



Fermi- LAT

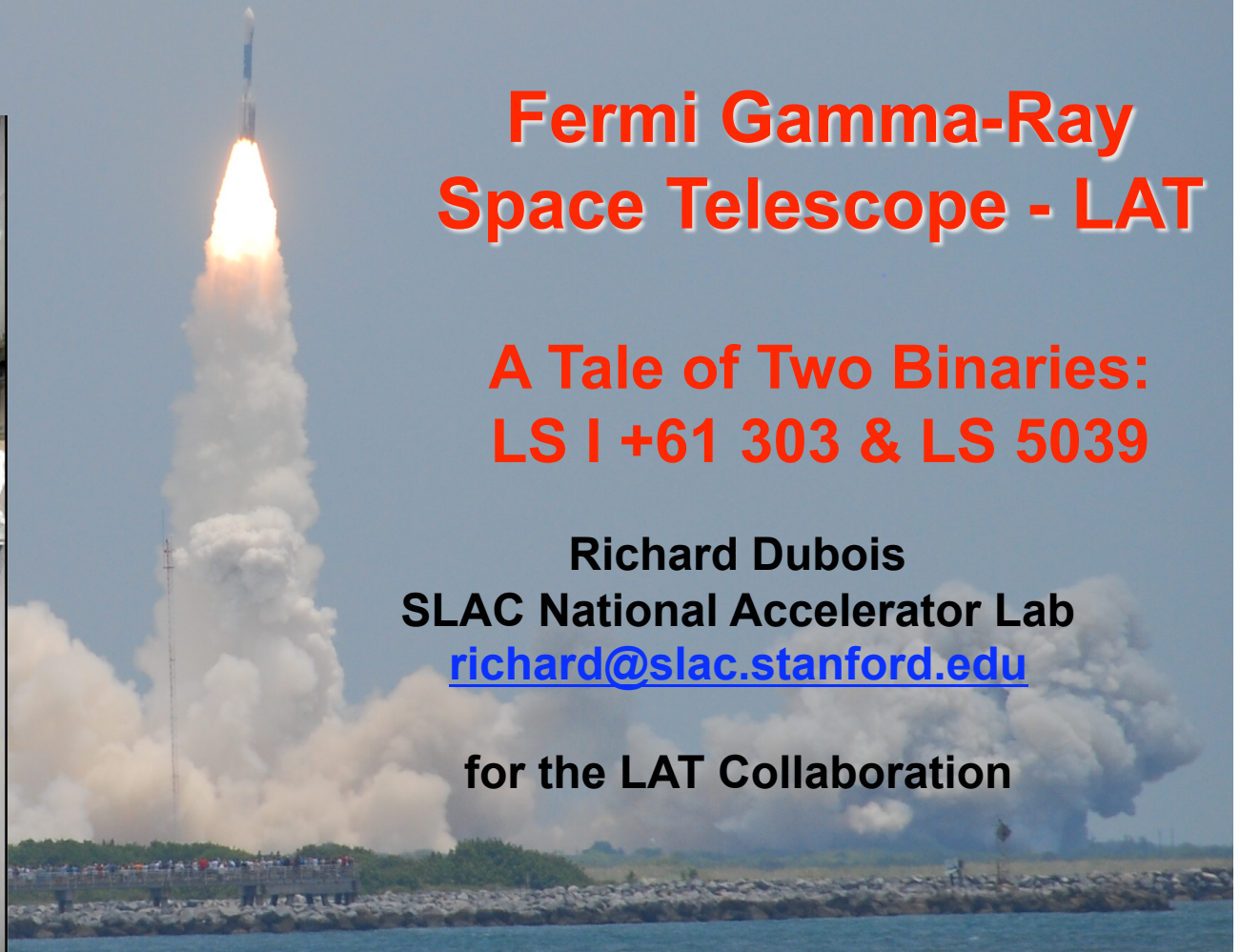
Fermi Symposium Washington DC Nov 4, 2009

# Fermi Gamma-Ray Space Telescope - LAT

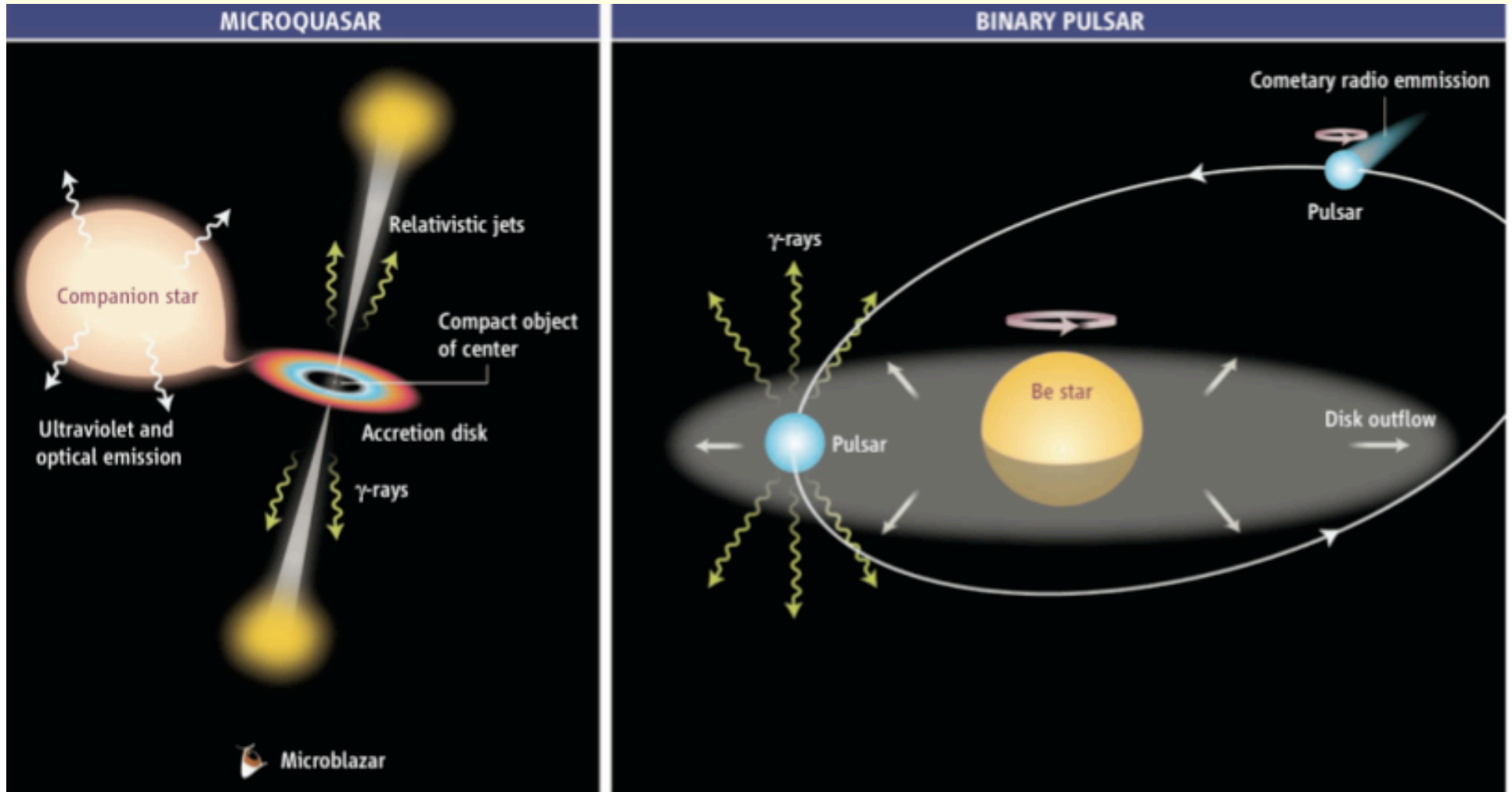
## A Tale of Two Binaries: LS I +61 303 & LS 5039

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for the LAT Collaboration



# Microquasar or Pulsar?

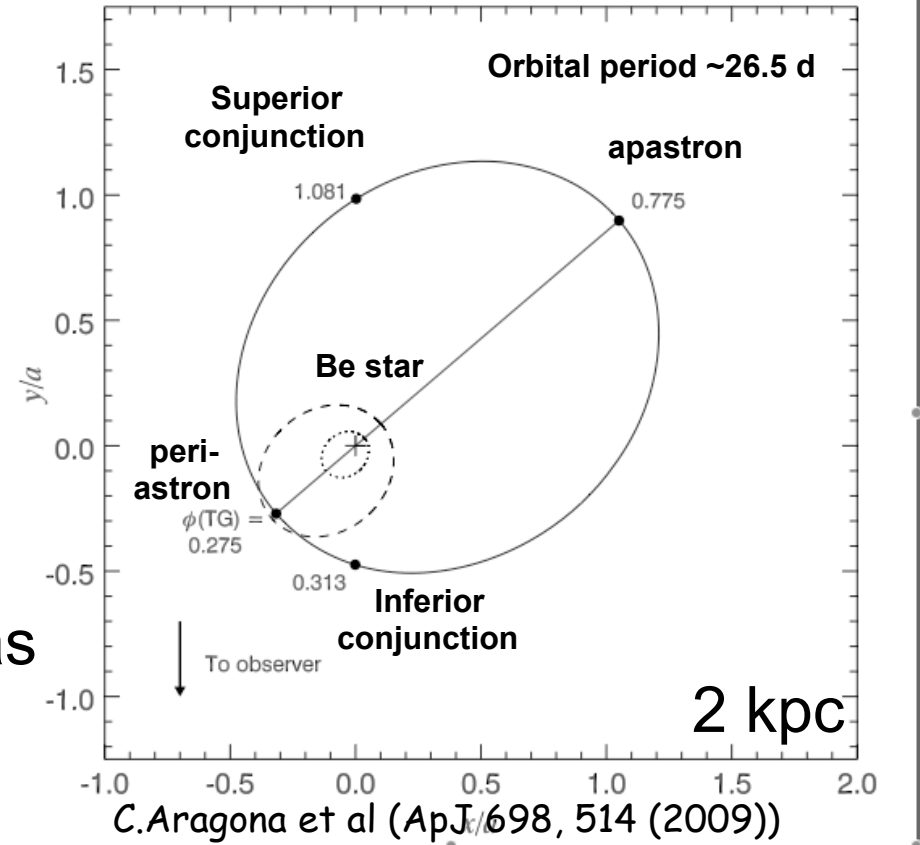
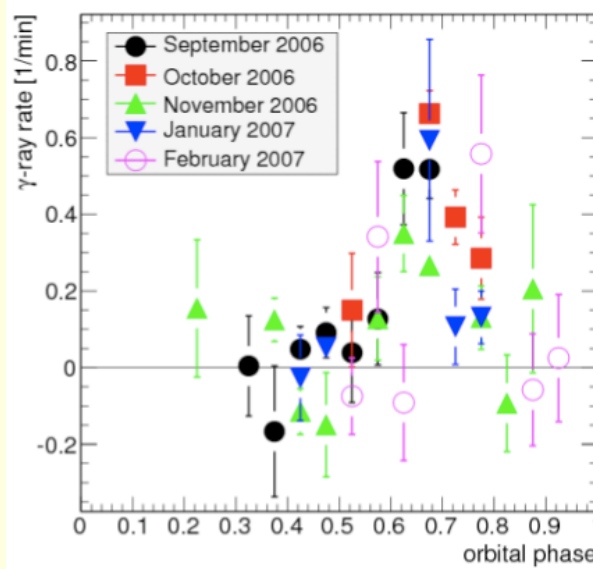


from: Mirabel (Science 309, 714, 2006)

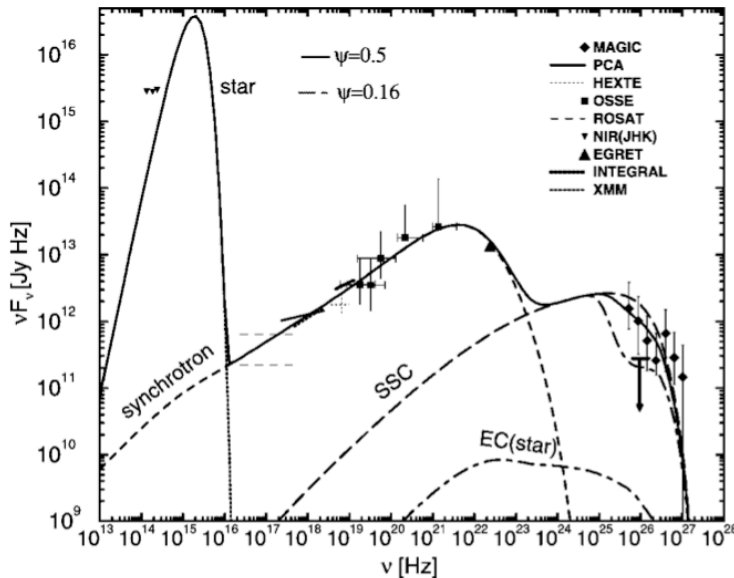


# The "Easy" Binary: LS I +61<sup>0</sup> 303

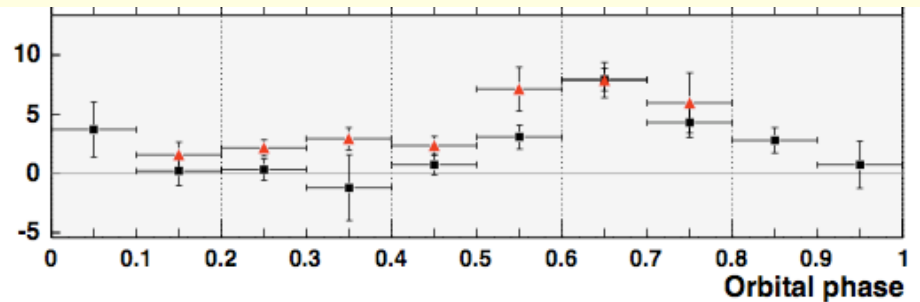
EGRET:  $\gamma = -2.19 \pm 0.07$   
 MAGIC:  $\gamma = -2.6 \pm 0.2$   
 Veritas:  $\gamma = -2.6 \pm 0.2$



Veritas



ApJ, 650:L123-L126, 2006



MAGIC

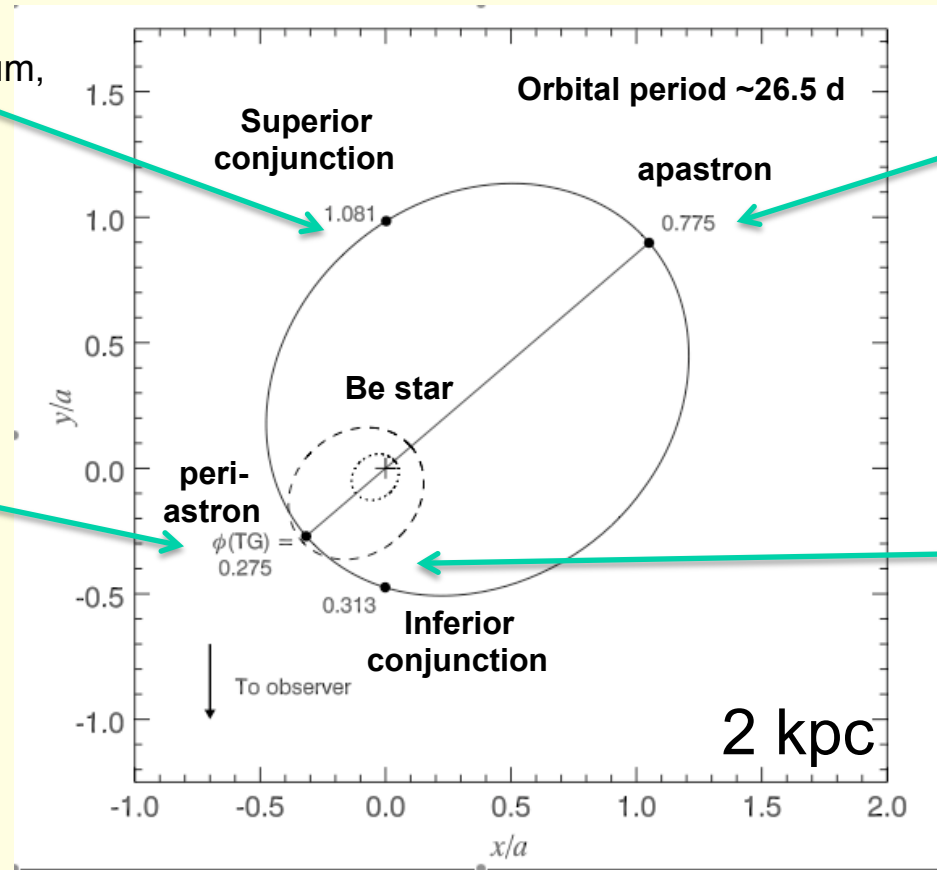
3/15

# Reminder of Periodic Effects

Backscatter to  
observer: softer spectrum,  
higher flux

Brightest scattering  
target:

bright @ GeV  
 $\gamma\gamma$  annihilation @ TeV



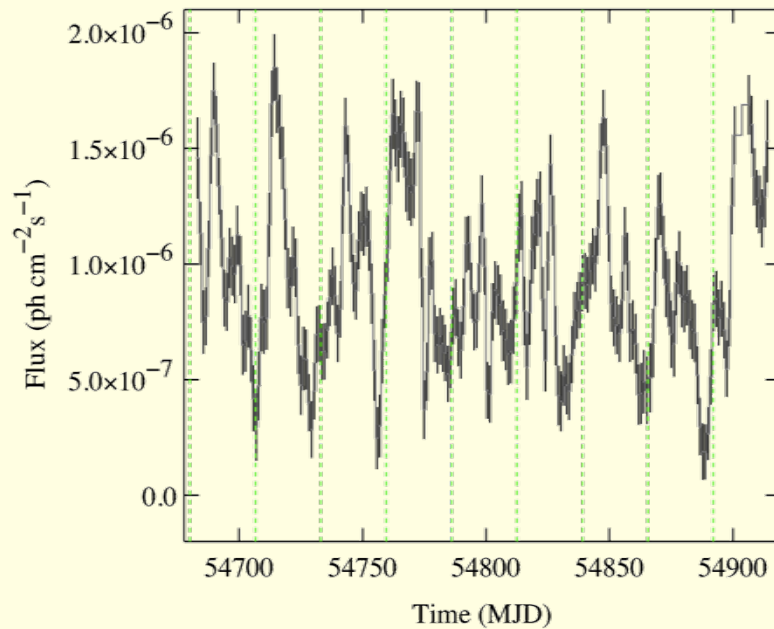
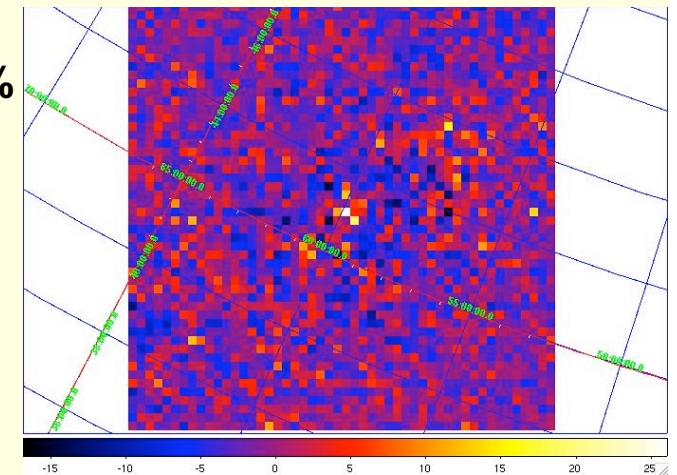
Dimmest scattering  
target

Forward scatter to  
observer: harder  
spectrum, lower flux

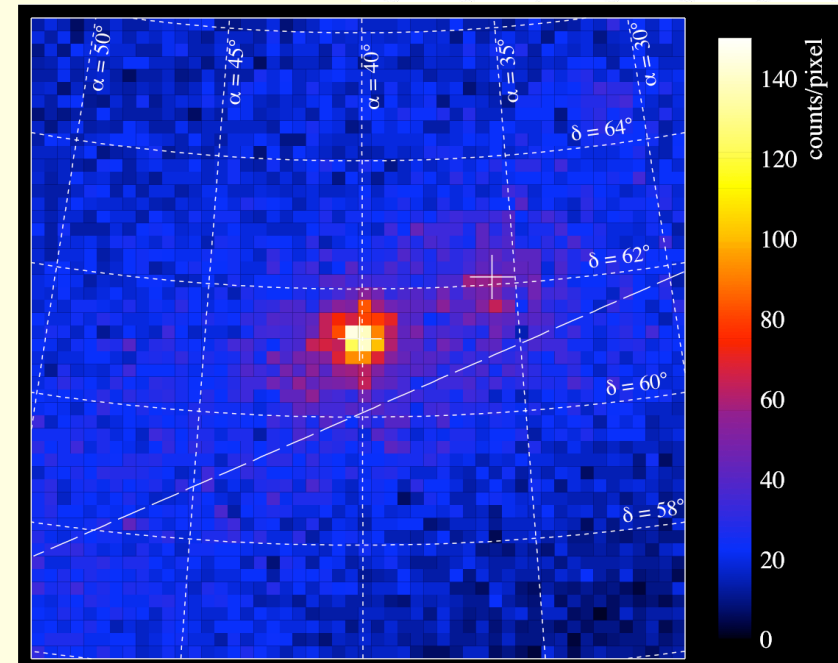
# Fermi view of LS I +61°303

- ID : position + orbital period
- LS I +61°303 fitted to R.A.=40.076, Dec.=61.233 with 95% error radius of 1.8'. This location is consistent with the known position of the optical counterpart.
- Flux variability is also clearly evident

Residuals map

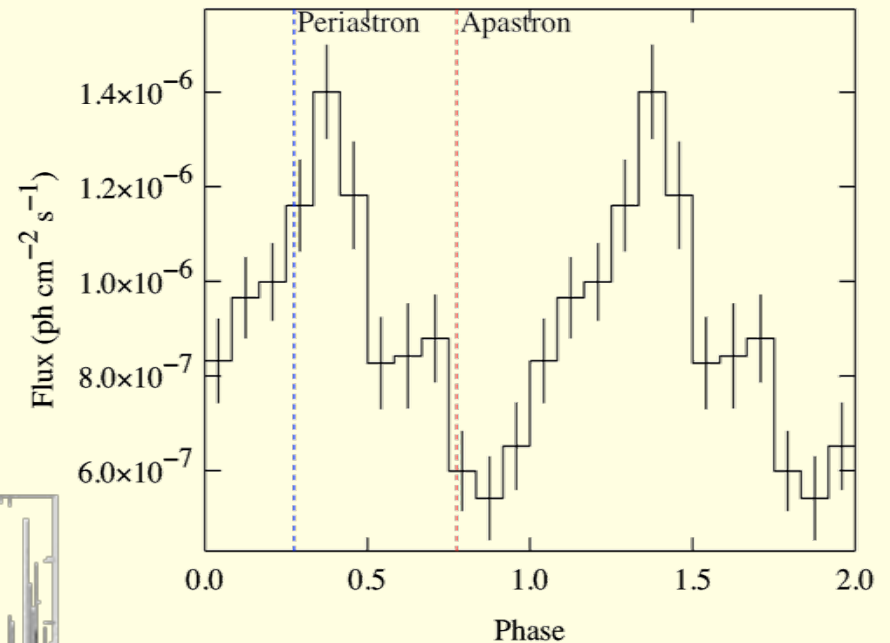
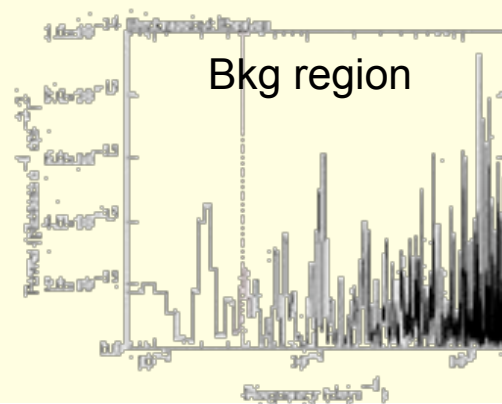
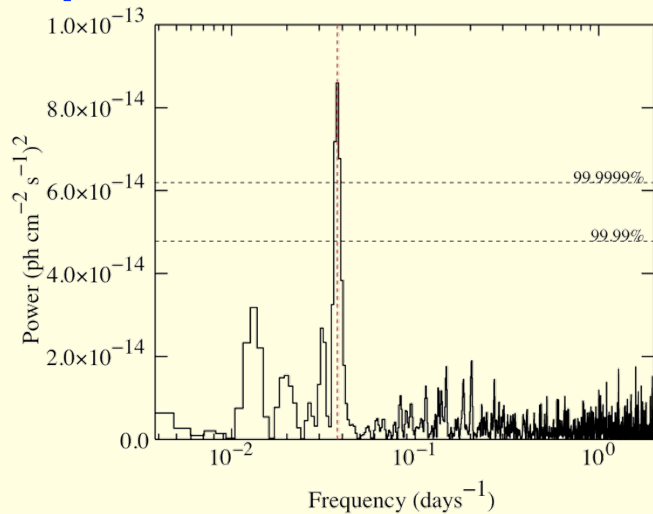


R.Dubois



# First definitive detection at GeV energies

- We detect a periodicity in the LS I +61°303 light curve at  $26.6 \pm 0.5$  days
- Folded light curve indicates peaks of emission around periastron.



See no statistically significant dependence of spectrum on phase

# LS I +61°303 spectrum

Exponential cutoff form clearly favoured over power law: chance prob for PL  $\sim 10^{-9}$

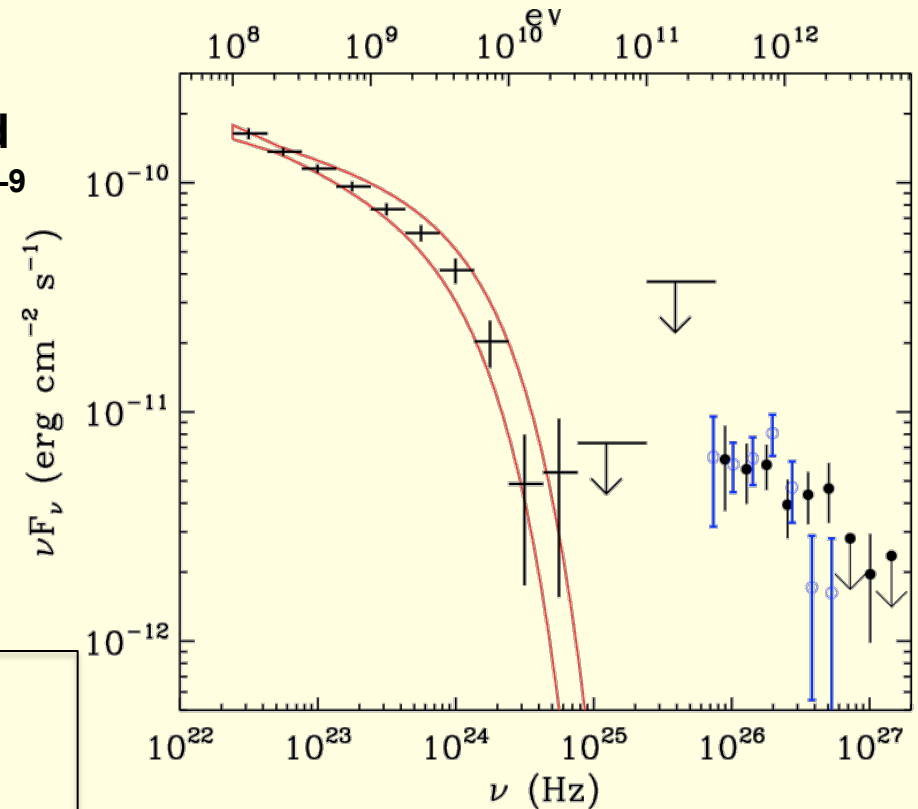
Unbinned likelihood fitting of the phase averaged flux yields

$$F = A E^{-\Gamma} \exp(-E/E_c)$$

Flux ( $E > 100$  MeV) =  $0.82 \pm 0.03$  (stat)  $\pm 0.07$  (syst)  $10^{-6}$  ph/cm<sup>2</sup>/s

$\Gamma = 2.21 \pm 0.04$  (stat)  $\pm 0.06$  (syst)

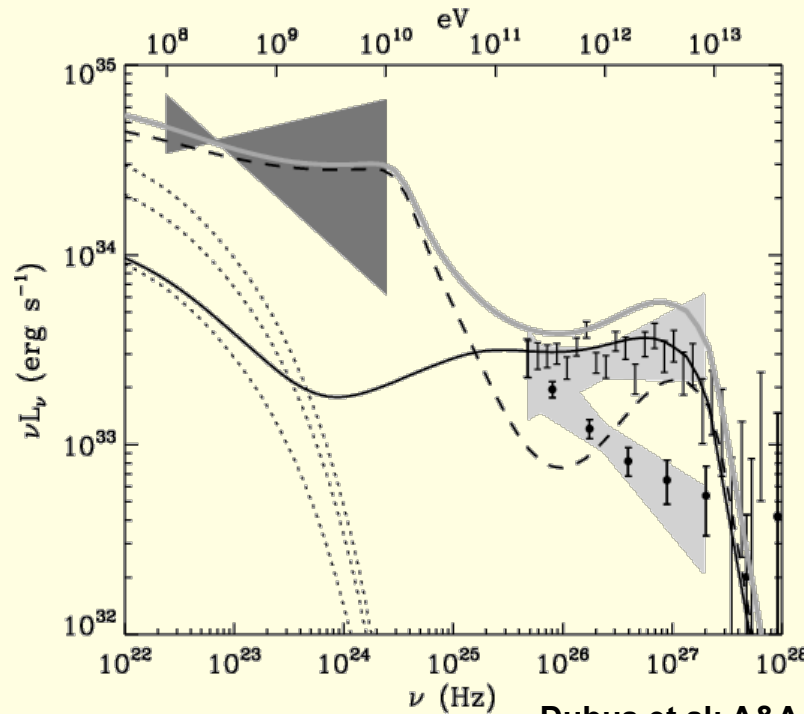
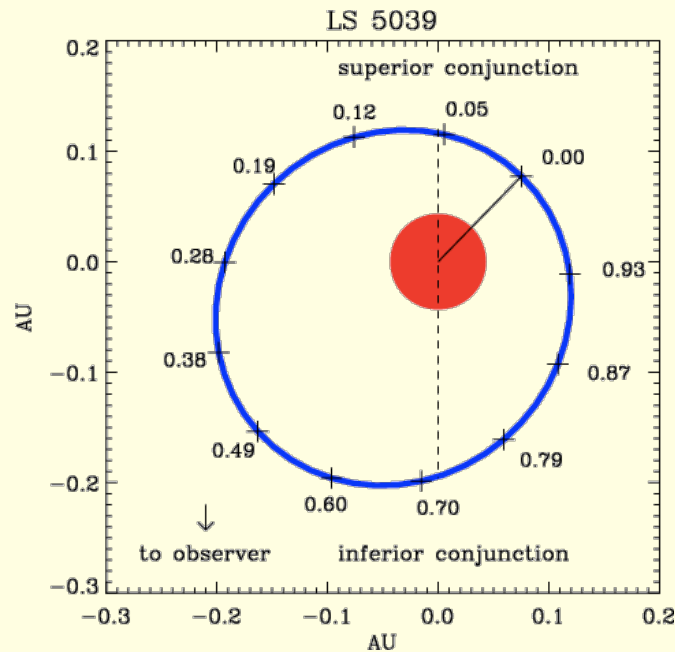
$E_c = 6.3 \pm 1.1$  (stat)  $\pm 0.4$  (syst) GeV



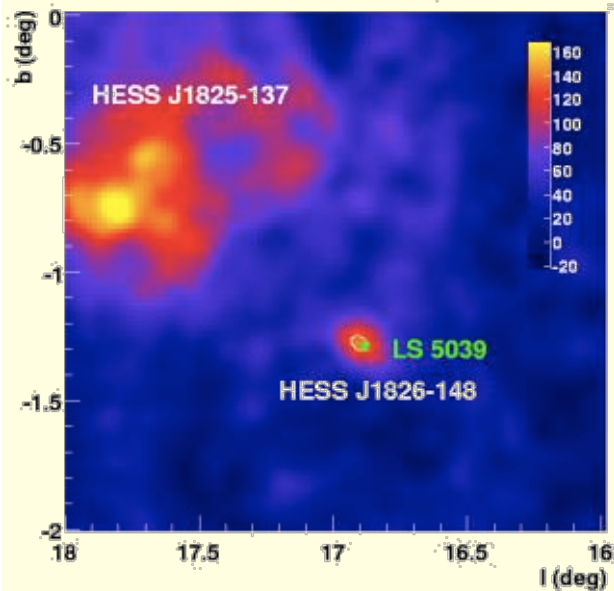
Points: Fitted energy bins  
 Red: unbinned power law fit envelope  
 Blue: MAGIC } phases 0.6-0.75  
 Black circles: Veritas }  
 (systematic errors not shown)

ApJL: 701 (2009) L123-L128

# LS 5039 @ HE: pre Fermi



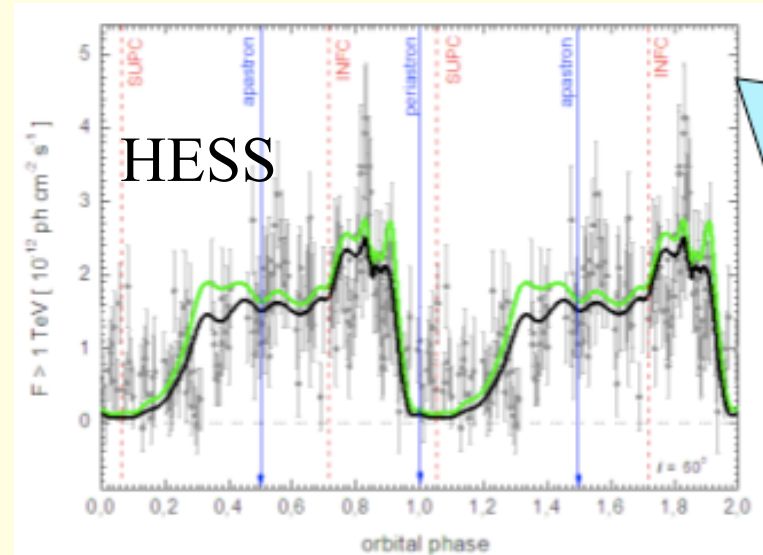
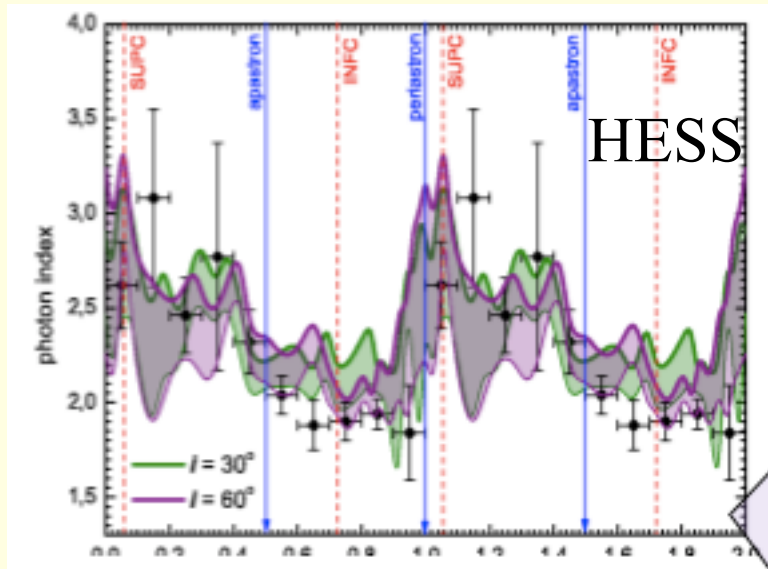
Dubus et al: A&A 477, 691-700 (2008)



- O6.5 companion star
- nature of compact object not nailed down
- HESS observed orbital period: 3.91 days
- no EGRET modulation seen – spatial coincidence only



# LS 5039: Fitting HESS Data



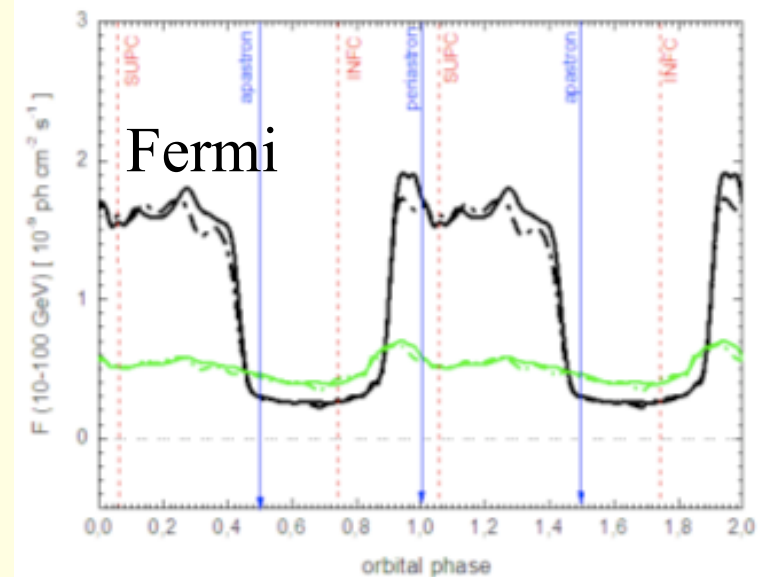
Sierpowska-Bartosik & Torres

**HESS sees high and low states,  
Depending on phase:**

**$\gamma\gamma$  absorption huge difference in obs flux**

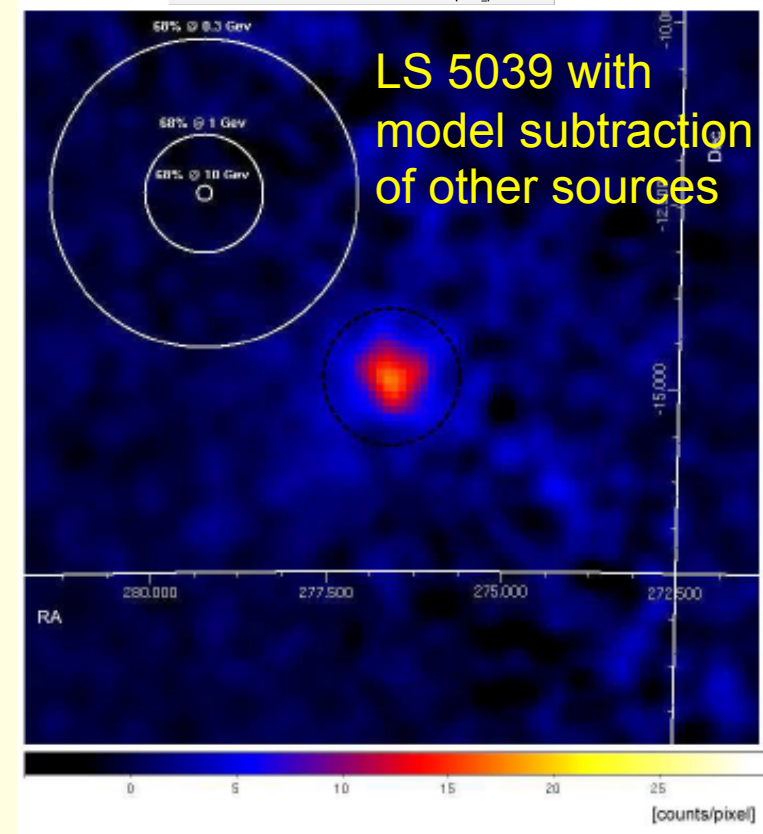
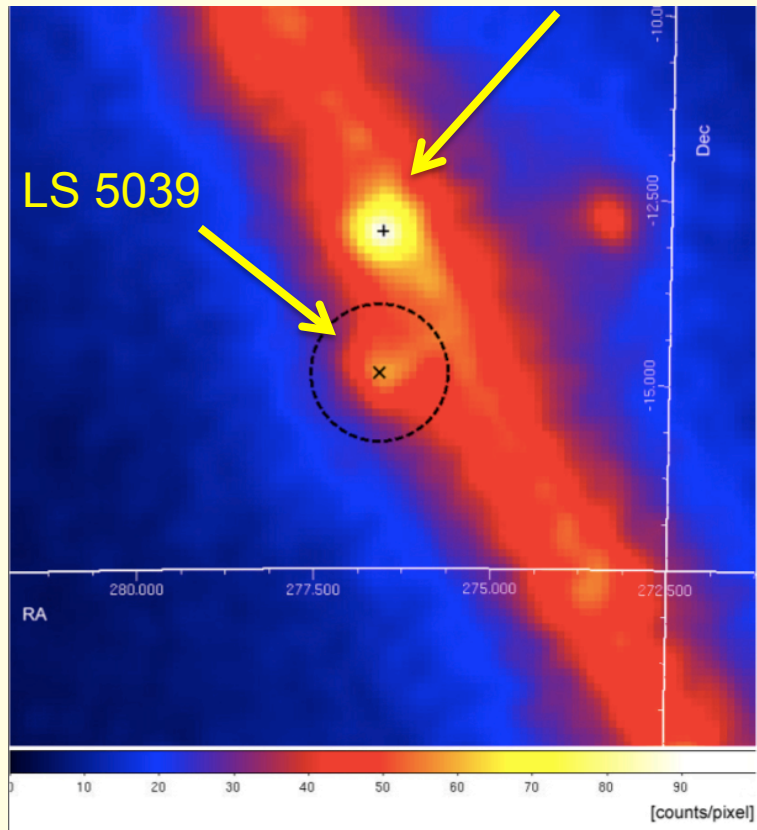
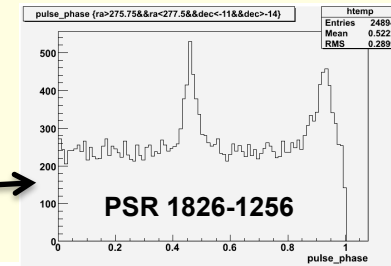
- higher flux, harder spectrum at INFC
- lower, softer at SUPC

• model Fermi by injecting e's with spectrum that matches HESS



# LS 5039

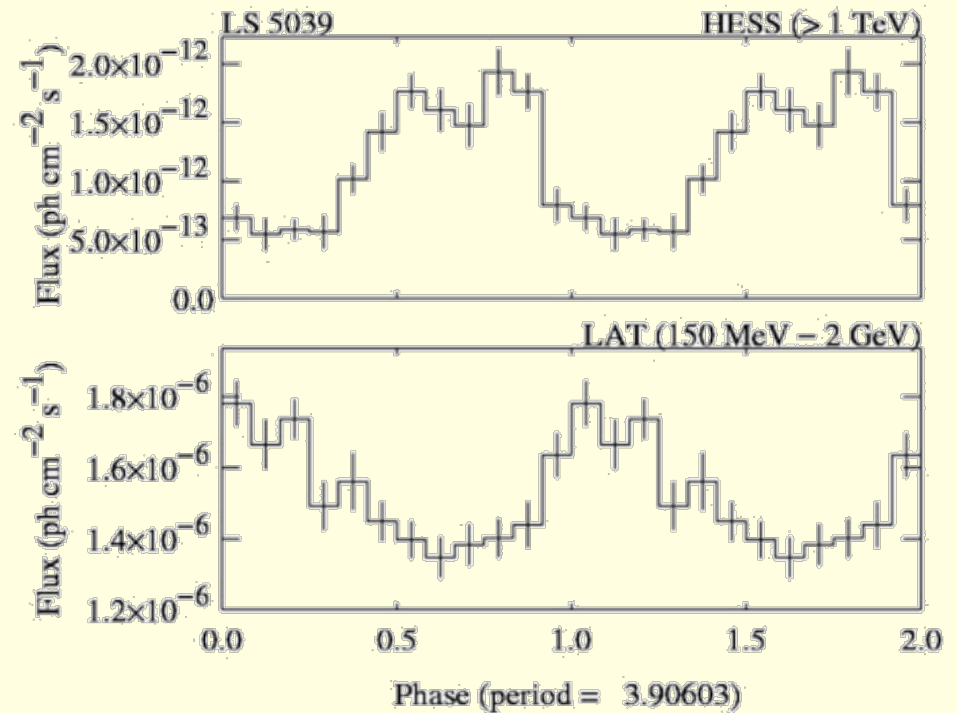
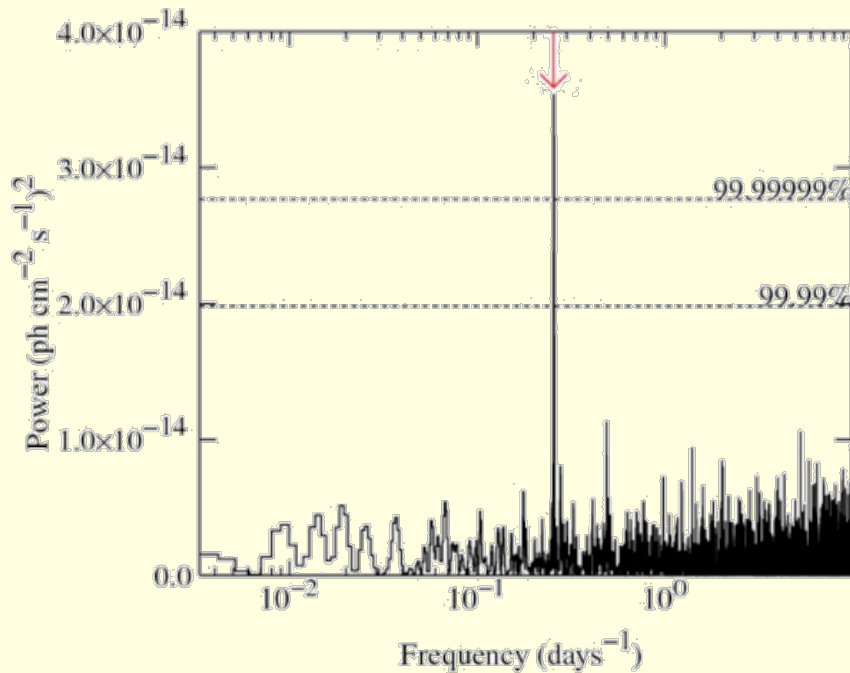
“background” PSR 1826-1256 removed using its pulse phase



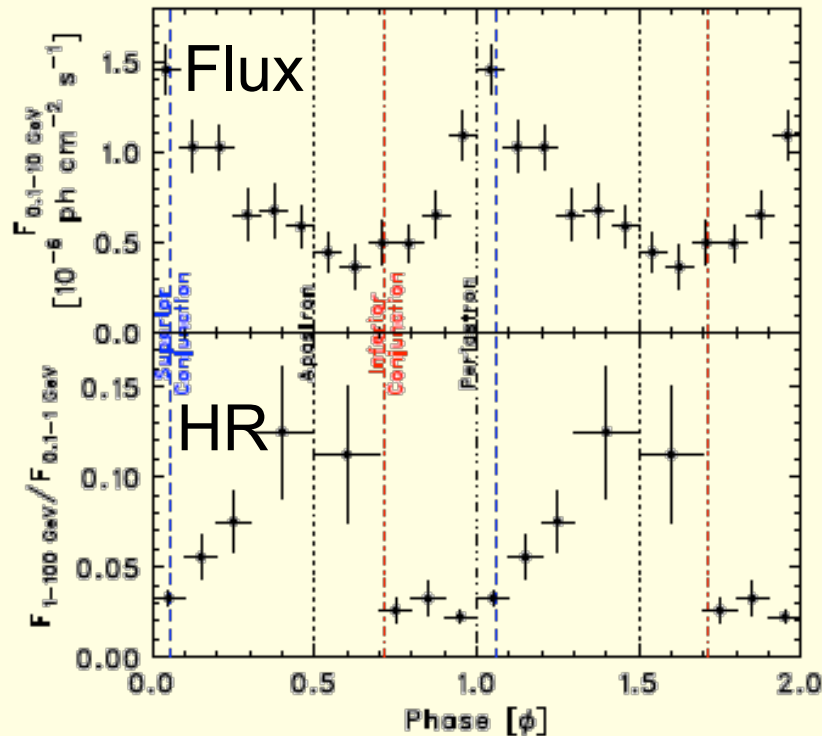
**LS 5039 sits in a bath of galactic diffuse emission!  
Detected at more than  $24.5 \sigma$**

# Definitive detection at GeV energies

- We detect a periodicity in the LS 5039 light curve at  $3.91 \pm 0.05$  days
- Folded light curve indicates peaks of emission around periastron – out of phase with VHE.

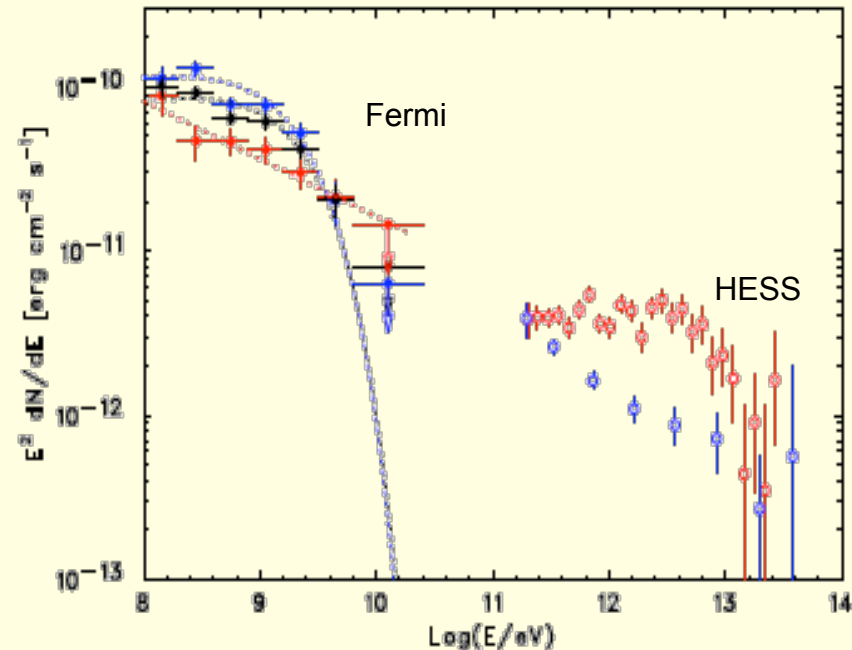


# LS 5039 Energy Dependence



Top: Flux > 100 MeV  
 Bottom: Hardness ratio – (1-100) GeV/ (0.1-1) GeV

Indications of spectral variability, most pronounced between inferior and superior conjunction

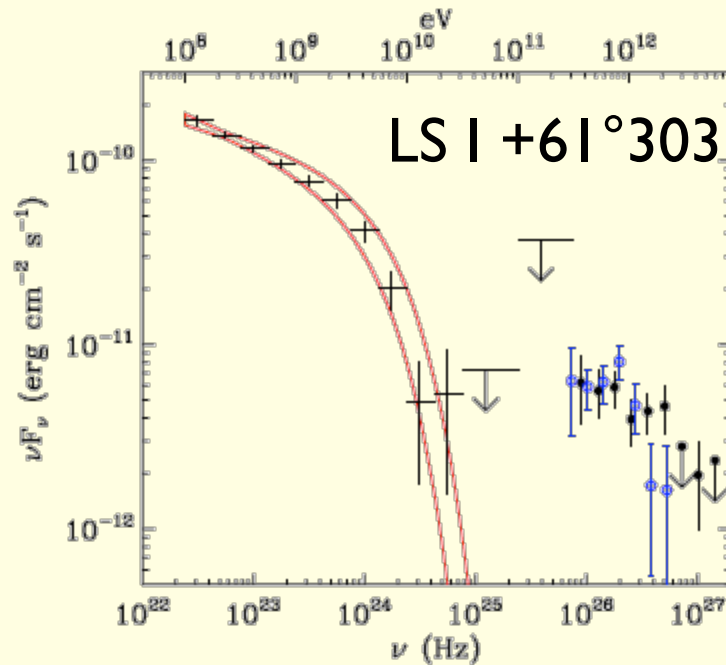


Blue – superior conjunction  
 Red – inferior conjunction

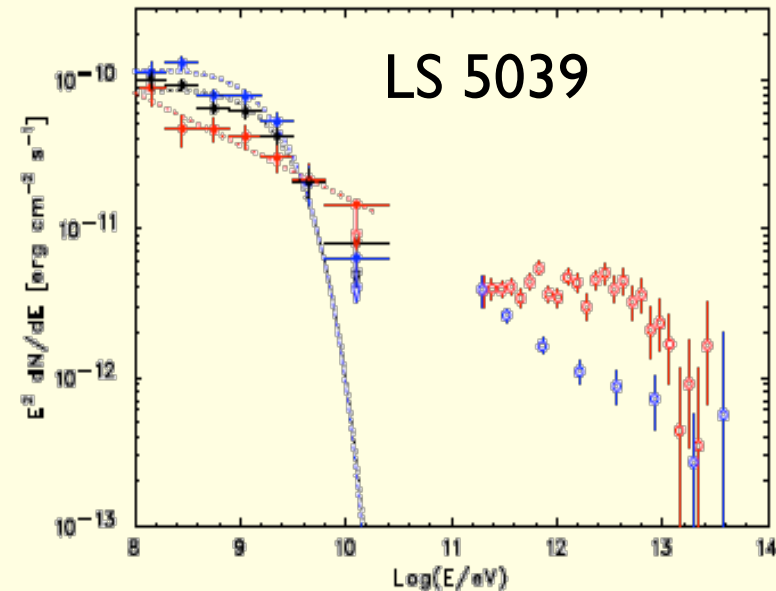
We see an exponential cutoff here too. Insufficient statistics at INFC to confirm exp cutoff. Bulk of data is at SUPC.



# Binaries: What sort of emission is this?



Average spectrum:  
Index: 2.21, Cutoff: 6.3 GeV



Average spectrum:  
Index: 1.9, Cutoff: 2.1 GeV

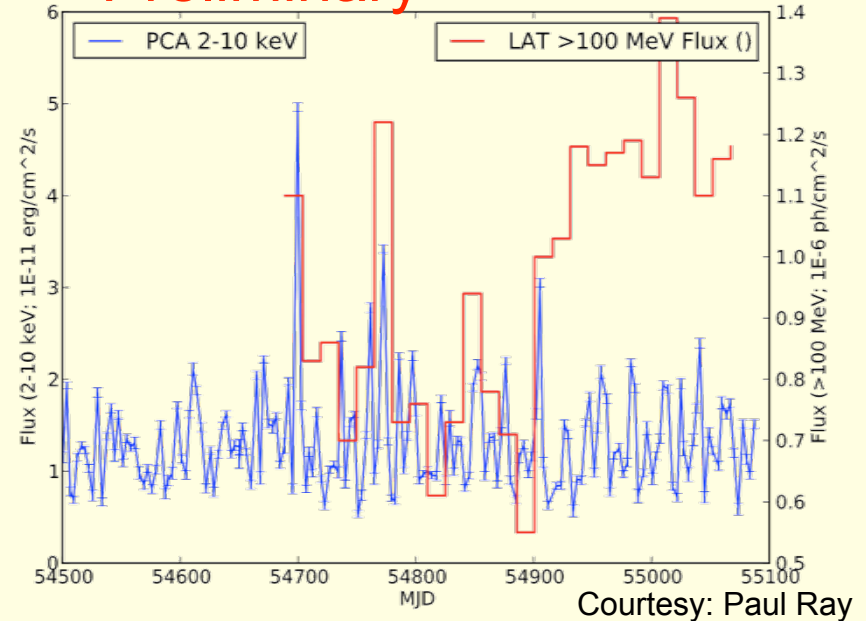
- **Exponential cut-offs are reminiscent of the Fermi pulsar spectra; is this a sign of magnetospheric emission in these systems?**
- **Difficult to reconcile with orbital variability of spectrum**
- **Further investigation required**

# Is LS I +61 303 Up to Something Lately?

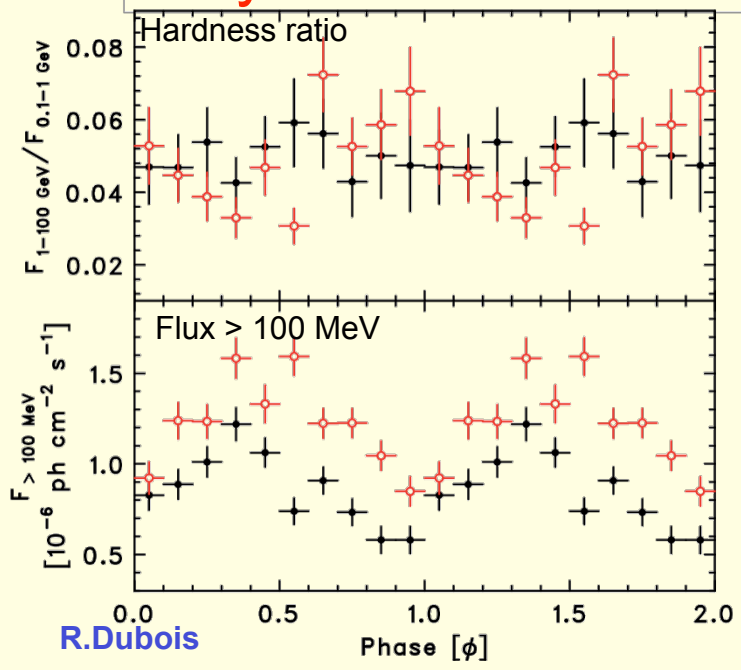
**Preliminary** LS I Flux by Week



**Preliminary**



**Preliminary**



- pre Mar '09  
- post Mar '09

RXTE – LAT correlation

- Flux increase of ~40% after March '09
- more flux in apastron region wrt periastron
- odd feature at phase 0.5-0.6
- “flares” appear to correlate with x-ray?
  - March event a change of state?
  - no x-ray counterpart to July flare
  - any relation to 4 year radio period?

# Summary

- First positive identifications of LS I +61 303 & LS 5039 at GeV energies
- Observation of exponential cutoff spectrum in both cases
  - Looks suspiciously like the spectra from our pulsars...
- We'll keep looking as more data comes in
- ... meanwhile, look for other "LS"s in the galaxy...

