

# Fermi LAT Collaboration Meeting

## Fermi LAT International Finance Committee Meeting

Peter F. Michelson  
Stanford University

Fermi Large Area Telescope Collaboration Meeting  
SLAC / Stanford University, August 31, 2010



# Agenda – August 31, 2010

08:50 – 9:00 am	Welcome and Introduction	P. Drell
09:00 – 09:30 am	The LAT at 2 years: recent science highlights and collaboration status	P. Michelson
09:30 – 9:50 am	Fermi Mission Status	J. McEnery
09:50 – 10:10 am	LAT Operational Status	G. Thayer
10:10 – 10:40 am	LAT Analysis Coordinator's Report	S. Digel / G. Tosti
10:40 – 11:10 am	Break	
11:10-11:25	LAT Collaboration Computing	R. Dubois
11:25-11:40	LAT Pulsar in a Globular Cluster	D. Parent
11:40-11:55	Multiwavelength Coordinator's Report	D. Thompson
11:55-12:05	Pan-STARRS update	J. E. Grove
12:15 – 1:15 pm	Lunch	



**The LAT at 2 years: Recent science highlights and collaboration status**

**Happy 2<sup>nd</sup> Birthday, Fermi!**

# Fermi began the year with recognition as one of the top 10 science breakthroughs of 2009

Science, December 2009

## THE RUNNERS-UP >>

### Opening Up the Gamma Ray Sky

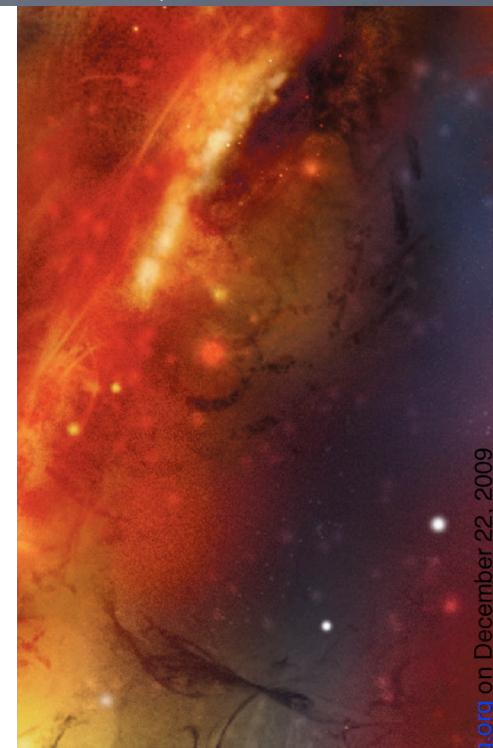
LIKE A LIGHTHOUSE BLINKING IN THE NIGHT, A pulsar appears to flash periodically as it spins in space, sweeping a double cone of electromagnetic radiation across the sky. Since the discovery of the first pulsar 4 decades ago, astronomers have detected hundreds more of these enigmatic objects from the pulsing radio waves they emit. Now, astronomers have opened a new channel of discovery—the highly energetic gamma ray spectrum—to find pulsars that radio observations could not detect. The advance, part of a torrent of recent gamma ray observations, is giving researchers an improved understanding of how pulsars work, along with a rich haul of new pulsars that could help in the quest to detect gravitational waves.

The findings come from the Fermi Gamma-ray Space Telescope, which has been mapping the gamma ray universe since it was launched by NASA in June 2008. Combing through data the telescope collected in its first few months, an international team discovered 16 new pulsars; strong gamma ray pulsations from eight

previously known pulsars with spin times of milliseconds, proving that these objects pulse brightly at gamma wavelengths as well as in the radio range; and high-energy gamma rays from the globular cluster 47 Tucanae indicating that the cluster harbors up to 60 millisecond pulsars.

Those Fermi results might be just the beginning. Armed with their new knowledge of pulsar behavior, researchers are checking whether some of the unidentified gamma ray sources Fermi has detected might be pulsars. In November alone, teams of astronomers in the United States and France discovered five new millisecond pulsars by training ground-based radio telescopes on candidate objects Fermi had pointed out—a much more targeted search technique than scanning the sky blindly with ground-based radio telescopes.

Gamma ray beams of pulsars are believed to be wider than their radio beams, so in principle a space-based gamma ray telescope should be more likely to encounter and discern a pulsar's sweep than a radio telescope on Earth is. However, Fermi's forerunner—



the Compton Gamma Ray Observatory, which flew from 1991 to 2000—did not have much luck finding these objects. What has made the difference is Fermi's high sensitivity, which enables it to detect pulsations that would have been too faint for Compton.

Already, the discoveries are shedding new light on the physics of pulsars. Researchers

from [www.sciencemag.org](http://www.sciencemag.org) on December 22, 2009

Breakthrough of the Year was the reconstruction of the 4.4-million-year-old *Ardipithecus ramidus* skeleton

Fermi LAT Collaboration has just  
published its 100<sup>th</sup> paper!

# Fermi LAT papers and citations

2,320 citations to date of ~100 Fermi LAT Collaboration papers

# citations

- “Measurement of the Cosmic Ray  $e^+e^-$  Spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope” (05/2009) 340
- “The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission” (09/2008) 292
- “Fermi/Large Area Telescope Bright Gamma-Ray Source List” (07/2009) 190
- “Fermi Observations of High-Energy Gamma-Ray Emission from GRB 080916C” (03/2009) 139
- “Bright Active Galactic Nuclei Source List from the First Three Months of the Fermi Large Area Telescope All-Sky Survey” (07/2009) 154
- “A limit on the variation of the speed of light arising from quantum gravity effects” (11/2009) 78
- “The First Fermi LAT Catalog of Gamma-Ray Pulsars” (04/2010) 63
- “The First Fermi LAT Catalog of High-Energy Gamma-Ray Sources” (06/2010) 57



# The Fermi LAT 1FGL Source Catalog

- 1,451 sources; *Ap. J. Suppl.* **188** 405 (2010)

Description	Designator	Number Assoc. (ID)
Pulsar, X-ray or radio, identified by pulsations	psr (PSR)	7 (56)
Pulsar, radio quiet (LAT PSR, <i>subset of above</i> )	PSR	24
Pulsar wind nebula	pwn (PWN)	2 (3)
Supernova remnant	† (SNR)	41 (3)
Globular Cluster	glc (GLC)	8 (0)
Micro-quasar object: X-ray binary (black hole or neutron star) with radio jet	mqq (MQO)	0 (1)
Other X-ray binary	hxb (HXB)	0 (2)
BL Lac type of blazar	bzb (BZB)	295 (0)
FSRQ type of blazar	bzq (BZQ)	274 (4)
Non-blazar active galaxy	agn (AGN)	28 (0)
Active galaxy of uncertain type	agu (AGU)	92 (0)
Normal galaxy	gal (GAL)	6 (0)
Starburst galaxy	sbg (SBG)	2 (0)
Unassociated		630

- AGN
- × AGN-Blazar
- AGN-Non Blazar
- No Association
- Possible Association with SNR and PWN
- Possible confusion with Galactic diffuse emission
- Starburst Galaxy
- + Galaxy
- SNR
- × PSR
- PWN
- ⊗ PSR w/PWN
- ◇ Globular Cluster
- × HXB or MQO

# LAT Collaboration publications: March – August 2010

- Fermi Large Area Telescope Observations of Misaligned Active Galactic Nuclei (09/2010)
- The Fermi-LAT High-Latitude Survey: Source Count Distributions and the Origin of the Extragalactic Diffuse Background (09/2010)
- Fermi-LAT Observations of the Geminga Pulsar (09/2010)
- Fermi Large Area Telescope Observations of Gamma-ray Pulsars PSR J1057–5226, J1709–4429, and J1952+3252 (09/2010)
- Fermi Large Area Telescope View of the Core of the Radio Galaxy Centaurus A (08/2010)
- Fermi Large Area Telescope Observations of the Supernova Remnant W28 (G6.4–0.1) (07/2010)
- Fermi Large Area Telescope First Source Catalog (06/2010)
- Suzaku Observations of Luminous Quasars: Revealing the Nature of High-energy Blazar Emission in Low-level Activity States (06/2010)
- The Spectral Energy Distribution of Fermi Bright Blazars (06/2010)
- The First Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope (05/2010)

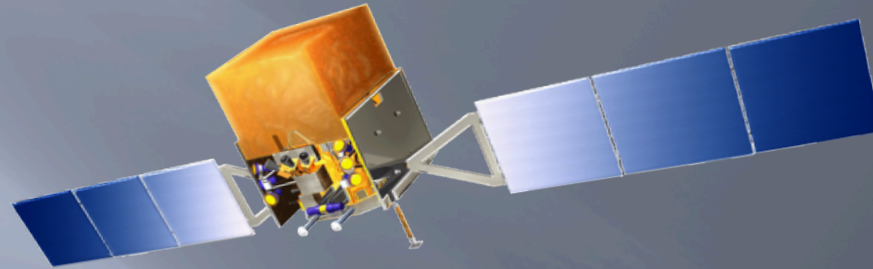
# LAT Collaboration publications: March – August 2010

- Fermi-Large Area Telescope Observations of the Exceptional  $\gamma$ -ray Outbursts of 3C 273 in 2009 September (05/2010)
- Detection of the Energetic Pulsar PSR B1509-58 and its Pulsar Wind Nebula in MSH 15-52 Using the Fermi-Large Area Telescope (05/2010)
- Constraints on cosmological dark matter annihilation from the Fermi-LAT isotropic diffuse gamma-ray measurement (04/2010)
- The First Fermi Large Area Telescope Catalog of  $\gamma$ -ray Pulsars (04/2010)
- The Vela Pulsar: Results from the First Year of Fermi LAT Observations (04/2010)
- Fermi Large Area Telescope Observations of the Vela-X Pulsar Wind Nebula (04/2010)
- Fermi Large Area Telescope Observations of PSR J1836+5925 (04/2010)
- Discovery of Pulsed  $\gamma$ -Rays from PSR J0034-0534 with the Fermi Large Area Telescope: A Case for Co-Located Radio and  $\gamma$ -Ray Emission Regions (04/2010)
- Spectrum of the Isotropic Diffuse Gamma-Ray Emission Derived from First-Year Fermi Large Area Telescope Data (03/2010)

# LAT Collaboration publications: March – August 2010

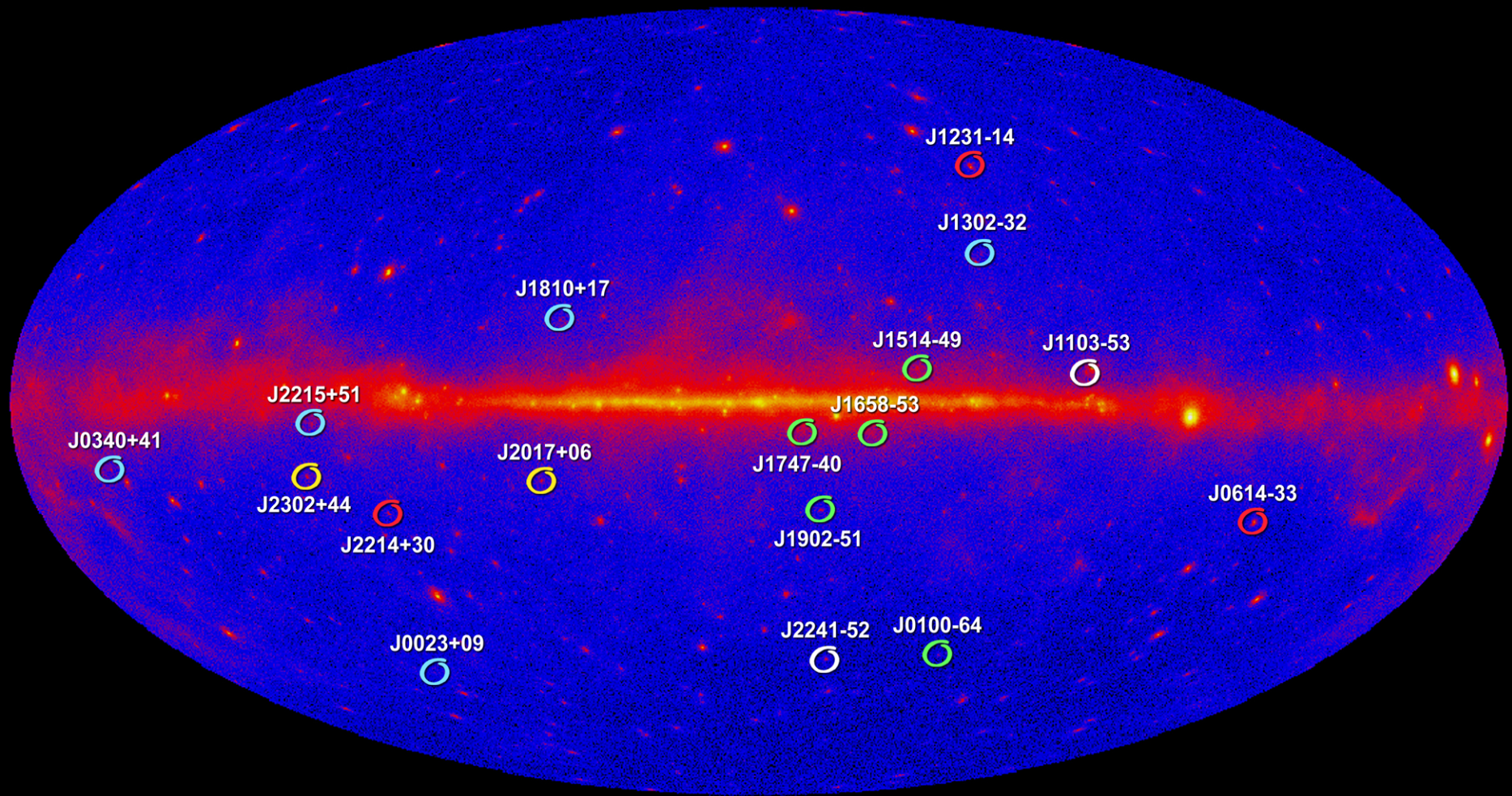
- Fermi Large Area Telescope Search for Photon Lines from 30 to 200 GeV and Dark Matter Implications (03/2010)
- Fermi Detection of Delayed GeV Emission from the Short Gamma-Ray Burst 081024B (03/2010)
- Observation of Supernova Remnant IC 443 with the Fermi Large Area Telescope (03/2010)
- Observations of Milky Way Dwarf Spheroidal Galaxies with the Fermi-Large Area Telescope Detector and Constraints on Dark Matter Models (03/2010)
- PSR J1907+0602: A Radio-Faint Gamma-Ray Pulsar Powering a Bright TeV Pulsar Wind Nebula (03/2010)
- Observations of the Large Magellanic Cloud with Fermi (03/2010)






# Some science highlights since March meeting



- Fermi continues to be a finder for millisecond radio pulsars, many in binary systems (nearly 20 to date)
- discovery of high-energy  $\gamma$ -ray emission from novae outburst
  - “Gamma-Ray Emission Concurrent with the Nova in the Symbiotic Binary V407 Cygni”, *Science* 329, 817 (2010)
- detection of local-group galaxy M31 (Andromeda): implications for cosmic-ray production
- Constraints on dark matter from LAT observations of dwarf spheroidal galaxies, diffuse radiation, and clusters of galaxies

# New Millisecond Radio Pulsars Found in Fermi LAT Unidentified Sources



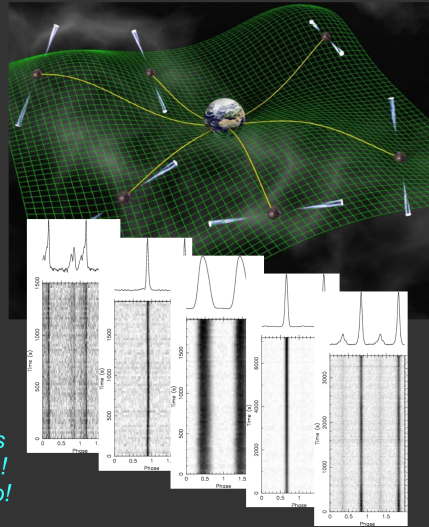
-  Led by Fernando Camilo (Columbia Univ.) using Australia's CSIRO Parkes Observatory
-  Led by Mallory Roberts (Eureka Scientific/GMU/NRL) using the NRAO's Green Bank Telescope
-  Led by Scott Ransom (NRAO) using the Green Bank Telescope
-  Led by Ismael Cognard (CNRS) using France's Nançay Radio Telescope
-  Led by Mike Keith (ATNF) using Parkes Observatory

# Fermi: millisecond pulsars

Scott Ransom (NRAO), HEAD meeting talk, March 2010

## Gravitational Wave Detection with a Pulsar Timing Array

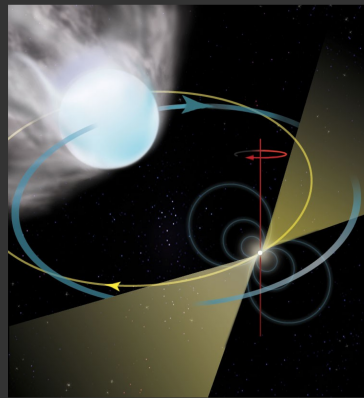
- Need **good MSPs**
- **Significance scales directly with the number of MSPs being timed.** Lack of good MSPs is currently the biggest limitation
- Must time the pulsars for **5-10 years** at a precision of **0.1-0.2 micro-sec!**
- North American (**NANOGrav**), European (EPTA), and Australian (PPTA) efforts



*Several of the new MSPs are fast, bright, and sharp! Several visible by Arecibo!*

## At least five new “Black-Widow” Systems


- Have **short period orbits** (3-10 hr) with **very low-mass companions** (10-80 Jupiter Masses) which are being ablated by the MSPs
- **Previously only 3 of these known in the Galactic disk!**
- Another “nearly” black-widow shows **eclipses of radio waves**
- Bad for timing, but good for evolution studies



*Why are these systems copious gamma-ray emitters?*

NEWS

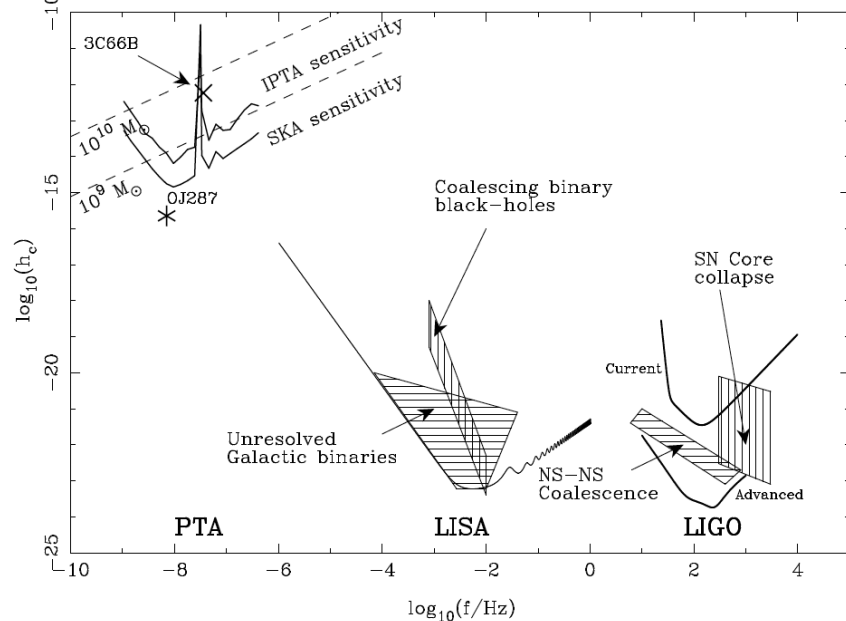
NATURE | Vol 463 | 14 January 2010



**DOES A MINOR KEY GIVE EVERYONE THE BLUES?**  
Subdued speech and downbeat music linked.  
[go.nature.com/zLO7RU](http://go.nature.com/zLO7RU)

STRAUSS/CURTIS/CORBIS

## Pulsar watchers race for gravity waves



Radio Astronomy Observatory in Charlottesville, Virginia, who last week announced the discovery of 17 millisecond pulsars at a meeting of the American Astronomical Society in Washington DC.

Ransom says that about 100 millisecond pulsars are known in the Milky Way, but only a handful are bright enough and regular enough to be measured to the precision necessary to hunt gravitational waves. Some 20–40 of these pulsars, enough for a full ‘pulsar timing array’, would have to be monitored for 5–10 years before a gravitational wave signal would stand out. But with new millisecond pulsars now

larger volume of the Universe. Pulsar astronomers thus have a shot at first detection.

“I think they have a really solid chance of beating the ground-based detectors,” says Bruce Allen, director of the Max Planck Institute for Gravitational Physics in Hanover, Germany, who manages shared data analysis among the ground-based detectors. “It’s a real race.”

The end of the race to detect gravitational waves will mark the beginning of gravitational wave astronomy — yet the different approaches are sensitive to vastly different phenomena. Whereas the interferometers would detect

because they use existing radio telescopes instead of requiring a detector such as LIGO, which cost US\$300 million to build and is getting another \$200 million for its upgrade.

Either way, detecting the Universe’s most violent events requires extraordinary sensitivity — temporal in the case of the pulsar timing arrays and spatial in the case of the interferometers. Interferometers already monitor the position of their test masses to better than one part in a million million billion (10<sup>21</sup>) — which Prince likens to measuring the distance to a nearby star to within the width of a human hair.

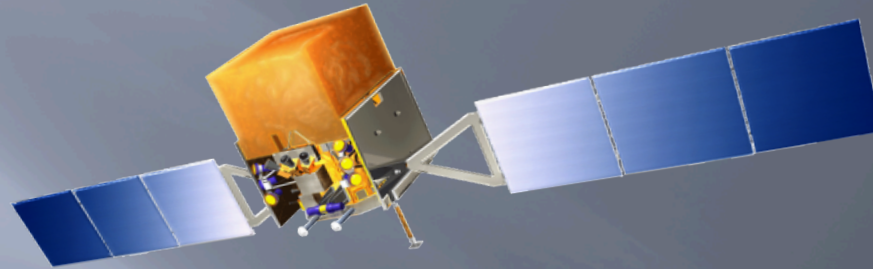
**Eric Hand**

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Nature January 14, 2010

# Some science highlights since March meeting

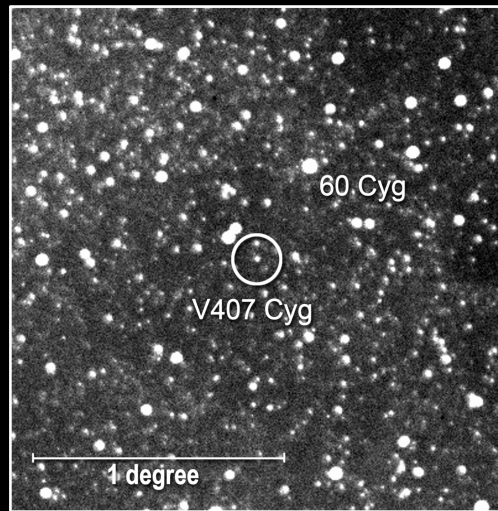


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  - “Gamma-Ray Emission Concurrent with the Nova in the Symbiotic Binary V407 Cygni”, *Science* 329, 817 (2010)
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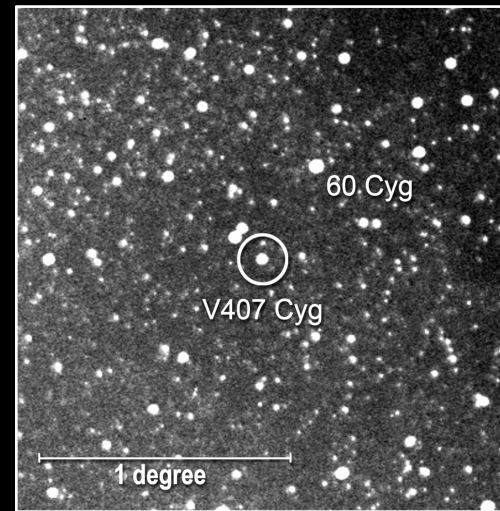


Amateur astronomers Fujio Kabashima, 68 (left), and Koichi Nishiyama, 70, show off their private observatory in Miyaki, Saga Prefecture, in January. KYODO PHOTO

### Nova Cygni 2010 in Visible Light

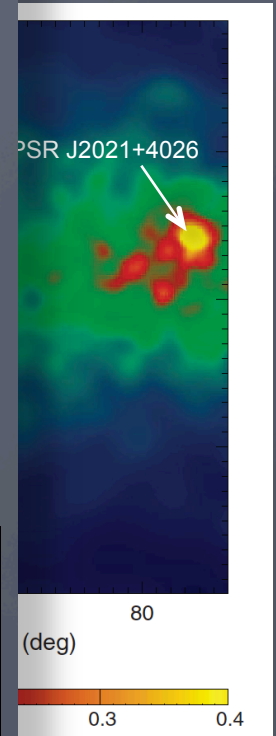


March 7, 20:36 UT



March 10, 19:08 UT

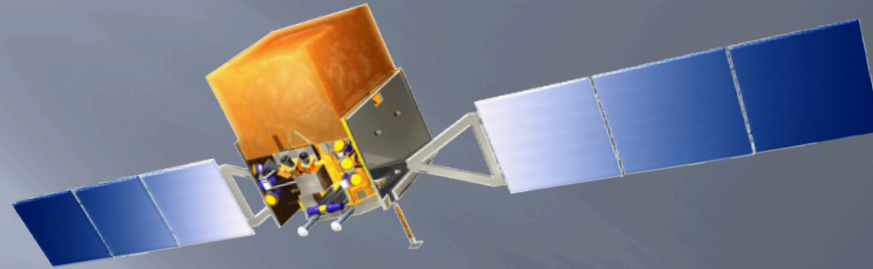
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-29 March  
March 2010

2010  
consistent with  
electrons  
in nova  
to RG wind

# Some science highlights since March meeting



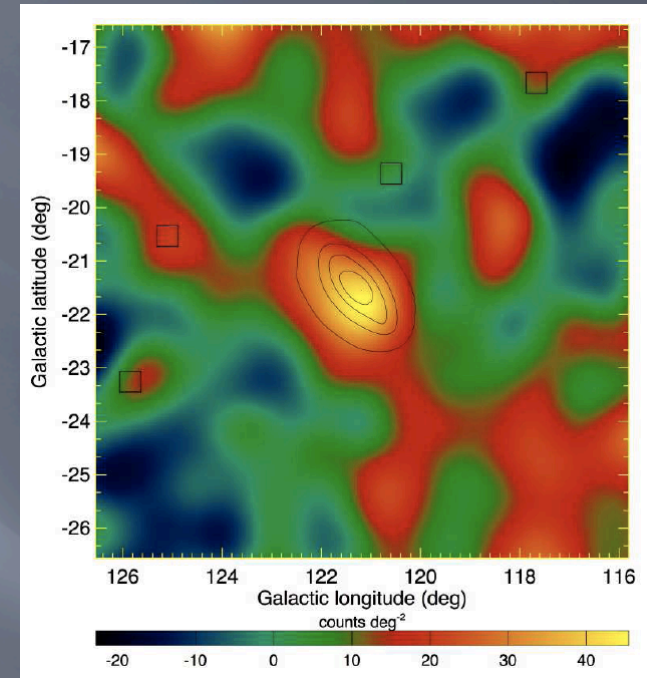
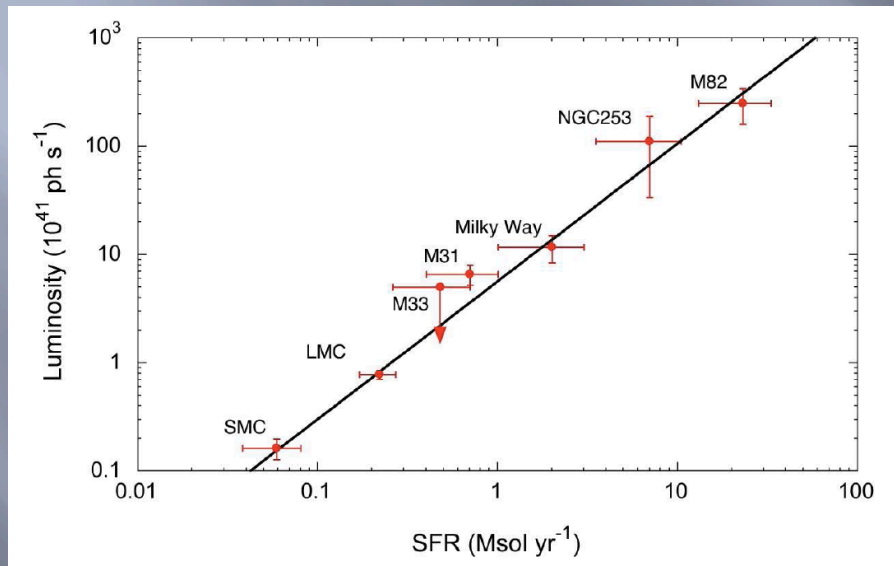
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# $\gamma$ -ray emission from Local Group Galaxies: detection of M31 (Andromeda)

paper in preparation

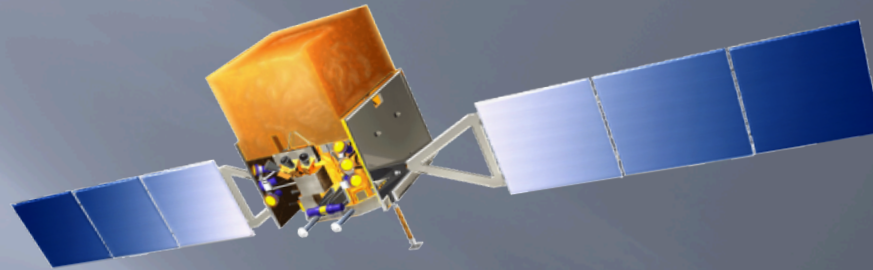
corres. authors: Keith Bechtol, Pierre Jean, Jürgen Knödseder, Pierrick Martin

- M31 flux measurement, along with measurements of MW, LMC, and SMC:
  - indicate  $\gamma$ -ray luminosity  $L_\gamma \sim 4 \times 10^{41} \times \text{SFR}$



Smoothed, background-subtracted LAT  $\gamma$ -ray counts map; overlay: IRIS 100  $\mu\text{m}$  contours (convolved with LAT psf)

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# Dark matter constraints

THE ASTROPHYSICAL JOURNAL, 712:147–158, 2010 March 20  
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doi:10.1088/0004-637X/712/1/147

March 2010

## OBSERVATIONS OF MILKY WAY DWARF SPHEROIDAL GALAXIES WITH THE *FERMI*-LARGE AREA TELESCOPE DETECTOR AND CONSTRAINTS ON DARK MATTER MODELS

$\gamma$ -ray flux upper limits, combined with improved determinations of dark matter density profiles in 8 dwarf galaxies, put limits on pair-annihilation cross section of WIMPs in several widely studied extensions of the standard model, including its supersymmetric extension. Able to rule out large parts of parameter space where thermal relic density is below the observed cosmological dark matter density and WIMPs (neutralinos here) are dominantly produced non-thermally, e.g., in models where supersymmetry breaking occurs via anomaly mediation. The  $\gamma$ -ray limits also constrain some WIMP models proposed to explain the *Fermi* and *PAMELA*  $e+e^-$  data, including low-mass wino-like neutralinos and models with TeV masses pair annihilating into muon–antimuon pairs.

PRL 104, 091302 (2010)

PHYSICAL REVIEW LETTERS

week ending  
5 MARCH 2010

## Fermi Large Area Telescope Search for Photon Lines from 30 to 200 GeV and Dark Matter Implications

March 2010

$\gamma$ -ray line flux upper limits from 30 to 200 GeV in the range  $0.6\text{--}4.5 \times 10^9 \text{ cm}^{-2} \text{ s}^{-1}$ , provide corresponding DM annihilation cross-section and decay lifetime limits.

**J**ournal of **C**osmology and **A**stroparticle **P**hysics  
An IOP and SISSA journal

## Constraints on cosmological dark matter annihilation from the Fermi-LAT isotropic diffuse gamma-ray measurement

April 2010

the isotropic diffuse  $\gamma$ -ray emission is in good agreement with a power law, not showing any signature of a dominant contribution from dark matter sources in the energy range from 20 to 100 GeV. Absolute size and spectral shape of measured flux used to derive cross section limits on 3 types of generic dark matter candidates: annihilating into quarks, charged leptons and monochromatic photons. Derived limits also start to probe cross sections expected from thermally produced relics.

**J**ournal of **C**osmology and **A**stroparticle **P**hysics  
An IOP and SISSA journal

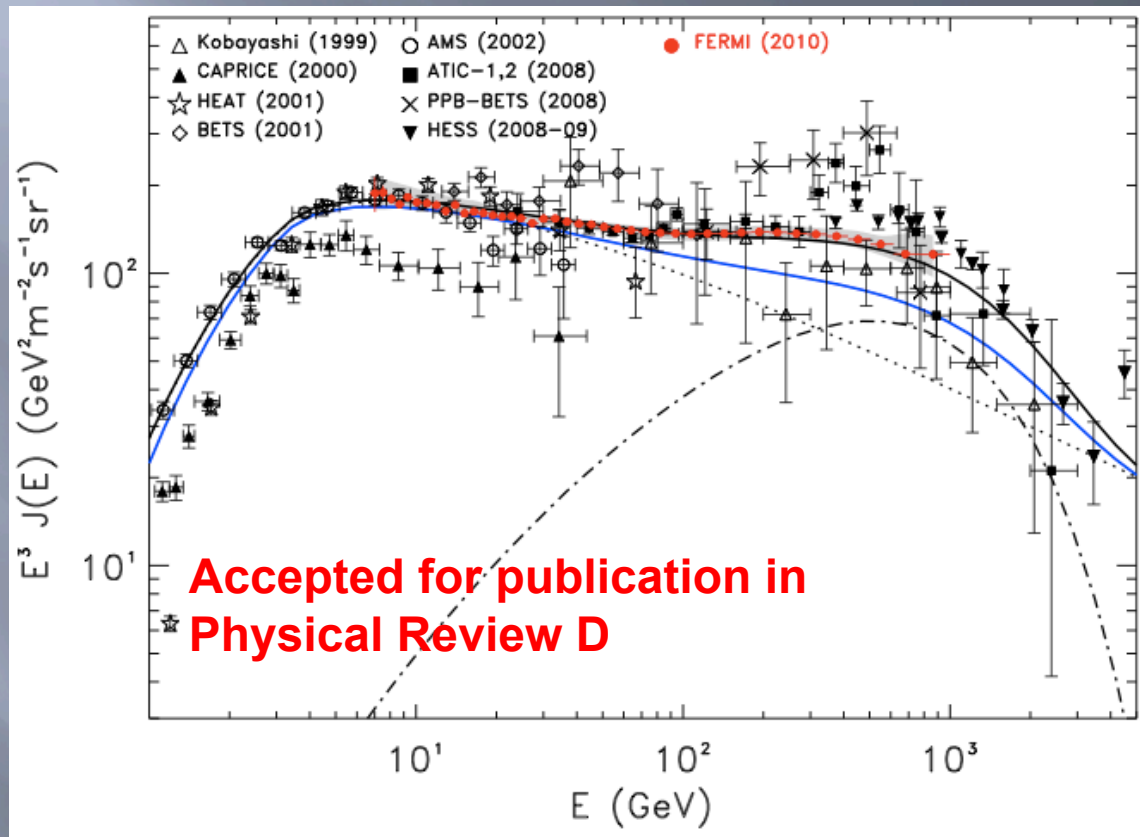
## Constraints on dark matter annihilation in clusters of galaxies with the Fermi large area telescope

May 2010

for leptonic annihilation final states and particle masses  $> 200 \text{ GeV}$ ,  $\gamma$ -ray limits exclude large regions of parameter space that would give a good fit to recent anomalous Pamela & Fermi-LAT electron-positron measurements

# Cosmic-Ray Electron Spectrum

7 GeV – 1 TeV




extension of analysis reported in Abdo, et al,  
*Phys. Rev. Lett.* **102**, 181101 (2009) .

# Summary and look ahead

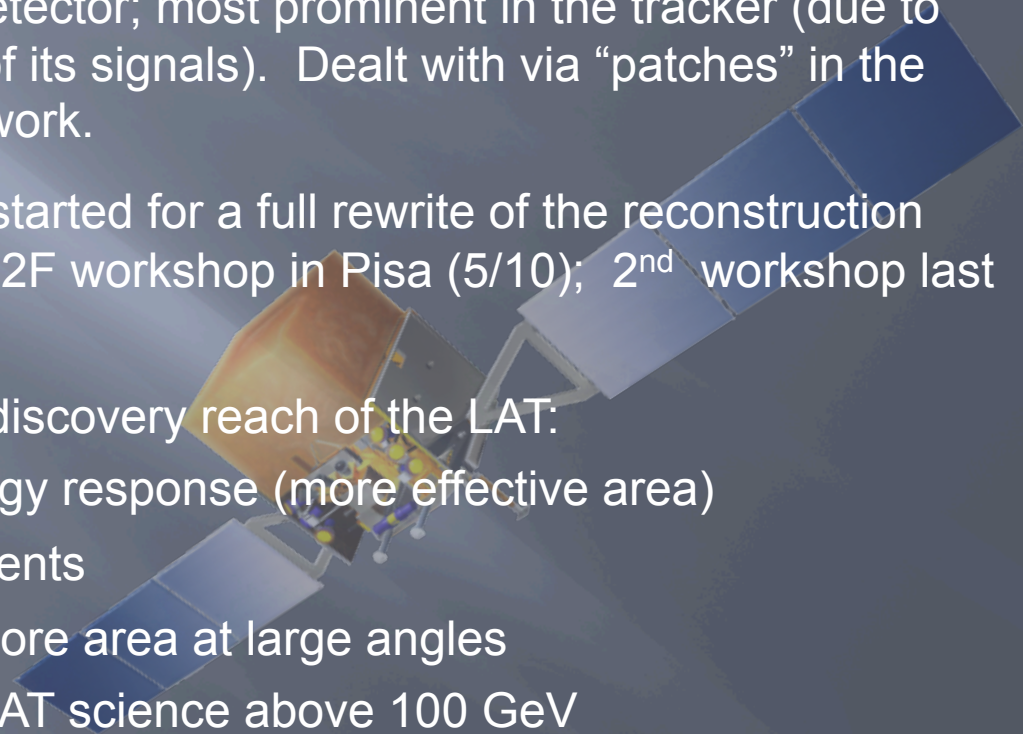
- ◆ Two years of Fermi observations and discoveries of several important new GeV source classes are now driving understanding of the high-energy Universe:
    - gamma-ray only pulsars and gamma-ray millisecond pulsars; rich harvest of initially unidentified LAT sources are millisecond pulsars
    - globular clusters
    - GeV emission from several SNRs and from PWNe
    - GeV afterglows from GRBs; short-duration GRBs
    - starburst galaxies and nearby local-group galaxies
    - Blazars are largest identified LAT source class; building multi  $\lambda$  datasets for many sources; constraints on EBL published; detecting emission from radio galaxies
    - Galactic and isotropic diffuse spectrum measured to 100 GeV; consistent with power-law
    - measurement of  $e^+e^-$  spectrum from 7 GeV to 1 TeV
- 

# Summary and look ahead

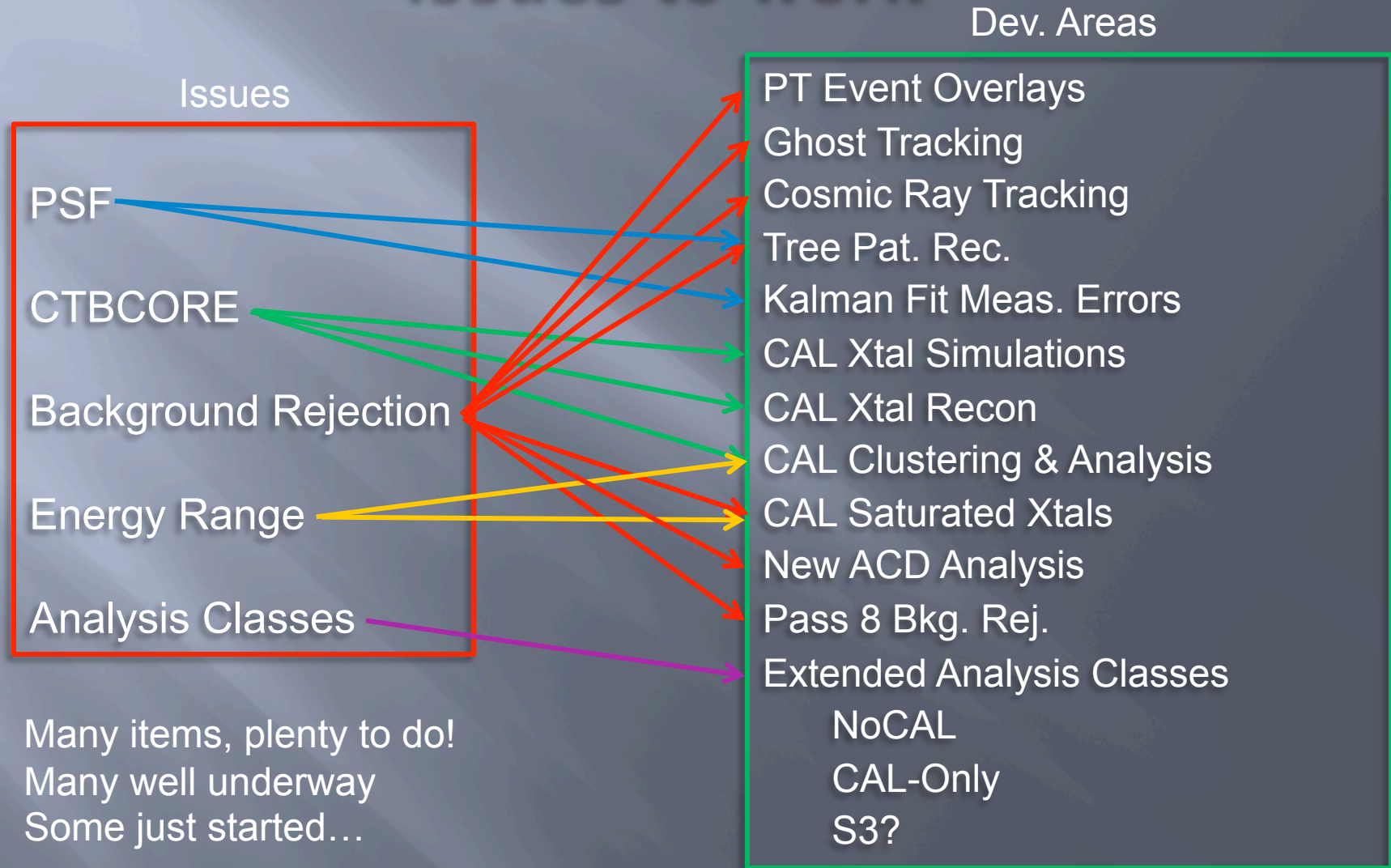
- ◆ with deeper exposure / Pass 8 event re-analysis, etc.,
    - continue to improve constraints on dark matter; e.g., stacking analysis of dwarf galaxies underway and (about factor of 2 above the annihilation cross section for a typical thermal WIMP)
    - chart EBL vs. redshift
    - search for pair-halo effect
    - extend diffuse radiation (Galactic and isotropic) above 100 GeV
    - expect major refinements/improvements in Galactic diffuse emission models; sort out what is going on in the Galactic center region
    - etc, etc., etc.
  - ◆ develop and implement major rework of event reconstruction and analysis (Pass 8): this is a big deal !
  - ◆ understanding the high-energy gamma-ray sky is a challenge; multiwavelength coverage remains important to most of the science including dark matter searches
- 

# Pass 8

- major rework of event reconstruction and analysis initially driven by “Ghost Events” – i.e. events with remnants of passage of previous particles through the detector; most prominent in the tracker (due to ~10 msec decay time of its signals). Dealt with via “patches” in the current analysis framework.
- Spring 2009, planning started for a full rewrite of the reconstruction code for the LAT. 1<sup>st</sup> F2F workshop in Pisa (5/10); 2<sup>nd</sup> workshop last week at SLAC
- Pass 8 will extend the discovery reach of the LAT:
  - improved low-energy response (more effective area)
  - exploit Cal-only events
  - extend FoV with more area at large angles
  - fully open-up the LAT science above 100 GeV



# Pass 8 re-analysis of data: mapping issues to work



from W. Atwood, 1<sup>st</sup> Pass 8 Workshop, Pisa, Italy May 2010

## Subsystem: Tracker

### PT Event Overlays

Mostly done – thanks Leon *et al*

### Ghost Tracking

Well advanced – Leon

### Cosmic Ray Tracking

Mostly done – needs integration – Robert

### Tree Pat. Rec.

Well advanced, beginning Sea Trials – Tracy

### Kalman Fit Meas. Errors

Problems found – under dev. – Tracy

### Merging CAL Clustering with Pat. Rec./Tracking

To be started.....

## Subsystem: ACD

### New ACD Recon

Done – thanks Eric! Needs sea trials & integration

## Subsystem: Calorimeter

### Xtal Simulation

Present Sim. simplistic – needs end-effects added

### Xtal Reconstruction

Needs much improved handling of Xtal End Effects

### Cluster Finding

Good start (Tracy), Needs Sea Trials to validate

### Cluster Analysis

Improve Moments Analysis

Classify Cluster Types (MIP, Ghost, EM Shower...)

Cluster pointing: up –or- down

Saturated Xtal compensation

## Event Level Analysis

### TMine

Replace GlastClassify with Tmine

Build Pass 8 with TMine & IM?

### Energy & PSF Analysis

Both will need updating given new Recon

### Background Rejection

Learn from current package, improve with fresh ideas

### Extended Photon Classes

NoCal

CAL-Only

Loose Def. Class (S3?)

### Develop Covariant Errors

Map Kalman Cov. Onto the Sky

Develop Cov. PDF

### Electrons & Other Particles

Will need re-work

### Output

review TDS & ROOT PDS

Revamp MERIT

the end