Fermi Gamma Ray Space Telescope: Launch+509

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(With considerable help from Fermi team members working at Stanford)

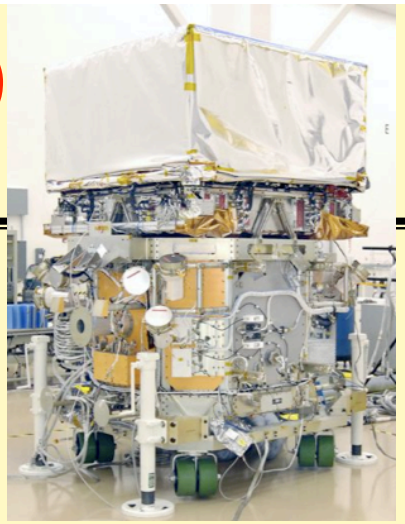
A Cosmic Reflection on Fermi's First Year

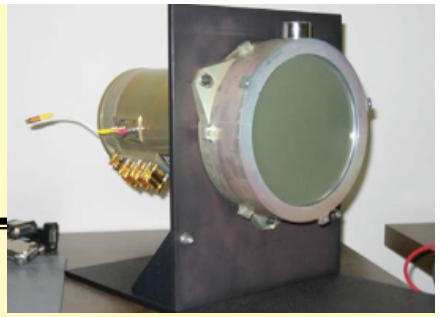
- **Goals**
  - To summarize the main published and preprinted astrophysical and cosmological conclusions from Fermi
  - To compare these to community expectations at the time of the First Symposium
  - To ignore genuine instrument, data and pure observing accomplishments
  - To avoid previewing results that will be presented here and/or published soon
  - To avoid prognostication on what Fermi should do in the next nine years!
- **Organization (from First Symposium).**
  - Stars
  - Jets
    - *Active Galactic Nuclei*
    - *Gamma Ray Bursts*
    - *Galactic Superluminals*
  - Pulsars
  - Supernova Remnants
  - Backgrounds

The Scientific Bottom Lines

GLAST -> Fermi GST(2007)

Pre-launch expectations





LAT

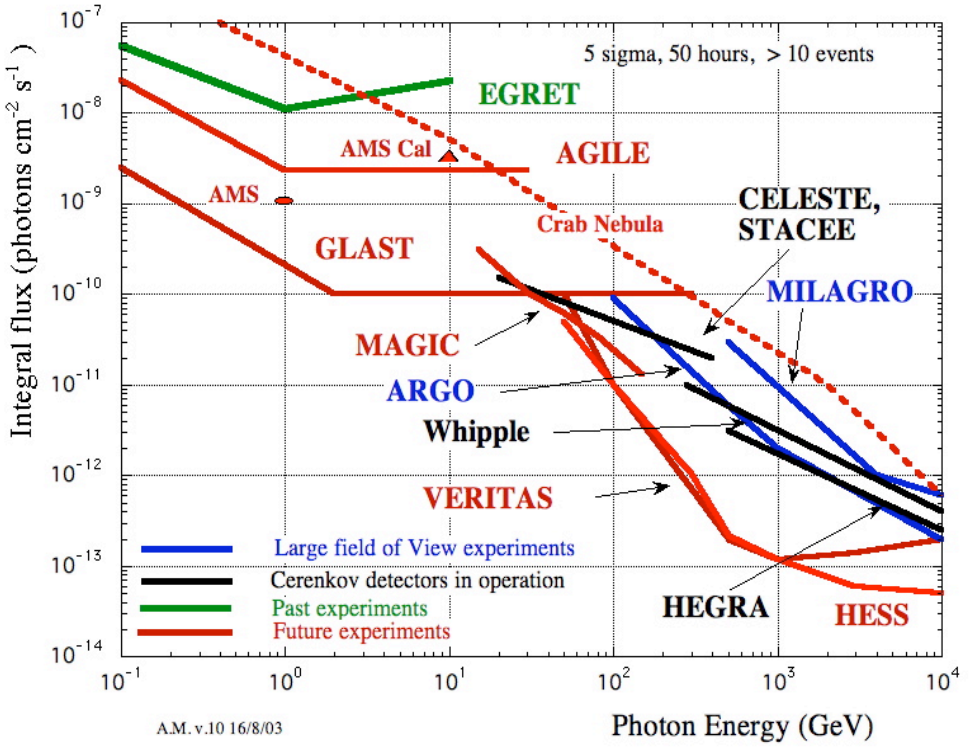
- *0.02 - 300 GeV*
- *2.5 sr, 0.3 - 0.9m²*
- *5° - 5'resolution*
- *Δln E ~ 0.1*
- *3 x 10⁻⁹ cm⁻² s⁻¹ (>0.1 GeV, point source)*
- *10⁹ photons (3Hz)*
- *All sky every 3hr*

GBM

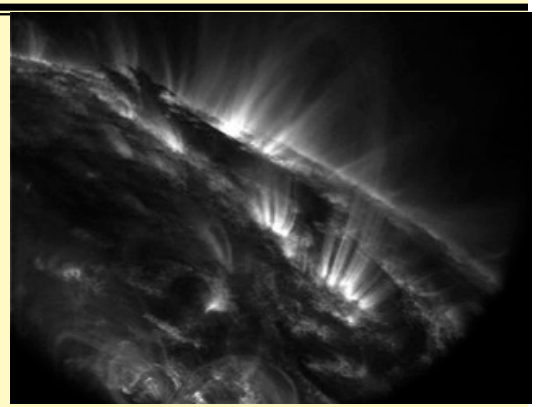
- *0.01-30 MeV*
- *9sr, 100 cm².*
- *1° resolution*
- *Δln E ~ 0.1*
- *1000 GRBs*

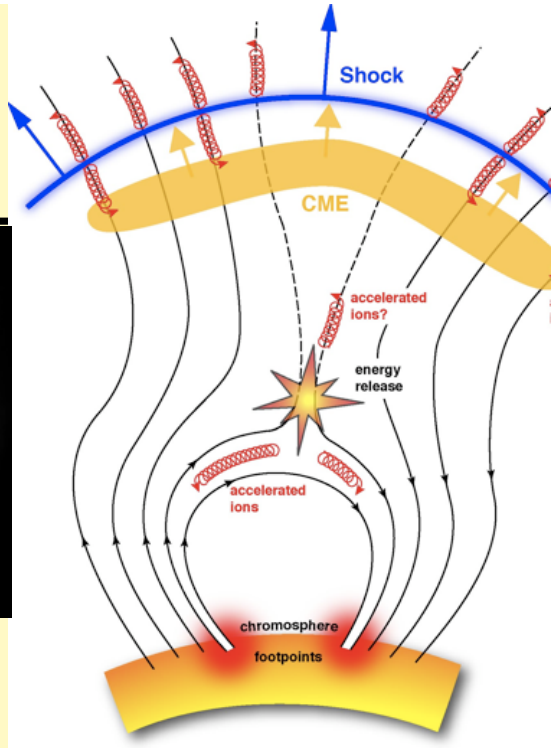
Sources after a decade

- *10,000 Active Galactic Nuclei*
- *100 Gamma Ray Bursts*
- *100 Pulsars*
- *100 Supernova Remnants*
- *10 Galaxies*
- *10 Clusters of Galaxies*
- *10 X-Ray Binaries*
- *? Unidentified Sources*

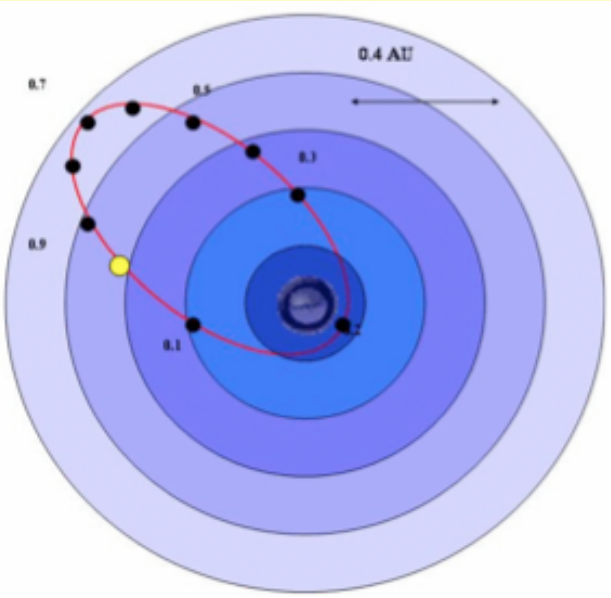


Stars (2007)



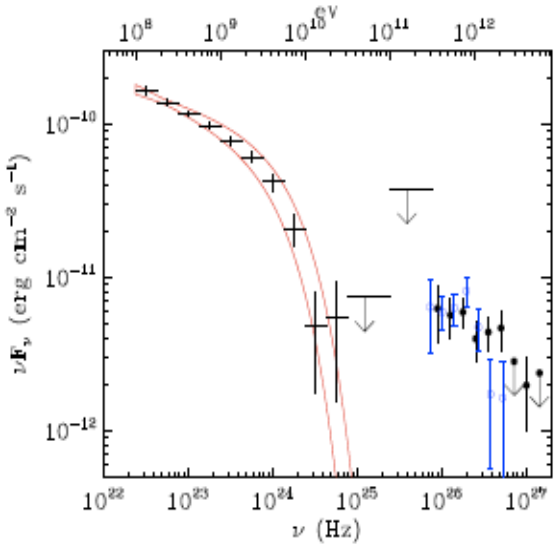


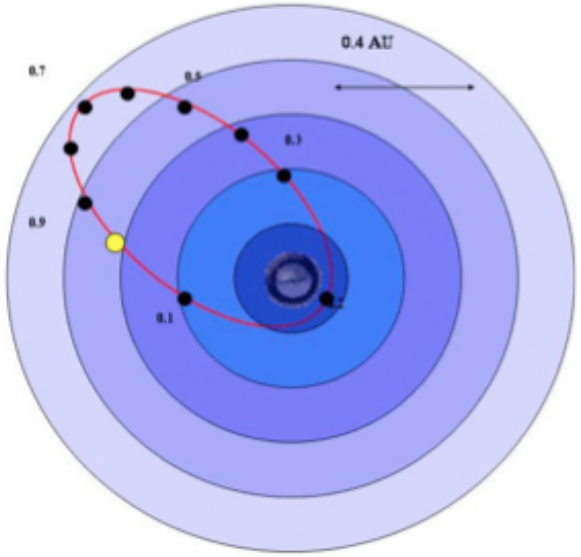
- **Sun** *Share*
  - Flares
  - Solar minimum->maximum
  - Observe neutrons
  - Radiation hazard
    - *Minutes!*
- **3 HMXB** *Dubus Cortina Hermsen*
  - LSI+61 303
    - *NS-Be*
    - *P=27d*
    - *e ~0.7*
    - *i ~ 60º*
  - PWN orbiting Be excretion disk?
  - Other Binaries
  - Cygnus Region

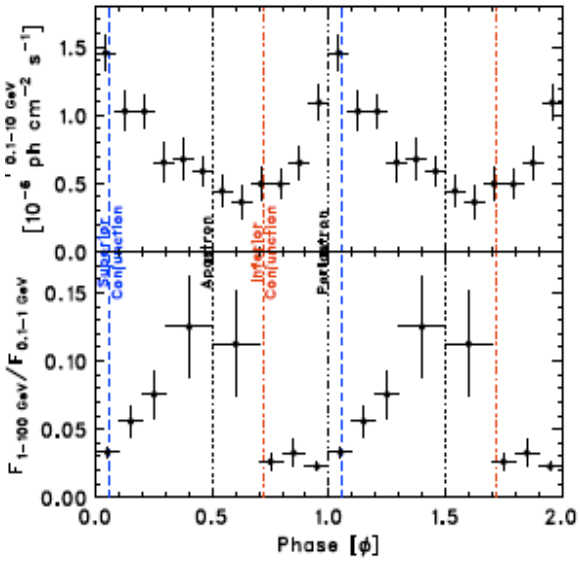


Stars

- **LS I+61 303, LS 5039**
  - **HMXB: 26.6d e~0.6, Be, 3.9d, e~0.3, O6 +BH/NS**
  - **Also seen as TeV sources but temporally and spectrally distinct**
  - **Reasons for modulation**
    - ***Absorption by stellar radiation and wind***
    - ***Eccentric orbit => variable flux to scatter***
    - ***Anisotropy of inverse Compton scattering, back scattering stronger***
    - ***Equatorial disk for hadronic emission***
  - **Are we observing modified pulsar emission or jets from BH**



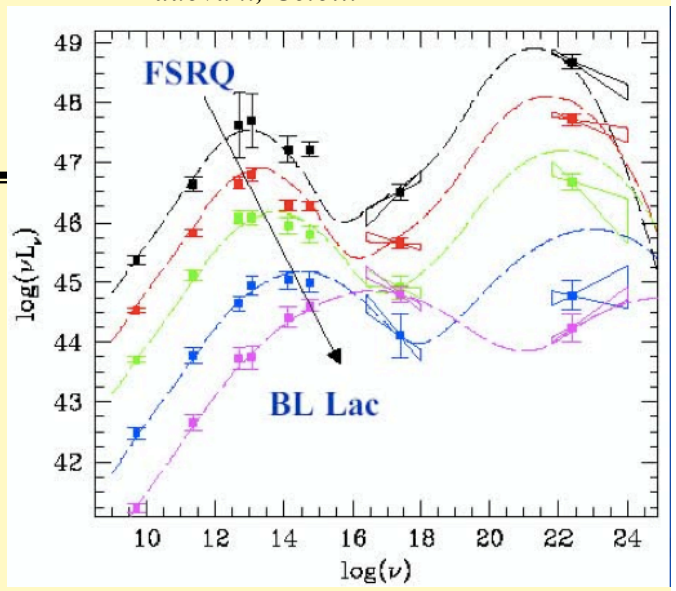


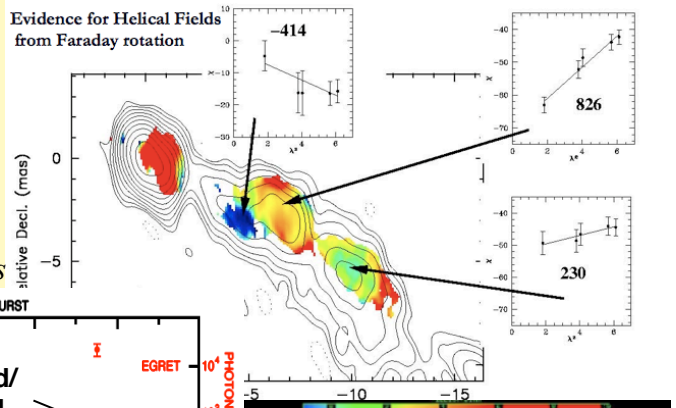


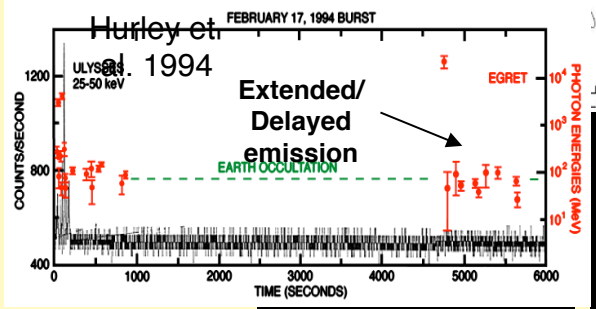
Jet Physics (2007)

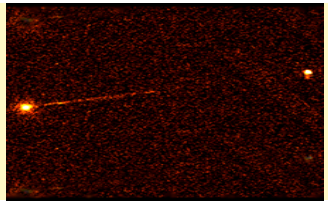
- **Blazar**
  - AGN classification
  - Blazar sequence (10^{-4} of galaxies)
    - *FR2->FR1?*
    - *GLAST observe more RG*
  - Variability *Wagner*
    - *M87*
    - *Mk 501* *Mazin*
    - *Contrary evolutions* *Fukazawa*
- **GRB** *Ptran, Granot*
  - Long - collapsars; short- NS coalescence??
  - Late emission, plateau, chromatic breaks *Butler Briggs*
  - Faster than Blazar jets
- **Jet Physics** *Taylor*
  - Emission mechanism
  - SSC vs EC
  - Opacity, location *Baring*
  - Bulk Comptonization and Cooling
  - Composition, Structure, Confinement
  - Impact

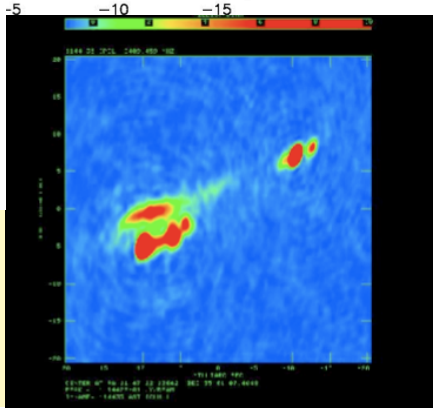
Padovani, Celotti





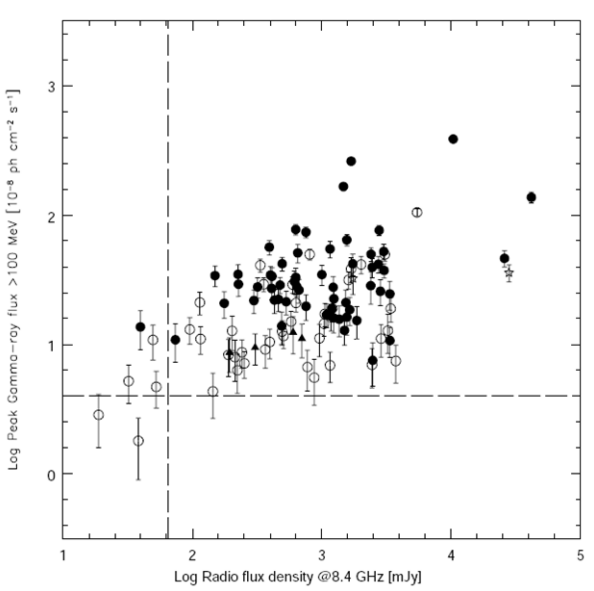






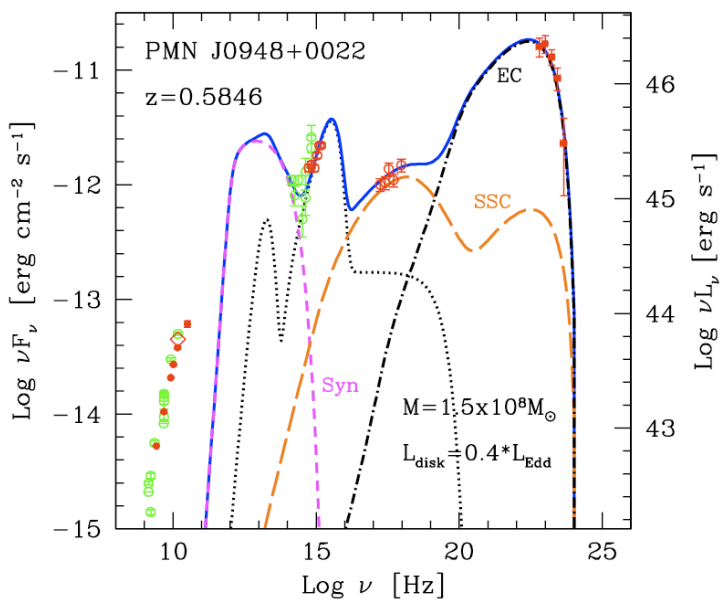
AGN

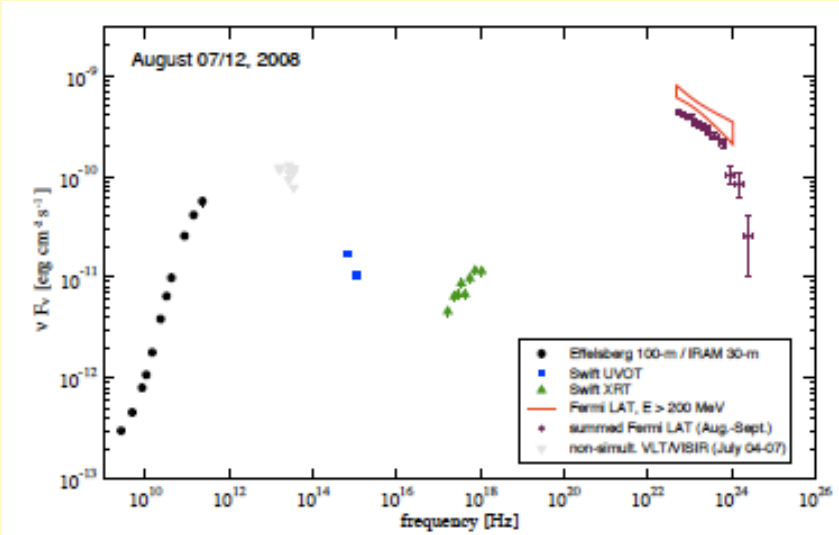
- **Demography:**
  - 200 source list >10σ @ 3month;
  - ~1000 today
  - Spectroscopic campaign going well
- **Multi wavelength campaigns well organized and delivering**
  - Radio (OVRO <1000 sources per day), Optical (polarimetry), X-ray, TeV
- **Comparable numbers of BL Lacs, FSRQ**
  - BL Lac – closer, dimmer, more numerous, evolve less…
- **<ten percent of GeV background**
  - Star-forming galaxies could dominate background
  - cf LMC

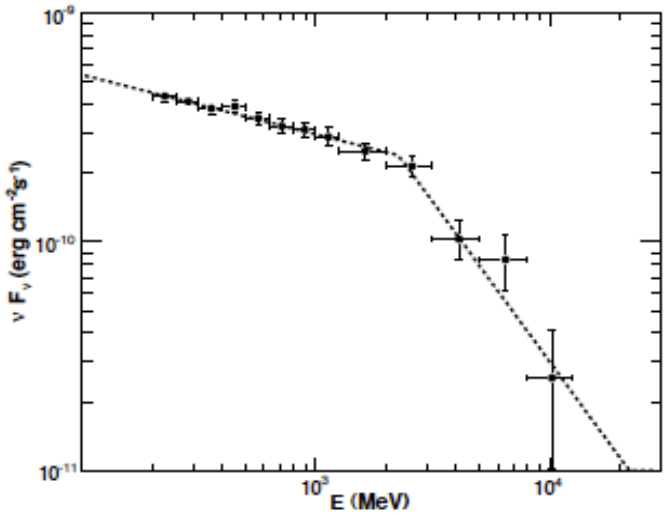


AGN

- **Specific sources**
  - **FSRQ:3C454.3, 1454-354**
    - *X 100, ~1d variation; γ_{VLBI}~16,; 2GeV break*
  - **BL Lac: PKS 2155-304**
    - *Low state; not SSC*
  - **RG: NGC 1275, M87, Cen A**
    - *Variability => not cluster; misdirected jets*
  - **NLQ/S:J0948+0022**
    - *Behavior depends upon Eddington ratio?*







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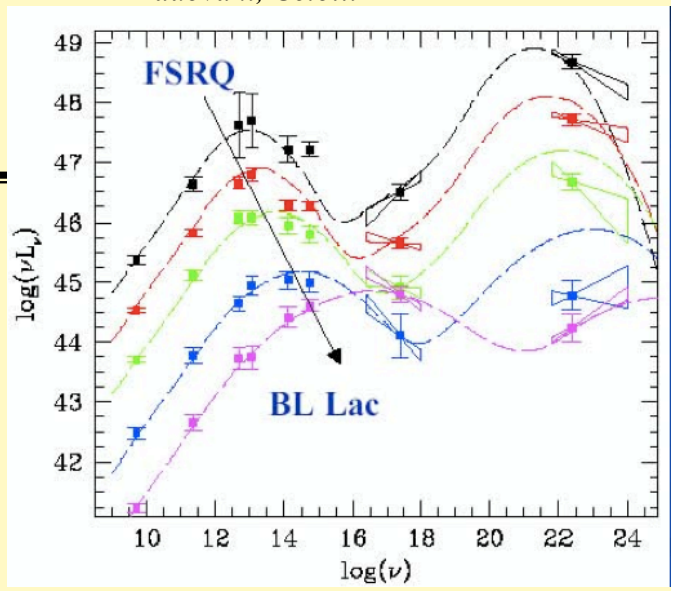
Padovani, Celotti



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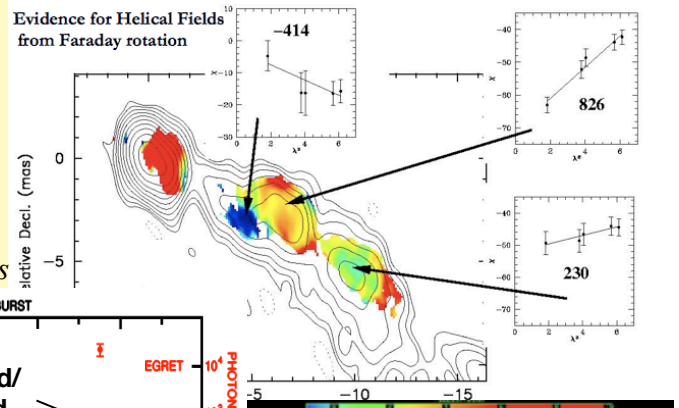
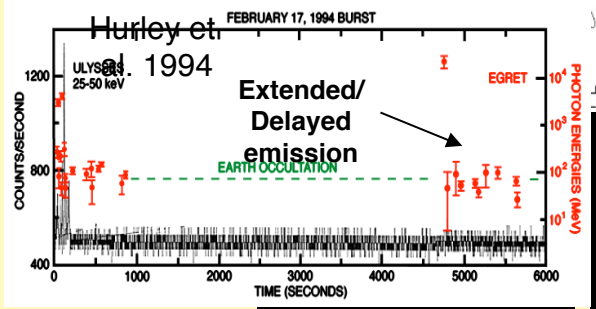
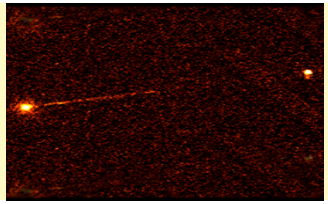
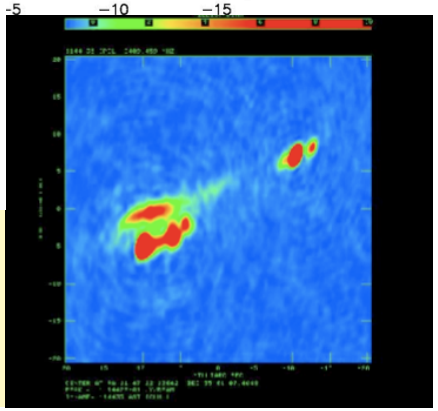
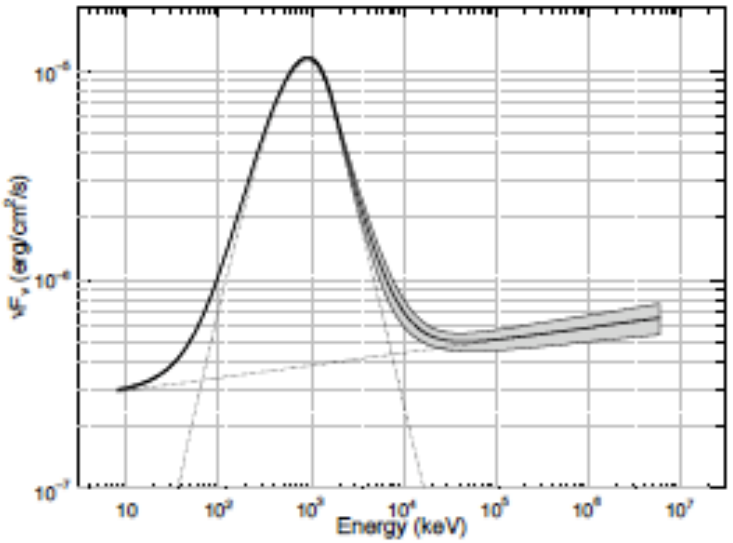








GRBs

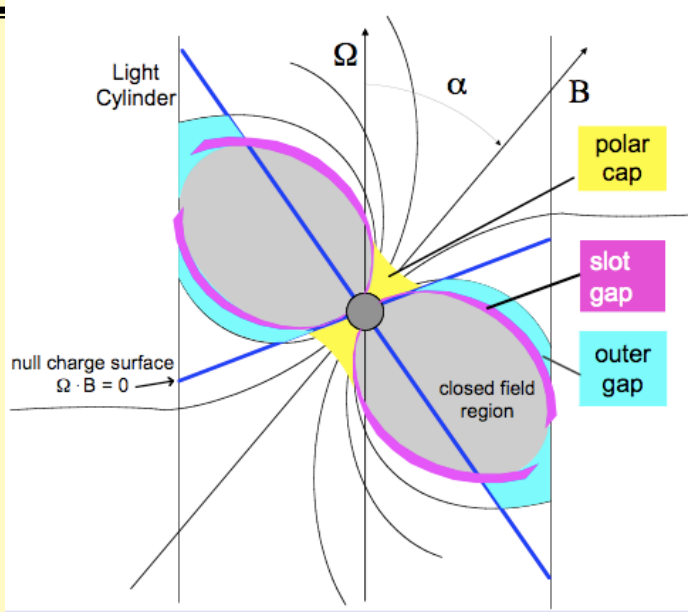


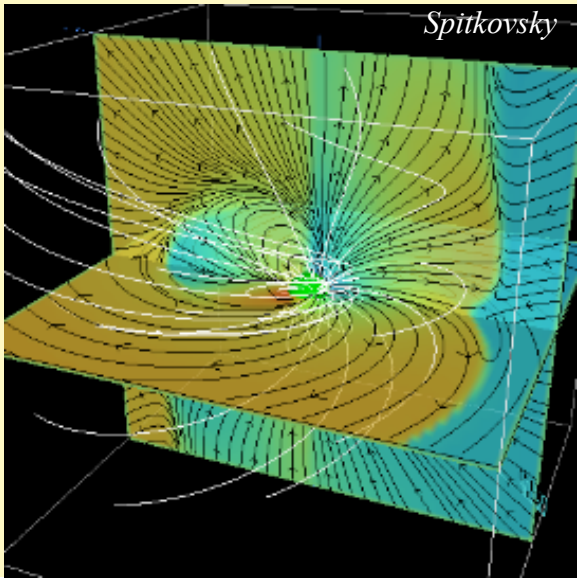
- **GBM+LAT+SWIFT+…**
  - 252 seen by GBM in 1 yr
  - 138 in LAT FoV
  - 9 detected w LAT
    - *z=4.35; not 8.2*
  - 2 short bursts
    - *GeV similar to long (core collapse?) bursts*
    - *Are they NS coalescence?*
  - 3 magnetars
- **Spectral and temporal properties**
  - $E_{iso} > 3 \times 10^{54}$ erg
  - Band +PL;
  - Thermal peak?
  - GeV emission later and more persistent; early 10 GeV; Late 33 GeV
    - *"Γ" >1000*
    - *Resuscitation or afterglow?*
  - 090510: z=0.9s; t~ 1s; Lorentz invariance confirmed;
    - *linear QG scale, > Planck mass…*
  - Modest EBL constraints

Pulsar Physics (2007)

Harding

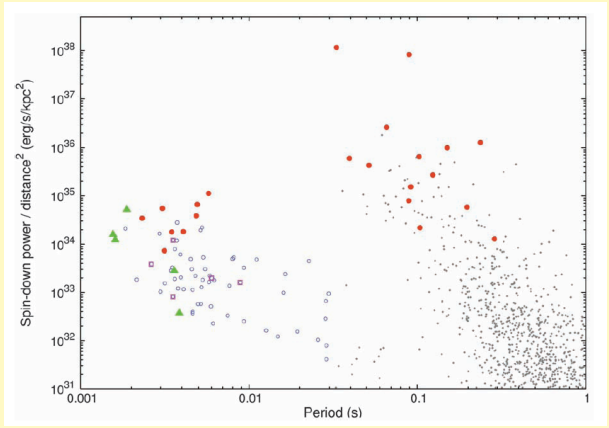
- **Detection**
  - 100s pulsars? *Johnston*
  - 50 RQ pulsars? *Ransom*
  - 10 MSP
  - RRATS
  - Blind searches
- **How do pulsars shine?**
  - Polar cap vs slot gaps vs outer gaps
  - Locate gamma ray and radio emission
  - Does gamma ray power ~ V?
- **Force free models**
  - Compute pulse profiles for different emission sites and fit to radio, gamma ray observations
  - Is the rotating vector model really supported by observations?
    - *Orthogonal polarization!*

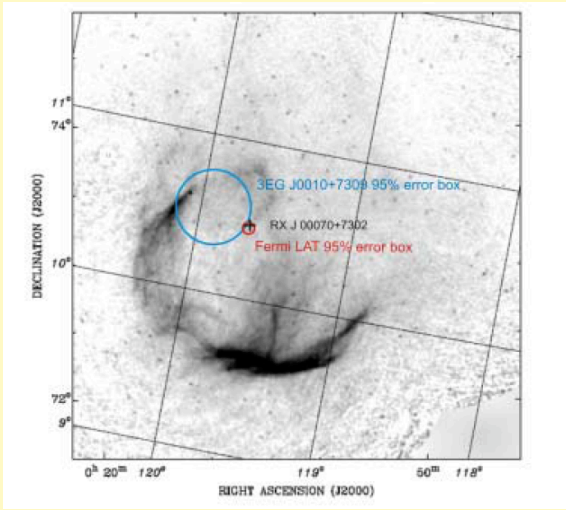




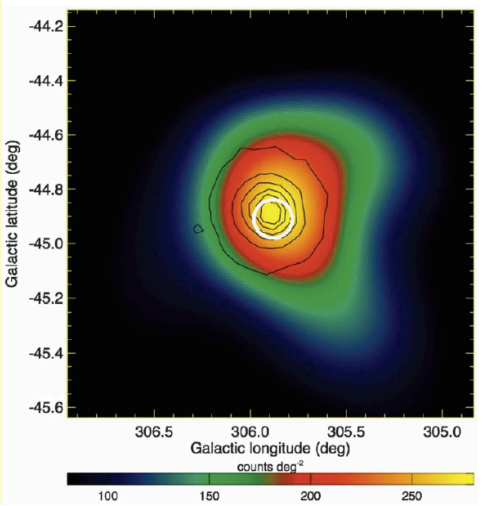
Pulsars

- **Abundant**
  - Young (10^5yr),
  - Regular(10^7yr),
    - *1/50 yr?*
  - Recycled(10^9yr)
    - *8/72 Field MSP*
    - *1/6 x 10^5 yr?*



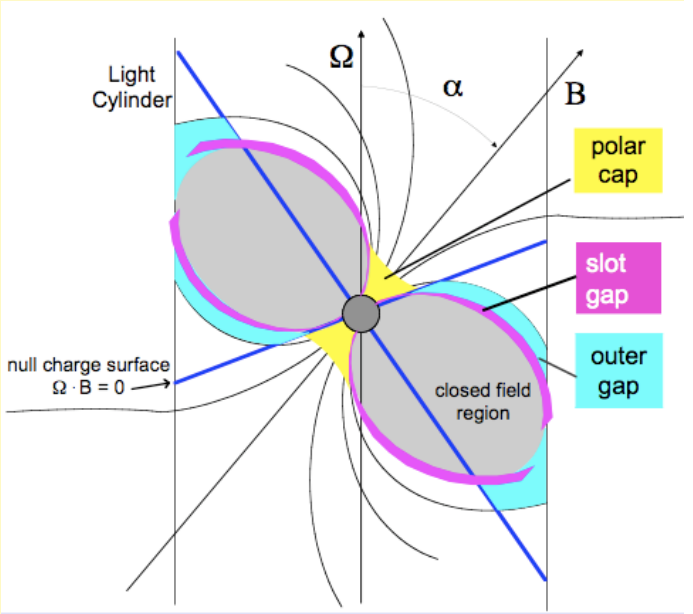


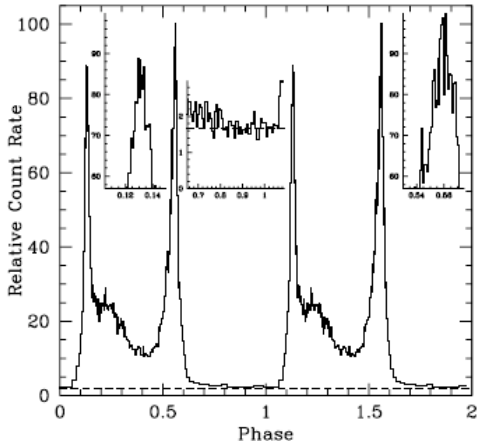
- **16/50 Radio-Quiet**
  - cf Geminga
  - 2 subsequently found
  - CTA1
  - Dominate low latitude unidentiied EGRET sources 15/36
- **47 Tuc**
  - 23 from Radio X-ray
  - May be seeing 60 in gamma rays
  - Not winds

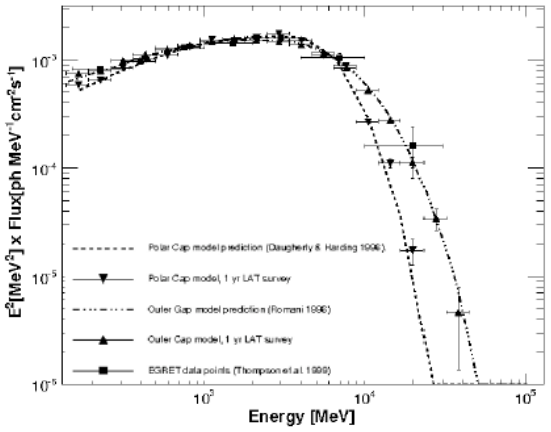


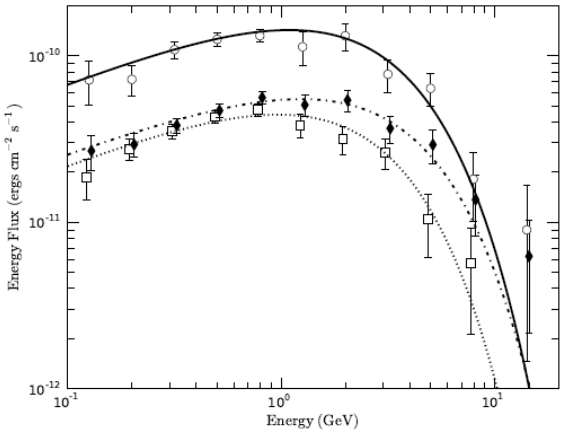
Emission Mechanism

- η~0.01-0.5 spin down power
- gamma ray beam > radio beam
- High energy cutoff
  - *Outer or slot gap emission*
  - *Curvature radiation*
  - *Young and MSP*
- Vela
  - **Cusped profile**
  - **Not wind**



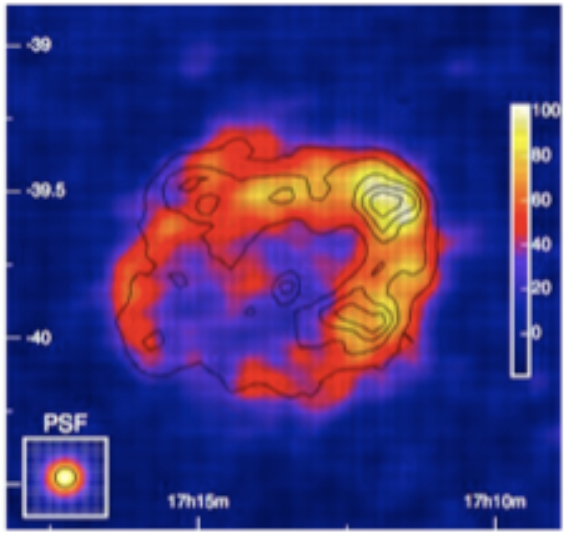


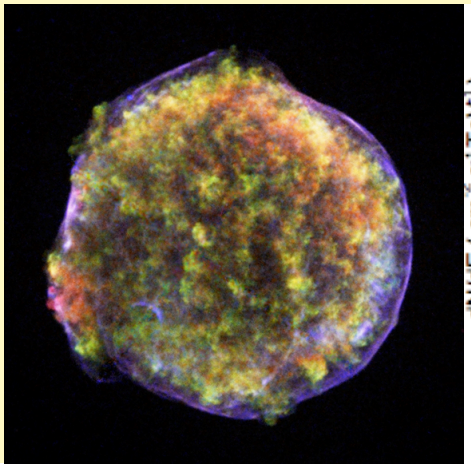


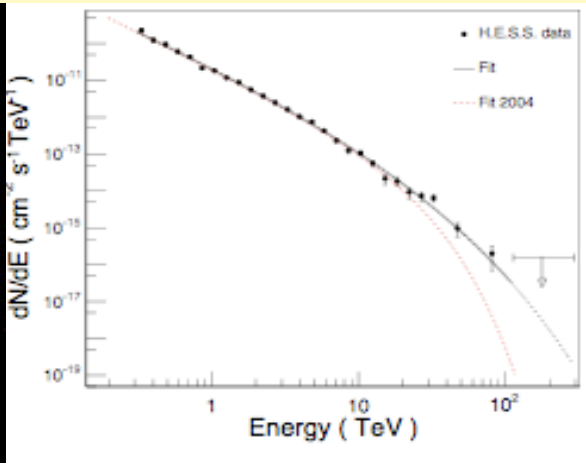


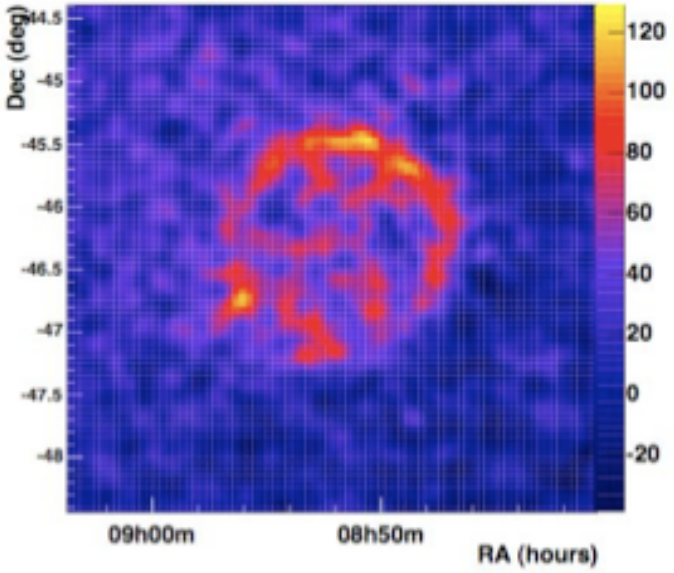
Supernova Remnants (2007)

- **Nonthermal accelerators** *Drury*
  - **>100TeV**
  - **Spectral curvature**
- **Hadronic vs leptonic**
  - **n problem or B problem?**
  - **GLAST should decide**
  - **Local FIR not CMB?**
- **Acceleration** *Slane*
  - **PeV-> mG** *Blandford*
  - **DSA vs F2 vs ?**
  - **If DSA do not need scattering behind shock!**



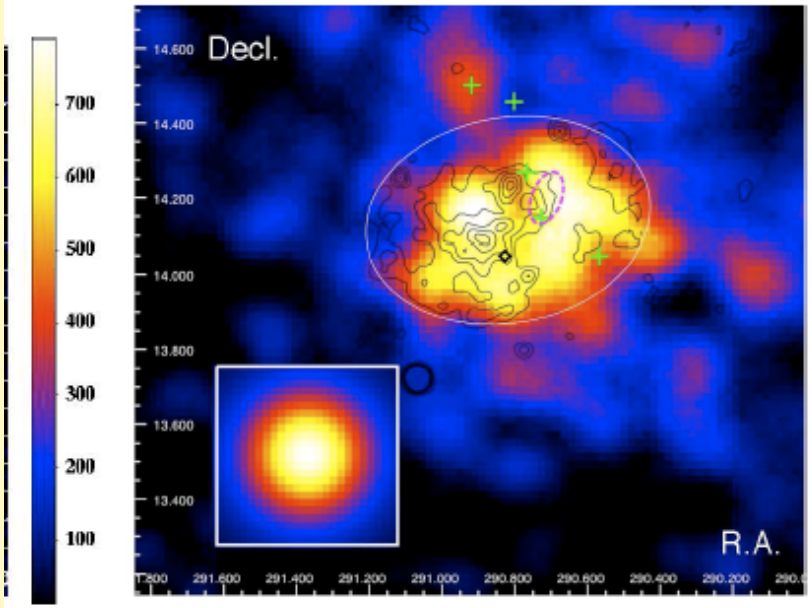


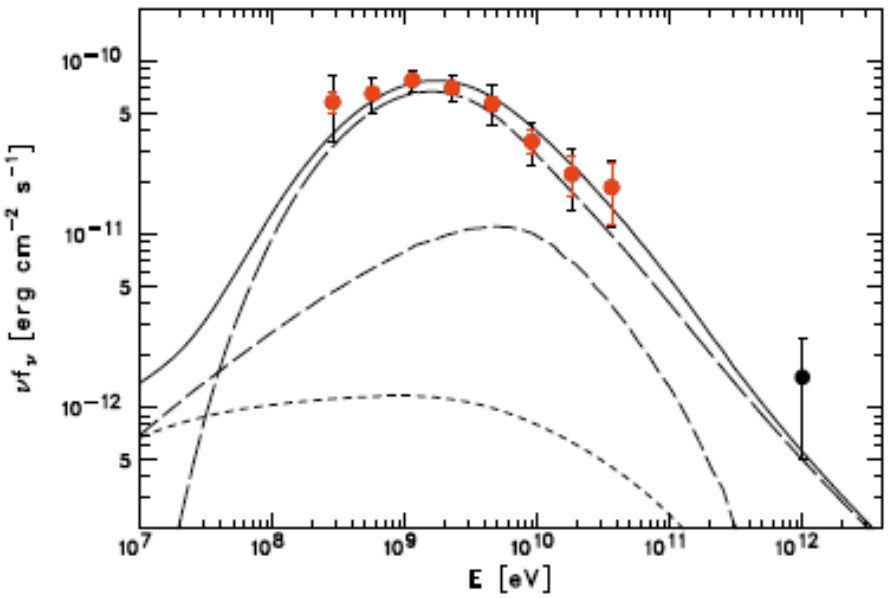




Supernova remnants

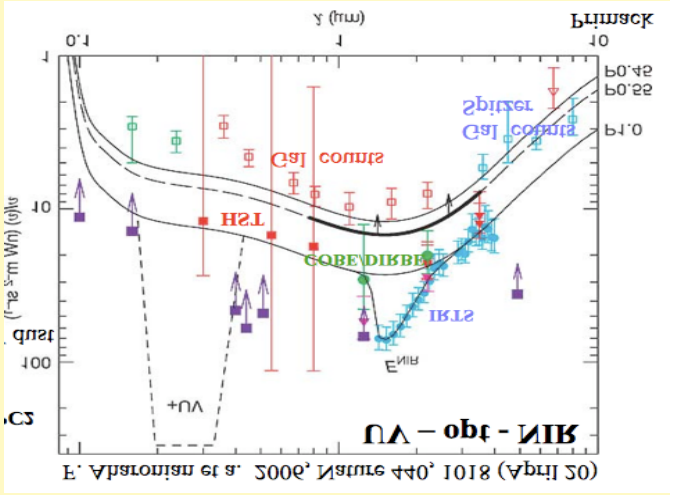
- W51C 3 x 10^4 yr SNR 400 km/s
- Shocked atomic and mol gas
- Hadronic emission not leptonic
  - 10^36 erg/s 5 x 10^{50} erg in protons
- Spectral break
  - Cooling, acceleration, loss …





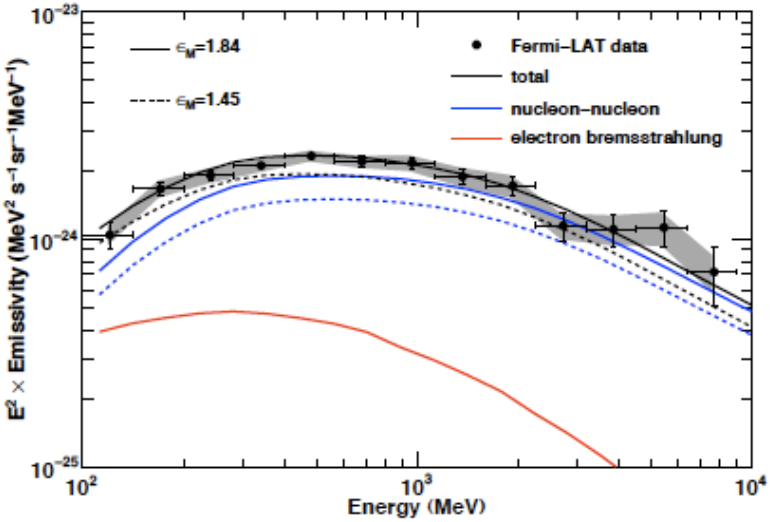
Backgrounds (2007)

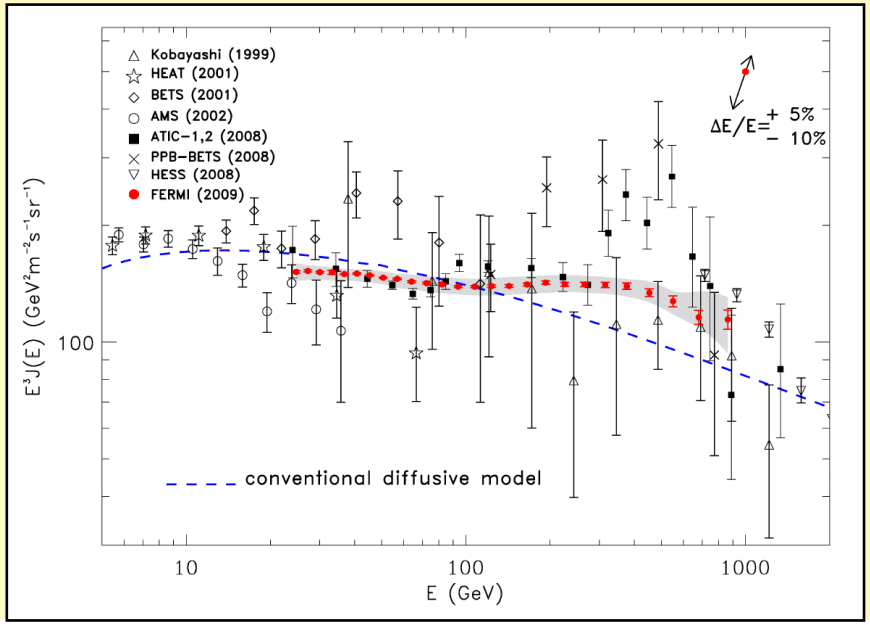
- **Interplanetary**
  - C^{-1} starlight
- **Diffuse interstellar**
  - GeV excess? Cygnus TeV? *Digel, Knodelseder, Abdo*
- **Extragalactic gamma ray background**
  - Sum of sources or new component ? *Dermer*
- **Extragalactic X-ray background**
  - INTEGRAL reports HEAO-1 spectrum x 1.1
- **Extragalactic stellar background**
  - TeV observations vs Spitzer - limits on Pop III contribution?
  - GLAST will see to greater distance and study evolution *Hartmann*
- **Extragalactic cosmic ray background**
  - AGN vs GRB
  - Auger - Hard for UHECR to escape either environment
- **Dark matter annihilation background** *Kuhlen, Wai, Koushiappas*
  - Lines?
    - *No "no go" theorem*
  - Bump
    - *Validation of DM signal will be a challenge*
    - *Confusion with PWN etc?*



Backgrounds

- 0.1-1000 GeV electrons featureless? spectrum $J \sim E^{-3}$.
  - No problem yet
- No 0.1-10 GeV diffuse excess
  - Galactic + extragalactic diffuse + unresolved sources
  - $E^{-2.4}$
- Line, subhalo, rich cluster upper limits





Summary

- Fermi has exceeded the already high expectations for it at the time of the first Symposium in terms of its performance and the science it has already delivered
  - stars, AGN, GRB, pulsars, SNR, backgrounds
- Fermi, working in combination with an army of other telescopes, is transforming our view of the high energy universe
  - Routine and opportunistic multi-wavelength campaigns are working
- It is also advancing our understanding of fundamental physics by shrinking the range of allowable possibilities
  - High confidence upper limits are extremely valuable
- We will learn much more over the next four days and, we hope, over the next nine years
  - Time to think hard about how we optimize the science return from the mission