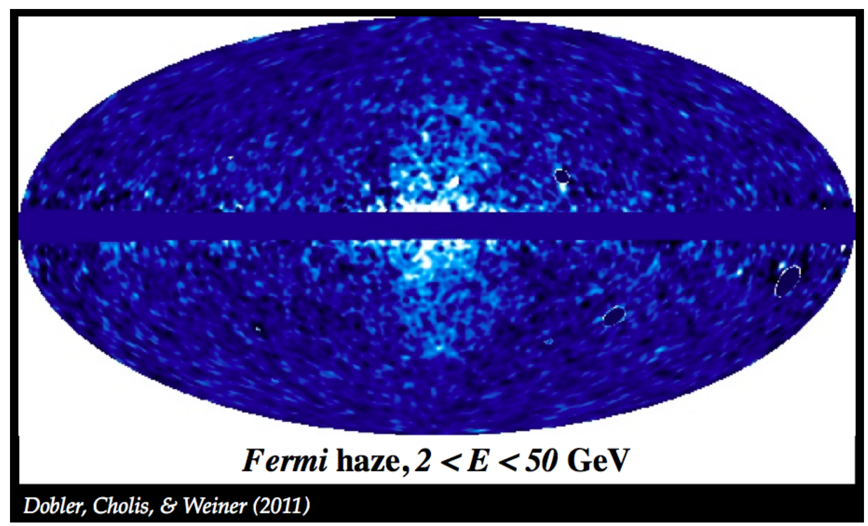
Remarkable Features

- Gamma-ray bubbles (Su et al 2010):
  - very extended (~ 50^{o} from plane)
  - hard spectrum (~E^{-2}, 1-100 GeV)
  - sharp edges
  - possible counterparts in other wavelengths (ROSAT, WMAP, and Planck)
- What is it?! Outflow from the center of the Milky Way: jets from the supermassive black hole? starburst?

"Gamma-ray Bubbles"
Su, Slatyer, and Finkbeiner (2010)



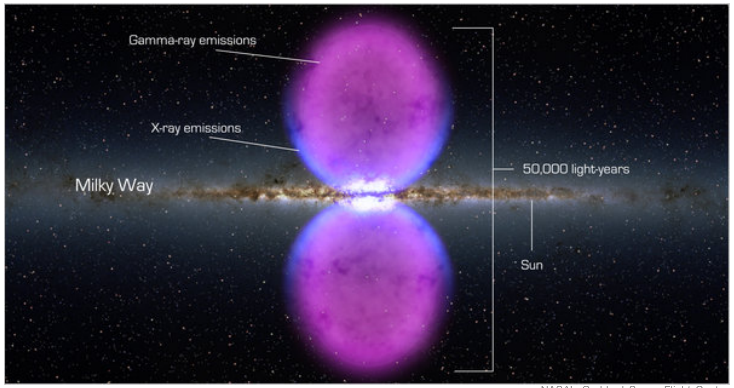




The New York Times

Space & Cosmos

Bubbles of Energy Are Found in Galaxy



NASA's Goddard Space Flight Center

From end to end, the newly discovered gamma-ray bubbles extend 50,000 light-years, or about half of the Milky Way's diameter, as shown in this illustration.

By DENNIS OVERBYE
Published: November 9, 2010

Something big is going on at the center of the galaxy, and astronomers are happy to say they don't know what it is.

A group of scientists working with data from NASA's Fermi Gamma-Ray Space Telescope said Tuesday that they had discovered two bubbles of energy erupting from the center of the Milky Way galaxy. The bubbles, they said at a news conference and in a paper to be published Wednesday in The Astrophysical Journal, extend 25,000 light years up and down from each side of the galaxy and contain the energy equivalent to 100,000 supernova explosions.

"They're big," said Doug Finkbeiner of the Harvard-Smithsonian Center for Astrophysics, leader of the team that discovered them.

The source of the bubbles is a mystery. One possibility is that they are fueled by a wave of star births and deaths at the center of the galaxy. Another option is a gigantic belch from the black hole known to reside, like Jabba the Hutt, at the center of the Milky Way. What it is apparently not is dark matter, the mysterious something that astronomers say makes up a quarter of the universe and holds galaxies together.

"Wow," said David Spergel, an astrophysicist at Princeton who was not involved in the work.

"And we think we know a lot about our own galaxy," Dr. Spergel added, noting that the bubbles were almost as big as the galaxy and yet unsuspected until now.

Jon Morse, head of astrophysics at NASA headquarters, said, "This shows again that the

Lobes: The Path Forward

Fermi Bubble

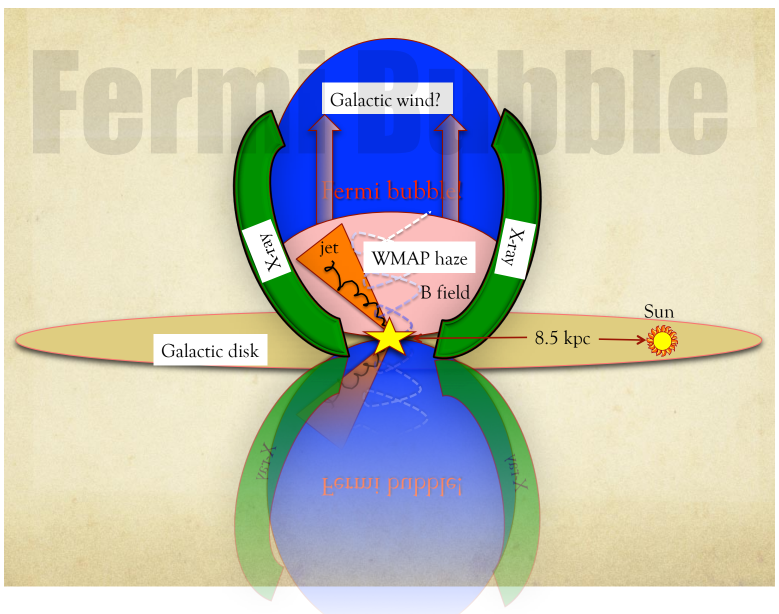
So far: there appear to be a pair of giant (50 degree high) gamma-ray bubbles at 1-5 GeV, and probably up to at least 50 GeV.

What are they?

Black hole "burp"

Superwind bubble?

Dark matter? (Dobler et al arXiv:1102.5095)



Talks at Fermi Symposium, Rome 2011

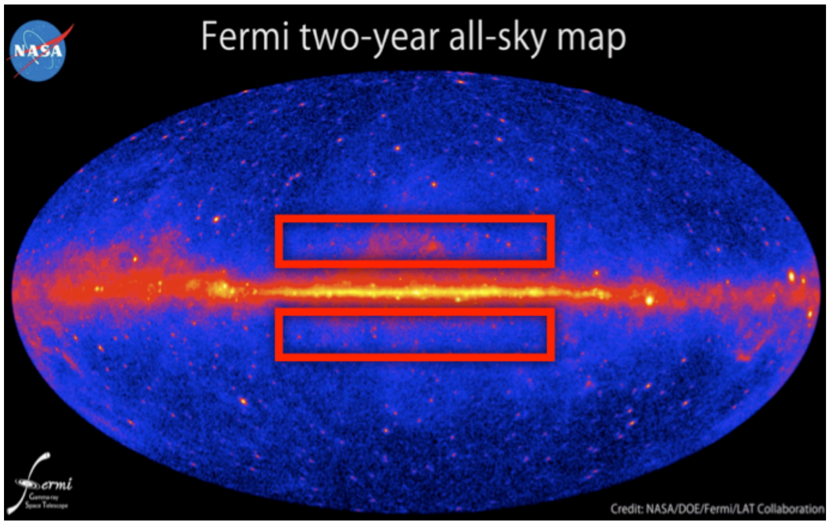
Fermi Bubble

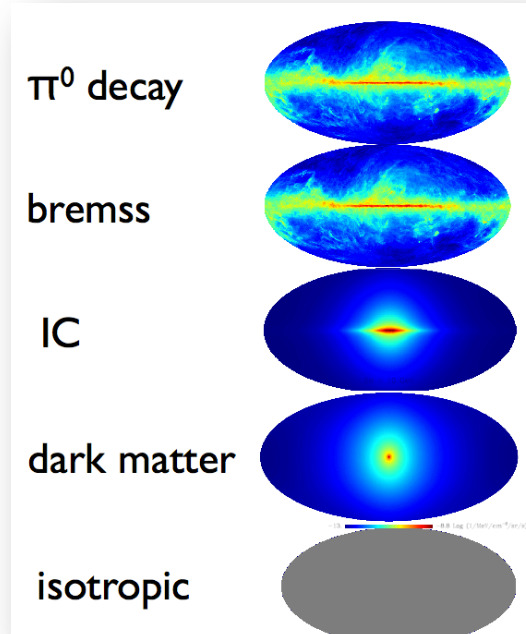
- *Continue observation of Fermi*
- *XMM-Newton data coming soon*
- *The eROSITA and Planck experiments will provide improved measurements of the X-rays and microwaves, respectively, associated with the Fermi bubbles*
- *Magnetic field structure of the bubbles*
- *Study of the origin and evolution of the bubbles also has the potential to improve our understanding of recent energetic events in the inner Galaxy and the high-latitude cosmic ray population.*

Meng Su talk

Constraints from the Milky Way halo

test the LAT diffuse data for a contribution from a Milky Way DM annihilation/decay signal





- data set: 24 months, p7 clean event selection (front+back) in the 1-100 GeV energy range
- ROI: 5° <|b|<15° and |l|<80°, chosen to:
  - minimize DM profile uncertainty (highest in the Galactic Center region)
  - limit astrophysical uncertainty by masking out the Galactic plane and cutting-out high-latitude emission from the Fermi lobes and Loop I

Halo Limits

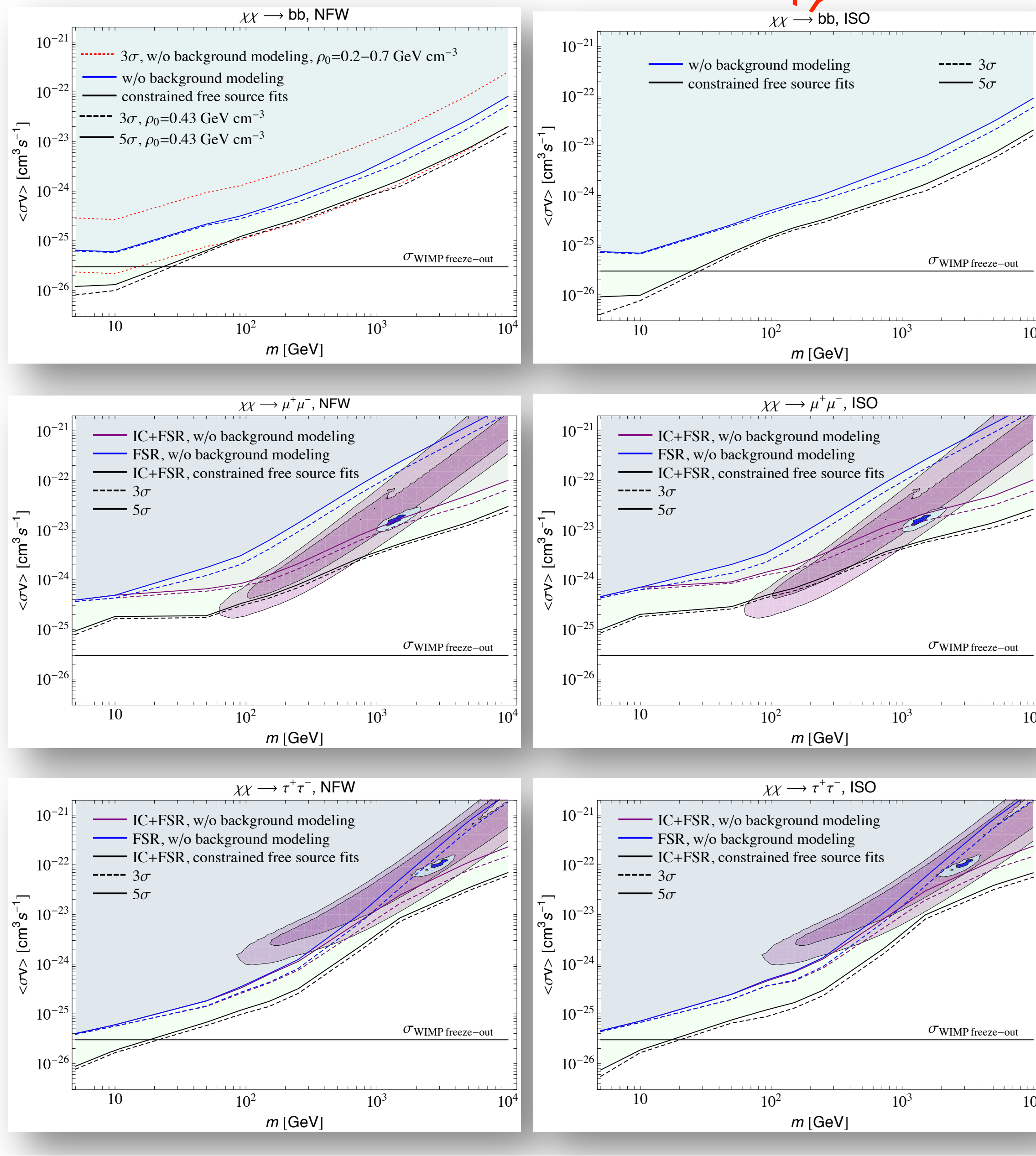
PRELIMINARY

DM limits with simultaneous modeling of astrophysical signal:

- uncertainties from diffusion models and gas maps taken into account by scanning over a grid of GALPROP models
- for each GALPROP (+DM) model, maps of different components of diffuse emission are generated and fit to the Fermi LAT data, incorporating both morphology and spectra

- the distribution of CR sources is highly uncertain, so is left free to vary in radial Galactic bins. To get more conservative DM constraints, *the distribution is set to zero in the inner 3 kpc*

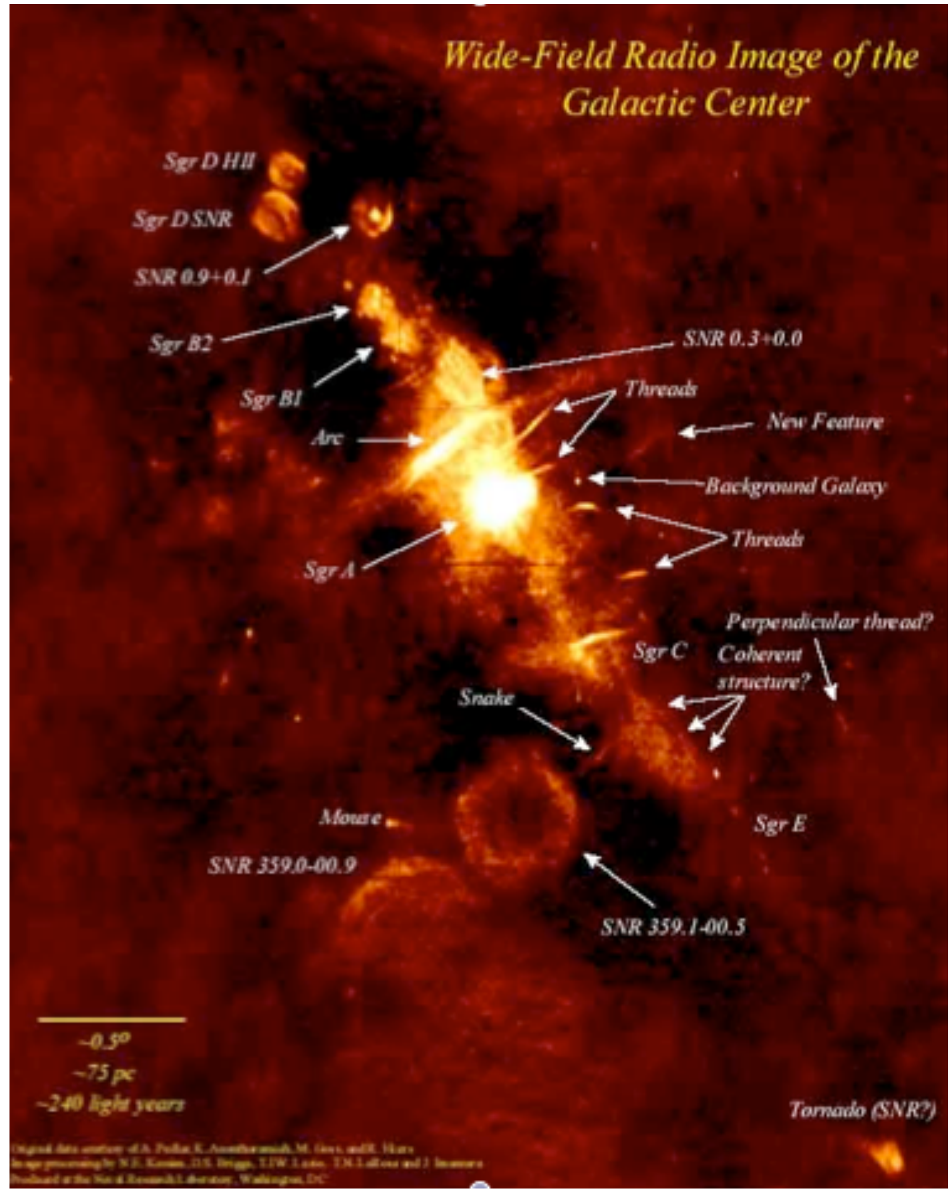
the profile likelihood method is used to combine all the models in the grid, and to derive the DM limits marginalized over the astrophysical uncertainties



Inner Galaxy

- "*Lasciate ogne speranza, voi ch'entrate"* – Dante Alighieri

- *"If you're going through hell, KEEP GOING!" - Winston Churchill* (emphasis added)

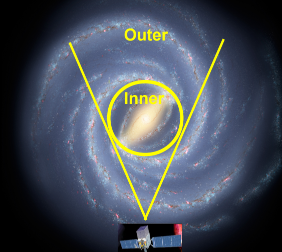


Inner Galaxy

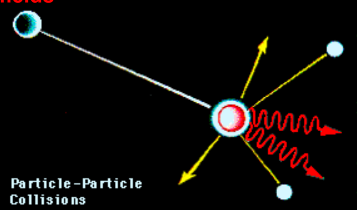
Disentangling the Many Sources of Gamma-Ray Emission is Challenging ...

The emission from the inner Galaxy consists of a number of components:

- Outer Galaxy
- True inner Galaxy
- Point sources
- Unresolved sources



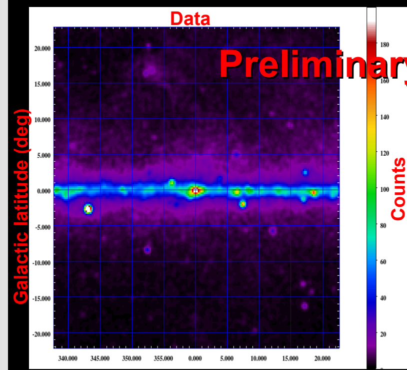
Diffuse gamma rays produced by cosmic rays interacting with the interstellar gas and radiation fields



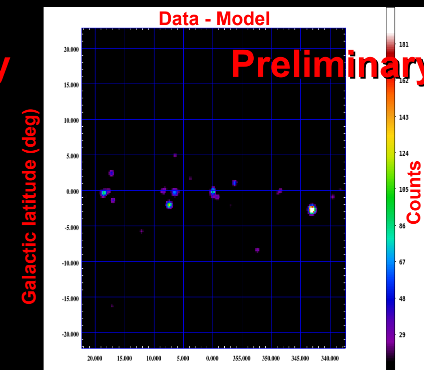
Use galprop cosmic ray propagation/diffuse emission code

http://galprop.stanford.edu

Subtraction of the Diffuse Emission



Data > 1 GeV for 45°x45° region about GC

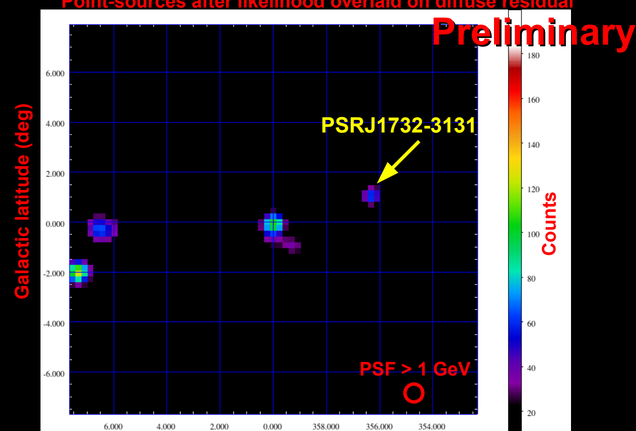


Data - Model > 1 GeV for 45°x45° region about GC

32 Months Data (Front)

Residual Emission for 15°x15° about GC

Point-sources after likelihood overlaid on diffuse residual



Galactic longitude (deg)

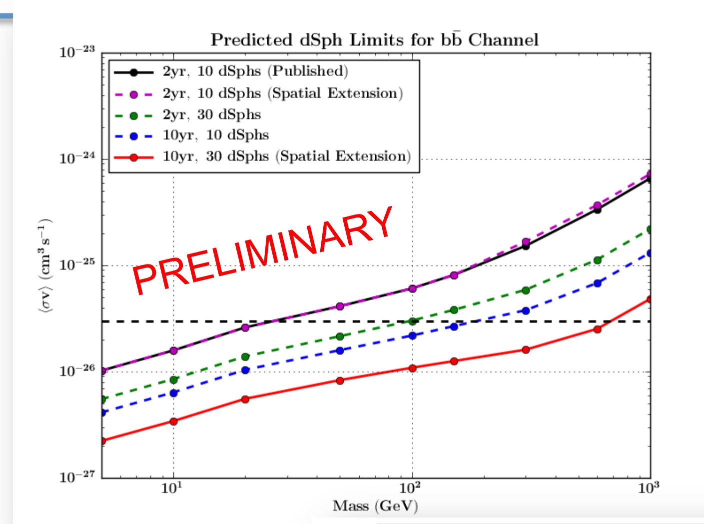
Bright excesses remain after model subtraction

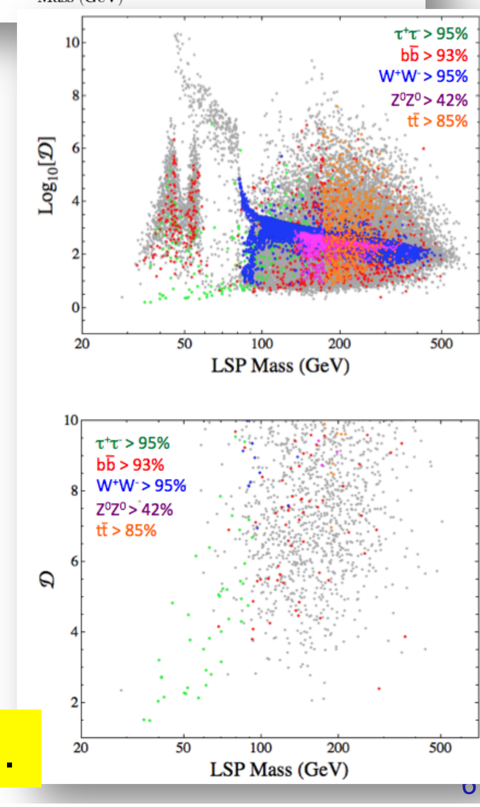
Summary

- The majority of the diffuse emission is removed using a physically-motivated model based on GALPROP
- Peaks in residual emission consistent with known sources
- Work in progress to characterise the low-level residual structures and point sources
- Forthcoming paper(s) will describe the method and results in detail

A look forward

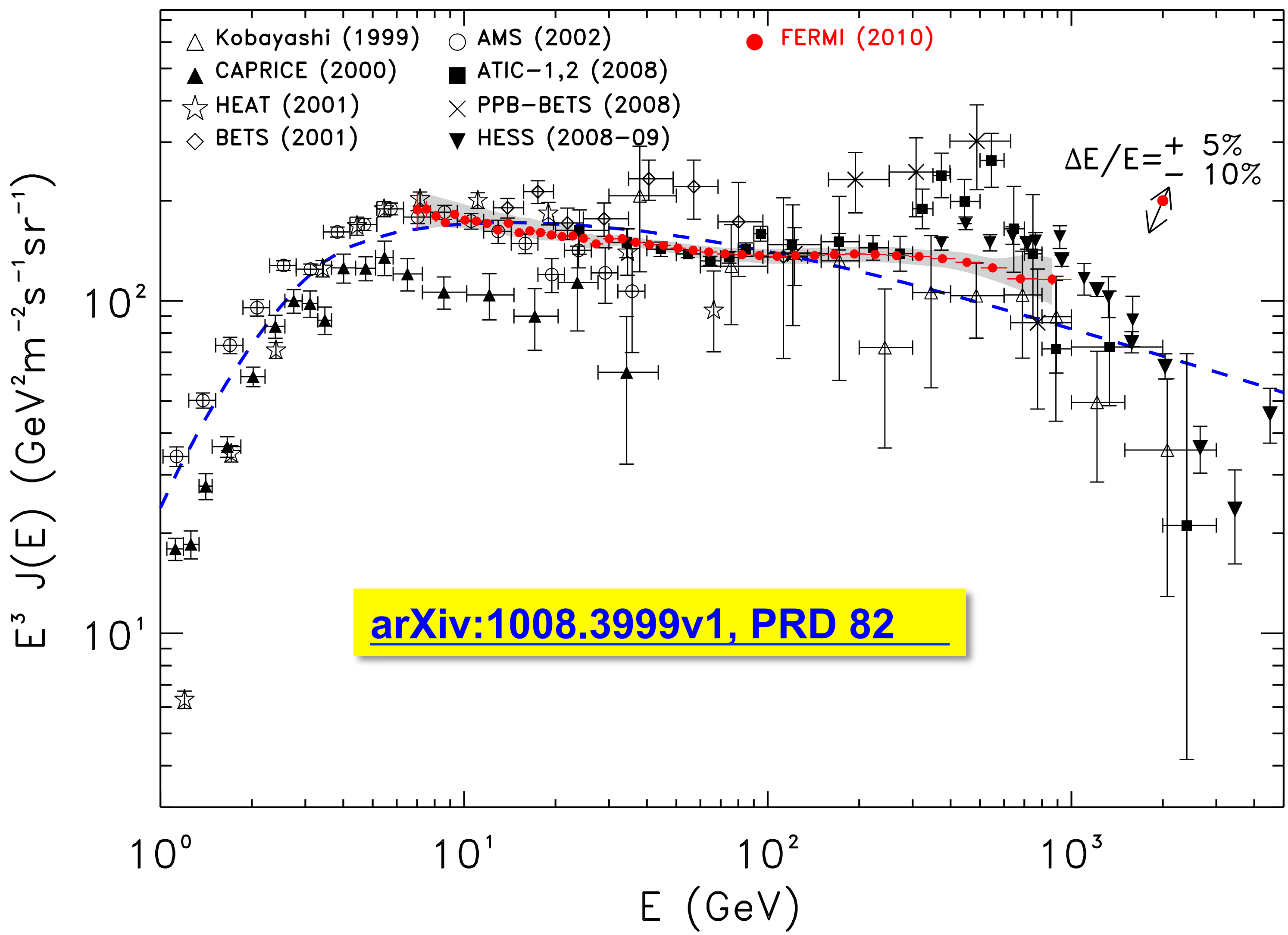
- Much more to do in all areas:
  - future DM limits from dSph projected to improve due to increased observation time, discovery of new dwarfs
  - Lines: more data, improved analysis of high-energy events, optimization of regions, checks!
  - Halo: more detailed accounting of uncertainties in limits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





arXiv:1111.2604 Cotta et al.

LAT e+e- Spectrum Update



arXiv:1008.3999v1, PRD 82

7 GeV – 1 TeV, double statistics (8M events)

Data/MC Comparisons

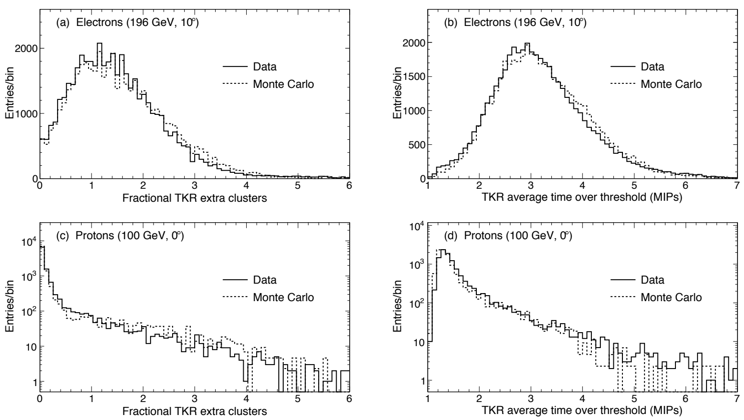


FIG. 1: Comparison of beam test data (solid line) and MC simulations (dashed line) for two fundamental tracker variables used in the electron selection: the number of clusters in a cone of 10 mm radius around the main track (left panels) and the average time over threshold (right panels). Both variables are shown for an electron and a proton beam.

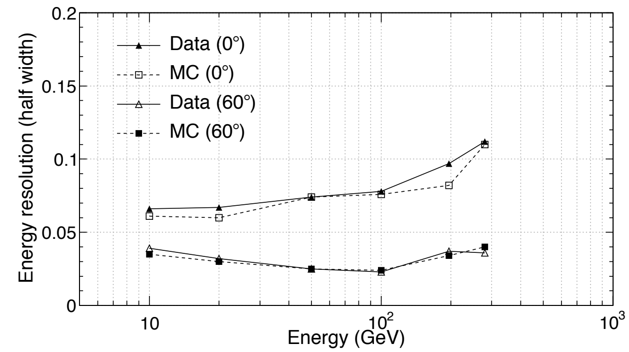


FIG. 3: Comparison of beam test data (triangles) and Monte Carlo simulations (squares) for the energy resolution for electron beams entering the CU at 0° and 60° and energies from 10 to 282 GeV. Lines are to guide an eye.

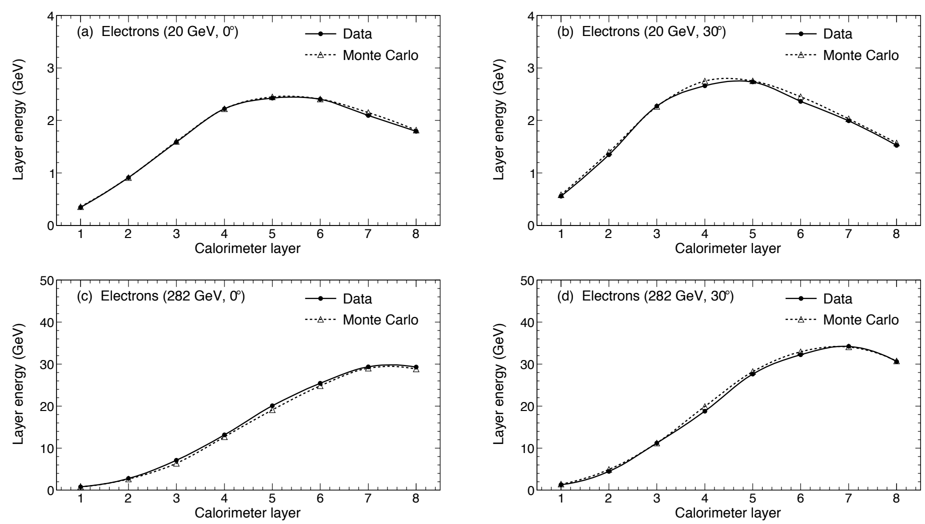
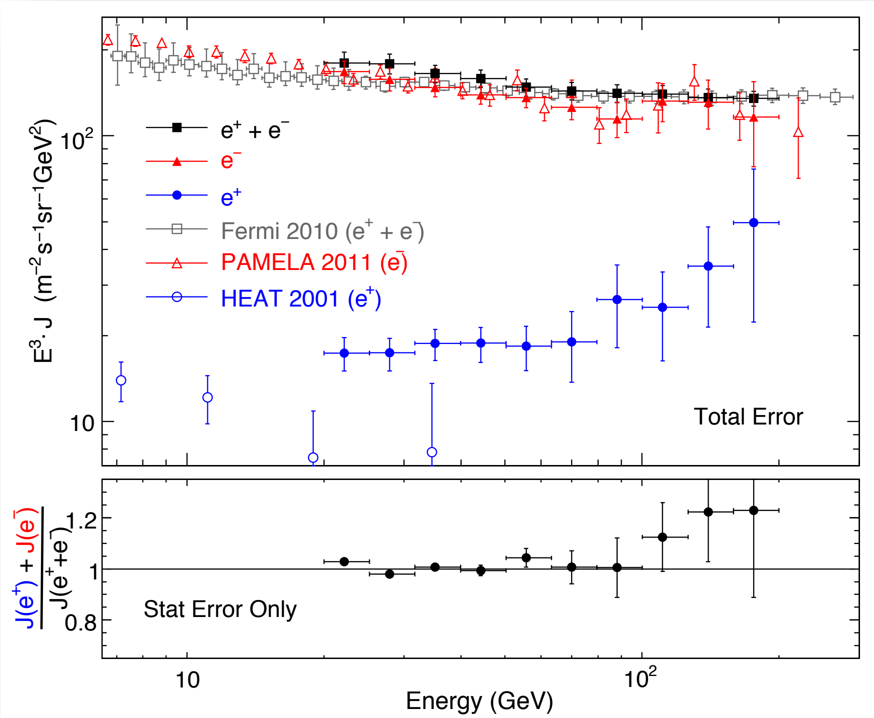


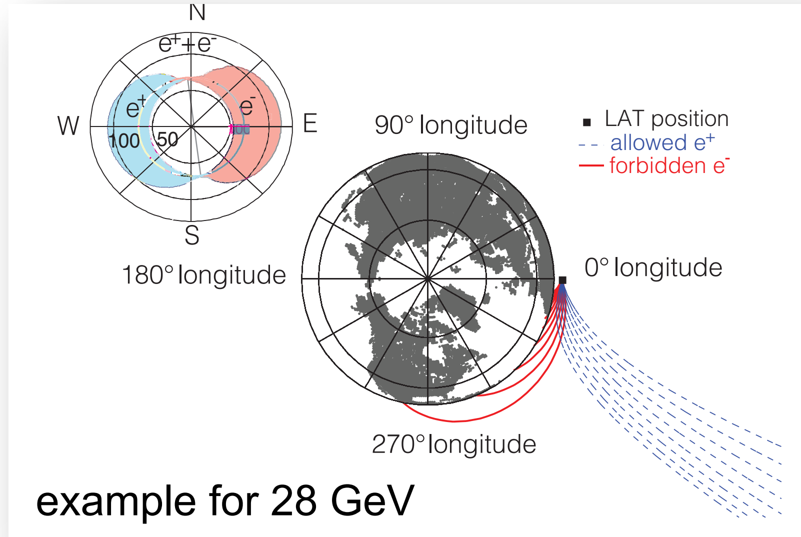
FIG. 4: Comparison of Beam test data and Monte Carlo simulations for the longitudinal shower profiles for electron beams entering the CU at 0° and 30° and energies of 20 and 282 GeV.

Many thanks to CERN, GSI, and SLAC!!

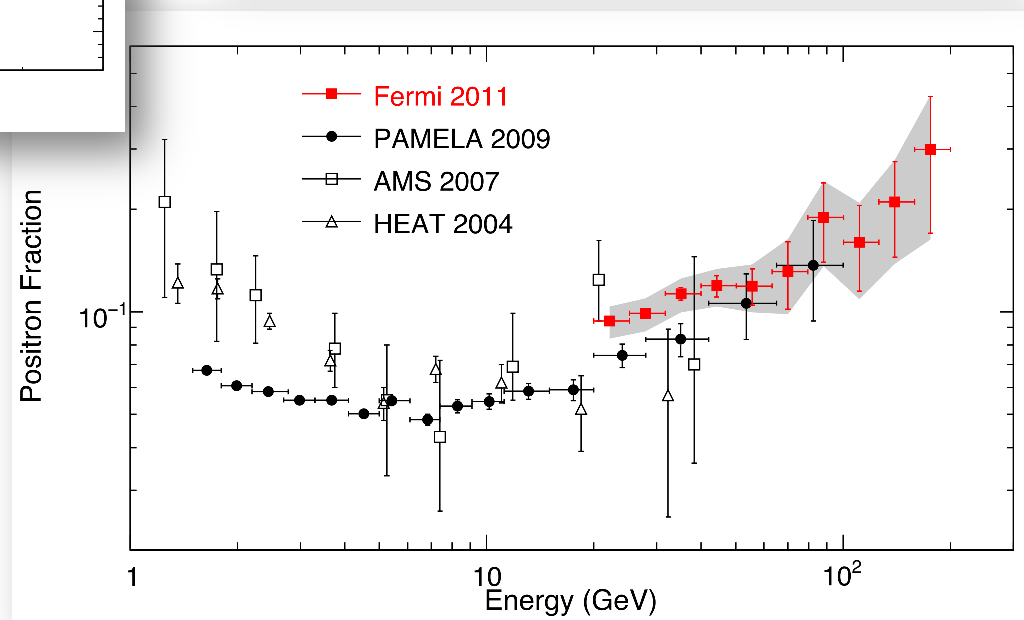
arXiv:1008.3999v1, PRD 82

LAT e+ and e- Measurement





arXiv:1109.0521



…and AMS-02 is flying!

No Significant e+e- Excess or Deficit from the Sun

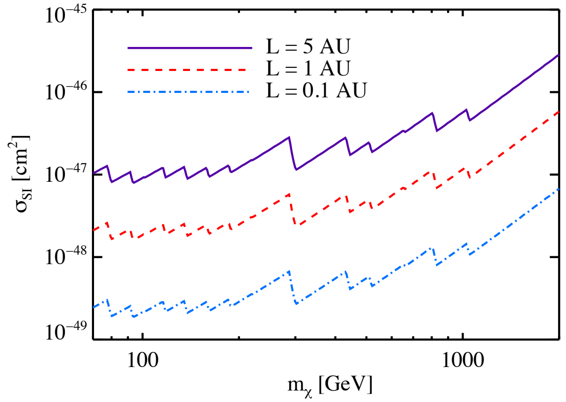


FIG. 6: Constraints on DM annihilation to e^+e^- via an intermediate state, from solar CRE flux upper limits. Solar capture of DM is assumed to take place via spin-independent scattering. The constraints obtained for three values of the decay length L of the intermediate state are shown. Models above the curves exceed the solar CRE flux upper limit at 95% CL for a 30° ROI centered on the Sun.

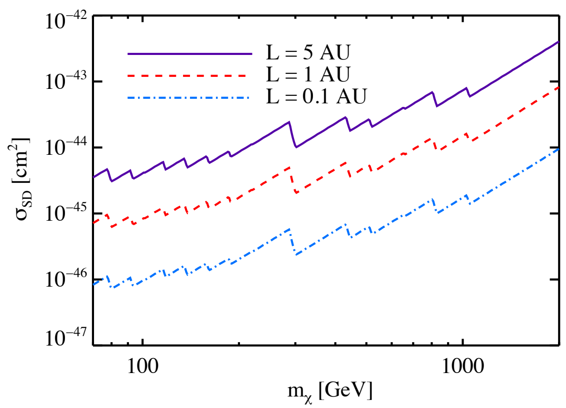
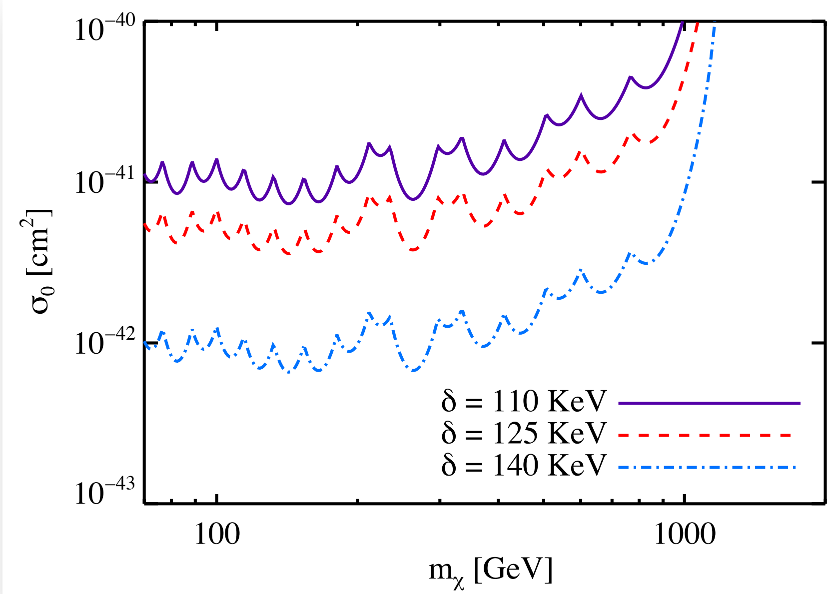


FIG. 7: Constraints on DM parameters for annihilation to e^+e^- via an intermediate state as in Fig. 6, except assuming solar capture by spin-dependent scattering.

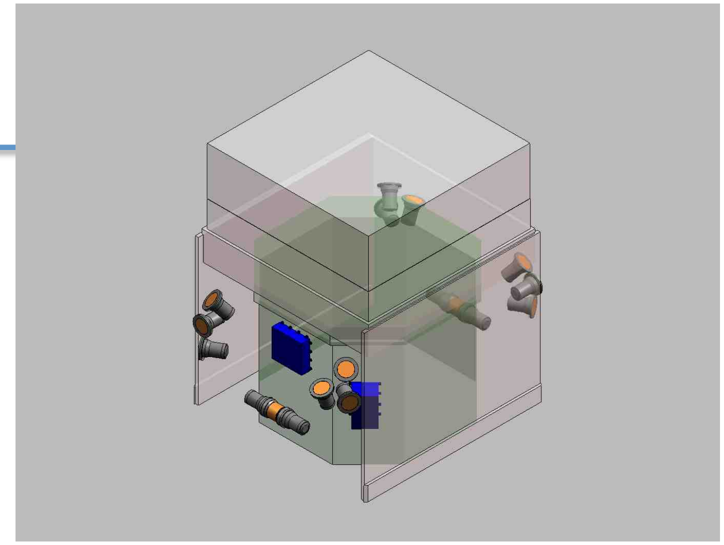
arXiv:1107.4272



strongly excludes iDM explanation for DAMA/LIBRA – CDMS inconsistency for m>70 GeV and annihilation to e+e-

Intermediate state ➔ e+e- constraints

GBM Collaboration



National Space Science & Technology Center

University of Alabama
in Huntsville

NASA
Marshall Space Flight Center

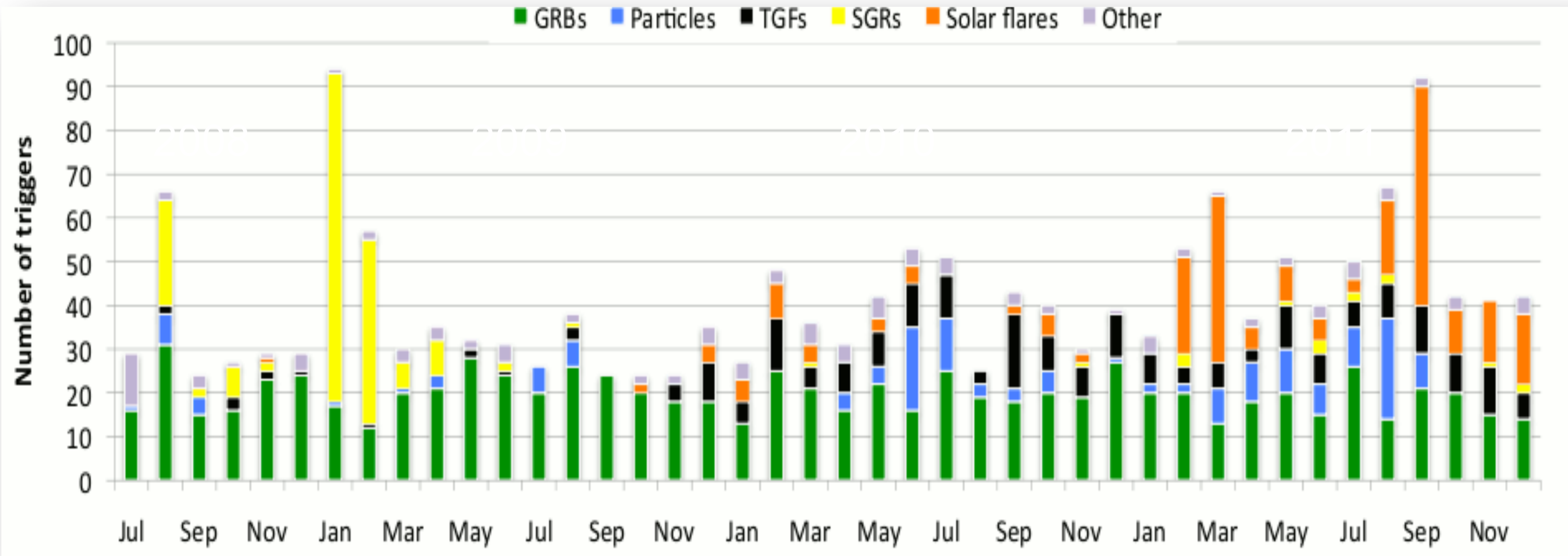
Max-Planck-Institut für
extraterrestrische Physik

Bill Paciesas (PI)
Jochen Greiner (Co-PI)

Gamma-ray Burst Monitor

Detecting MeV transients from Earth, Sun, Galaxy and distant Universe

2-yr GBM Catalog: arXiv:1201.3099v1



250 GRB/year detected by GBM
plus much more!

LAT GRB: What do we see?

the Brightest and Most Distant Sources Seen by Fermi

GRB Name	GBM T90	N Pred. Events (>100MeV, Trans.)	HE Delayed Onset?	Long Lived HE Emission?	Maximum Energy (GeV)	Arrival time of the highest events (seconds since trigger)	Redshift
GRB080825C	Long	10	√	√	0.6	28.3	-
GRB080916C	Long	188	√	√	13.2	16.5	4.35
GRB081006	Long	13	√	√	0.8	1.8	-
GRB081024B	Short	11	√	√	3.1	0.6	-
GRB081207	Long	LLE	-	-	-	-	-
GRB090217	Long	17	√	√	1.2	179.1	-
GRB090227B	Short	3	-	-	0.0	0.0	-
GRB090323	Long	30	√	√	7.5	195.4	3.57
GRB090328	Long	50	√	√	24.5	261.7	0.736
GRB090510	Short	186	√	√	31.3	0.8	0.903
GRB090531B	Short	LLE	-	-	1.6	115.2	-
GRB090626	Long	LLE	√	√	2.1	111.6	-
GRB090902B	Long	314	√	√	33.4	81.8	1.822
GRB090926	Long	249	√	√	19.6	24.8	2.106
GRB091003	Long	3231	√	√	2.8	6.5	0.897
GRB091031	Long	15	√	√	1.2	79.8	-
GRB100116A	Long	14	-	√	13.1	296.4	-
GRB100225A	Long	LLE	-	-	-	-	-
GRB100325A	Long	6	-	√	1.9	71.4	-
GRB100414A	Long	27	√	√	4.7	288.3	1.368
GRB100724B	Long	22	-	-	0.2	61.8	-
GRB100728A	Long	4	-	-	0.1	81.2	-
GRB100728A	Long	LLE	-	-	0.1	81.2	-
GRB101014A	Long	LLE	-	-	-	-	-
GRB101123A	Long	LLE	-	-	-	-	-
GRB110120A	Long	5	-	-	1.8	72.5	-
GRB110328B	Long	LLE	-	-	1.6	514.7	-
GRB110428A	Long	17	√	√	2.6	14.8	-
GRB110529A	Short	LLE	-	-	-	-	-
GRB110625A	Long	12	-	√	2.4	272.4	-
GRB110721A	Long	29	-	√	1.7	0.7	0.38
GRB110731A	Long	65	√	√	3.4	436.0	2.83

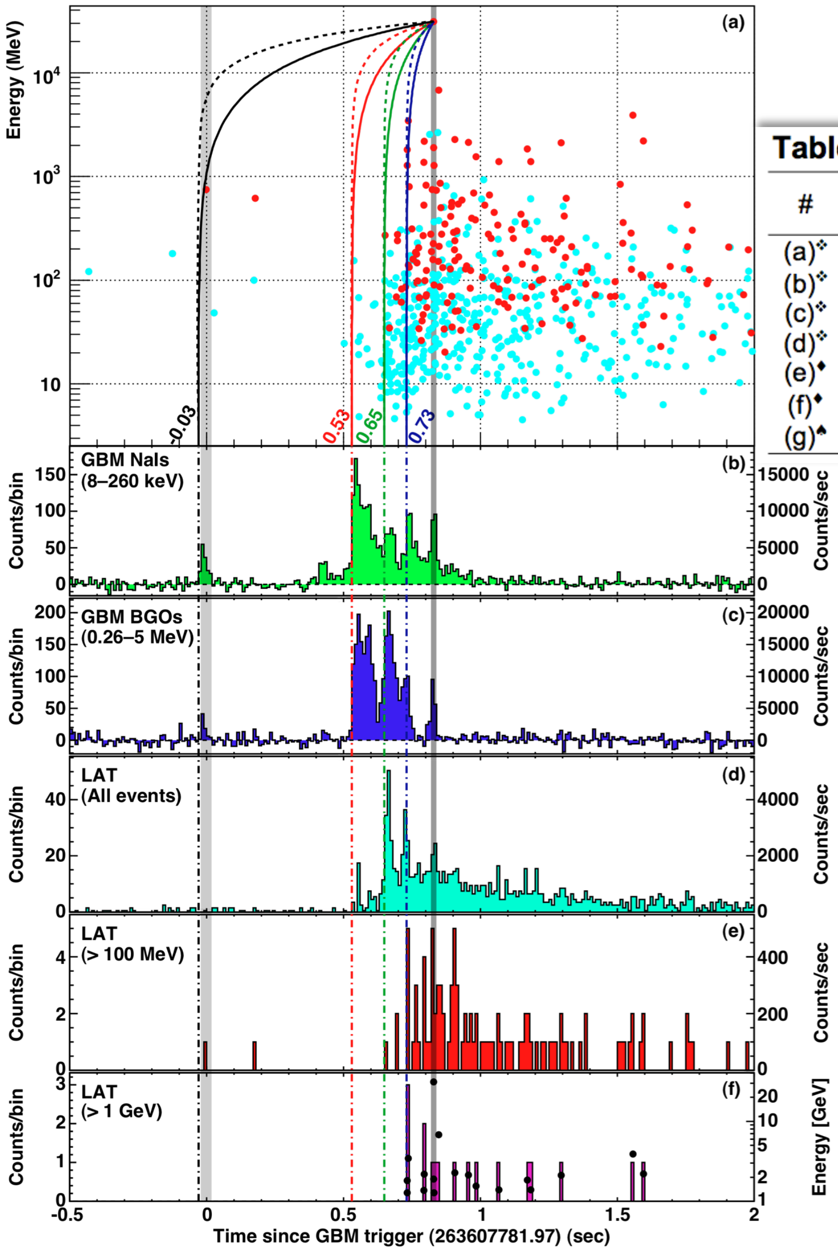
PRELIMINARY

- 32 GRB have been seen by LAT above 100 MeV;
- Both long (>2 sec) and short (<2 sec) bursts have been seen;
- Some bursts are only visible in LAT Low Energy events;
- Most of the bursts show high-energy emission afterglow and delayed high-energy onset;
- Constraint: lower limit of bulk Lorentz factor of the colliding shells: ~1000;
- Some bursts have an extra spectral component (a different mechanism at high energy?);

These short, distant and bright flashes can be used as tools to probe basic physics…

See http://fermi.gsfc.nasa.gov/ssc/resources/observations/grbs/grb_table/

QG-Related Limits from GRB 090510



Published in Nature, vol 462, p331 (plus comment on p291)

Table 2 | Limits on Lorentz Invariance Violation

#	$t_{start} - T_0$ (ms)	Limit on $\lvert\Delta t\rvert$ (ms)	Reasoning for choice of t_{start} or limit on Δt or $\lvert\Delta t/\Delta E\rvert$	E_l † (MeV)	Valid for s_n*	Lower limit on $M_{QG,1}/M_{Planck}$
(a)✧	−30	< 859	start of any < 1 MeV emission	0.1	1	> 1.19
(b)✧	530	< 299	start of main < 1 MeV emission	0.1	1	> 3.42
(c)✧	*648*	< 181	start of main > 0.1 GeV emission	100	1	> 5.63
(d)✧	730	< 99	start of > 1 GeV emission	1000	1	> 10.0
(e)♦	—	< 10	association with < 1 MeV spike	0.1	±1	> 102
(f)♦	—	< 19	If 0.75 GeV‡ γ-ray from 1st spike	0.1	−1	> 1.33
(g)♠	$\lvert\Delta t/\Delta E\rvert$ < 30 ms/GeV		lag analysis of > 1 GeV spikes	—	±1	> 1.22

…with the assumption that the HE photons are not emitted *before* the LE photons.

also see, e.g., Ellis, Mavromatos, and Nanopoulos **arXiv:0901.4052** / **Phys.Lett. B674 (2009) 83-86** and Amelino-Camelia, Ellis, Mavromatos, Nanopoulos and Sarkar, **Nature 393, 763 (1998)**.

EBL Constraints

arXiv:1005.0996

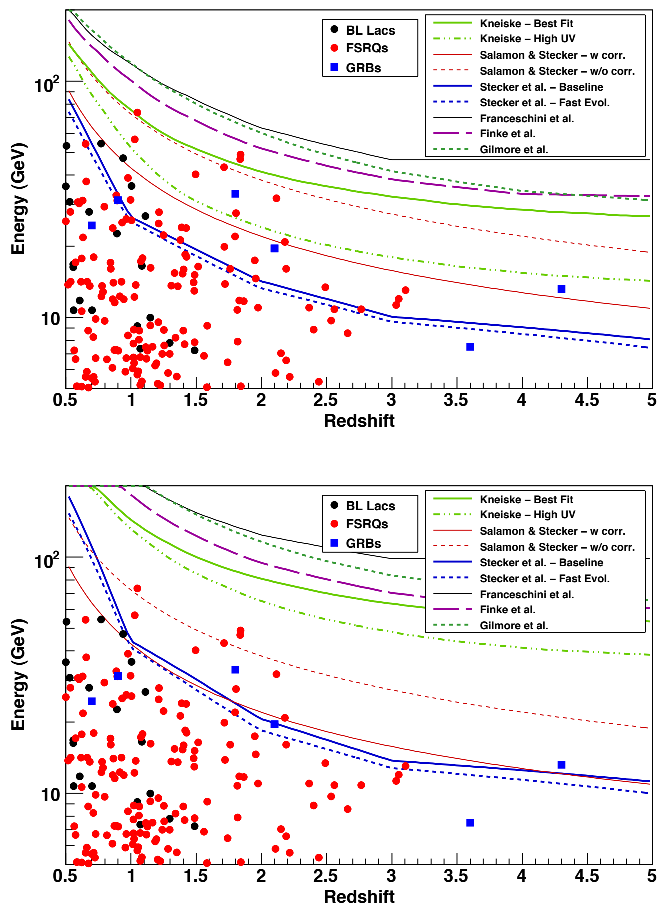


Fig. 2.— Highest-energy photons from blazars and GRBs from different redshifts. Predictions of $\gamma\gamma$ opacity $\tau_{\gamma\gamma} = 1$ (top panel) and $\tau_{\gamma\gamma} = 3$ (bottom panel) from various EBL models are indicated by lines. Photons above model predictions in this figure traverse an EBL medium with a high γ-ray opacity. The likelihood of detecting such photon considering the spectral characteristics of the source are considered in the method presented in section 3.2.1.

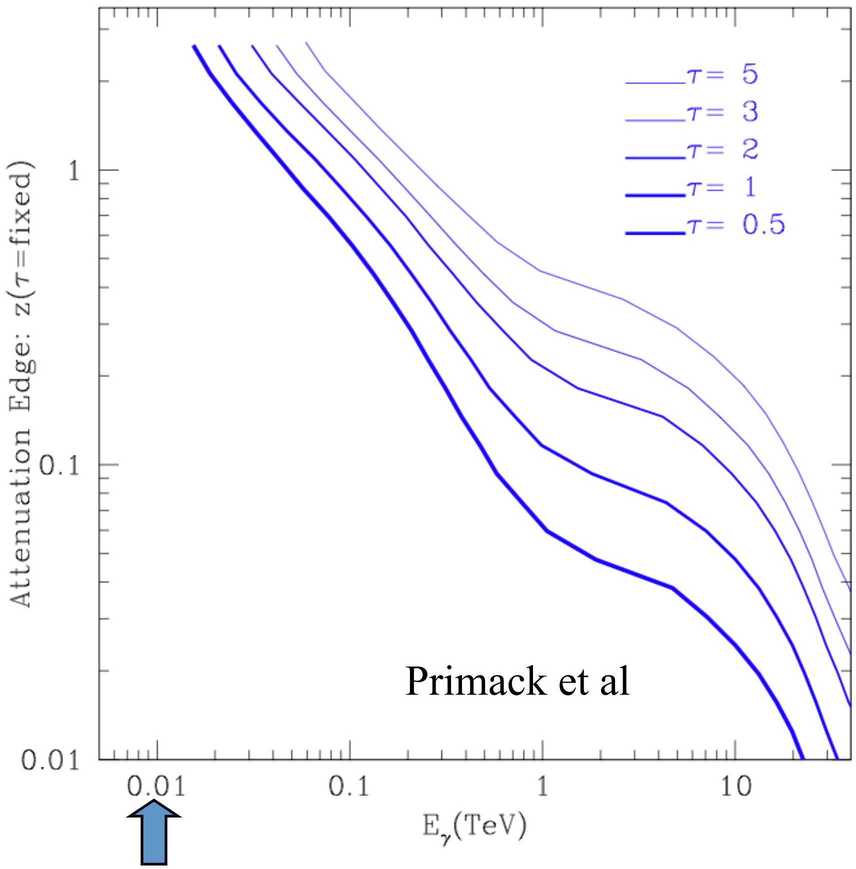
Source	z	Energy (GeV)	P_{bkg}	HEP method applied to Stecker 06: P_{HEP}	$P_{rejection}$	HEP Rejection Significance
J1147-3812	1.05	73.7	7.0×10^{-4}	1.2×10^{-4}	8.1×10^{-4}	3.2 σ
J1504+1029	1.84	48.9	5.6×10^{-3}	6.7×10^{-5}	5.7×10^{-3}	
		35.1	9.8×10^{-3}	6.8×10^{-3}	1.7×10^{-2}	
		23.2	5.6×10^{-3}	1.8×10^{-1}	1.9×10^{-1}	
				Combined $P_{rej} = 1.7 \times 10^{-5}$		4.1 σ
J0808-0751	1.84	46.8	1.5×10^{-3}	1.9×10^{-4}	1.7×10^{-3}	
		33.1	2.7×10^{-3}	3.7×10^{-3}	6.4×10^{-3}	
		20.6	6.9×10^{-3}	2.5×10^{-1}	2.6×10^{-1}	
				Combined $P_{rej} = 2.8 \times 10^{-6}$		4.5 σ
J1016+0513	1.71	43.3	1.1×10^{-3}	5.4×10^{-4}	1.6×10^{-3}	
		16.8	8.2×10^{-3}	4.9×10^{-1}	4.9×10^{-1}	
		16.1	8.2×10^{-3}	6.5×10^{-1}	6.5×10^{-1}	
				Combined $P_{rej} = 5.3 \times 10^{-4}$		3.3 σ
J0229-3643	2.11	31.9	1.7×10^{-3}	8.9×10^{-5}	1.8×10^{-3}	2.9 σ
GRB 090902B	1.82	33.4	2×10^{-6}	2.0×10^{-4}	2.0×10^{-4}	3.7 σ
GRB 080916C	4.24	13.2	8×10^{-8}	6.5×10^{-4}	6.5×10^{-4}	3.4 σ

Table 4: Listed are the significance of rejecting the "baseline" model (Stecker et al. (2006)), calculated using the HEP method as described in Section 3.2.1. For completeness, we also report individually the probability of the HEP to be a background event (P_{bkg}) and the probability for this HEP not to be absorbed by the EBL if it were emitted by the source (P_{HEP}). As explained in the text: $P_{rejection} = P_{bkg} + P_{HEP} \times (1 - P_{bkg})$. For those sources with more than one constraining photon, the individual and combined $P_{rejection}$ are calculated. The "fast evolution" model by Stecker et al. (2006) is more opaque and leads to an even higher significance of rejection. Applying this method to less opaque models leads to no hints of rejection since the probability P_{HEP} is large in those cases (e.g. $\gtrsim 0.1$ for the Franceschini et al. (2008) EBL model). Note that a log parabola model was used as the intrinsic model for source J1504+1029 since evidence of curvature is observed here even below 10 GeV (see Table 2).

Even just a few high-Z GRBs and additional HE photons from Pass8 reanalysis will be VERY helpful

An Important Energy Band

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



No significant attenuation below ~10 GeV.

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

EBL over cosmological distances is probed by gammas in the 10-100 GeV range.

In contrast, the TeV-IR attenuation results in a flux that may be limited to more local (or much brighter) sources.

A dominant factor in EBL models is the star formation rate -- attenuation measurements can help distinguish models.

The Sun is Waking Up!

Talks at Fermi Symposium, Rome 2011

SUMMARY

The M2-class solar flare, SOL2010-06-12T00:57, was modest in many respects yet exhibited remarkable acceleration of energetic particles.

The flare produced an ~50 s impulsive burst of hard X-and gamma-ray emission up to at least 400 MeV.

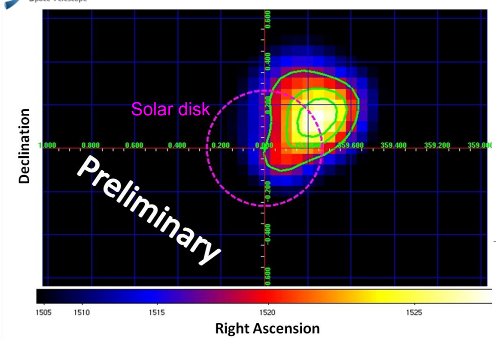
The gamma-ray line fluence from this flare was about ten times higher than that typically observed from this modest class of X-ray flare.

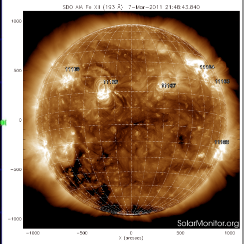
Analysis of the combined nuclear line and high-energy gamma-ray emissions suggests that the accelerated proton spectrum at the Sun softened from a power-law index of ~-3.2 between ~5-50 MeV, to ~-4.5 between ~50-300 MeV, to one softer than ~-4.5 >300 MeV (Preliminary).

G. Share talk

Also see J. Ryan overview talk

Gamma-ray emission region





SDO/193A image

- Sigificance map (so-called TS map) was produced for the LAT data accumulated during the whole duration
- Green lines show the 1sigma, 2sigma, 3sigma contours
- The LAT HE photons came from the North-western part of the Sun, from where M3.7 flare was emitted (active region 11164)

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Summary

- Fermi-LAT detected the longest HE emission from the Sun following the 2011 March 7 flare. The duration was ~12 hours.
- The LAT emission came from the North-West part of the Sun, from where the M3.7 flare is emitted
- The LAT spectrum showed clear turnover around 200 MeV, suggesting that pion decay is promising
- The March 7 flare is associated with a fast CME of 2200 km/s
- We considered three possible scenarios which might explain the long-lived LAT emission
- Further quantitative discussion is ongoing, and paper is now being prepared

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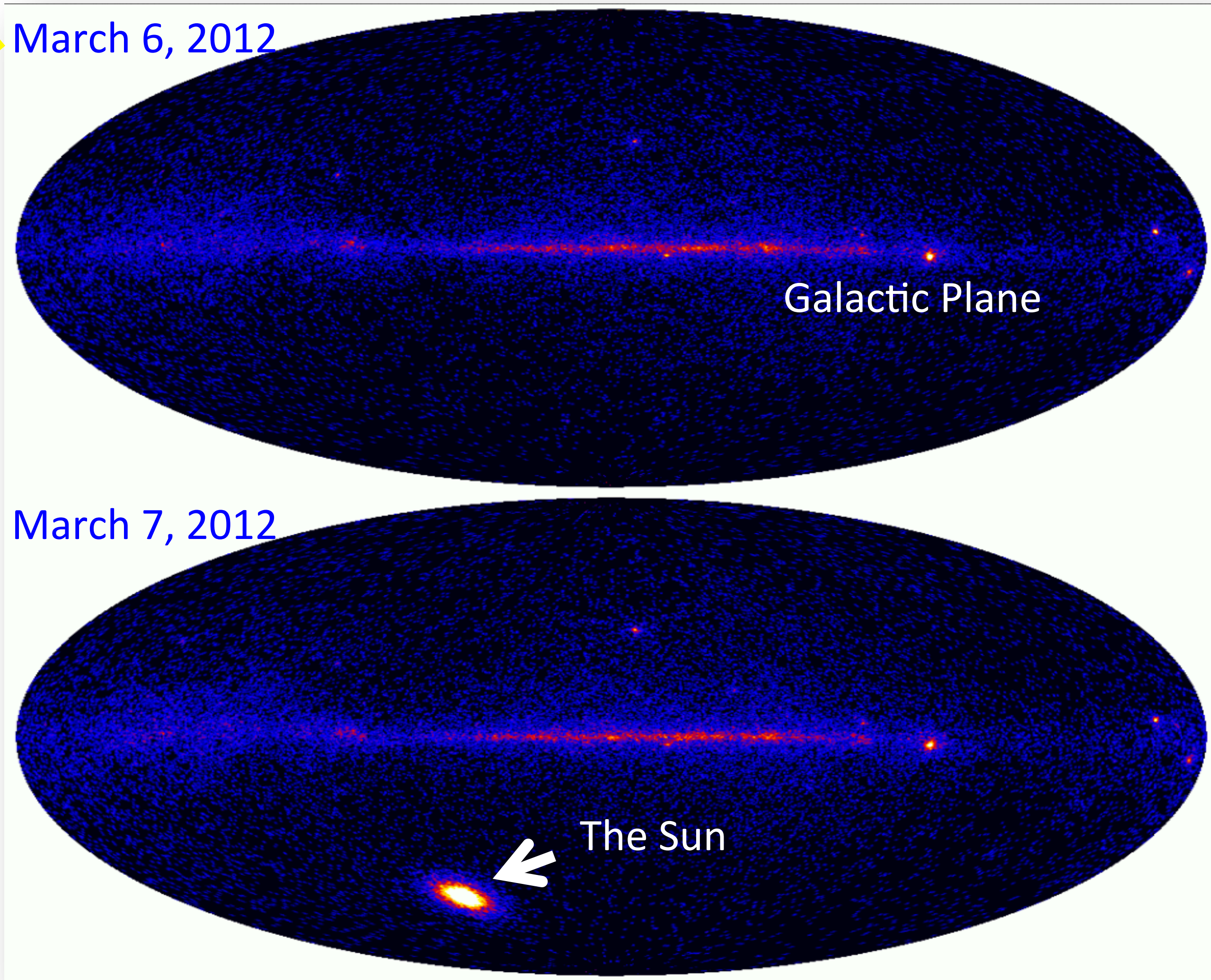
Y. Tanaka talk

APOD 15 March 2012



Credit: Fermi Large Area Telescope Collaboration

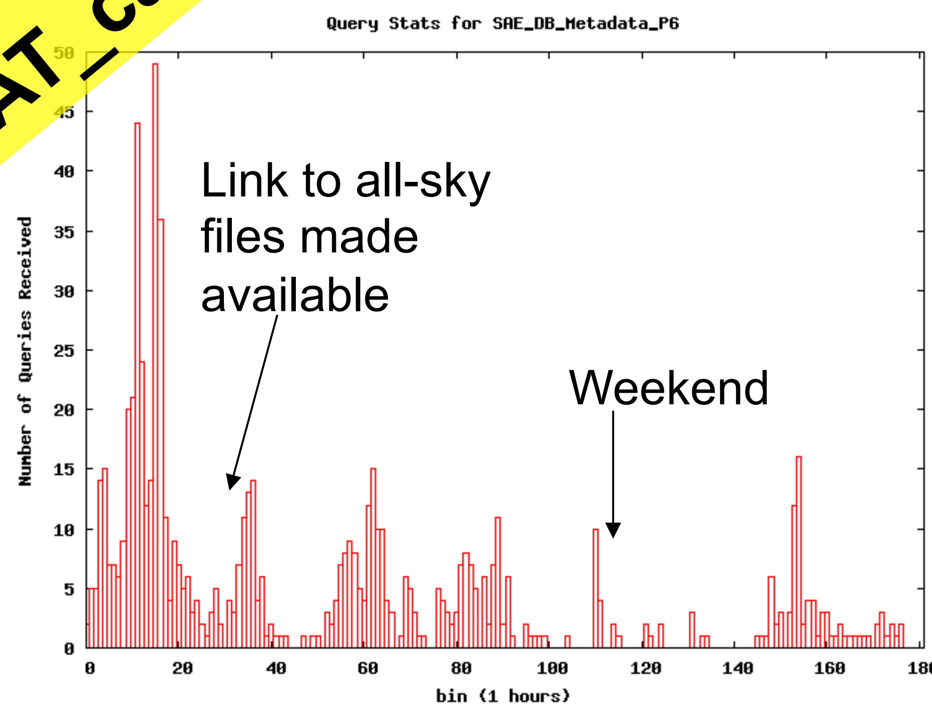
On March 7, the bright X5.4 solar flare was detected by the Fermi Large Area Telescope in gamma-rays. For almost one day, the Sun became 1000 times brighter than its usual gamma-ray flux. It exceeded by a factor of 100 the brightest point source in the gamma ray sky (Vela). On March 7, Fermi LAT detected approximately 10000 events above 100 MeV coming from the Sun, some of them exceeding 1 GeV in energy, equivalent to a billion times the energy of the visible light. The image on the top shows the gamma-ray full sky as viewed by the LAT on March 6. The Sun during March 6 was not visible in gamma-rays while on March 7 (bottom figure) the Sun exceeded all other sources in the sky.

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.

Data Releases

- **Beginning of science operations: GBM data + LAT high level data from start of science operations**
- **Feb 6, 2009: LAT bright source list, first LAT analysis software release**
- **Aug 25, 2009: commense release of LAT photon data, second LAT analysis software release**

- **~400 queries in first day, many requesting the entire dataset.**
- **Made link to weekly all-sky files more obvious (so number of queries dropped)**



Science Support Center (FSSC)

- Supports guest investigator program
  - Regular funding cycle
  - see http://fermi.gsfc.nasa.gov/ssc/proposals/
- Provides training workshops
- Provides data, software, documentation, workbooks to community
- Archives to HEASARC
- Joint software development with Instrument Teams, utilizing HEA standards
- Located at Goddard

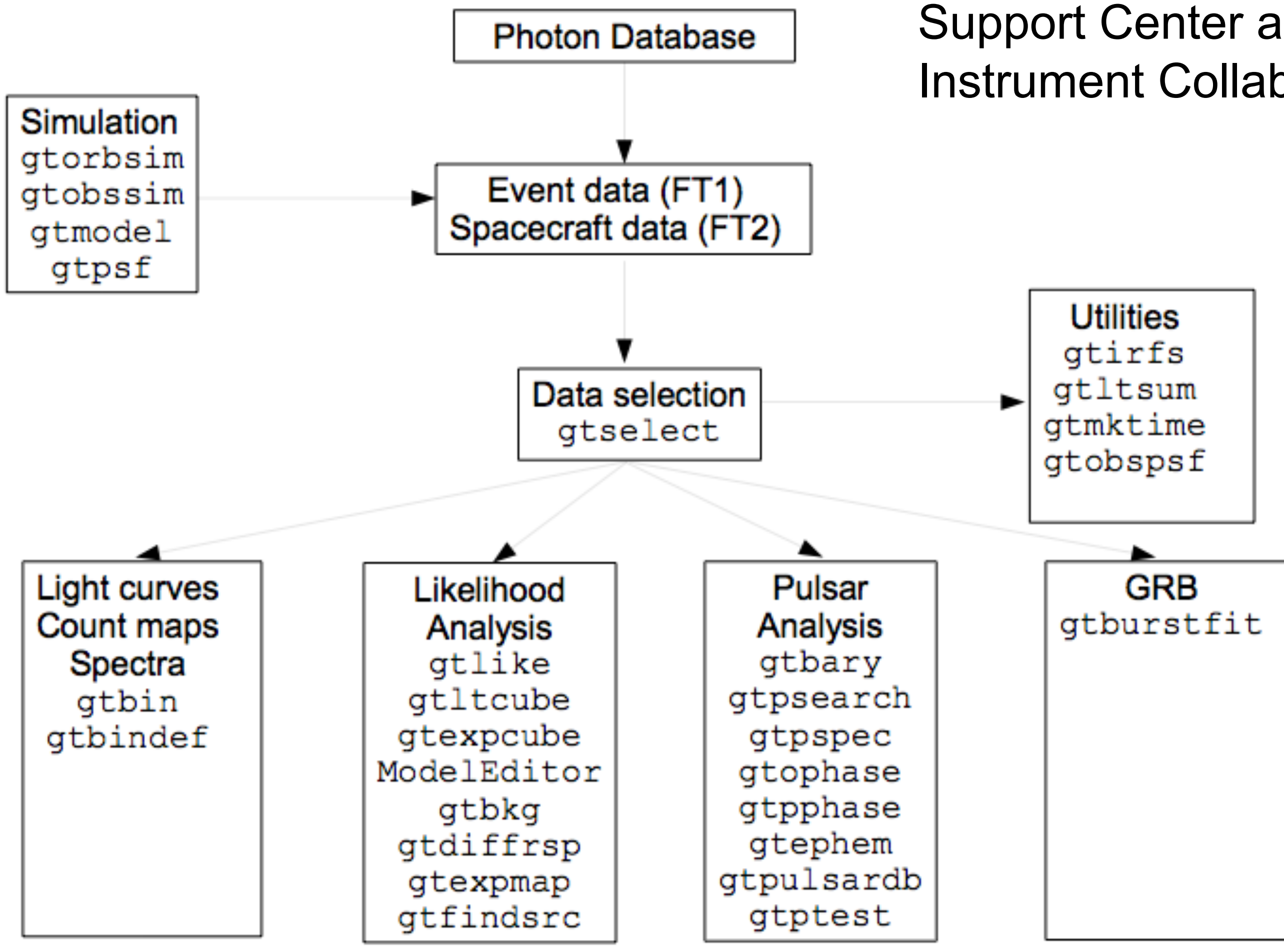
PLEASE SEE http://fermi.gsfc.nasa.gov/ssc/data/analysis/LAT_caveats.html

see http://fermi.gsfc.nasa.gov/ssc/

and help desk http://fermi.gsfc.nasa.gov/ssc/help/

Tools

Developed jointly by Science Support Center and Instrument Collaborations



Gamma-ray Schools

National Aeronautics and Space Administration
Goddard Space Flight Center

Search: Fermi GO

Fermi • HEASARC • Sciences and Exploration

Fermi Summer School 2012

The Fermi Gamma-ray Space Telescope has initiated an era of very broad energy coverage in the gamma-ray band. The combination of Fermi GBM and LAT provide observations of gamma-ray bursts and transients from 8 keV to >300 GeV. The combination of Fermi-LAT and ground-based gamma-ray observatories currently allows us to probe the high-energy emission from astrophysical sources over at least five orders of magnitude, including the previously unexplored territory from 10 to 100 GeV. These combinations of telescopes allow the measurement of broad-band spectra, the study of energy-dependent source morphologies, and correlated observations of time-variable sources, both within the gamma-ray energy range and with observations at longer wavelengths. These measurements provide critical diagnostics with which to identify source characteristics, particle acceleration and photon emission mechanisms. The 2012 Fermi Summer School will focus on the overlap between ground-based and space-based gamma-ray astronomy, both technically and scientifically, and will include hands-on workshops and science talks by experts in both fields. The school will be held at the University of Delaware Conference Center in Lewes, Delaware, from May 29 - June 8, 2012.

Find information about last year's school at: http://fermi.gsfc.nasa.gov/science/mtgs/summerschool/2011/

Material will be aimed at graduate students and recent PhDs. Topics will include space-based and ground-based instrumentation; spectral, spatial, and time-based analysis of gamma-ray data; particle acceleration and gamma-ray production mechanisms; and astrophysical source classes such as AGN, GRBs, pulsars, binary systems, supernova remnants, and pulsar wind nebulae.

Important Dates

- Application Deadline: March 15, 2012
- School: Tuesday, May 29 - Friday, June 8, 2012

Program

The 2012 instructors will be Luca Baldini (INFN/University of Pisa), Pasquale Blasi (Osservatorio Astrofisico di Arcetri), Michael Briggs (UAH), Seth Digel (SLAC/Stanford), Markos Georganopoulos (UMBC), Nepomuk Otte (Georgia Tech), and Andy Smith (UMCP). Lecturers will include Alan Marscher (BU), Trevor Weekes (FLWO/CfA), and Martin Weisskopf (MFSC).

See last year's program here: http://fermi.gsfc.nasa.gov/science/mtgs/summerschool/2011/schedule.html.

Fermi Users Group Members

- Alan Marscher (Chair)
- Matthew Baring
- Dieter Hartmann
- Buell Januzzi
- Don Kniffen
- Savvas Koushiappas
- Jamie Holder
- Wei Cui
- Scott Ransom
- Pat Slane
- Alicia Soderberg
- Anna Watts

Plus

- Neil Gehrels
- Ilana Harrus
- Julie McEnery
- Bill Paciesas
- Peter Michelson
- Steve Ritz
- Chris Shrader
- Dave Thompson
- Kathy Turner
- Lynn Cominsky

http://fermi.gsfc.nasa.gov/ssc/resources/fug/

Looking Ahead

- Many further improvements in instrument performance in progress
  - 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 Pass6.
    - Some known issues, described in Caveats on FSSC site and in LAT papers, addressed with patch to IRFs.
    - Pass7 and Pass8 to address the remaining issues.
  - Pass7 released
      - » Improved standard photon classes
      - » Event analysis taking into account "ghost" events
    - Working closely with FSSC on ease of use for user community.
  - Exciting progress on Pass8, expected to be the ultimate version.

Final Thoughts

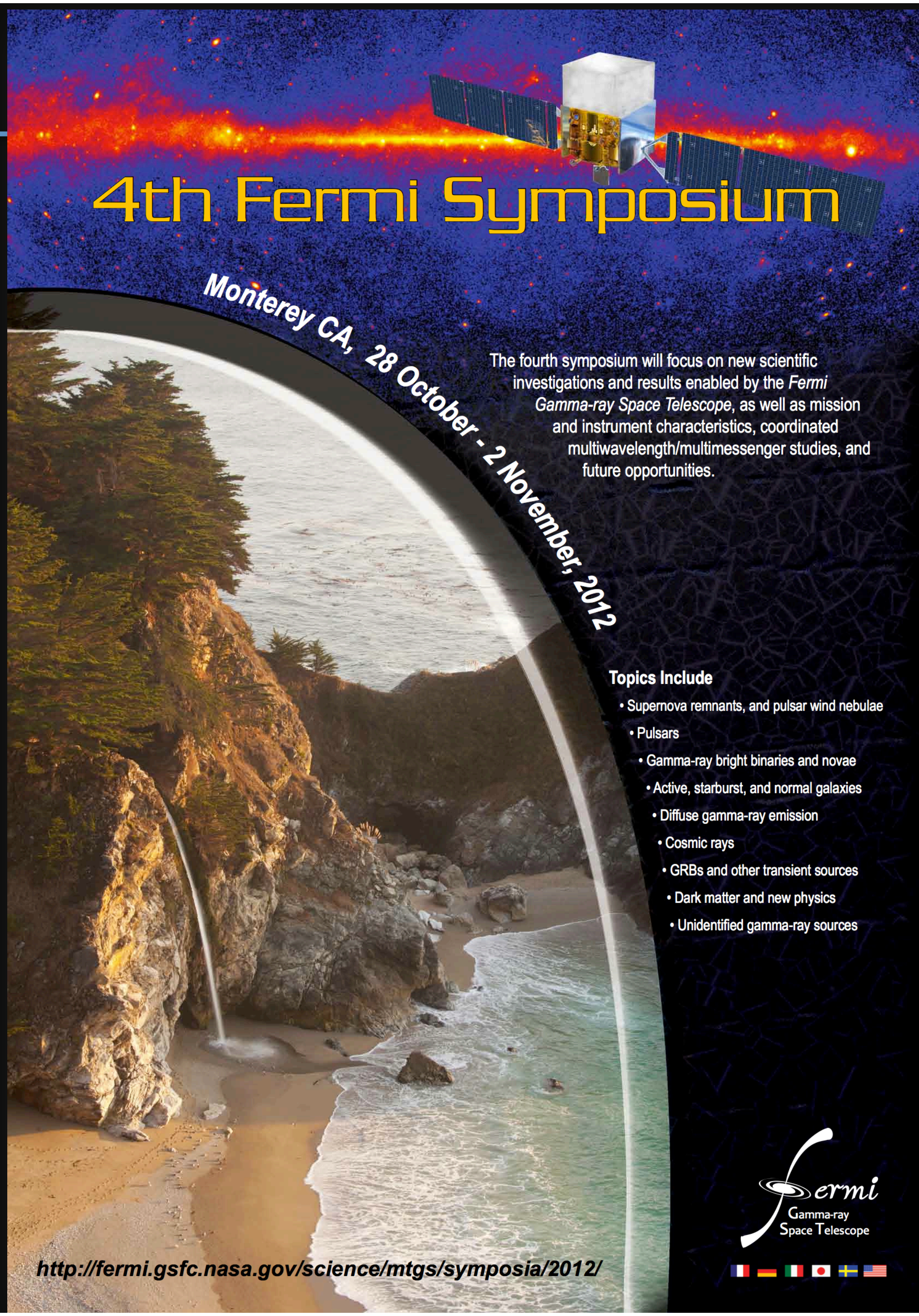
- *Fermi* would not have been possible without great international and multicultural cooperation!
- Cultural differences among communities are not necessarily impediments, but rather reinforcing capabilities enabling important new opportunities. We're lucky to have each other!
- Great leaps in capabilities have broad impacts, *e.g.*,
  - Sloan Dwarf Spheroidal galaxies discoveries opening new opportunities for DM signal searches.
  - Fermi all-sky sensitivity => millisecond pulsars for use by Nanograv for gravitational wave searches
  - …
- Great leaps in measurement capabilities demand new analysis approaches *and* new theory.
- What a wonderful time – so much great data and new results!

Summary

- Fermi is going strong
  - Continuing surprises in the gamma-ray sky. Great cooperation across the whole international team. Large user community. Mission extended at least two years (2015)
- Addressed many important pre-launch questions and moving beyond
  - new analysis techniques and approaches to match the new data; new topics. **The look ahead.**
  - the challenge of great discovery potential
  - the transformational all-sky capability is paying off.
- Multiwavelength observations are key to many science topics for Fermi.
  - LAT collaboration has numerous MOUs and other cooperative agreements with other observatories.
  - For campaigners' information and coordination, see http://fermi.gsfc.nasa.gov/science/multi
- JOIN THE FUN!

Sign up for newsletters:
http://fermi.gsfc.nasa.gov/ssc/resources/newsletter/

Fermi Gamma-ray Space Telescope



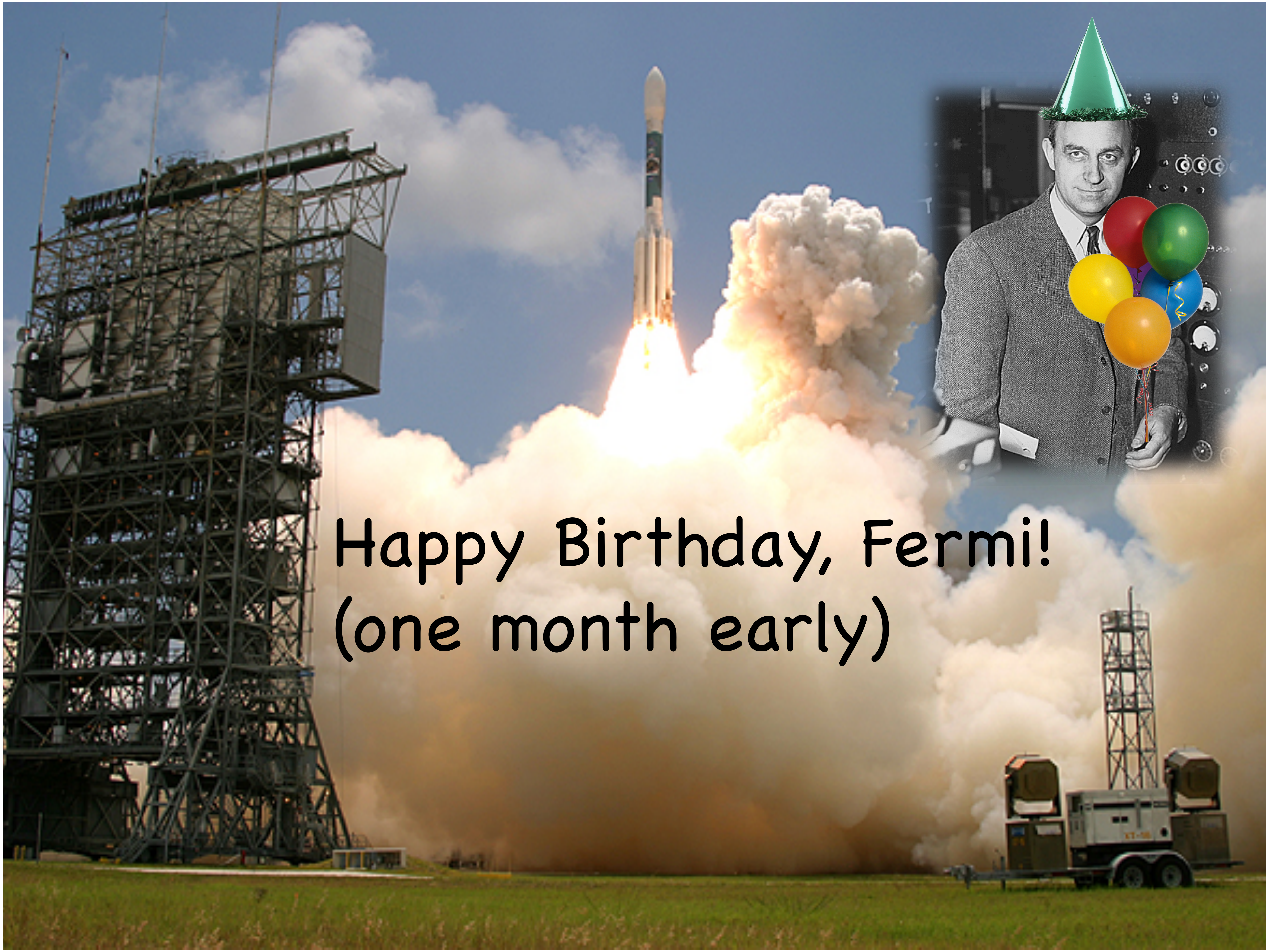
Advert Aside: Snowmass 2013

- The American Physical Society's Division of Particles and Fields is initiating a long-term planning exercise for the high-energy physics community. Its goal is to develop the community's long-term physics aspirations. Its narrative will communicate the opportunities for discovery in high-energy physics to the broader scientific community and to the government.

- The long-term planning exercise is anchored by two meetings:
  - A Community Planning Meeting (CPM2012), at Fermilab, October 11-13,2012,
  - A Community Summer Study (CSS2013), at Snowmass, June 2-22, 2013.

- Ten prominent members of the community have kindly agreed to serve as conveners representing the:
  - Energy Frontier: Raymond Brock (Michigan State U), Michael Peskin
  - (SLAC)
  - Intensity Frontier: JoAnne Hewett (SLAC), Harry Weerts (Argonne)
  - Cosmic Frontier: Jonathan Feng (UC Irvine), Steve Ritz (UC Santa Cruz)
  - Instrumentation: Marcel Demarteau (Argonne), Howard Nicholson (Mt.Holyoke)
  - Facilities: William Barletta (MIT), Murdock Gilchriese (LBNL)

More to follow soon!


Happy Birthday, Fermi!
(one month early)