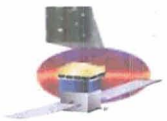

Gamma-Ray Pulsar Studies with GLAST

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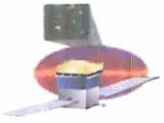
NASA Goddard Space Flight Center
GLAST Large Area Telescope Collaboration
David.J.Thompson@nasa.gov

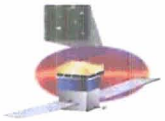
Outline

1. Gamma-ray pulsars – what and why
2. Gamma-ray Large Area Space Telescope (GLAST)
3. Pulsar prospects with GLAST



A Quick History of Gamma-ray Pulsars

Decade	Gamma-ray telescopes	Pulsar discoveries
1967-77	Balloons, SAS-2, COS-B	Crab, Vela
1977-87	None	None
1987-97	Compton Observatory (all 4 instruments)	Geminga, B1706-44, B1509-58, B1055-52, B1951+32, + ??
1997-2007	INTEGRAL	See next talk
2007-17	AGILE, GLAST	Coming soon!



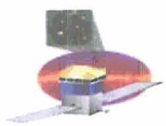
Gamma-ray Pulsars – Challenges

Measurements are made from a moving telescope, circling the Earth about every 90 minutes.

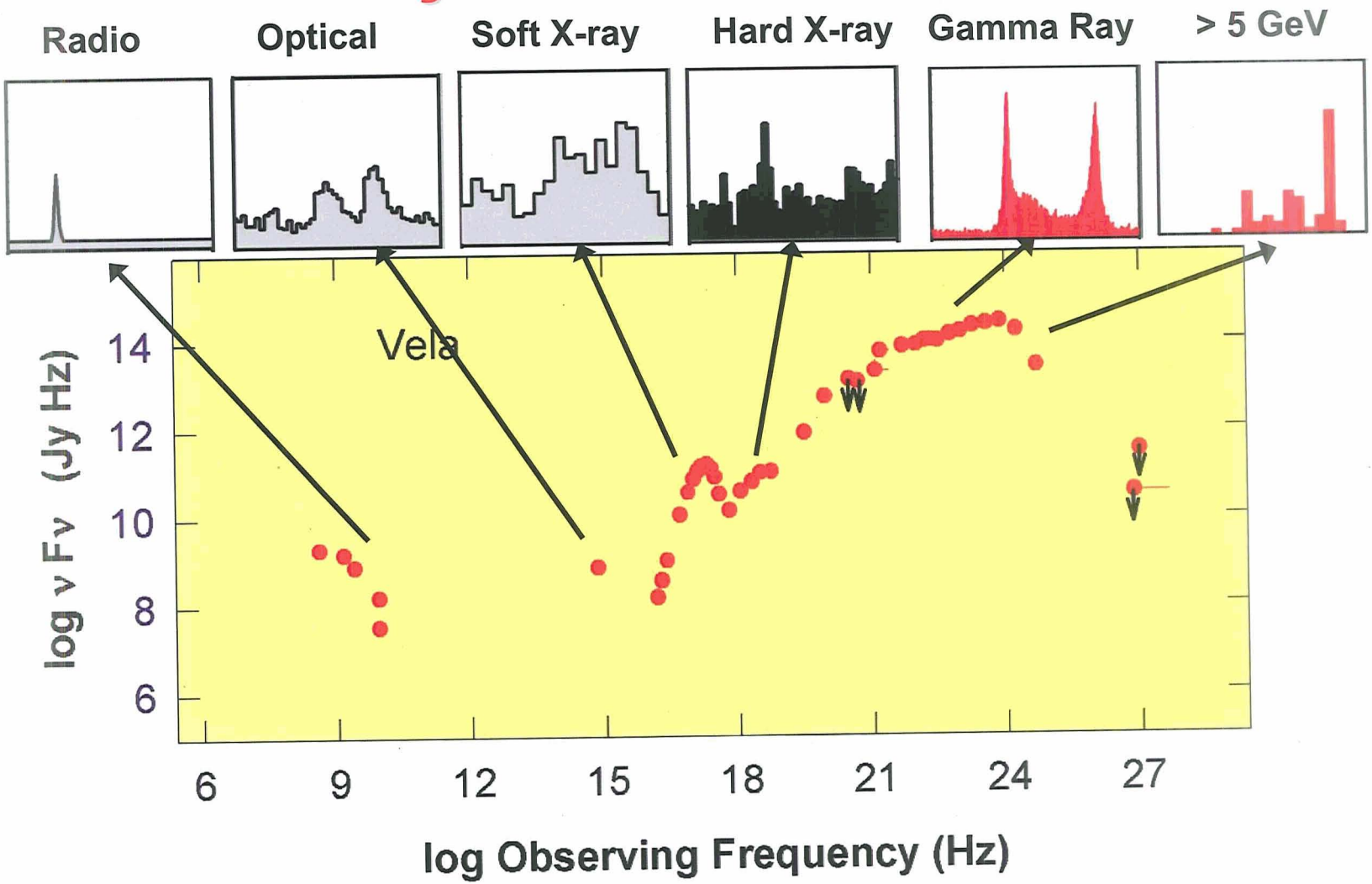
Fluxes are tiny – EGRET detected 3 photons/day from PSR B1055-52. The neutron star rotated more than 400,000 times during that day.

Gamma-ray astronomers are indebted to radio and X-ray astronomers for timing information. For GLAST, we appreciate the support from scientists using RXTE, GBT, Jodrell, Nançay, Parkes, Arecibo facilities. We welcome other long-term timing information. Contact Steve Thorsett, Alice Harding, Roger Romani, or me.

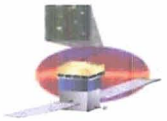
See poster by David Smith.



Gamma-ray Pulsars – Why Bother?

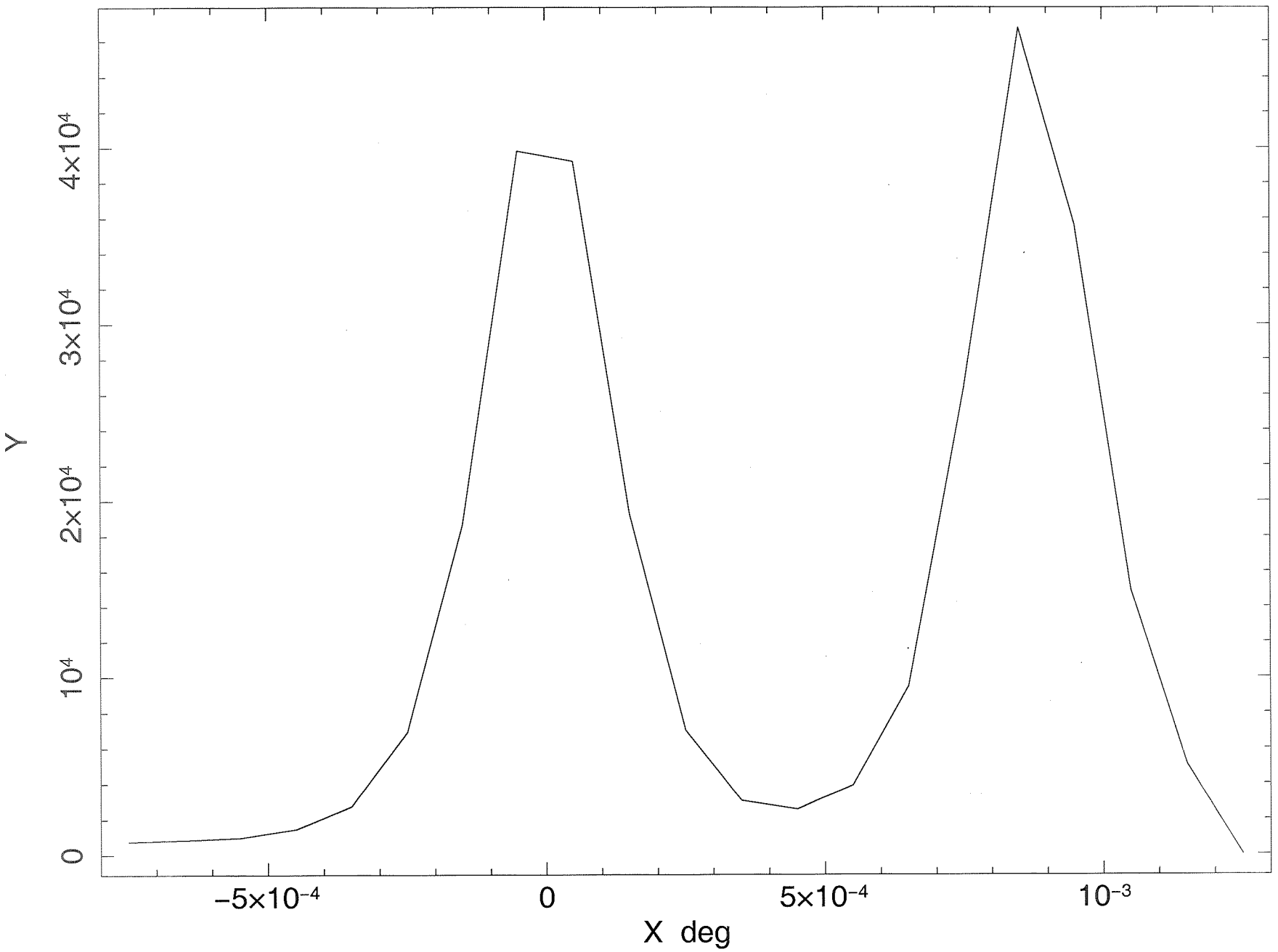


At least some pulsars are multiwavelength objects, with different information in different bands. Gamma rays are important in the total pulsed energy budget and the extreme of particle acceleration and interaction.



LIMITED OBSERVATIONS OF A FEW GAMMA-RAY PULSARS HAVE LEFT OPEN FUNDAMENTAL QUESTIONS:

- Where and how are particles accelerated – polar cap, slot gap, outer gap?
- How do the particles interact? With what?
- Is it the same for all neutron star systems?
- How does the complex environment (frame dragging, aberration, strong magnetic and electric fields, high currents) produce the observed radiation patterns?



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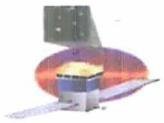
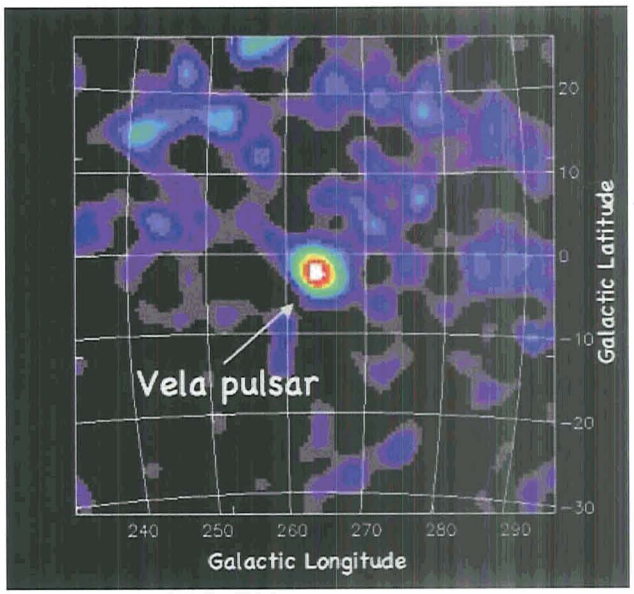
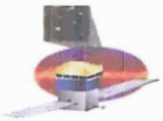


NEW GAMMA-RAY SATELLITES

First New Gamma-Ray Satellite: AGILE (Astro-rivelatore Gamma a Immagini LEggero)

- Italian collaboration
- Launched April 23
- Two years operation planned (minimum)
- High-energy gamma-ray telescope (30 MeV – 30 GeV)
- Pulsar timing and imaging
- Somewhat more sensitive than EGRET





GLAST: Gamma-ray Large Area Space Telescope

Two GLAST instruments:

Large Area Telescope

LAT: 20 MeV – >300 GeV (LAT was originally called GLAST by itself)

LAT field of view ~2.5 sr

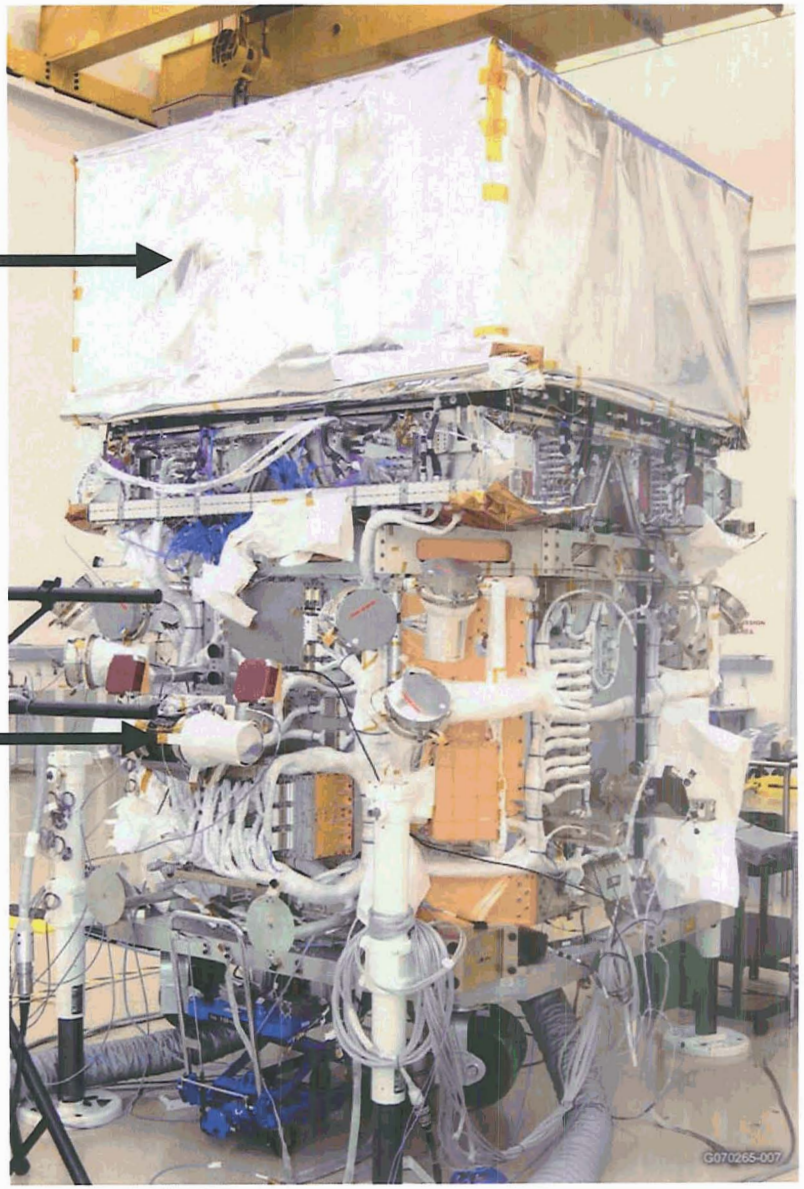
GLAST Burst Monitor

GBM: 10 keV – 25 MeV

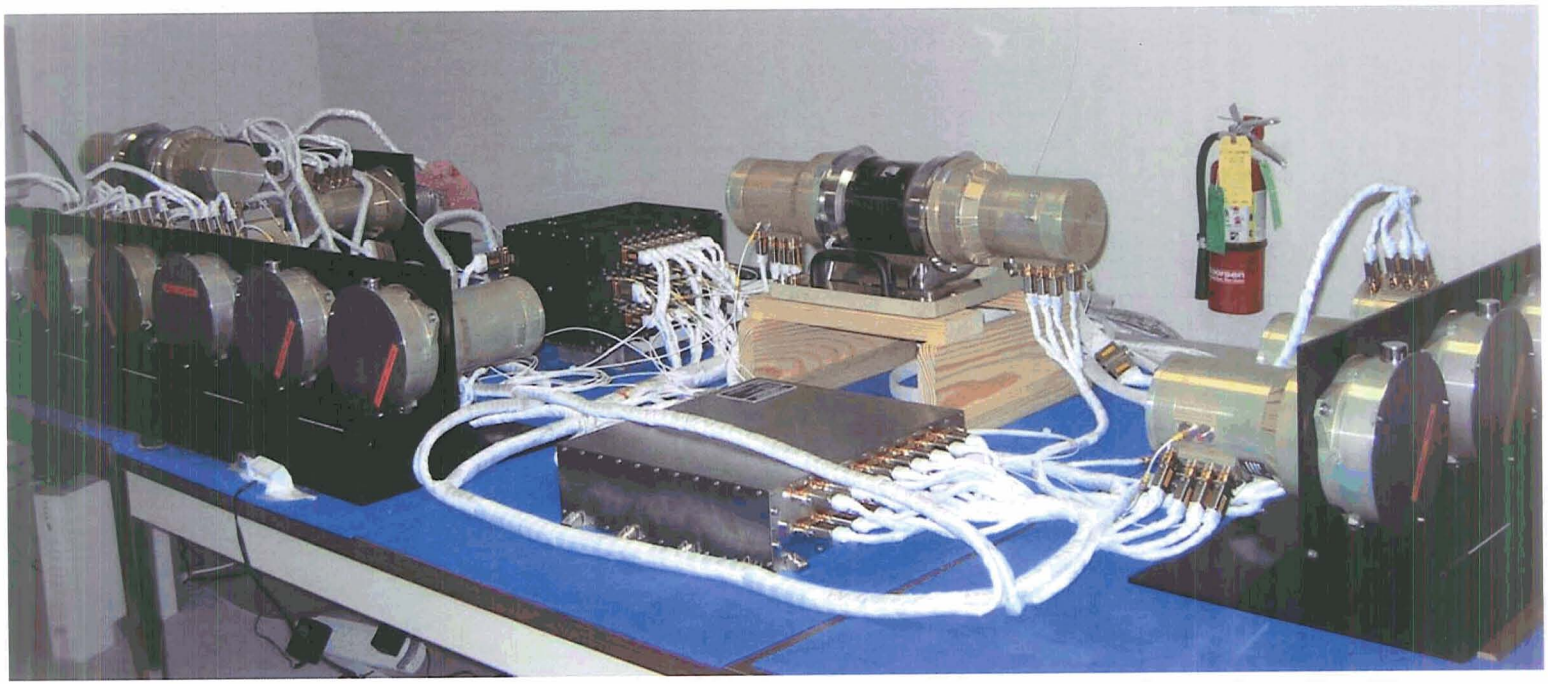
GBM field of view ~9 sr

Launch: Early next year (2008)

Lifetime: 5 years minimum, 10 years goal

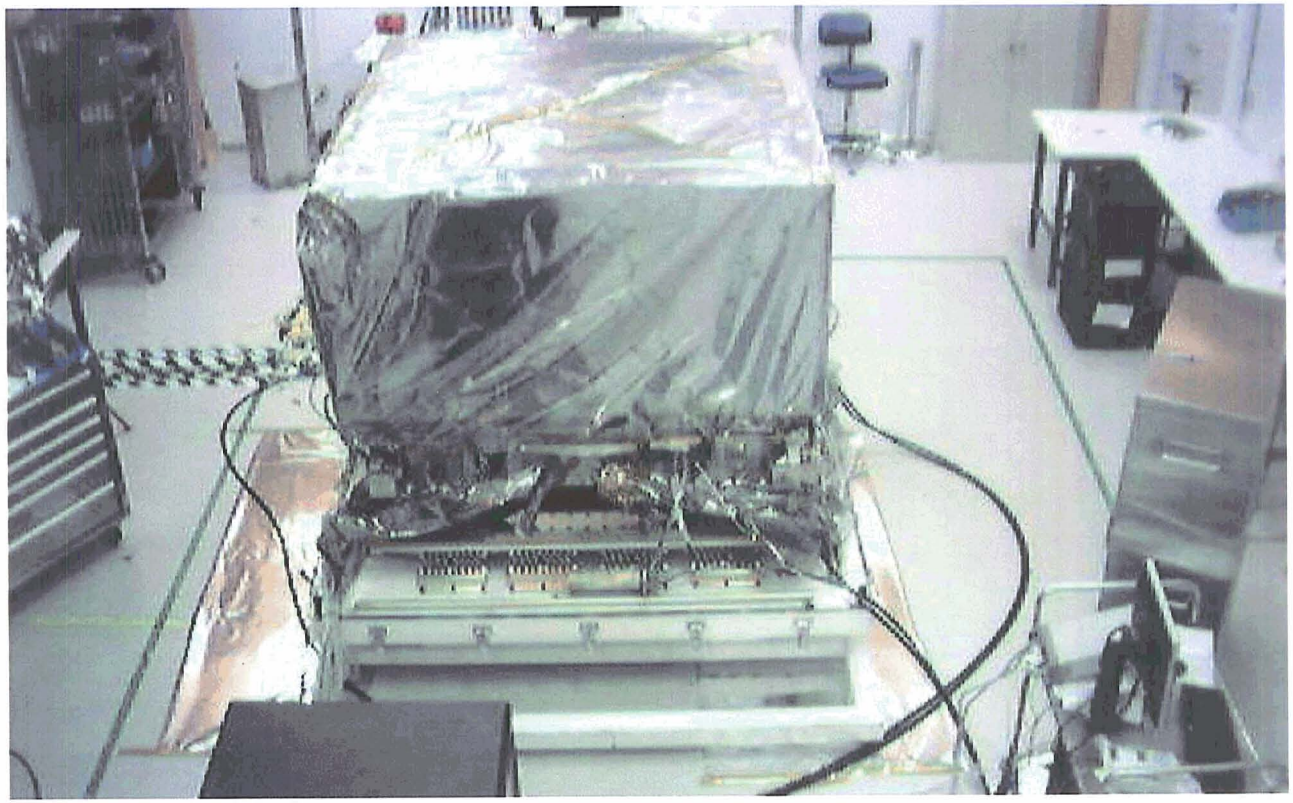


GLAST Burst Monitor (GBM)

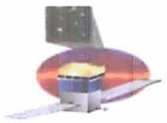


- Successor to BATSE on the Compton Observatory.
- No pulsar timing mode. GBM will detect magnetars as Soft Gamma Repeaters

GLAST Large Area Telescope (LAT)

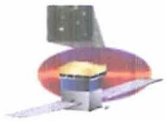


- Successor to EGRET on the Compton Observatory.
- Significantly larger than EGRET and uses improved technology.



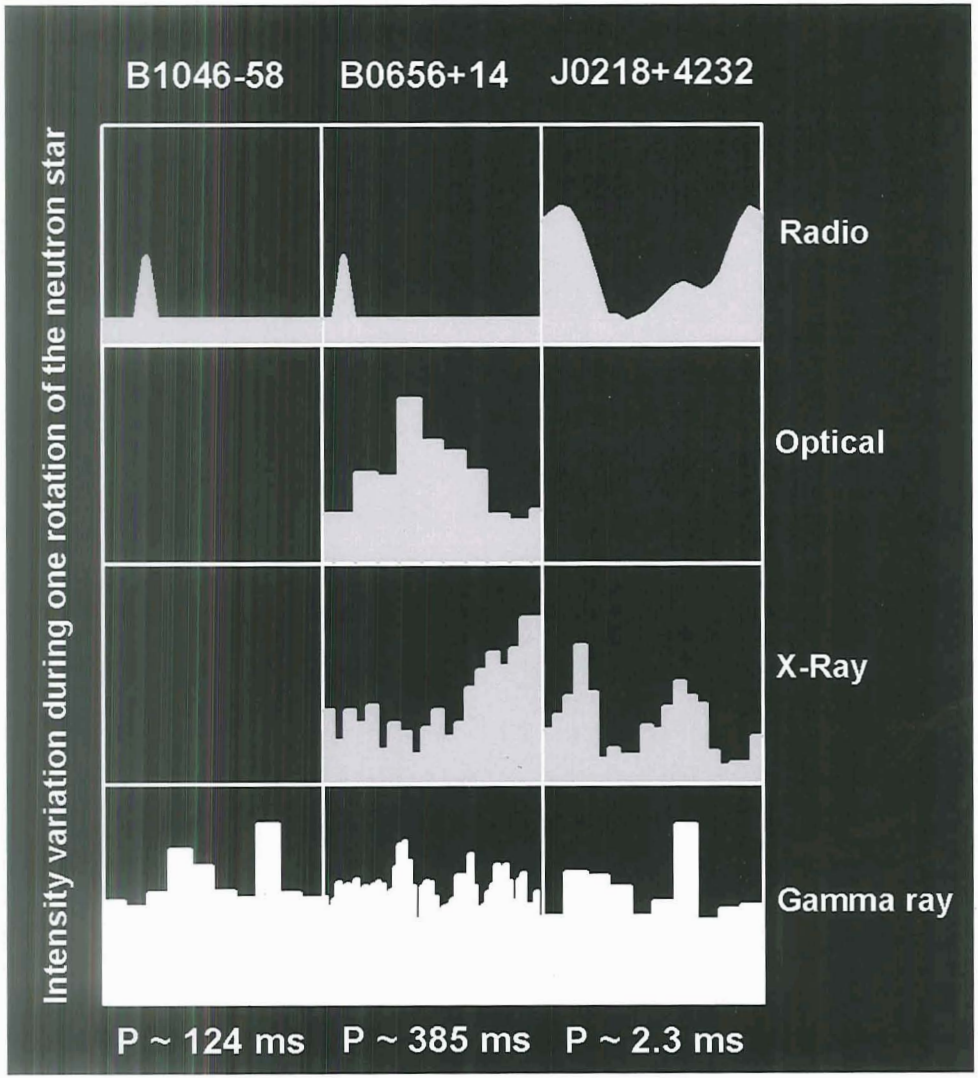
GLAST LAT Capabilities

- Huge FOV (~20% of sky)
- Scanning mode views the whole sky every day
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Improved Point Spread Function for gamma rays (factor > 3 better than EGRET for E > 1 GeV)
- Single photon timing accuracy ~ 10 μ seconds
- Large effective area (factor > 4 better than EGRET)
- Results in factor > 30-100 improvement in sensitivity
- No expendables - long mission without degradation



PULSAR SCIENCE WITH THE NEW GAMMA-RAY SATELLITES

Step one – EGRET Follow-up



Are these lower-confidence EGRET pulsar detections real?

How many of the new pulsars found in EGRET error boxes are gamma-ray pulsars?

Examples:

PSR J1016-5857

PSR J1015-5719

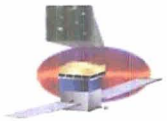
PSR J1420-6048

PSR J1637-4642

PSR J1837-0559

PSR J2229+6114

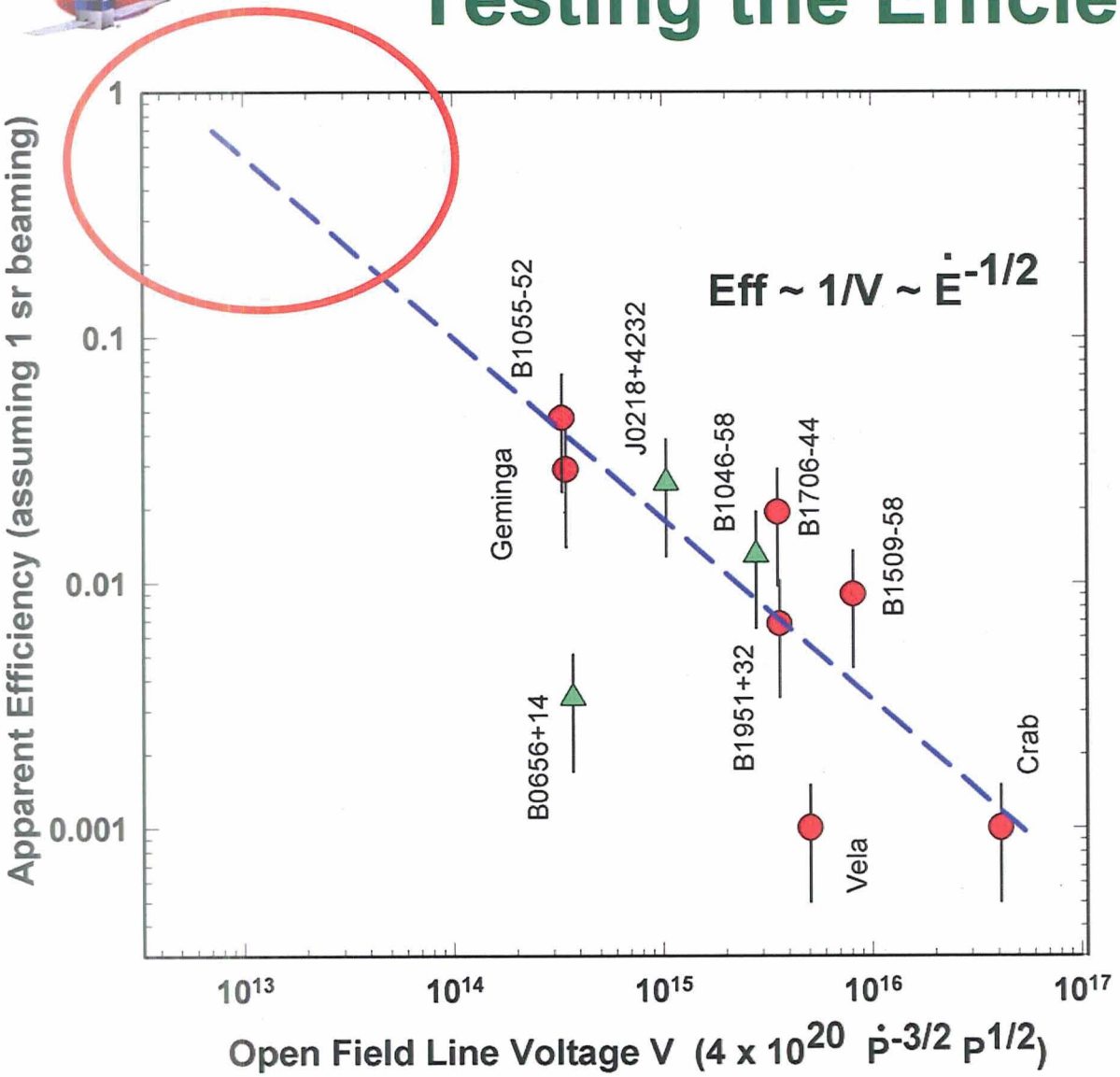
All have energy budgets consistent with EGRET sources. No timing information for EGRET era.



GLAST LAT Science - Pulsars

- To first order, detecting pulsed gamma radiation is limited by photon statistics.
- In two years with its scanning mode, LAT will detect 25-30 times as many photons for any given pulsar as EGRET did in its lifetime.
- This improvement results in detections intrinsically 25 times fainter or 5 times farther away.
- Several of the known gamma-ray pulsars are at distances of 2 kpc; therefore LAT will be able to detect some pulsars at the distance of the Galactic Center or farther (although the GC region itself is difficult).
- Estimates of the number of new gamma-ray pulsars range from a few dozen to more than 100.

Testing the Efficiency Trend



The apparent efficiency

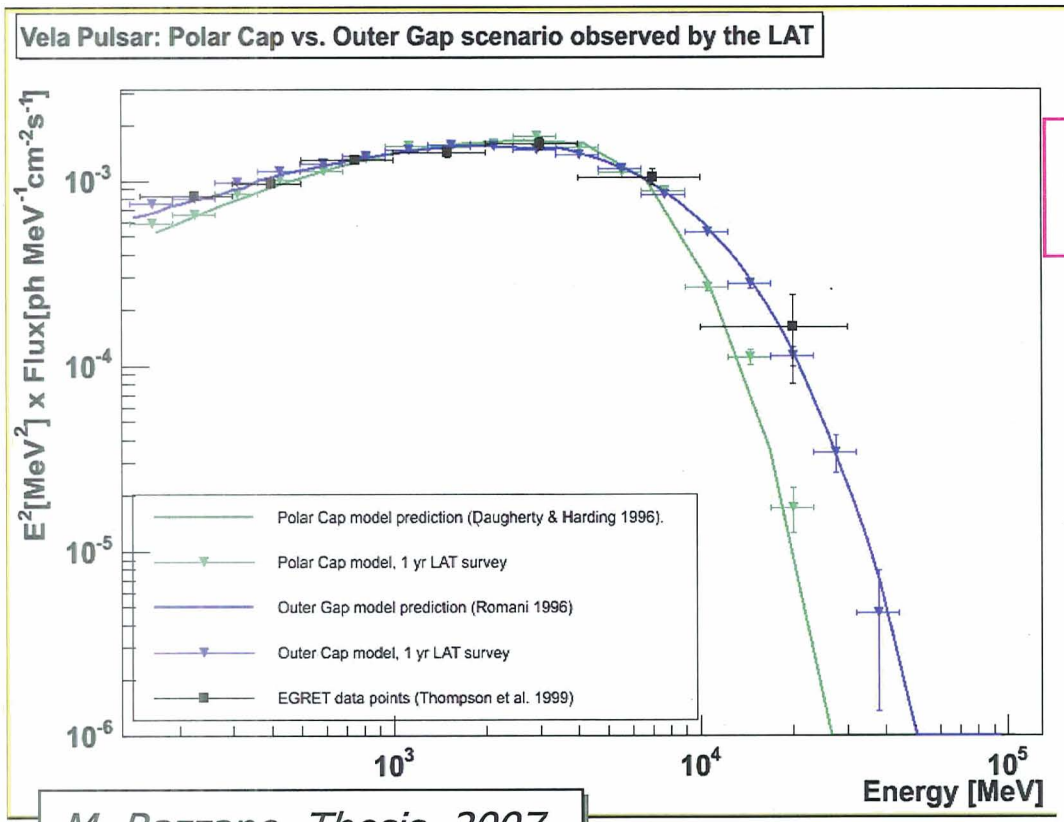
gamma-ray luminosity / spin-down luminosity

varies approximately inversely with the open field line voltage V (Arons, 1996).

What happens to pulsars with lower V as the efficiency approaches 1?

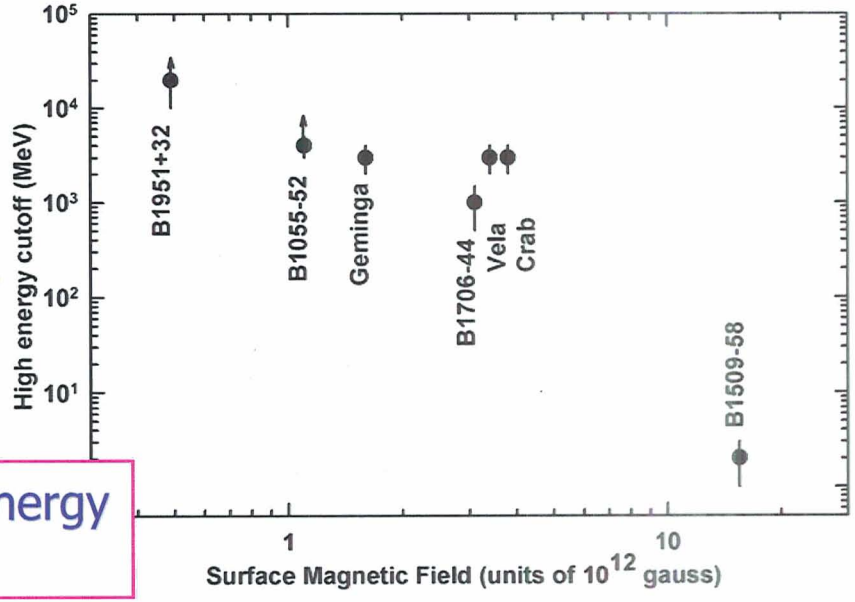
How much effect does the beaming assumption have?

Using LAT High-Energy Response for Spectral Analysis



M. Razzano, Thesis, 2007

Super-exponential (PC) or exponential cutoff (OG) ?



Is there a real high-energy cutoff energy vs. magnetic field trend?

LAT Pulsar Science: Testing Models

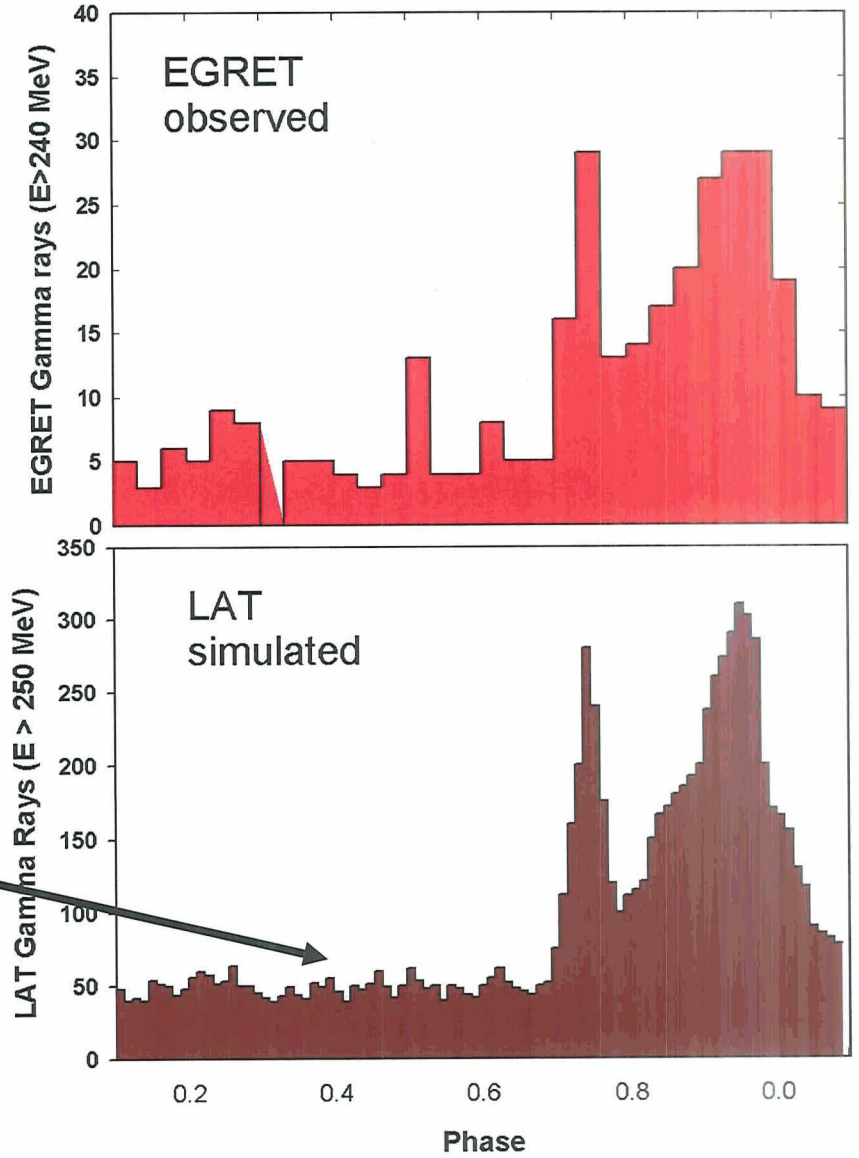
Light Curves - Example

PSR B1055-52 light curve with EGRET provided insufficient information to compare to models.

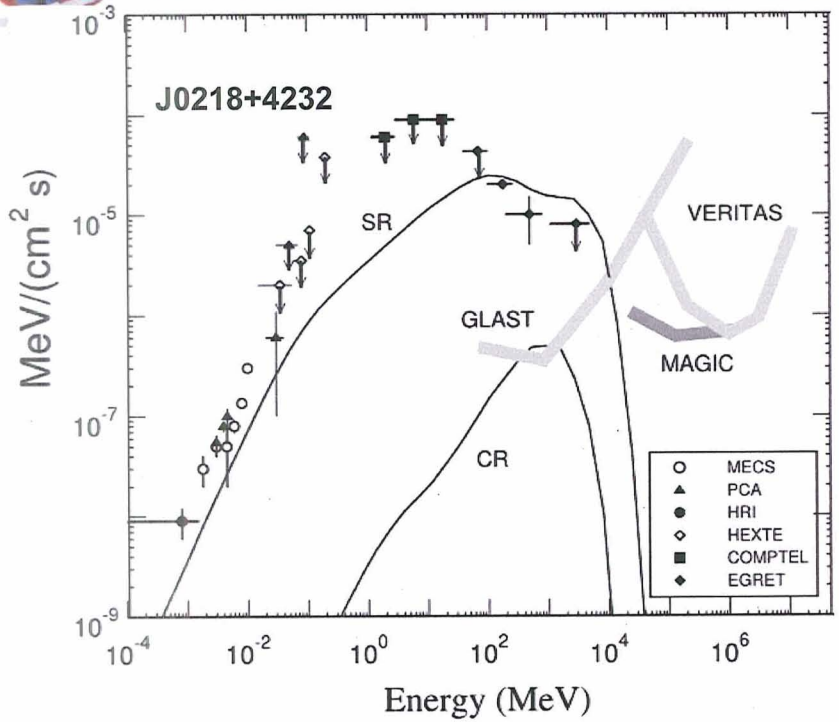
With LAT, the statistics will allow some real tests.

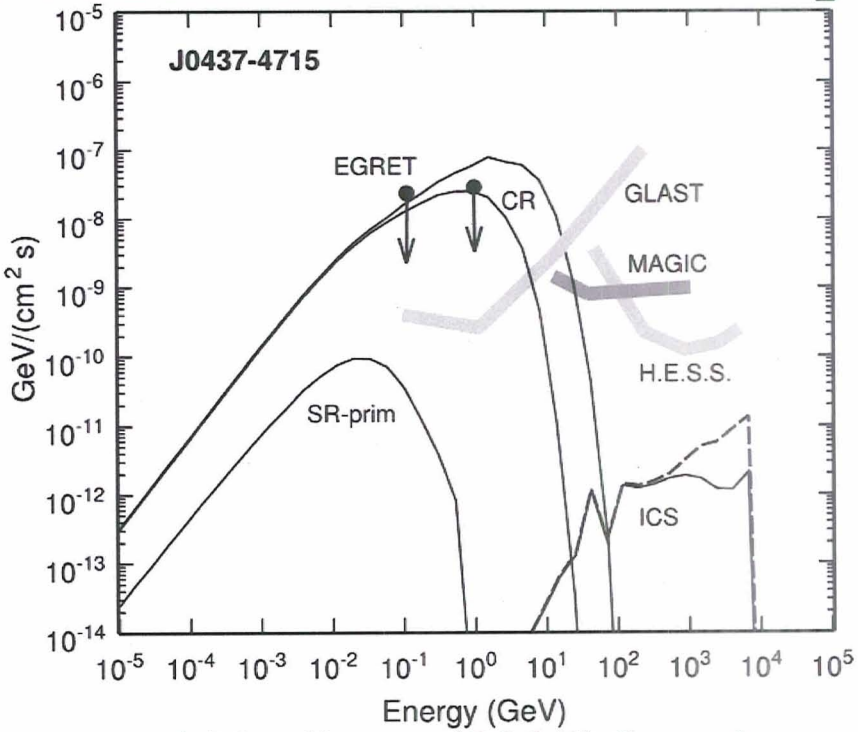
How are the pulse shapes, separation, and relationship to pulses seen at other wavelengths explained in different models?

Is the emission away from the pulse associated with the source (as predicted by the slot gap) or not (predicted by outer gap)?



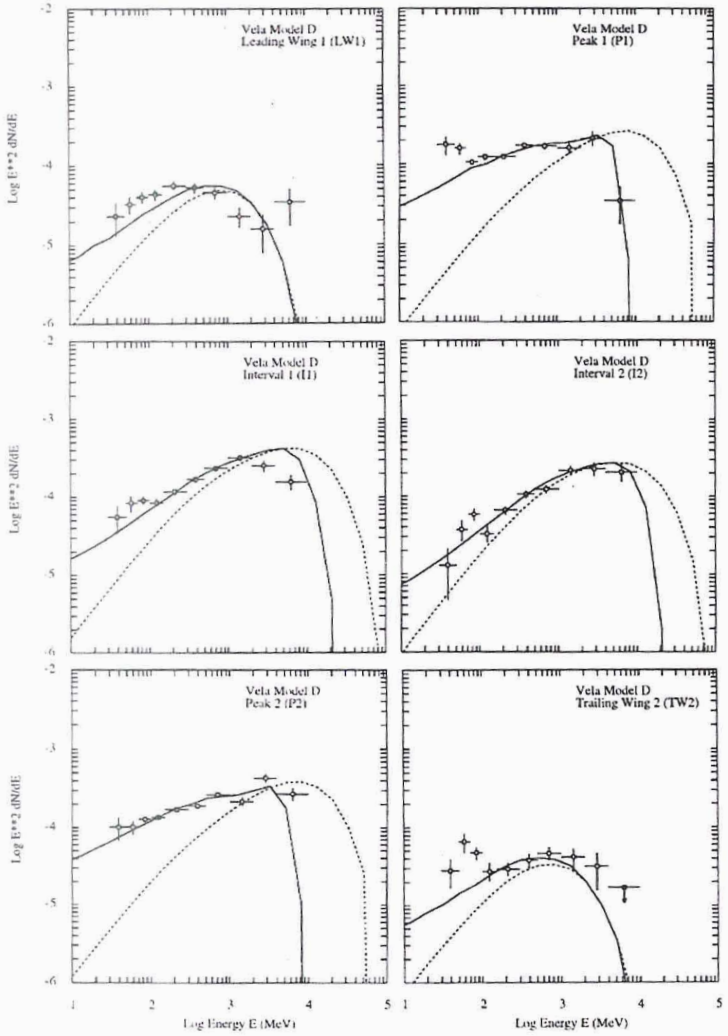
LAT Pulsar Science: Test MS Pulsar Theory





- Using a polar cap model, Harding, Usov, and Muslimov (2005) found an approach that can explain the observations. It uses cyclotron resonant absorption of radio emission to produce strong synchrotron gamma-ray emission from J0218. Other ms pulsars like J0437 are predicted to have curvature radiation just below the EGRET limits, but easily visible to LAT.
- Possible problem: this model seems to predict that EGRET should have seen some other ms pulsars and 47 Tuc.
- Other models (e.g. Zhang and Cheng, 2003; Bulik, T., Rudak, B. & Dyks, J. (2000) make different predictions for millisecond pulsars.

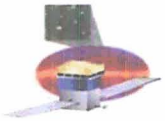
LAT Pulsar Science: Phase-Resolved Spectra



Polar Cap model for Vela
(Daugherty & Harding, 1996)

Models have calculated phase-resolved spectra for some gamma-ray pulsars. Comparison with the data is largely limited by the data uncertainties.

LAT will provide high-quality phase-resolved spectra for the bright pulsars, with error bars smaller than these by about a factor of five.



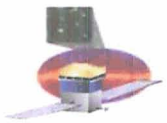
LAT Pulsar Science – Radio-Quiet Pulsars

In retrospect, it was realized that EGRET could have detected pulsations from Geminga without the information provided by the Halpern and Holt X-ray timing information.

LAT will have the capability to do blind searches for pulsars in cases where the gamma-ray source has sufficient signal to background.

Simulations indicate that LAT is about an order of magnitude less sensitive to pulsations in a blind search than a search with a known timing solution.

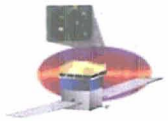
How many new "Geminga"s is hard to predict. 3EG J1835+5918 is a prime candidate.



SUMMARY

Within the next 2-3 years, the new gamma-ray telescopes should answer many of the questions about gamma-ray pulsars left from the Compton Observatory era.

In particular, they should provide robust tests of phenomenological and theoretical models.



Theorists' Contributions: Model Light Curves

Summary by Alice Harding