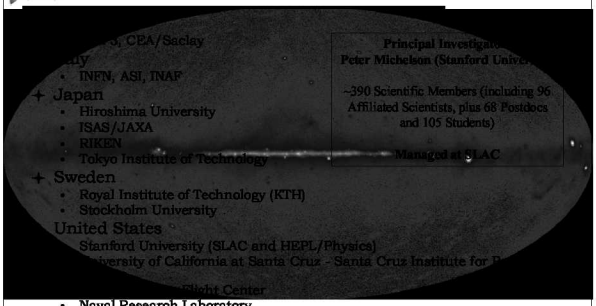
Fermi-LAT Observations of Galactic Transients

Elizabeth Hays
(NASA/GSFC)
on behalf of the Fermi-LAT Collaboration

Fermi LAT Collaboration



- CEA/Saclay
- INFN, ASI, INAF

+ Japan
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology

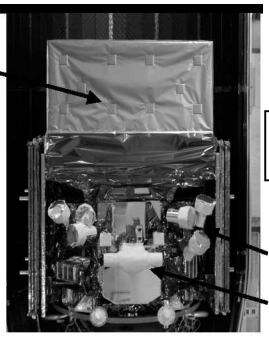
+ Sweden
  - Royal Institute of Technology (KTH)
  - Stockholm University

United States
- Stanford University (SLAC and HEPL/Physics)
- University of California at Santa Cruz - Santa Cruz Institute for P
- Flight Center
- Naval Research Laboratory
- Sonoma State University
- Ohio State University
- University of Washington

The Fermi Observatory

Large Area Telescope (LAT)

- Large field of view (>2.4 sr)
- Entire sky every 3 hrs (every 2 orbits)
- Broad energy range (20 MeV - >300 GeV)



Gamma-ray Burst Monitor (GBM)

- Views entire unocculted sky
- **NaI:** 8 keV - 1 MeV
- **BGO:** 150 keV - 40 MeV

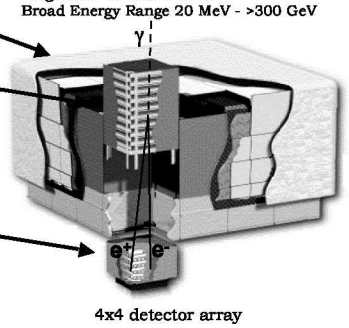
Large Area Telescope (LAT)

Large Field of View >2.4 sr
Broad Energy Range 20 MeV - >300 GeV

ACD
scintillator
89 tiles

Tracker
Si strip detectors
Tungsten foil converters
pitch = 228 um
8.8×10^5 channels
18 planes

Calorimeter
CsI crystals
hodoscopic array
6.1×10^3 channels
8 layers



4x4 detector array

LAT Sensitivity with Time

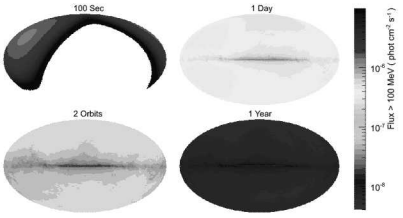
Transient Science: Flares, bursts, multiwavelength campaigns, unidentified transients

Accumulated Science: New source types, populations, long-term monitoring, spatially extended and diffuse studies

Deepest and most uniform survey of the sky at these energies

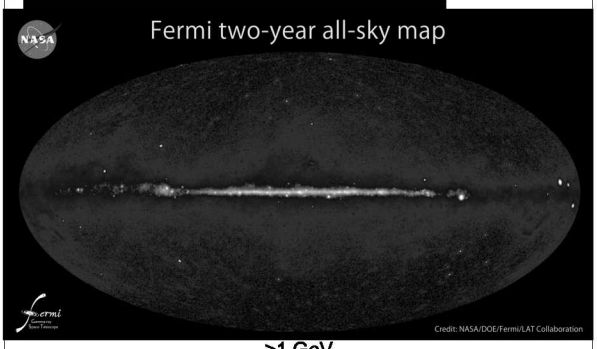
All-sky in ~3 hrs (2 orbits)

Minor asymmetry due to passages through South Atlantic Anomaly



February 14, 2011 E. Hays

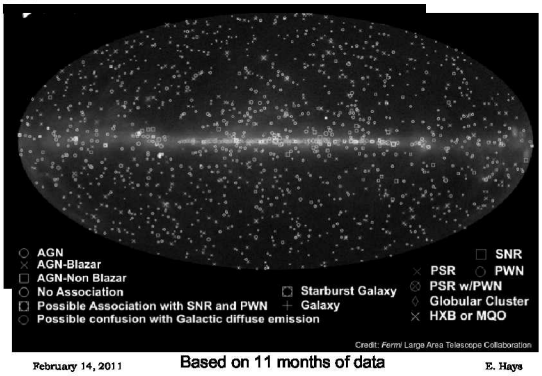
The Steady Sky



>1 GeV

February 14, 2011 E. Hays

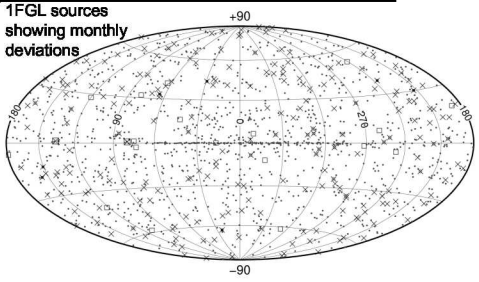
1FGL Catalog



February 14, 2011 Based on 11 months of data E. Hays

The Variable Sky

1FGL sources showing monthly deviations

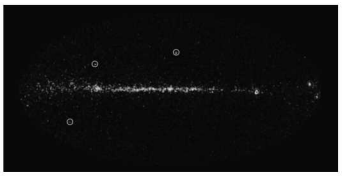


No association	Possible association with nearby SNR or PWN		
AGN – blazar	Starburst Gal	Pulsar	Pulsar w/PWN
AGN – unknown	Galaxy	PWN	Globular cluster
AGN – non blazar		SNR	XRB or MQO

February 14, 2011 E. Hays

LAT Automated Science Processing

All-sky search runs every 6 hours, 1 day, 1 week



LAT counts map
E>100 MeV, 6 hours

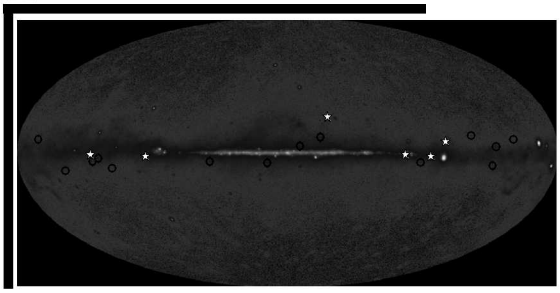
LAT flare advocates monitor data daily and trigger multiwavelength follow-up. Also check for interesting transients reported in other wavebands.

- >100 Astronomer's Telegrams
- Public lightcurves through FSSC at http://fermi.gsfc.nasa.gov/ssc
- Weekly and Special Reports http://fermisky.blogspot.com

Flaring Galactic Sources in the LAT

- Search for new transients near the Galactic plane
- Cygnus X-3
- Nova of V407 Cygni
- Crab Nebula

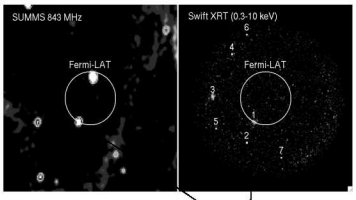
LAT Unassociated Transient Detections



☆ Unassociated transients from daily search

○ Low latitude blazars from First LAT Catalog

Counterpart Search - Fermi J0910-5041



Fermi J0910-5041
(ATEL #1788)

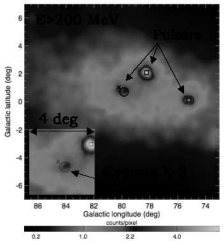
- October 15, 2008
- ~10x above average gamma-ray flux for 2 days
- Swift XRT ToO within 1 day

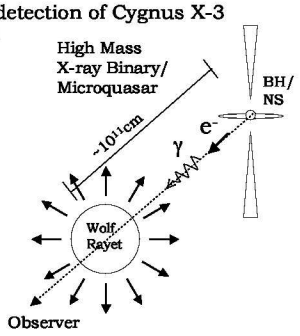
-1 of 2 high confidence LAT transients without a firm counterpart

LAT 95% error circle contains Swift XRT source (Landi et al. ATEL #1822) coincident with flat-spectrum radio source from SUMMS and AT20G (Sadler ATEL #1843)

Cygnus X-3

First secure gamma-ray detection of Cygnus X-3
- high significance source and binary modulation

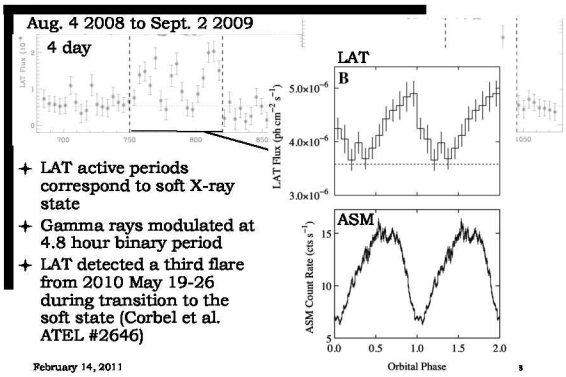




Science 326, 1512 (2009)

Gamma-ray Flares and Modulation

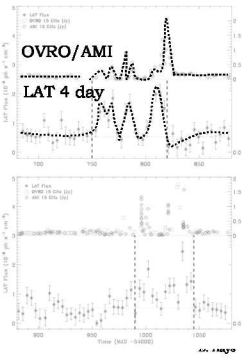
Aug. 4 2008 to Sept. 2 2009



- LAT active periods correspond to soft X-ray state
- Gamma rays modulated at 4.8 hour binary period
- LAT detected a third flare from 2010 May 19-26 during transition to the soft state (Corbel et al. ATEL #2646)

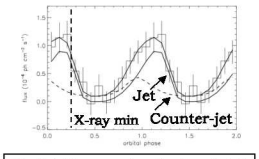
Connection to Jet Activity

- LAT active periods correspond to radio flares
  - Possible radio lag is not well constrained by correlation analysis
- Expect high energy electrons somewhere along the jet to scatter the stellar radiation field (UV) via inverse Compton
  - Superior conjunction favored for gamma-ray production

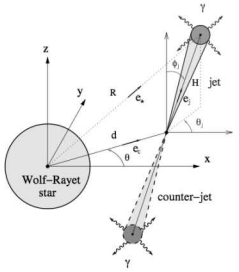


Probing the Jet

- Gamma ray origin away from accretion disk to avoid absorption on soft X-rays
- Modulation provides test of jet inclination
- Also sensitive to jet precession



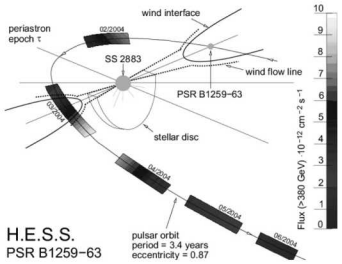
Model fits require inclined jet and prefer site slightly outside orbital separation



Dubus, Cerutti, and Henri, MNRAS, 404, L55 (2010)

A Binary Transient in the LAT Future?

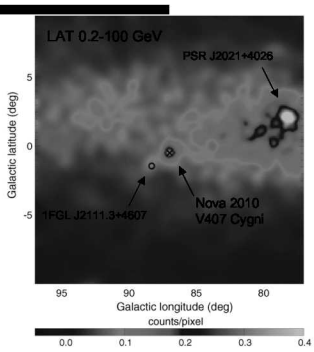
- First periastron passage of PSR B1259-63 since Fermi launch
  - Superior conjunction Dec. 7
  - Closest approach on Dec. 14
- Multiwavelength campaign Nov. - Feb.
- LAT contact: aous.abdo at nrl.navy.mil
- Actively monitored by team - stay tuned!



No significant emission in LAT data yet
Abdo et al. ATEL #3054

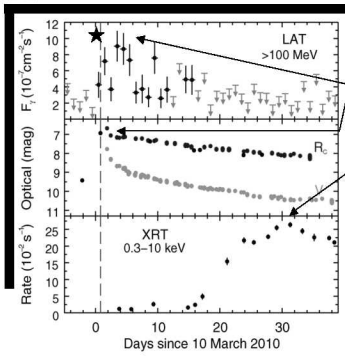
Gamma Rays Concurrent with a Nova

- Fermi J2102+4542: First detection of a nova in gamma rays
- 6-8σ in automated processing on 2010 March 13, 14 (Cheung et al. ATEL #2487)
- LAT position within 3.7' of V407 Cygni (white dwarf, red giant binary)
- Further analysis shows gamma rays close in time to nova discovery on March 10 by Nishiyama and Kabashima



Science 329, 817 (2010)

Nova Lightcurves



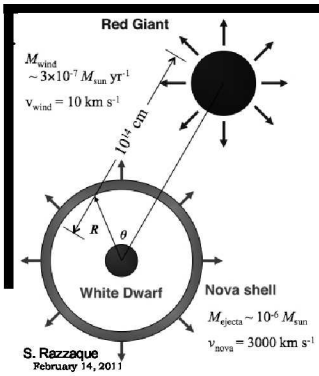
1) Optical peaks first

2) Gamma rays peak at 3-4 days and last ~2 weeks

3) X-rays peak at ~30 days, last and longest

Relative timing can be understood from the system geometry

V407 Cygni System

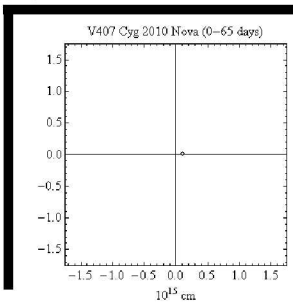


Uncommon symbiotic binary - accretion fed by stellar wind

Nova shell provides means to accelerate electrons and ions.

RG atmosphere and wind provide asymmetric distribution of radiation and material for gamma-ray production processes.

Gamma-ray and X-ray Evolution



Sedov condition is reached in a few days toward the red giant

Gamma rays peak early when efficiency for pion and inverse-Compton processes is favorable

X-rays peak later, increasing with volume of shock-heated gas

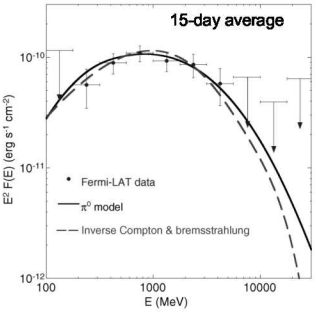
S. Razzaque

Shell expansion is nonuniform in space

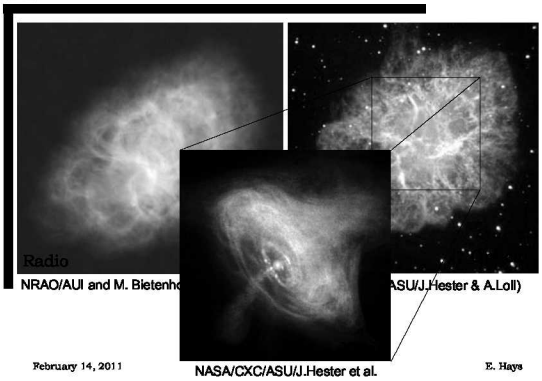
Emission Mechanisms

Spectral curvature does not evolve significantly

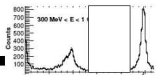
- Energetics
  - Kinetic energy of the shell: ~10^{44} erg
  - Total energy in γ-rays: ~$4x10^{41}$ erg
  - This means 0.4% efficiency for leptonic scenarios
  - Or 9% for hadronic (similar to Fermi SNR)



The Crab Nebula

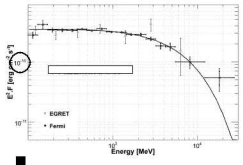


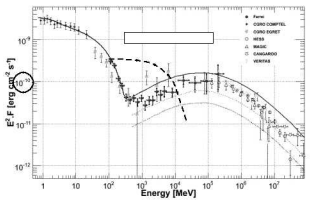
The Crab in LAT



Pulsar 100 MeV to 20 GeV

Nebula from MeV to TeV





Hyper-exponential cutoff excluded at ~5 sigma

Consistent with emission well above the neutron star surface

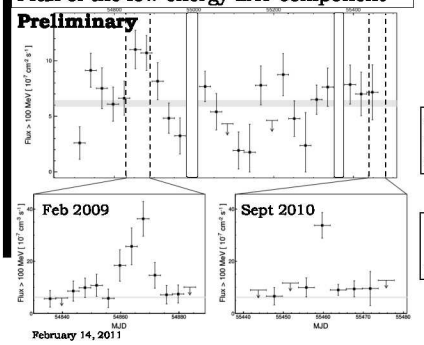
Two components: Synchrotron + Inverse Compton extending to TeV. Fit consistent with mean nebula B field of 100 to 200 μG

Our candle is not so standard

- Crab flickers in hard X-ray
  - Fermi GBM reports hard X-ray variability on ~yearly time scales. Confirmed by multiple instruments (C. A. Wilson-Hodge et al. arXiv:1010.2679v1)
- Crab flares at high energy (>100 MeV)
  - AGILE reports enhanced Crab flux over a few days, Sept. 19-21 (M. Tavani et al. ATEL #2855)
  - Fermi LAT confirms flare and triggers LAT ToO (R. Buehler et al. ATEL #2681)
    - Earlier flare found using new offline all-sky variability search developed by R. Buehler
  - Fermi LAT reports end of flare. Variability present in off-pulse phase of pulsar (E. Hays et al. ATEL #2893)

Two Short Flares from the Nebula

Flux of the low energy LAT component



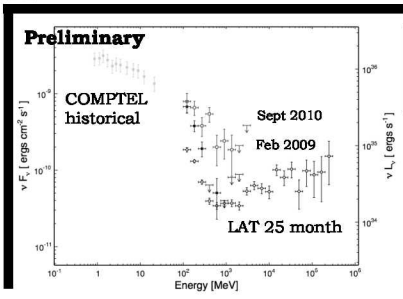
No variability found in pulsar or high energy LAT component

4 week intervals *Sun passages excluded*

4 day intervals covering flare periods

arXiv:1011.3855v2

Crab Flare Spectra



Low energy LAT component shows spectral variability

25 month index: 3.69 ± 0.11

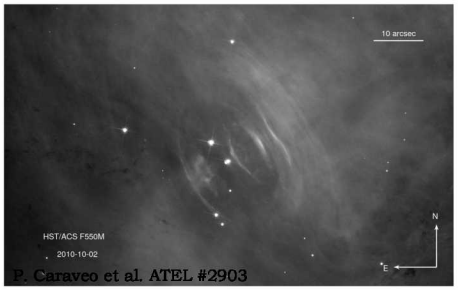
Feb 2009 index: 4.3 ± 0.3

Sept 2010 index: 2.7 ± 0.2

Origin of the Gamma-ray Flares?

- Gamma-ray luminosity is a small fraction of the pulsar power (10^{35} erg/s -> ~10^{-3} L_{rot})
- 4 day duration implies small region size, diameter < 1.4 x 10^2 pc (1.5 arcsec)
- Electron synchrotron cooling time in 200 uG < ~15 days
- LAT low energy spectral form + short timescale variability support a synchrotron interpretation
  - Implies electrons accelerated to >PeV in structures in the inner region near the termination shock and base of the jet

Searching for the Emission Region



P. Caraveo et al. ATEL #2903

No corresponding variability found in radio, optical, infrared, soft and hard X-rays at time or shortly after the 2nd LAT flare

Summary

- LAT all-sky monitoring is producing spectacular results for the GeV transient sky
  - New blazars and unidentified transients
  - Probing the jet of the Cygnus X-3 microquasar
  - Discovery of gamma rays from V407 Cygni nova
  - Fast high-energy gamma-ray flares from the Crab
  - All-sky monitoring continues. What's next?

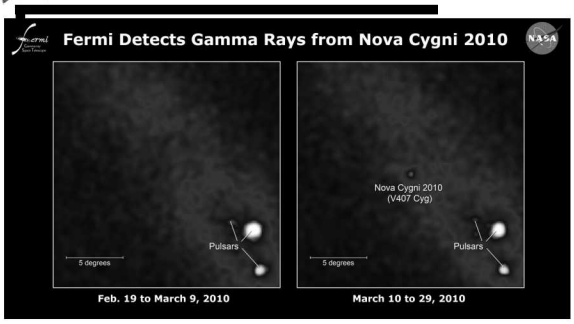
http://fermi.gsfc.nasa.gov

Extras

Other Binary Outbursts in LAT?

- No LAT detections of Cygnus X-1
  - Flux (0.1-3 GeV) < 4x10-7 ph cm^{-2} s^{-1} during flare reported by AGILE 2009 Oct 16
  - Nothing found for 2010 March 23-24 period reported by AGILE of during MAXI/GSC soft X-ray brightening June 2010
- Nothing found yet for black hole candidates GX 339-4, GRS 1915+105
- Eta Carinae consistent with steady emission (includes 2008 periastron)

LAT Before and After



LAT >100 MeV counts maps

Historical Optical Lightcurve