

Tenth International Fermi Symposium

9th-15th October 2022

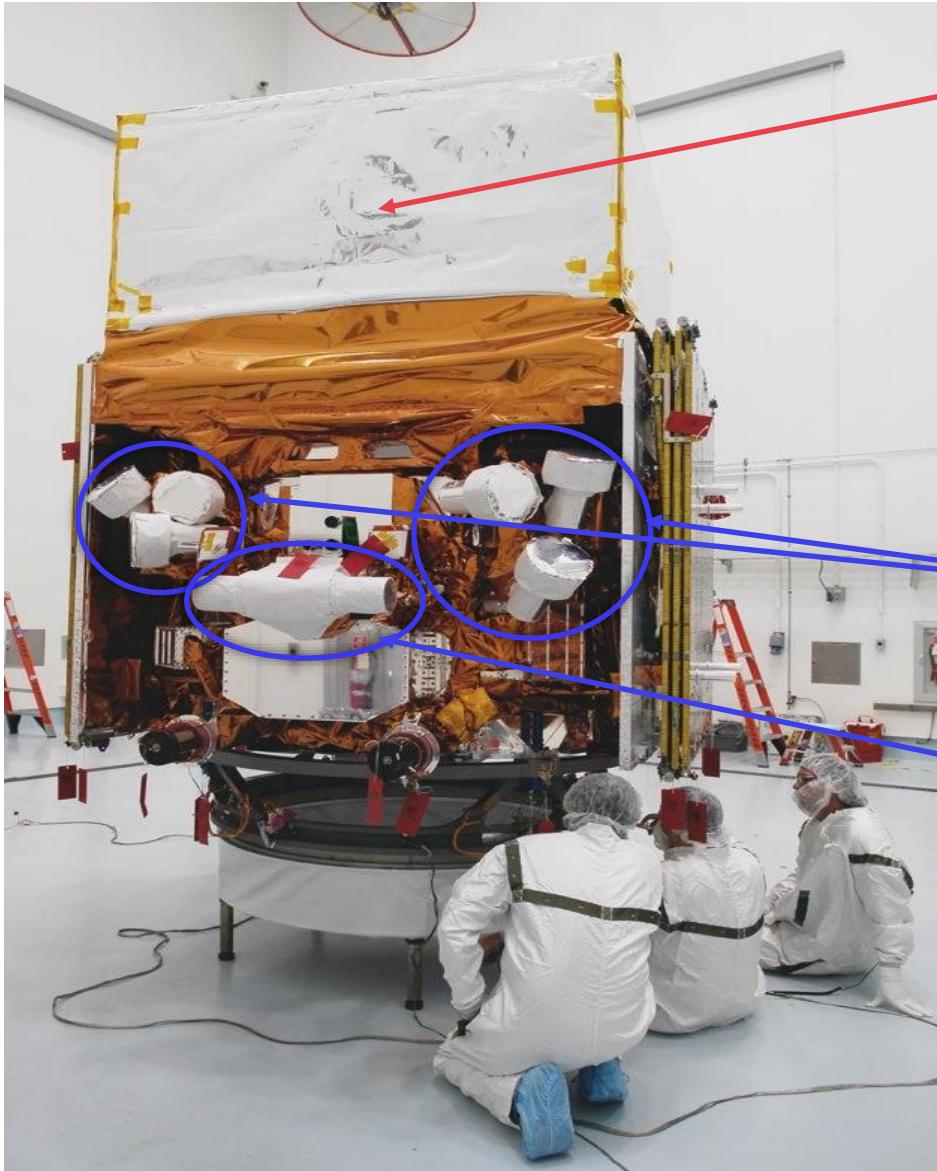


The GBM Accreting Pulsar Program (GAPP) – 20 Years

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Obligatory Slide of the Spacecraft



Large Area Telescope

20 MeV - 300 GeV

Triggering, localization and spectroscopy

Gamma Ray Burst Monitor

12 Sodium Iodide detectors
8.0 - 1000 keV

Triggering, localization and spectroscopy

2 Bismuth Germanate detectors
200 keV - 40 MeV
spectroscopy

Bridges gap between NaI and LAT

Small size vs. long observations

Why GBM excels at observing accreting pulsars

GBM is not an imaging instrument but has the advantage that it observes the entire unocculted sky all the time.

Large Instantaneous Field of View
>40,000 s/day for a typical source

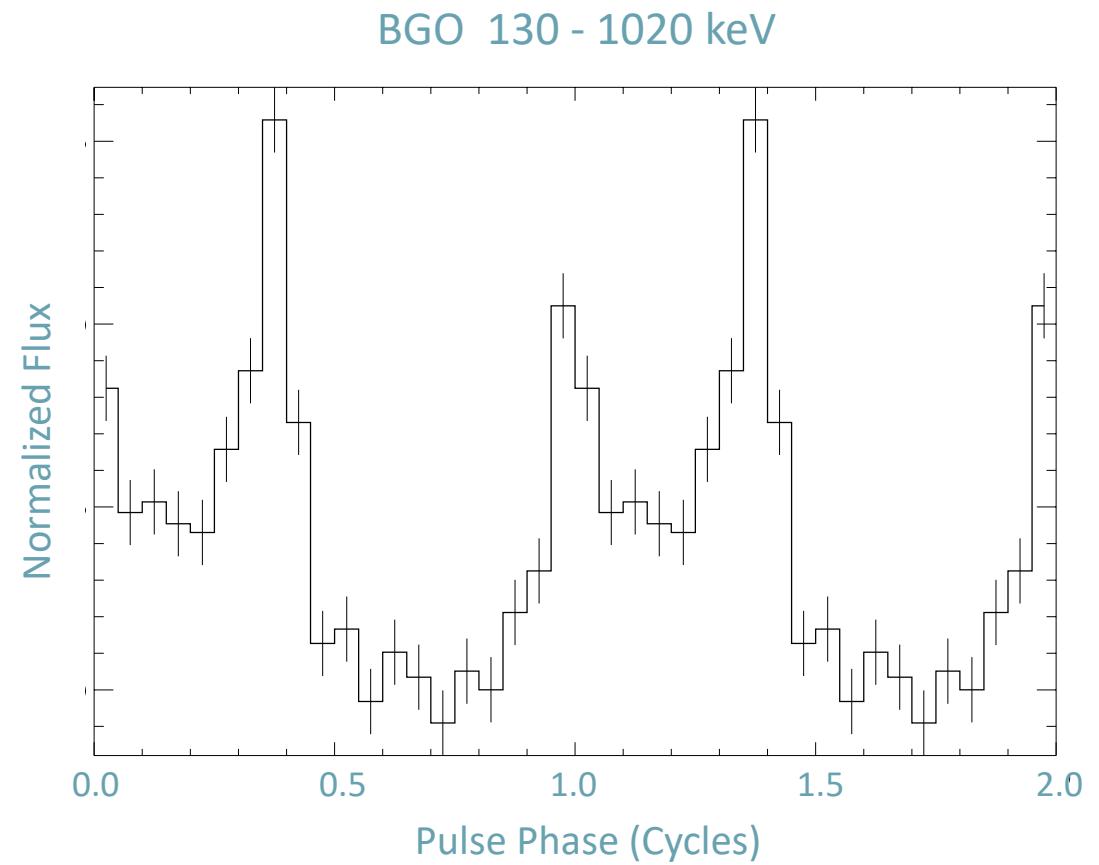
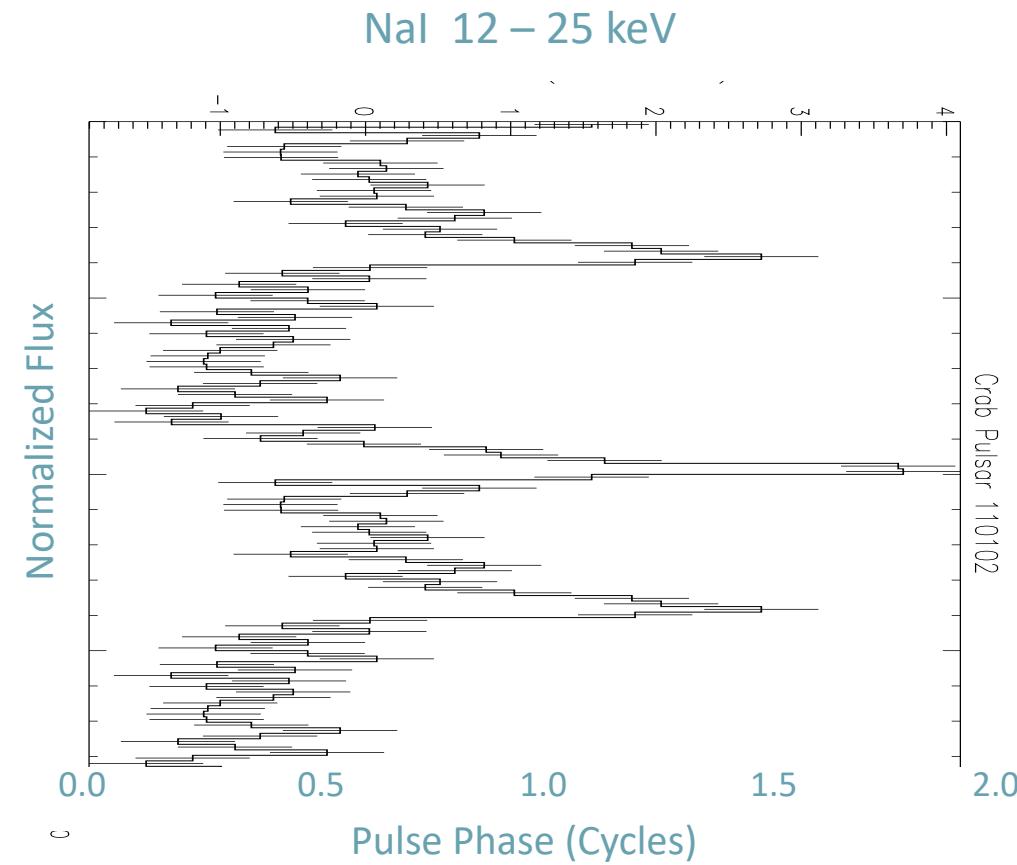
Fourier Modeling to extract the pulsed portion of the signal from the data.

So... What can we see?

GAPP Strengths and Weaknesses

1. GBM Pulsed Frequency
 2. GBM Pulsed Flux
 3. BATSE Pulsed Flux and Frequencies where available
 4. Pulse Profiles
 5. Orbit phase* and pulse phase*
-
1. Observe pulsed sources with pulse periods between 0.01 – 1000s.
 - I. 0.01 – 0.5s uses CTTE data but..
 - II. 0.5 – 1000s uses CTIME data. With the low end is bound at the Nyquist frequency and the upper end is a loose bound on data segment length and background subtraction.
 - III. Pulsed sensitivity is around **20 mCrab** (100% pulse fraction) between 8 and 50 keV. We can do better for some sources and worse for others. Depends on background, if the orbit is known, and accuracy of the phase model.
 2. In principle we can perform pulse searches throughout the NaI's energy range (8-1000 keV). In practice we limit our searches between 8-50 keV and for some sources 25-50 keV.
 3. Public GAPP pulse frequencies, pulse flux and pulse profiles are provided in 8-12, 12-25, and 25-50 keV bands. Upon request, we can provide them in any band available with CTTE data.

Exceptions

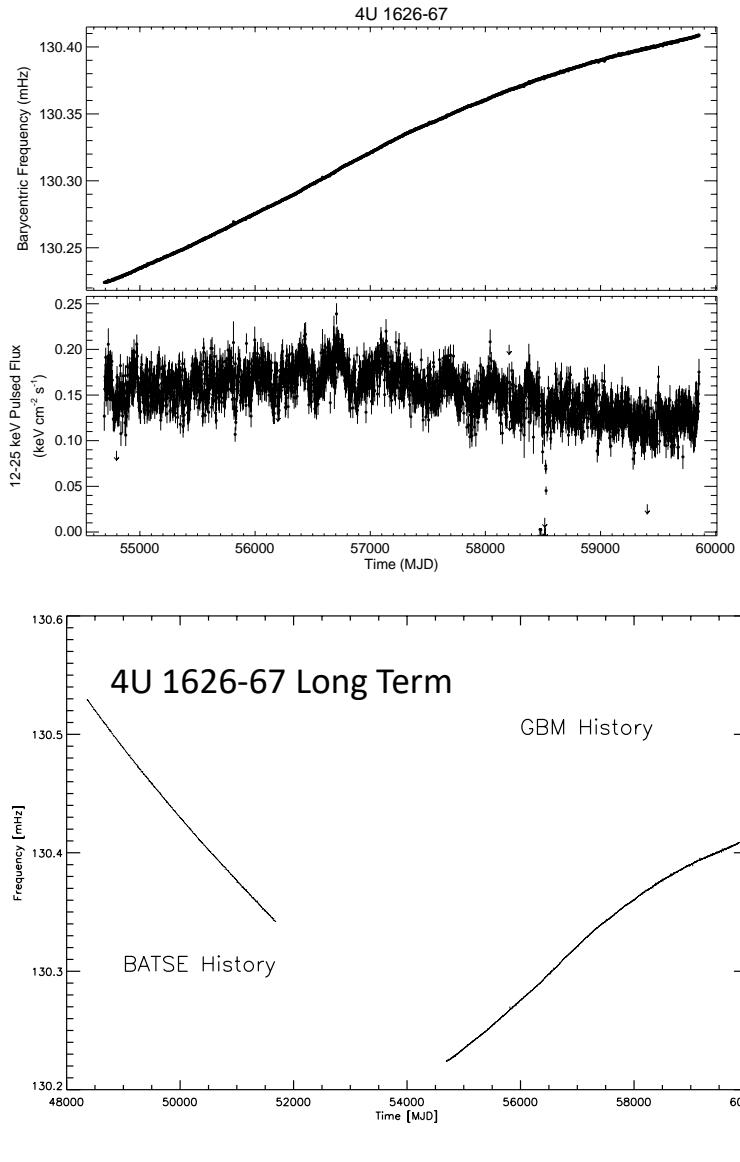


In principle we can time fast pulsars but GBM is sensitive to only a few, most notably the Crab.

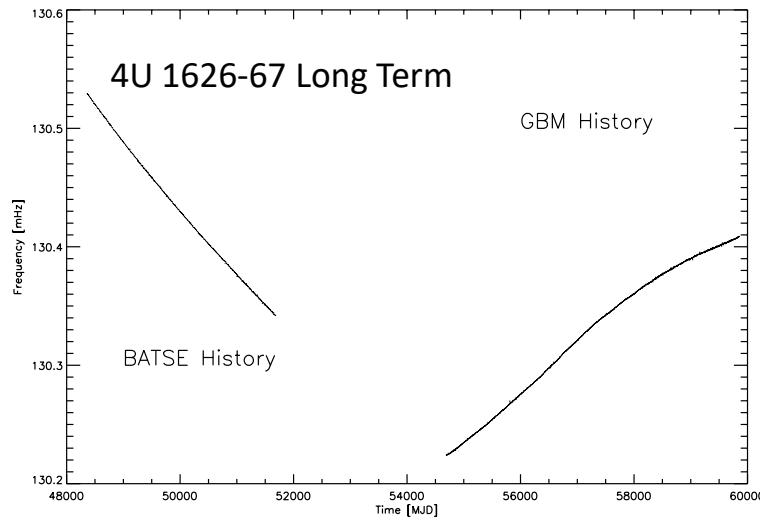
Persistent Sources Detected By GBM

Source	Frequency	Classification	Orbital period
➤ GX 1+4	4.65 mHz	LMXB	No orbit used > 304 days
➤ Her X-1	807.9 mHz	LMXB	Orbit 1.7 days
➤ Vela X-1	3.53 mHz	Wind-Fed HMXB	Orbit 8.9 days
➤ Cen X-3	208.5 mHz	Disk-Fed HMXB	Orbit 2.08 days
➤ GX 301-2	1.49 mHz	Wind-Fed HMXB	Orbit 41.47 days
➤ 4U 1626-67	130.4 mHz	LMXB	No orbit used << 1 day
➤ 4U 1538-52	1.90 mHz	Wind-Fed HMXB	Orbit 3.73 days
➤ OAO 1657-415	26.0 mHz	Wind-Fed HMXB	Orbit 10.447 days

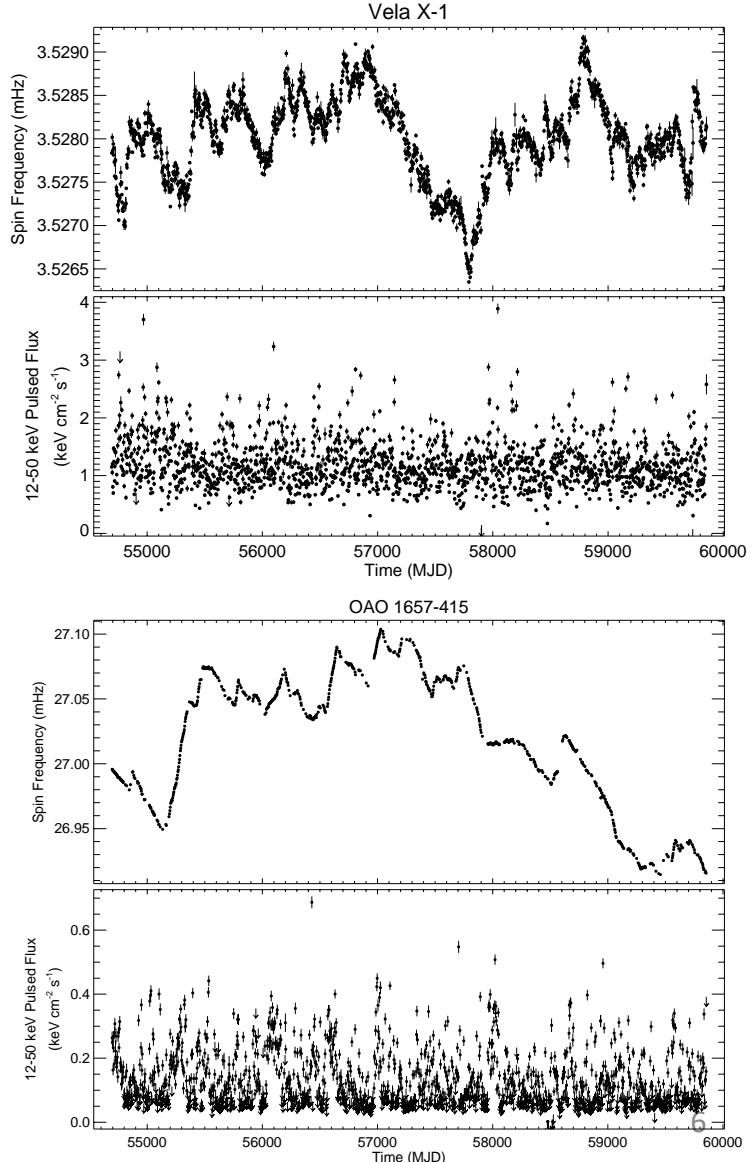
Examples - Persistent



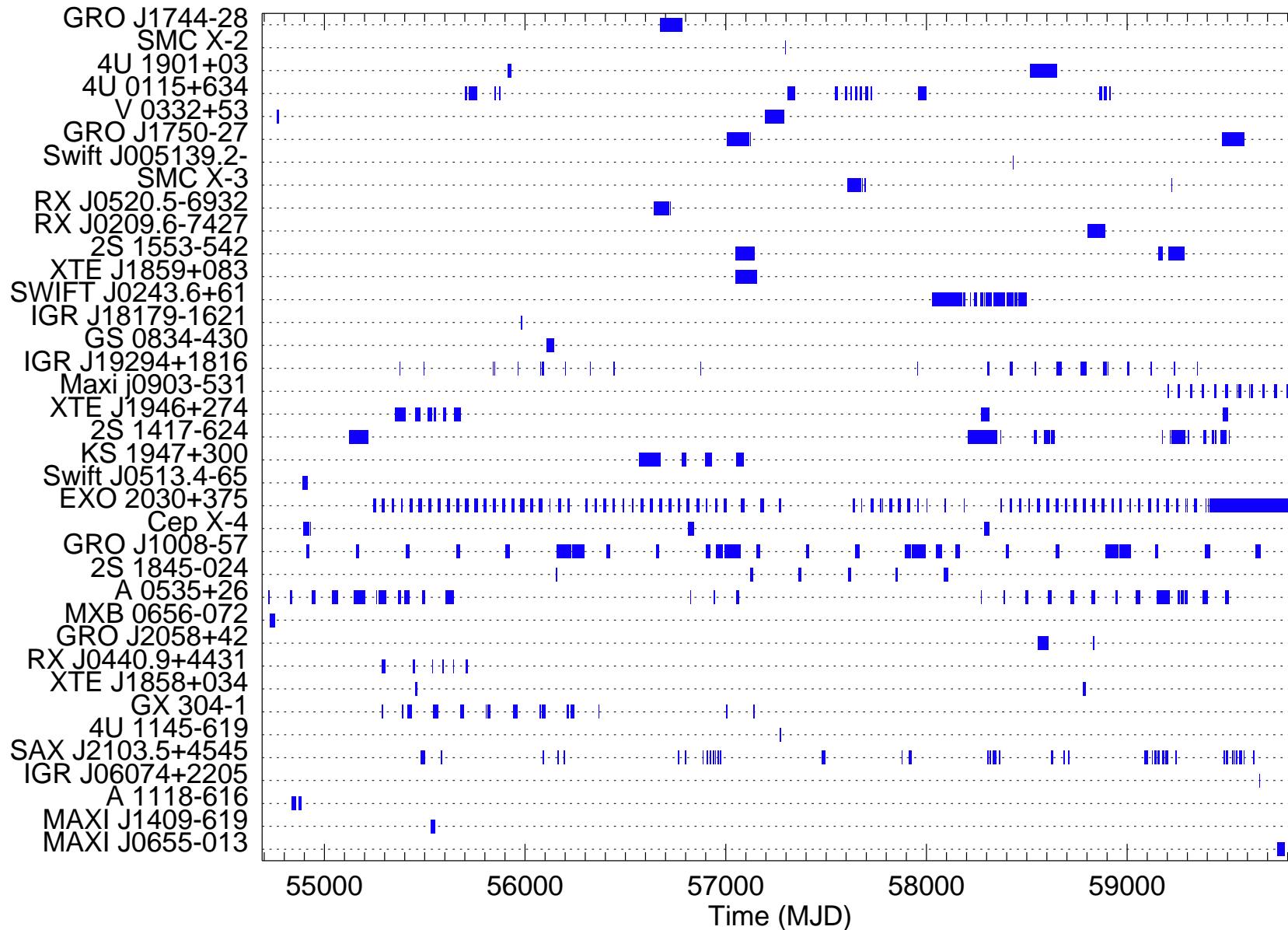
Roche-Lobe Overflow



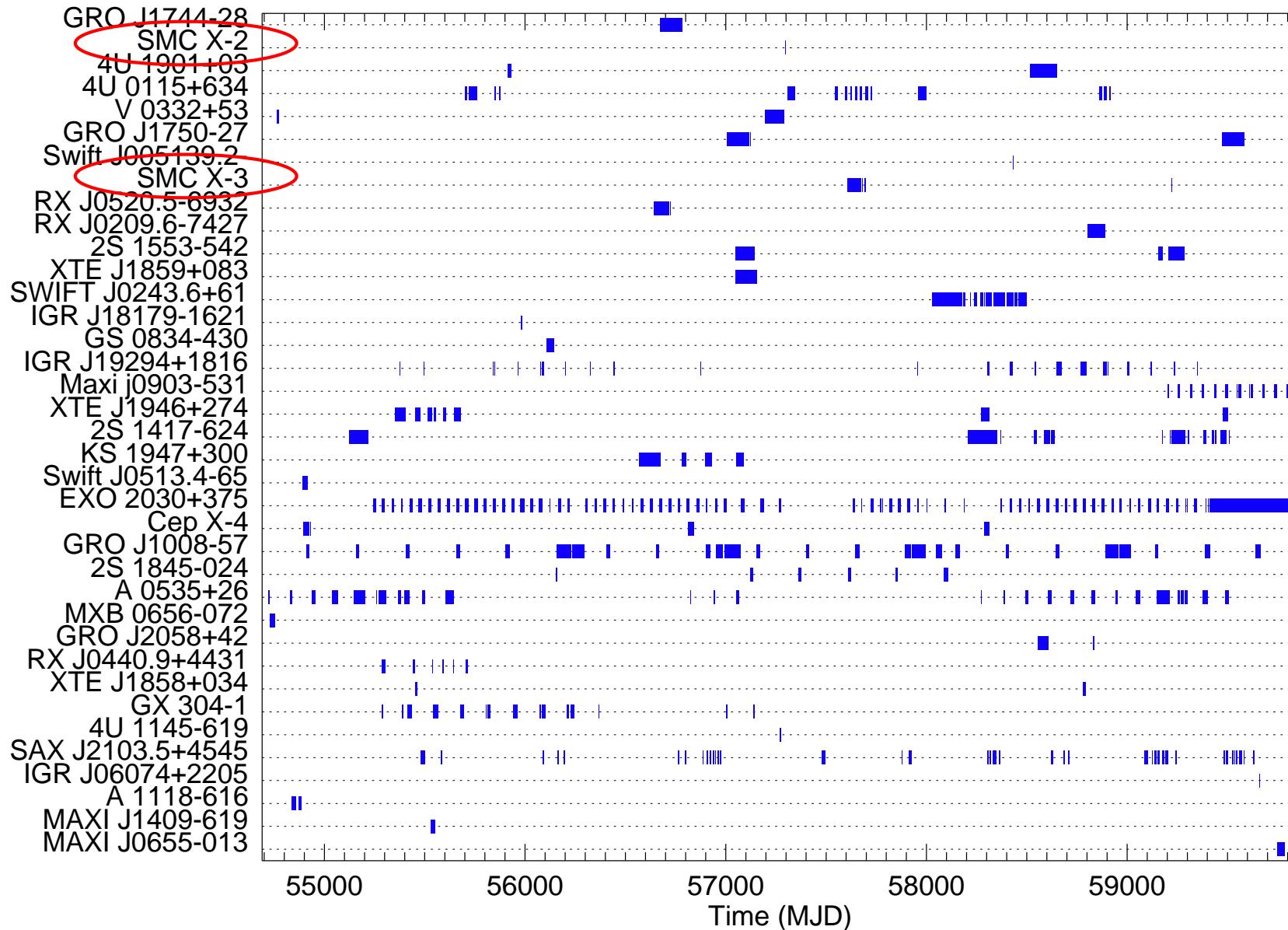
Wind Feed



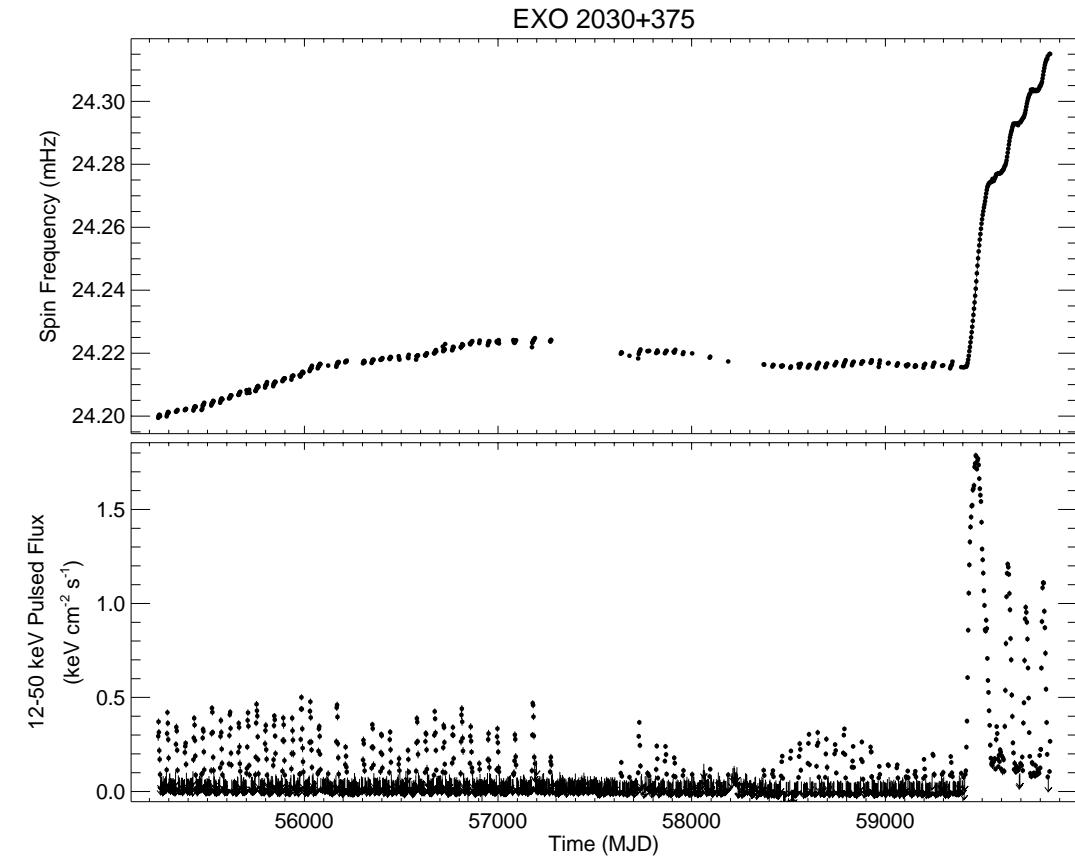
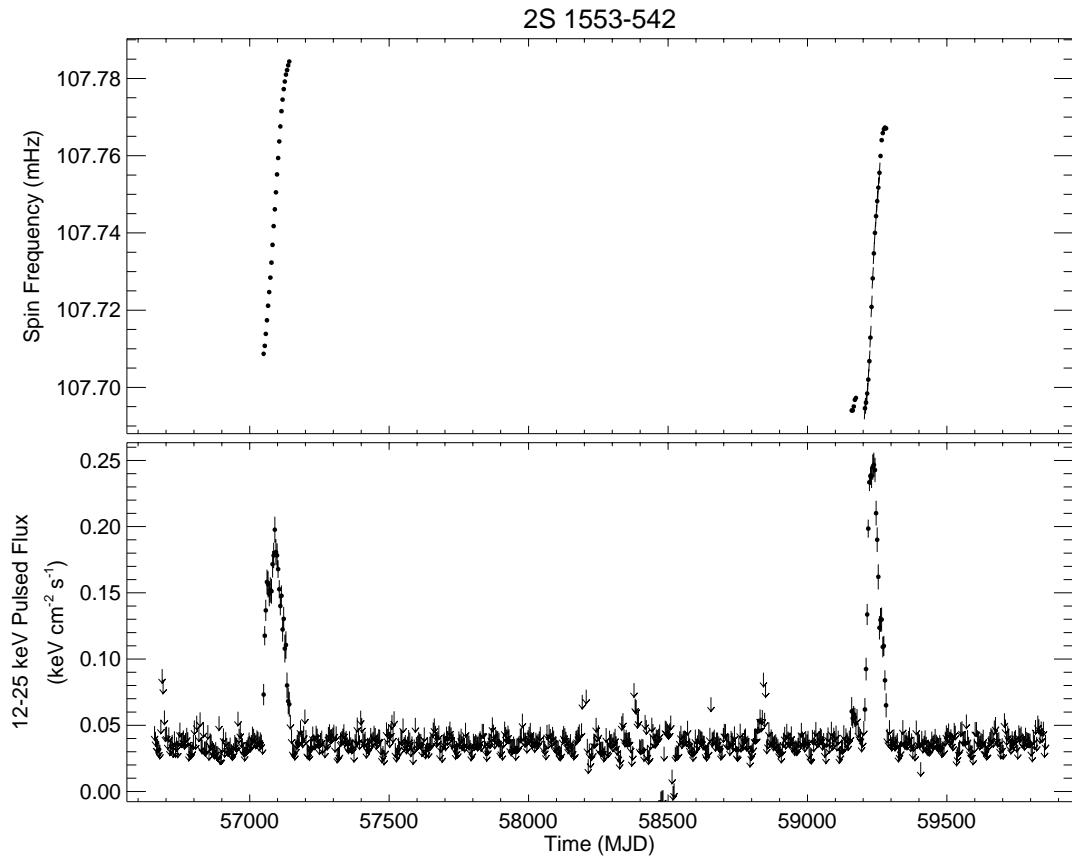
Transients Detected By GBM – Most are Be XRBs



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Examples - Transients



Source we hope to detect (monitored but not detected)

We are encouraged by sources that were detected in BATSE and sources with high pulse flux and periods between 0.5 and 1000 seconds. GBM tends to be more sensitive to sources with periods between 2 and 800 seconds. We search multiple harmonics.

➤ GS 1843+00	29.5s	Detected with BATSE
➤ 4U 1145-619	292.4s	Detected with BATSE
➤ XTE J0111.2-7317	30.72s	Detected with BATSE
➤ XTE J1543-568	27.07	Detected with BATSE
➤ Swift J1626.6-5156	15.4s	????

The Nitty Gritty

Estimate the frequency and phase model

$$\phi_k(t_k) = \phi_0 + \nu_0(t_k - t_0)$$

Fit pulse profiles using a harmonic expansion in pulse phase

$$m_k = \sum_{h=1}^N a_h \cos(2\pi h \phi(t_k)) + b_h \sin(2\pi h \phi(t_k))$$

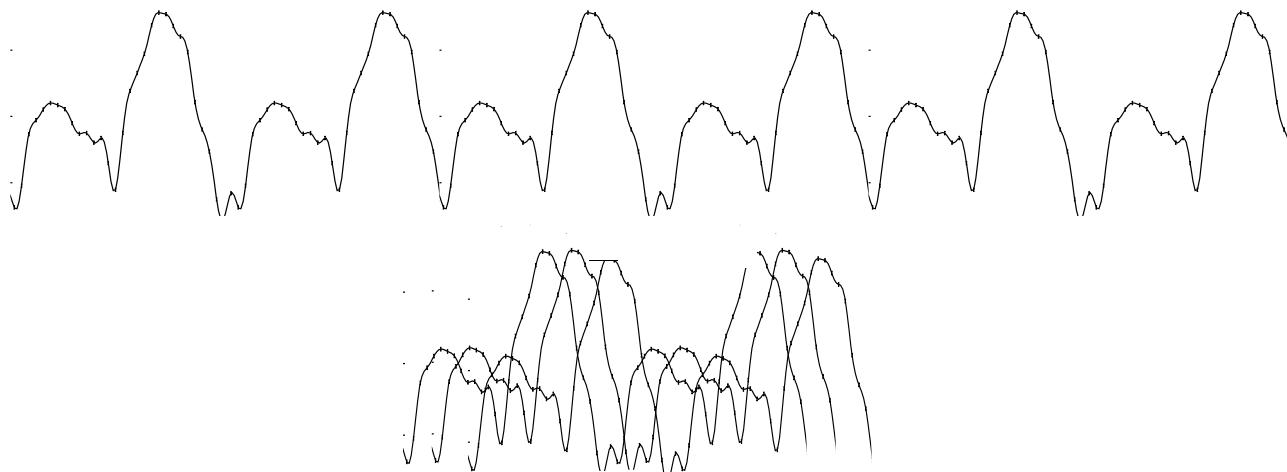
Model photon rate Harmonic coefficients Harmonic number time

By minimizing:

$$\chi^2 = \sum_{k=1}^M = \frac{(x_k - (m_k + B_k))^2}{\sigma_{x_k}^2}$$

Photon rates Errors Background

Find the phase model that gives the most significant average pulse profile over the search interval.



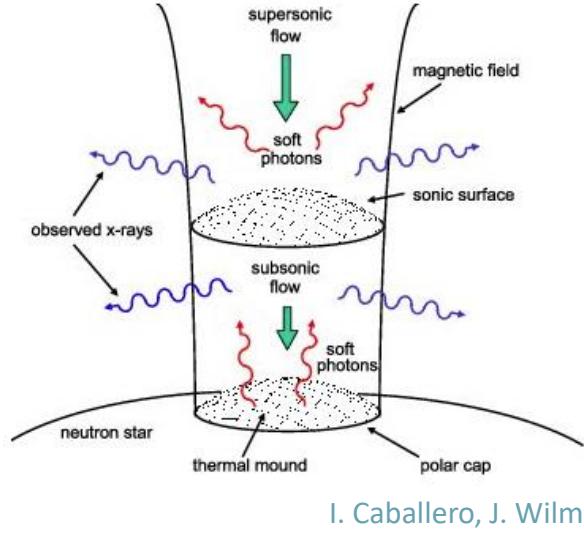
Grid of phase Offsets

$$\delta\phi_k(\delta\nu_p, \dot{\nu}_q) = \delta\nu_p(\bar{t}_k - \tau) + \frac{1}{2}\dot{\nu}_q(\bar{t}_k - \tau)^2$$

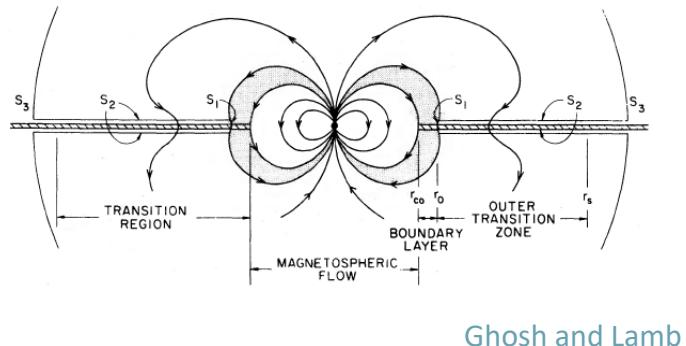
For each offset in pulse phase, we shift the individual pulse profiles:

$$\beta_{kh}(\delta\nu_p, \dot{\nu}_q) = (a_{kh} - ib_{kh}) \exp\{-i2\pi h\delta\phi(\delta\nu_p, \dot{\nu}_q)\}$$

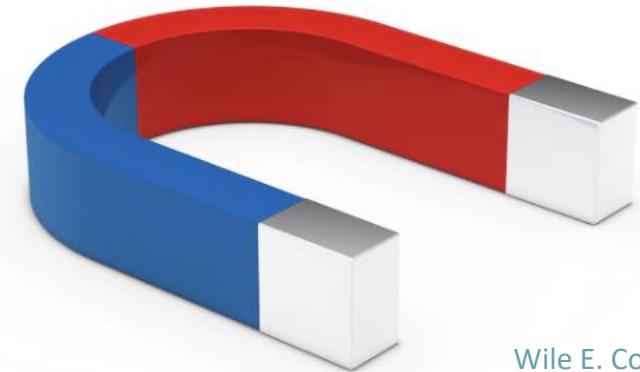
What are we doing with the data?



Accretion Column Geometry



Disk Magnetosphere interactions



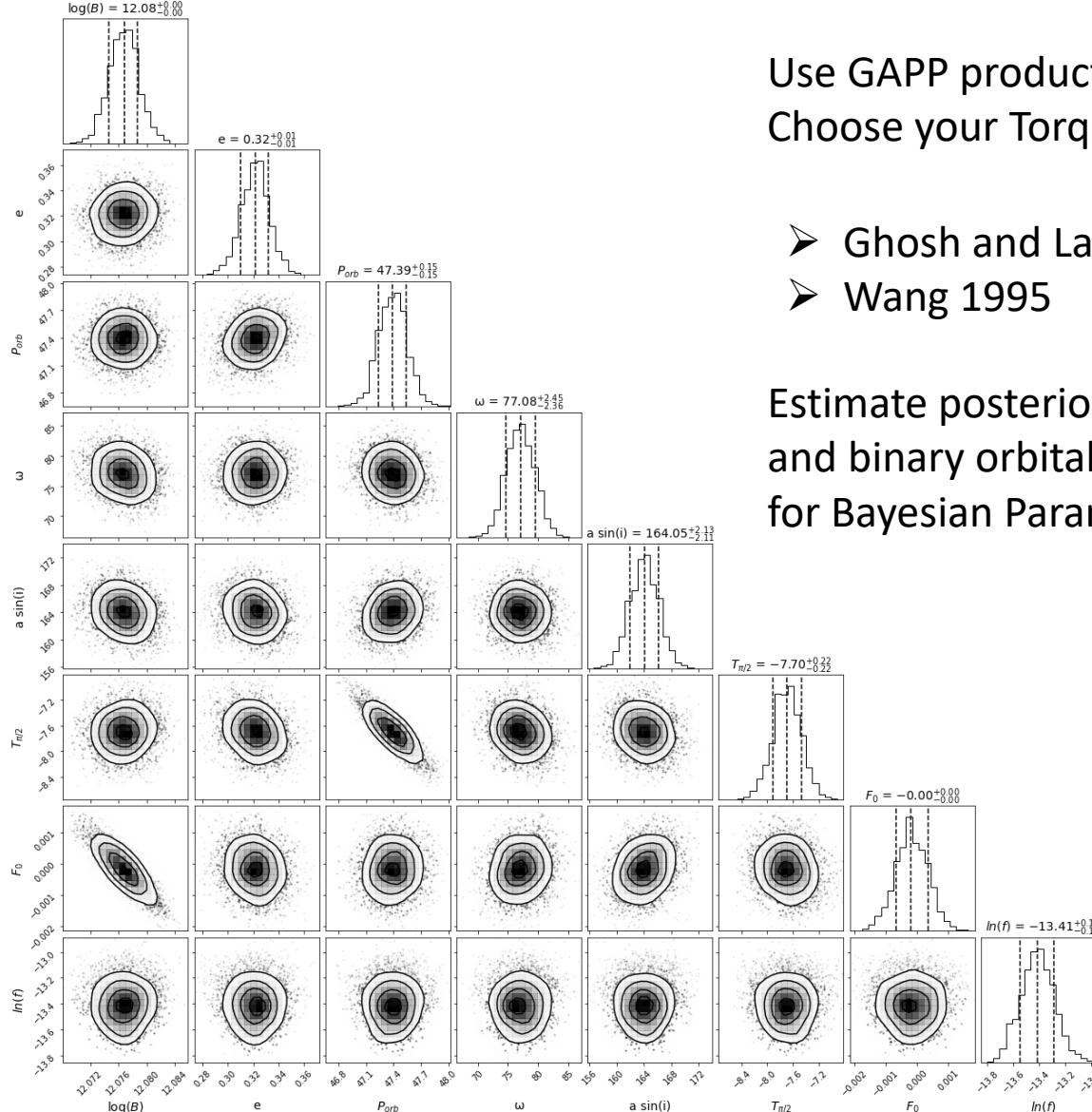
Wile E. Coyote

Fundamental Parameters

- a. Magnetic field
- b. Distance
- c. Mass fraction
- d. Orbital elements
- e. Orbital Decay

What will you do with or data?

Coming Soon – Orbital modeling simplified



Use GAPP products and a proxy for luminosity (Swift/BAT data perhaps)
Choose your Torque Model

- Ghosh and Lamb 1979
- Wang 1995

Estimate posterior distributions for standard accretion torque model parameters and binary orbital parameters for X-ray binaries using a nested sampling algorithm for Bayesian Parameter Estimation.

A Bayesian approach for torque modelling of BeXRB pulsars with application to super-Eddington accretors
(Submitted for Publication in MNRAS).

A. S. Karaferias, G. Vasilopoulos, M. Petropoulou, P. A. Jenke, C. A. Wilson-Hodge, C. Malacaria

How we can help further

- Custom requests
 - New source search
 - Different integration period
 - different energy range
 - More harmonic content for more detailed pulse profiles
- We have python scripts to create pulse frequency, flux and profiles
- We can provide orbital and pulse phases for many of our detected sources

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<https://gammaray.nsstc.nasa.gov/gbm/science/pulsars.html>

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Thank you for your attention!

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