

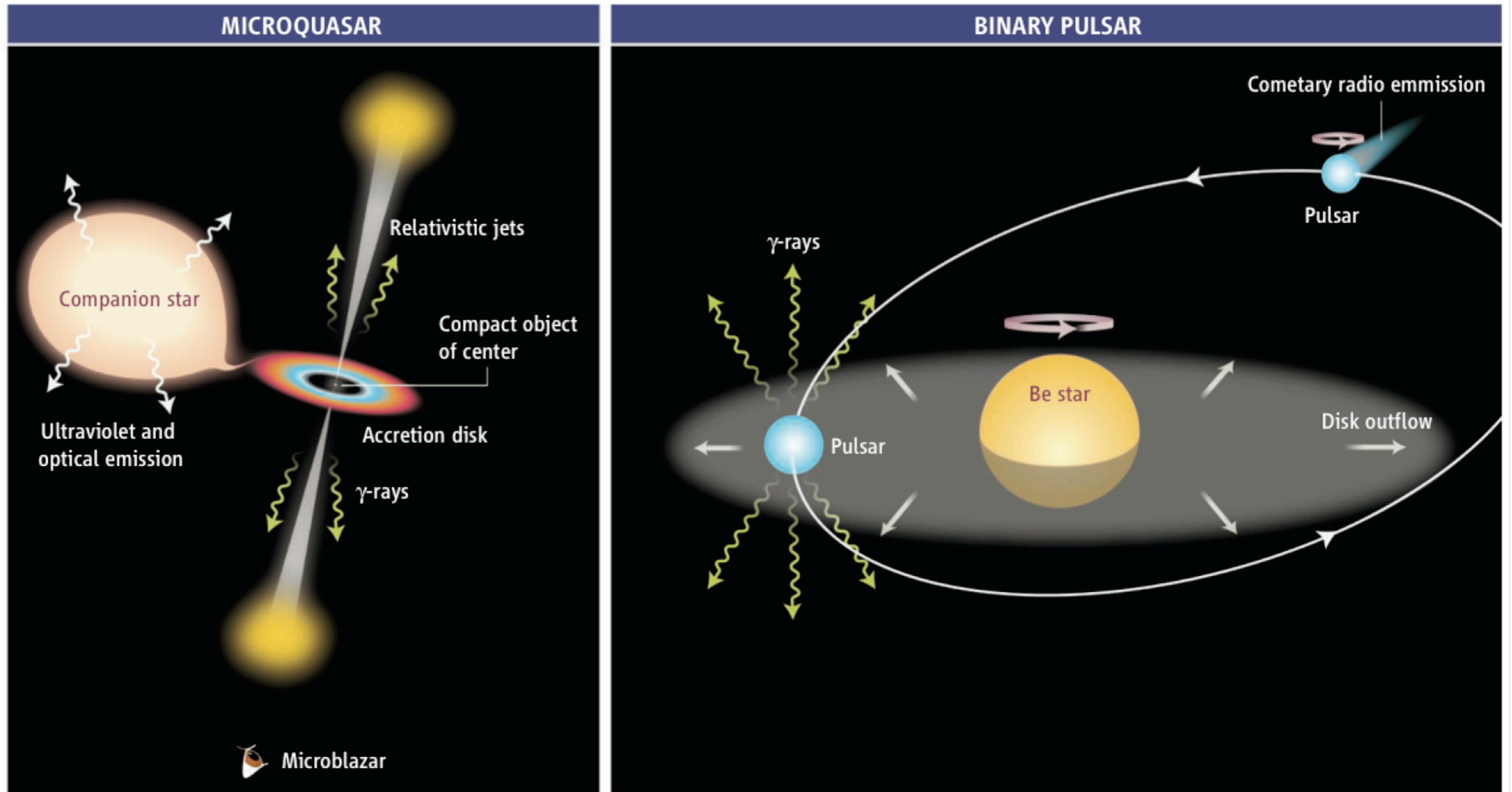
**Multi-wavelength
Observations
of LS I +61 303 and LS 5039:
Two GeV + TeV Binaries**

Paul S. Ray
2009 November 5
on behalf of a larger collaboration

Gamma-Ray Binaries

- Only a few known:
 - LS I +61 303, LS 5039, PSR B1259-63, Cyg X-1, HESS J0632+057, and now Cyg X-3 (Fermi & AGILE)
- Fermi LAT detects AND sees orbital modulation from three: LS I +61 303, LS 5039 and Cyg X-3
- Here we focus on LS I +61 303 and LS 5039

Two primary models



from: Mirabel (Science 309, 714, 2006)

What is compact object? If accretion, where are the X-rays?

Observations

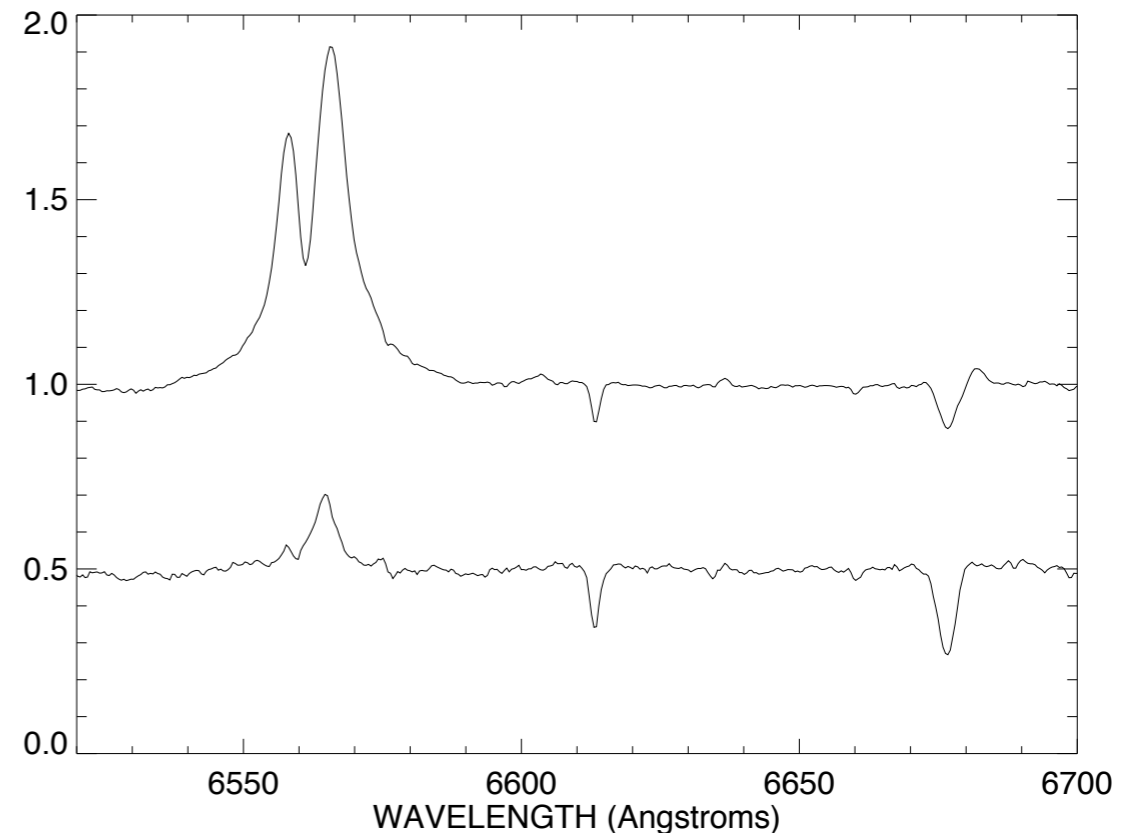
- RXTE PCA Monitoring 1.5 ks every 3-4 days since 2007 Aug 28 (Kaaret, Ray, Core Program)
- PCA intensive orbit 2008 Oct–Nov
- Fermi LAT monitoring since 2008 August
- Optical spectroscopy with KPNO Coudé Feed (McSwain, Aragona, others)
- VLA/VLBA/ATCA observations (V. Dhawan, S. Dougherty, M. Roberts)
- AMI 15 GHz radio monitoring of LSI (G. Pooley)
- Radio pulsation search at GBT (S, C, and X bands) in May 2008
- VERITAS has also made independent observations

LAT Results

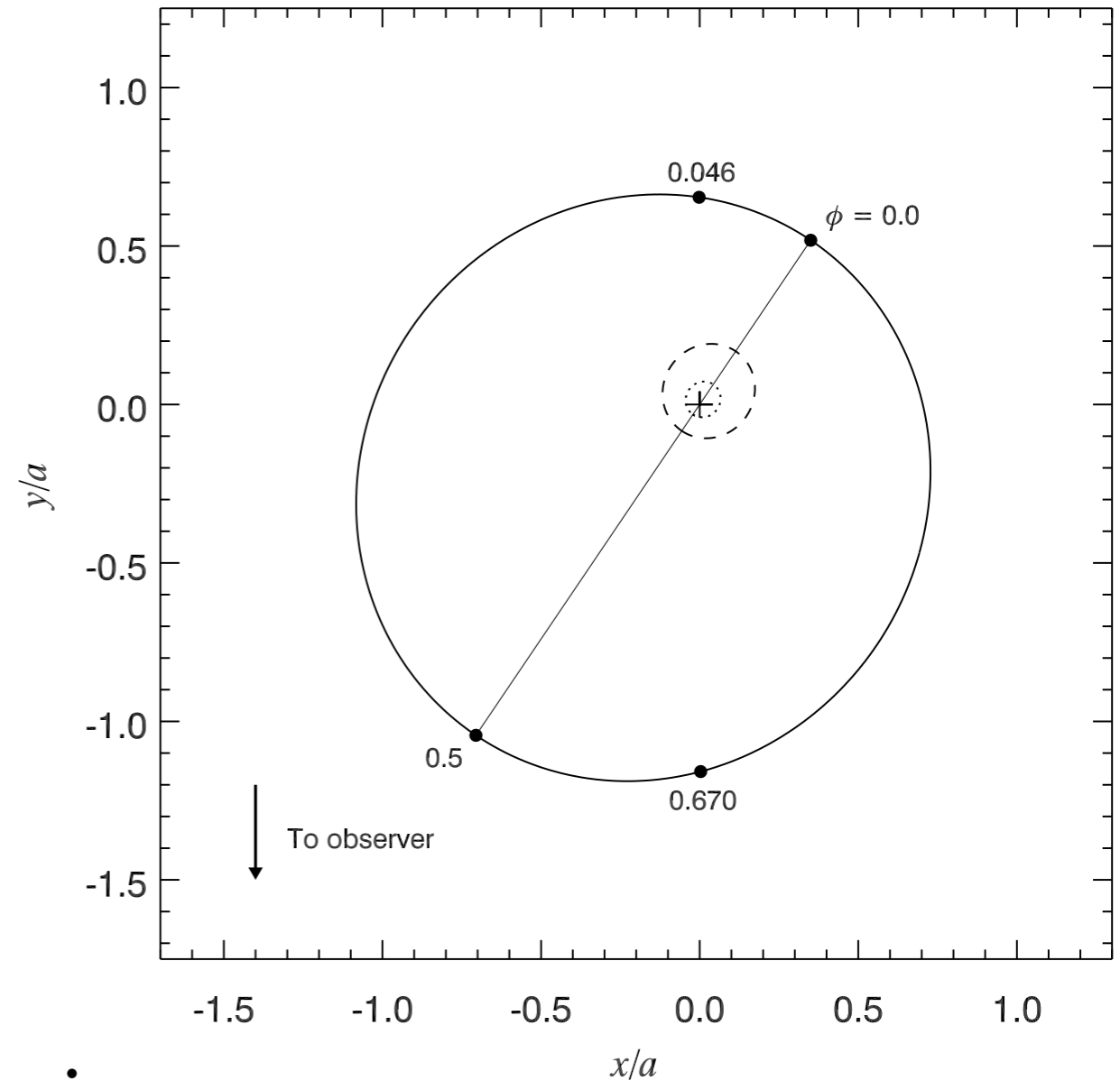
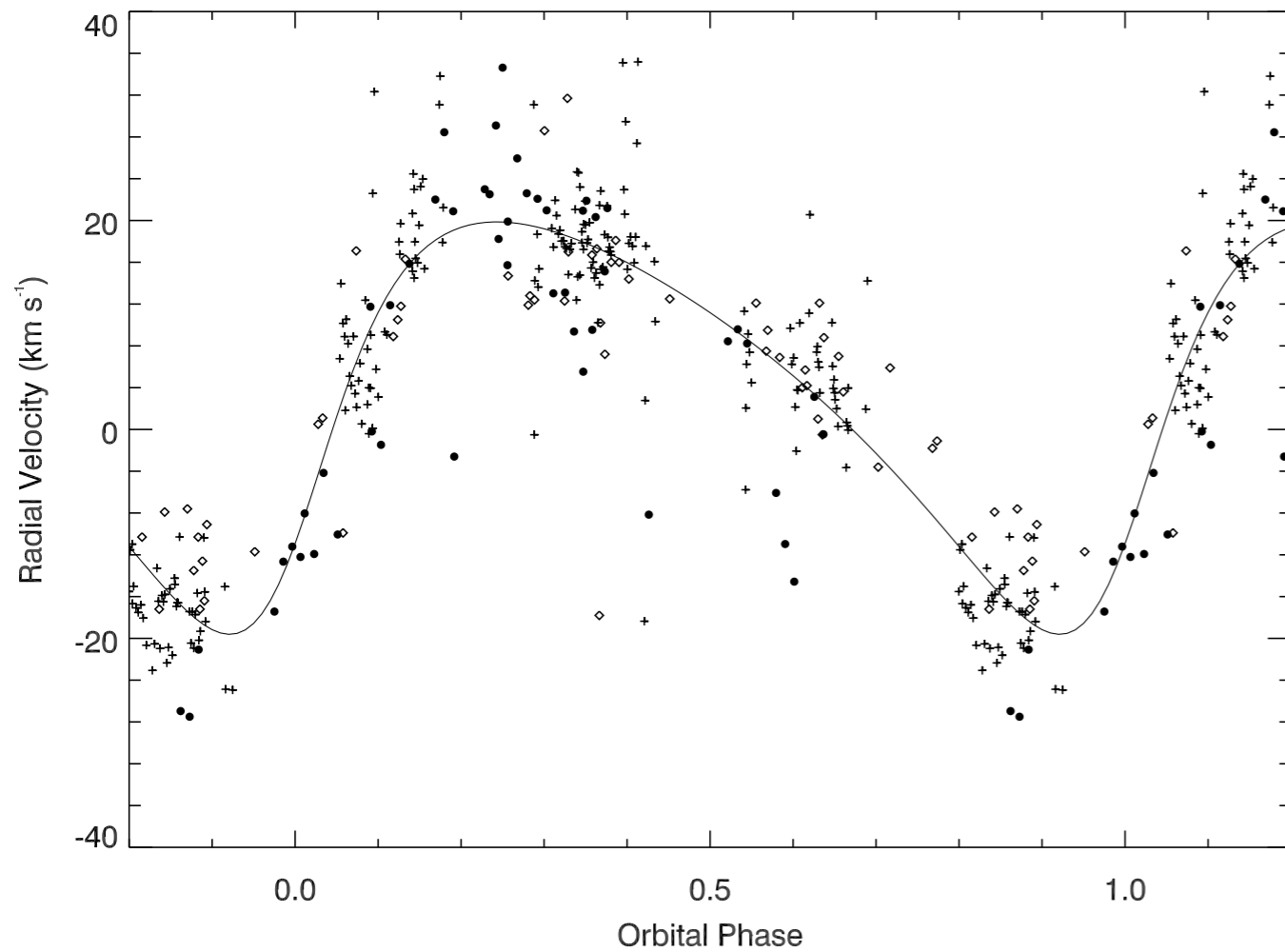
- Orbital modulation seen in both with GeV maxima near periastron
 - Different phase than seen in TeV
- Both have cutoff powerlaw spectra, similar to gamma-ray pulsars
- Is the emission magnetospheric?
 - No pulsations discovered so far

Optical Observations

- **Every night** from 2008 Oct 16 to Nov 20 at KPNO Coudé Feed
- Get the disk state from $H\alpha$
 - Look for transient episodes of ionization (as seen by Grundstrom 2007)
- See the orbital variability and improve the orbital parameters
- Important to constrain orbital separation and eccentricity for modeling

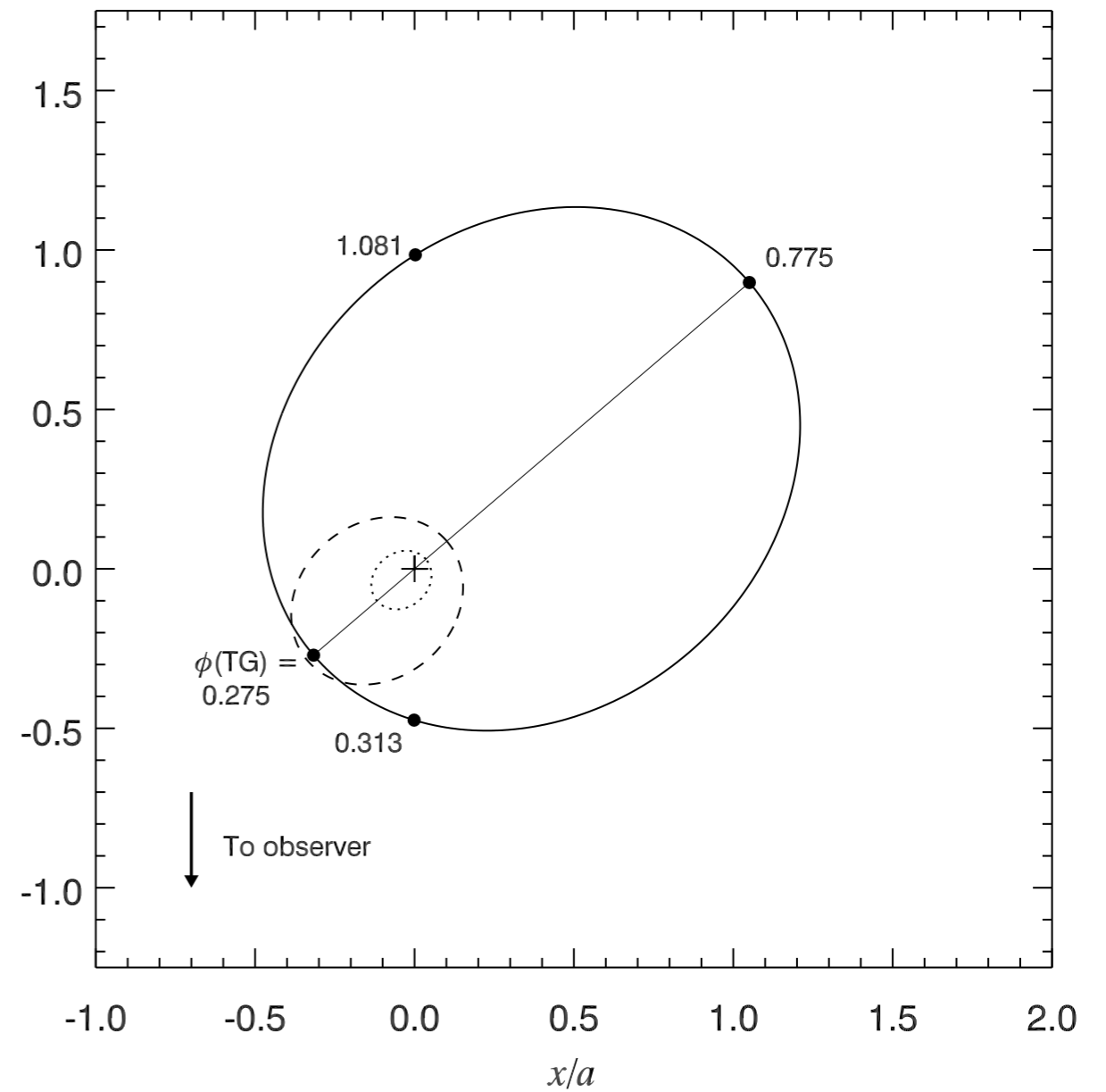
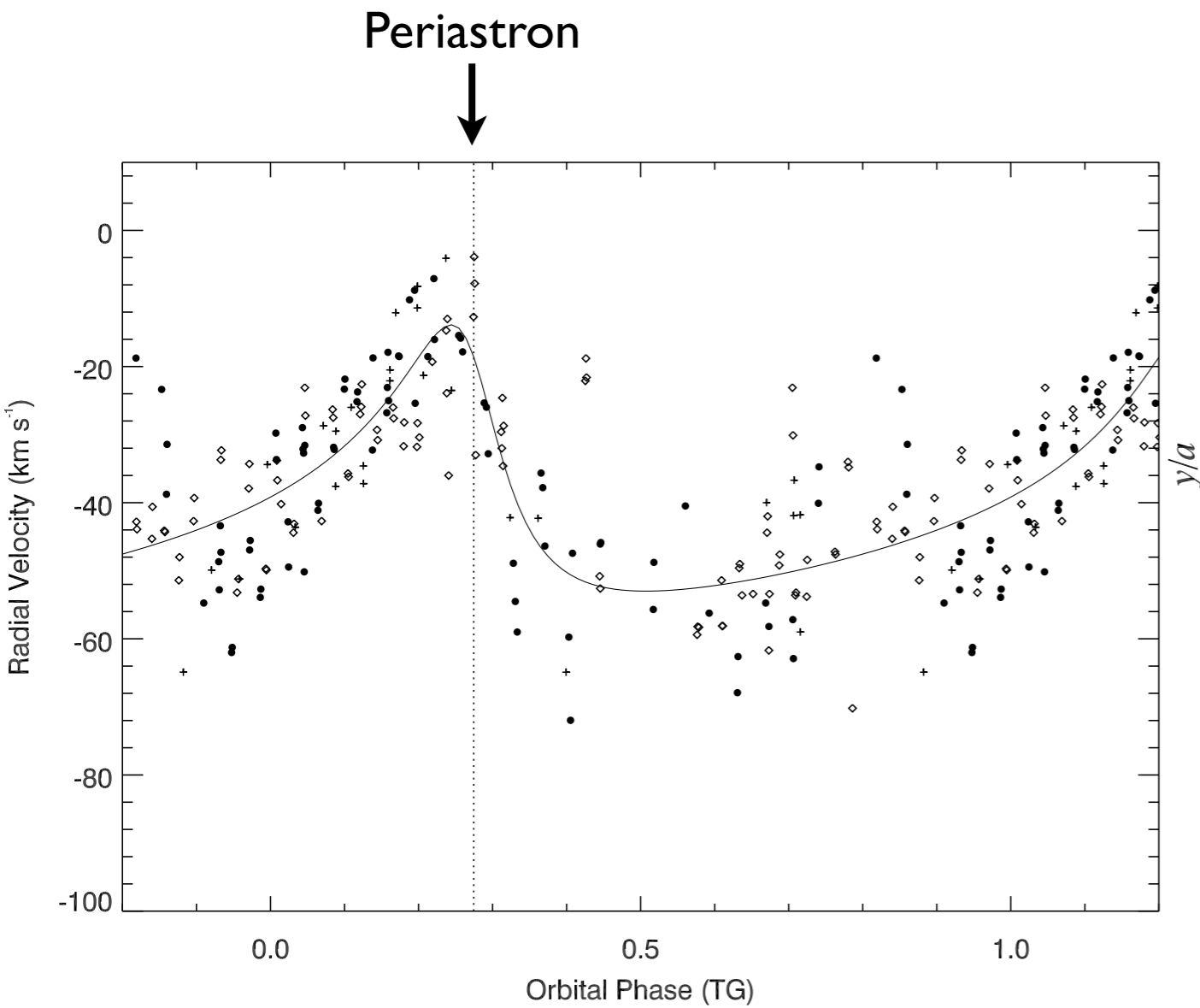


LS 5039 Orbit



- Additional optical monitoring
- Published by Aragona et al. (2009)

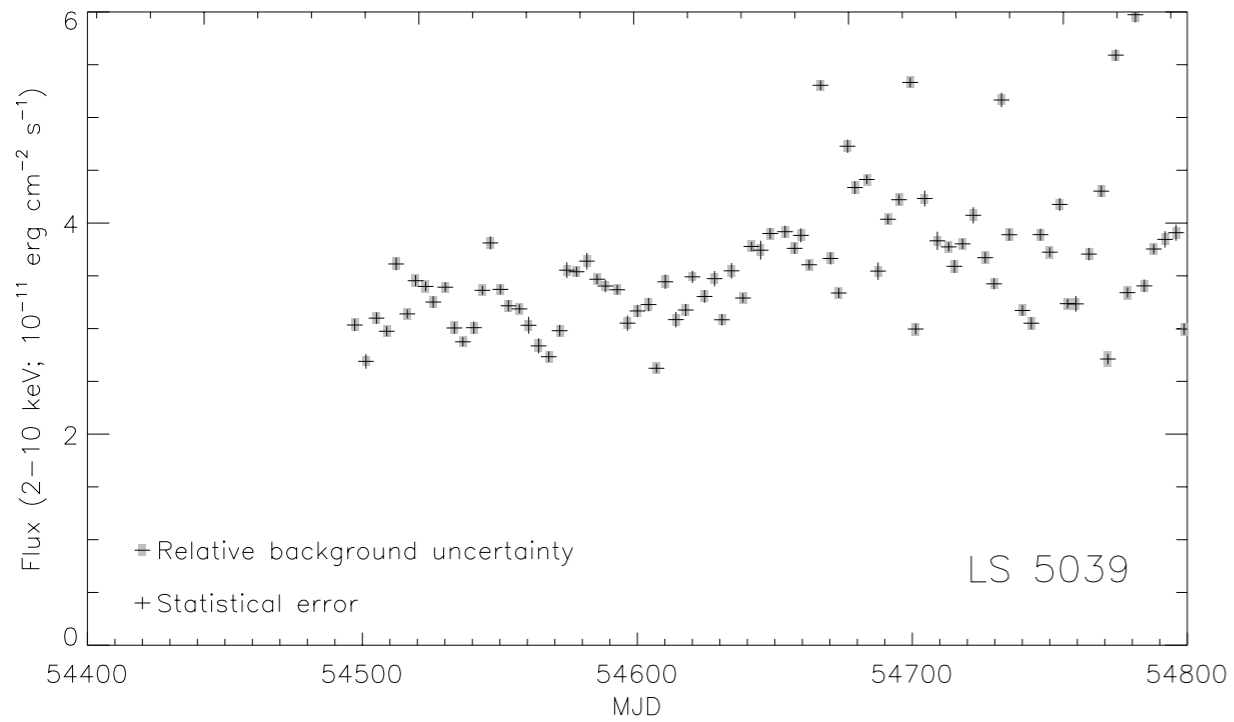
LSI +61 303 Orbit



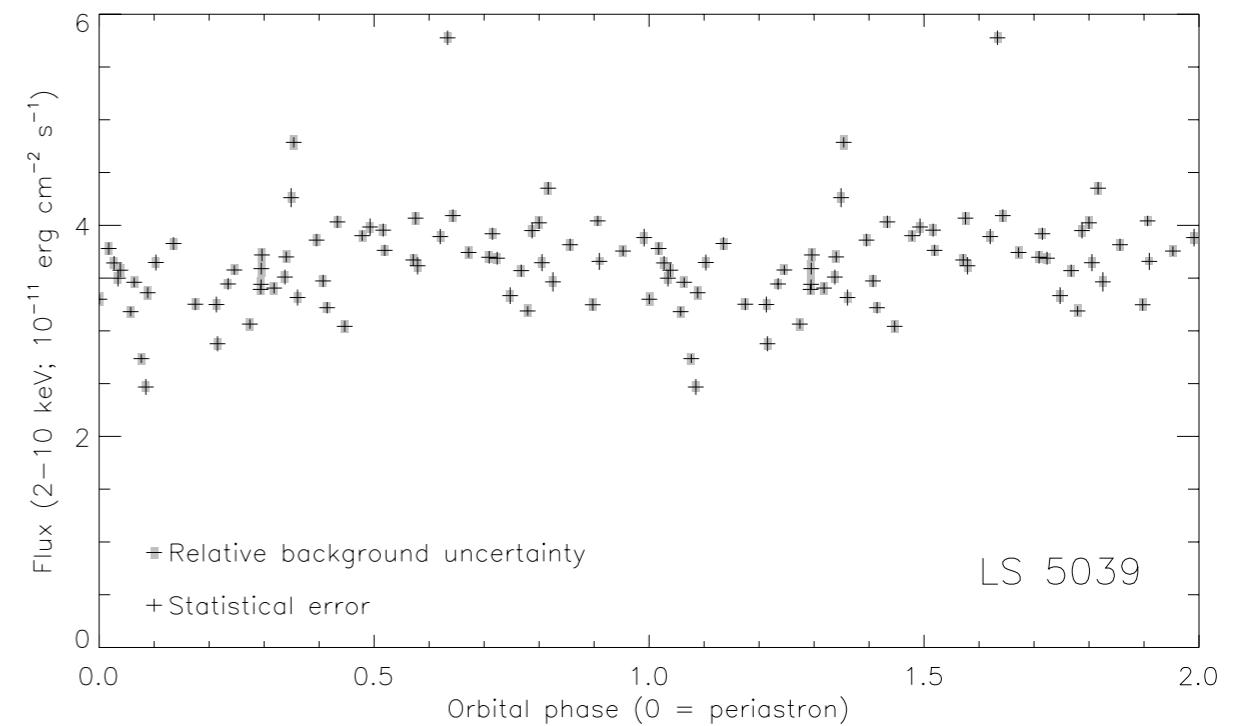
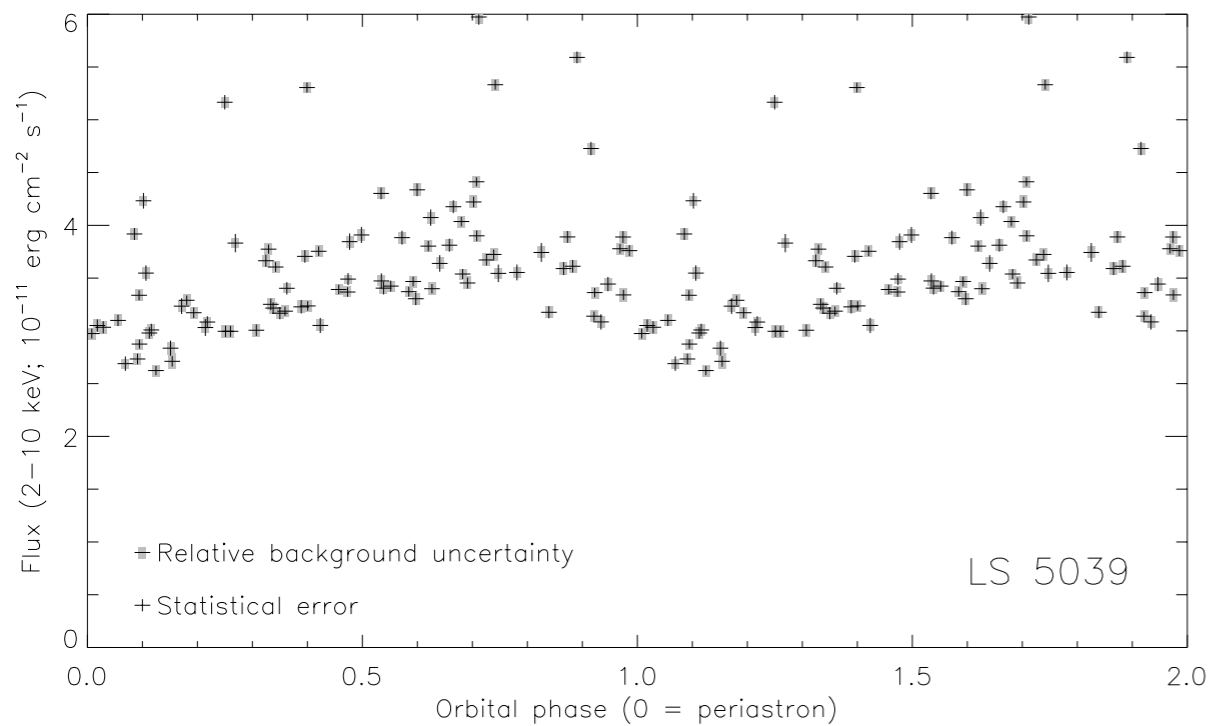
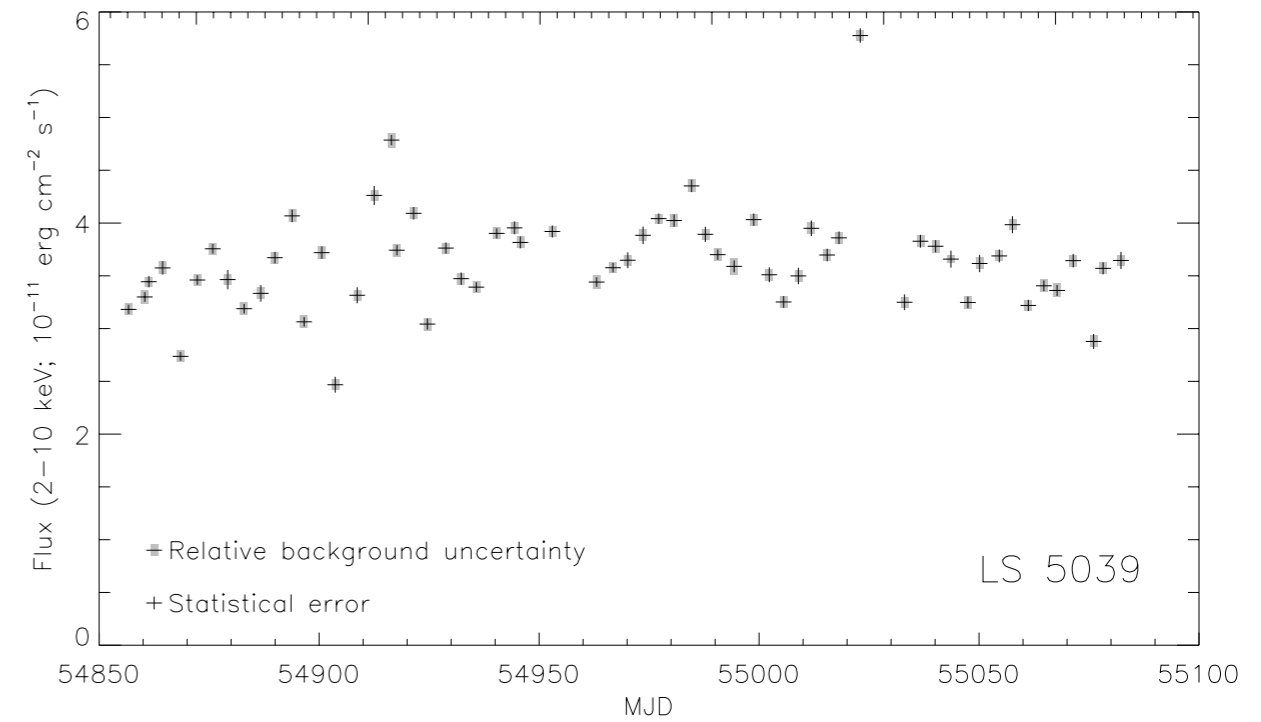
- Published by Aragona et al. (2009)

LS 5039 PCA Monitoring

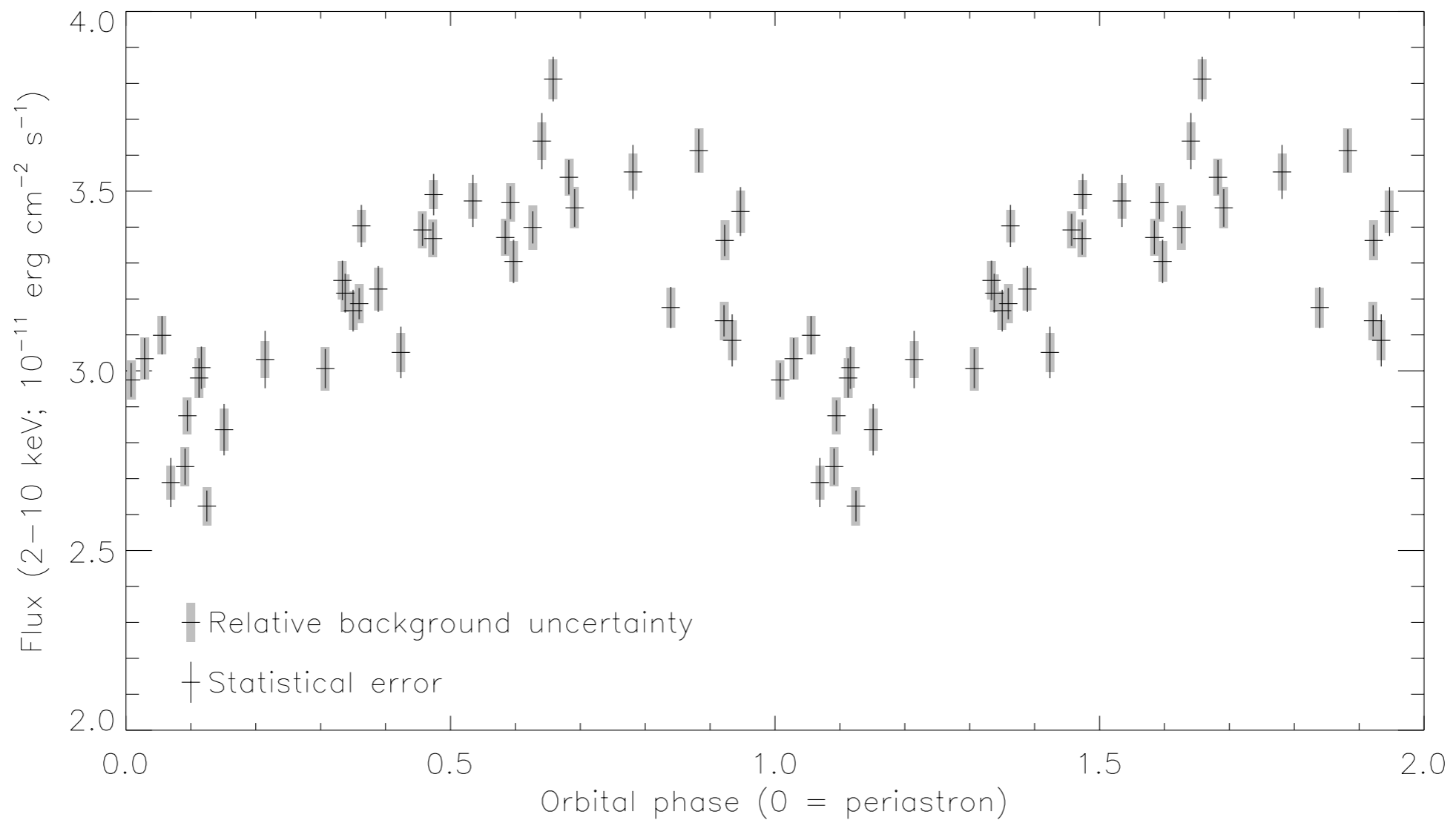
Orbital phase (tick marks at periastron)



Orbital phase (tick marks at periastron)



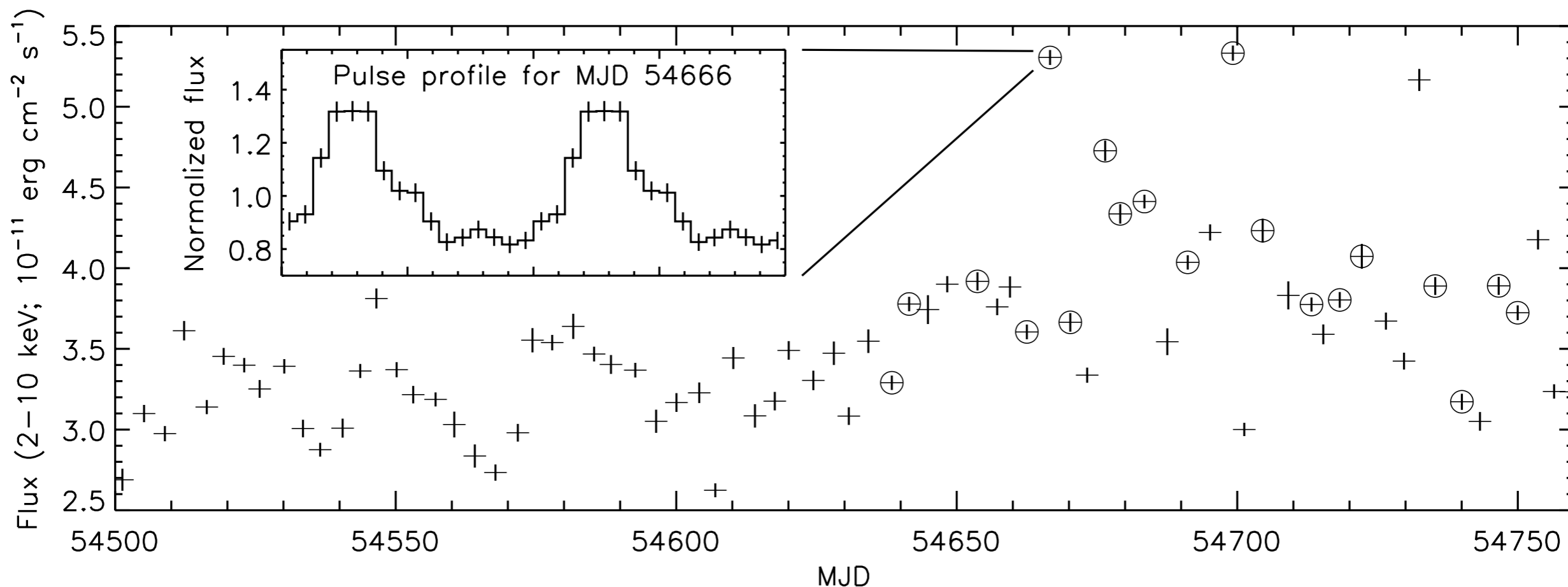
LS 5039 folded with orbit



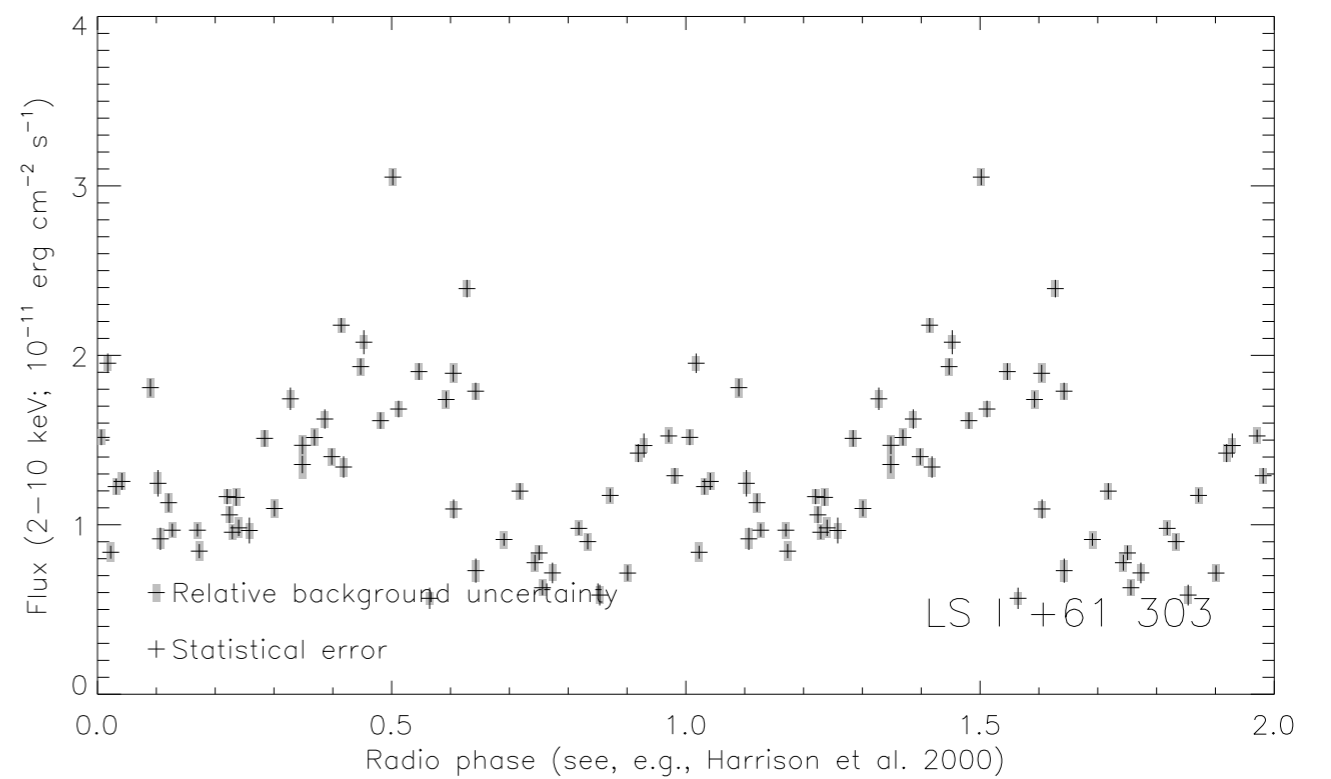
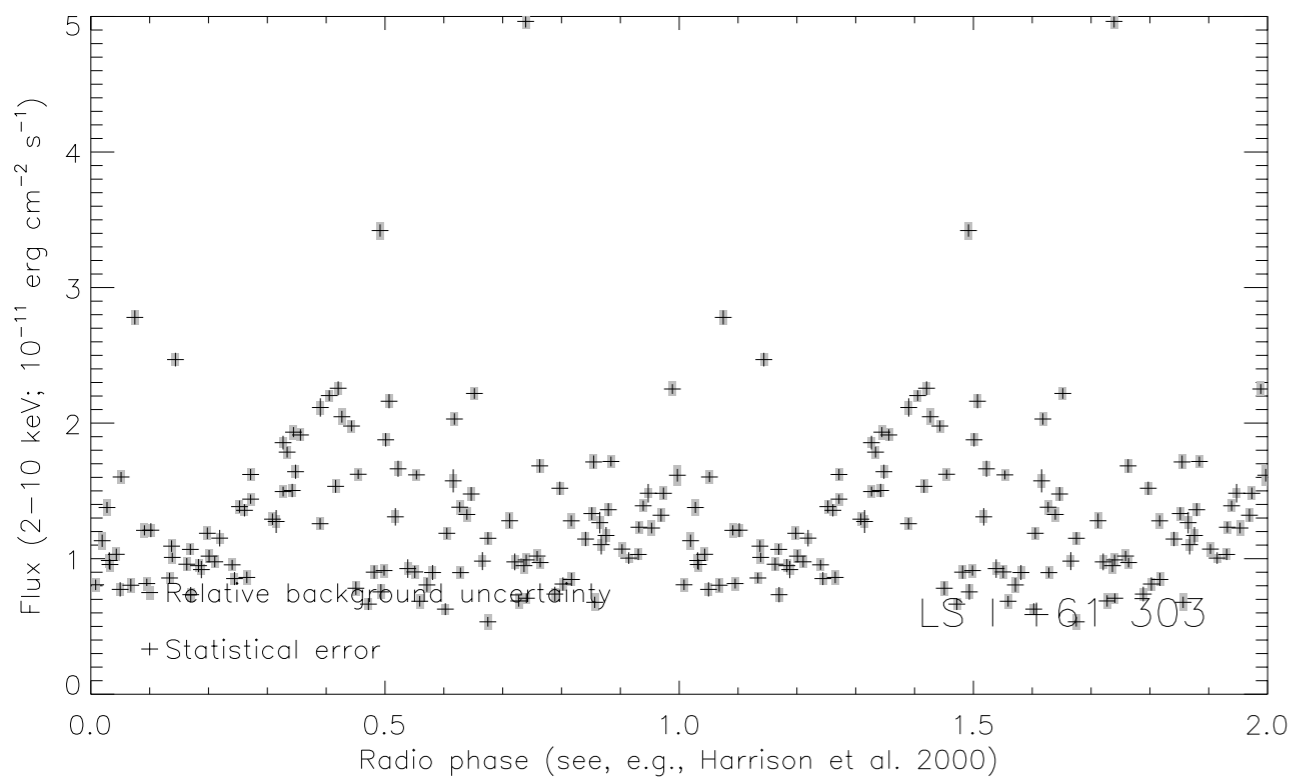
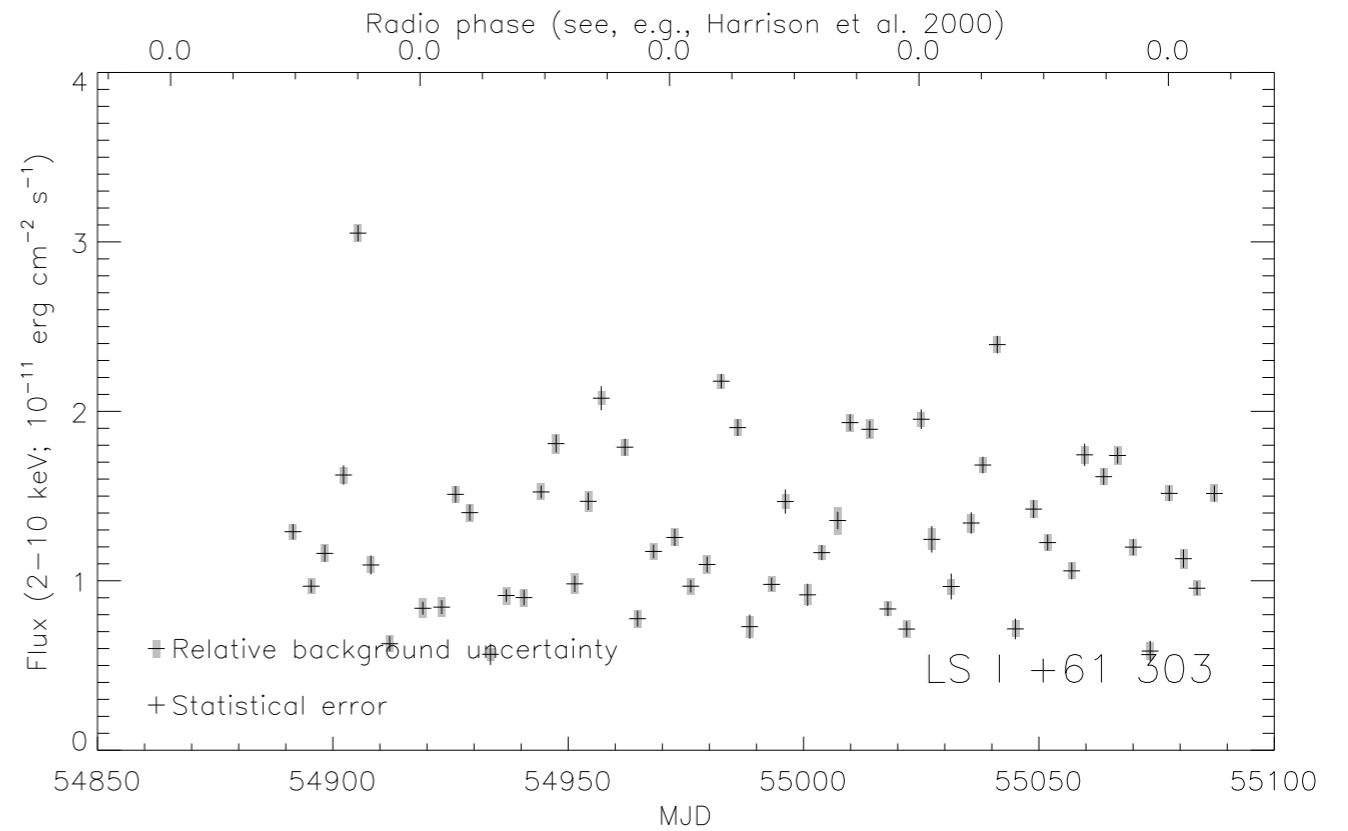
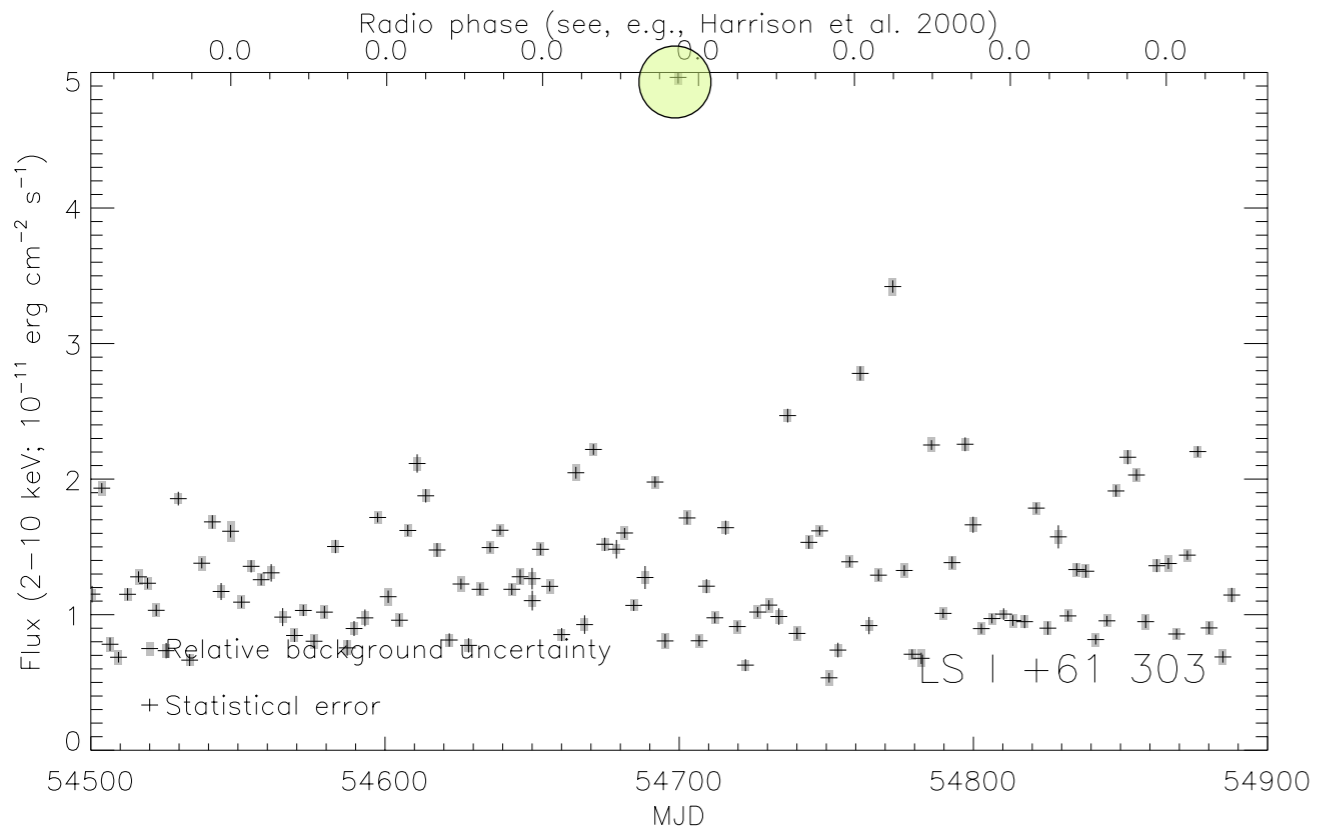
- Includes only data from before pulsar turned on

IGR J18246-1425

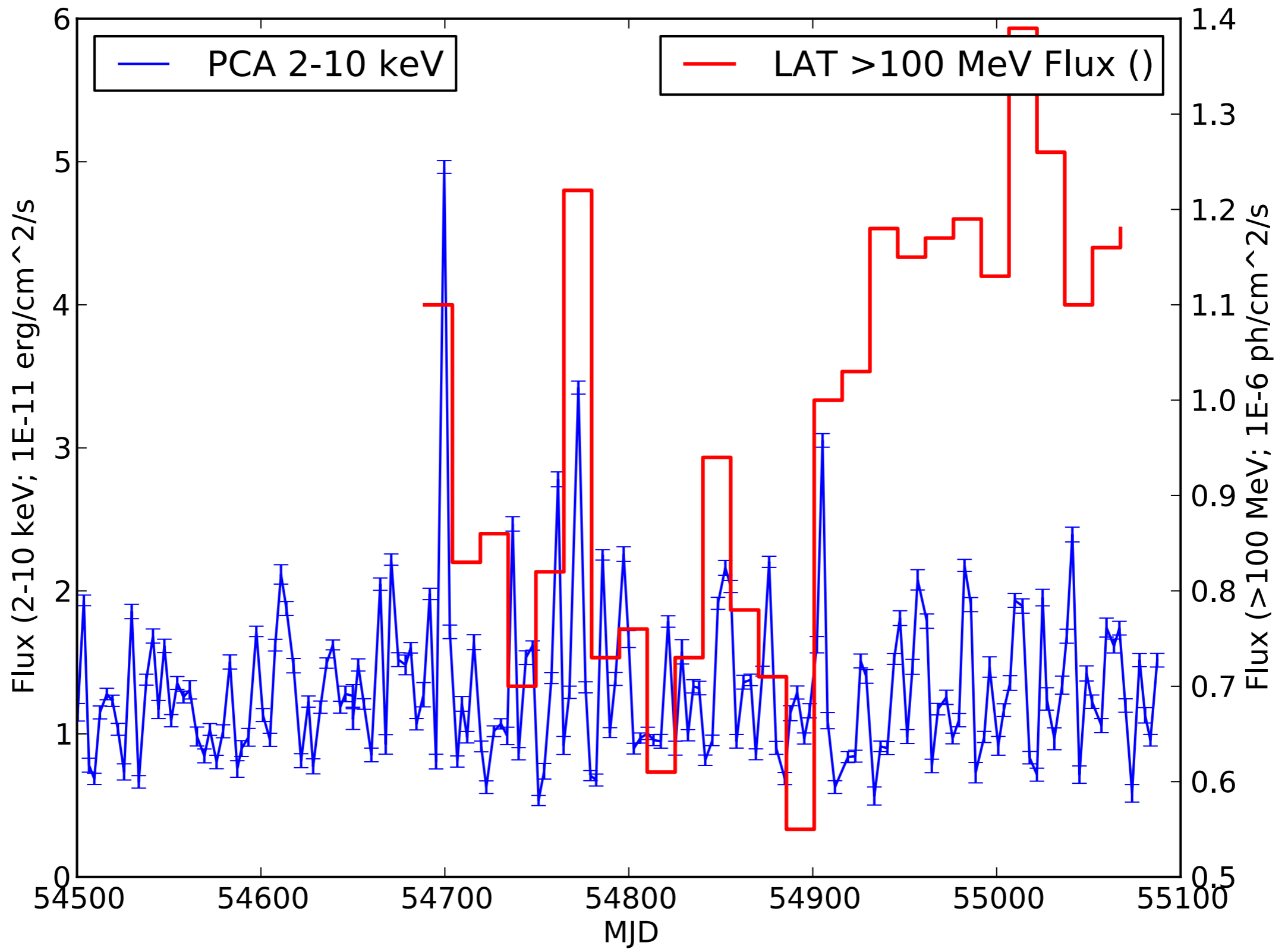
- 120 s transient X-ray pulsar, 0.6° from LS 5039
- Still seems to be sporadically contaminating monitoring data



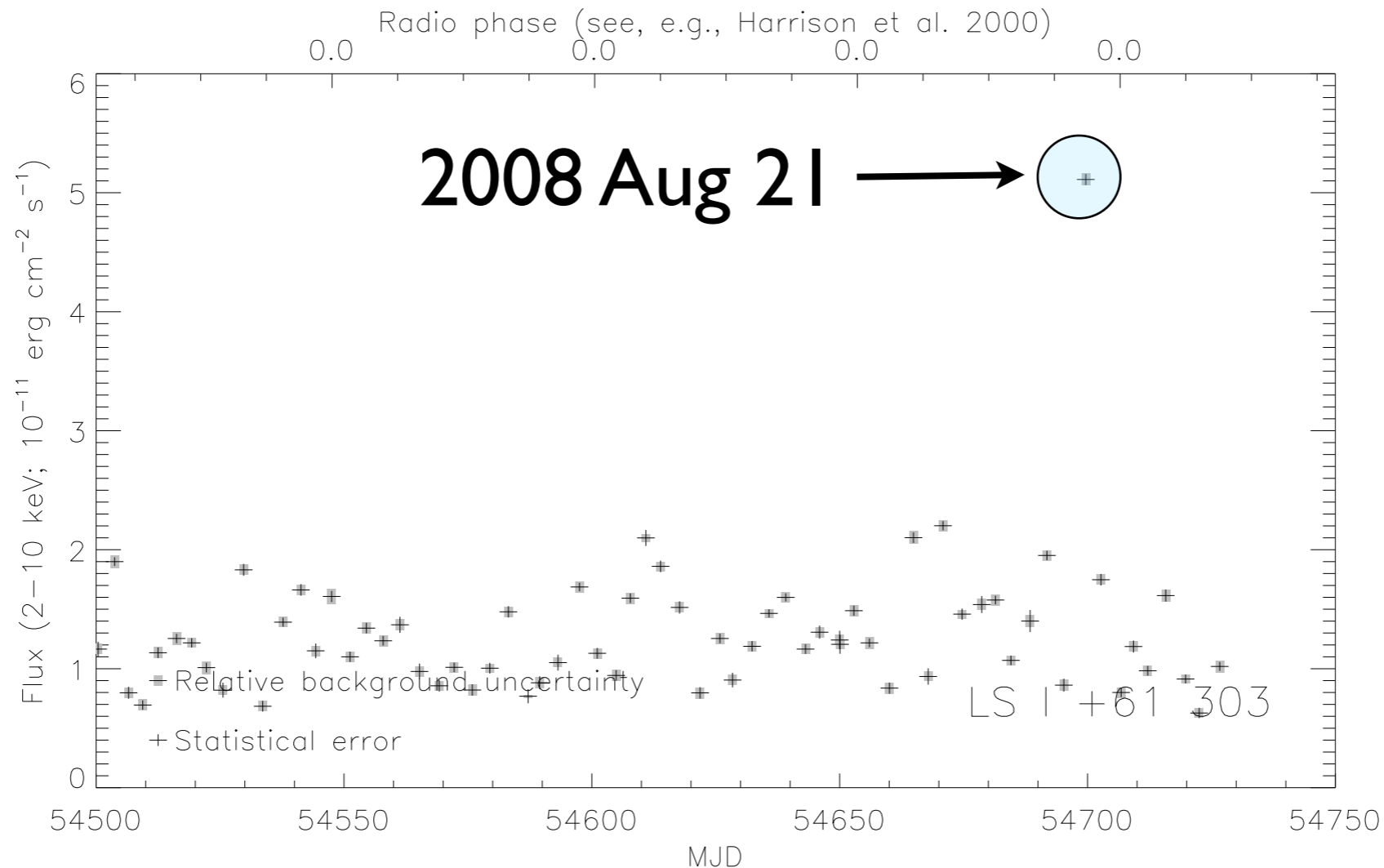
LS I +61 303



LAT & RXTE Data

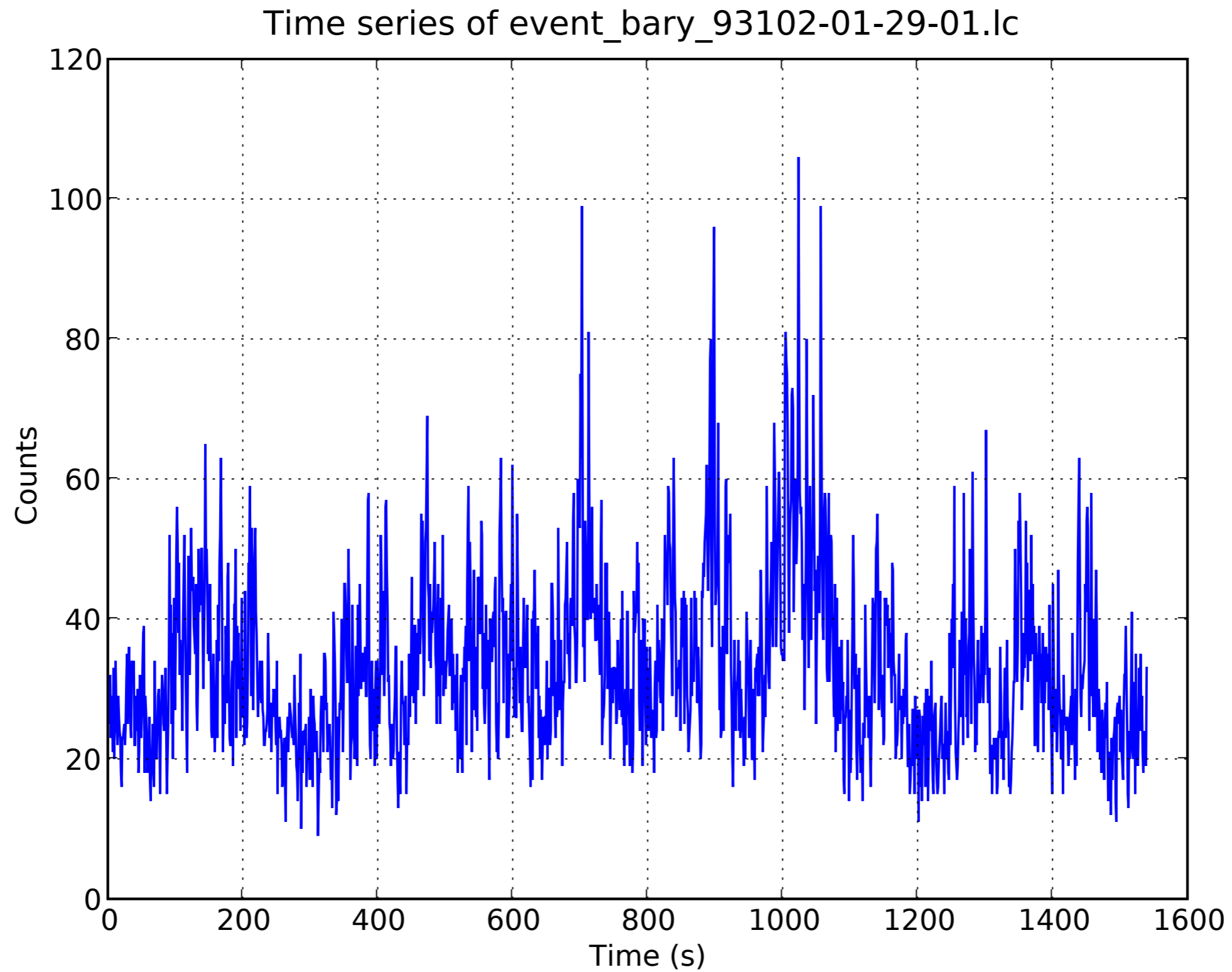


RXTE Monitoring



- Flare reported in ATel #1730, with harder spectrum than normal and very unusual variability characteristics.
- This kind of flare also seen by Smith et al. (2008)

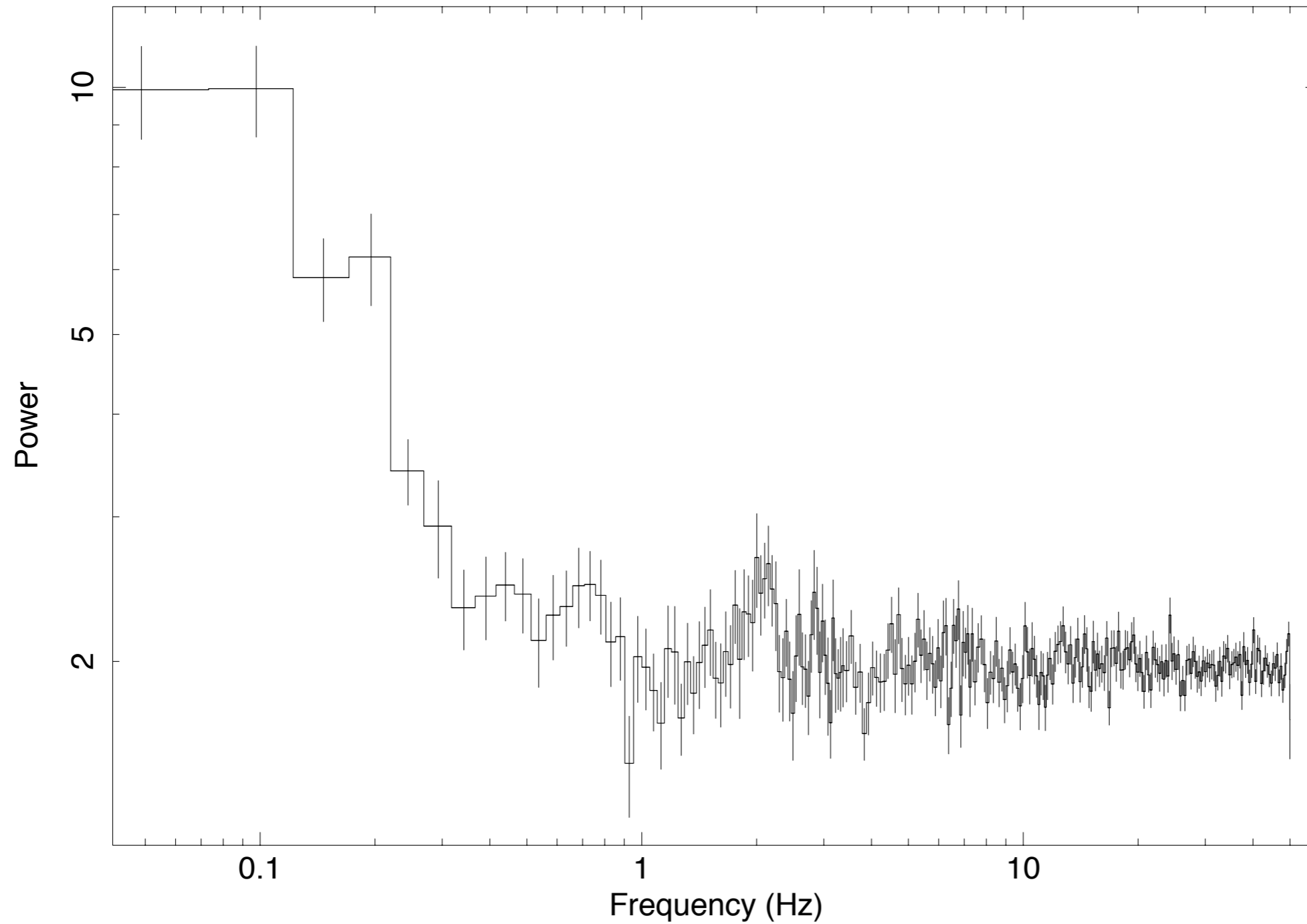
Time series (1 s bins) from 2008 Aug 21



Power Spectrum from 2008 Aug 21

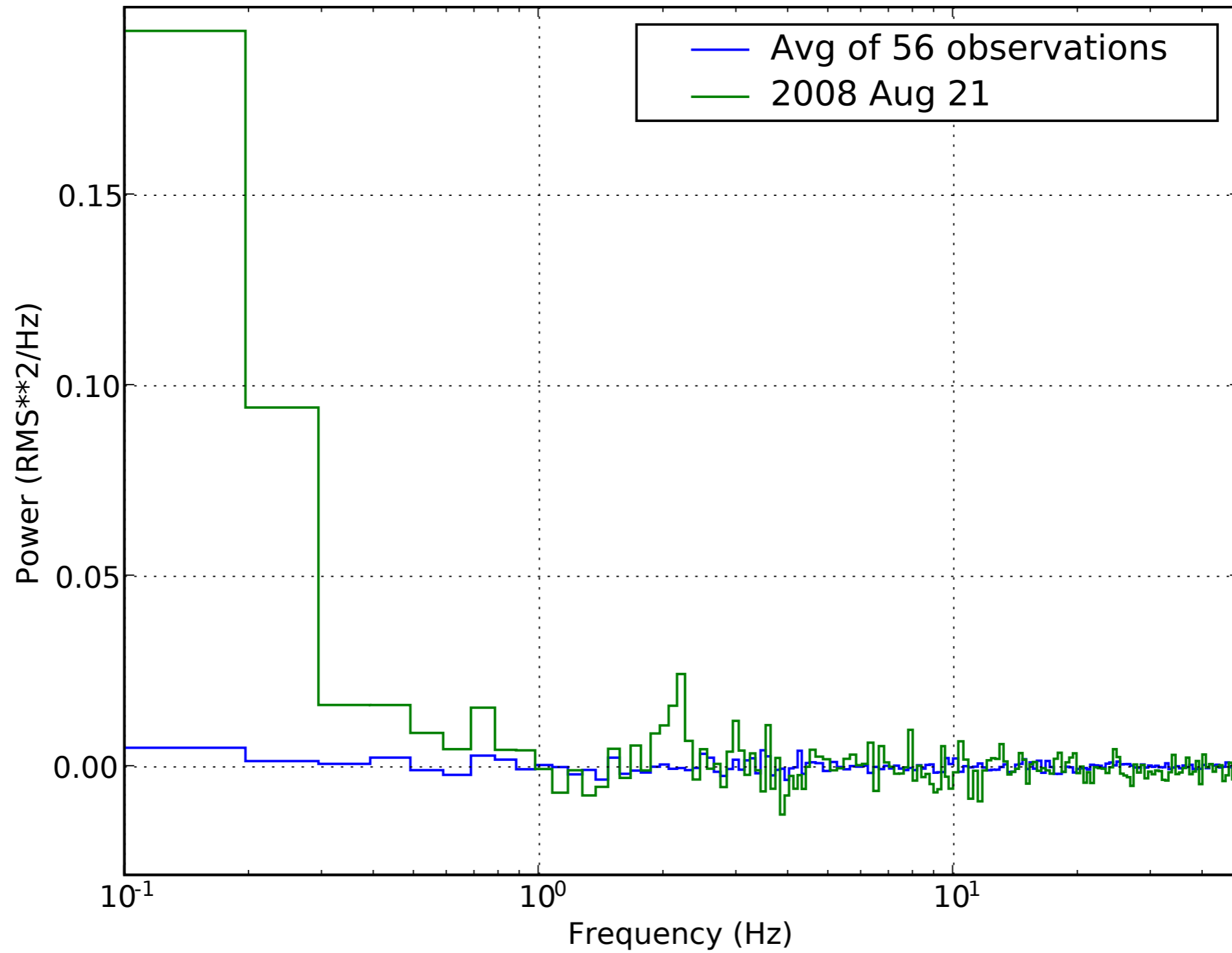
LSI_+61_303

Bin time: 0.1000E-01 s



Start Time 14699 15:23:27:567 Stop Time 14699 15:49:03:557

LS I +61 303 PCA Power Spectra



Swift Burst

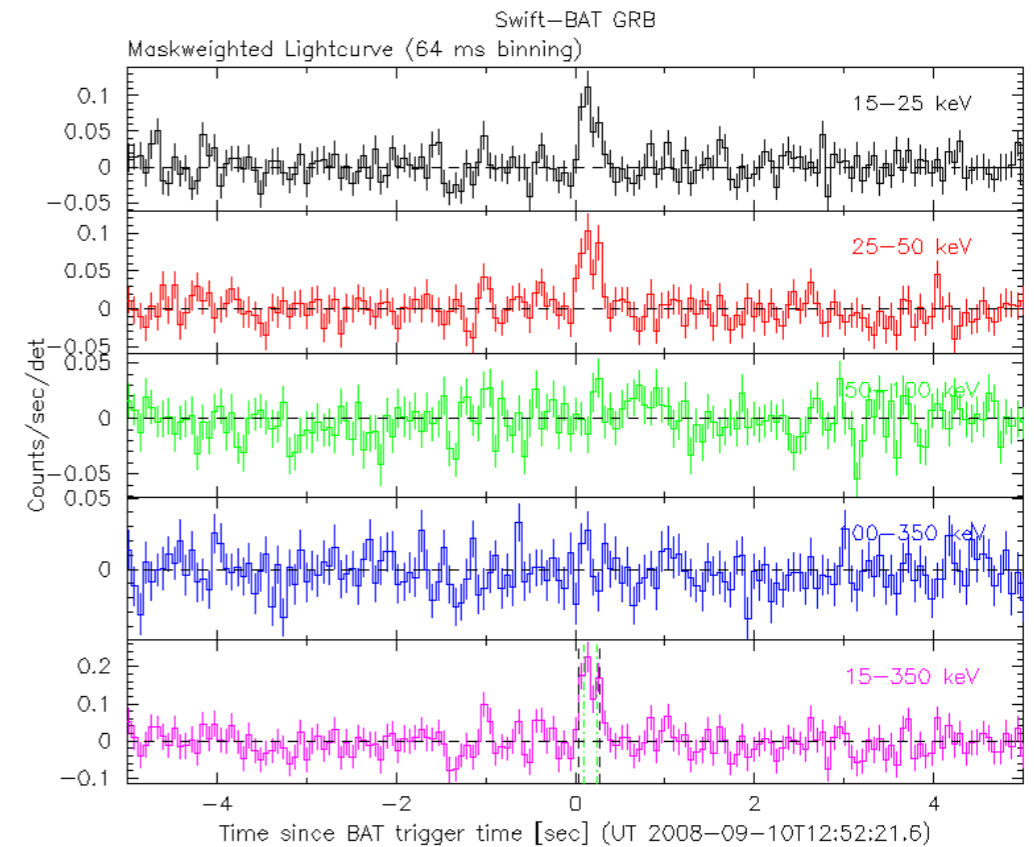
- Swift BAT triggered on 200 ms burst at 2008-09-10 12:52:21 UT

- Questions

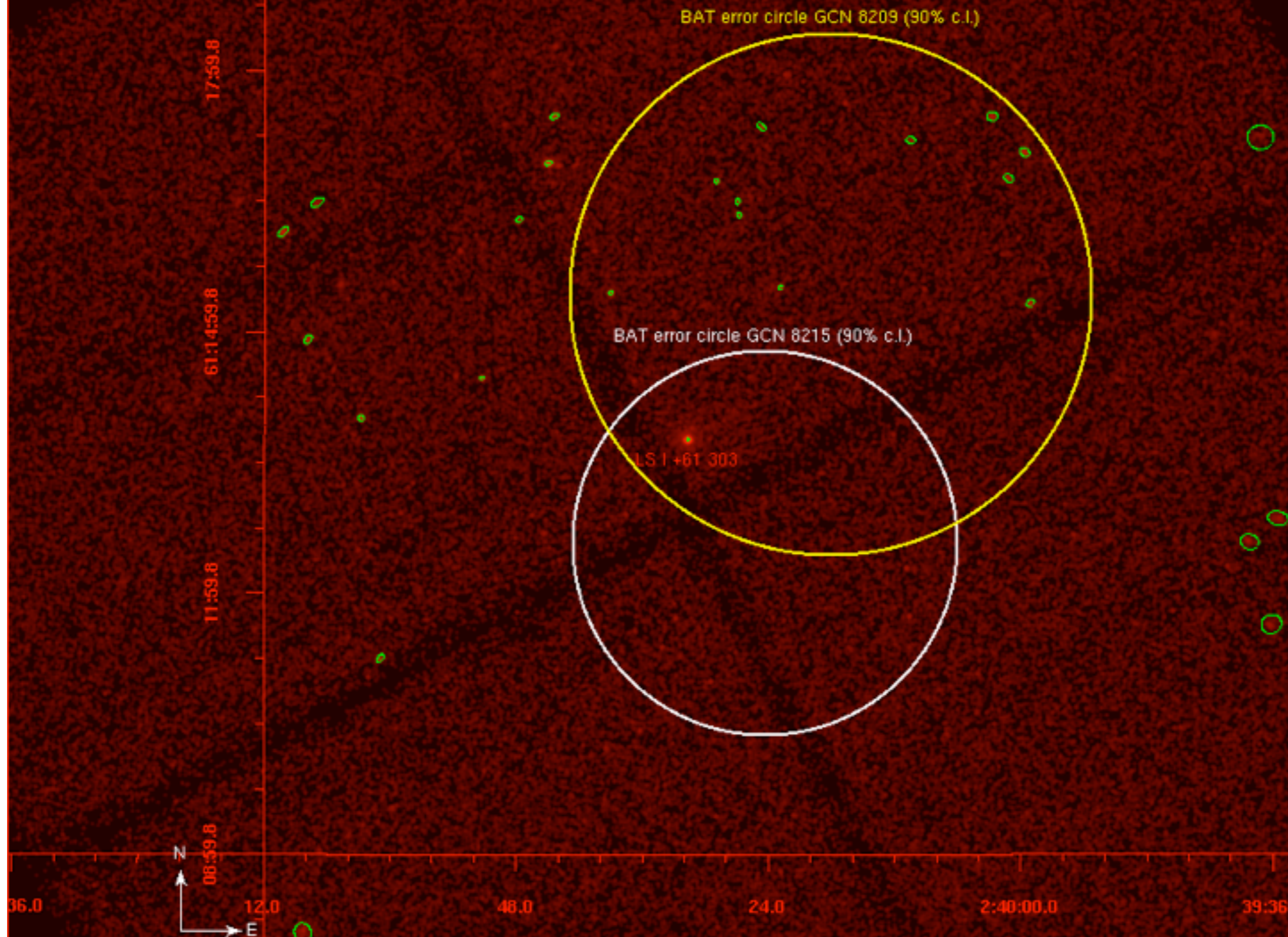
- ▶ Is burst from LSI +61 303?

Position is 1.5 arcmin from LSI, with 2.2 arcmin error circle. Could be a GRB or magnetar burst from some other source in field (see ATel #1731)

- ▶ So far, no evidence at other wavelengths for the association and no other bursts like this have been reported.



Chandra Field



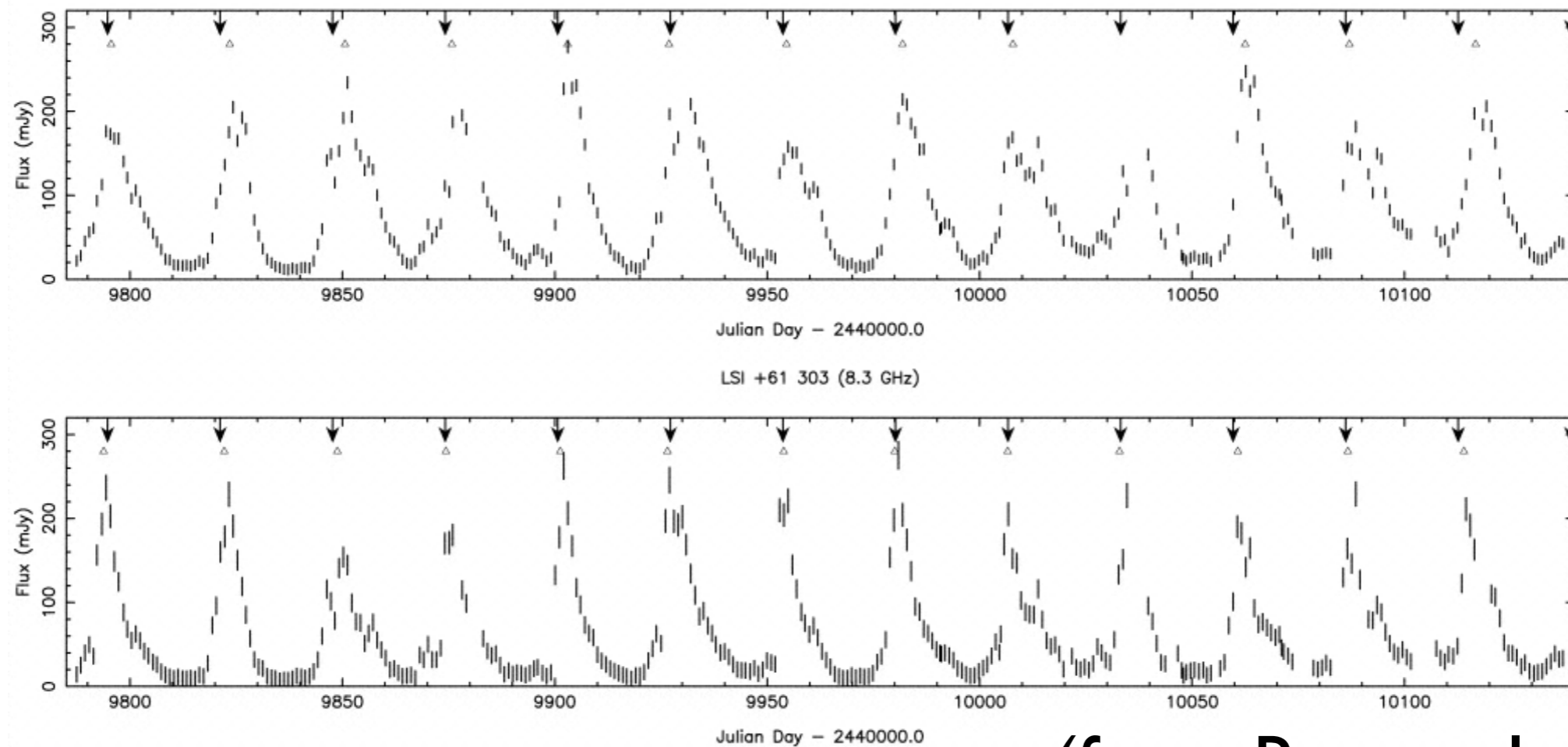
From Rea & Torres (ATel #1731)

Summary

- LSI +61 303 and LS 5039 being monitored as part of the public core program
 - LSI +61 303 providing valuable context information for Fermi LAT and other studies
 - LS 5039 was very nice early on but has been confused with nearby transient pulsar recently

Radio Flux Monitoring

- Using AML (formerly Ryle Telescope) at 15 GHz
- Track radio emission during the orbit
 - Radio light curve varies a lot from cycle to cycle



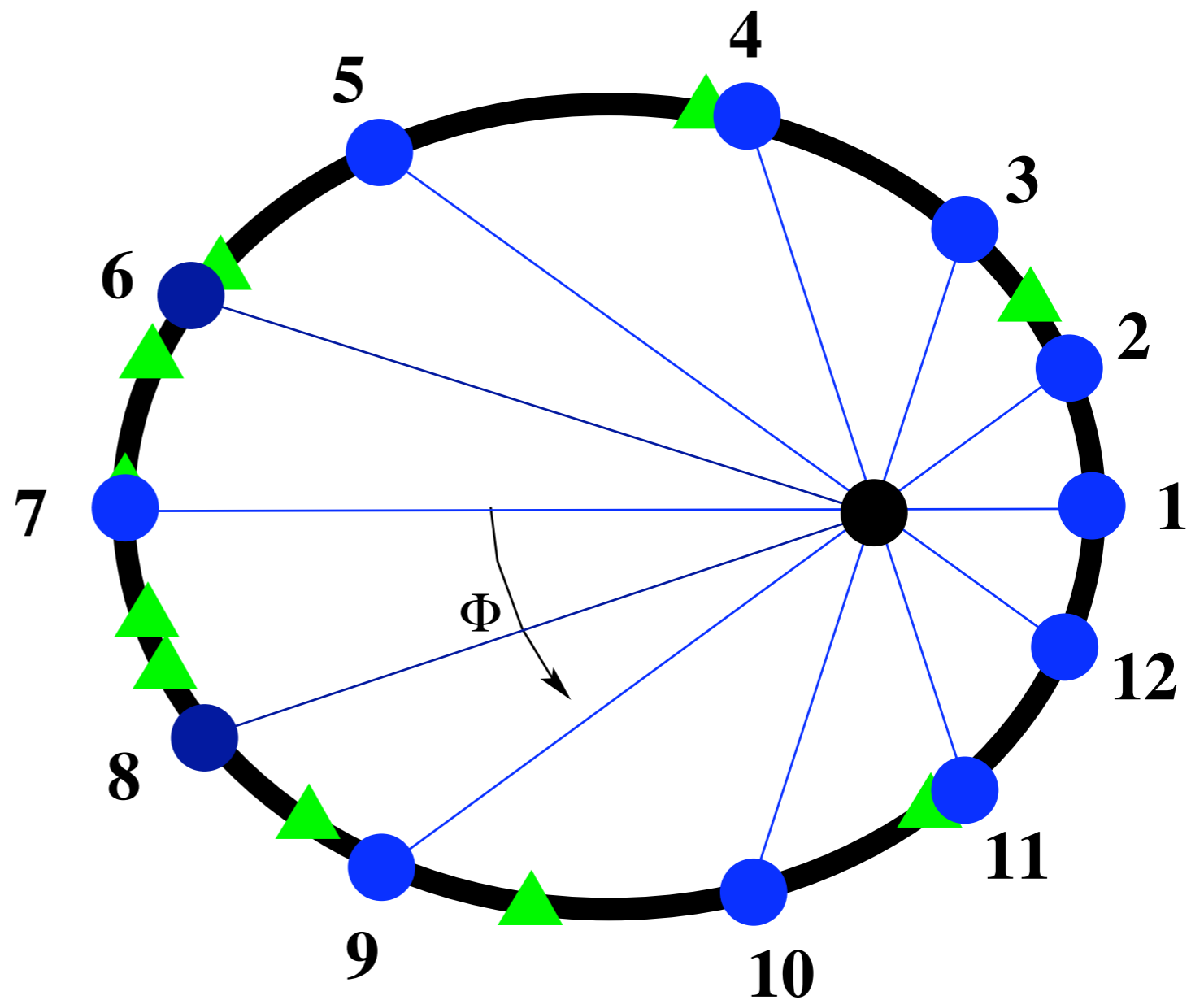
(from Ray et al. 1997)

Multi-Band VLA Observations

- Broad band radio spectra
 - 6 bands covering 1.4 – 43 GHz
- A configuration, 6 epochs
 - October 15/16, 0100-0300 LST
 - October 22/23, 0100-0300 LST
 - October 29/30, 0100-0300 LST
 - November 5/6, 0100-0300 LST
 - November 12/13, 0100-0300 LST
 - November 19/20, 0130-0330 LST

RXTE Intensive Look

- 12 x 6-ks observations spaced around the orbit



Multiwavelength Follow Up

- LSI team is:
 - ▶ Studying RXTE observations before and after outburst. One was ~6 hours after burst.
 - ▶ Looking at ToO observations made with VLA and VLBA on Sunday (Sept 14) and continuing for 5 days
 - ▬ VLBA data still waiting to be correlated
 - ▶ Going to look for radio pulsations again at GBT
 - ▶ Will have optical data starting Oct 16 in case of additional bursts