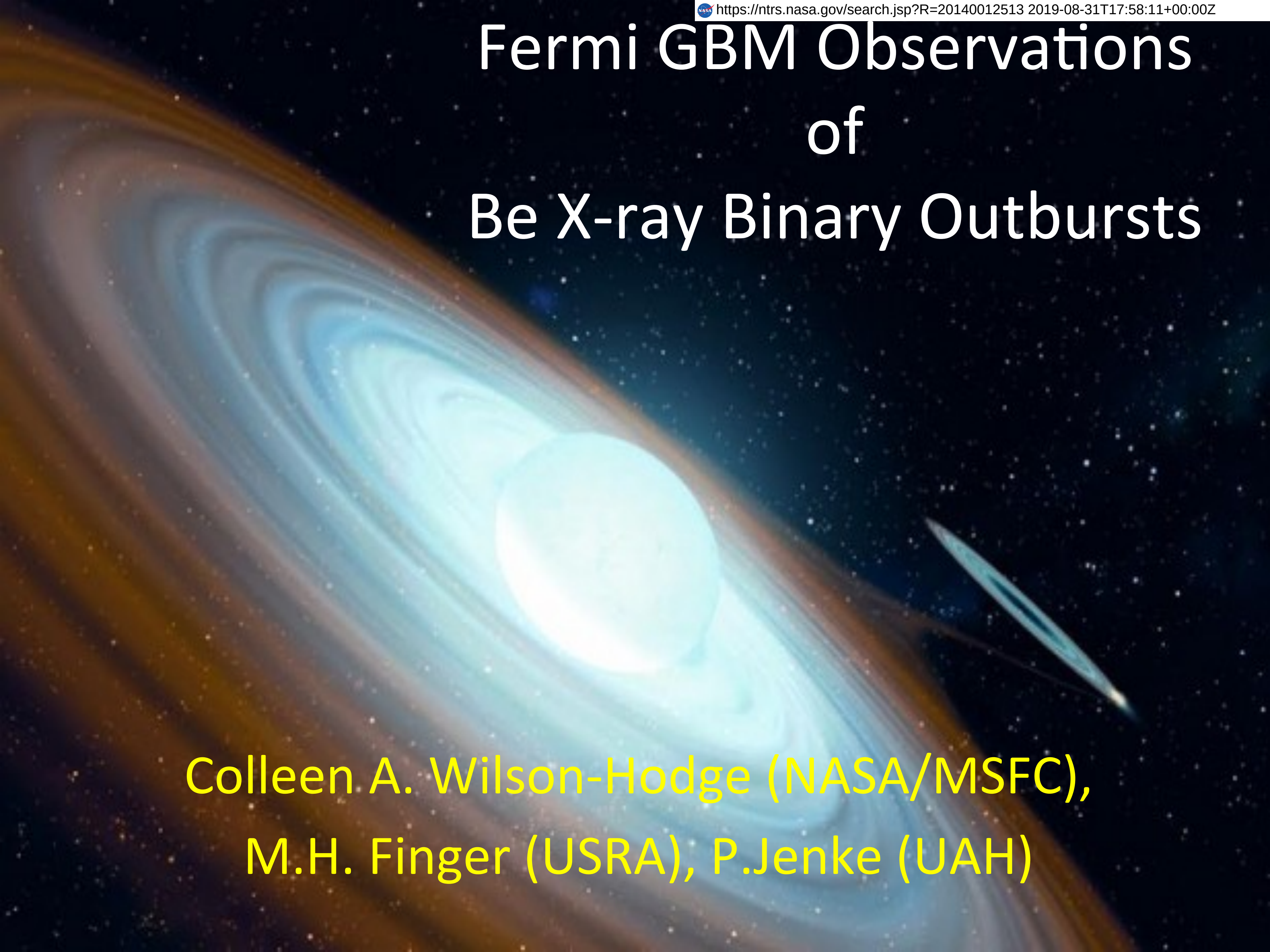

Fermi GBM Observations of Be X-ray Binary Outbursts

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M.H. Finger (USRA), P.Jenke (UAH)

Teams

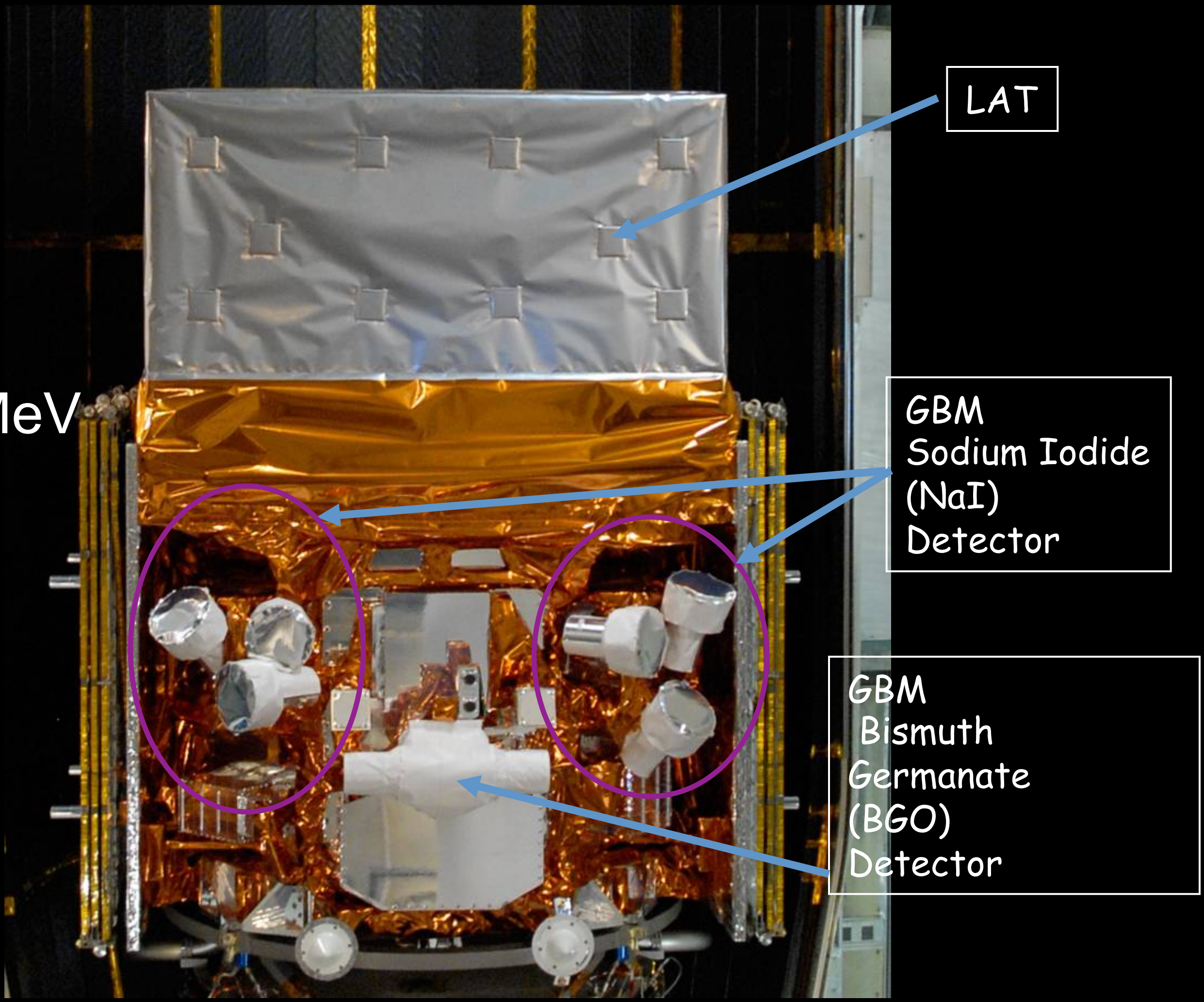
- GBM Pulsar Team
  - Mark H. Finger (PI), E. Beklen, P.N. Bhat, D. Buckley, A. Camero-Arranz, M.J. Coe, V. Connaughton, P. Jenke, G. Kanbach, I. Negueruela, W.S. Paciesas, C.A. Wilson-Hodge
- GBM Earth Occultation team
  - Colleen A. Wilson-Hodge (PI), E. Beklen, P.N. Bhat, A. Camero-Arranz, G.L. Case, M.L. Cherry, V. Connaughton, M.H. Finger, P. Jenke, J. Rodi

Outline

- Introduction
  - Fermi GBM
  - Techniques
    - Pulsed frequency and pulsed flux monitoring
    - Earth occultation monitoring
- Science topics
  - Source Monitoring
  - Torque switching
  - QPO in A0535+262
  - Outburst behaviors
- Summary and Conclusions

Fermi Gamma Ray Burst Monitor (GBM)

- GBM
  - 12 NaI detectors
    - 8keV - 1 MeV
  - 2 BGO detectors
    - 150 keV - 40 MeV



Pulsed Frequency and Pulsed Flux Monitoring

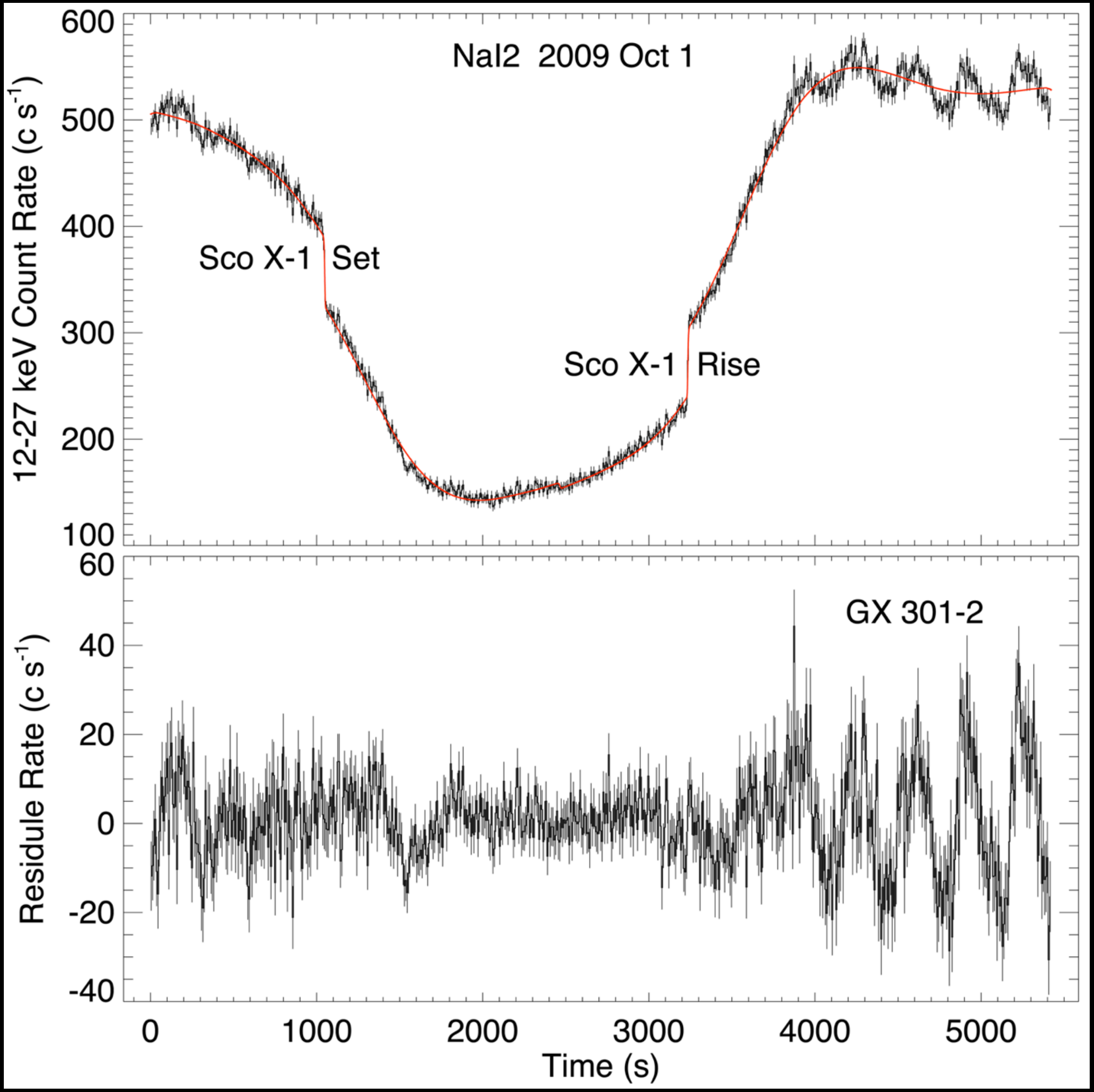
The analysis of GBM observations of pulsars presents two main challenges:

- The background rates are normally much larger than the source rates, and have large variations.
- The responses of the detectors to a source are continuously changing because of Fermi's continuous re-orientation.

The initial steps of the pulsed data analysis are:

- Data Screening
- Background subtraction of the NaI detector count rates
- Determination of fluxes from remaining rates

Background Subtraction



The rates in each channel of the 12 NaI detectors are fit with a model with the following components:

- Models for bright sources.
- A stiff empirical model that contains the low-frequency component of the remaining rates.

The fits are made independently for each channel and subtracted from the rates.

Estimating Pulsed Fluxes

For a given source we combine the rate residuals over detectors and obtain an estimate of the variable part of the source flux. Using a model of the source spectrum and the time dependent detector responses we compute the source induced rate μ_{ik} expected in detector *i* at time t_k if the source has unit flux in the channel's energy range. The variable part of the flux $\tilde{f}_k$ is then estimate by minimizing

$$\chi_k^2 = \sum_i \frac{(\tilde{r}_{ik} - \tilde{f}_k \mu_{ik})^2}{\sigma_{ik}^2}$$

where $\tilde{r}_{ik}$ is the residual rates and σ_{ik} the associated errors.

Pulse Searches

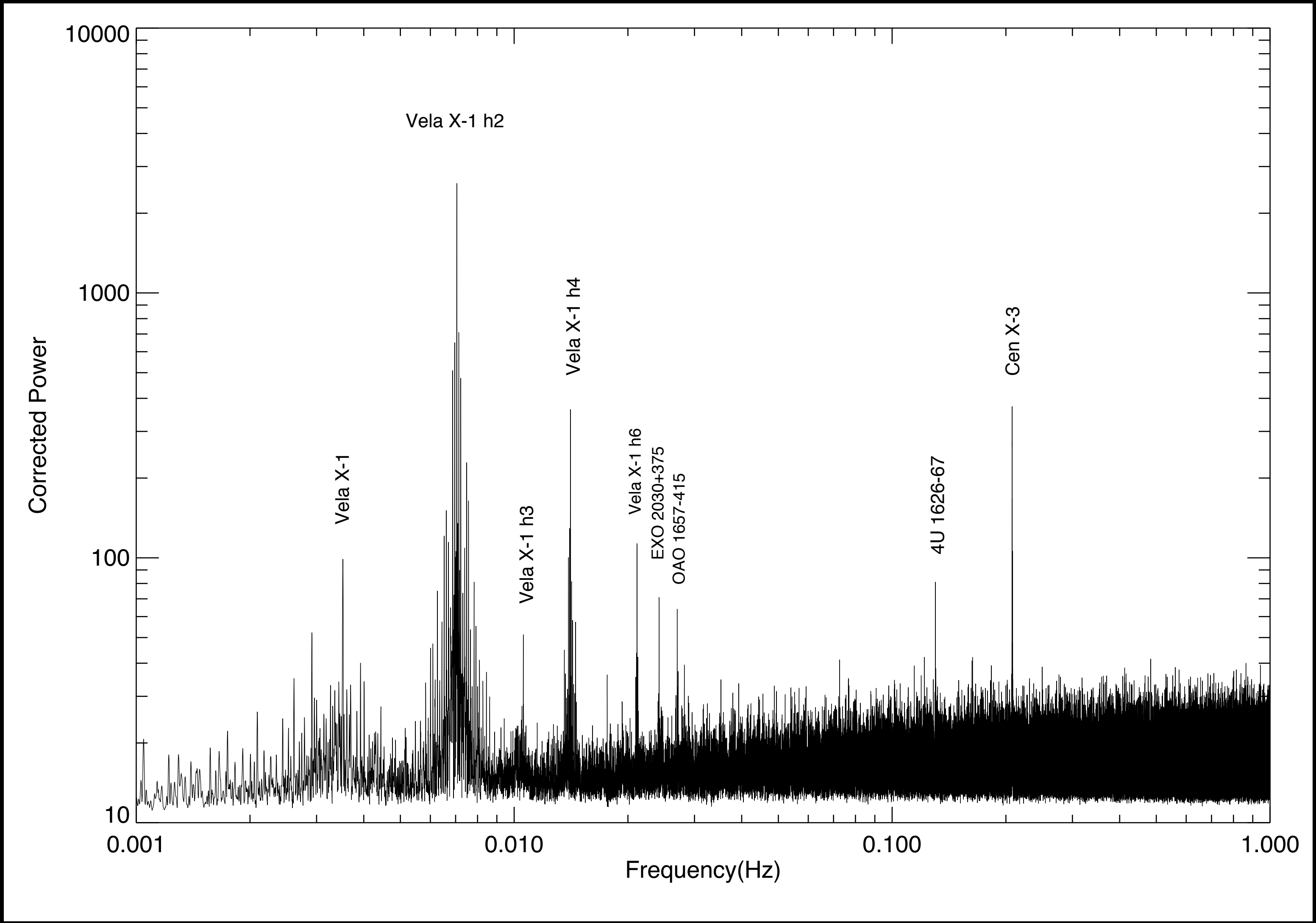
We have implemented two different pulse search strategies:

- Daily Blind Search. For this we compute fluxes from a days data for 24 source directions equally spaced on the galactic plane. For each direction we do an FFT based search from 1 mHz to 2 Hz.

- Source Specific Searches. These are searches over small ranges of frequency and sometimes frequency rate based on phase shifting and summing pulse profiles that are made from short intervals of data, using barycentered and possibly orbitally corrected times. Typical exposure times are ~40 ks/day.

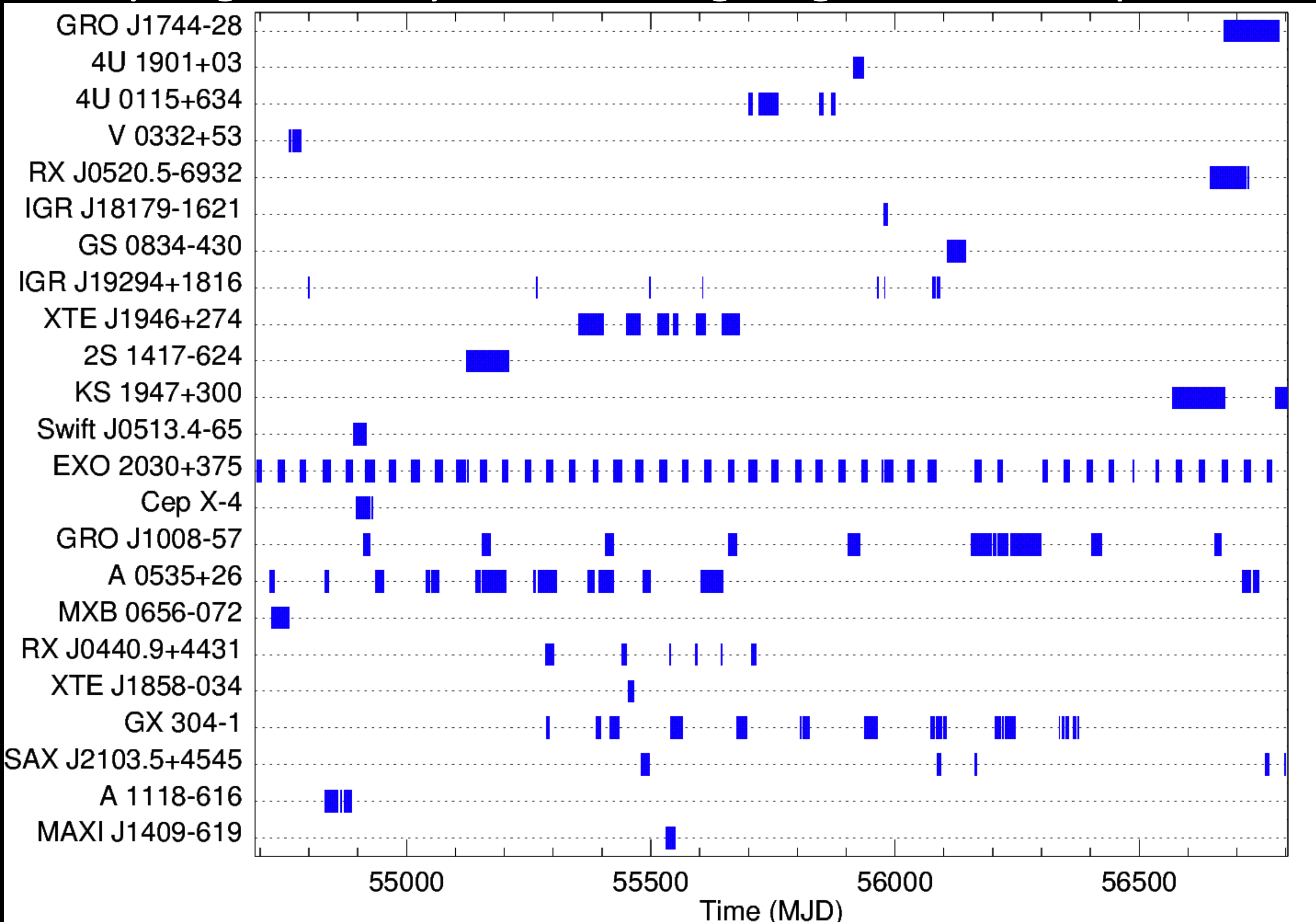
- Detected 8 persistent sources, 20 of 23 monitored transients

Blind Pulse Search



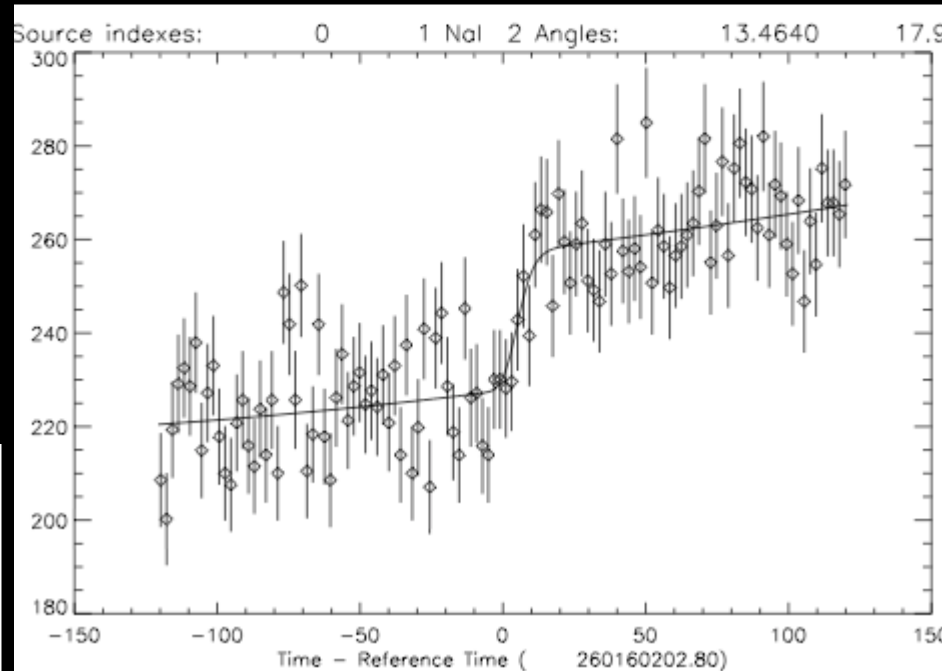
Blind pulse search in 20-50 keV band, for 2010 January 8.

http://gammaray.nsstc.nasa.gov/gbm/science/pulsars



GBM Earth Occultation Monitoring

The observed count rate in a 240-s window of data is fitted by a model consisting of a quadratic background plus source terms.



$$r(t, E_{ch}) = b_0(E_{ch}) + b_1(E_{ch}) * (t - t_0) + b_2(E_{ch}) * (t - t_0)^2 + \sum_{i=1}^{n} a_i(E_{ch}) * S_i(t, E_{ch}) \quad (2)$$

The source count rate is modeled using an assumed energy spectrum, convolved with the atmospheric transmission function and folded through the detector response matrix

$$S(t, E_{ch}) = R(E_{ph}, E_{ch}, t) \left(T(E_{ph}, t) \right) \int_{E_{ph}} f(E_{ph}) dE_{ph} \right) \quad (3)$$

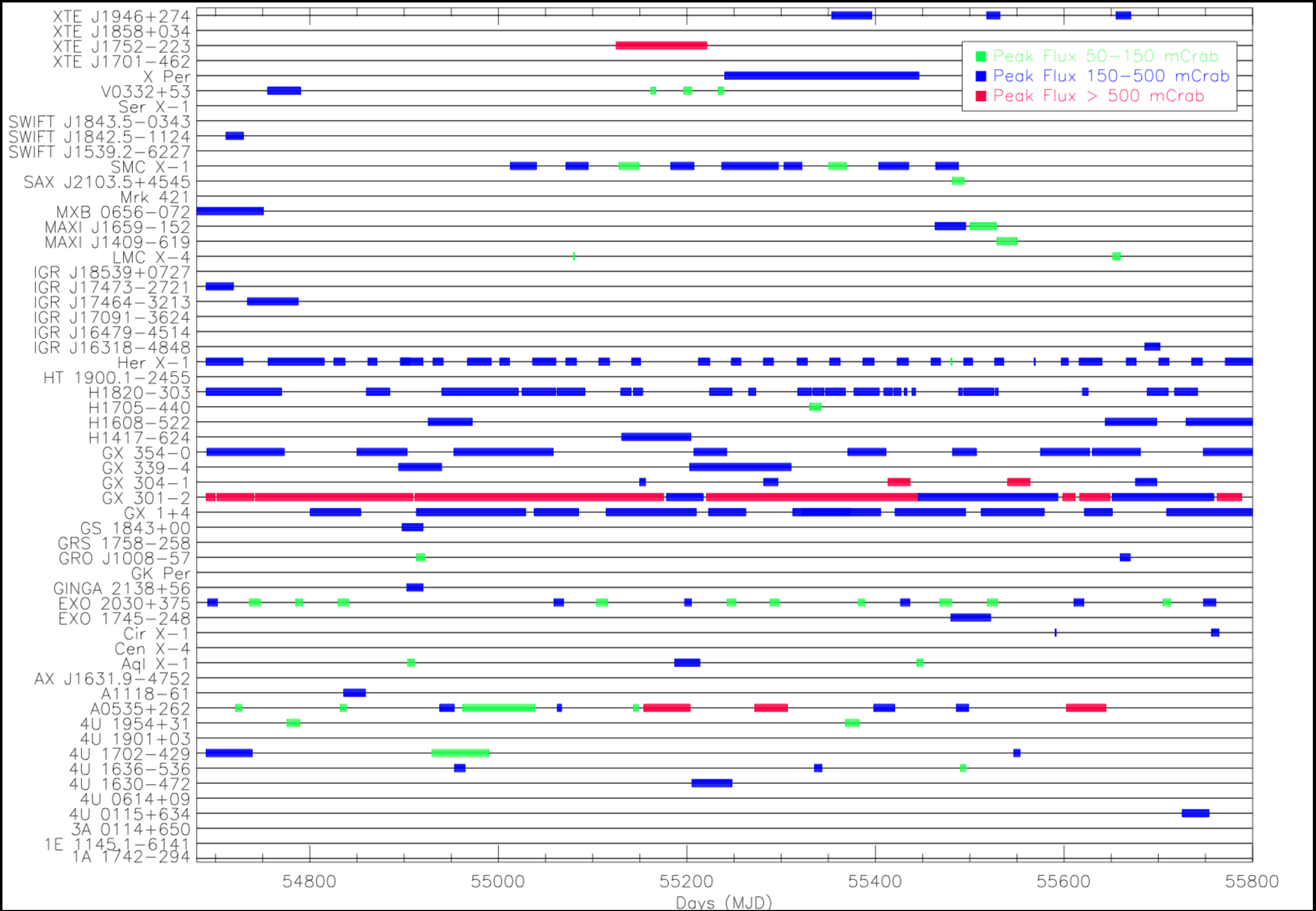
GBM Earth occultation Monitoring (2)

- Using the first 3 years of GBM data, a catalog of 209 sources was monitored, with 99 sources detected, including 41 of 52 LMXBs, 31 of 39 HMXBs, 12 of 19 BHCs, 12 of 71 AGN, the Ophiuchus Cluster, the Sun, and the Crab.
- 7 BHCs, 1 AGN (Cen A), and the Crab are detected above 100 keV.
- Typical source exposure times are 3ks/day.

Wilson-Hodge et al. 2012, ApJ, Accepted, arXiv:1201.3585

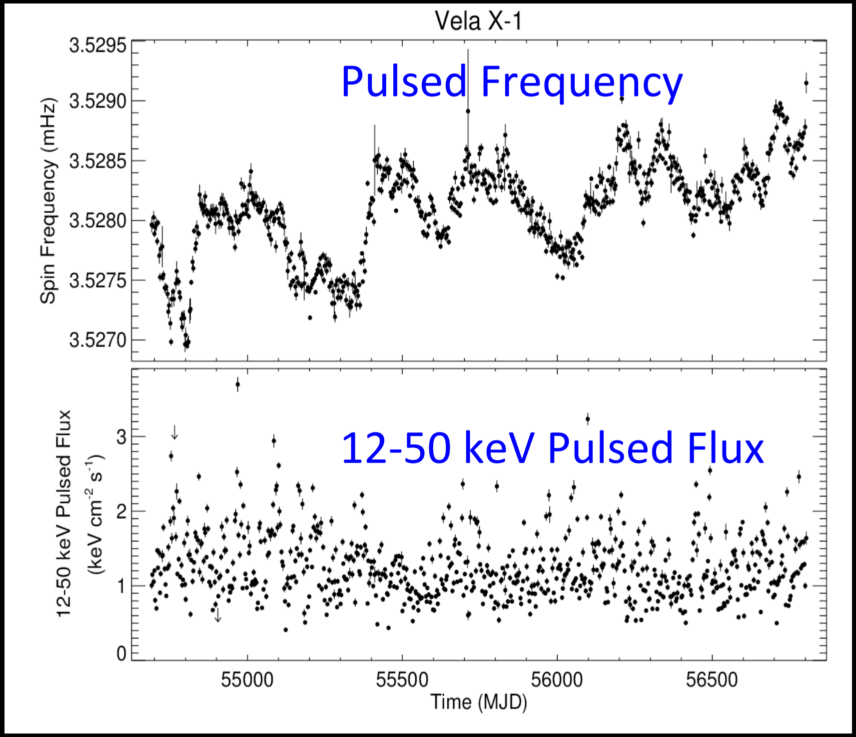
http://heastro.phys.lsu.edu/gbm

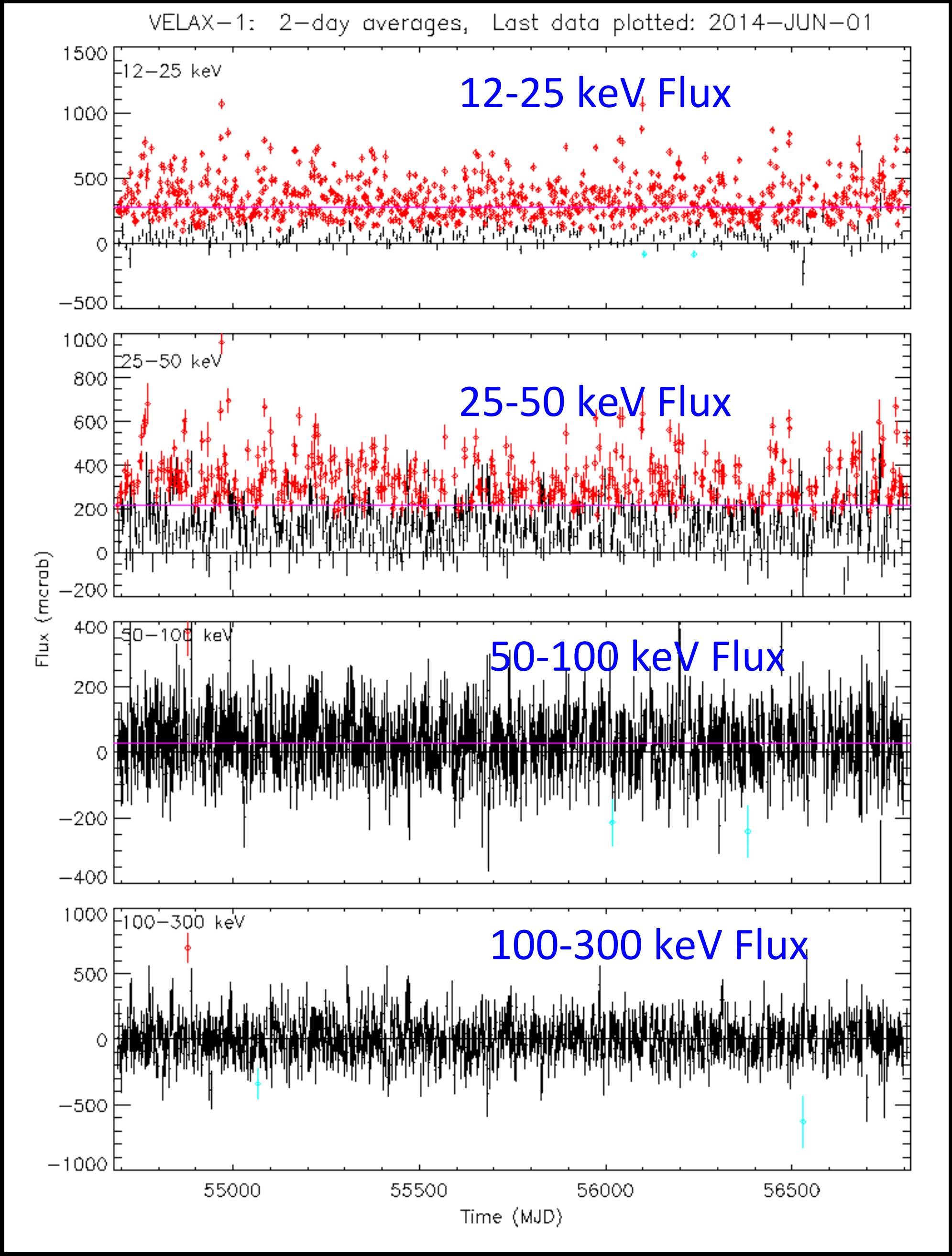
http://heastro.phys.lsu.edu/gbm



Source Monitoring: Vela X-1

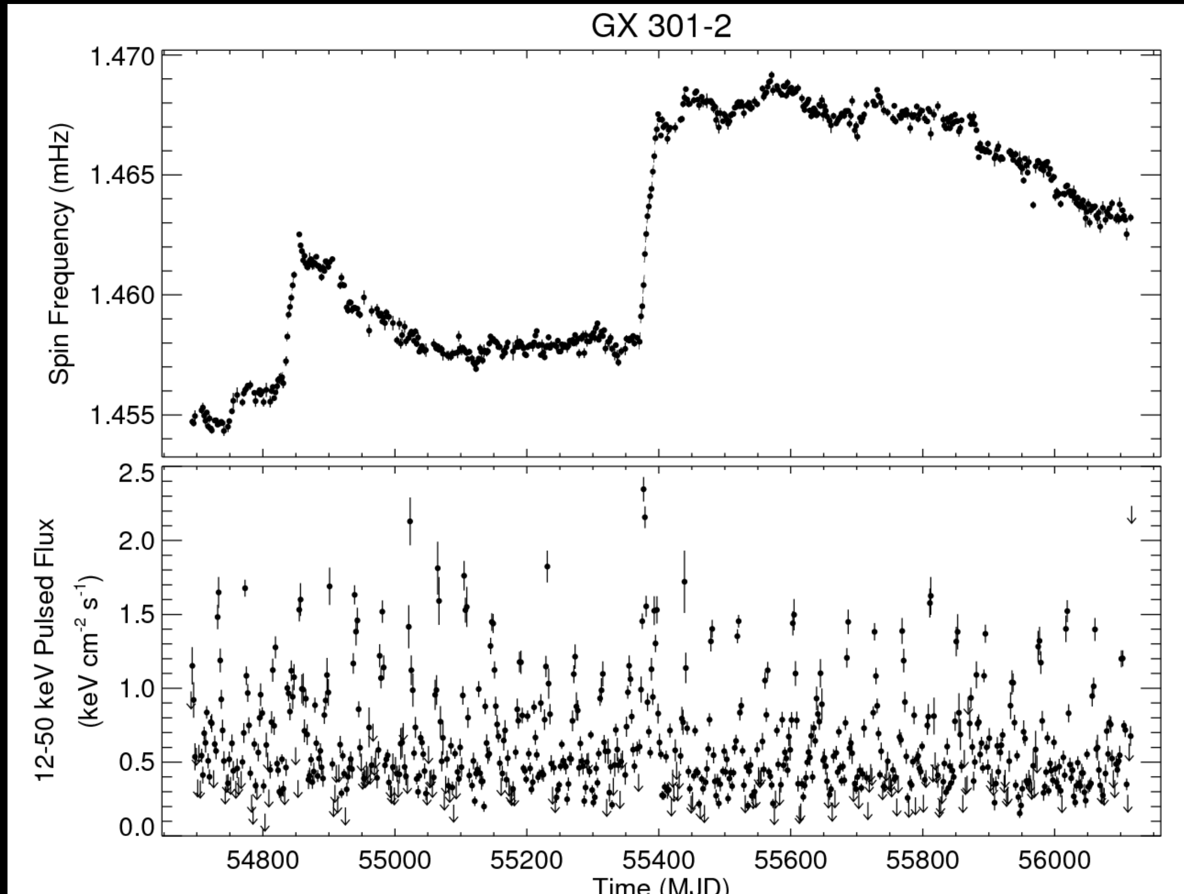
P_{spin} = 283 s
P_{orbit} = 8.96 d
wind-fed supergiant





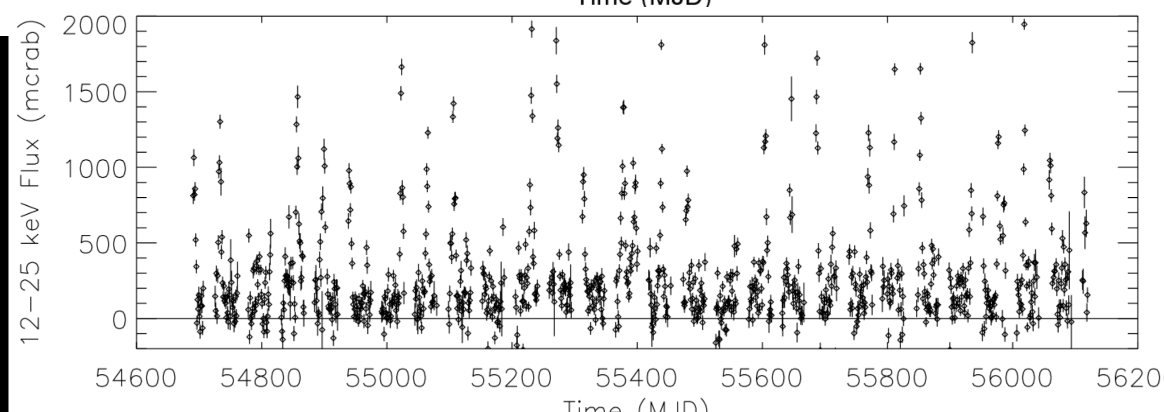
Source Monitoring: GX 301-2

P_{spin} = 681.6 s
P_{orbit} = 41.472 d
wind-fed
supergiant



Frequency

12-25 keV
Pulsed Flux

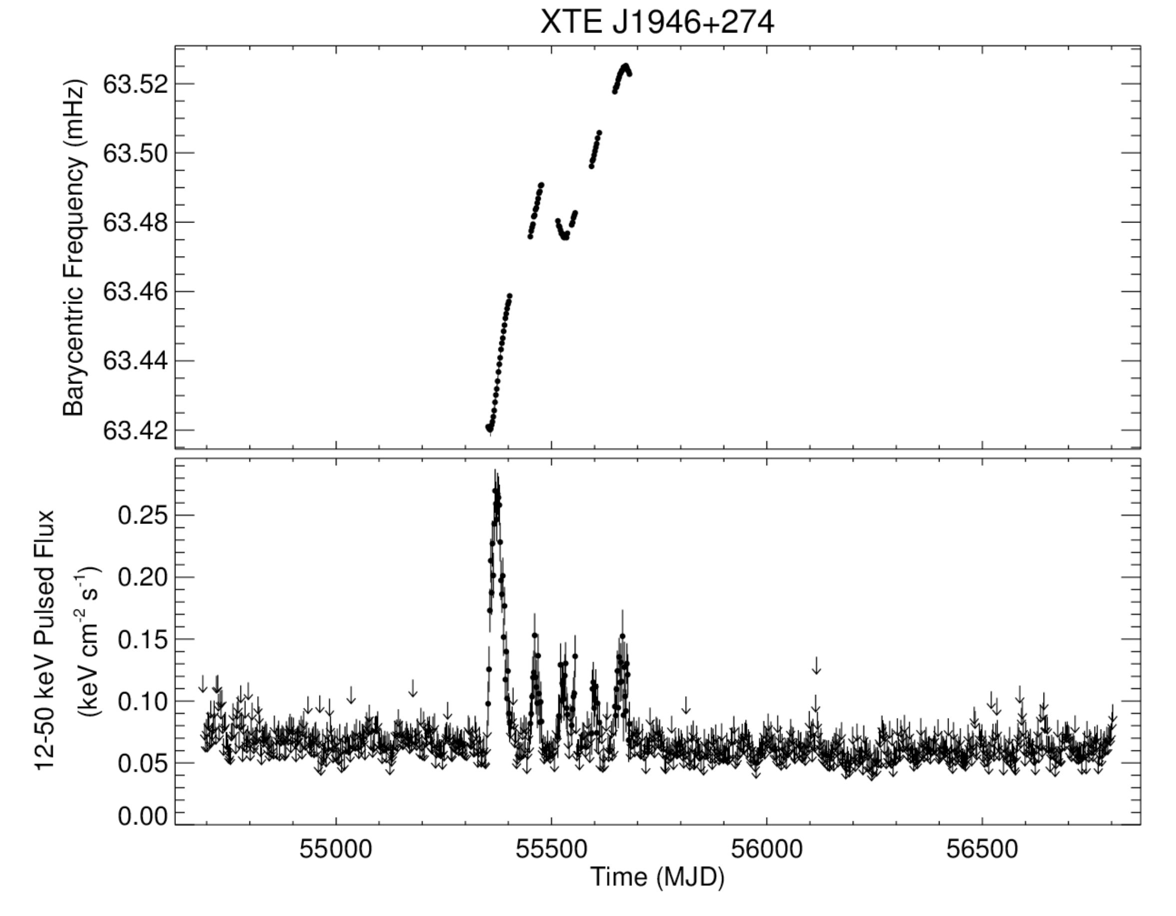


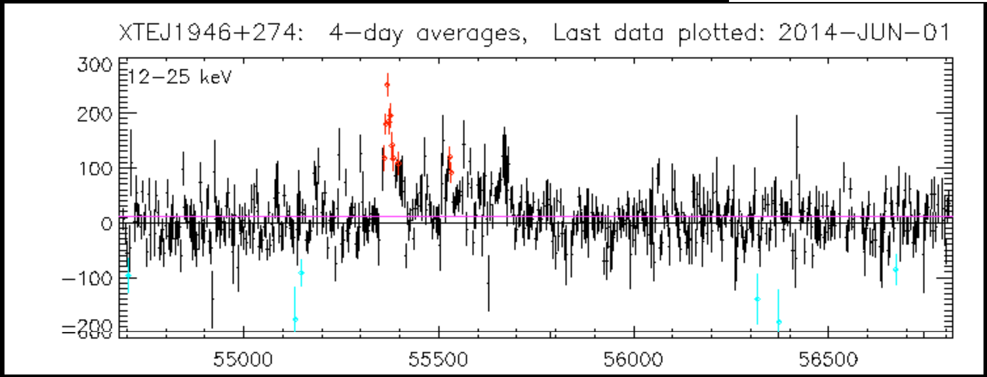
12-25 keV
Phase-averaged
flux

GX 301-2
Poster:
Pustilnik
E1.5-0033

XTE J1946+274

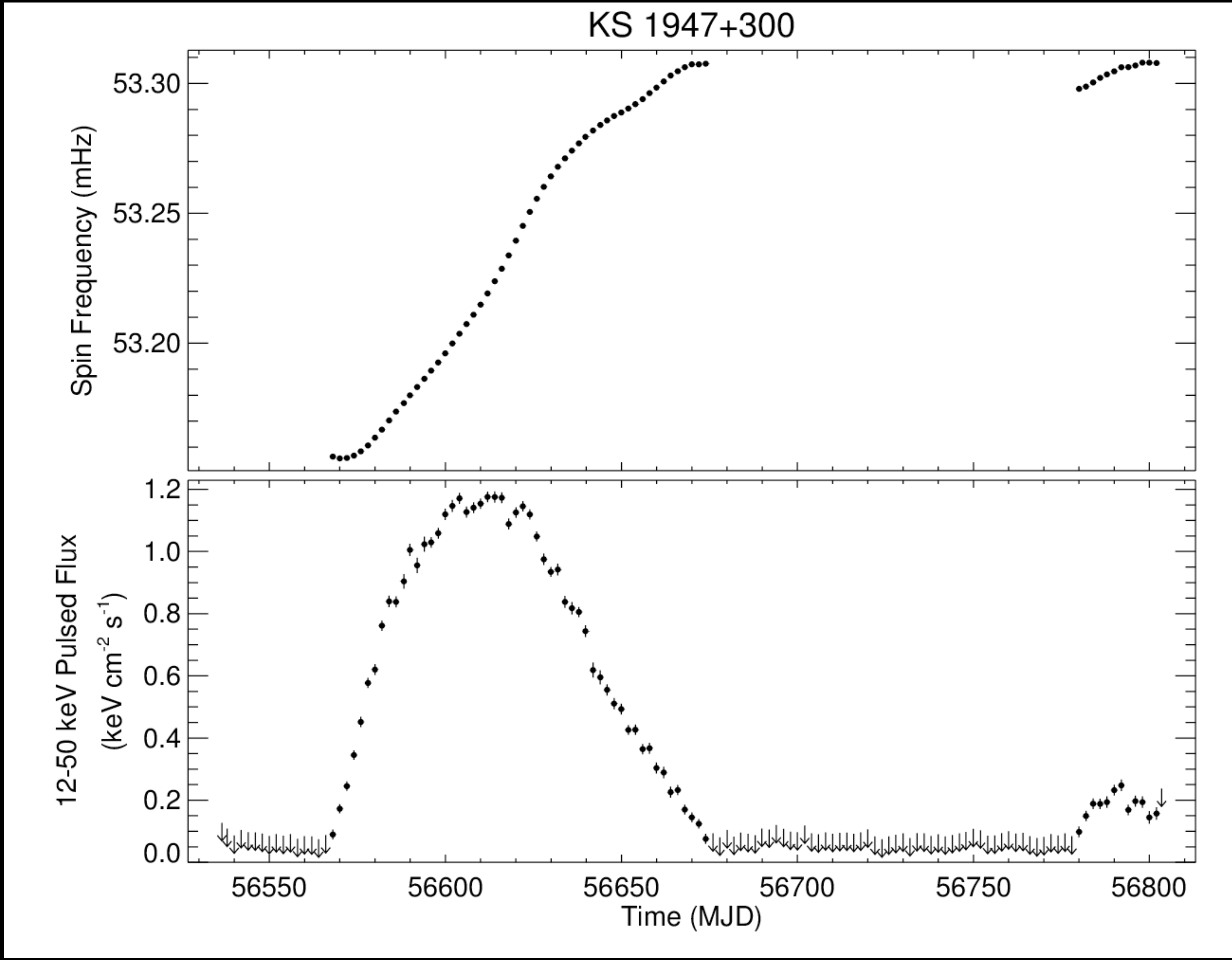
Pspin = 15.8 s
Porb = 167 d



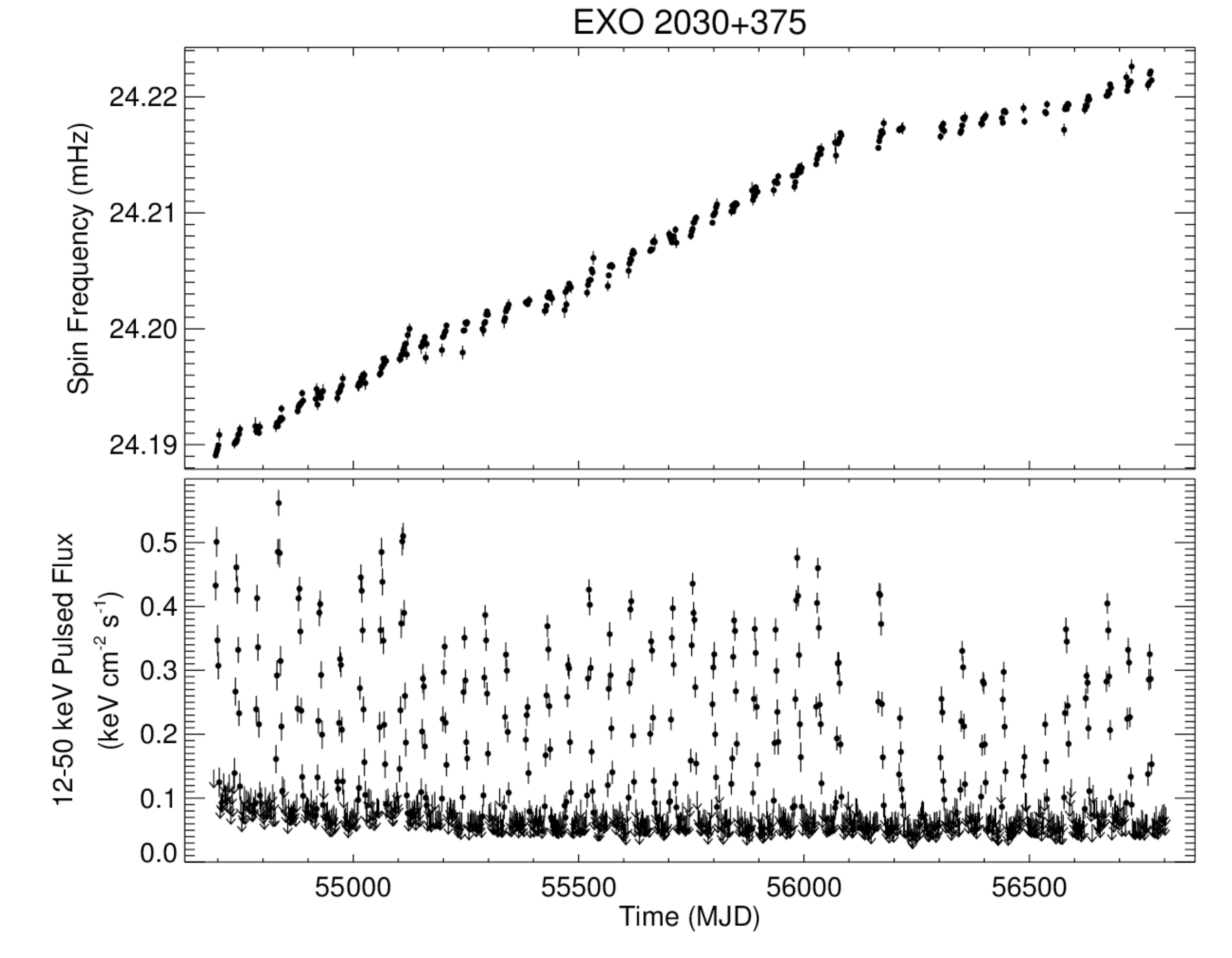


KS 1947+300

Pspin = 18.8 s
Porb = 40.4 d

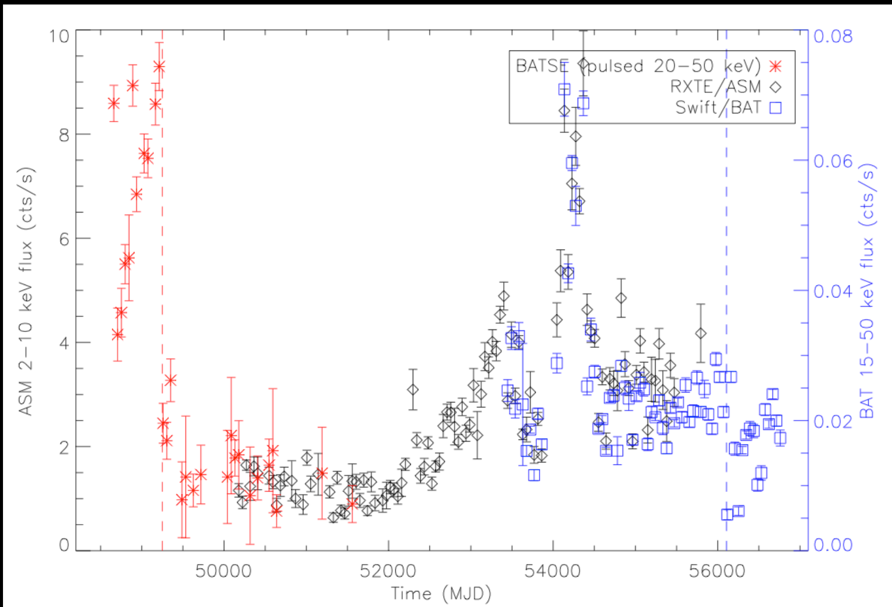


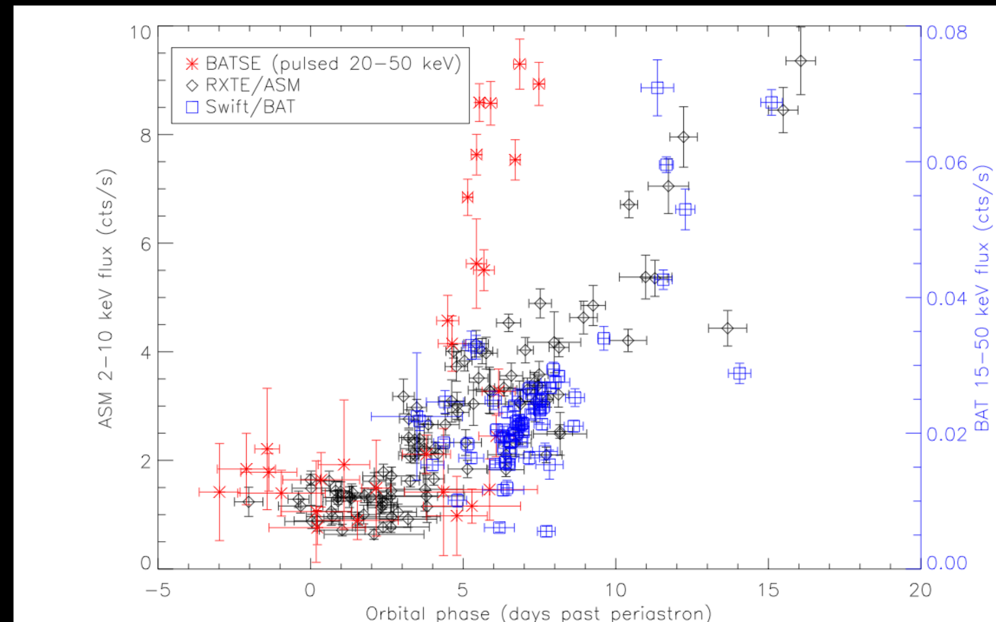
EXO 2030+375



EXO 2030+375
Spin Frequency (mHz)
24.22
24.21
24.20
24.19
12-50 keV Pulsed Flux
(keV cm^{-2} s^{-1})
0.5
0.4
0.3
0.2
0.1
0.0
55000
55500
56000
56500
Time (MJD)

EXO 2030+375 Long Term Behavior

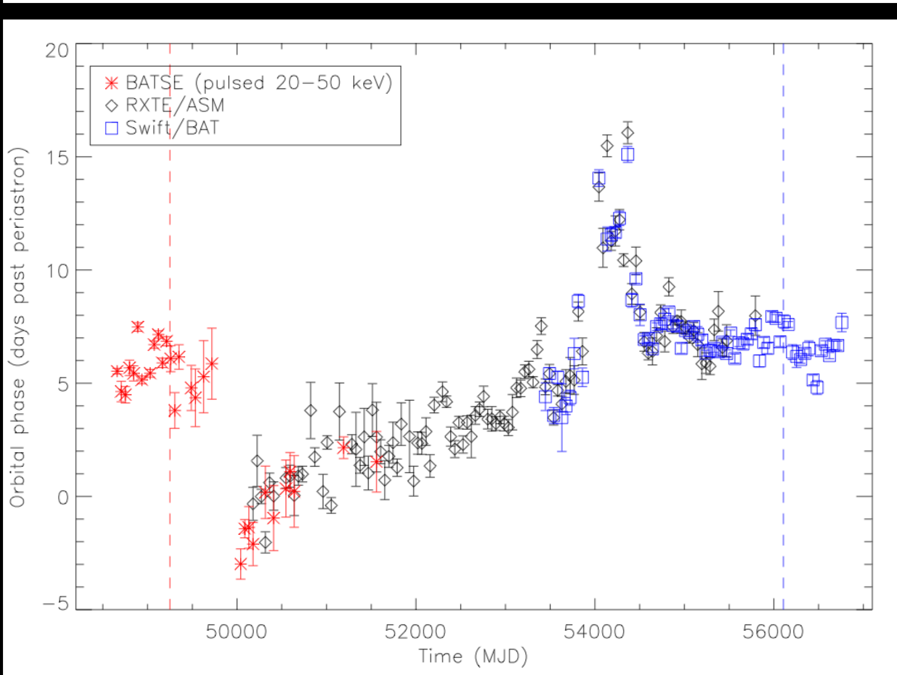




XTE correlation coef: 0.852861 prob: 7.83253e−31

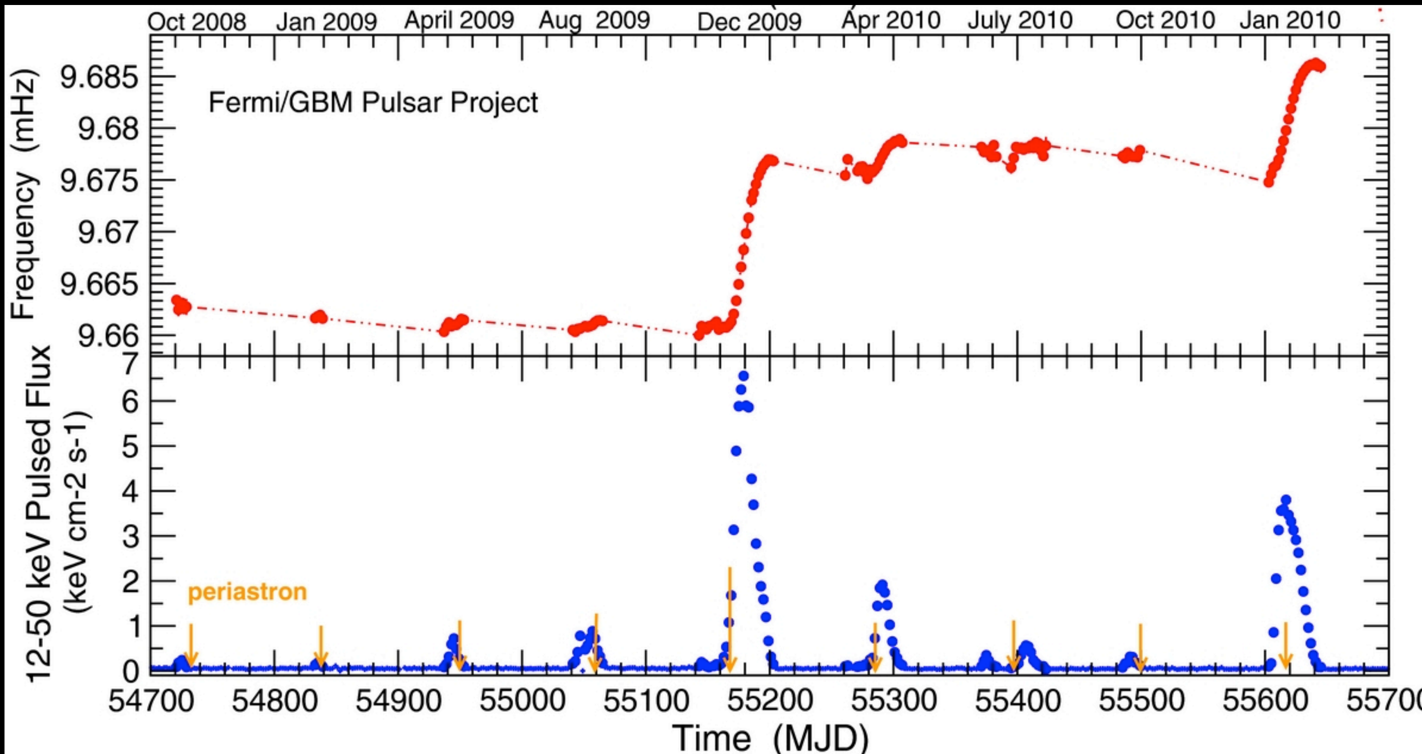
BAT correlation coef: 0.541322 prob: 1.87523e−06

BATSE correlation coef: 0.682314 prob: 3.27967e−05



A0535+26

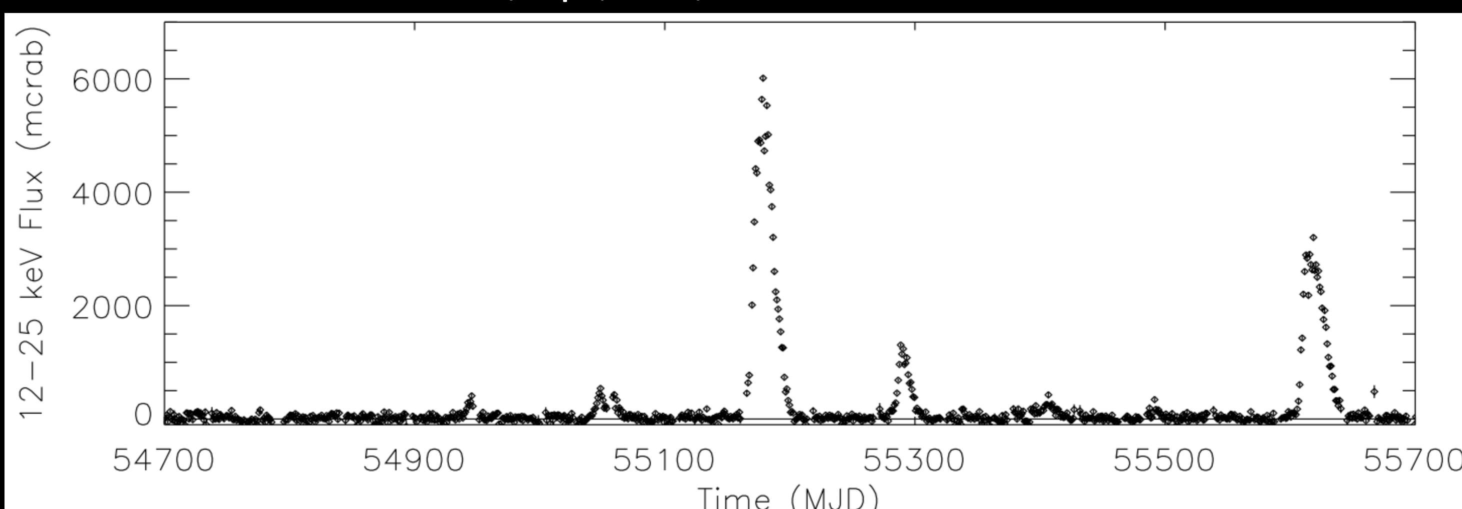
P_{spin} = 103.5 s
P_{orbit} = 111.1 d
Be companion



Frequency

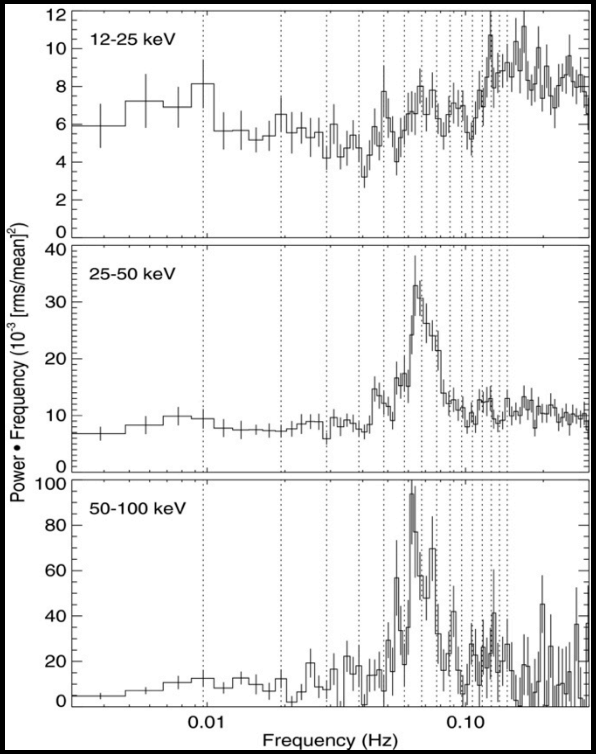
12-50 keV Pulsed Flux

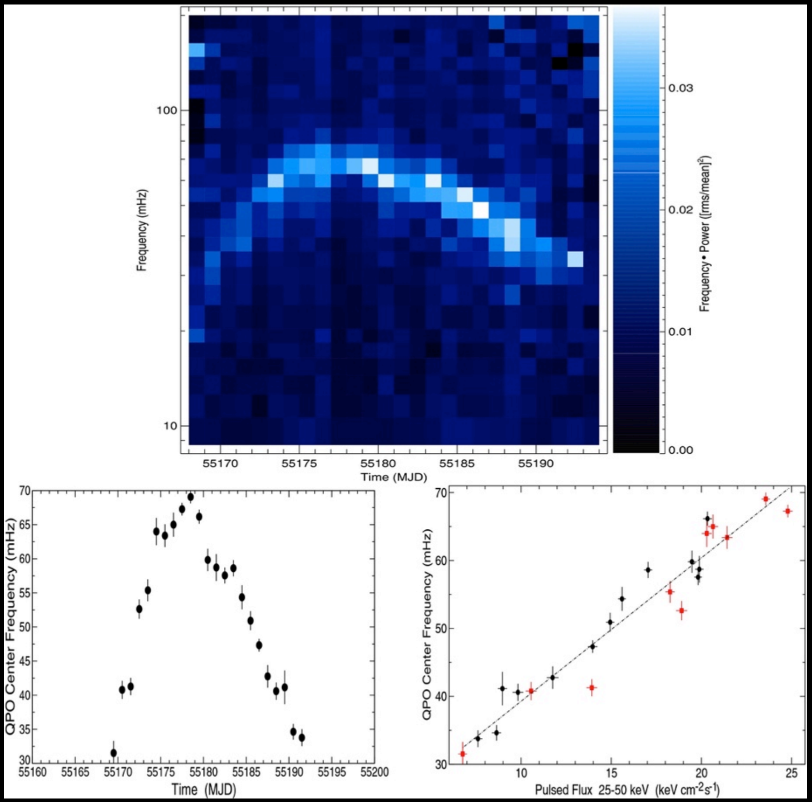
Camero-Arranz et al. 2012, ApJ, 754, 20



12-25 keV Phase-averaged flux

A0535+26 QPO in 2009 December Outburst





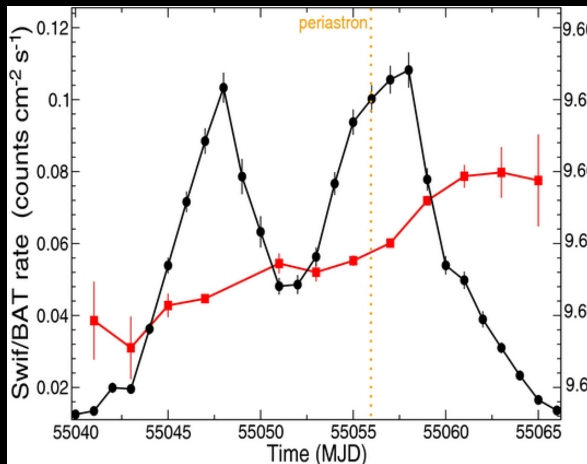
- Centered at 62 mHz (Dec 10 , 2009)
- Strongest in 50-100 keV band
- Not detected in 12-25 keV band
- Inconsistent with beat-frequency model
- Could indicate obscuration by thick inner disk

- Central frequency rose from 30 to 70 mHz
- 1994 QPO – rose from 27 to 72 mHz
- QPO central frequency correlated with pulsed flux
- Indicates an accretion disk is present.

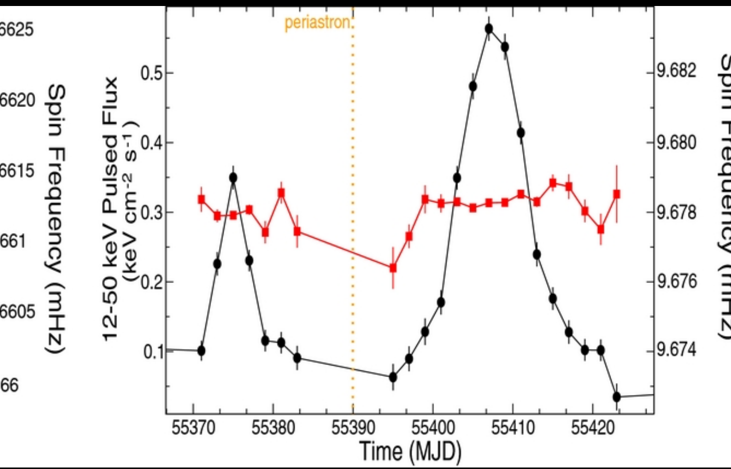
Camero-Arranz et al. 2012, ApJ, 754, 20

Double-peaked normal outbursts

A0535+26

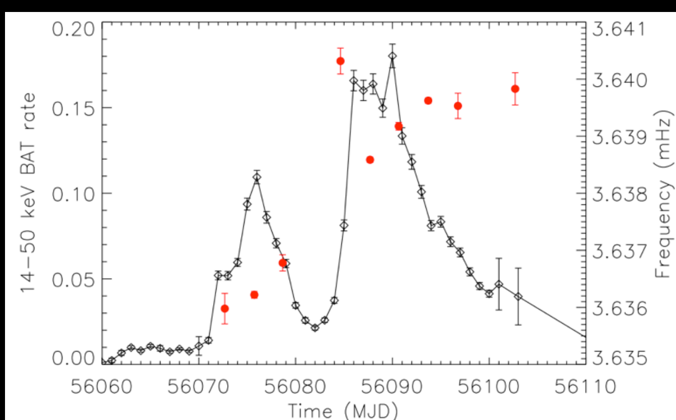


2009 August

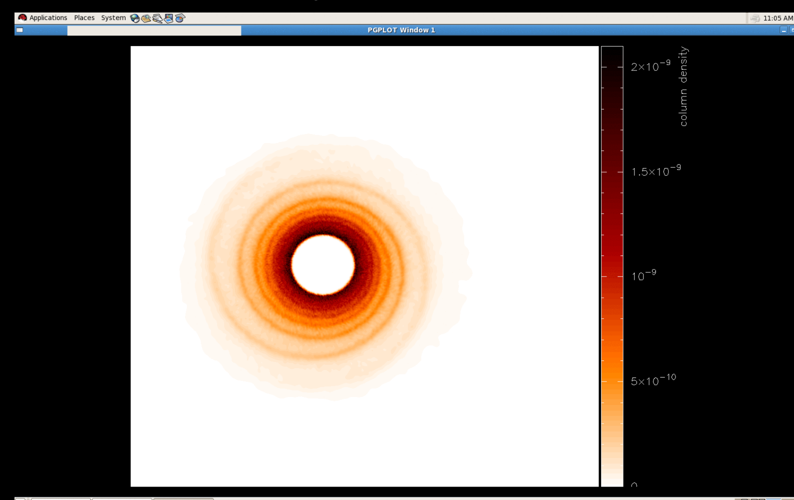


2010 July

GX 304-1



2012 May-June



Jones, Okazaki, & Coe (in prep.)

GS 0834-430

P_{spin} = 12.3 s
P_{orbit} = 105.8 d
Be companion

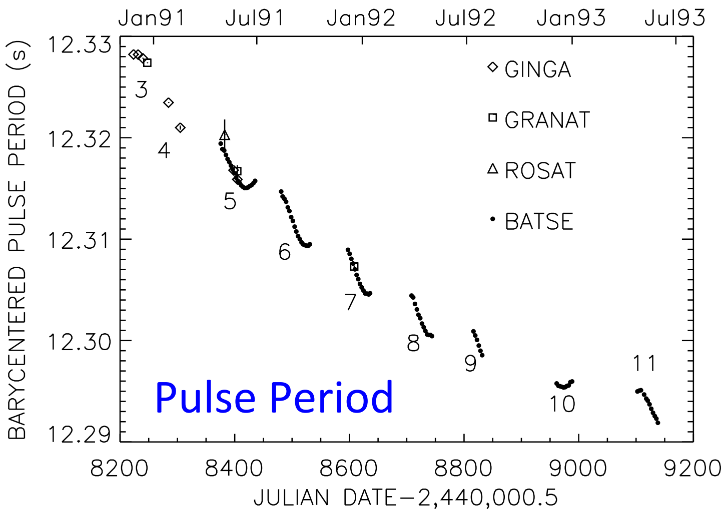
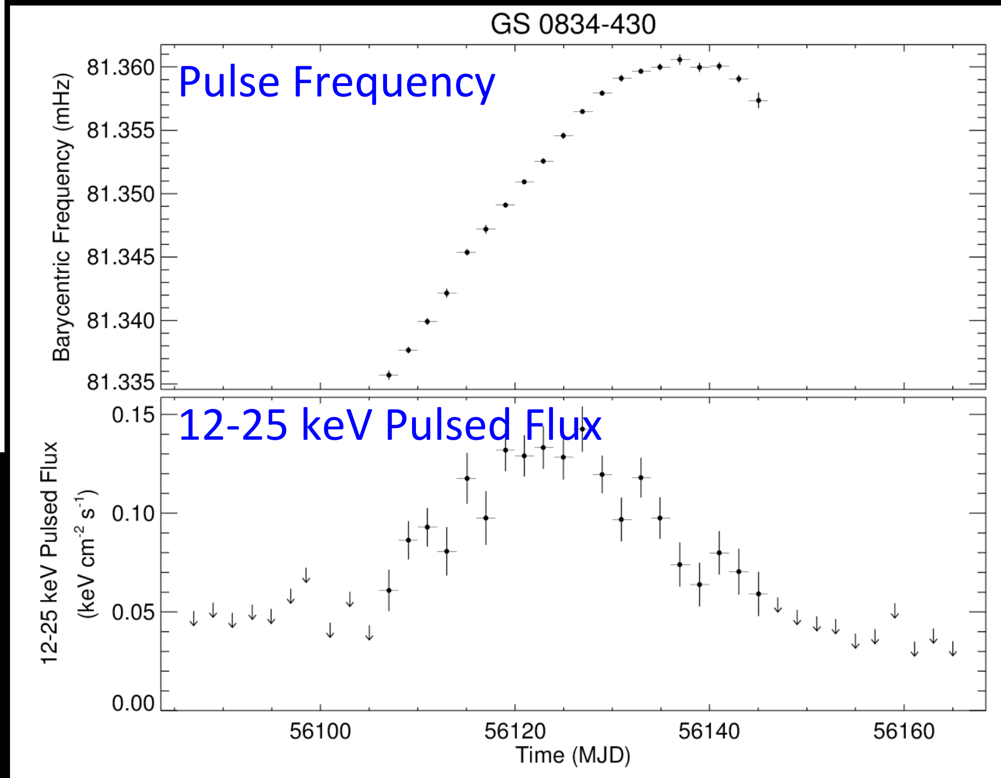


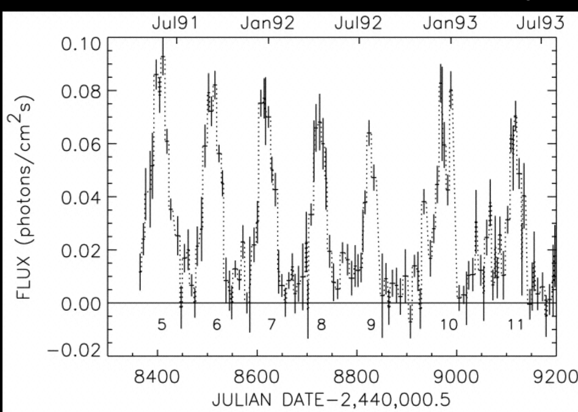
FIG. 5.—Pulse period history of GS 0834−430, corrected to the solar system barycenter, with no binary orbital corrections included. Period measurements from *Granat* (Sunyaev 1991; Grebenev & Sunyaev 1991; Sunyaev et al. 1992), *Ginga* (Aoki et al. 1992), and *ROSAT* (Belloni et al. 1993) are also shown.

2012 Jun

2012 Aug



Wilson, C.A. et al. 1997, ApJ, 479, 388



20-100 keV flux

Summary and Conclusions

The full sky coverage of GBM enables long term monitoring of the brighter accreting pulsars allowing:

- Precise measurements of spin frequencies and orbital parameters.
- Study of spin-up or spin-down rates and hence the flow of angular momentum.
- Detection and study of new transient sources or new outbursts of known transients.
- Tracking of QPOs throughout giant outbursts
- Observations of unexpected outburst behaviors

GBM Pulsar Project

http://gammaray.nsstc.nasa.gov/gbm/science/pulsars/

GBM Earth Occultation Project

http://heastro.phys.lsu.edu/gbm