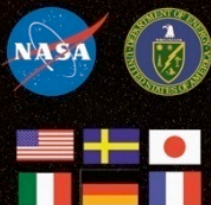
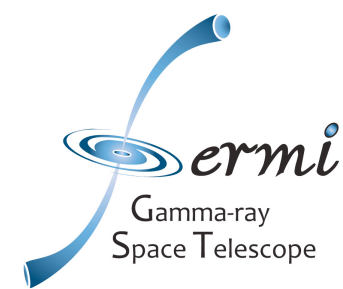


National Aeronautics and Space Administration



Fermi  
Gamma-ray Space Telescope

[www.nasa.gov/fermi](http://www.nasa.gov/fermi)



# X-ray Binaries by Fermi LAT

Takaaki Tanaka  
(SLAC/KIPAC)



on behalf of the Fermi collaboration

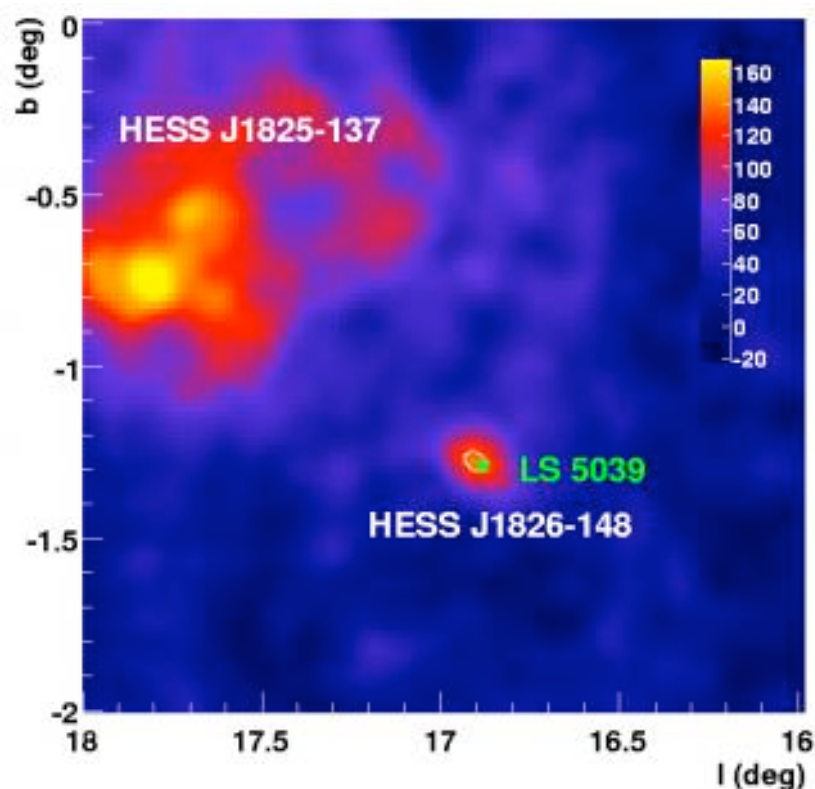
First Results from Fermi Gamma-ray Space Telescope  
@ Tokyo Institute of Technology, Mar. 7, 2009



# Binaries in Gamma-rays

Four Sources are claimed as TeV emitters  
All of the four are high-mass X-ray binaries

LS 5039

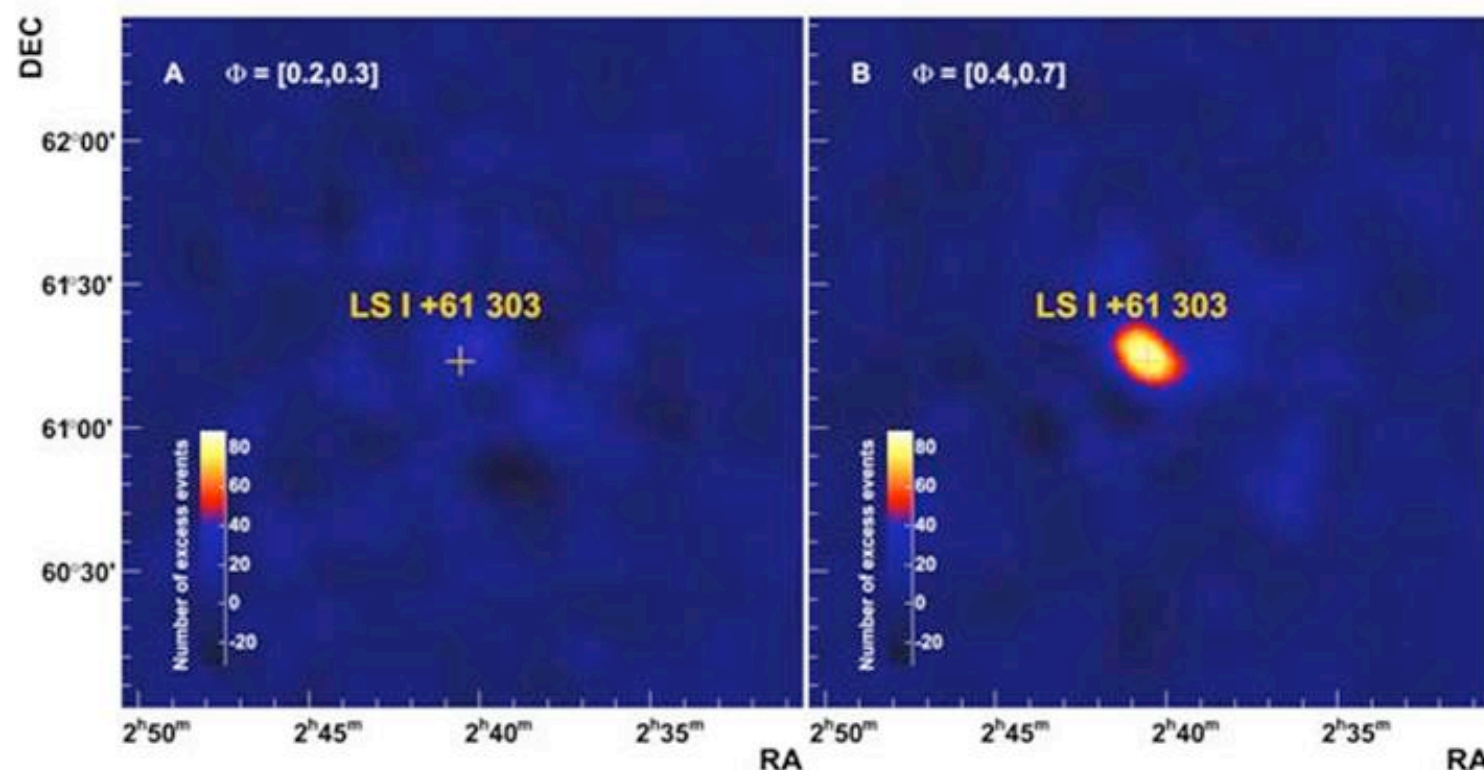


O star + ?

H.E.S.S. detected

Periodicity

LS I +61° 303



Be star + ?

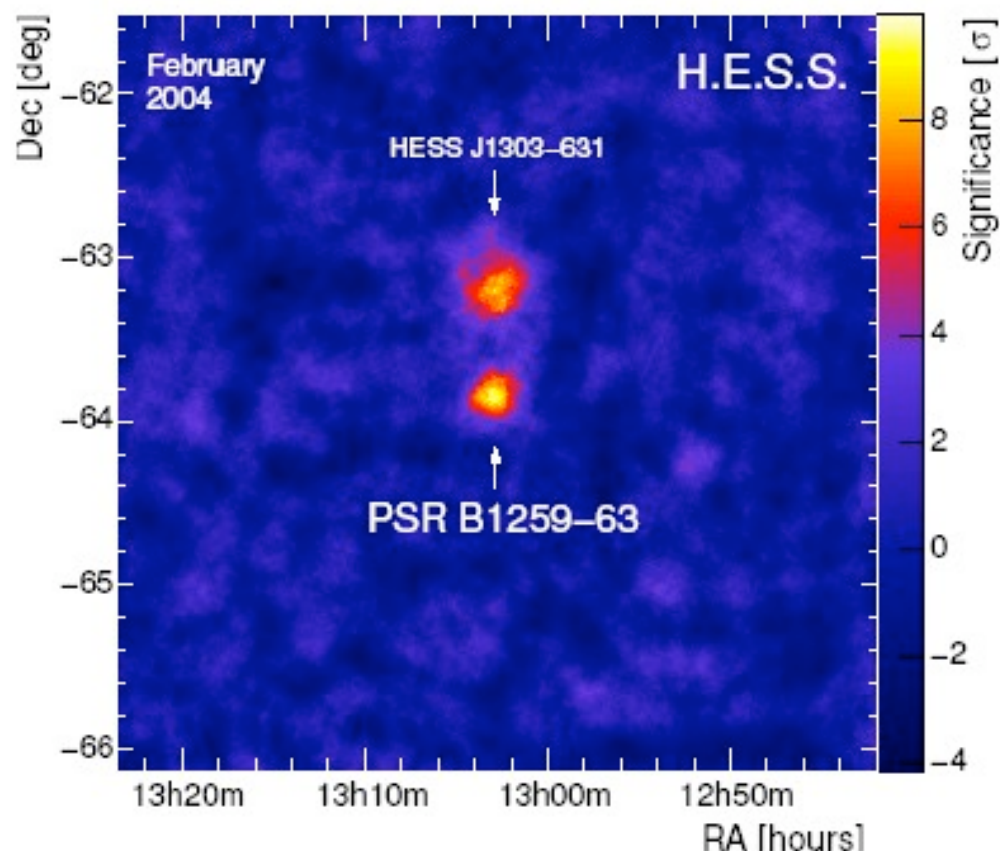
MAGIC & VERITAS detected

Periodicity

# Binaries in Gamma-rays

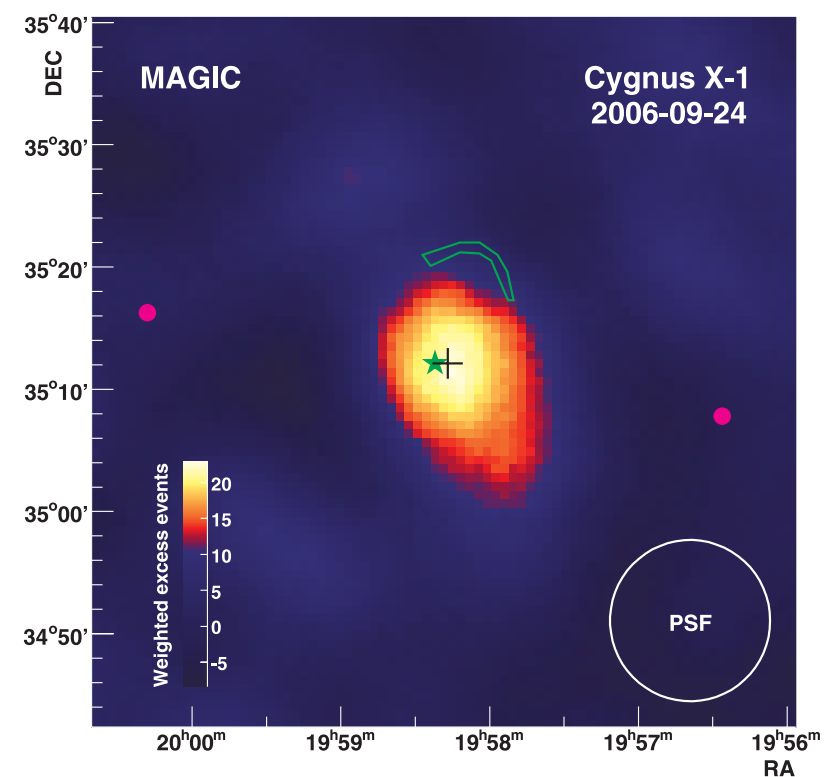
Four Sources are claimed as TeV emitters  
All of them are high-mass X-ray binaries

PSR B1259-63



Be star + Radio Pulsar  
H.E.S.S. detected  
around Periastron

Cyg X-1

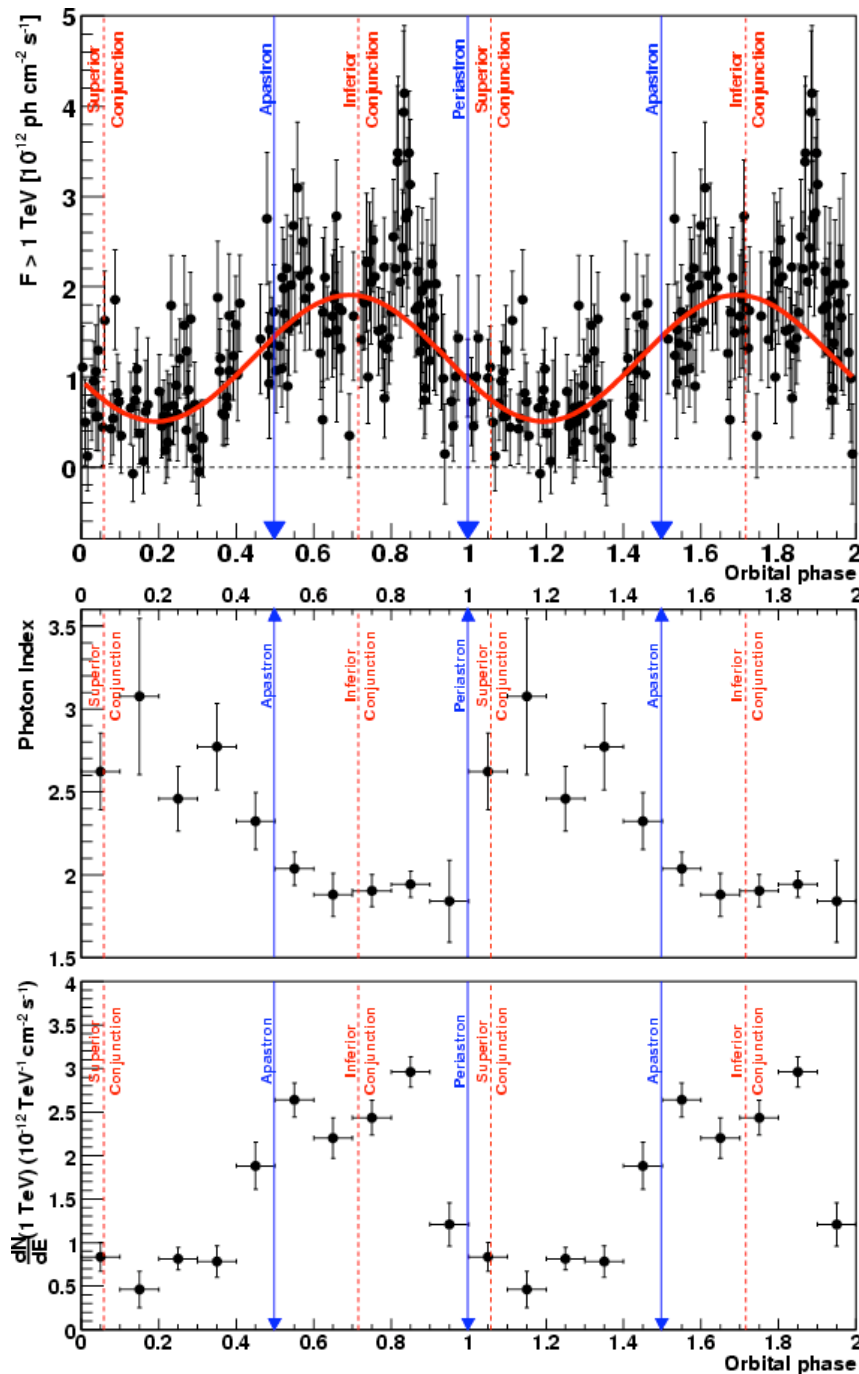


O star + Black Hole  
MAGIC reported a flare

# Periodic Behavior in TeV

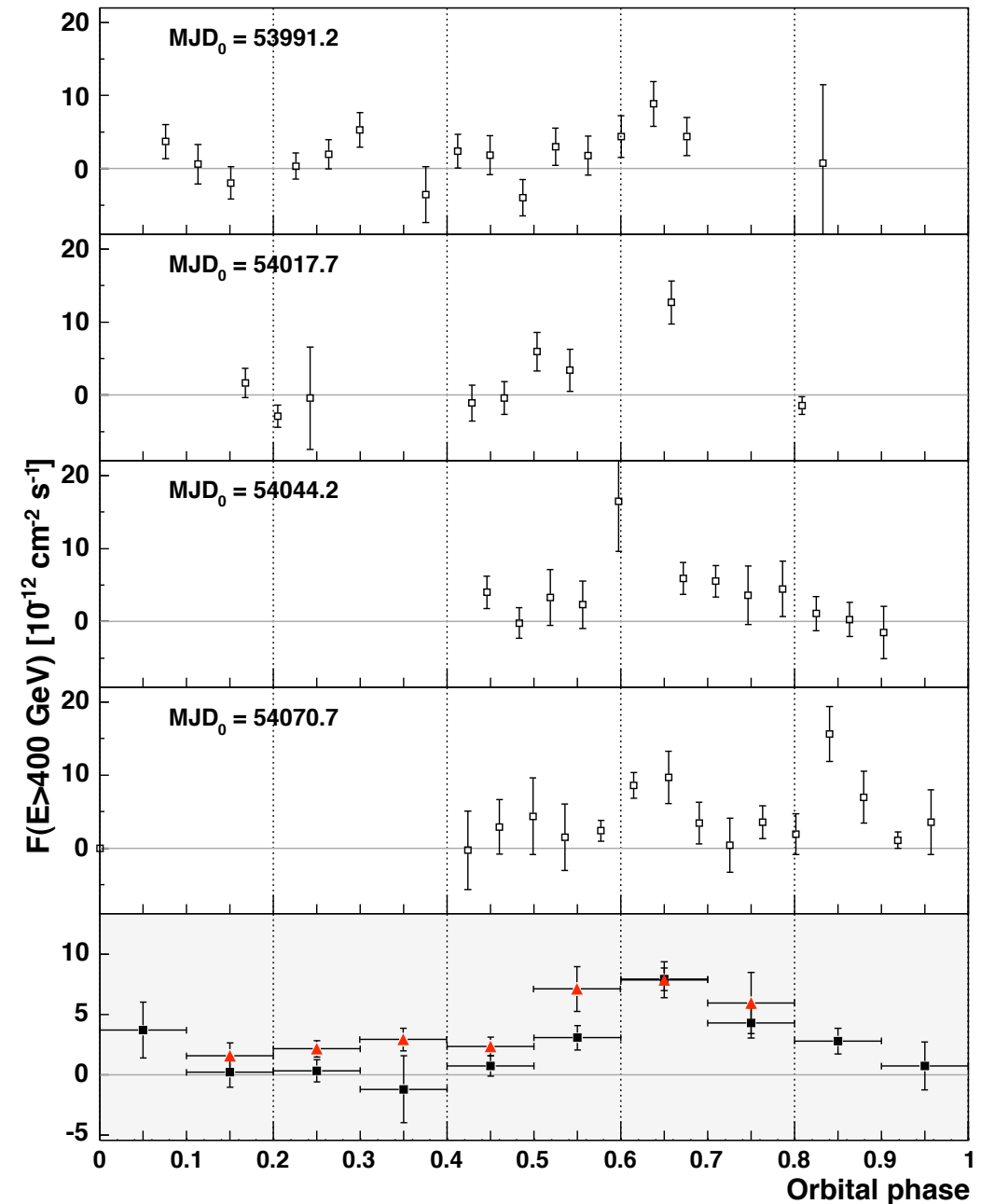
**LS 5039** P = 3.9 days

H.E.S.S. (Aharonian et al., 2006)



**LS I +61° 303** P = 26.5 days

MAGIC (Albert et al., 2008)



Periodic behaviors reflect geometry & physical processes in the binary systems

# EGRET Era

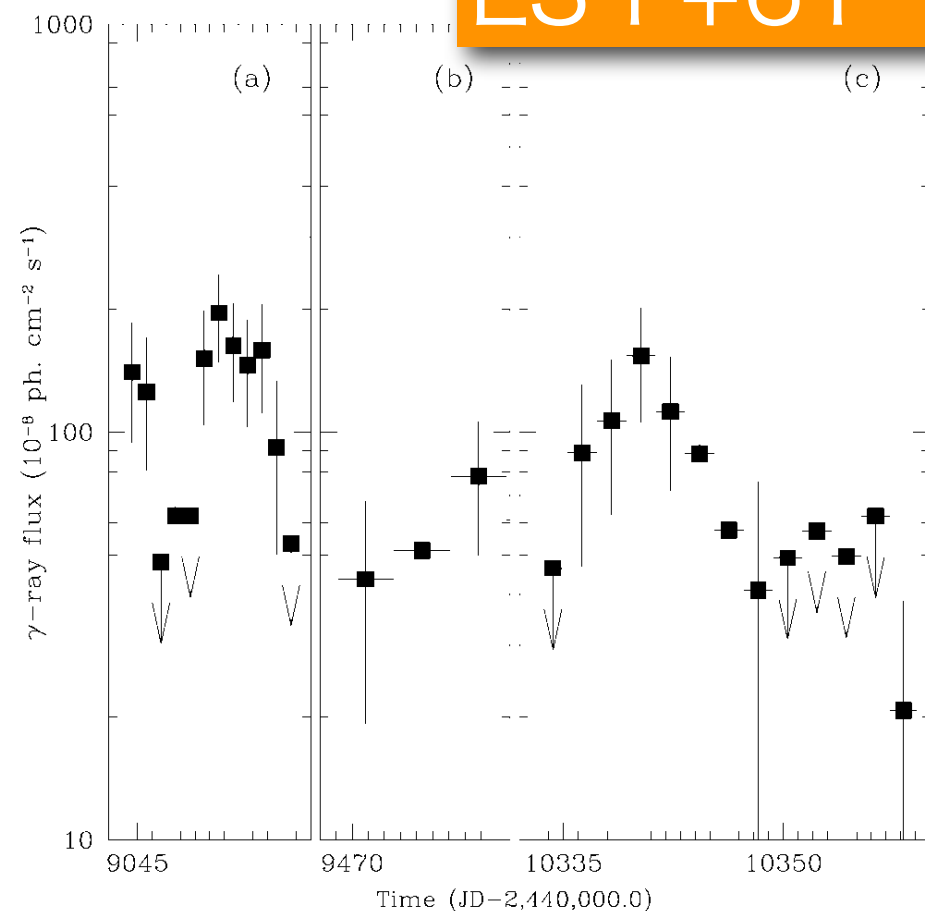
## Association

- ◆ 3EG J0241+6130 ↔ LS I +61° 303
- ◆ 3EG J1824-1514 ↔ LS 5039
- ◆ GRO J1125-6005 ↔ Cen X-3

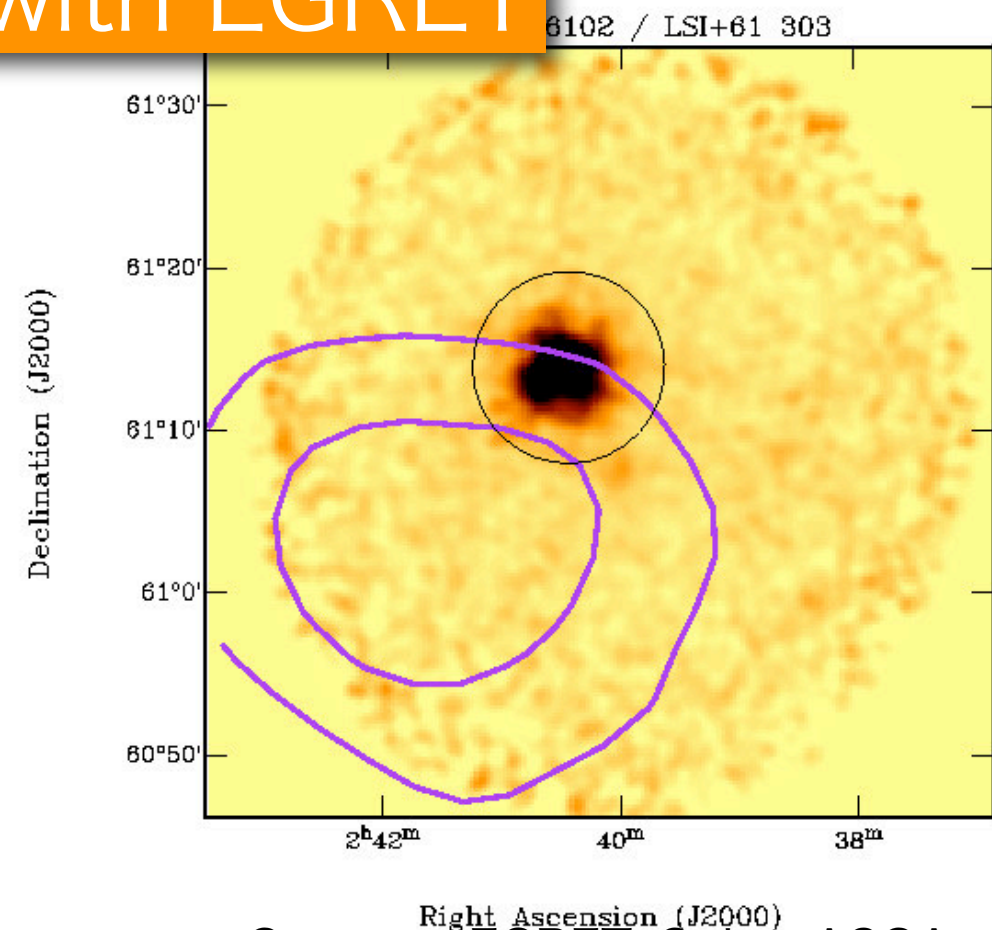
However.... Error circles are large

No clear periodicity detection

LS I +61° 303 with EGRET



Tavani et al. (1998)



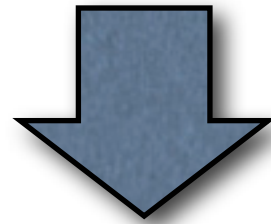
Contour: EGRET, Color: ASCA



# Expectation for Fermi-LAT

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- ◆ Larger effective area
- ◆ Better angular resolution
- ◆ Covers the all sky ~ every 3 hr



- ◆ Precise spectral/timing information
- ◆ Better localization
- ◆ Periodicity/Flare detection
- ◆ Connection with the TeV emission?
- ◆ Simultaneous observations with other wavelengths  
(Large contribution from the Hiroshima group with Suzaku, Kanata.....)

# In the Bright Source List

Submitted to Astrophysical Journal Supplement - Not Yet  
Refereed

## Fermi Large Area Telescope Bright Gamma-ray Source List

The *Fermi* LAT Collaboration

A. A. Abdo<sup>1,2</sup>, M. Ackermann<sup>3</sup>, M. Ajello<sup>3</sup>, W. B. Atwood<sup>4</sup>, M. Axelsson<sup>5,6</sup>, L. Baldini<sup>7</sup>,

arXiv: 0902.1340

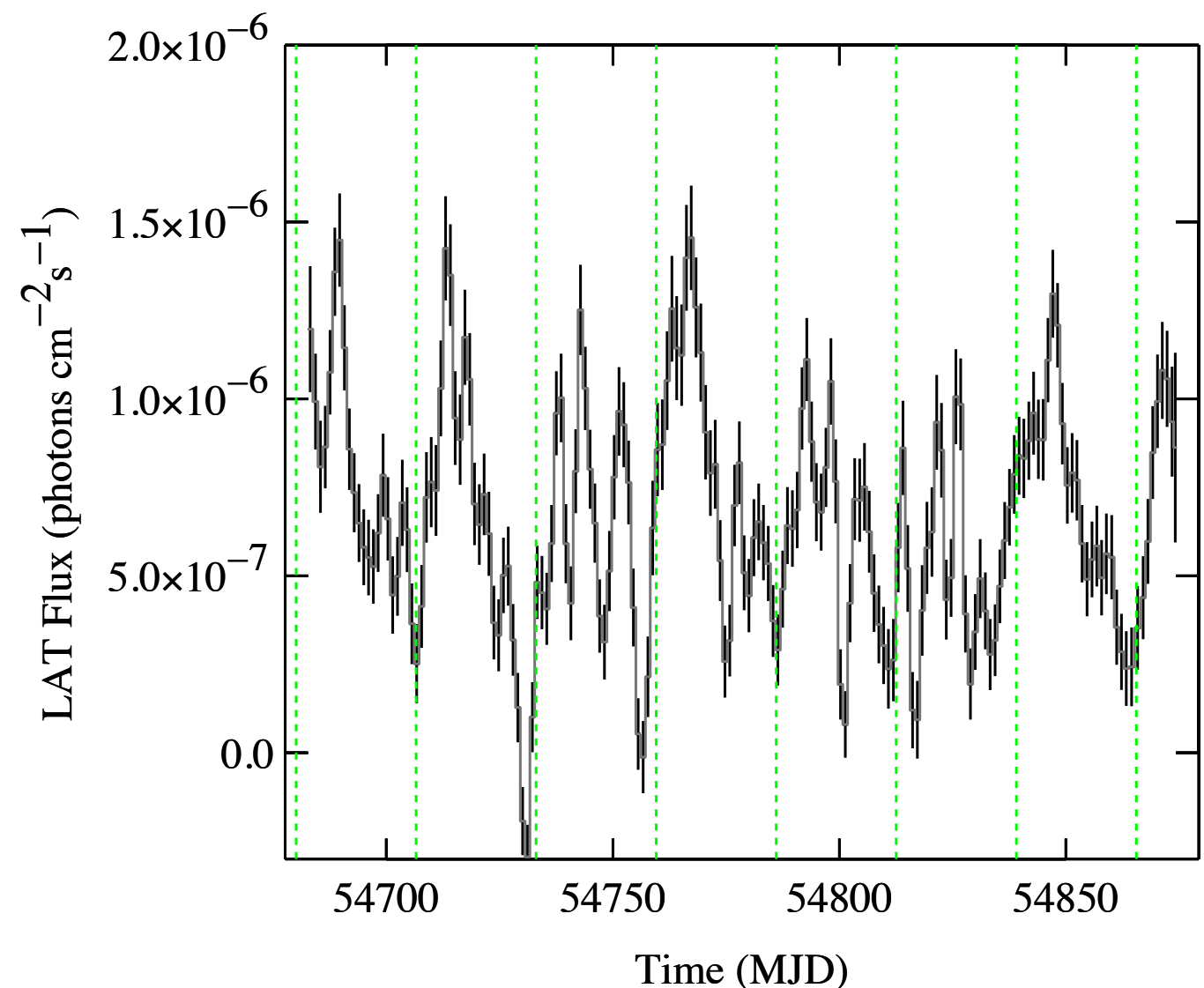
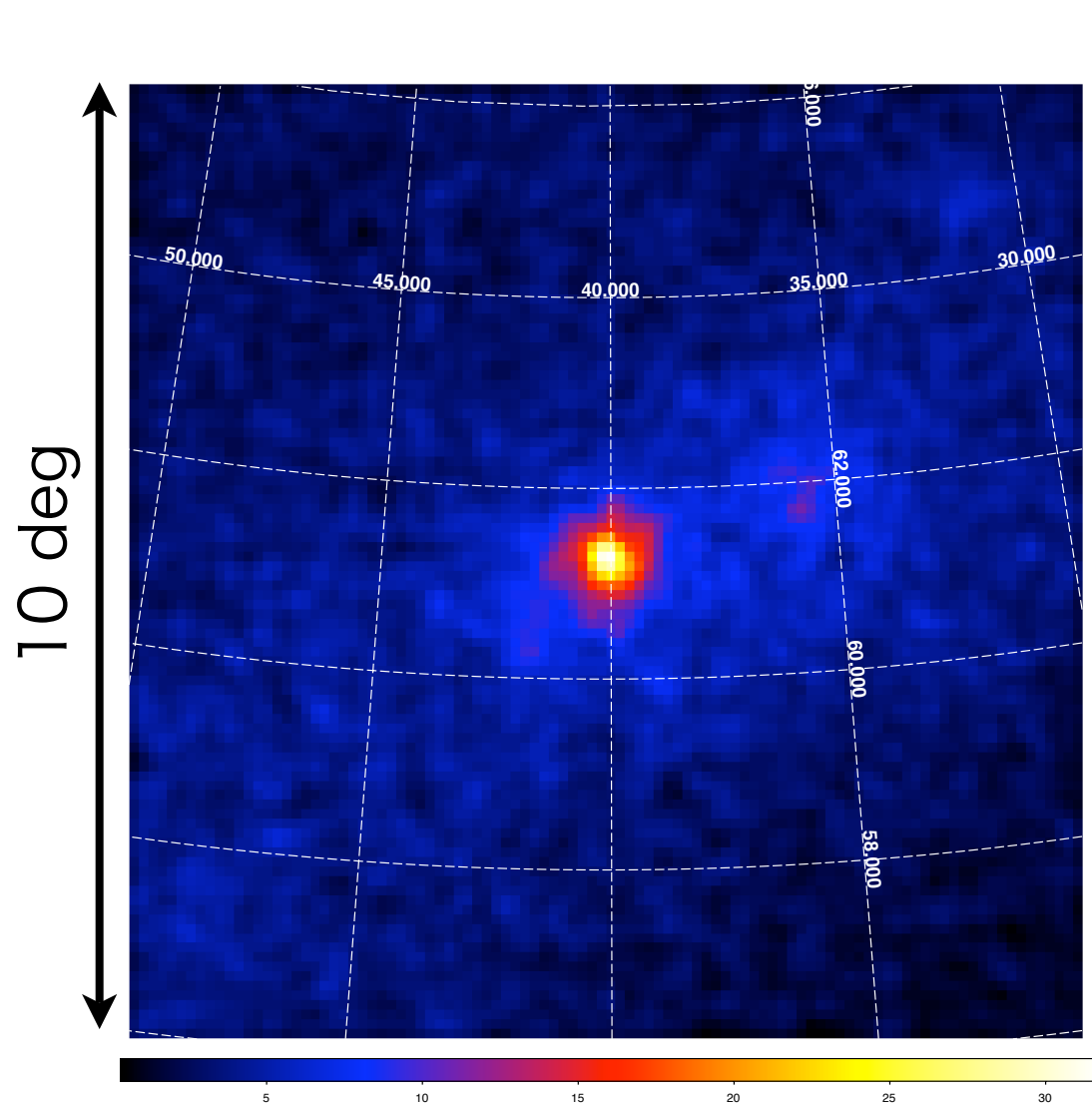
Class	Number
Radio/X-ray pulsar (PSR)	15
LAT gamma-ray pulsar (LAT PSR)	14
HMXB	2
BL LAC (bzb)	46
FSRQ (bzq)	62
Other blazar (Uncertain type, bzu)	11
Radio galaxy (rdg)	2
Globular Cluster (glb, see text)	1
LMC (see text)	1
† Special cases (see Table 2)	13
Unassociated	38

**2 sources are  
associated with HMXBs**

- ◆ LS I +61° 303  
(Main topic of this talk)
- ◆ LS 5039  
(Work in progress..... )

# LS I +61° 303

- ◆ We clearly detect the source ( $> 50 \sigma$ )
- ◆ The best fit position is  $(\alpha, \delta) = (40.076, 61.233)$  with a 95% error radius of 1.8 arcmin, which is consistent with the location of the known optical counterpart
- ◆ Clear variability seen in the light curve

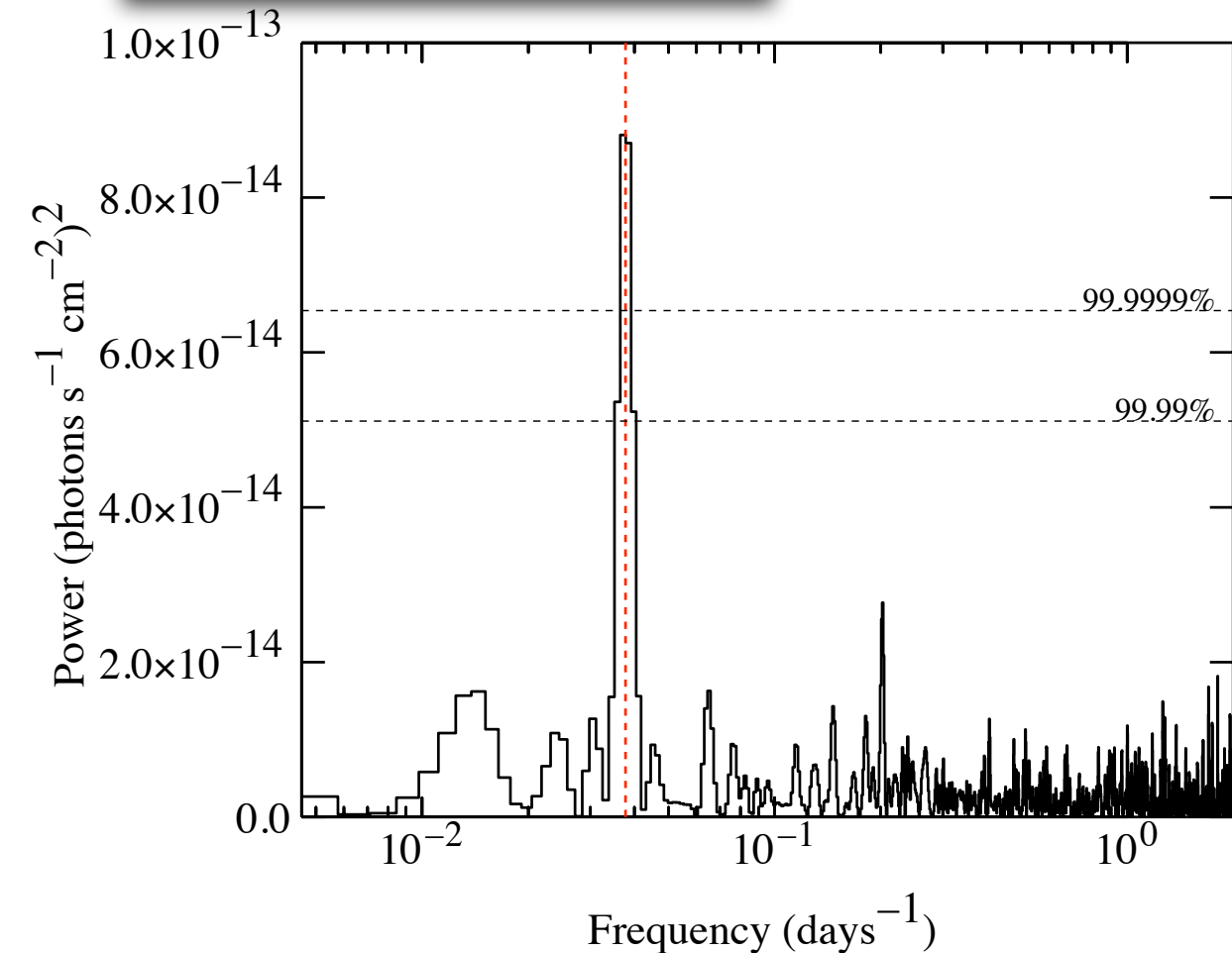




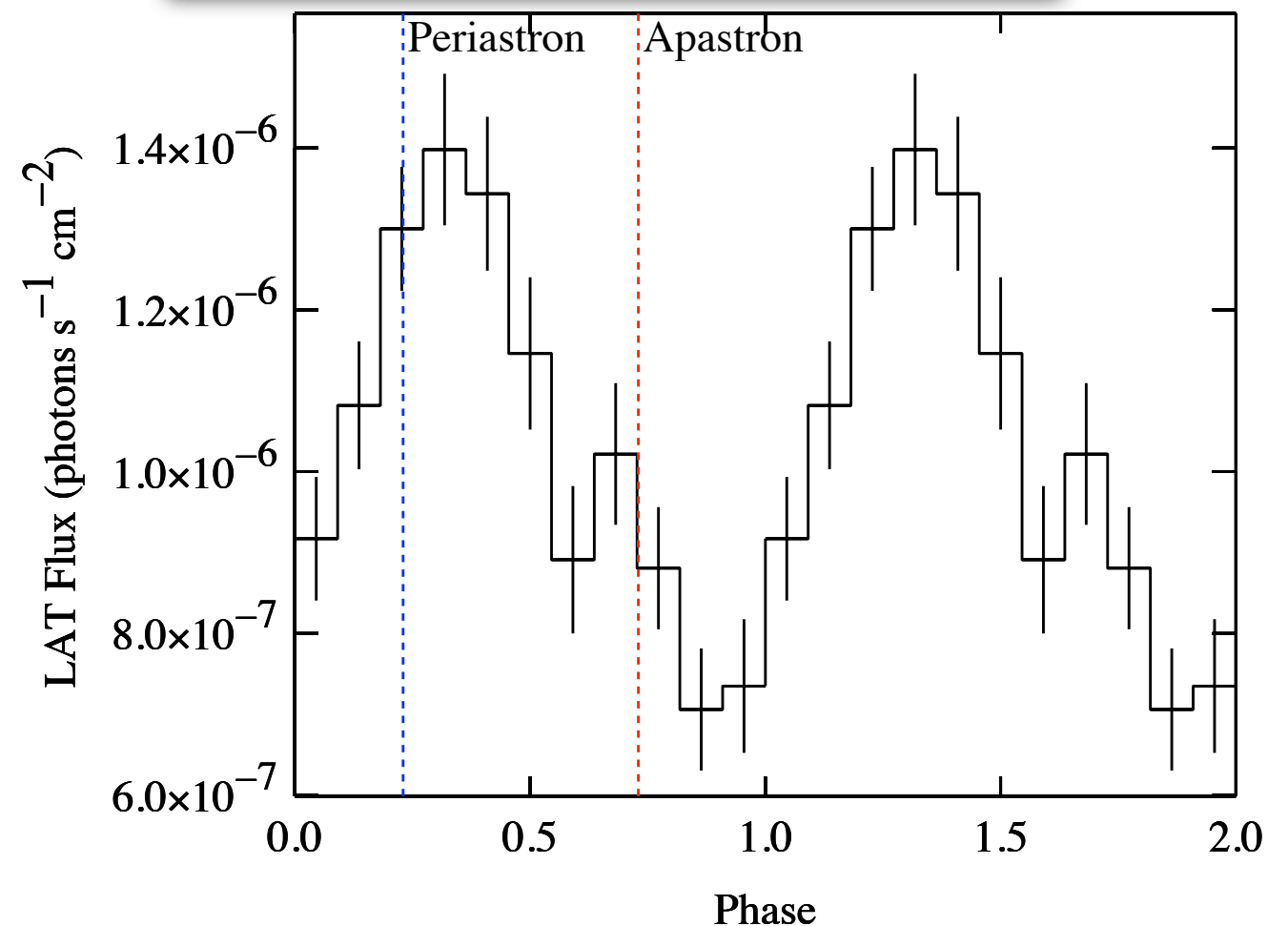
# Periodicity Detection!!

- ◆ We detect a significant periodicity
- ◆ Period =  $26.34 \pm 0.25$  days, which is compatible with the known orbital period
- ◆ Highest flux around phase 0.3 and a smaller peak around phase 0.7

## Periodogram

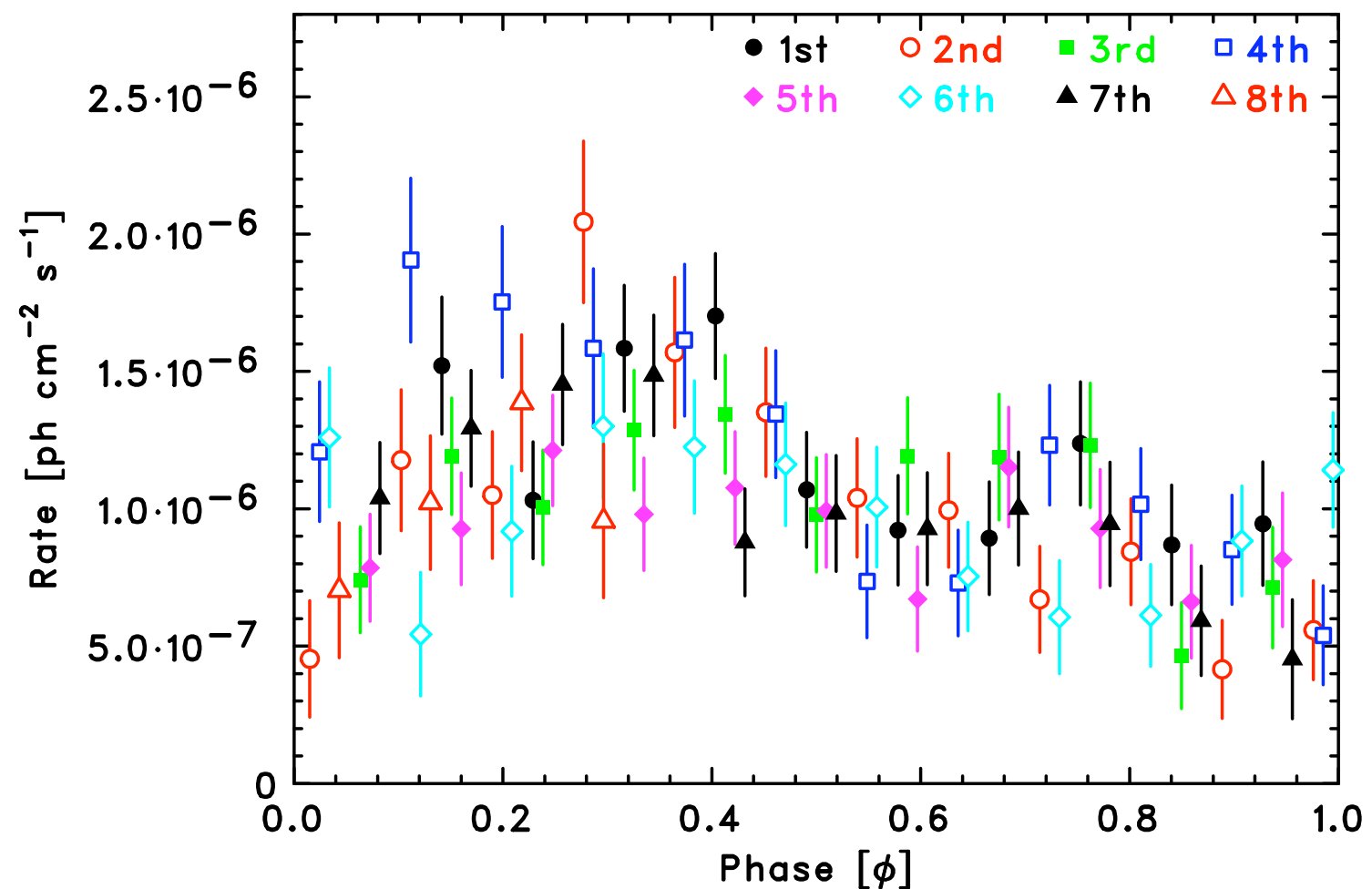
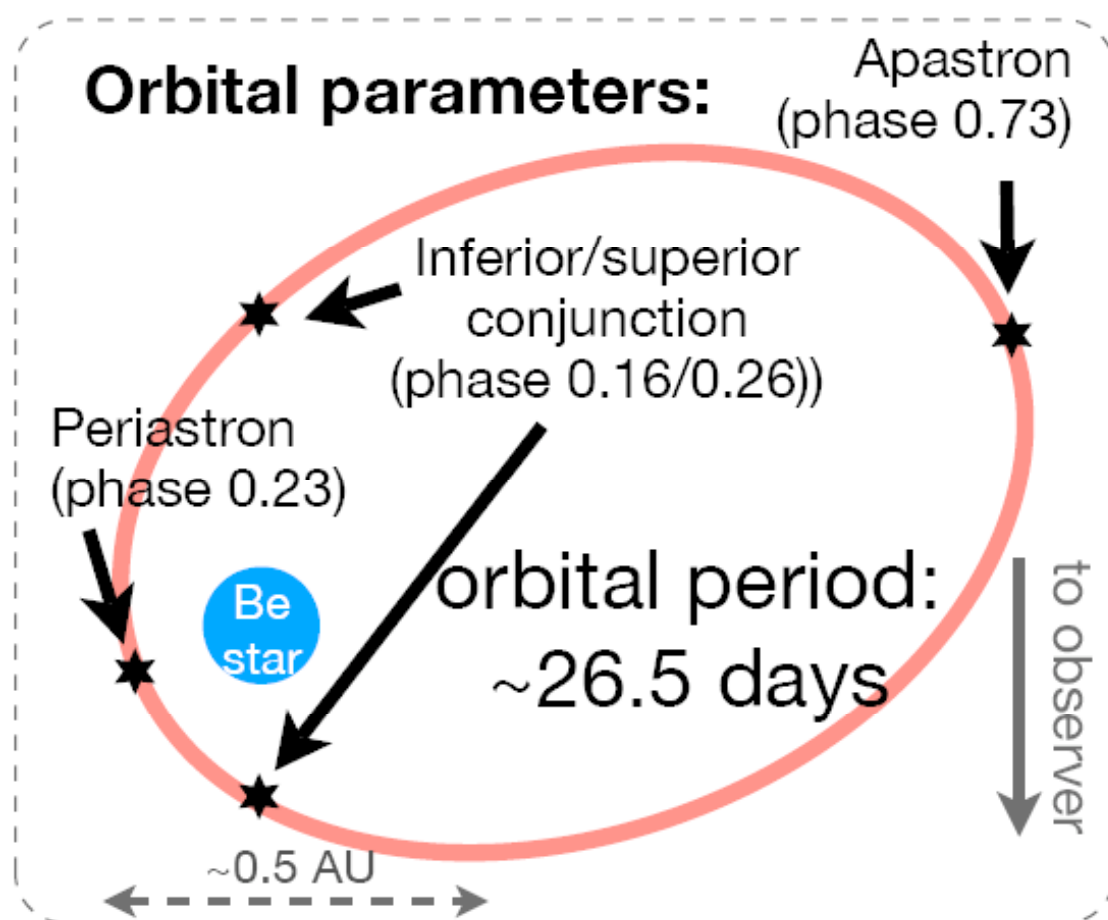


## Folded Light Curve



# Orbit-by-Orbit

- ◆ We've covered ~ 8 orbits
- ◆ Investigating signs of orbit to orbit variability
- ◆ More data is needed to give an answer



# Spectrum

Unbinned likelihood fitting of the Fermi flux to a power law yields

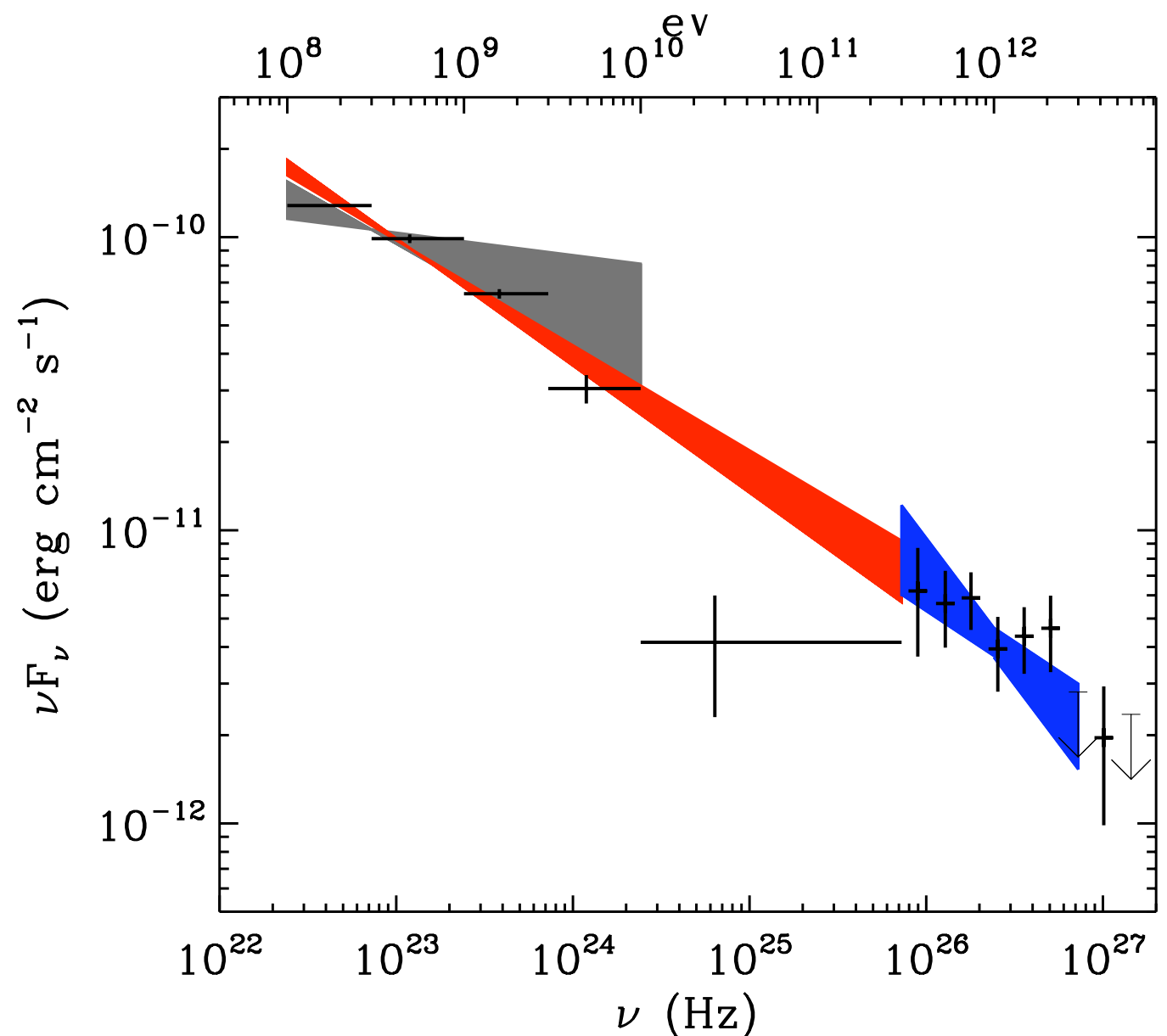
$$dN/dE = A E^{-\Gamma}:$$

$$\begin{aligned} \text{Flux (E>100 MeV)} \\ &= 0.77 \pm 0.03 \text{ (stat)} \pm 0.21 \text{ (sys)} \\ &10^{-6} \text{ ph/cm}^2/\text{s} \end{aligned}$$

$$\Gamma = 2.40 \pm 0.03 \text{ (stat)} \pm 0.17 \text{ (sys)}$$

No apparent dependence of photon index on orbital phase

**Note: The Fermi and TeV data are NOT simultaneous**



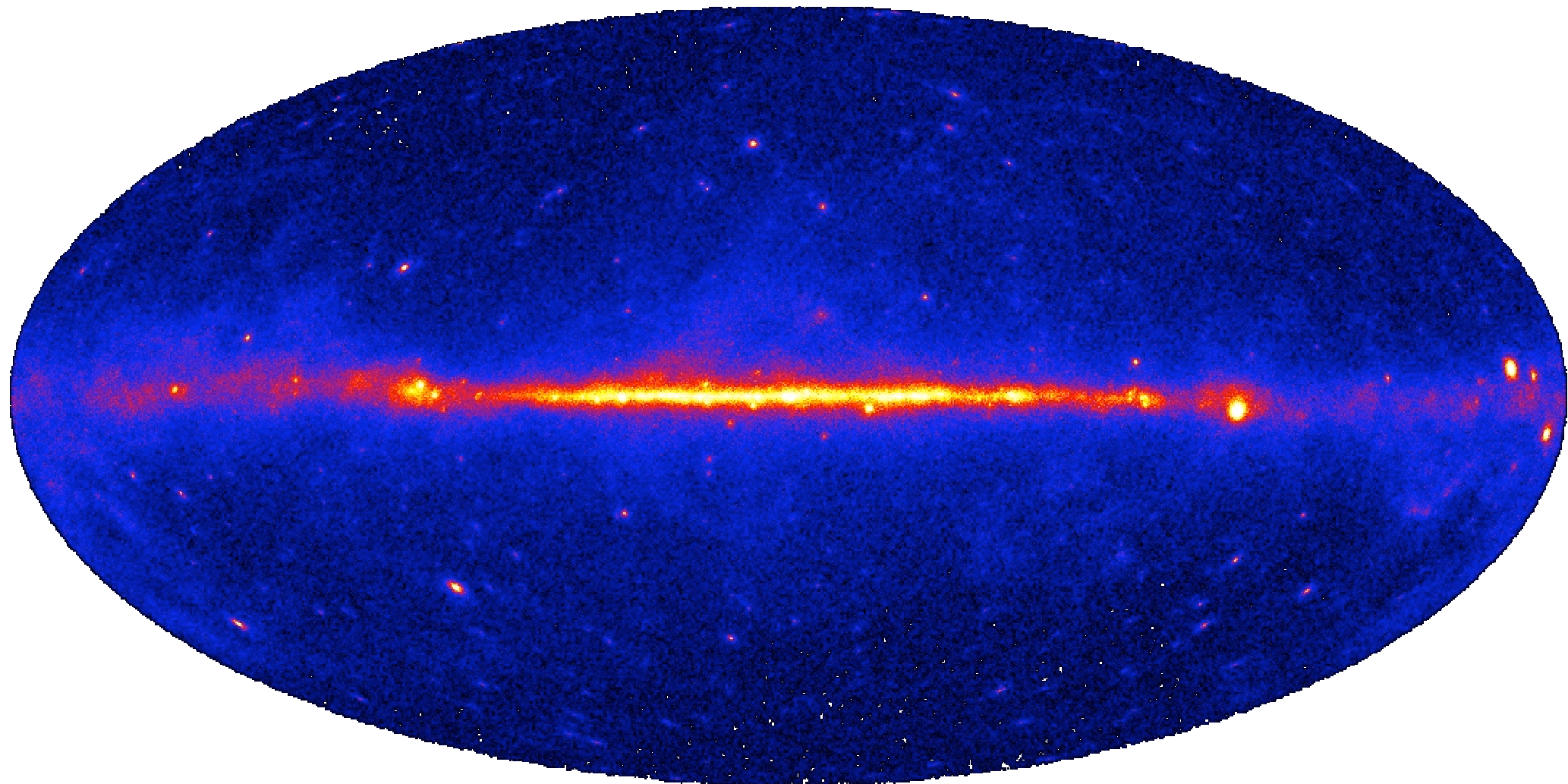
Points: Fitted energy bins  
Red: Fermi unbinned power law fit  
Grey: EGRET  
Blue: MAGIC (Only phase 0.4-0.7)  
VERITAS data points overlaid  
(systematic errors not shown)



# Other Sources?

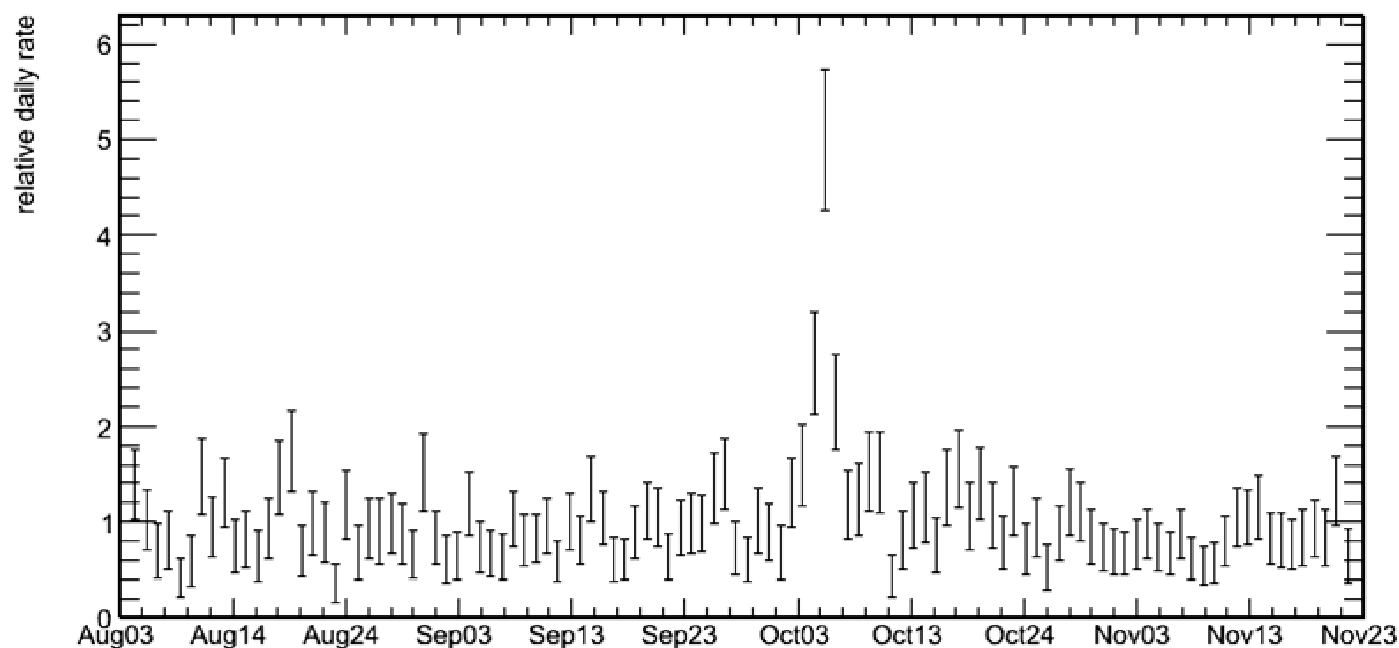
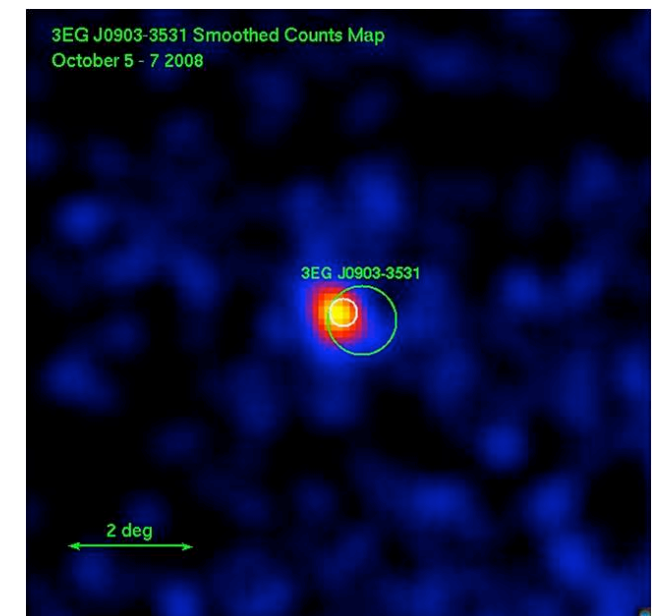
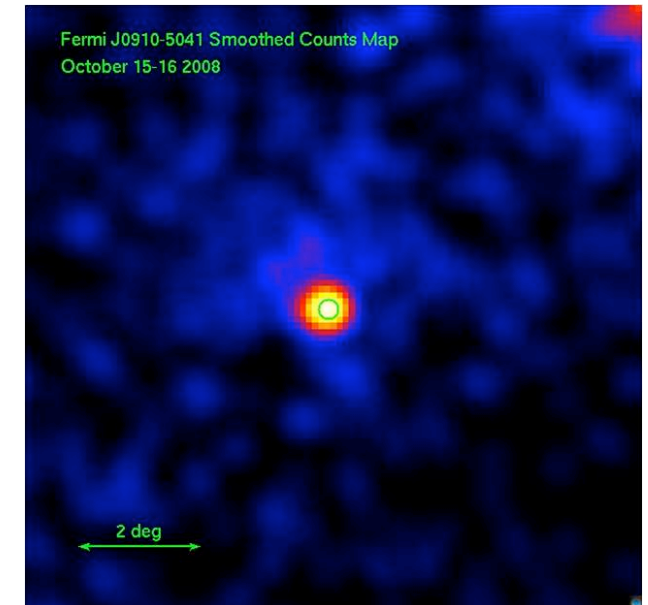
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- ◆ MAGIC reported a flare at VHE from Cyg X-1 in 2006
- ◆ We are monitoring 68 sources on a daily basis
- ◆ Challenging work due to the high contribution of diffuse emission in the galactic plane.



# Flaring Sources

- ◆ The LAT has and will discover new unknown sources; some of which could potentially be gamma-ray binaries.
- ◆ 2 bright transients detected in the Galactic Plane (ATels 1771 & 1788)



# Summary

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- Two HMXBs are detected by the Fermi LAT
- Firm detection of LS I +61° 303
- First detection of orbital modulation ( $P = 26.5$  days) in the GeV domain from LS I +61° 303
- LS 5039 under investigation
- More binaries to look for both persistent and flaring