2011 Fermi Symposium

A Look Back and a Look Ahead

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THANKS!

- Julie McEnery !
  - And the SOC…and all the speakers, poster creators, and participants…and…

- Local organizers: Aldo, Emilia, Luca, Ronaldo, Patrizia, Elisabetta, Tonino Capone…and all the local people who made this meeting so enjoyable.

Caveat

- Apologies in advance:
  - Able just to touch upon a subset of highlights.
  - A full summary of all the great results is not possible!
- For each topic, big-picture:
  - What we have learned
  - Path forward

Non-trivial “Trivia” (circa May 2011)

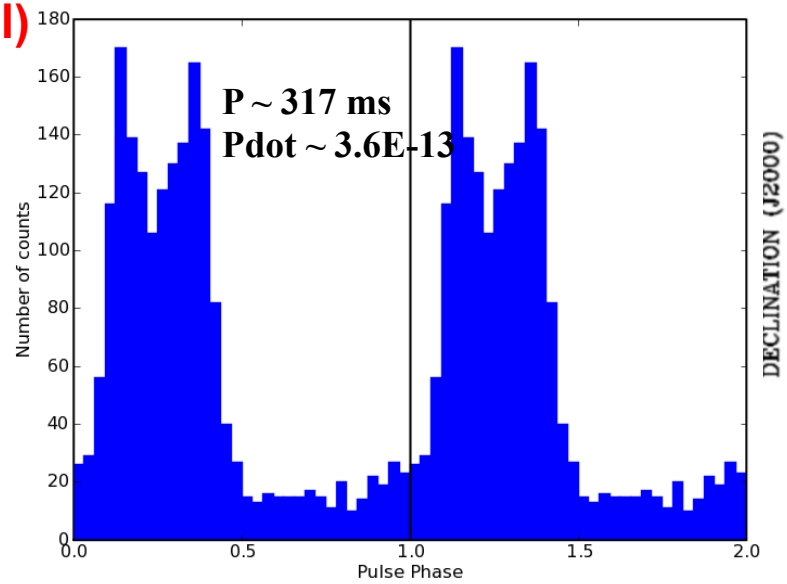
- ~170 billion LAT event triggers
- GBM Triggers: 1194 (654 GRB, 141 TGF, 174 SGR, 56 solar flare)
- # Autonomous Repoint Requests (ARR): 58
- Highest-z LAT GRB: 4.35
- Highest-energy photon from a GRB: 33 GeV (at 82s, z=1.82)
- Highest-z LAT AGN: 3.1
- # Gamma-ray pulsars: 88
  - # MSPs: 27
  - # Gamma-ray-only (blind) pulsars: 26
  - # new radio MSPs due to LAT data: 31
- Public data access: >8TB

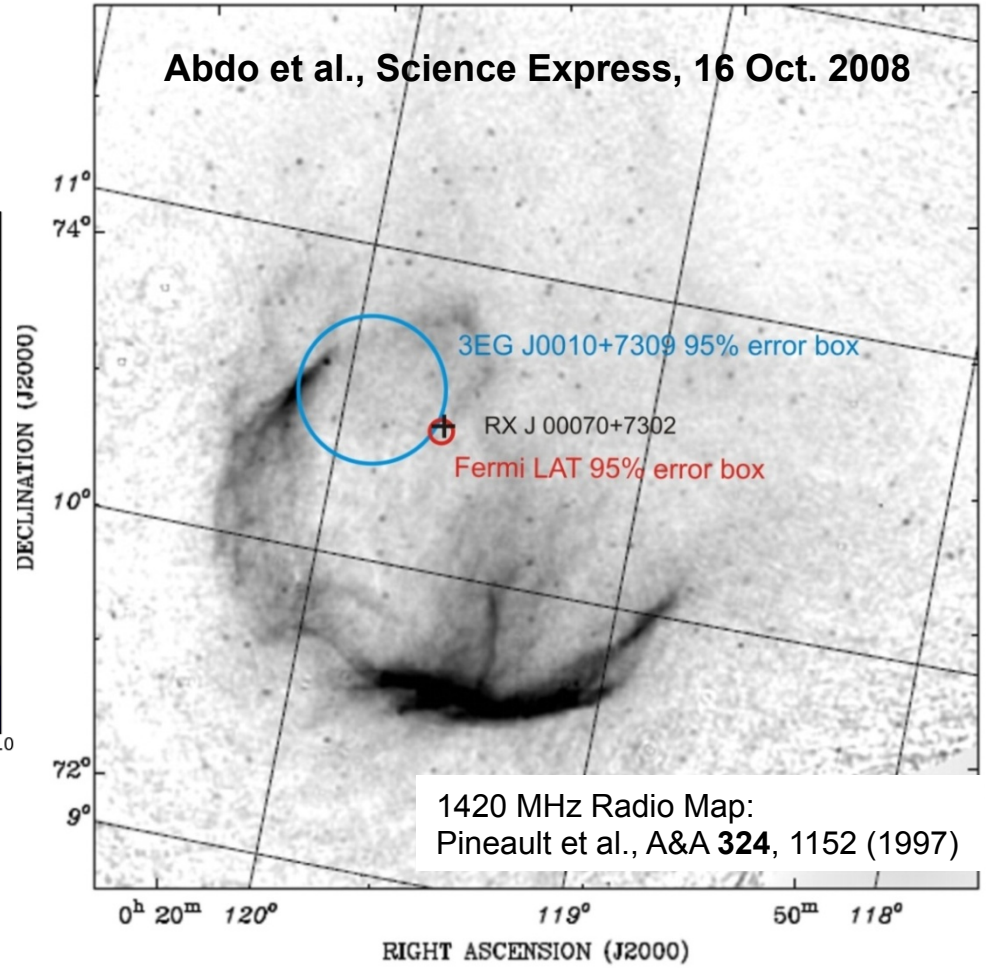
An Important Reminder!

A radio-quiet, gamma-ray only pulsar, in Supernova Remnant CTA1

Quick discovery enabled by

- **large leap in key capabilities**
- **new analysis technique (Atwood et al)**





- Spin-down luminosity ~10^{36} erg s^{-1}, sufficient to supply the PWN with magnetic fields and energetic electrons.

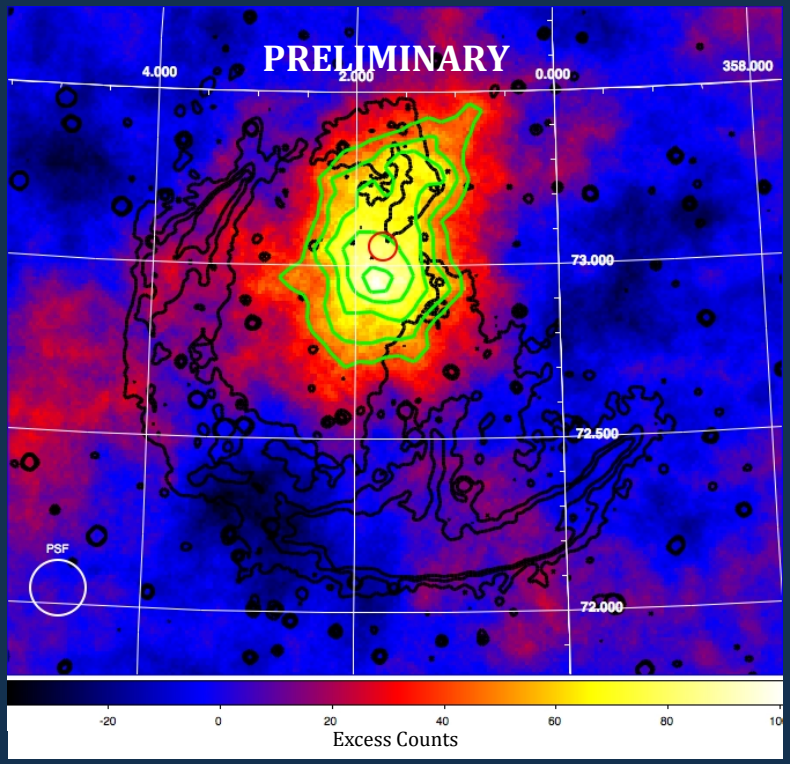
- The γ-ray flux from the CTA 1 pulsar corresponds to about 1-10% of E_{rot} (depending on beam geometry)

Age ~(0.5 – 1)x10^4 years
Distance ~ 1.4 kpc
Diameter ~ 1.5°

CTA 1: New TeV Source

S. McArthur: VHE observation of CTA 1 with VERITAS

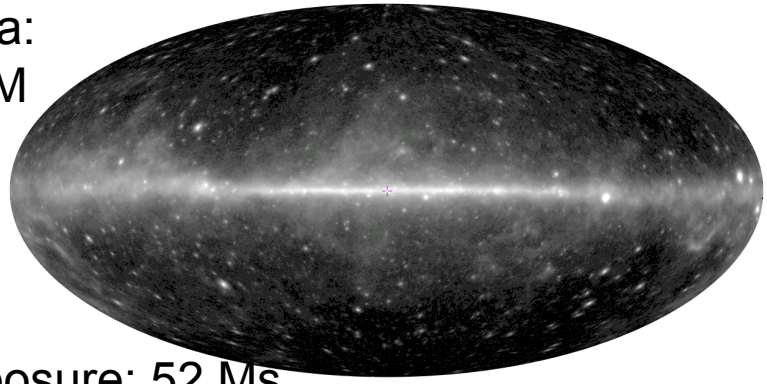
- 26.5 hrs observations Oct 2010 – Jan 2011.
- **Detection: 7.3 σ / 6.2 σ pre-/post-trials.**
- VERITAS excess map:
  - Black contours: Radio 1420 MHz showing SNR shell (T. Landecker).
  - Red Circle: Fermi pulsar error circle.
  - VERITAS 3-7σ contours in green.
- Flux ~ 4 % Crab Nebula.
- Extended emission.
- **Morphology suggests young PWN.**



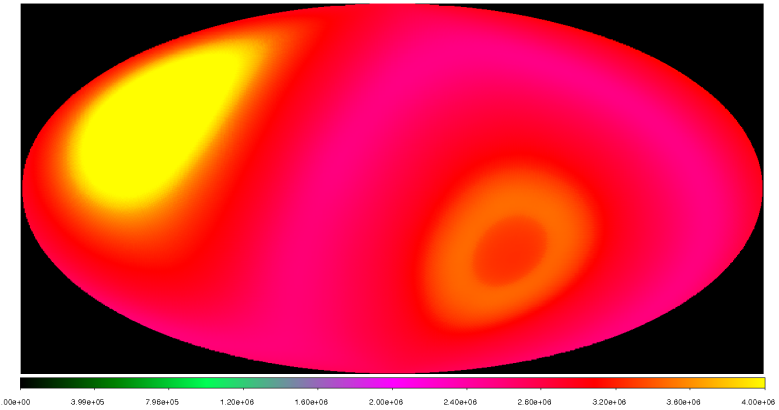
2FGL !

Toby Burnett talk

Data:
28 M



Exposure: 52 Ms



2FGL Table

1888 entries
[1FGL: 1451]

preliminary

	Source_Name	NickName	RAJ2000	DEJ2000	
1	2FGL J0000.9-0748	P72Y0002	0.233711	-7.8155	88
2	2FGL J0001.7-4159	P72Y0005	0.43	-41.9965	334
3	2FGL J0002.7+6220	P72Y0008	0.	62.3396	117
4	2FGL J0004.2+2208	P72Y0013		22.365	106
5	2FGL J0004.7-4736	P72Y0015			323
6	2FGL J0006.1+3821	P72Y0016	1.5		113
7	2FGL J0007.0+7303	PSRJ0007+7303	1.7735		
8	2FGL J0007.7+6825	P72Y0024	1.92505		
9	2FGL J0007.8+4713	P72Y0025	1.97432	47.	
10	2FGL J0008.7-2344	P72Y0027	2.19605	-23.75	
11	2FGL J0009.0+0632	P72Y0028	2.26231	6.54235	
12	2FGL J0009.1+5030	P72Y0030	2.2914	50.5062	
13	2FGL J0009.9-3206	P72Y0031	2.48449	-32.1118	
14	2FGL J0010.5+6556	P72Y0034	2.64068	65.9339	116
15	2FGL J0011.3+0054	P72Y0036	2.82765	0.903578	102
16	2FGL J0012.9-3954	P72Y0040	3.24638	-39.9005	332
17	2FGL J0013.8+1907	P72Y0043	3.46375	19.126	110
18	2FGL J0014.3-0509	P72Y0045	3.58116	-5.15295	95
19	2FGL J0017.4-0018	P72Y0054	4.364	-0.302	104
20	2FGL J0017.8-0510	P72Y0055	4.40364	-5.18249	101
21	2FGL J0018.5+2945	P72Y0057	4.63305	29.7602	114
22	2FGL J0018.8-8154	P72Y0058	4.71587	-81.9027	304
23	2FGL J0019.4-5845	P72Y0059	4.85732	-56.7558	311
24	2FGL J0021.6-2551	P72Y0063	5.41178	-25.852	42
25	2FGL J0022.2-1853	P72Y0064	5.55909	-18.8884	82
26	2FGL J0022.3-5141	P72Y0065	5.59589	-51.6913	311
27	2FGL J0022.5+0607	P72Y0066	5.64299	6.12368	110
28	2FGL J0023.2+4454	P72Y0068	5.81783	44.9046	117
29	2FGL J0023.5+0924	P72Y0069	5.89215	9.40666	111
30	2FGL J0023.9-7204	P72Y0070	5.98558	-72.0825	305
31	2FGL J0024.5+0346	P72Y0073	6.14599	3.78296	110
32	2FGL J0029.2-7043	P72Y0082	7.30062	-70.7255	305
33	2FGL J0030.2-4223	P72Y0085	7.57263	-42.3863	317
34	2FGL J0030.4+0450	PSRJ0030+0451	7.60105	4.83868	113
35	2FGL J0031.0+0724	P72Y0090	7.775	7.414	114
36	2FGL J0032.7-5521	P72Y0094	8.17868	-55.3563	308
37	2FGL J0033.5-1921	P72Y0096	8.39111	-19.357	94
38	2FGL J0034.4-0534	PSRJ0034-0534	8.61312	-5.58218	111
39	2FGL J0035.2+1515	P72Y0098	8.80866	15.2583	117
40	2FGL J0035.8+5951	P72Y0099	8.96431	59.8537	120
41	2FGL J0037.8+1238	P72Y0101	9.47307	12.6449	117
42	2FGL J0038.1+0015	P72Y0102	9.54151	0.264987	115
43	2FGL J0038.3-2457	P72Y0103	9.5827	-24.9632	66
44	2FGL J0038.7-2215	P72Y0104	9.6918	-22.2522	91
45	2FGL J0038.8+6259	P72Y0106	9.72048	62.9967	121
46	2FGL J0039.1+4331	P72Y0108	9.78034	43.5271	120
47	2FGL J0042.5+4114	P72Y0112	10.633	41.245	121
48	2FGL J0043.7+3426	P72Y0116	10.9409	34.4394	121
49	2FGL J0044.7-3702	P72Y0118	11.1951	-37.0404	310
50	2FGL J0045.3+2127	P72Y0120	11.3351	21.4524	121
51	2FGL J0045.5+1218	P72Y0121	11.3964	12.3121	120
52	2FGL J0046.7-8416	P72Y0123	11.6926	-84.27	303

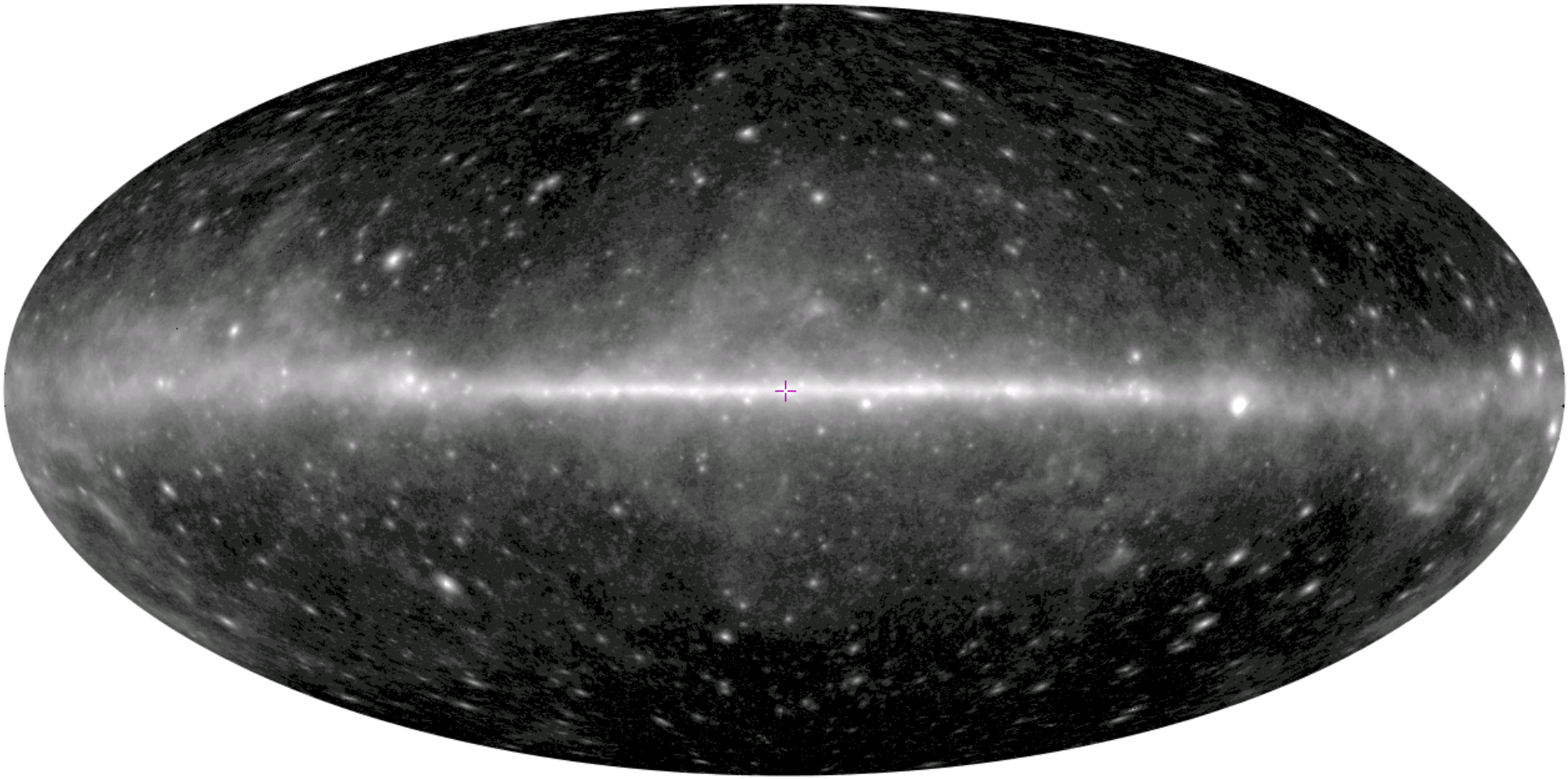
Two years (excluding 3 GRBs)
"Pass7 processing"

NEW

NEW

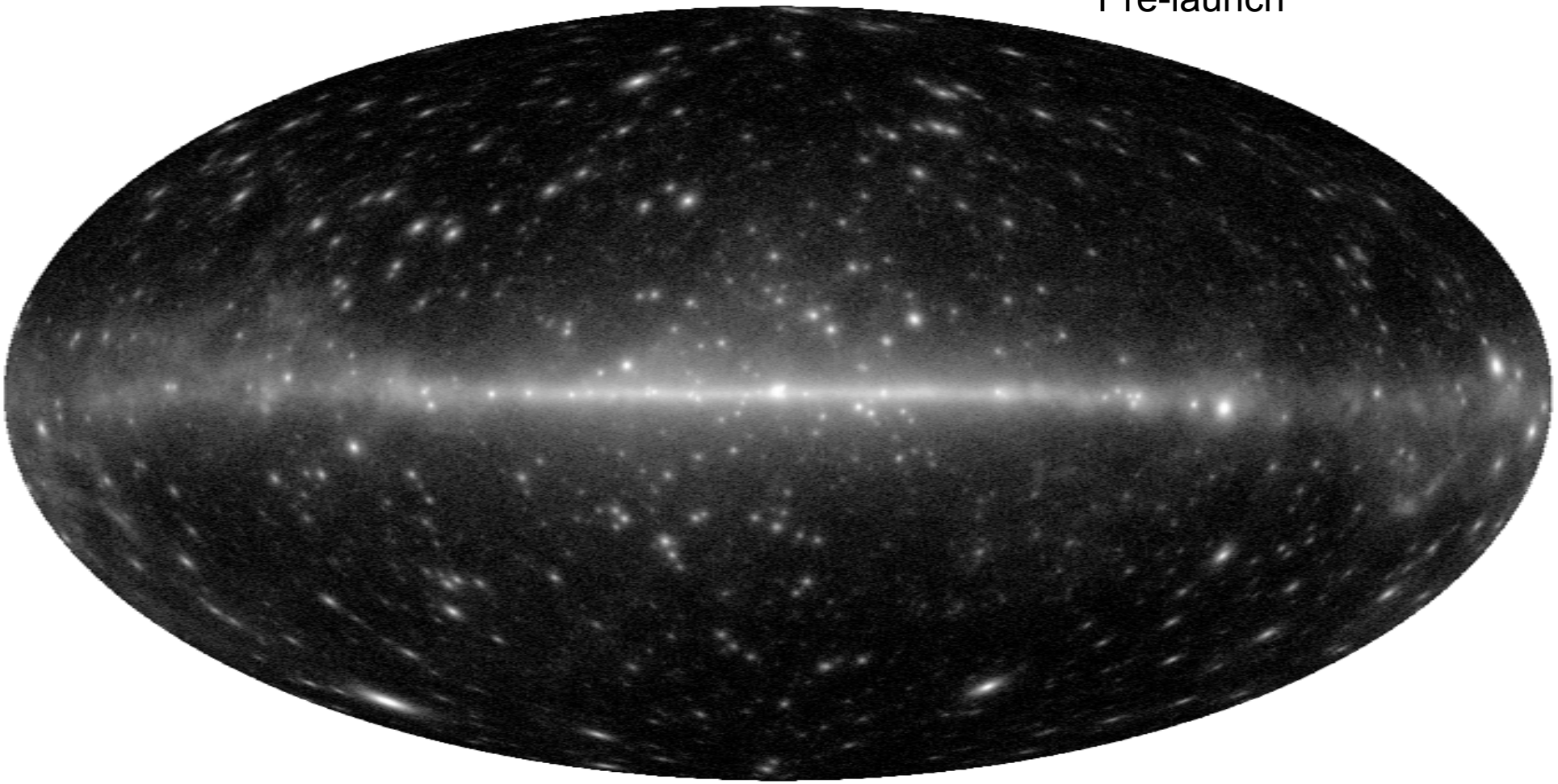
[1FGL: 11 months]

+ Light curves, SED plots, associations



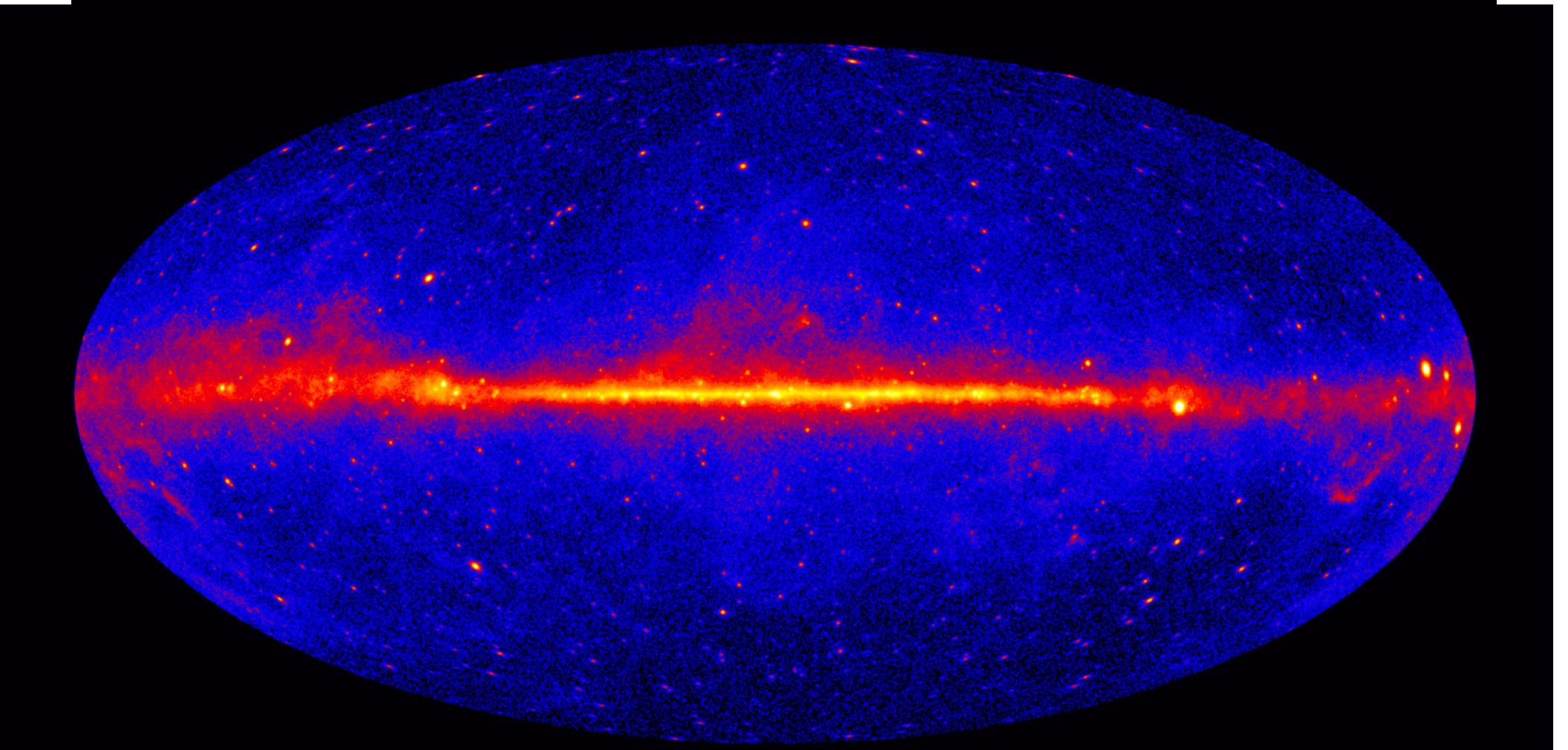
GLAST One-year Simulated Observation

Pre-launch



Careful! Different scales, techniques, energy ranges, …

Latest Photon Intensity Map



2FGL Summary

Toby Burnett talk

2FGL almost ready to go, with following features

- Much improved diffuse representation, new limb component
- ~1888 sources, vs. 1451 (1134) for 1FGL
- 12 extended sources
- Pulsars fit with exponential cutoff, others log parabola if appropriate
  - better characterization of sources, improved fits to nearby weaker sources
- Better source finding efficiency: both detecting faint sources and resolving nearby sources

But: is not perfect, D. Thompson will next discuss caveats

2FGL Classifications

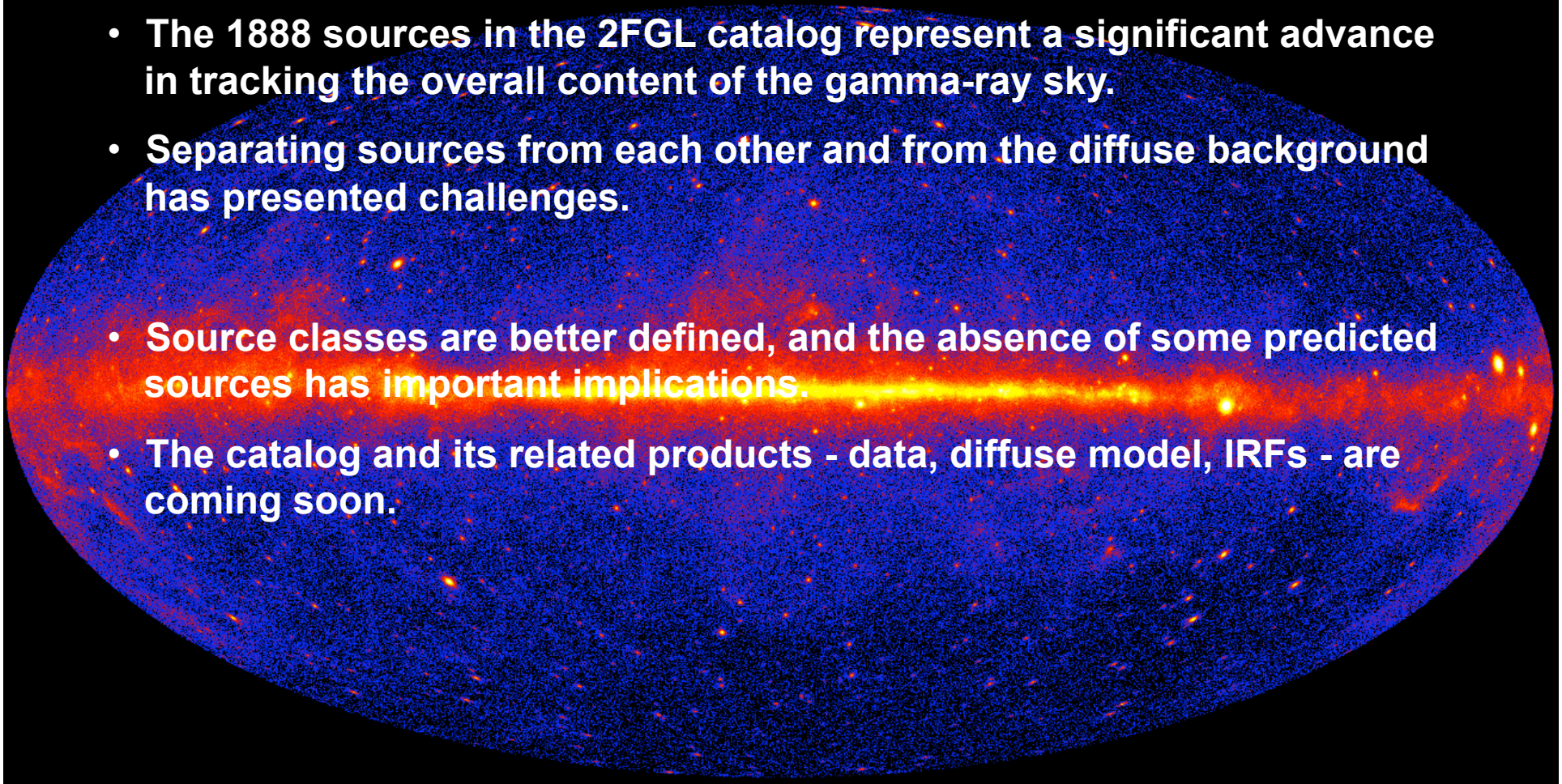
Type	Number	Percentage of total
Active Galactic Nuclei	832	44%
Candidate Active Galactic Nuclei	268	14%
Unassociated	594	32%
Pulsars (pulsed emission)	86	5%
Pulsars (no pulsations yet)	26	1%
Supernova Remnants/ Pulsar Wind Nebulae	60	3%
Globular Clusters	11	< 1%
Other Galaxies	7	< 1%
Binary systems	4	< 1%
TOTAL	1888	100%

Dave Thompson talk

Very Preliminary - Work Still In Progress

2FGL Summary

- The 1888 sources in the 2FGL catalog represent a significant advance in tracking the overall content of the gamma-ray sky.
- Separating sources from each other and from the diffuse background has presented challenges.



- Source classes are better defined, and the absence of some predicted sources has important implications.
- The catalog and its related products - data, diffuse model, IRFs - are coming soon.

Dave Thompson talk

Looking Forward: Diffuse Model

Next Public Model Characteristics

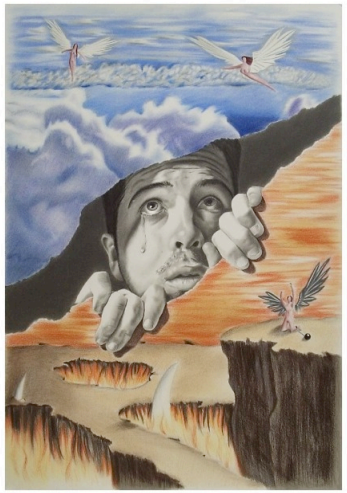
Jean-Marc Casandjian talk

- *The grid for the model is 0.125°*
- *Cube with 30 energy planes from 50 MeV to 600 GeV.*
- *Size ~500 Mbyte.*
- *Fitted with 24 months of LAT data in 14 bands from 63 MeV to 40 GeV with 0.25° resolution.*
- *Based on P7.6 "clean" class with isotropic also provided for "source" class.*
- *Row centered on b=0°.*
- *New HI, CO column density map (no Magellanic stream for example).*
- *New GALPROP-derived template for IC*
- *Patches for unaccounted excess of photons*

The model is optimized for point and extended sources studies.

Conclusion

There are lots of interesting studies in the paradise of diffuse emission physics...



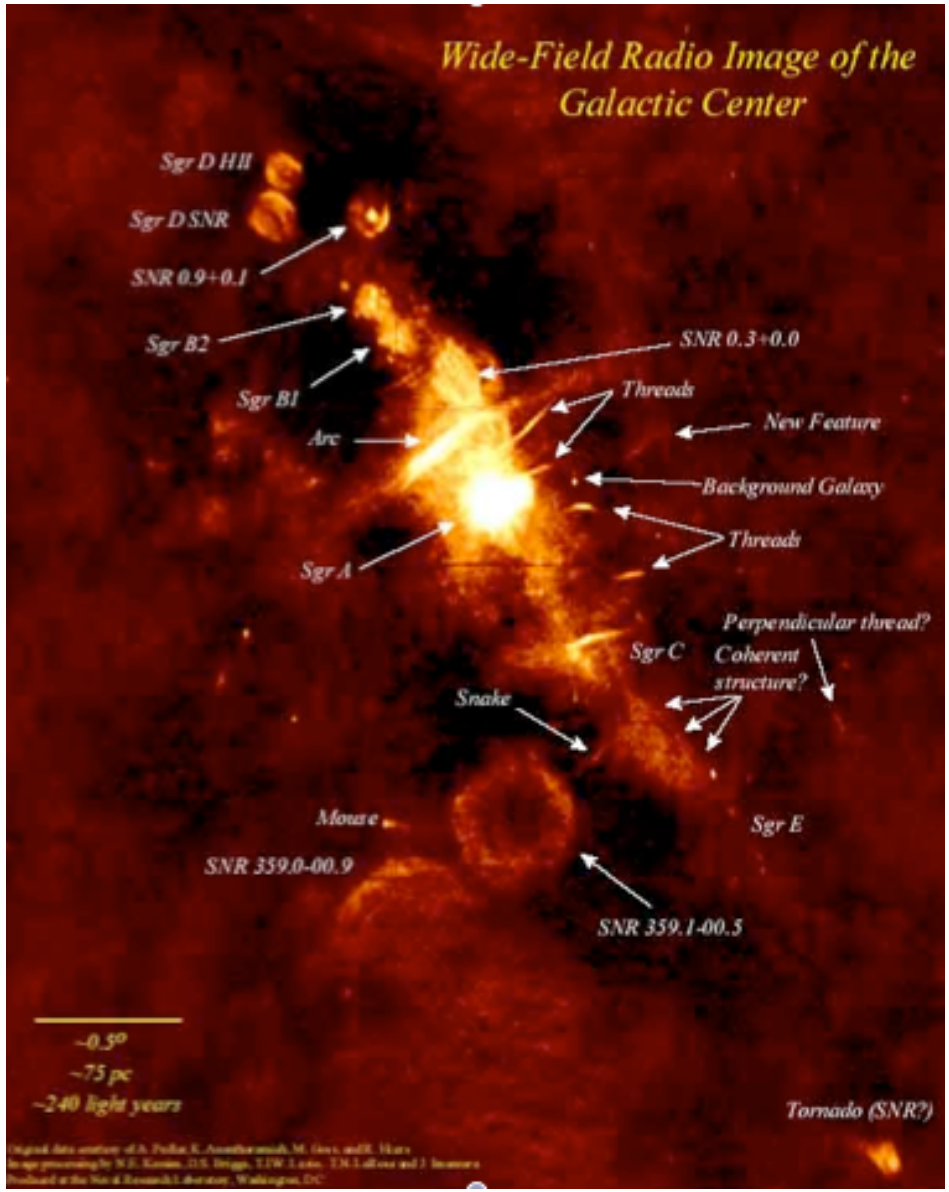
Torn Between Heaven and Hell
-golfiscool

... but we still have to work like hell to make sure we understand the systematic errors.

Inner Galaxy

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

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



Inner Galaxy

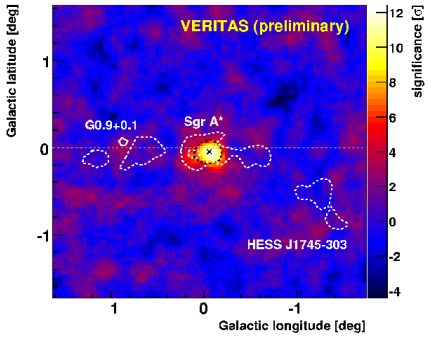
Summary

- 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

- What we have learned: many new features (not a surprise!)
- Path forward: “keep going”!

Summary and Conclusion

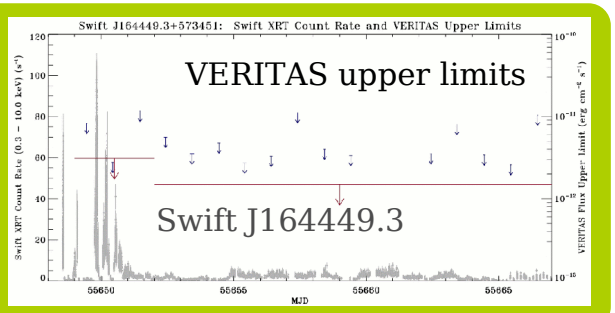
- **VERITAS detected GC:**
  - 12 std.dev. (15 hrs)
  - Spectrum compatible with H.E.S.S./MAGIC
- **Future observations:**
  - Constrain energy cut off
  - Search for E > 10 TeV variability
- **Prospects:**
  - Understand astrophysics of GC region
    VHE spectrum, hadronic acceleration? Etc.
  - Obtain UL on DM annihilation (E > ~few TeV)



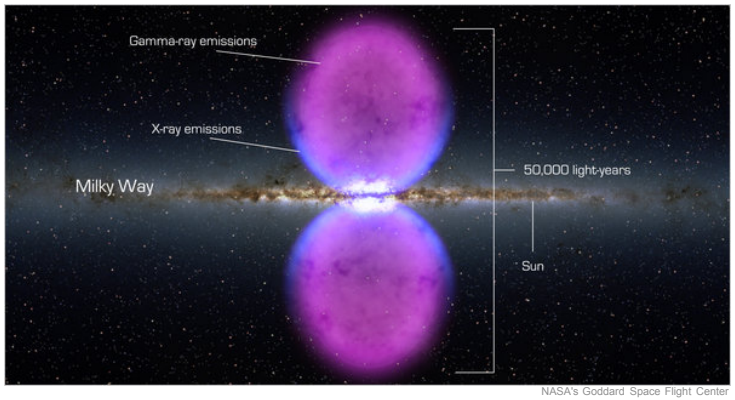
Poster (M. Vivier): Indirect searches for DM annihilation towards spherical galaxies with VERITAS'

+++ telegram +++ telegram +++

- Another galactic center: Onset of rapid accretion by dormant massive BH?
  Burrows et al., arXiv 1104.4787 (2011)
- 25h of VERITAS observations: upper limits (during Swift outburst & decline)
- Fermi/VERITAS: constrain emission models



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

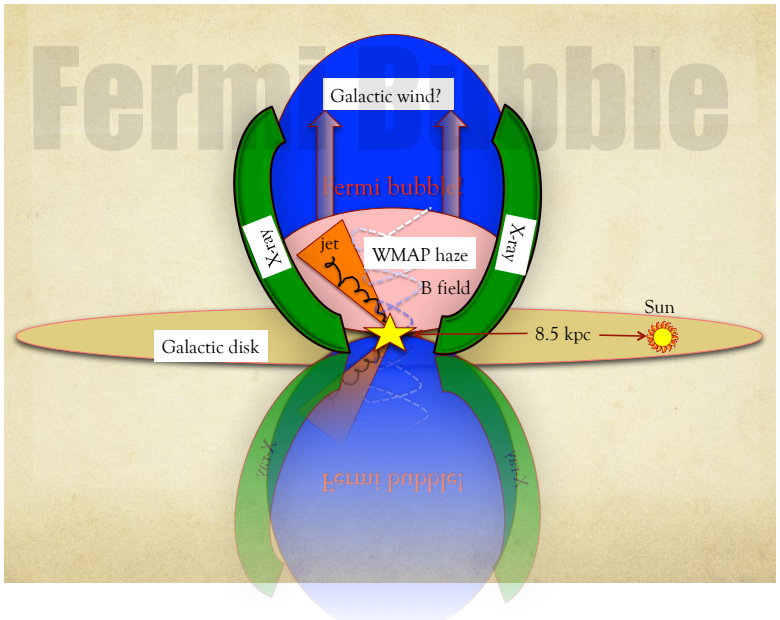
So far: there appear to be a pair of giant (50 degree high) gamma-ray bubbles at 1-5 GeV, and probably up to at least 50 GeV.

What are they?

Black hole "burp"

Superwind bubble?

Dark matter? (Dobler et al arXiv:1102.5095)

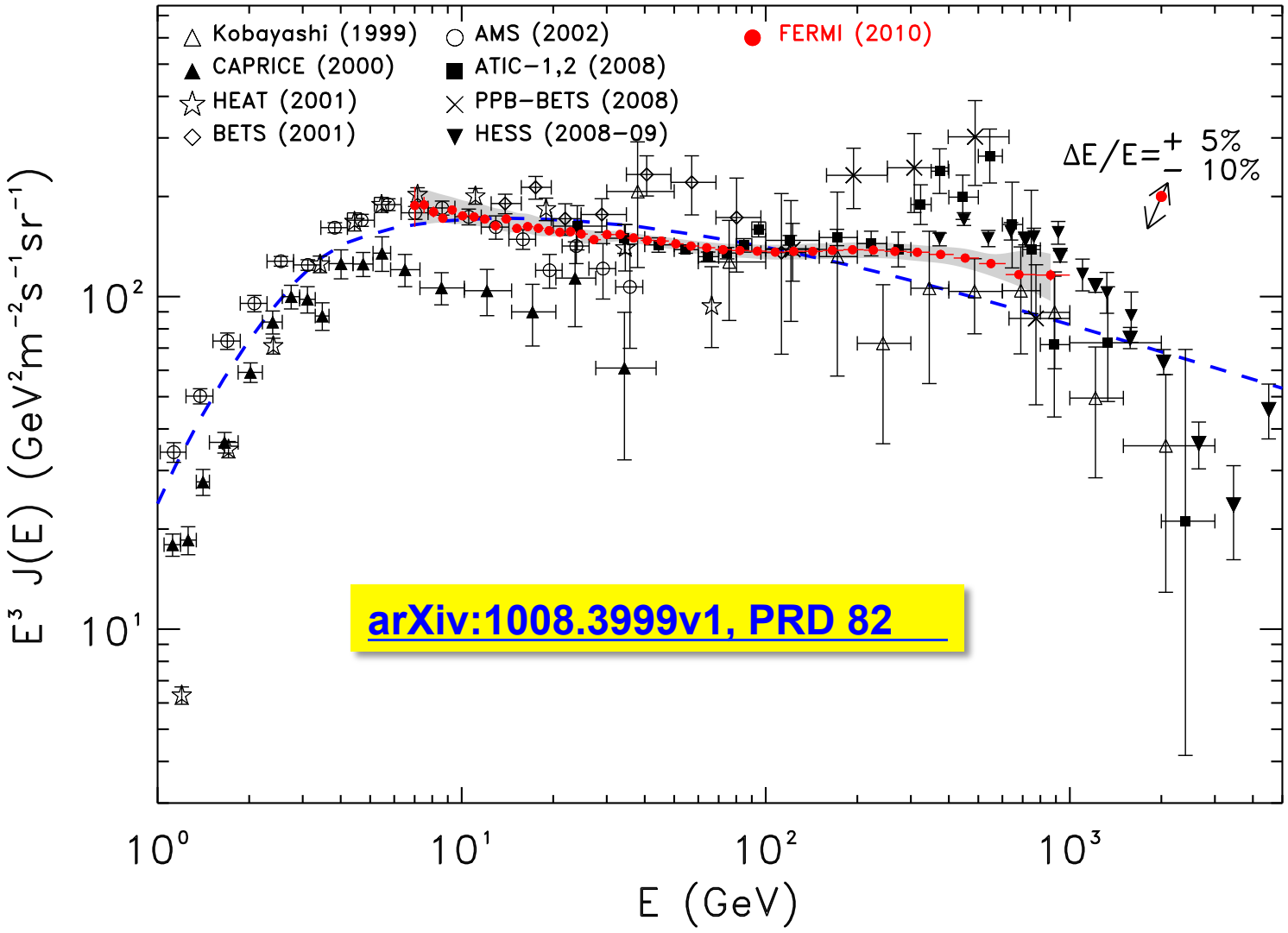


Fermi Bubble

- *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

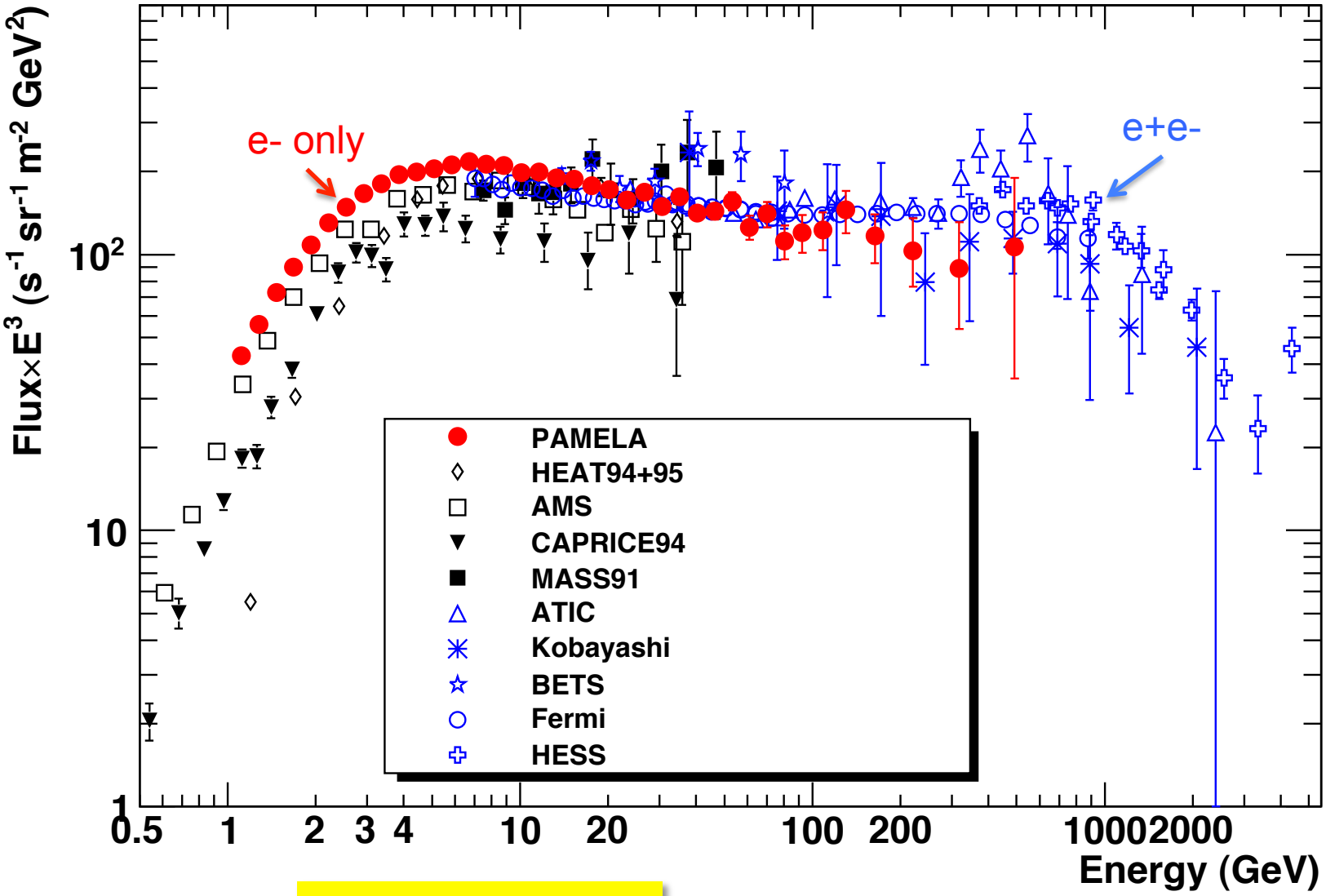
LAT e+e- Spectrum Update



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

e- from PAMELA!

Talk by E. Vannuccini

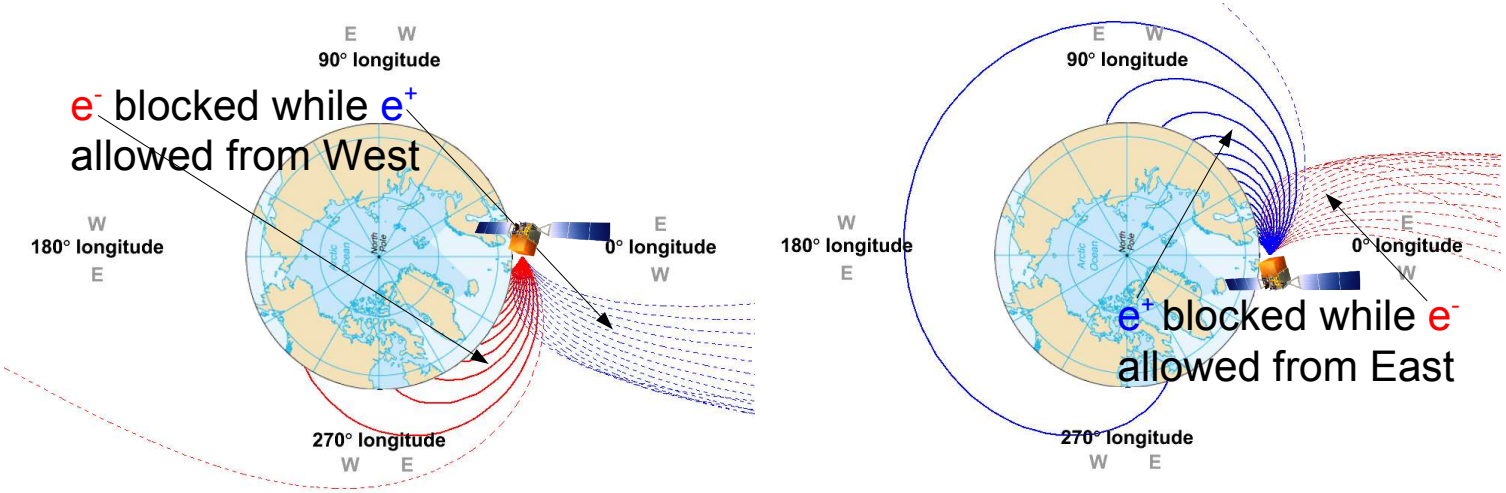


arXiv:1103.2880

…and AMS-02 launch soon!

Simon Swordy

Principle: Use the Earth's Magnetic Field to Distinguish e^+ and e^-

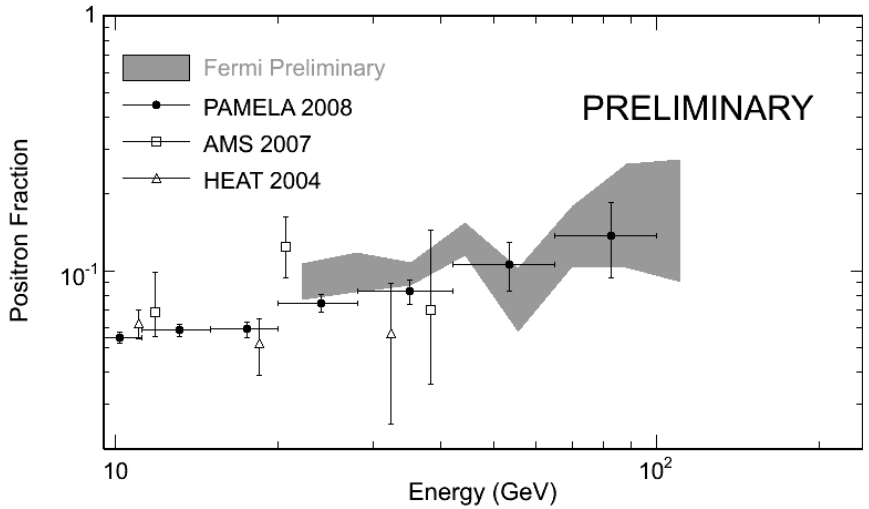


- **Pure e^+ region is in the west and same for e^- in the east**
- **The regions vary with particle energy and the LAT position**
- **To locate these regions, we use a code written by Smart, D. F. and Shea, M. A.* which numerically calculates a particle's trajectory in the geomagnetic field**

Center for Space Plasmas and Aeronomic Research, The University of Alabama in Huntsville

Conclusion

- **The Fermi-LAT has measured the cosmic-ray positron and electron spectra separately, between 20 – 130 GeV, using the Earth's magnetic field as a charge discriminator**
- **The two independent methods of background subtraction, Fit-Based and MC-Based, produce consistent results**
- **The observed positron fraction is consistent with the one measured by PAMELA**



The Sun is Waking Up!

SUMMARY

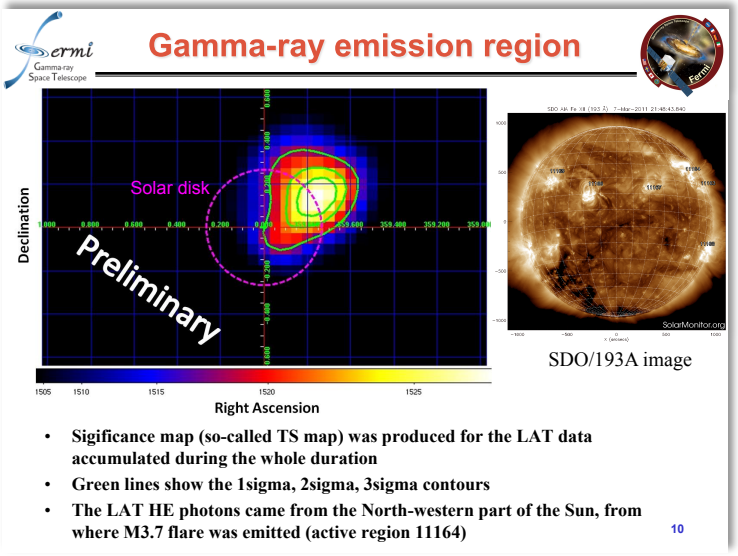
The M2-class solar flare, SOL2010-06-12T00:57, was modest in many respects yet exhibited remarkable acceleration of energetic particles.

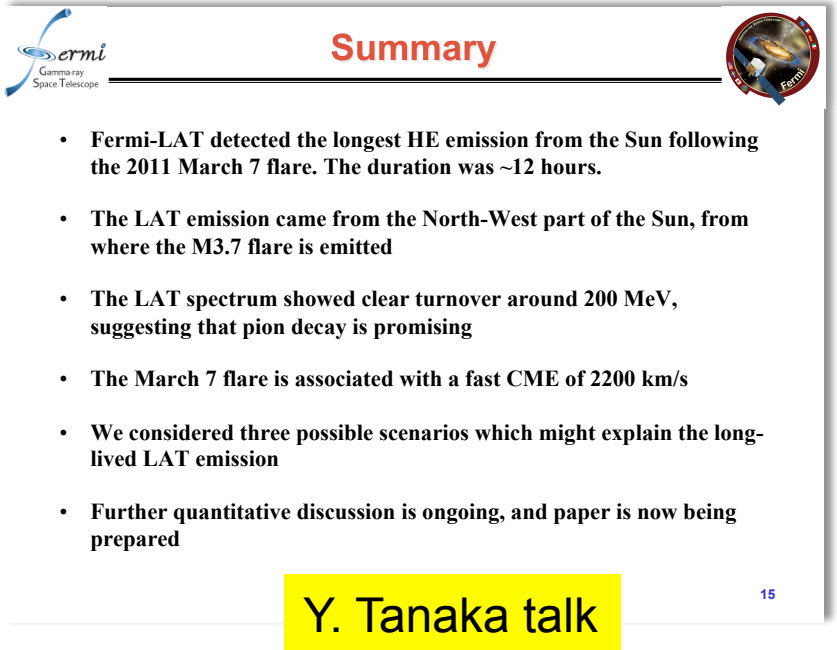
The flare produced an ~50 s impulsive burst of hard X-and gamma-ray emission up to at least 400 MeV.

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

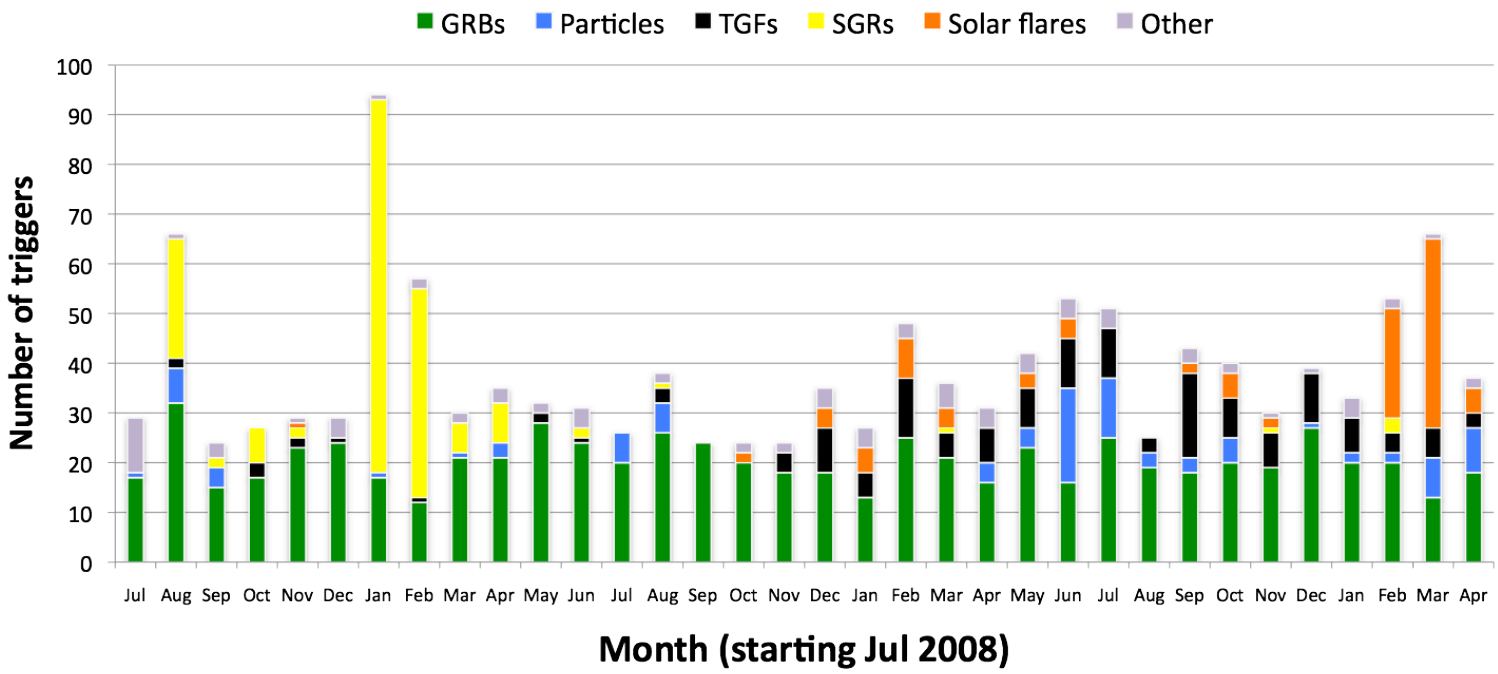




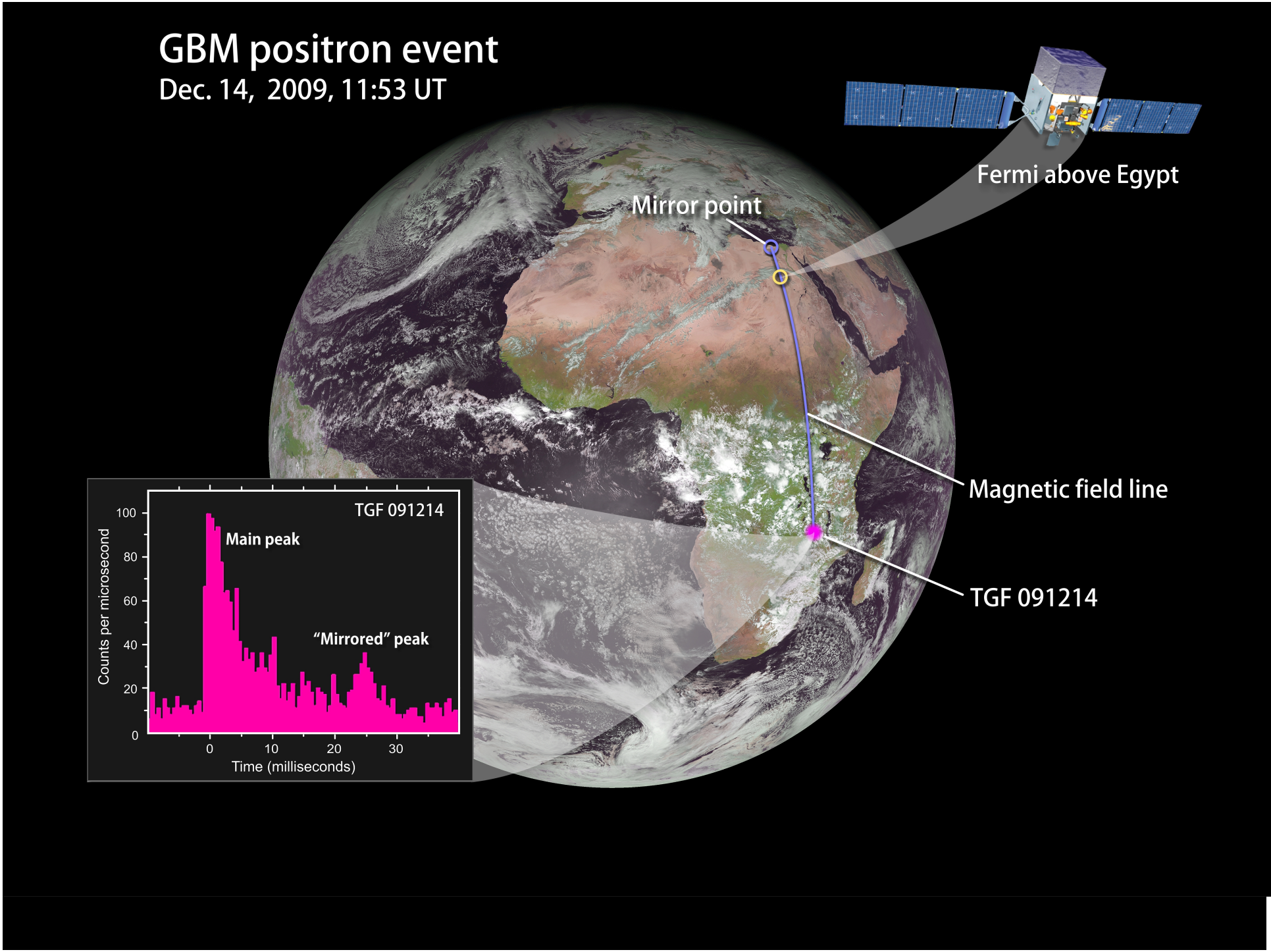
Also see J. Ryan overview talk

Y. Tanaka talk

GBM Triggers/Month



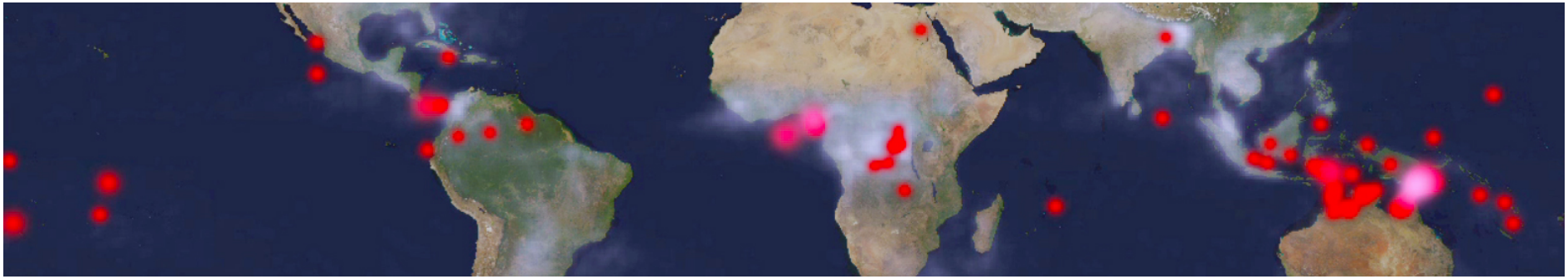
- **Nov 9, 2009 - add new TGF trigger**
  - **TGF trigger rate increased by factor of ~10 to 1 per 3.7 days (see talk by S. Foley)**
- **Feb/Mar 2011 - solar activity (see talk by Y. Tanaka)**

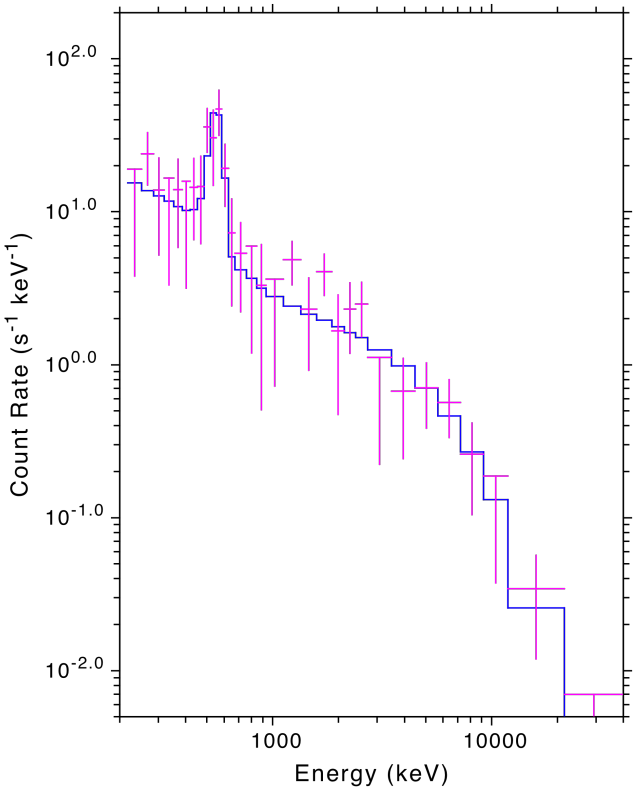

GBM positron event
Dec. 14, 2009, 11:53 UT
Fermi above Egypt
Mirror point
Magnetic field line
TGF 091214
TGF 091214
Main peak
"Mirrored" peak
Counts per microsecond
Time (milliseconds)
0
20
40
60
80
100
0
10
20
30

Terrestrial Gamma-ray flashes

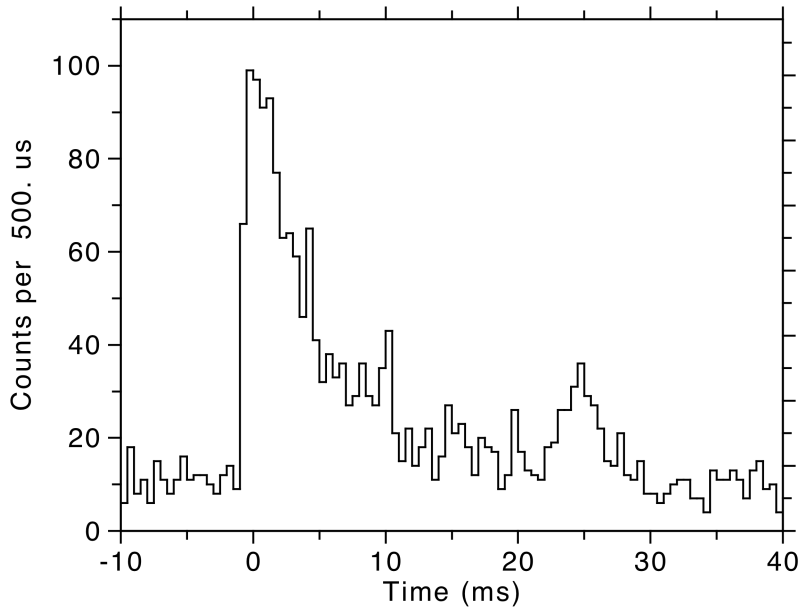
S. Foley talk

Briggs et al, GRL, 2011





TGFs are concentrated in the tropics near thunderstorms



Antimatter from Thunderstorms!

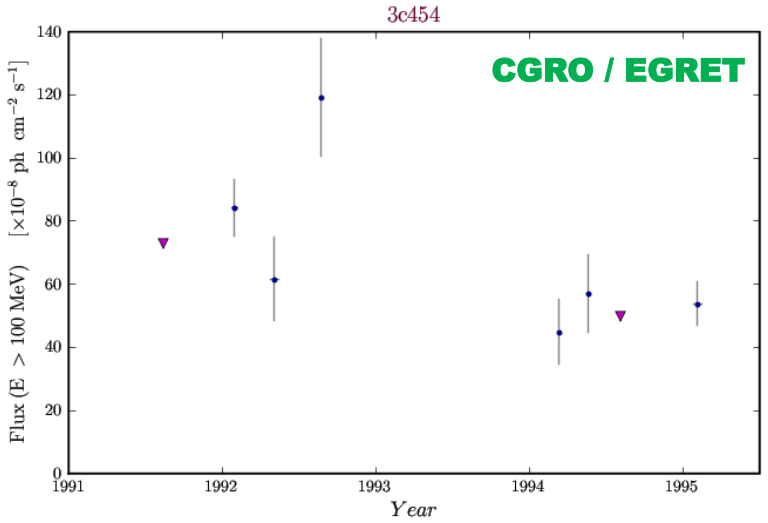
AGN

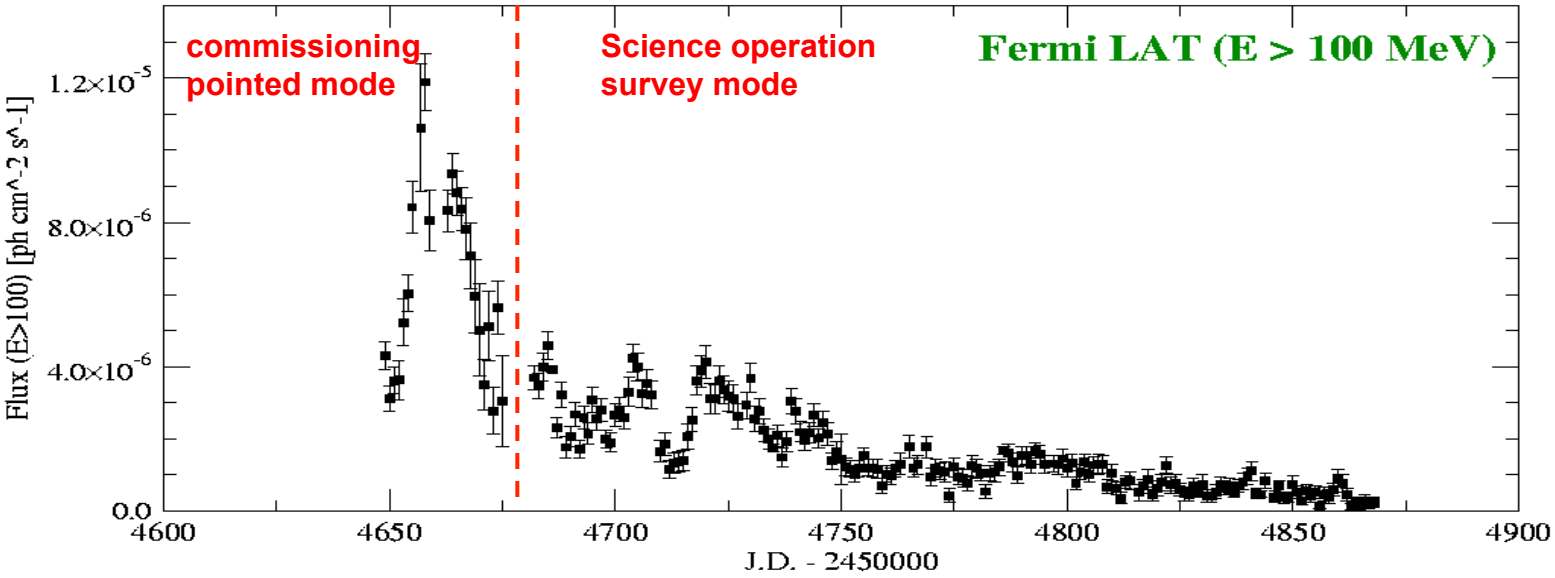
- The (many!) results are beautiful!
- We want answers, for the different types:
  - Where is the gamma-ray emission primarily, and what are the dominant mechanisms?
  - What are the underlying jet characteristics?
  - How do the jets form and propagate?
  - What is this telling us specifically about the BH and the environment?

- Factorizable?
  1. Connect the gamma emission characteristics to the jets
  2. Connect the jets to the rest of the system

Tremendous Observational Progress!

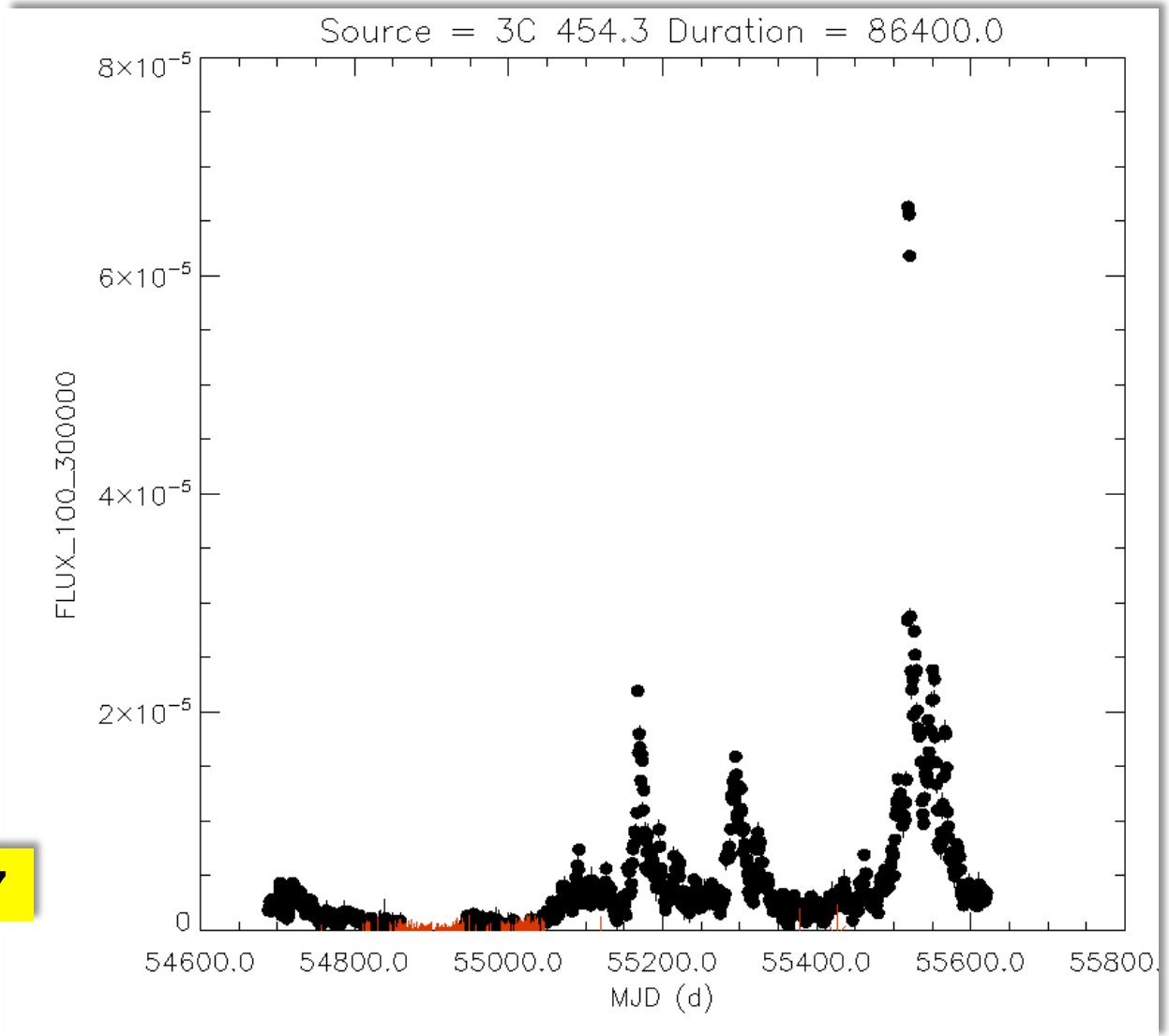
- **Well-known radio source at z = 0.859; also detected by EGRET, AGILE**





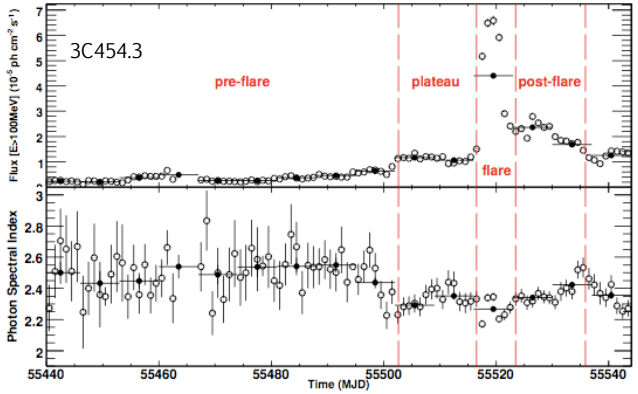
3C454.3

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



Also see **arXiv:1102.0277**

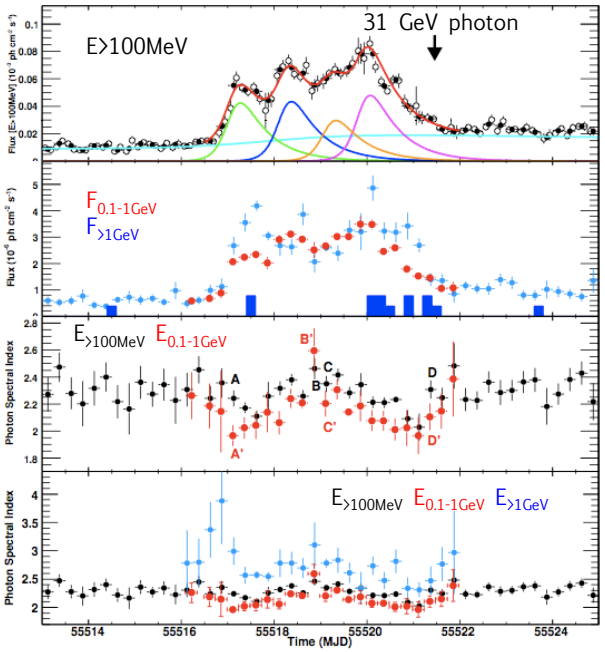
Flaring sources - 3C454.3 flare in Nov 2010

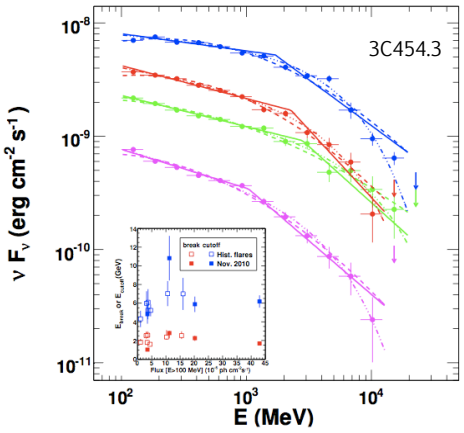


Daily light curve pre, during and after the flare
(common pattern to all its flares detected by LAT)

The highest ever recorded blazar $L_\gamma \sim 2\times10^{50}$ erg/s (>5 Vela)

Flare: longer in duration and higher in flux, shorter in doubling the flux (2xF in 6hrs) than the shortest detected by PKS 1502-106 and PKS 1510-089





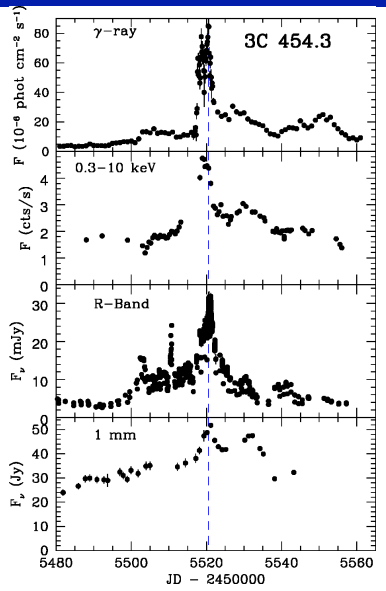
Significant difference between light curves for $F_{0.1\text{-}1GeV}$ and $F_{>1GeV}$
⇒ clear spectral variability

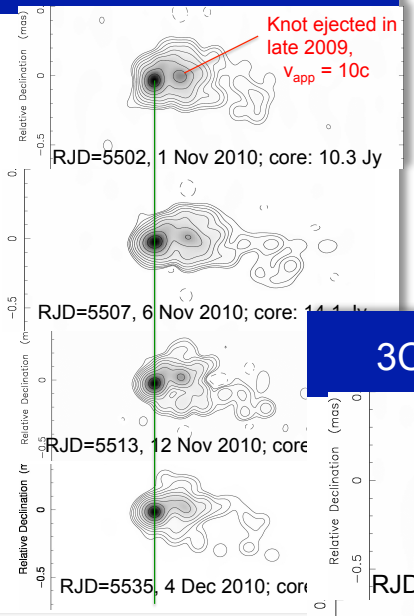
E_{break} constant within a factor of ~2 while flux varies by a factor of ~40.

G. Madejski, Parallel Session 10A - AGN II, Poster AGN S1.N27 Fuhrmann, L.

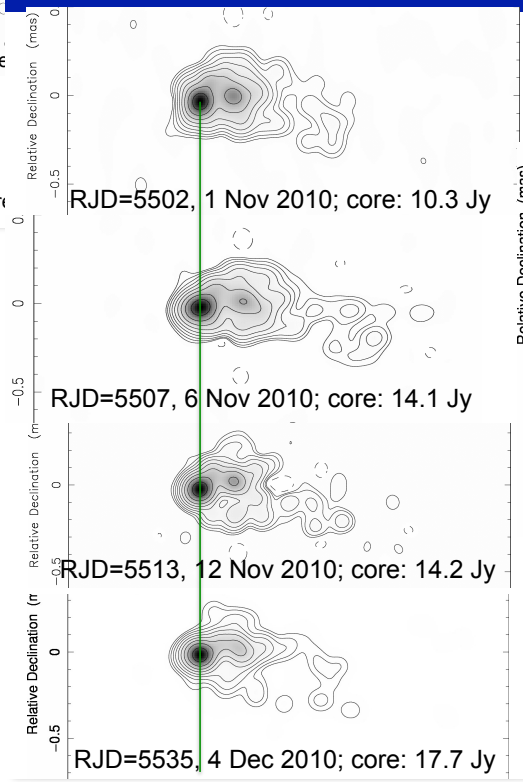
(Abdo, A. A. et al. 2011, ApJ, 733, L26)

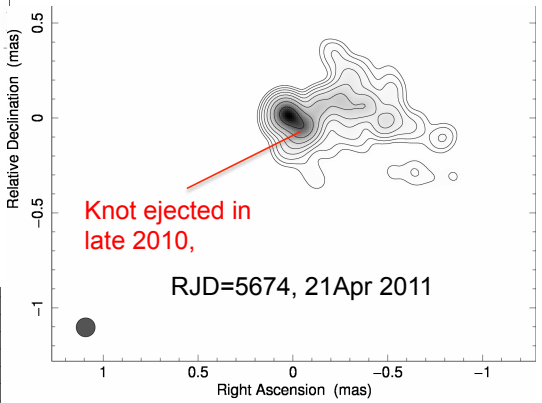
3C 454.3: 2010 super-outburst from gamma-ray to mm-wave





3C 454.3: Knot from mega-outburst moving in new direction





Alan Marscher talk

Jorstad et al. (2010 ApJ): core has triple structure, with a flare occurring as a knot passes each feature

Conclusions: 3C454.3 the champion

* Remarkable object, remarkable Nov. 2010 flare seen in all bands

• γ-ray flux ($L_{app} \sim 10^{50}$ erg s^{-1}) might set a record for the LAT lifetime…

• Rich features in the γ-ray band (Abdo et al. 2011)
rapid variability, yet 30 GeV flux not γ–γ absorbed by disk photons
-> compact source at a considerable distance from the BH?

• MW correlations essential! In summary:
* Radio flux relatively steady –
- source becomes fully optically thin only in the sub-mm / IR band
* Optical lagging γ-rays by ~ a day – competition between U_{ph} & U_B
- Optical (synchrotron) emission delayed due to gradual increase of B field associated with the same event (shock?) that accelerates particles
- Gamma-rays (inverse Compton) are more prompt, since U_{ph}(ext) is relatively steady

Also see S. Wagner talk, a larger sample!

Optical-GeV, more sources

Conclusions

Optical and GeV gamma-ray flares match in almost all sources with sufficiently complete data sets.

There is no significant indication for > 50h lags in sets with multiple flares.

Optical/GeV fluxes follow power-law relations with 0.2 < <slope> < 3.1.

Frequency bands are fixed but peak frequencies of synchrotron and IC components vary throughout the sample, affecting the slopes.

All cases exhibit statistically significant scatter beyond power-law relationship, resulting from different tracks in different flares.

Different flares (which often superpose) are likely to exhibit different specific SEDs, implying different physical states in emission volumes.

Simultaneous SEDs characterize events - but not necessarily sources.

S. Wagner talk

Interpreting 3C454.3 Observations

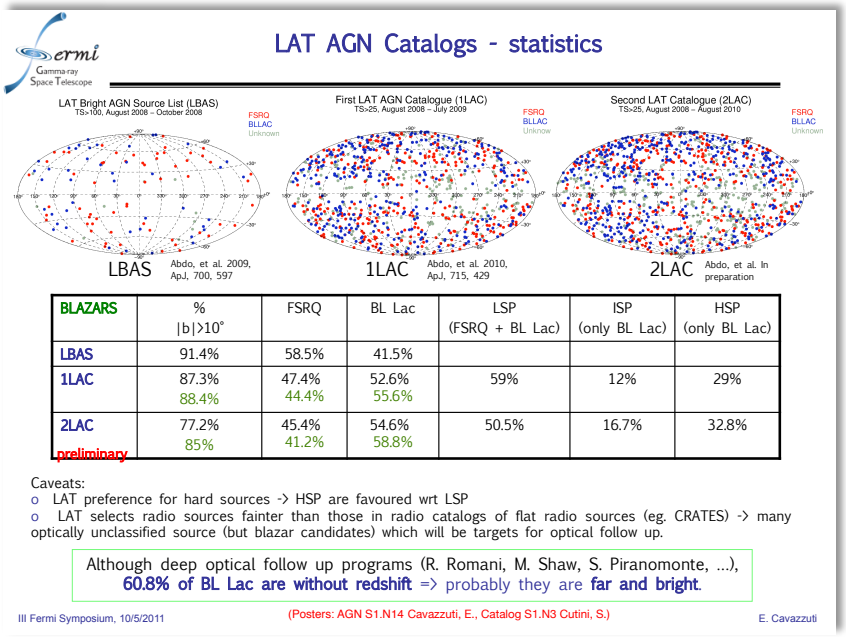
Conclusions

- GeV breaks are consistent with being produced by absorption on He II and H I recombination continua.
- Gamma-ray emitting region in 3C454.3 lies within the highest ionization zone of BLR at sub-parsec distances from the central black hole.
- This implies that the jet is accelerated to relativistic velocities at these distances.
- Additional features in a sub-GeV range are predicted due to the high-ionization soft X-ray lines.
- The underlying continuum does not have a break, but is well represented by a lognormal distribution.
- Opacity in He II varies with flux. The gamma-ray emission region moves away from the high-ionization region at high fluxes.

Poutanen talk

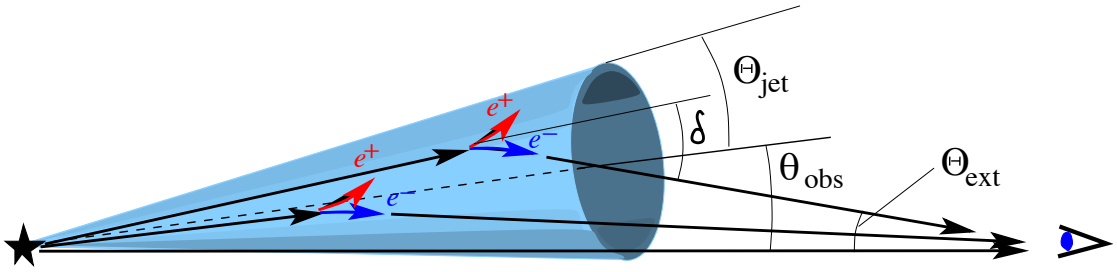
AGN

- Path forward
  - More correlated observations to answer “where”
  - Move from “where” and characterization of sources to connect to primary goals
  - 2LAC correlations
  - All those gorgeous LAT light curves begging analysis!
  - Breaks
  - Compact region emission
- NEED FOR NEW THINKING!



Using AGN: EBL and IGMF!

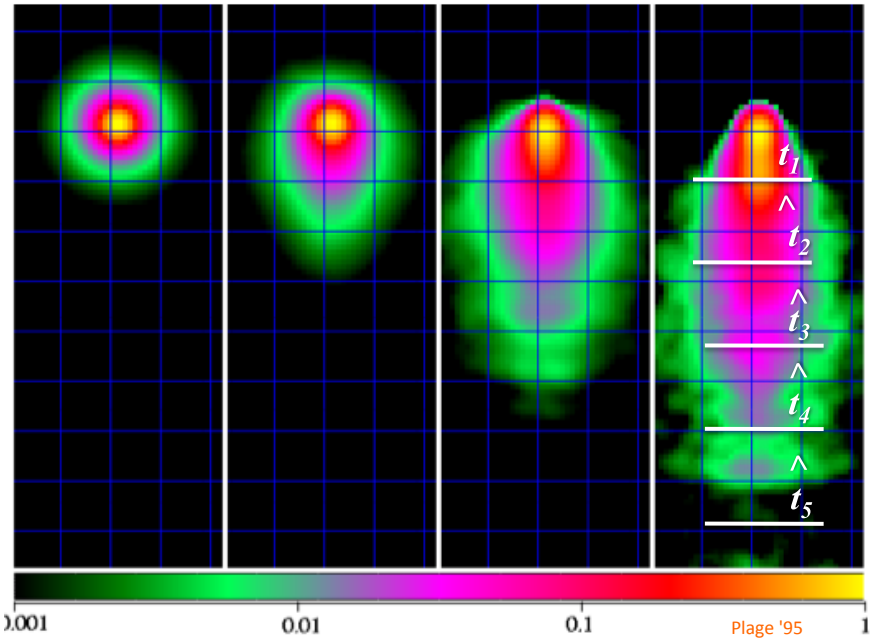
IGMF suppression of the cascade signal



Cascade γ-rays travel along different path than direct γ-rays from the source.

Cascade signal is, in general, delayed compared to the direct source signal.

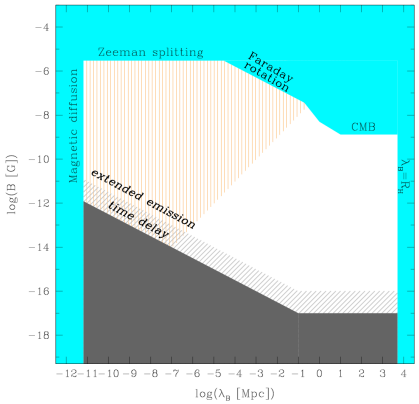
Time delay of the cascade emission grows with the increase of B. Cascade emission is suppressed as soon as the time delay of the cascade emission is larger than source activity time.



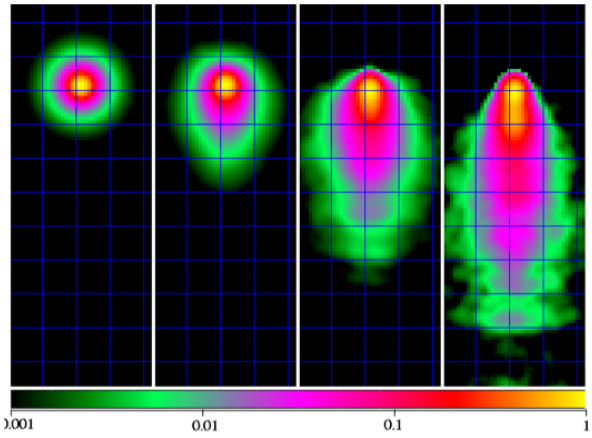
Neronov talk

Summary

Absorption of TeV gamma-rays from distant blazars and subsequent re-emission of gamma-rays from electromagnetic cascade leads to appearance of extended/ delayed gamma-ray emission around extragalactic sources.



Non-detection of cascade emission from TeV blazars by Fermi imposes a lower bound on the intergalactic magnetic field at the level of $\sim 10^{-16}$ G if suppression of the cascade emission is due to extended nature of the cascade source and $\sim 10^{-17}$ G if the suppression is due to the time delay.



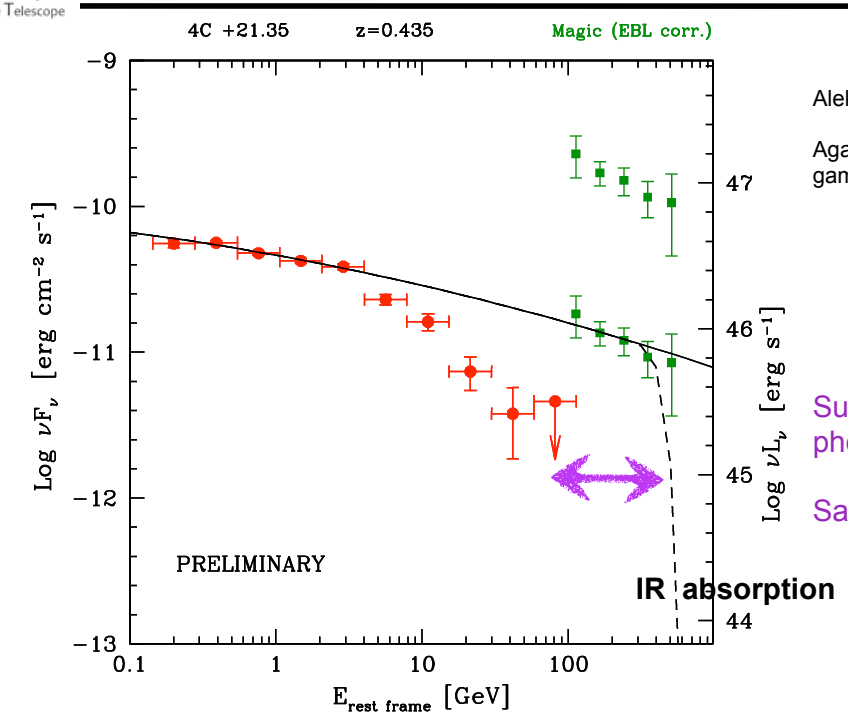
If typical IGMF strengths are not far (within an order of magnitude) from the lower bound, extended and/or delayed cascade emission from extragalactic sources will be detected by Fermi.

➔ Positive detection of cascade emission would provide a measurement of IGMF (rather than just a lower bound).

Neronov talk

Intrinsic- and EBL-absorption developments

$R_{diss} > R_{BLR}$, so EC (HD) is ok ? Not really !



Aleksic et al. 2011 (MAGIC coll)

Again IR photons absorb VHE gamma-rays !

Survival zone for VHE photons is narrow !

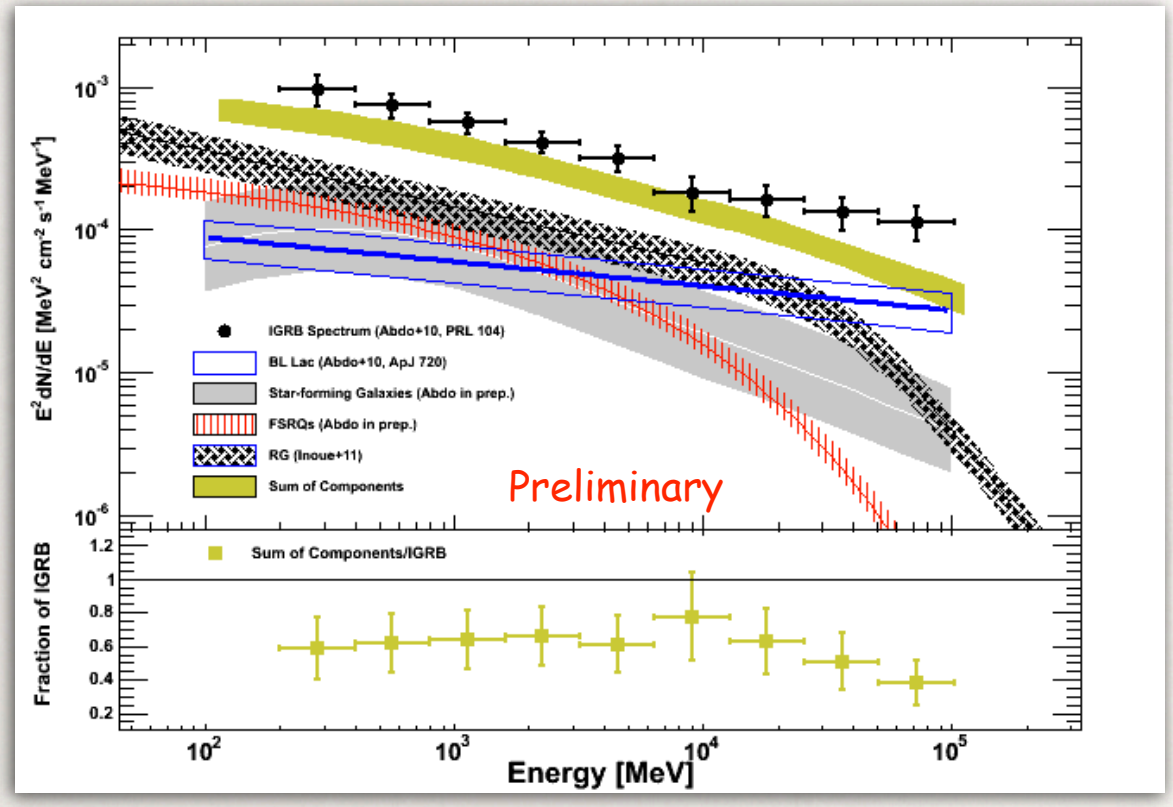
Same problem for 1510-08

4C 21.35 has strong IR emission from HD, T~1200K, $L_{IR} \sim 8 \times 10^{45}$ erg/s (Malmrose et al. 2011)

L. Costamante

Update on the IGRB

M. Ajello



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

What has similar challenges, but no repeatability?…

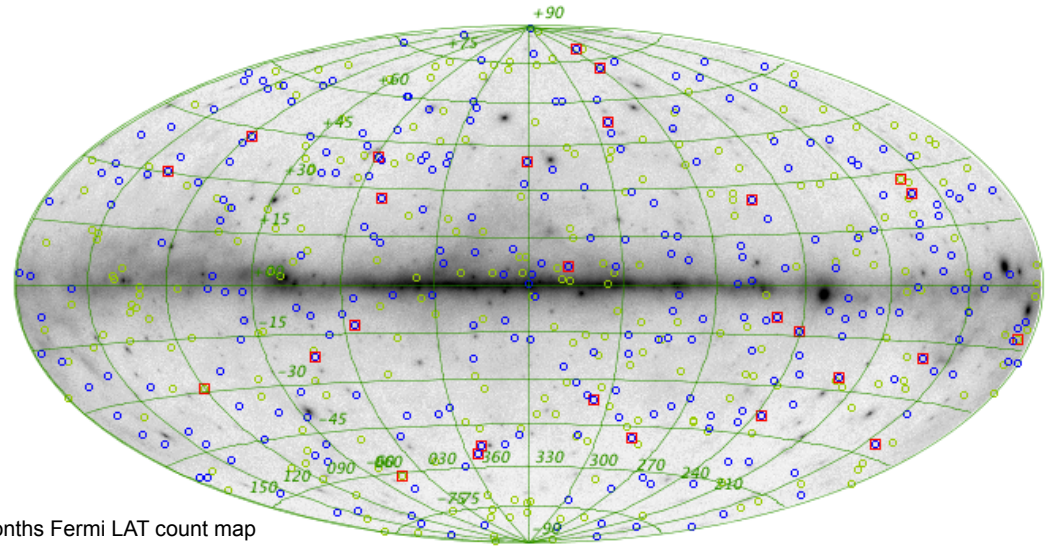
GRB!

GRB: what do we see?

Fermi detections as of 2011-01-20

~550 GBM GRB (since Aug 2008)
27 LAT GRB (7 LAT LLE-only GRB)

Circles:
In Field-of-view of LAT (<70˚): 275
Out of the FOV
Squares:
LAT detections



11 months Fermi LAT count map

PRELIMINARY

GRB: what do we see?

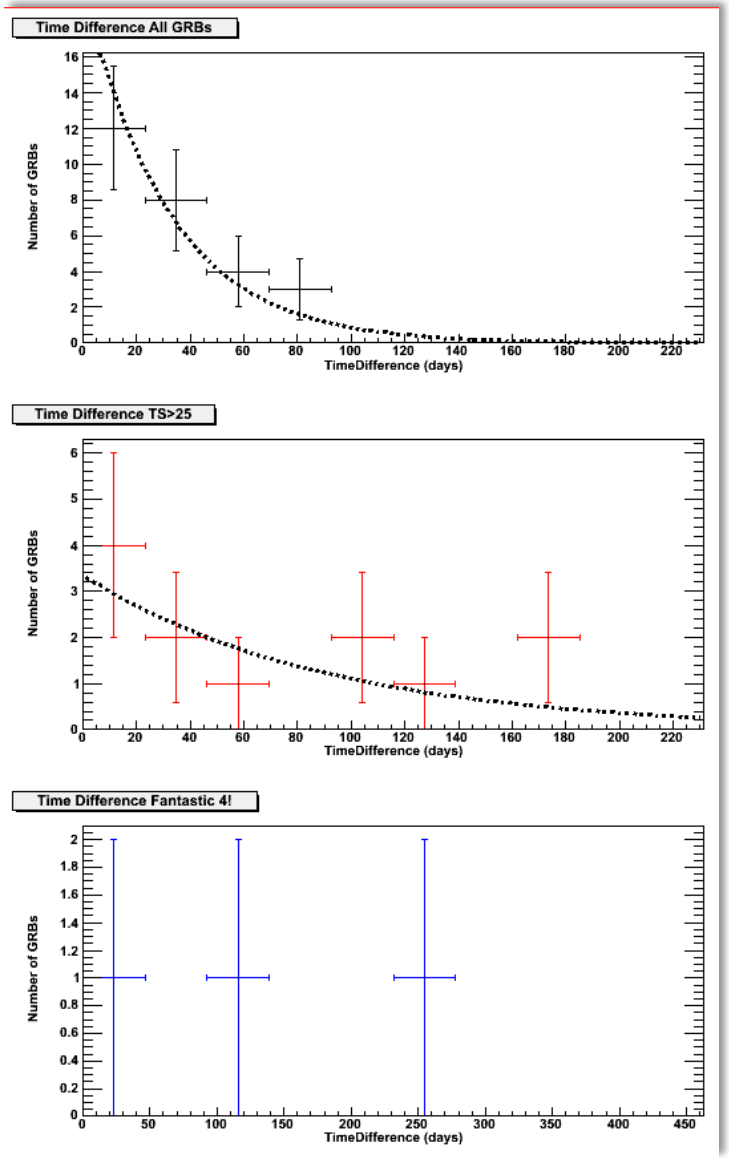
Summary Table & Highest Energy Events compatible with the GRB position

GRB Name	Likelihood Detection >100 MeV	LLE Detection	LAT off axis angle at T_0 (degrees)	GBM T_{90}	N Pred. Events (>100MeV, Trans.)	HE Delayed Onset?	Long Lived HE Emission?	Maximum Energy (GeV) meas. during the LAT detection	Arrival time of the highest events (seconds since trigger)	Redshift
GRB080825C	√	√	60.3	21	10	√	√	0.6	28.3	-
GRB080916C	√	√	48.8	63	211	√	√	13.2	16.5	4.35
GRB081006	√	x	10.7	6.4	13	-	√	0.6	1.8	-
GRB081024B	√	√	18.6	0.6	11	√	√	3.1	0.6	-
GRB081215	x	√	97.1	5.6	-	-	-	-	-	-
GRB081224	x	√	17	16.4	-	√	√	-	-	-
GRB090217	√	√	34.5	33.3	17	√	√	0.9	14.8	-
GRB090227B	√	√	70.1	1.3	3	-	-	-	-	-
GRB090323	√	√	57.2	135.2	39	√	√	7.5	195.4	3.57
GRB090328	√	√	64.6	61.7	58	√	√	5.3	698.3	0.736
GRB090510	√	√	13.6	1	183	√	√	31.3	0.8	0.903
GRB090531B	x	√	21.9	0.8	-	-	-	-	-	-
GRB090626	√	√	18.2	48.9	30	√	√	2.1	111.6	-
GRB090902B	√	√	50.8	19.3	323	√	√	33.4	81.7	1.822
GRB090926	√	√	48.1	13.8	252	√	√	19.6	24.8	2.106
GRB091003	√	√	12.3	20.2	33	√	√	2.8	6.5	0.897
GRB091031	√	√	23.8	33.9	16	√	√	1.2	79.7	-
GRB100116A	√	√	26.6	102.5	21	-	√	2.2	105.7	-
GRB100225A	x	√	54.9	13	-	-	-	-	-	-
GRB100325A	√	x	7.4	7.1	5	-	√	0.8	0.4	-
GRB100414A	√	√	69	26.5	28	√	√	4.3	39.3	1.368
GRB100707A	x	√	90.3	81.8	-	-	-	-	-	-
GRB100724B	√	√	48.8	87	24	-	-	0.1	15.4	-
GRB100728A	√	x	59.9	162.9	17	-	√	1.7	709	-
GRB101014A	x	√	54.1	450.9	-	-	-	-	-	-
GRB101123A	x	√	84.2	~160	-	-	-	-	-	-
GRB110120A	√	x	13.7	~20	9	-	√	1.8	72.5	-

Last bright GRB: Sept 2009!

PRELIMINARY

It doesn't always *feel* Poisson…



…but it is!

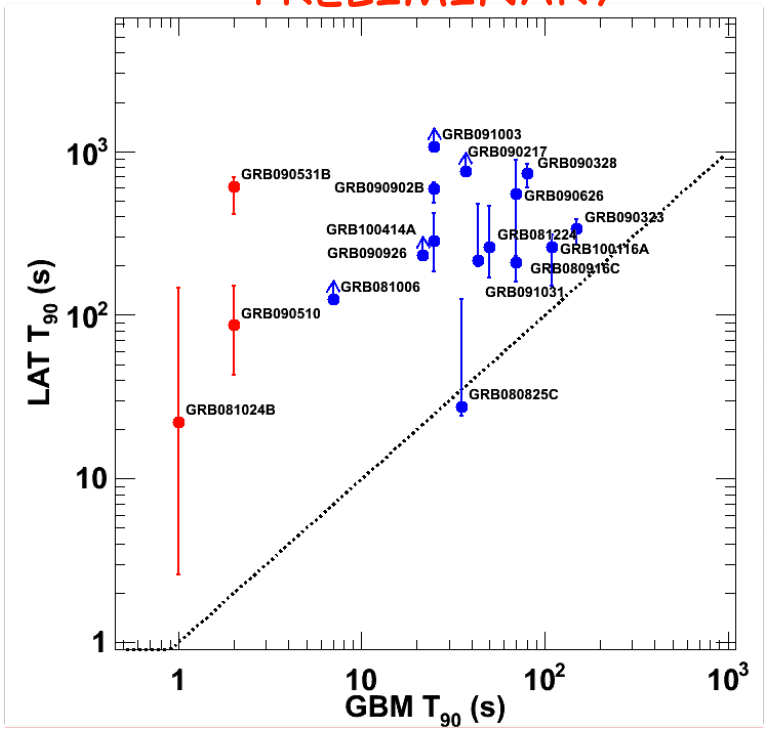
Thanks to N. Omodei

Duration: Study of the extended emission

All about estimating the background!

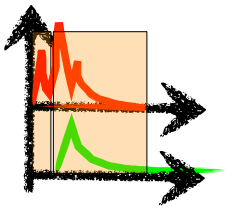
T_{90}: time between the 5% and the 95% of the integrated signal above background;
Estimation of the errors done running simulations (Upper and lower bounds)

PRELIMINARY



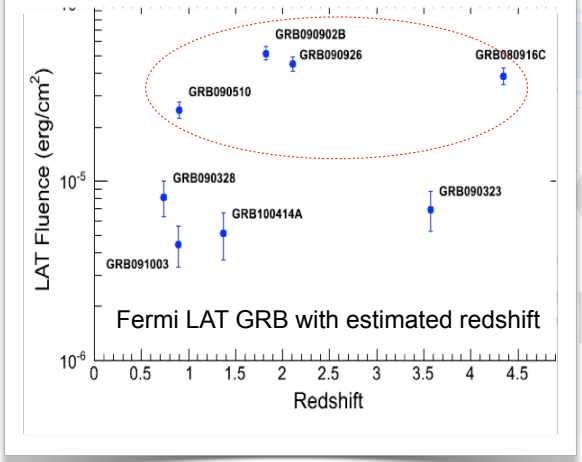
- **We measure a systematically longer duration in the LAT**
  - **Emission at GeV energy lasts longer than the emission at MeV energy**
    - **Different component?**
  - **OR, better sensitivity of the LAT detector (low background) than the GBM detector (background dominated)**
- **We also systematically measure a delayed onset between the GBM and the LAT emission**

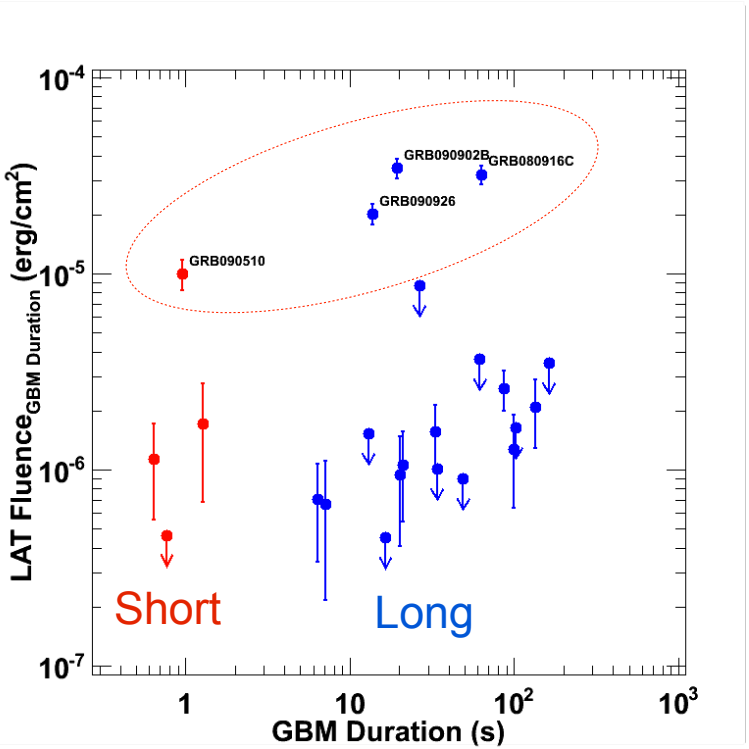
The Fantastic 4 !



- **Four bursts show an exceptionally high fluence (100 MeV - 10GeV)**
- **These bursts are not the closest to us**

PRELIMINARY





Summary

- First Fermi/LAT catalog of GRBs on its way!
  - Systematic study of LAT GRBs
    - First catalog of GRB at high energy;
    - Also includes methodology to reproduce the analysis;
  - Using both LLE data + standard transient class data
  - 27 GRB (7 LLE only, 4 likelihood only, 4 very bright bursts)

- Common observed properties:
  - Temporal extended emission (long lasting);
  - Delayed onset between LAT and GBM emission;
  - "Extra component"
- All numbers here are preliminary, a paper will come out soon!

Omodei talk

What does it mean?

"fireball" model: general framework

Source of energy

↓

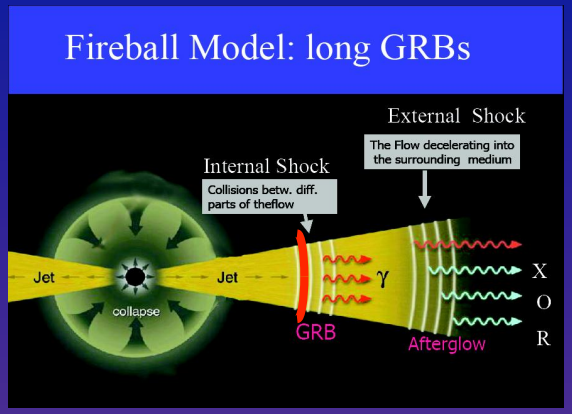
Kinetic energy (jet)

↓

Dissipation

↓

Radiation



What do we want to know ??

Basic (GRB) physics

1. Progenitor /Central engine
2. Jet launching mechanism; - jet composition
3. Jet dynamics, dissipation & radiative processes

4. How are GRBs connected to other objects ?
Stellar evolution, star formation, host galaxies, pop-III stars, SNe, Binaries, GW, cosmic rays, ν's…

5. GRBs and basic physics: Cosmology, Lorentz violation,…

Pe'er talk

The basic questions

	FERMI's driven works
1. Nature of the progenitor:	Continuous works; further constraints by higher Γ
2. Jet launching mechanism:	Continuous works; **interest in magnetic models**
3. Why relativistic speeds ?	Still unclear
4. Jet composition:	Still unclear; many possibilities
5. Dissipation mechanism:	**More than a single region;** **Connection between prompt and early AG**
7. Radiative processes: -> particle acceleration	**Interest in photospheric models;** constraints by lack of LAT detection

Pe'er talk

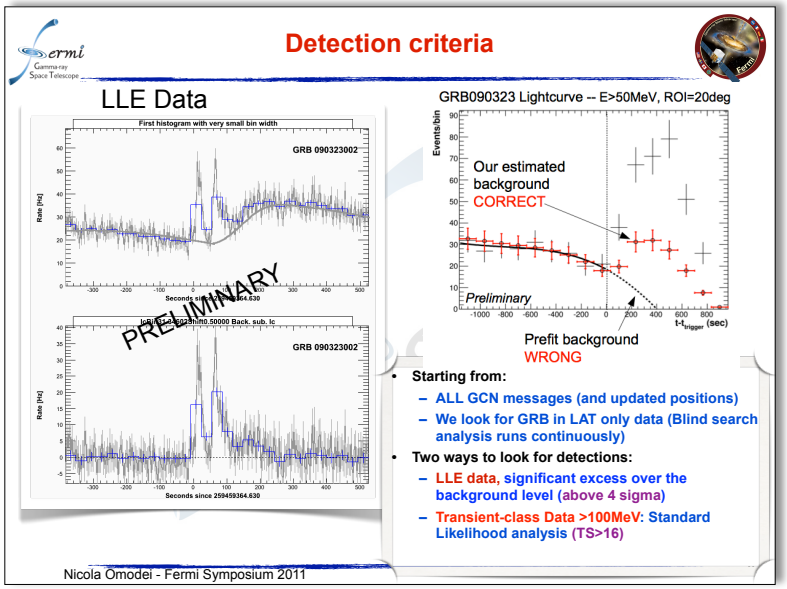
Bottom line

- The broad band spectra seen by Fermi does not fit into any of the frameworks of existing models.

- Fermi results forces us to re-think of questions that were thought to be solved.

Pe'er talk

- Path forward
  - More bursts are on their way!
  - LLE data
  - Common issues with AGN, galactic sources – jets!
  - Short vs long bursts
- NEED FOR NEW THINKING!
  - Lags in the data
  - Lags in the interpretation



Dark Matter: Many Places to Look!

Galactic Center

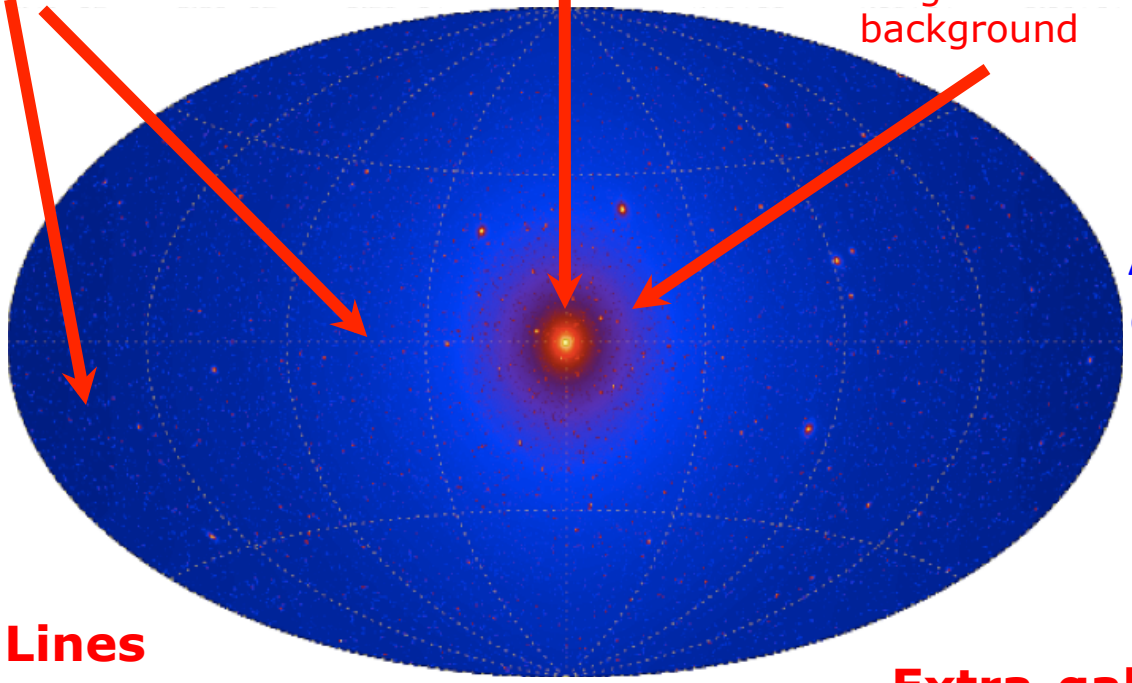
Good Statistics but source confusion/diffuse background

Satellites

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

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

See summary talks by Sandick and Latronico, and many contributions

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.

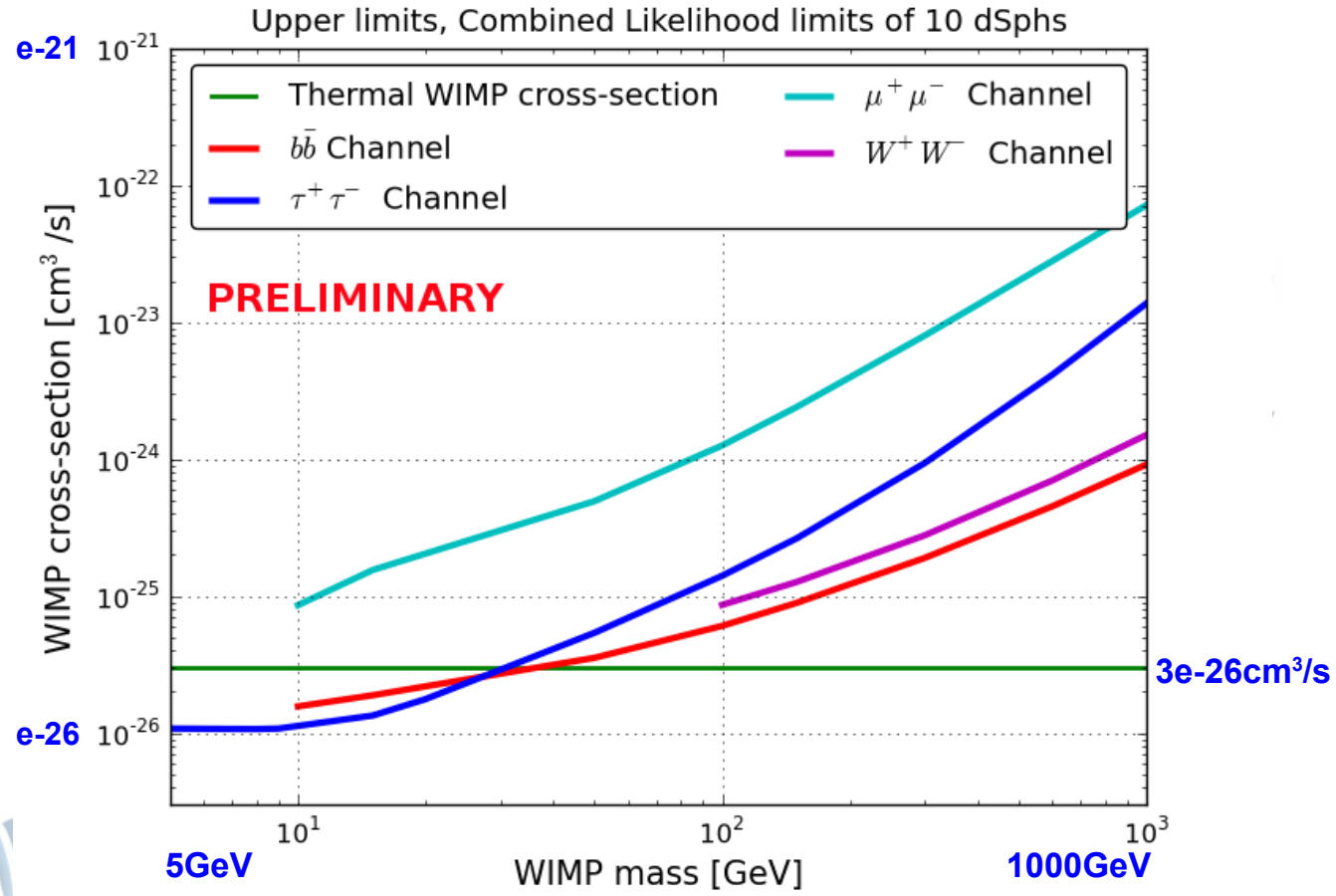
Dwarf Spheriodal (dSph) Galaxies

- 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!

Combining dSph Limits

Results all channels



Maja Llena Garde
on behalf of the Fermi-LAT collaboration

So Many Surprises!

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

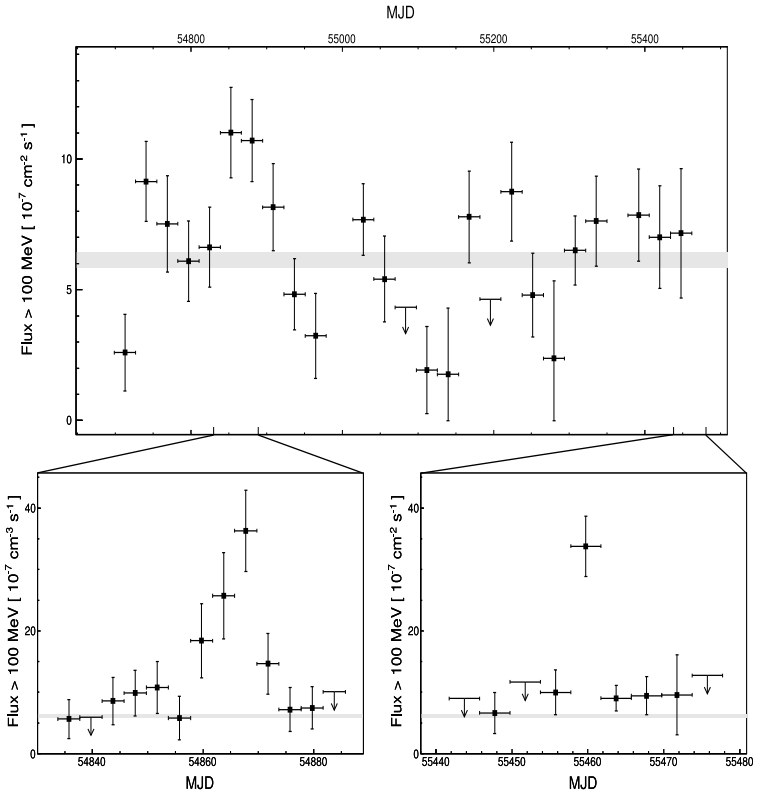


Figure 2: Gamma-ray flux above 100 MeV as a function of time of the synchrotron component of the Crab Nebula. The upper panel shows the flux in four-week intervals for the first 25 month of observations. Data for times when the sun was within 15° of the Crab Nebula have been omitted. The gray band indicates 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**

Latest LAT Crab Atel

[Previous | Next]

Extreme gamma-ray outburst during the current Crab Nebula flare

ATel #3284; *E. Hays (NASA/GSFC), R. Buehler (SLAC/KIPAC), F. D'Ammando (INAF-IASF Palermo, CIFS) on behalf of the Fermi Large Area Telescope Collaboration*
*on **15 Apr 2011; 14:18 UT***
Credential Certification: Elizabeth Hays (elizabeth.a.hays@nasa.gov)

Subjects: Gamma Ray, >GeV, Neutron Star, Transient, Pulsar

Referred to by ATel #: 3286

The Large Area Telescope (LAT), one of the two instruments on the Fermi Gamma-ray Space Telescope, previously reported a new gamma-ray flare from the direction of the Crab Nebula beginning on the 9th of April (ATel #3276). The increased emission was afterwards confirmed by the AGILE satellite (ATel #3282).The Crab Nebula is currently also being monitored by Chandra, which observed a bright knot east of the pulsar (ATel #3283), similar to previous observations in the September 2010 flare.

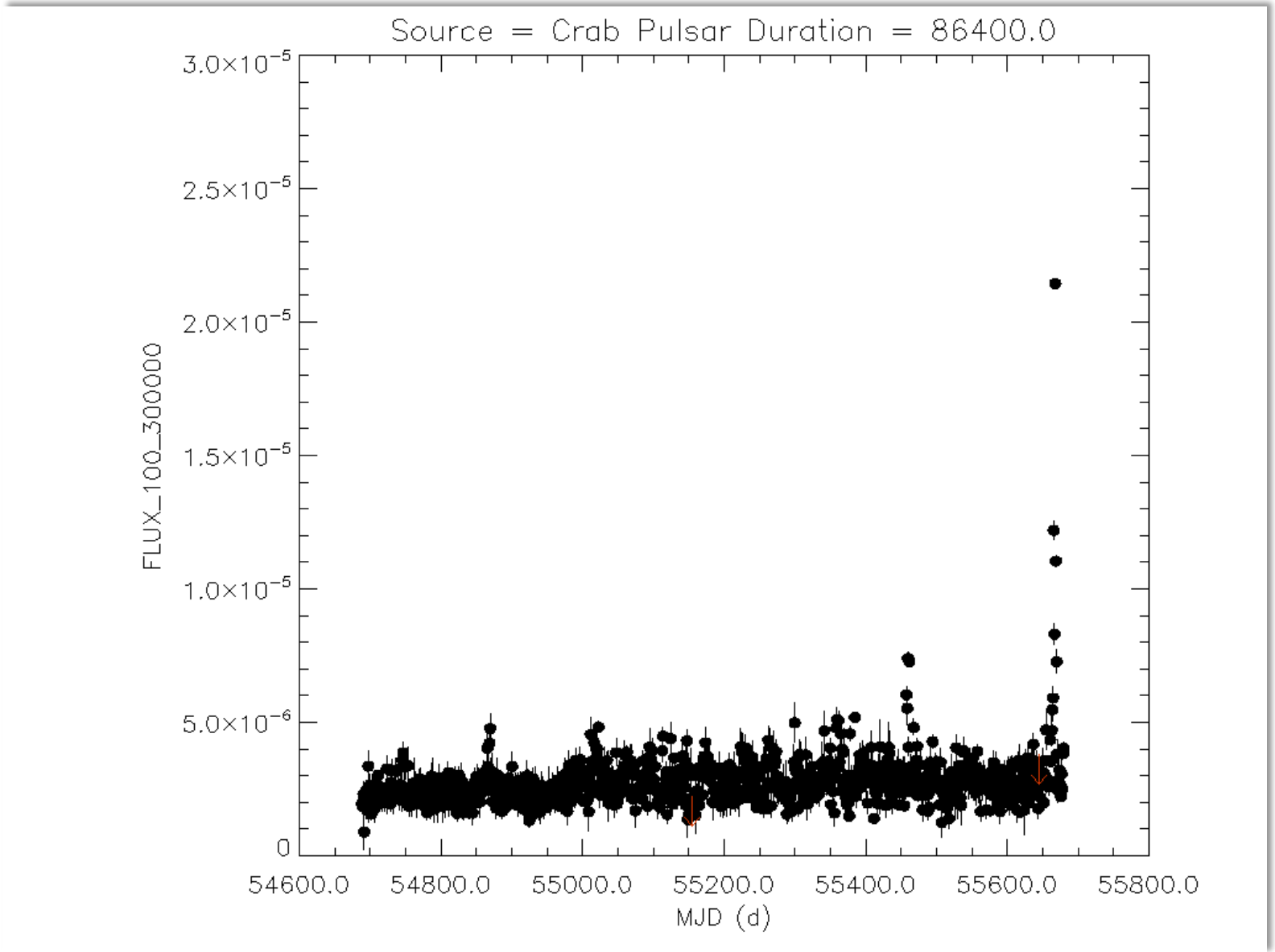
Preliminary LAT analysis indicates that the gamma-ray emission (E >100 MeV) from the direction of the Crab continues to increase, reaching a peak flux of (12.1 +/-0.6) x10^-6 ph/cm2/sec (statistical errors only) on April 14th. This is the highest gamma-ray flux on daily scales which has been observed from this source. Preliminary analysis indicates flux variation on shorter time scales, reaching flux values of >15 x10^-6 ph/cm2/sec in 12-hour time periods. The average flux from the Crab is (2.9 +/- 0.1) x10^-6 ph/cm2/sec, estimated for the entire Fermi operation period. All given fluxes are the sum of the pulsar and nebula emission.

Fermi has interrupted all-sky scanning mode starting at 2011-04-12 16:47 UTC to observe the Crab Nebula and is expected to remain in this observing mode until the 19th of April, unless the flare fades before this date. 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.

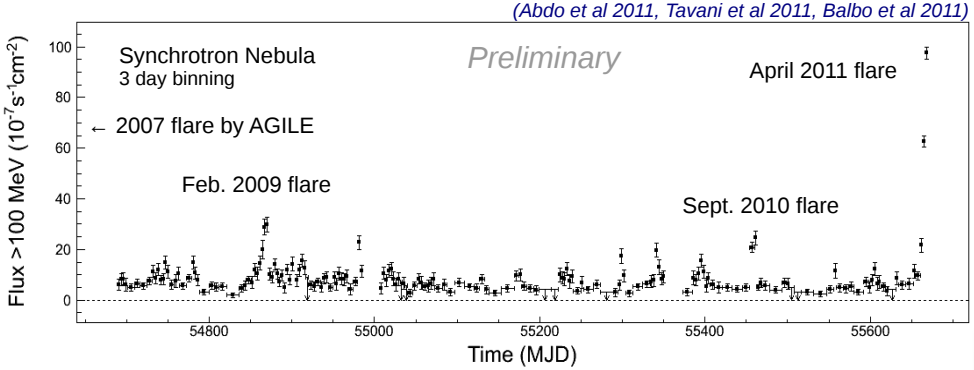
Related
3286 AGILE monitoring of the strongly variable gamma-ray emission from the Crab Nebula
3284 Extreme gamma-ray outburst during the current Crab Nebula flare
3283 Chandra observations of the Crab Nebula following the new gamma-ray flare observed by the Fermi-LAT
3282 AGILE monitoring of the enhanced gamma-ray emission from the Crab Nebula region
3279 Swift/XRT observation of the Crab Nebula after the gamma-ray flare observed on April 11, 2011
3276 Fermi LAT detection of a new enhanced gamma-ray emission from the Crab Nebula region
3058 Chandra follow-up observation of the Crab nebula after the high energy flare
2994 Chandra follow-up observation of the Crab nebula after the very high energy flare
2968 Search for an Enhanced TeV Gamma-Ray Flux from the Crab Nebula with VERITAS
2967 No significant enhancement in the VHE gamma-ray flux of the Crab Nebula measured by MAGIC in September 2010
2921 Enhanced TeV gamma ray flux from the Crab Nebula observed
2903 HST observation of the Crab Nebula following the September 2010 gamma-ray flare
2893 Swift/BAT spectral analysis

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



Three day Crab synchcrotron curve

(Abdo et al 2011, Tavani et al 2011, Balbo et al 2011)

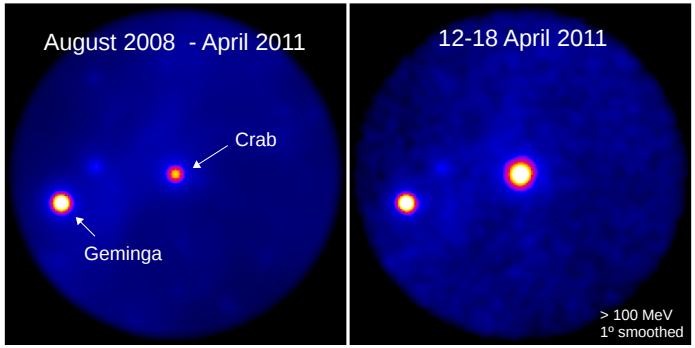


Average flux ~6 10^{-7} ph/cm^2/s above 100 MeV, whith three flares as extreme persistent variability. Flux increase by ~5 during 2009 and 2010 flares.

See poster by Liz Hays

R. Buehler talk

The 2011 outburst

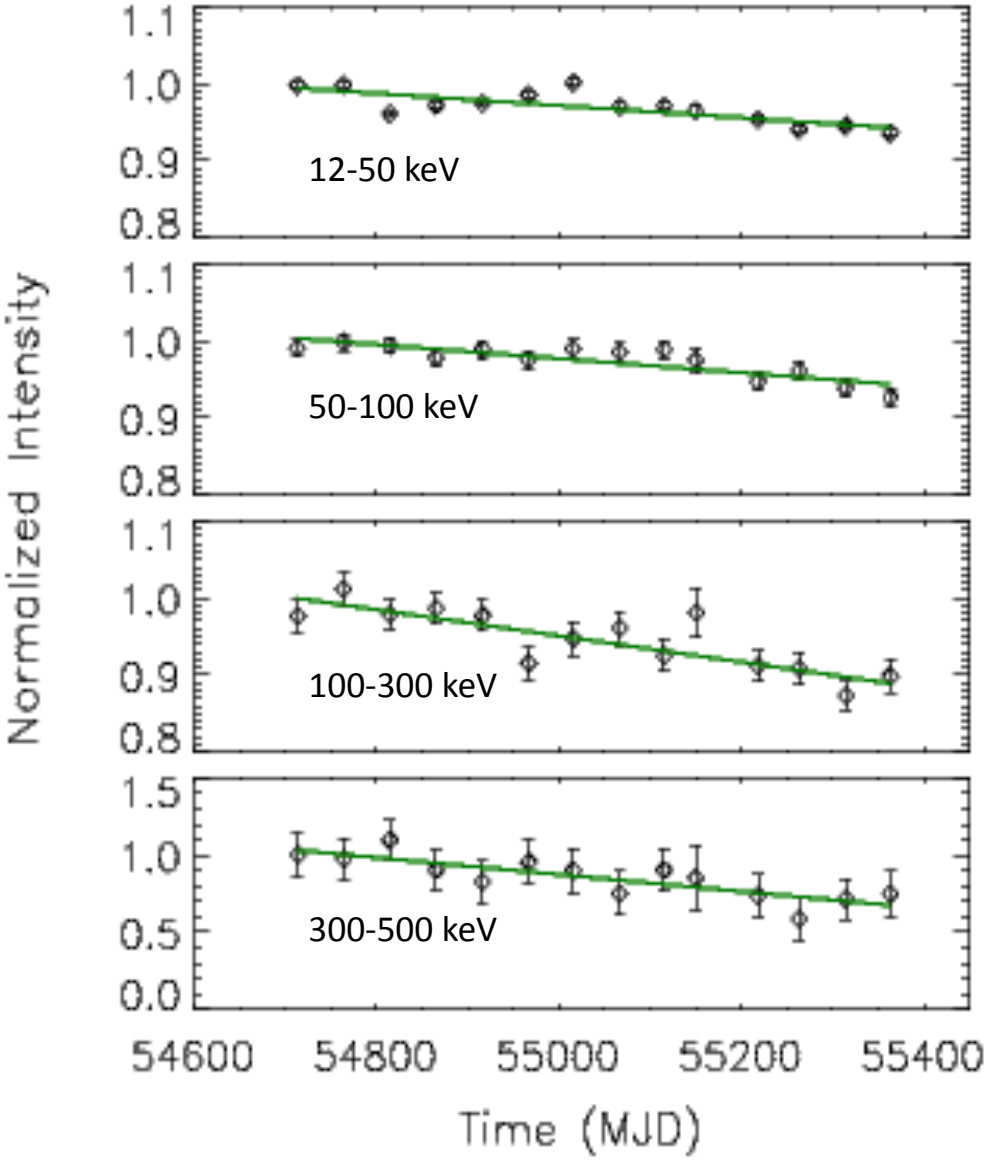


During the flare, the Crab was the brightest source in the gamma-ray sky

5

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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home of the San Francisco Chronicle
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Dungeness crab season opens after short delay

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

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

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

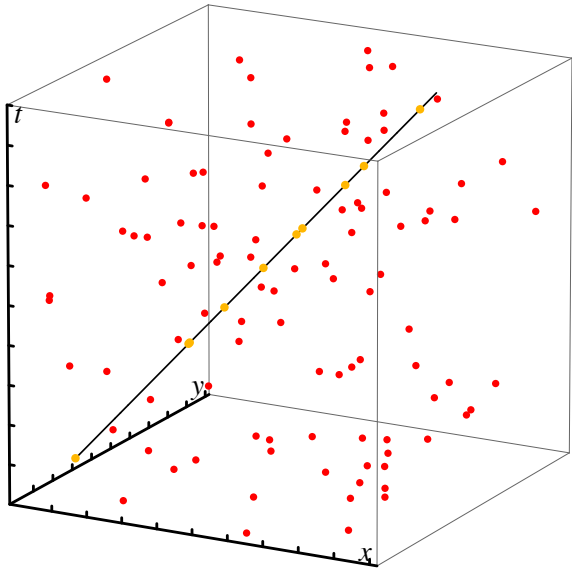
IMAGES

View All Images (31)

MORE NEWS

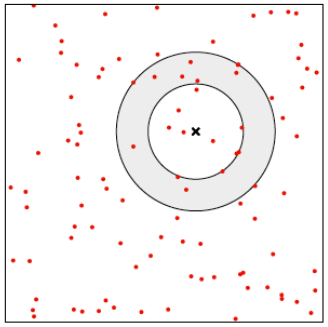
- Senate to vote again on military gay ban 11.17.10
- Obama enlists big guns to help save nuclear treaty 11.17.10
- UCSF shuttle bus strikes, kills pedestrian 11.17.10

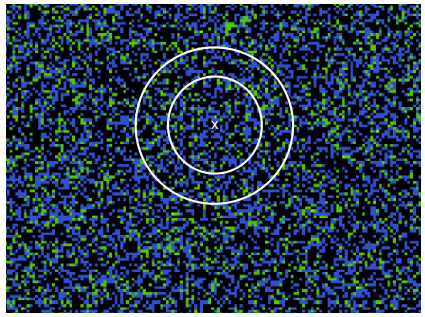
New Ways of Looking at the Data



Alex Geringer-Sameth & Koushiappas [arXiv:1012.1873]

The two-point space-time correlation function



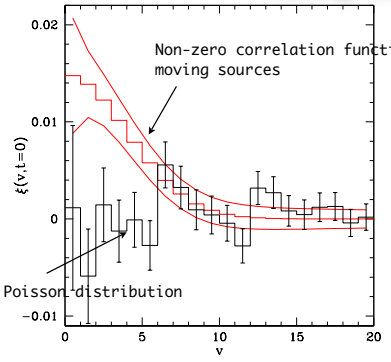


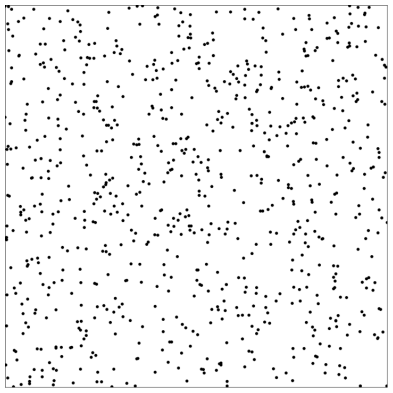
$$\xi_\theta(\Delta\theta) = \left\langle \frac{C(\Delta\theta) - \bar{\mathcal{N}}(\Delta\theta)}{\bar{\mathcal{N}}(\Delta\theta)} \right\rangle_p \qquad \xi_{\theta,t}(\Delta\theta,\Delta t) = \left\langle \frac{C(\Delta\theta,\Delta t) - \bar{\mathcal{N}}(\Delta\theta,\Delta t)}{\bar{\mathcal{N}}(\Delta\theta,\Delta t)} \right\rangle_{\text{events}}$$

Alex Geringer-Sameth & Koushiappas [arXiv:1012.1873]

If $\xi \neq 0$ → signal

Testing the formalism





Less than 5% of events comes from sources which generated more than 1 events

95% of these generate exactly 2 events

Alex Geringer-Sameth & Koushiappas [arXiv:1012.1873]

Koushiappas talk

New Ways of Looking at the Data

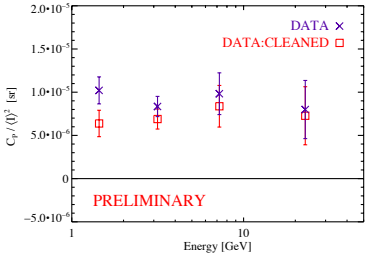
Detecting unresolved sources with anisotropies

- in addition to the energy spectrum and average intensity, the large-scale isotropic gamma-ray background (IGRB) contains angular information
- diffuse emission that originates from one or more unresolved source populations will contain fluctuations on small angular scales due to variations in the number density of sources in different sky directions
- the amplitude and energy dependence of the anisotropy can reveal the presence of multiple source populations and constrain their properties

Energy dependence of anisotropy

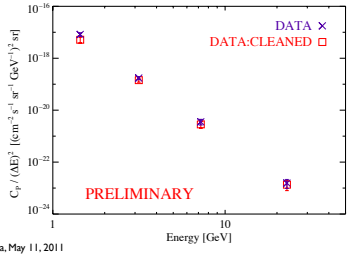
Fluctuation anisotropy energy spectrum

- consistent with no energy dependence, although mild or localized energy dependence not excluded
- consistent with all anisotropy contributed by one or more source classes contributing same fractional intensity at all energies considered



Intensity anisotropy energy spectrum

- consistent with that arising from a source class with power-law energy spectrum with $\Gamma = -2.40 \pm 0.07$
- implied source spectral index is good agreement with mean intrinsic spectral index of blazars inferred from detected members



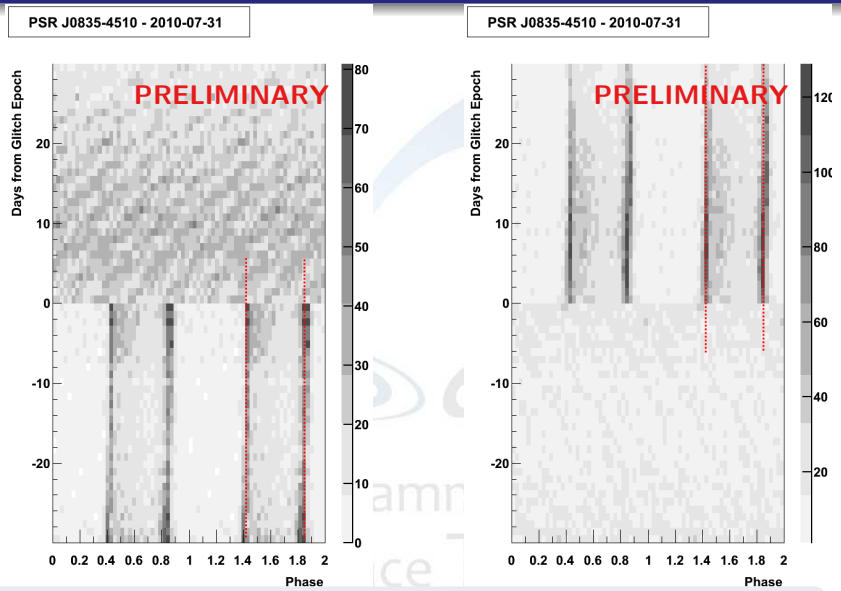
Siegal-Gaskins talk

Summary

- at multipoles $155 \leq l \leq 504$, angular power is robustly measured in the data at energies from 1 to 10 GeV; lower significance angular power is detected in the 10-50 GeV energy bin
  - scale independence of the power at these multipoles suggests a contribution to the IGRB from one or more unclustered point source populations
- the fluctuation angular power measured in all energy bins is consistent with a constant value ~ 1e-5 sr
  - falls in the range of predicted angular power for some astrophysical source populations and dark matter scenarios
  - can be used to constrain the IGRB contribution from these sources
- energy dependence in the fluctuation angular power is not evident
  - suggests that the anisotropy is contributed primarily by one or more source populations with constant fractional contributions to the IGRB intensity over this energy range
- the measured energy dependence of the intensity angular power is consistent with the IGRB anisotropy originating from a source population with a power-law energy spectrum with $\Gamma = -2.40 \pm 0.07$
  - this spectral index closely matches the inferred mean intrinsic spectral index of blazars

LAT is an All-sky Glitch Detector!

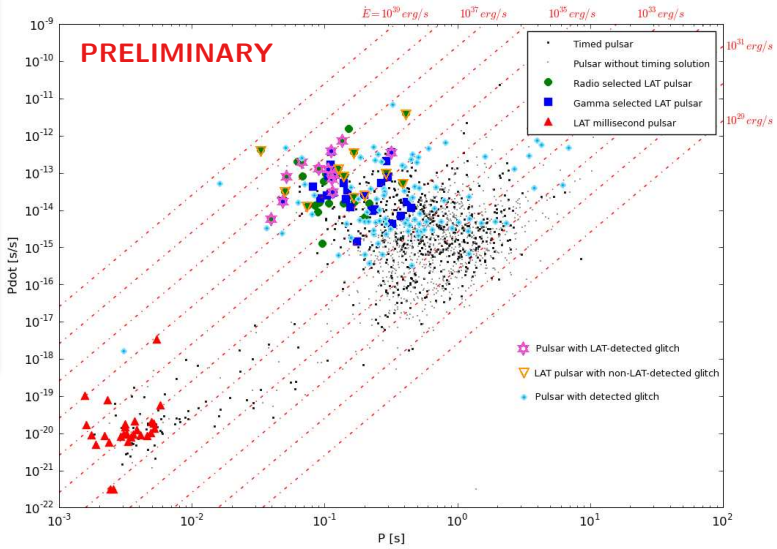
Measuring Glitch Parameters with the LAT
Reading the profile evolution plot



- We get 2 distinct timing solutions: before and after the glitch (Ray et al. 2011)
- We fold the event times over the two ephemerides obtained in each of the periods
- Pulse profile evolution for PSR J0835-4510 (Vela) around the glitch (Jul 31th 2010)

A. Belfiore talk

Sample of LAT-detected Glitches in 32 Months
LAT pulsars and glitches



- This plot (from the talk of D.Smith) uses data from:
  - The ATNF catalog (http://www.atnf.csiro.au/people/pulsar/psrcat/)
  - Espinoza et al. 2011 (http://www.jb.man.ac.uk/pulsar/glitches.html)

Additional Topics

- Lots of great results and new directions
  - Other AGN
  - Diffuse emissions, other galaxies
  - Other PWNe, SNR, Binaries, CR sources, …
  - Other new physics searches
  - Pulsars, Magnetars, … (see previous talks this session!)
  - Instrument performance improvements

Looking Ahead

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

- 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.
    - Longer-term: Pass7 and Pass8 to address the remaining issues.
  - Pass7 release imminent
    - » 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.

A Healthy Extended Mission

- “More data are required to obtain a deeper understanding”

- “A deeper understanding is required to obtain more data.”

Future Surprises

- **We're just beginning…**
  - **Exposure continues to increase**
    - **Fainter sources become detectable**
    - **Increasingly detailed studies of bright sources**
    - **Catalogs become deeper and more detailed**
  - **Time domain studies enter longer regimes**
  - **Solar cycle beginning to warm up**
  - **Plus, efforts continue to further improve performance and enhance analysis, particularly at low and high energies**
- **The longer we look, the more surprises we will see**

Liz Hays talk

Next Huntsville GRB Symposium

- Planned for Spring in 2013 (probably April)
- Tentatively will be held in Nashville, Tennessee
- Hosted by GBM team
- Details later

Public Lecture Tonight at 18:30!

Prof. G.F. Bignami

Da Roma all'Universo: Fermi in orbita

Final Thoughts

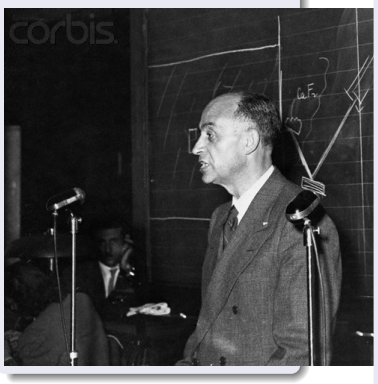
- Fermi would not have been possible without great international and multicultural cooperation!
- Cultural differences among communities are not necessarily impediments, but rather reinforcing capabilities enabling important new opportunities. We're lucky to have each other!
- Great leaps in capabilities 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!

From Steve Shore...

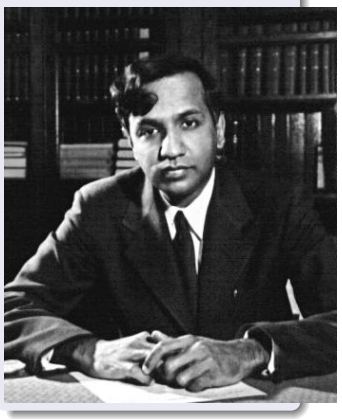
"It's nice to think that Fermi and Chandra are continuing to work together"

The protagonists

Enrico Fermi, 1949

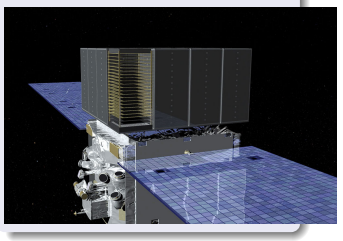


Chandrasekhar, ca. 1947



"Tell me, Chandra. When I die, will I come back as an elephant?"

Fermi/LAT



Chandra

Enrico Fermi and the other “ragazzi di Via Panisperna”

October 1934: discovery of artificial radioactivity induced by slow neutrons

Discovery:	**Saturday**	**20.10.34 (*)**
First paper:	**Monday**	**22.10.34**
Patent:	**Friday**	**26.10.34**

(*) A. De Gregorio : not on October 22!

O. D’Agostino E. Segrè E. Amaldi F. Rasetti E. Fermi

+ B. Pontecorvo = The boys of Via Panisperna

Amaldi talk

“Ragazzi di Fermi”

Grazie!