



Fermi- LAT

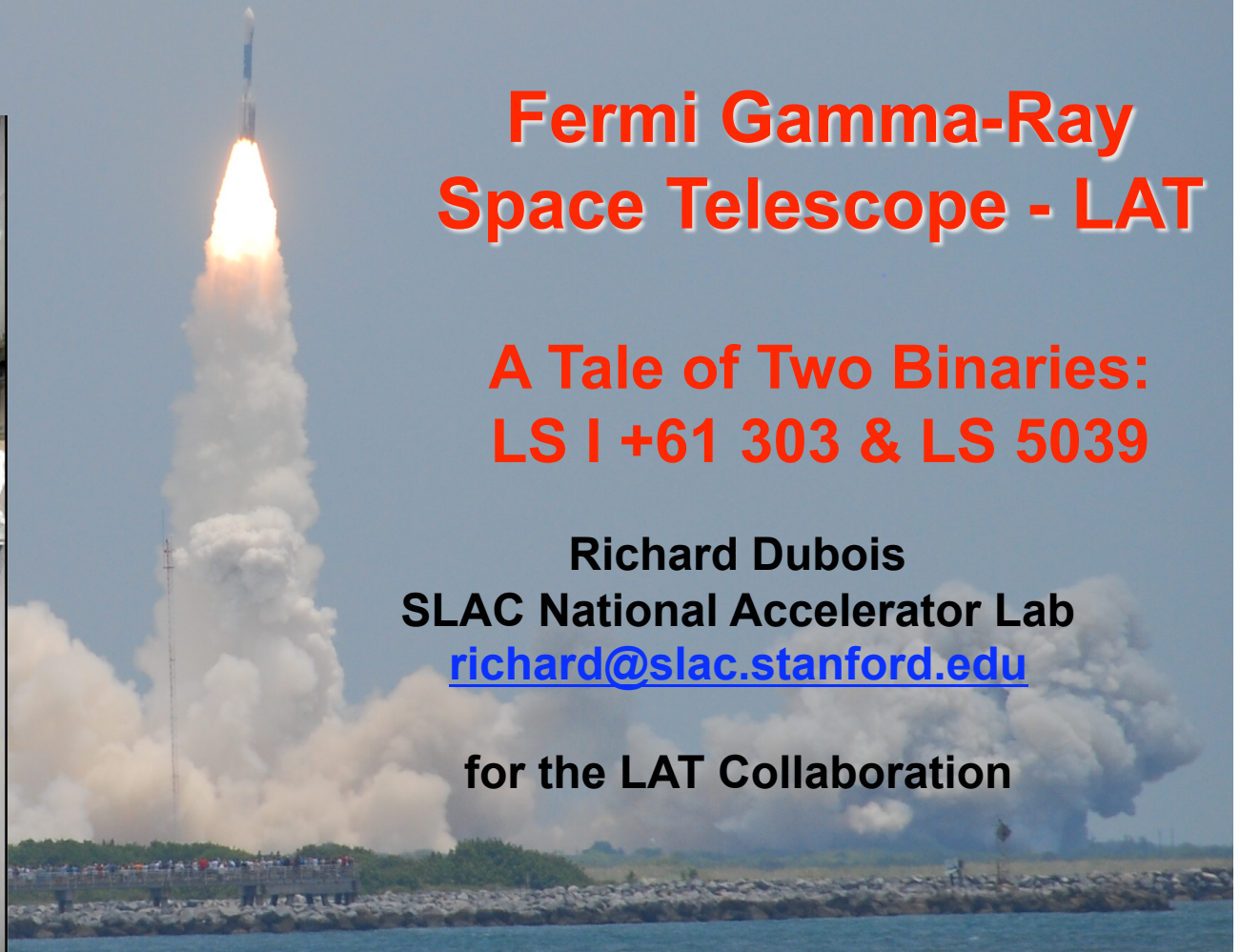
Fermi Symposium Washington DC Nov 4, 2009

Fermi Gamma-Ray Space Telescope - LAT

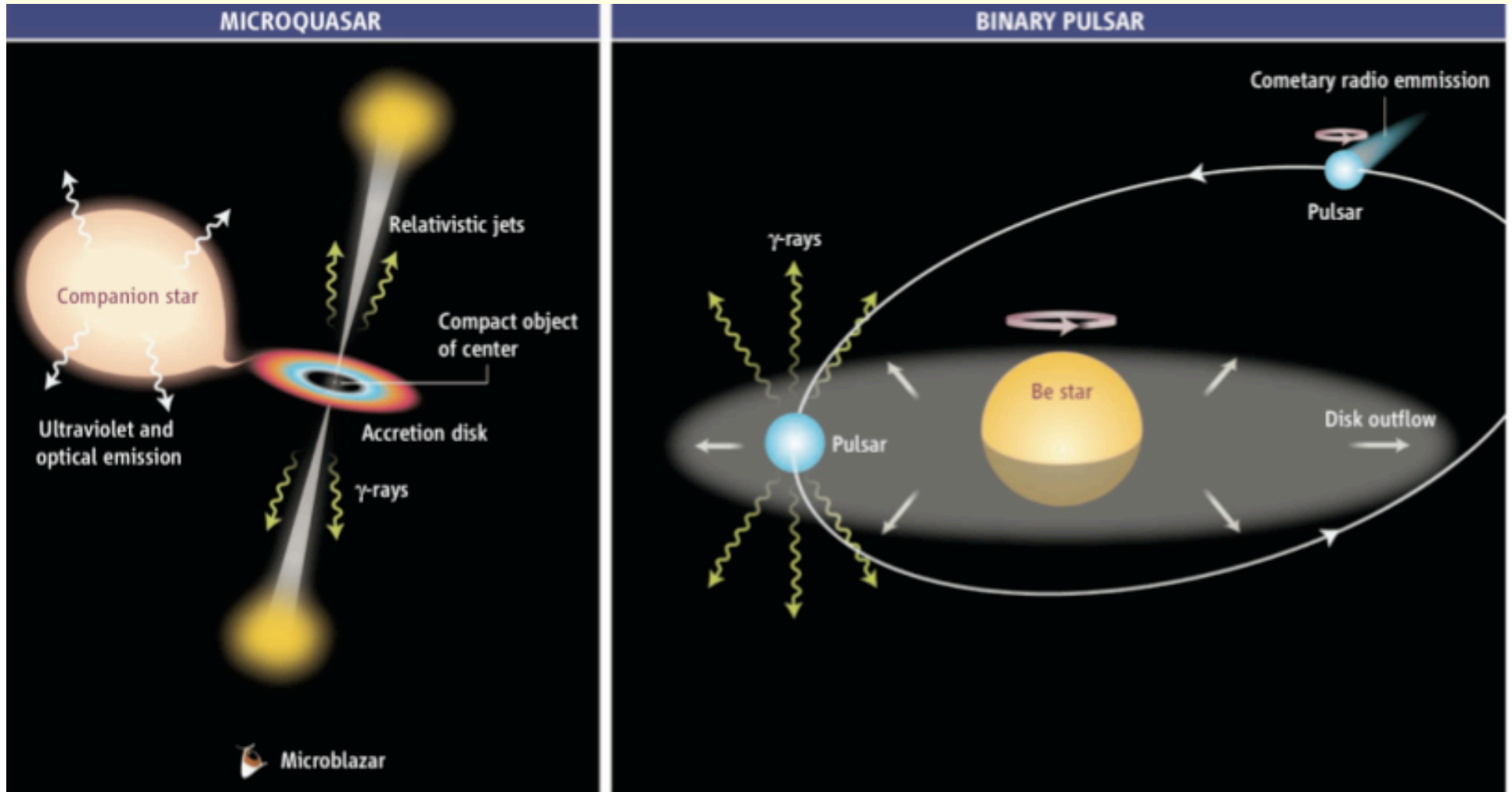
A Tale of Two Binaries: LS I +61 303 & LS 5039

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for the LAT Collaboration



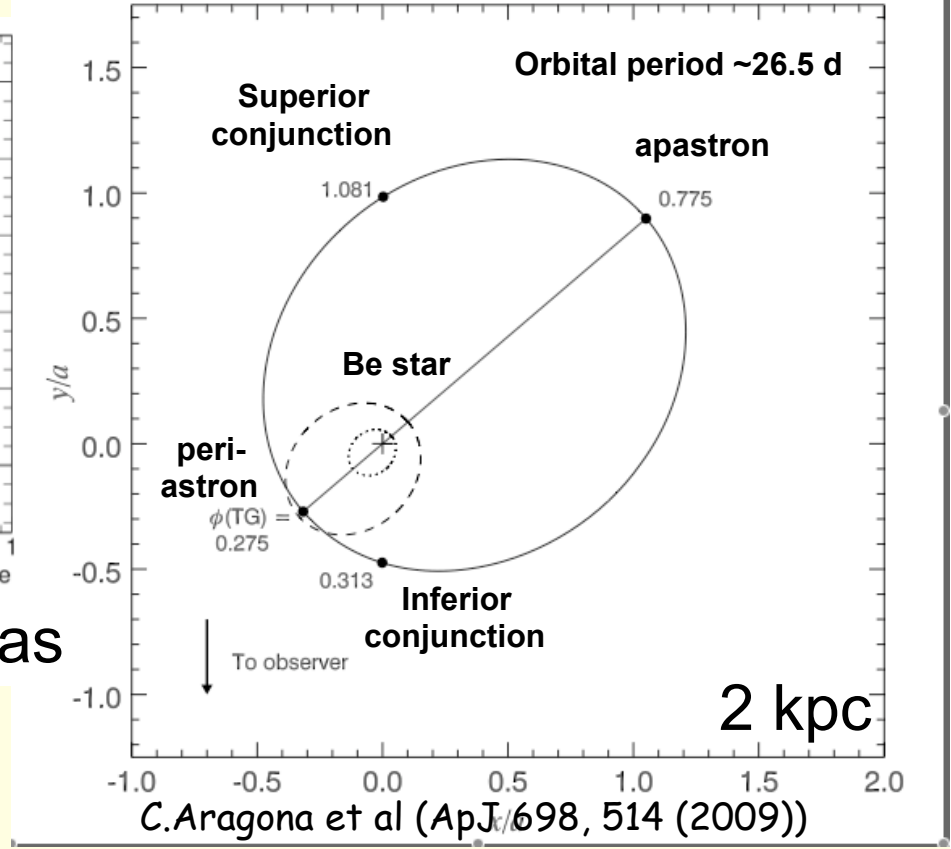
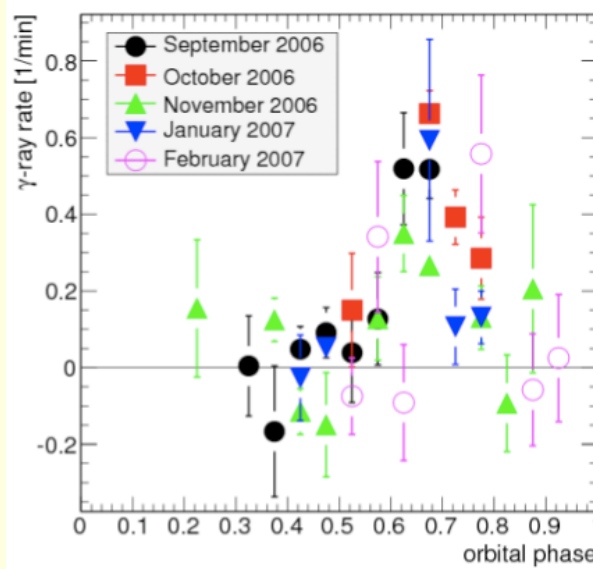
Microquasar or Pulsar?



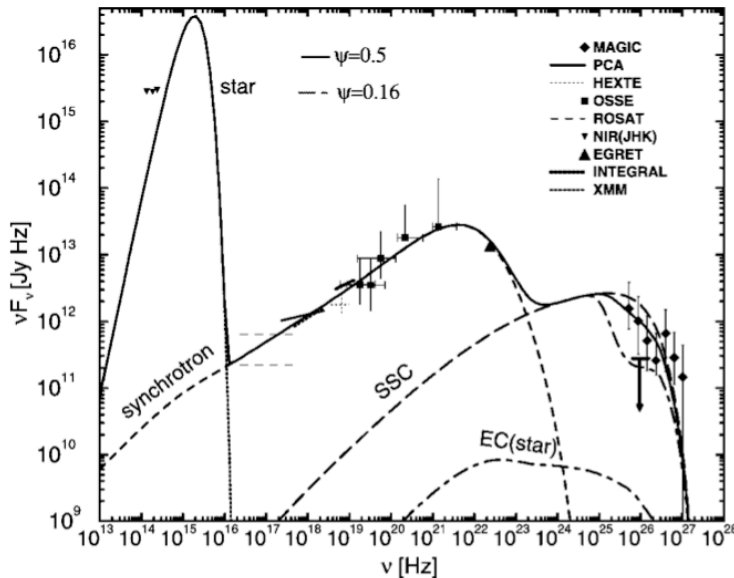
from: Mirabel (Science 309, 714, 2006)

The "Easy" Binary: LS I +61⁰ 303

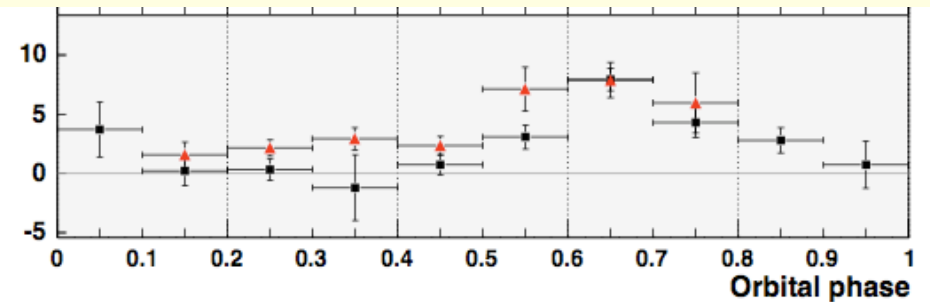
EGRET: $\gamma = -2.19 \pm 0.07$
 MAGIC: $\gamma = -2.6 \pm 0.2$
 Veritas: $\gamma = -2.6 \pm 0.2$



Veritas



ApJ, 650:L123-L126, 2006



MAGIC

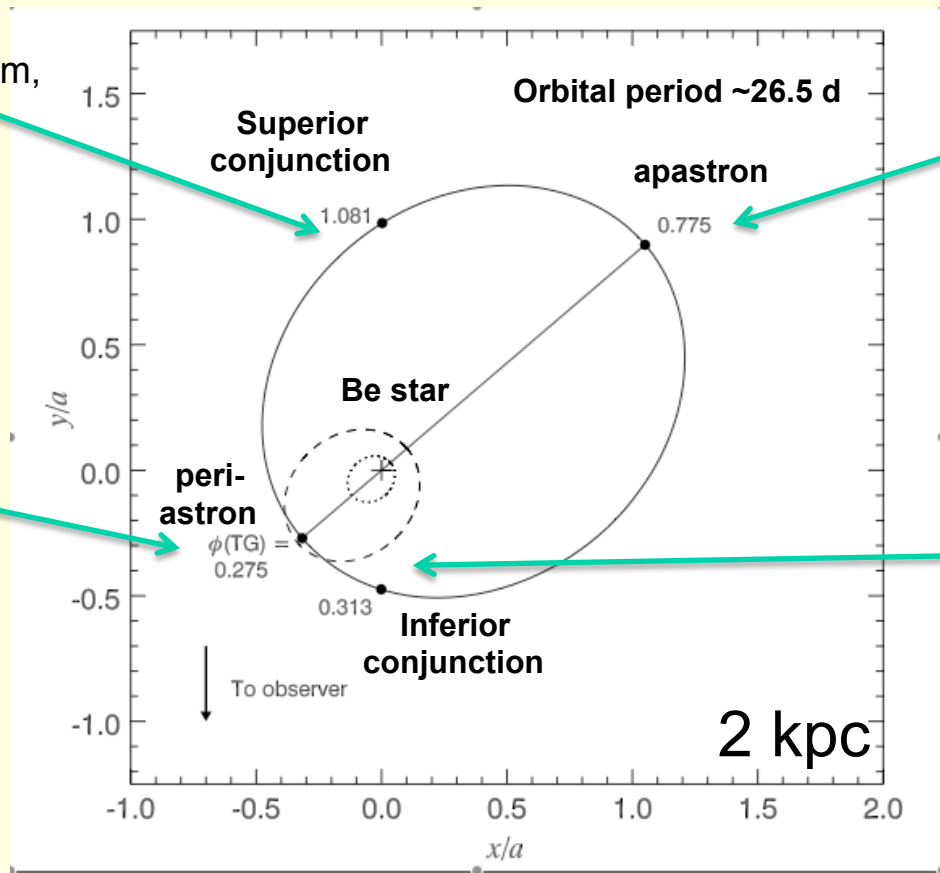
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Reminder of Periodic Effects

Backscatter to observer: softer spectrum, higher flux

Brightest scattering target:

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



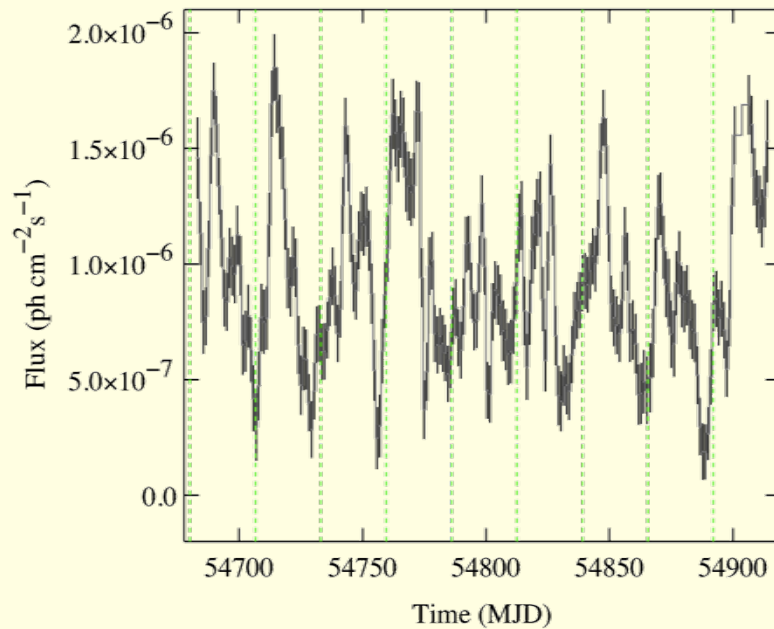
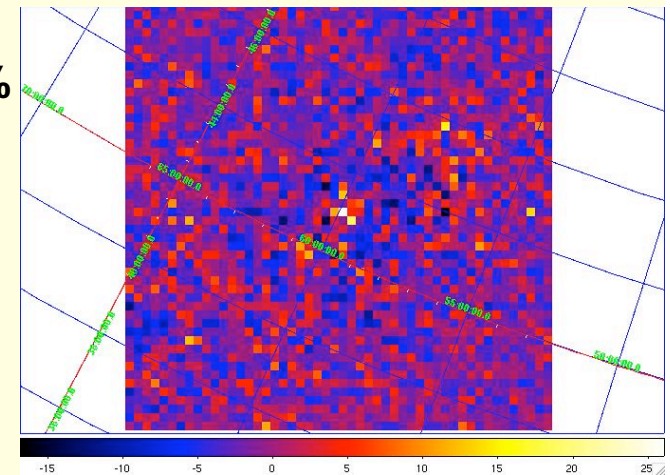
Dimmest scattering target

Forward scatter to observer: harder spectrum, lower flux

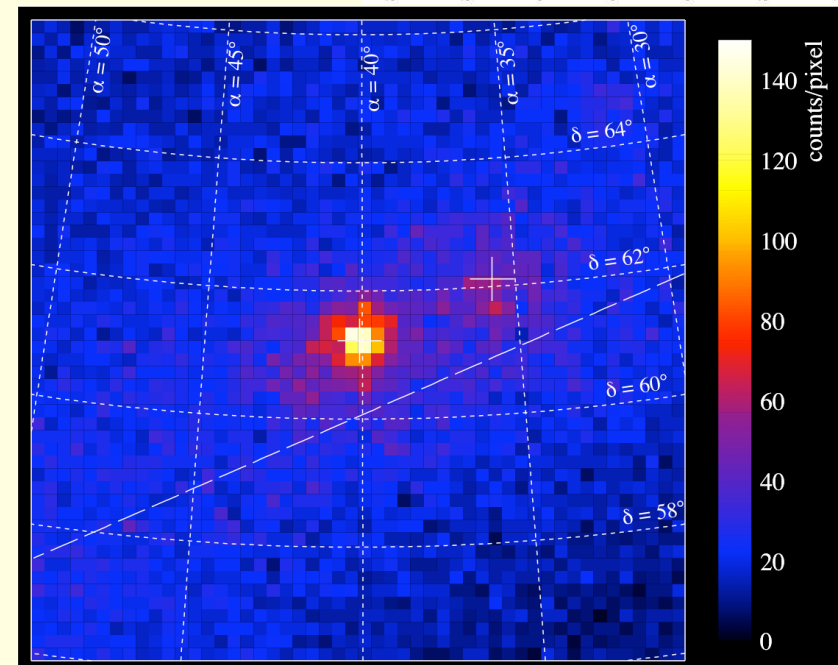
Fermi view of LS I +61°303

- 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

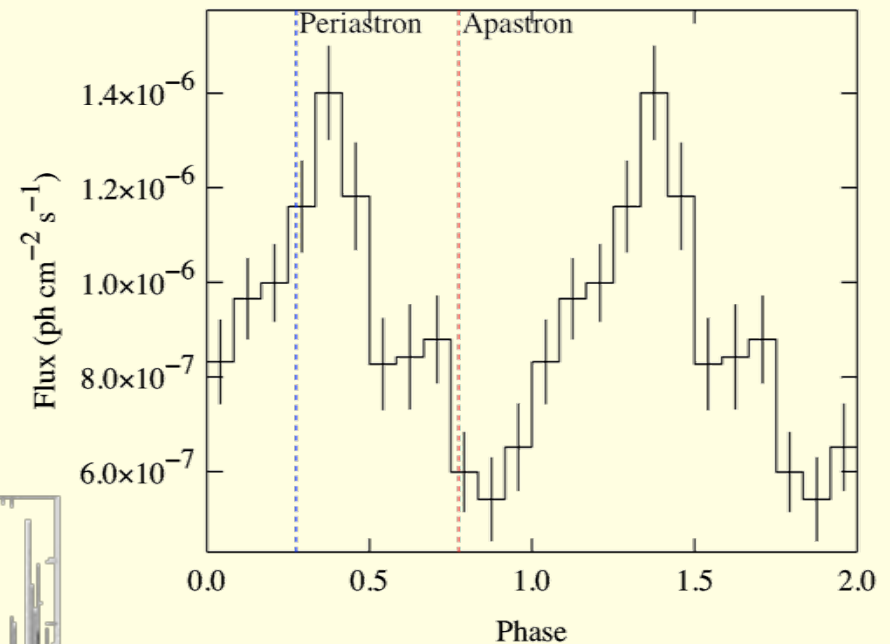
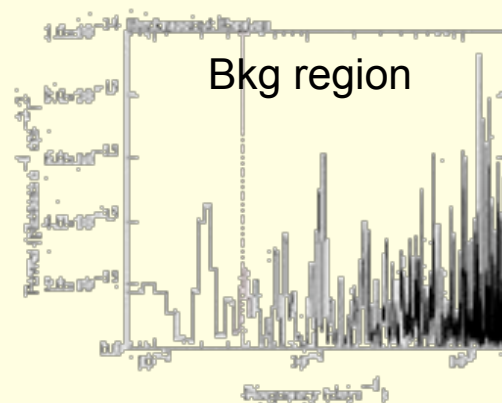
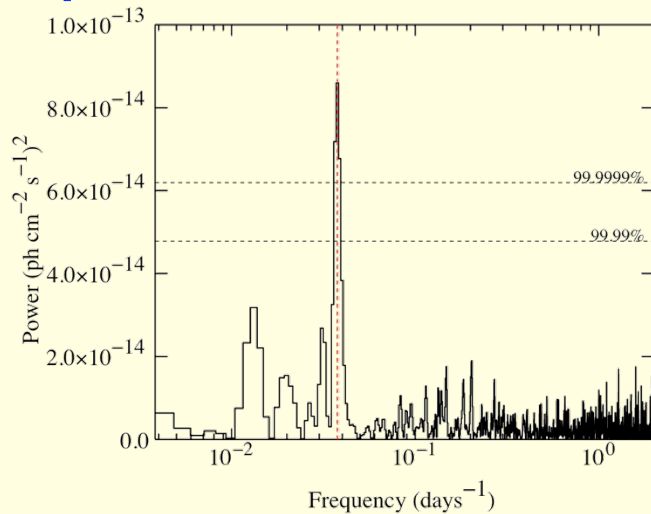


R.Dubois



First definitive detection at GeV energies

- We detect a periodicity in the LS I +61°303 light curve at 26.6 ± 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 $\sim 10^{-9}$

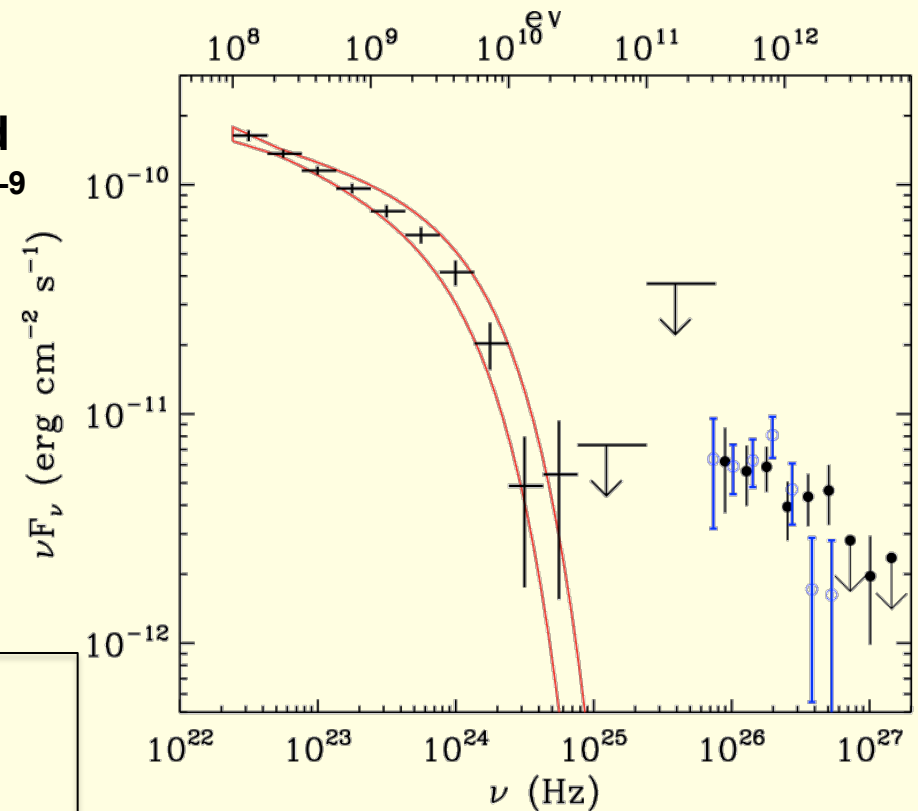
Unbinned likelihood fitting of the phase averaged flux yields

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

Flux ($E > 100$ MeV) = 0.82 ± 0.03 (stat) ± 0.07 (syst) 10^{-6} ph/cm²/s

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

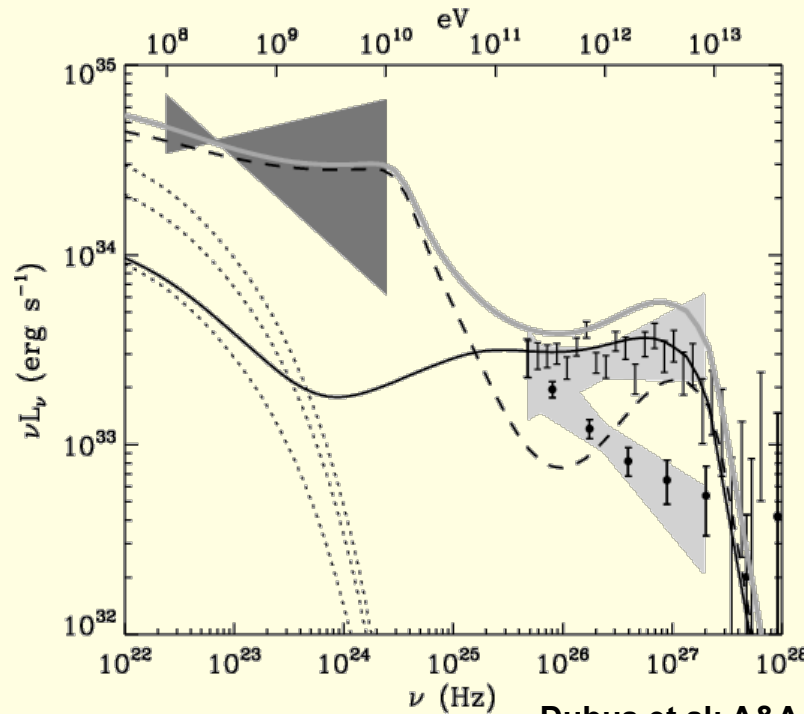
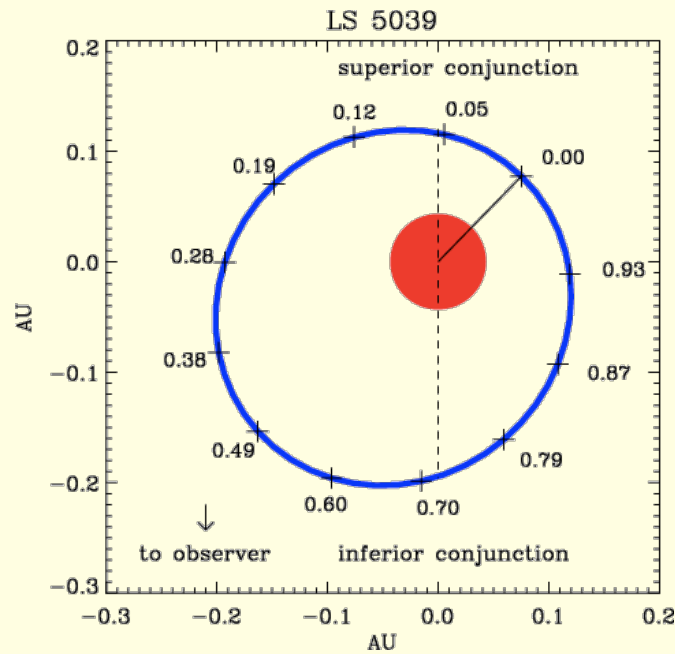
$E_c = 6.3 \pm 1.1$ (stat) ± 0.4 (syst) GeV



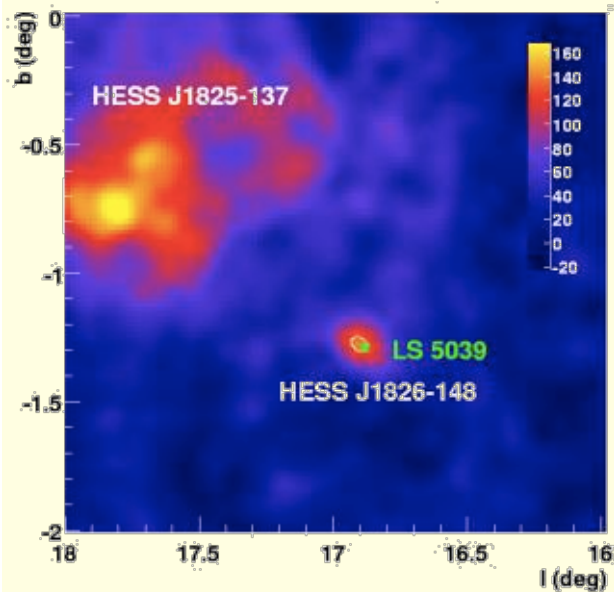
Points: Fitted energy bins
 Red: unbinned power law fit envelope
 Blue: MAGIC
 Black circles: Veritas } phases 0.6-0.75
 (systematic errors not shown)

ApJL: 701 (2009) L123-L128

LS 5039 @ HE: pre Fermi

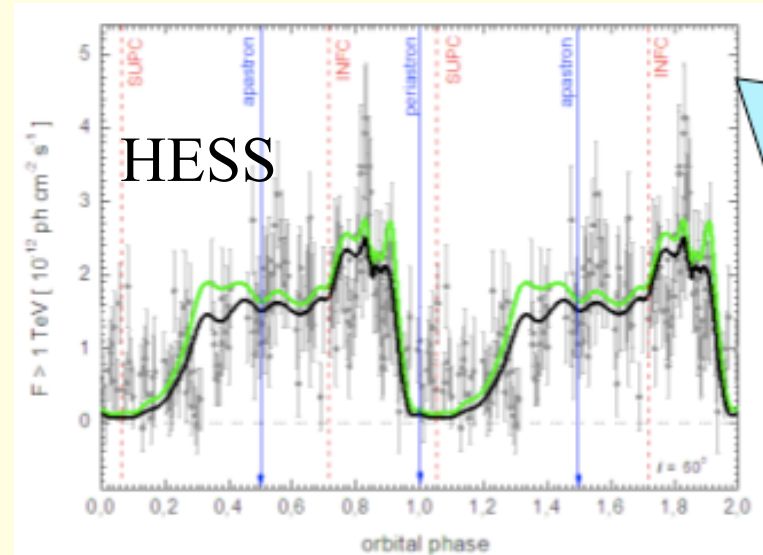
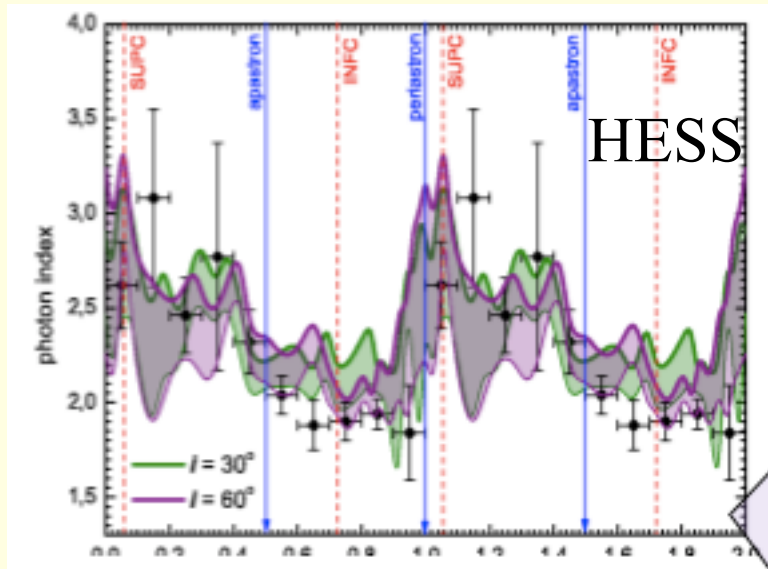


Dubus et al: A&A 477, 691-700 (2008)



- 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



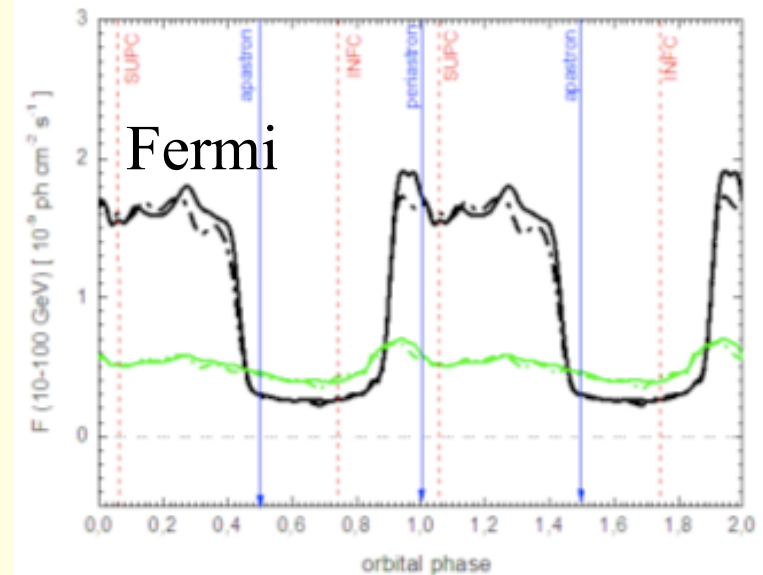
Sierpowska-Bartosik & Torres

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

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

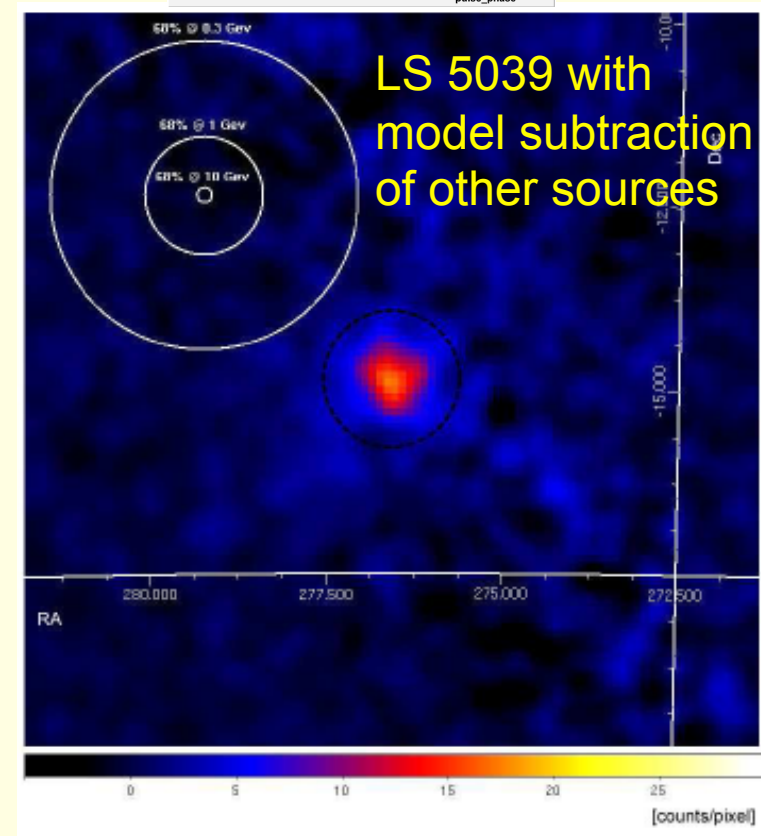
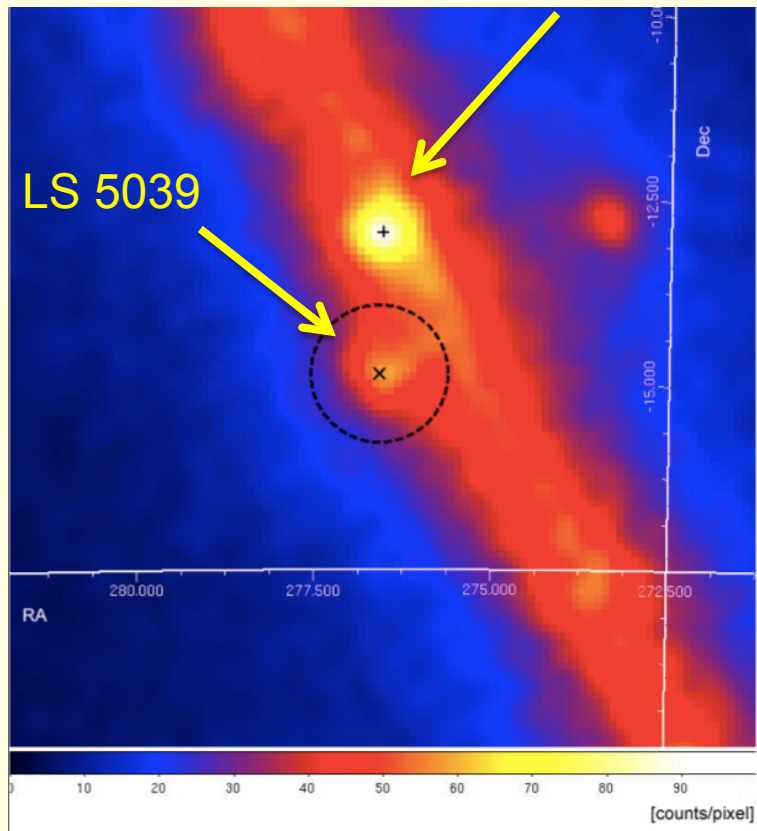
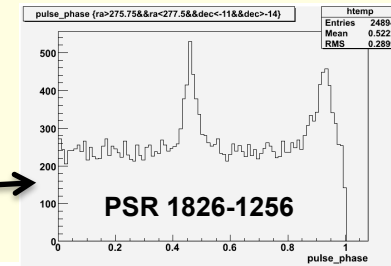
- higher flux, harder spectrum at INFC
- lower, softer at SUPC

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



LS 5039

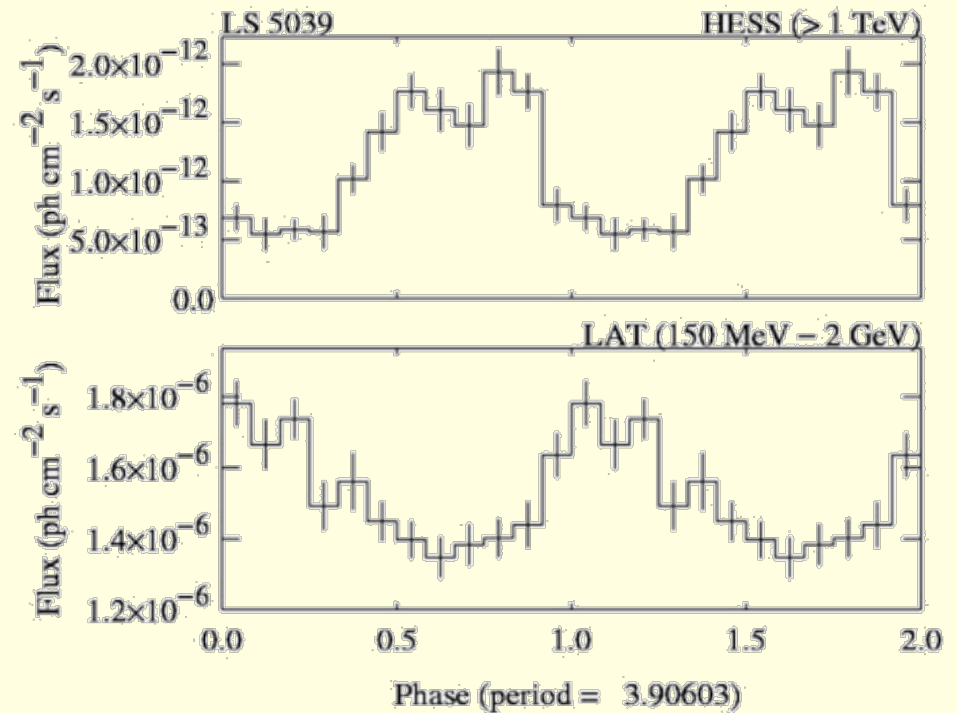
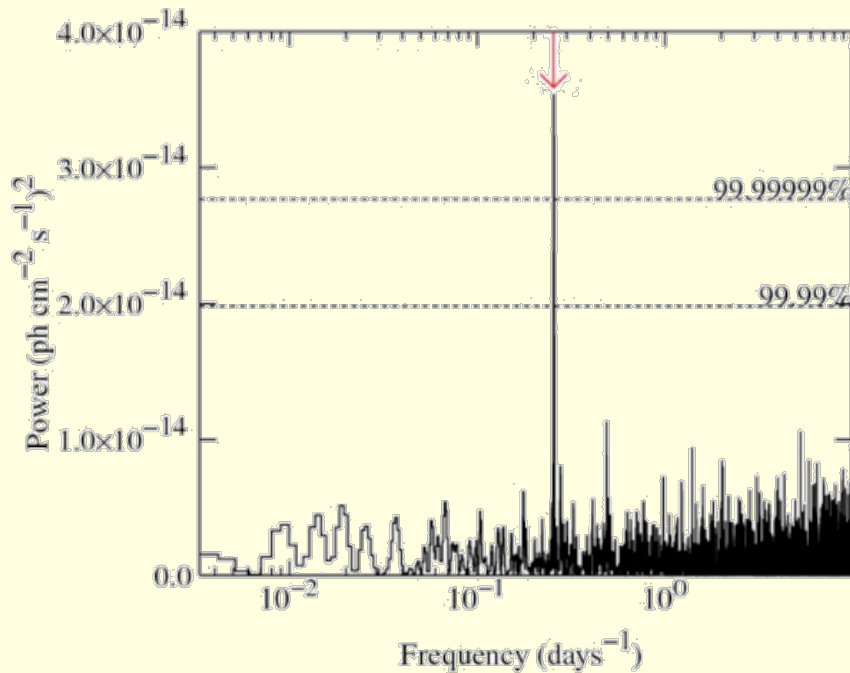
“background” PSR 1826-1256 removed using its pulse phase



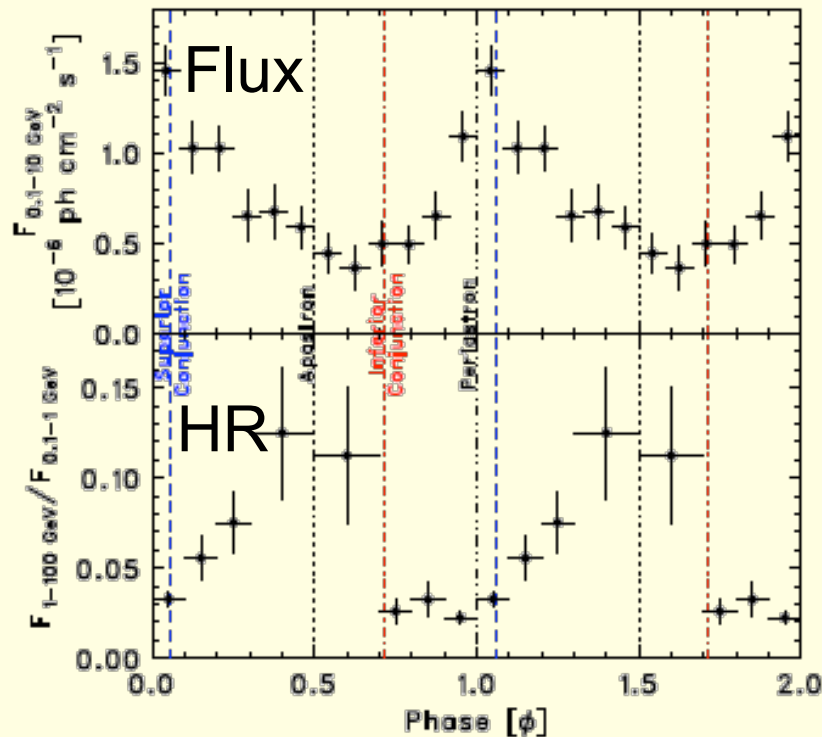
**LS 5039 sits in a bath of galactic diffuse emission!
Detected at more than 24.5σ**

Definitive detection at GeV energies

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

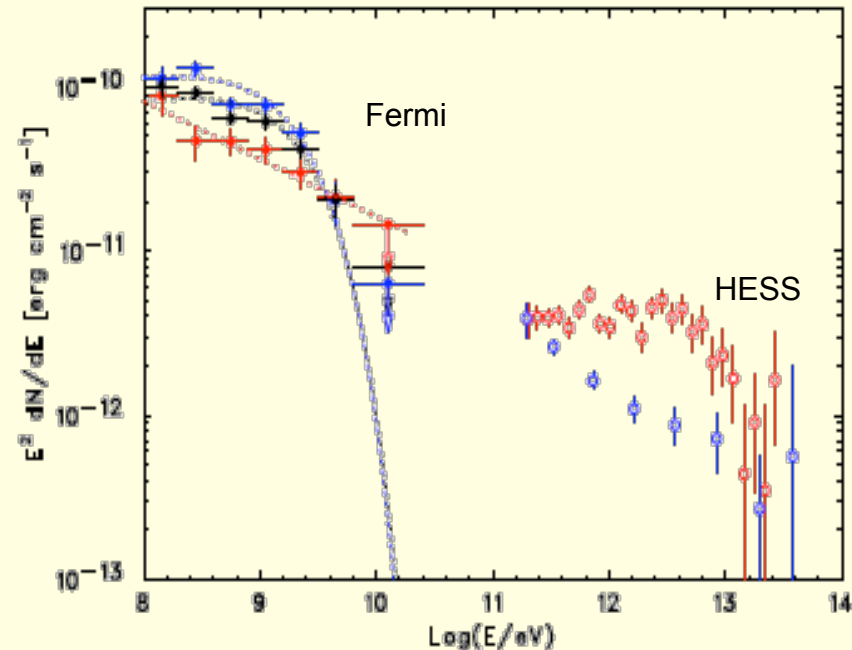


LS 5039 Energy Dependence



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

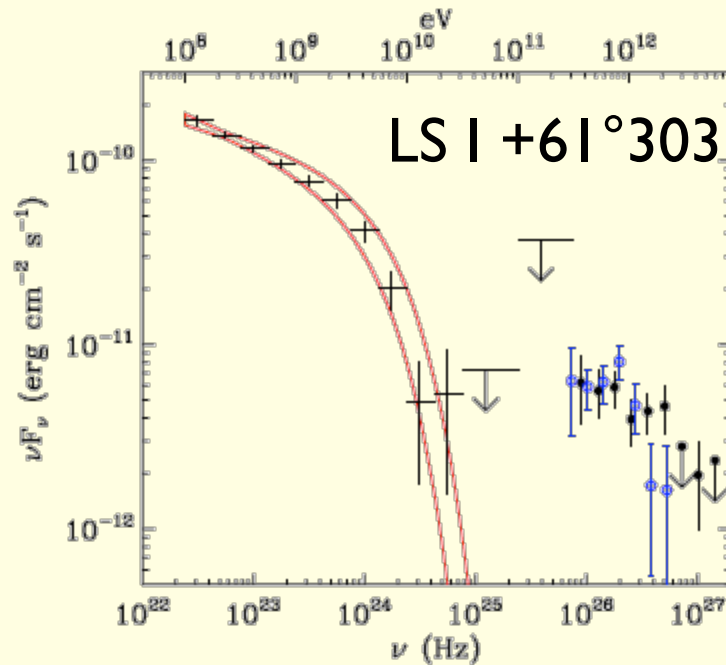
Indications of spectral variability, most pronounced between inferior and superior conjunction



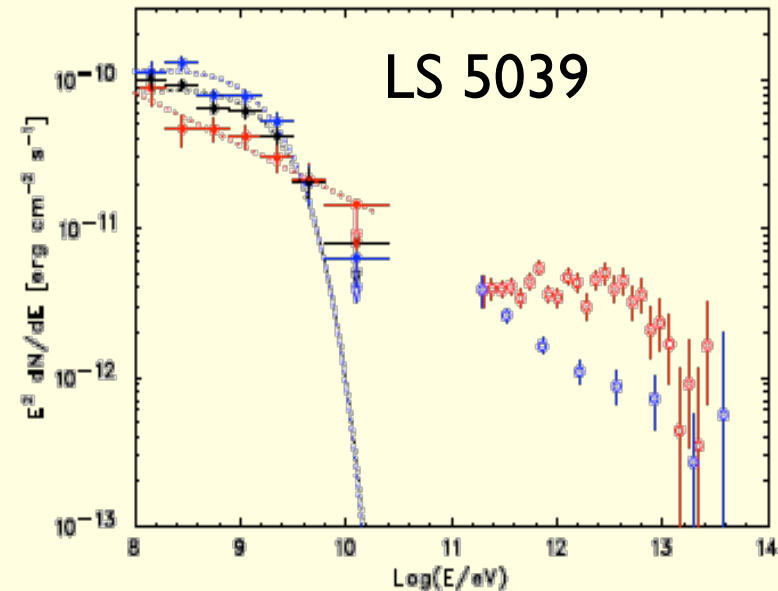
Blue – superior conjunction
 Red – inferior conjunction

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

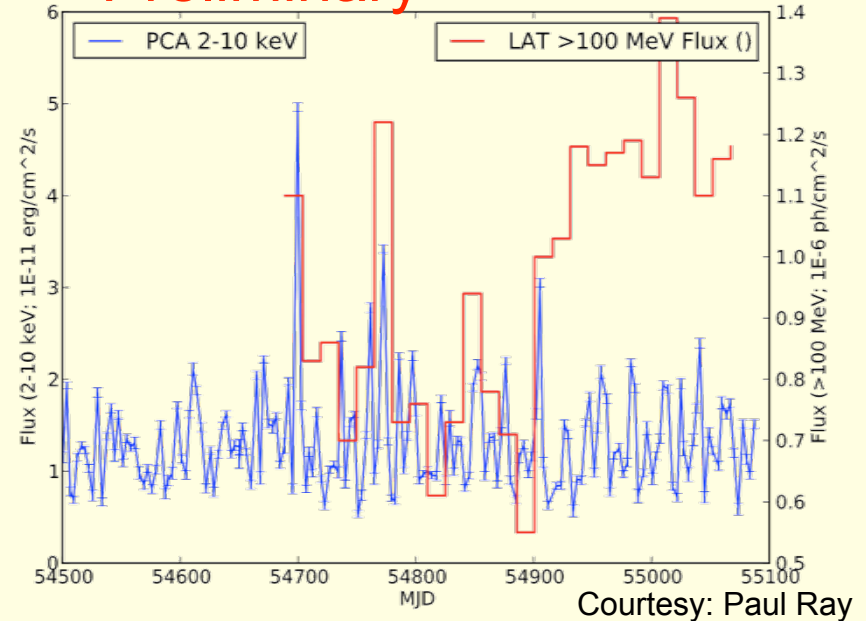
- Exponential cut-offs are reminiscent of the Fermi pulsar spectra; is this a sign of magnetospheric emission in these systems?
- Difficult to reconcile with orbital variability of spectrum
- Further investigation required

Is LS I +61 303 Up to Something Lately?

Preliminary LS I Flux by Week

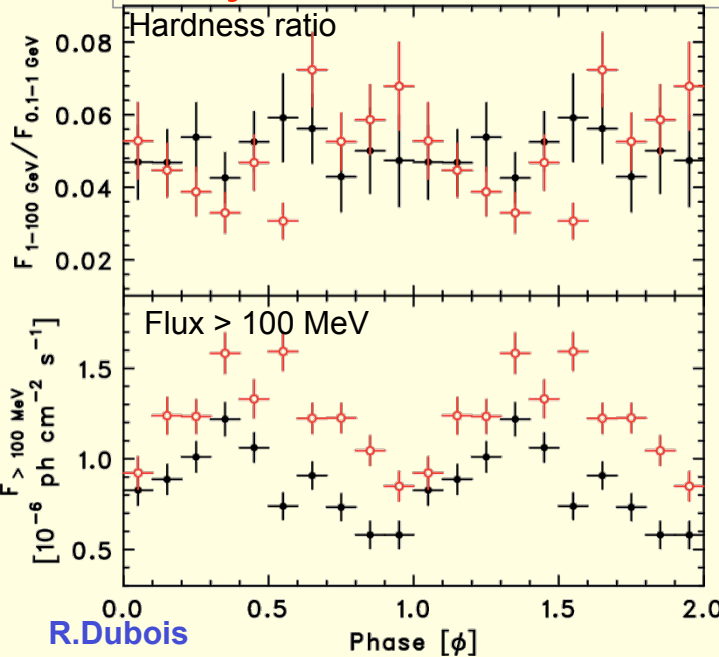


Preliminary



Courtesy: Paul Ray

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...

