Energy dependent timing behaviour of MAXI J1535-571

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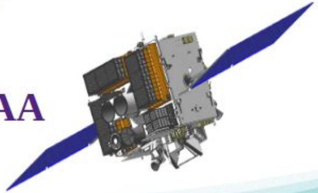


Introduction

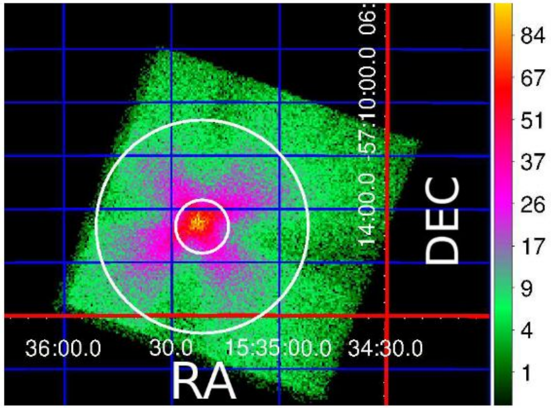
- ❑ Black Hole X-ray transient.
- ❑ Mass - 5.14-7.83 solar mass ,Sheehari et al. (2019).
- ❑ Discovered by SWIFT and MAXI satellites independently on **Sep 2, 2017**.
- ❑ AstroSat observed the source from 2017 Sep 12 to 17.
- ❑ **Sreehari et al. (2019)** detected type-**C QPOs** in the frequency range

  1.85–2.88 Hz in the hard-intermediate state of the source.

- ❑ **Bhargava et al. (2019)** found **1.7–3.0 Hz** QPO frequency to be

  Tightly correlated with power-law spectral index

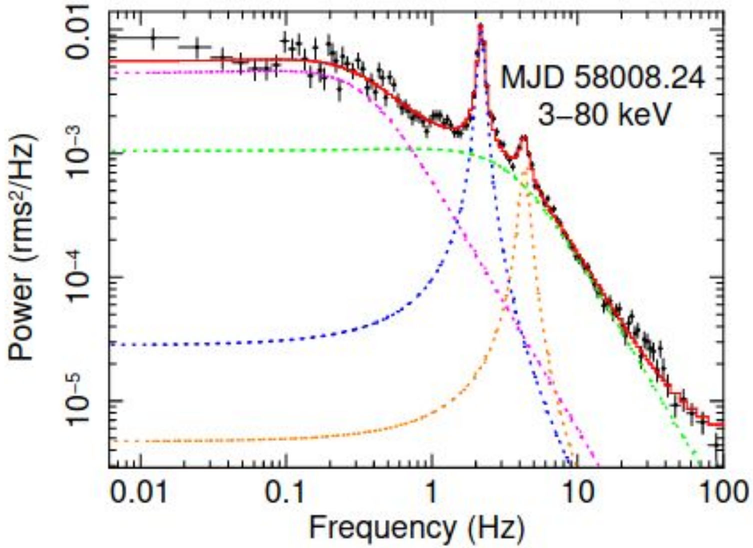
- ❑ **Akash et al. (2022)** studied the energy dependence of the QPO



Shreehari et al. (2019)

Motivation

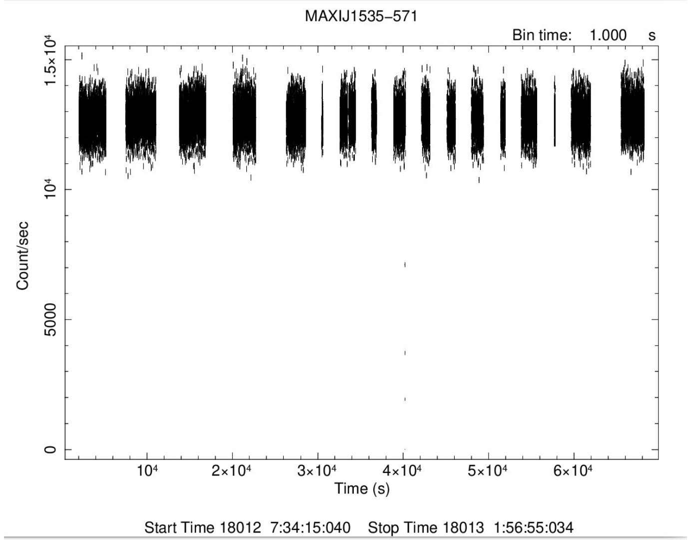
- If there is any other physical origin of Harmonic present !
- The evolution of harmonic is same as the QPO or not !
- Is there any dependency on the spectral parameters!



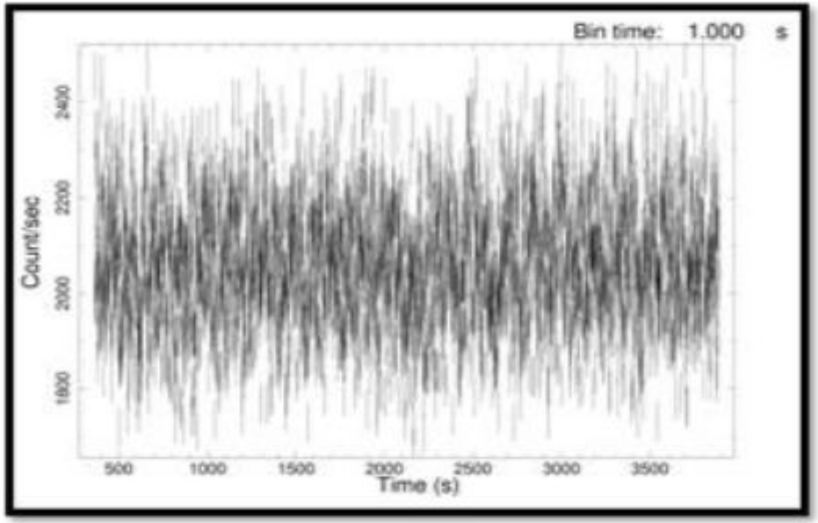
Bhargava et al. (2019)

Observation and Data Reduction

- From September 12 to 17, 2017, total observation time 400 ksecs.
- 62 segments
- 8 group members each of them handled around 7-8 segments
- Extracted LAXPC and SXT data
- PDS for LAXPC data and fitted with lorentzians
- Using lorentzian to QPO as well as Harmonic
- Later on we fitted our spectra for different segment
- Using a modified model **thcomppth, Garg et al. (2020)**



Variability in X-ray emission



Light curve for

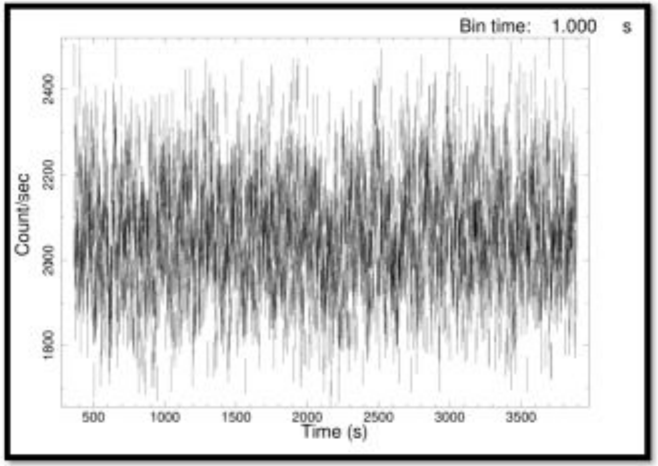
Rapidly time varying Photon flux.

Time domain → **Frequency domain**

Power Spectrum

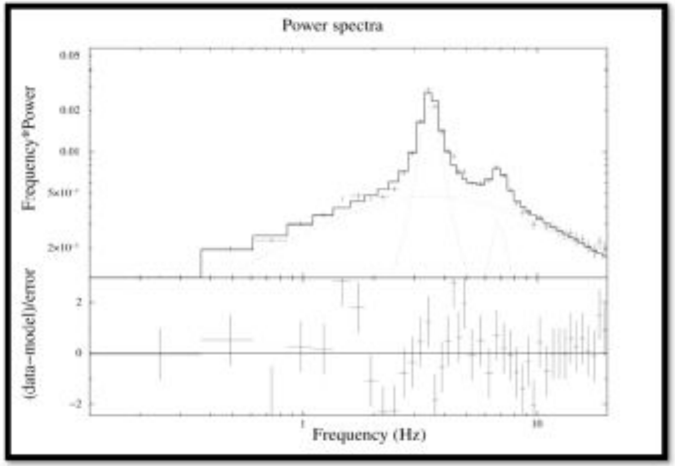
$$P_j = \frac{2}{N_{ph}} |a_j|^2, \ j = 0, ..., N/2$$

$$N_{ph} = \Sigma x_k = a_0$$



Amplitude squared

of Fourier transform



Light curve

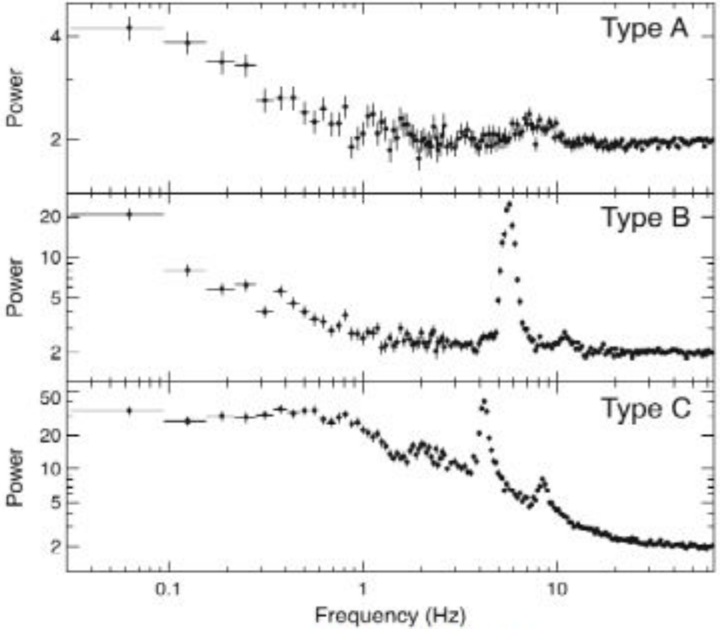
Ref: Yadav et al., 2016, Rawat et al. , 2019

Power density spectrum

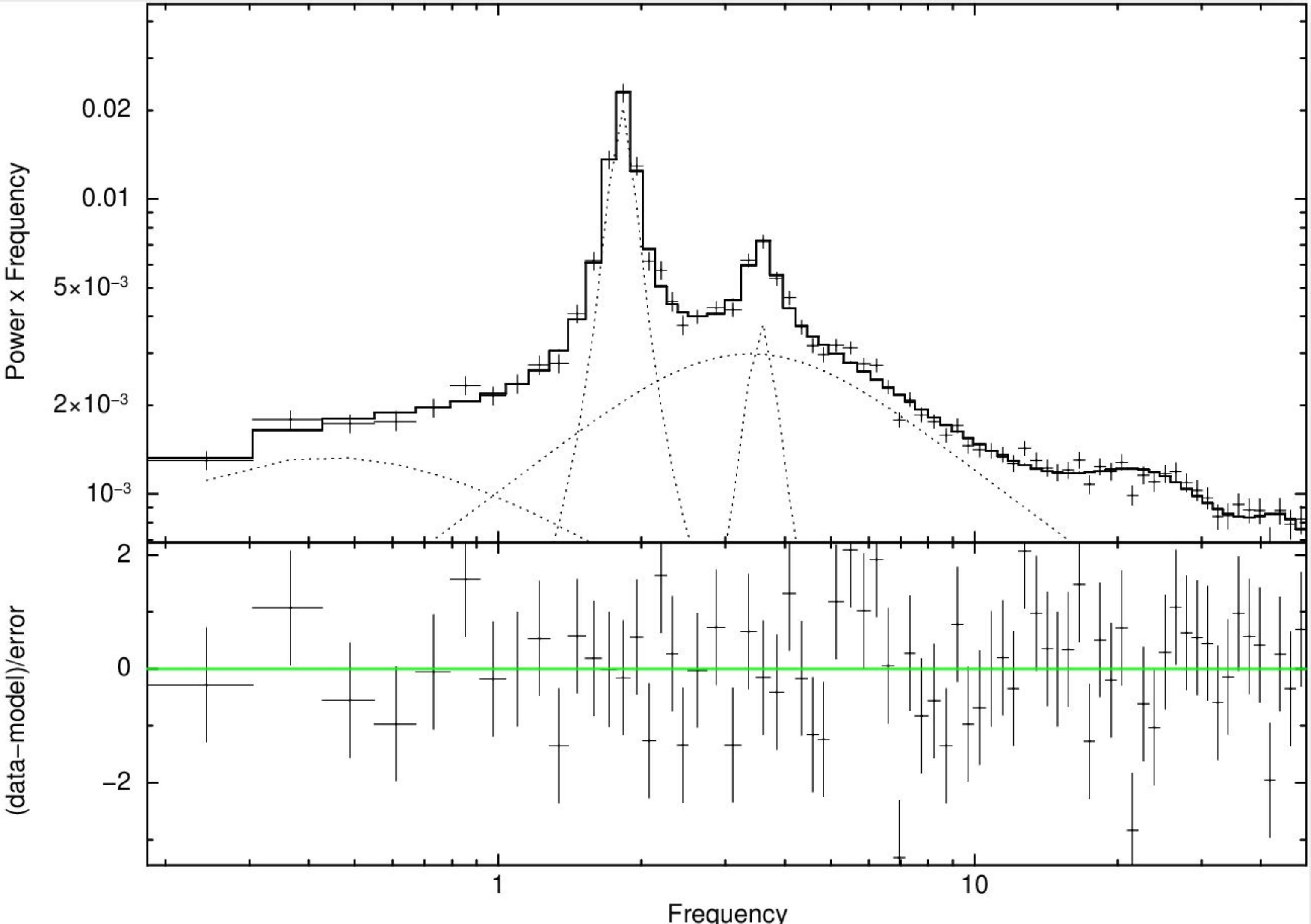
Shows narrow features known as Quasi Periodic Oscillations (QPOs).

Low-frequency QPOs

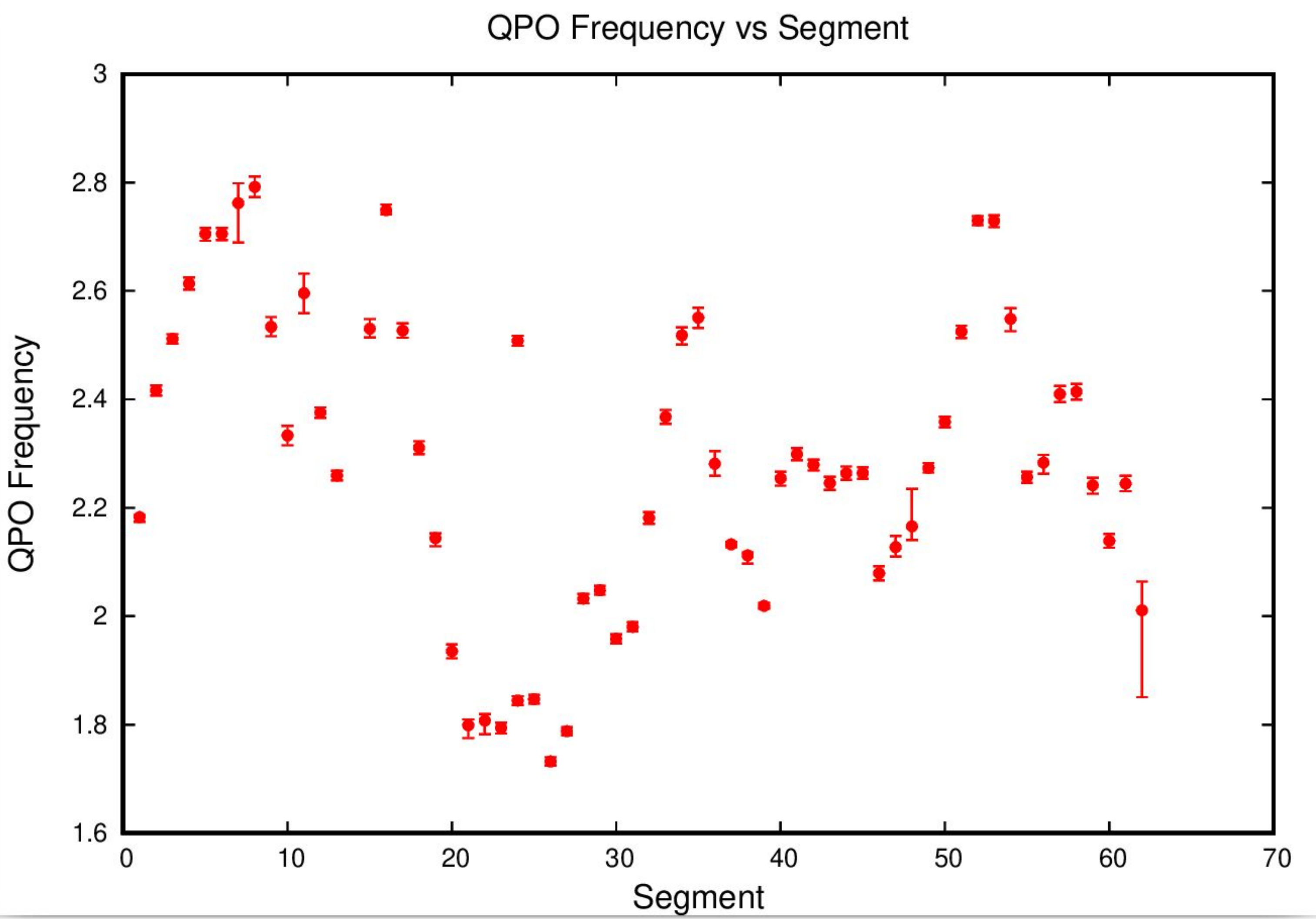
Type A	Type B	Type C
Found in HSS	Found in intermediate state	Found in LHS
Weak and broad	Strong and narrow around 6 Hz	Strong and narrow in range mHz to 30 Hz



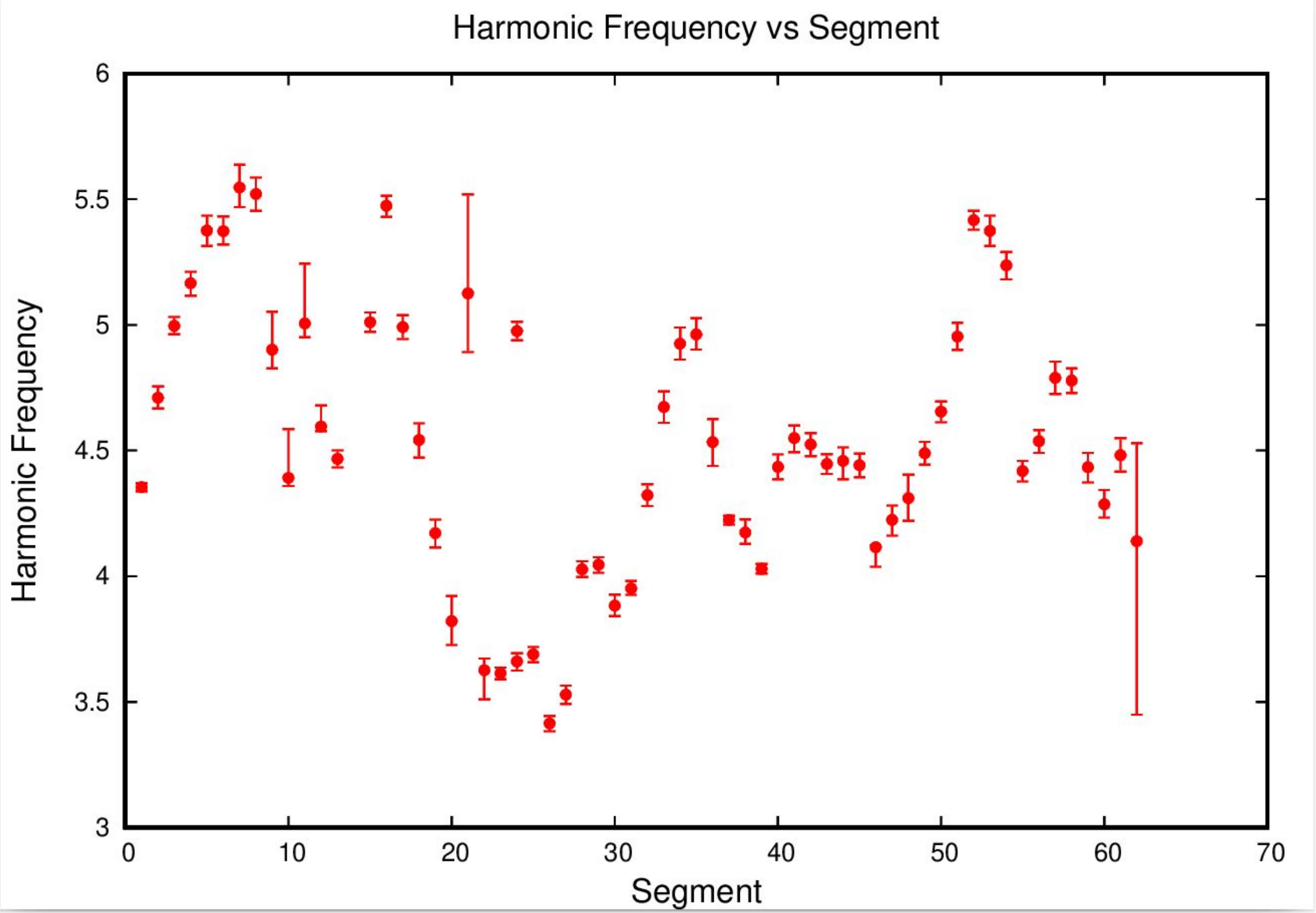
Credit: S.E. Motta



Power x Frequency
0.02
0.01
5×10⁻³
2×10⁻³
10⁻³
(data−model)/error
2
0
−2
1
10
Frequency



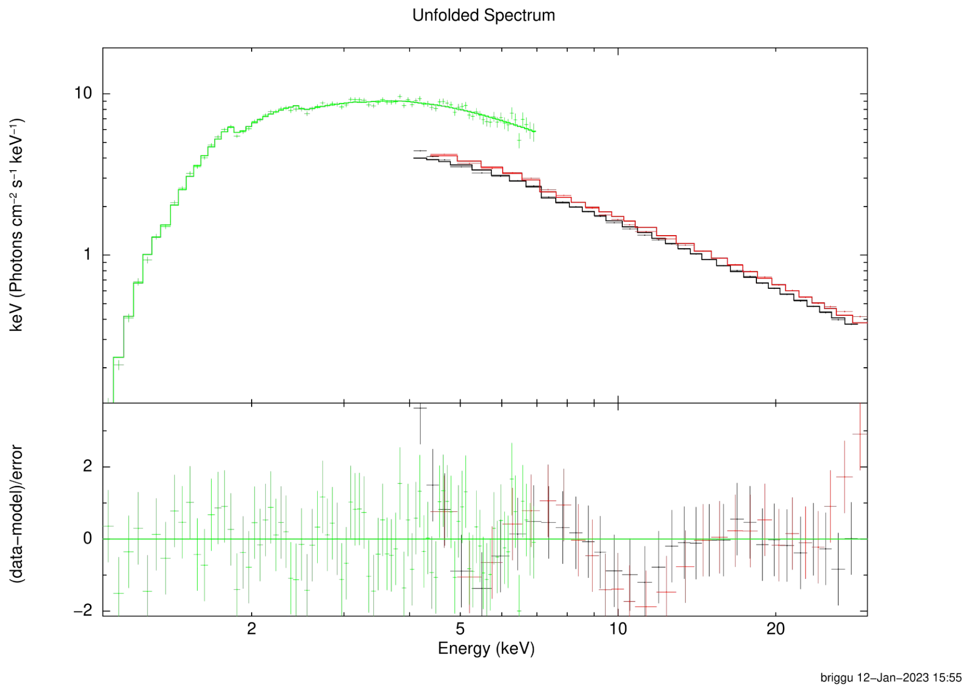
QPO Frequency vs Segment
QPO Frequency
Segment
3
2.8
2.6
2.4
2.2
2
1.8
1.6
0
10
20
30
40
50
60
70


Harmonic Frequency vs Segment
Harmonic Frequency
Segment
6
5.5
5
4.5
4
3.5
3
0
10
20
30
40
50
60
70

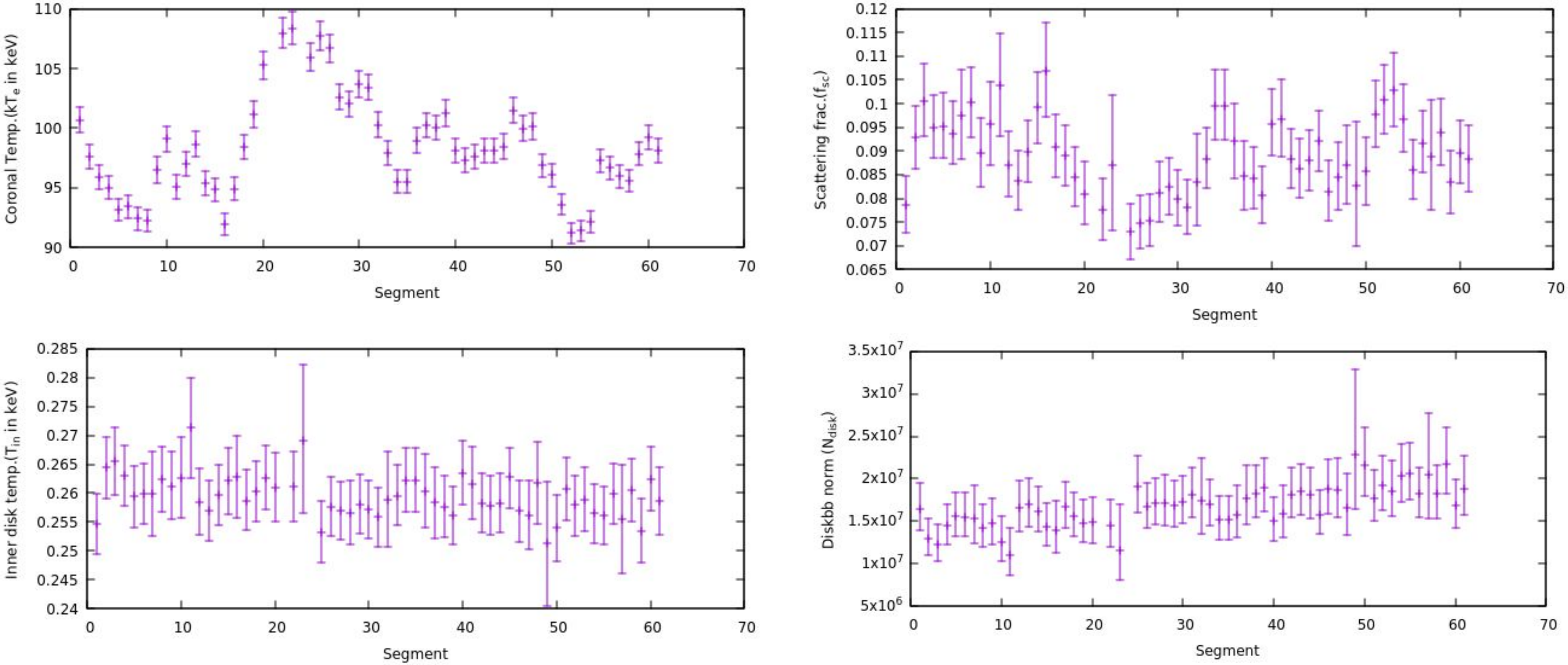
Photon spectrum in 1.0-30.0keV as observed by SXT, LAXPC 10 and 20

XSPEC MODEL

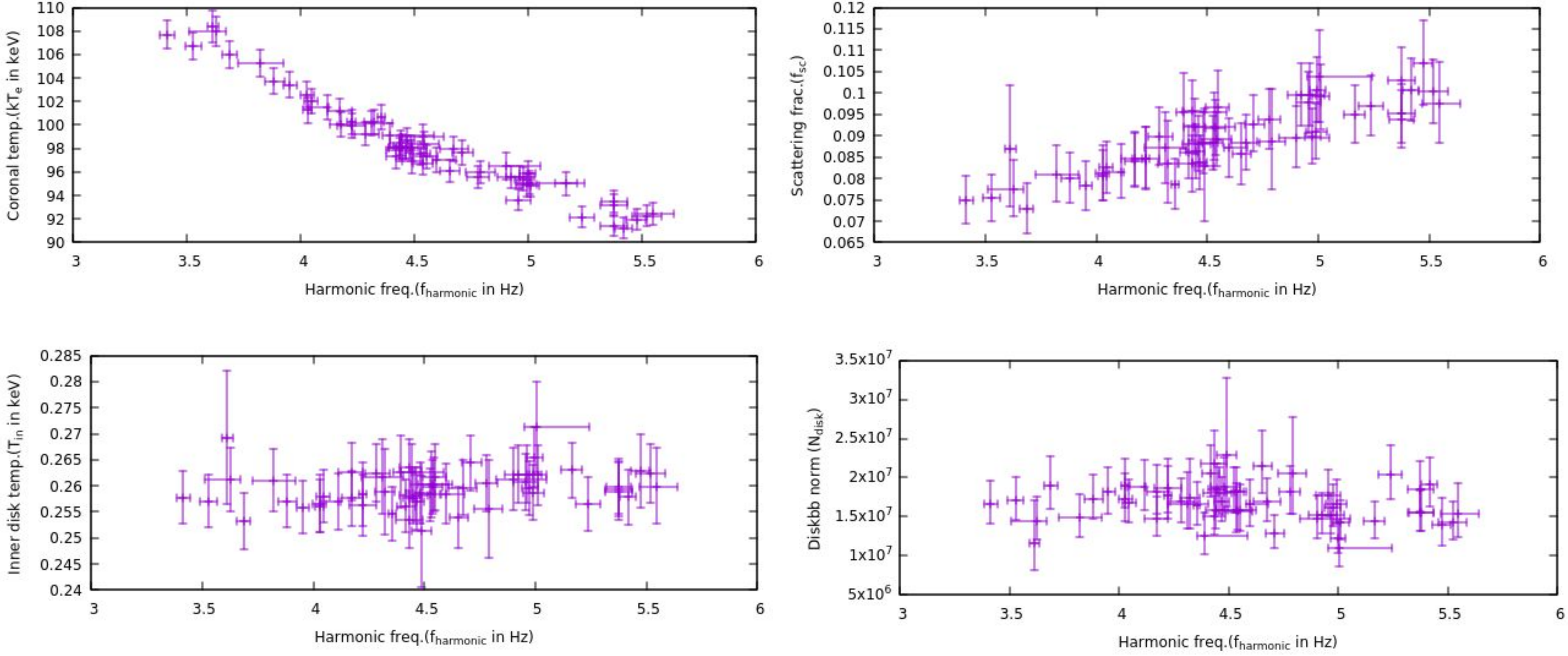
Constant*tbpcf*tbabs*thcomp*diskbb



Time evolution of spectral parameters



Correlations



POSSIBLE WAYS TO EXPLAIN ORIGIN OF QPOS

Identifying QPO frequency with a theoretical model

- **Lense-Thirring precession** (Ingram, Done & Fragile (2009))
- **Disk oscillations between compact object and disk** (Titarchuk & Osherovich(2000))
- **Shock oscillation model** (Chakrabarti & Manickam (2000))

And many more.....

Identifying radiative process that gives rise to QPO

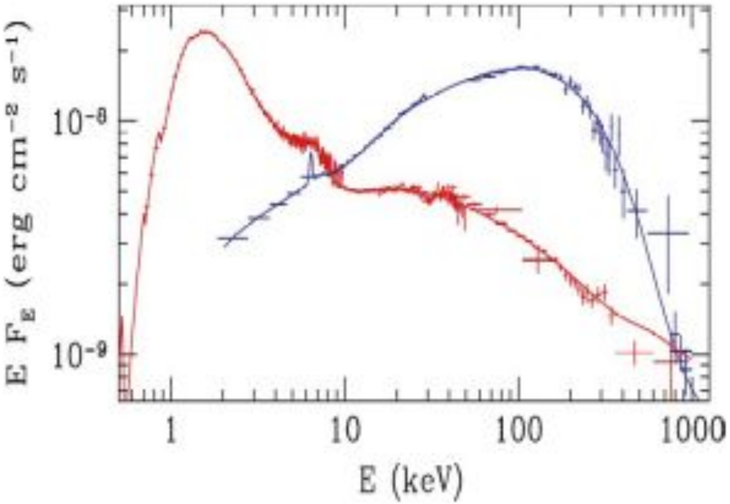
- **Associating QPOs characteristics with Spectral states of BHXB** (Belloni et al. (2000))
- **Correlation between spectral parameters and QPO frequency** (Bhargava et al.(2019))
- **Droid model** (Mir et al. (2016))
- **One zone stochastic propagation model** (Maqbool et al. (2019))

ENERGY SPECTRUM

THE TIME-AVERAGED PHOTON SPECTRA OF BLACK HOLE BINARIES ARE OFTEN DOMINATED BY TWO RADIATIVE COMPONENTS.

Soft Component (Red points)

- Dominated in low energy band.
- Emitted by an optically thick and geometrically thin disc.
- Blackbody in nature.



Credits- Done et al. (2007)

Hard Component (Blue points)

- Dominated in high energy band.
- Emitted by an optically thin and geometrically thick hot region.
- Power law in nature.
- Inverse comptonization of soft photons by thermal electrons.

ENERGY SPECTRUM

Multicolored Accretion Disc

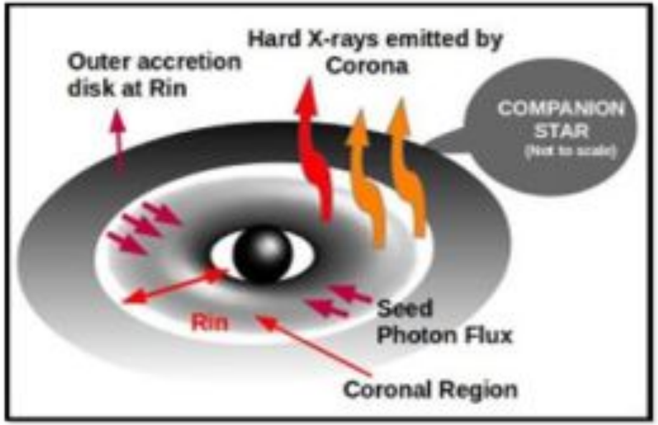
In XSPEC, modelled using "***Diskbb***"

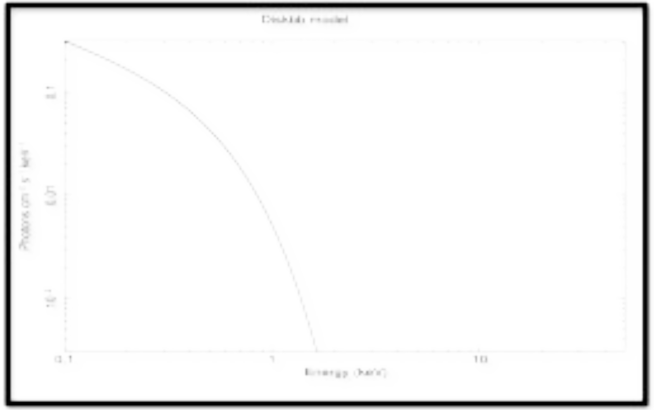
Inner disc temp. (KT_{in}) ⟷ Accretion rate

Normalization (N_{disk}) ⟷ Inner disk radii

$$T_{in} = \left(\frac{3GM\dot{M}}{8\pi R_{in}^3 \sigma}\right)^3 \qquad norm = \left(\frac{R_{in}}{D_{10}}\right)^2 \cos\theta$$

where R_{in} is the inner disc radius, D_{10} is the distance to the source in units of 10 kpc and $\dot{M}$ is the mass accretion rate.





ENERGY SPECTRUM

Thermal comptonized spectrum from hot corona

In XSPEC, modelled using "***Nthcomp***"

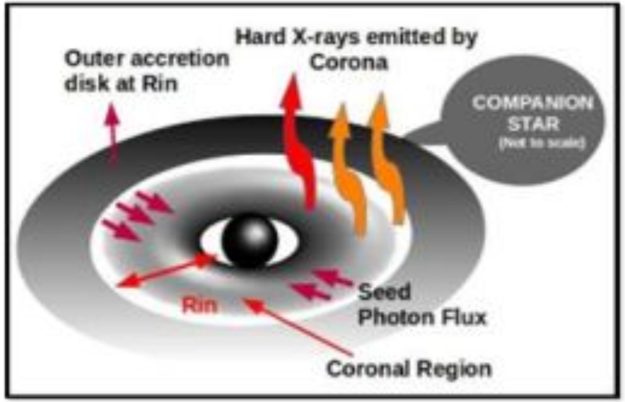
Electron temp. (KT_e) ⟺ Heating rate

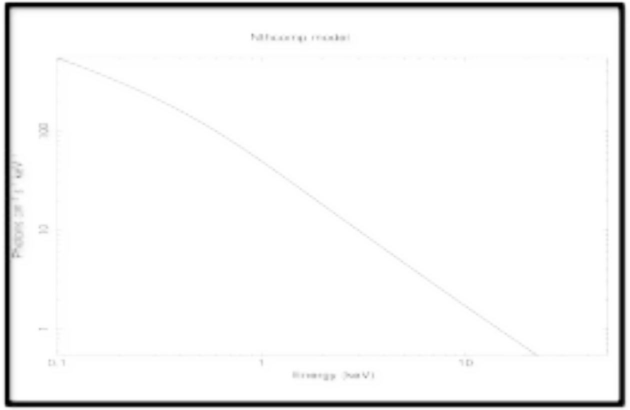
Spectral index ⟺ Optical depth

$$\dot{H} = \int E(F_c(E, kT_e, \tau) - F_{inp}(E))\mathrm{d}E$$

where F_c is the photon flux from the corona, $F_{inp}(E) = f * F_d$ is the seed photon flux, and $F_d(E, kT_{in})$ is the disc flux.

$$\Gamma = [9/4 + (3m_e c^2)/(kT_e((\tau + 3/2)^2 - 9/4))]^{1/2} - 1/2.$$





Variation of the spectrum using physical parameters

$$\Delta F(E) = \sum_{j=1}^{M} \frac{\partial F(E)}{\partial \alpha_j} \Delta \alpha_j$$

Where F(E) is the steady state Spectrum, α are the parameters M is the number of parameters.

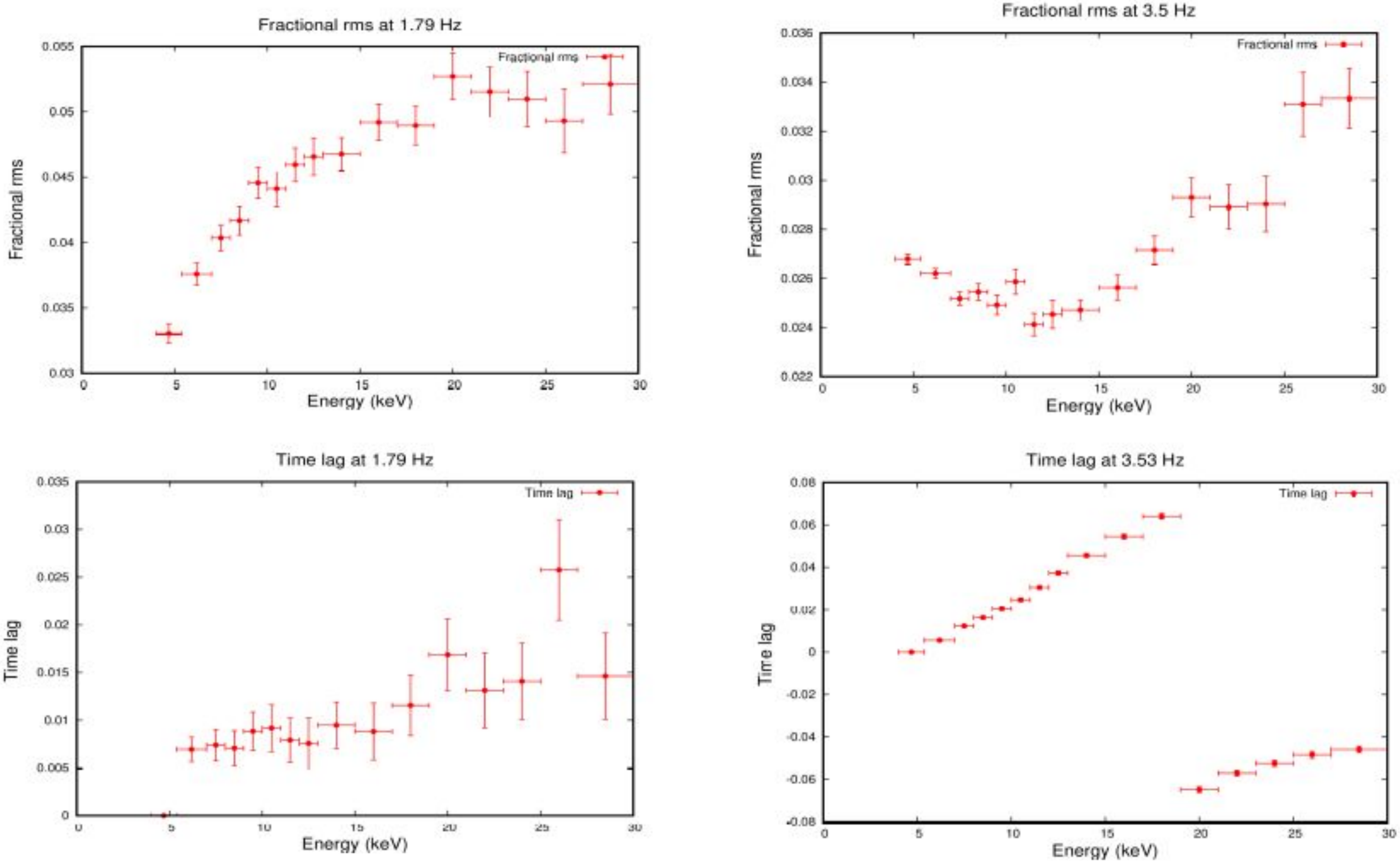
$$\frac{\partial F(E)}{\partial \alpha_j} \sim \frac{F(E, \alpha_j^o + \delta\alpha_j) - F(E, \alpha_j^o)}{\delta\alpha_j},$$

Fractional r.m.s. $= (1/\sqrt{2})|\Delta F(E)|/F(E)$,

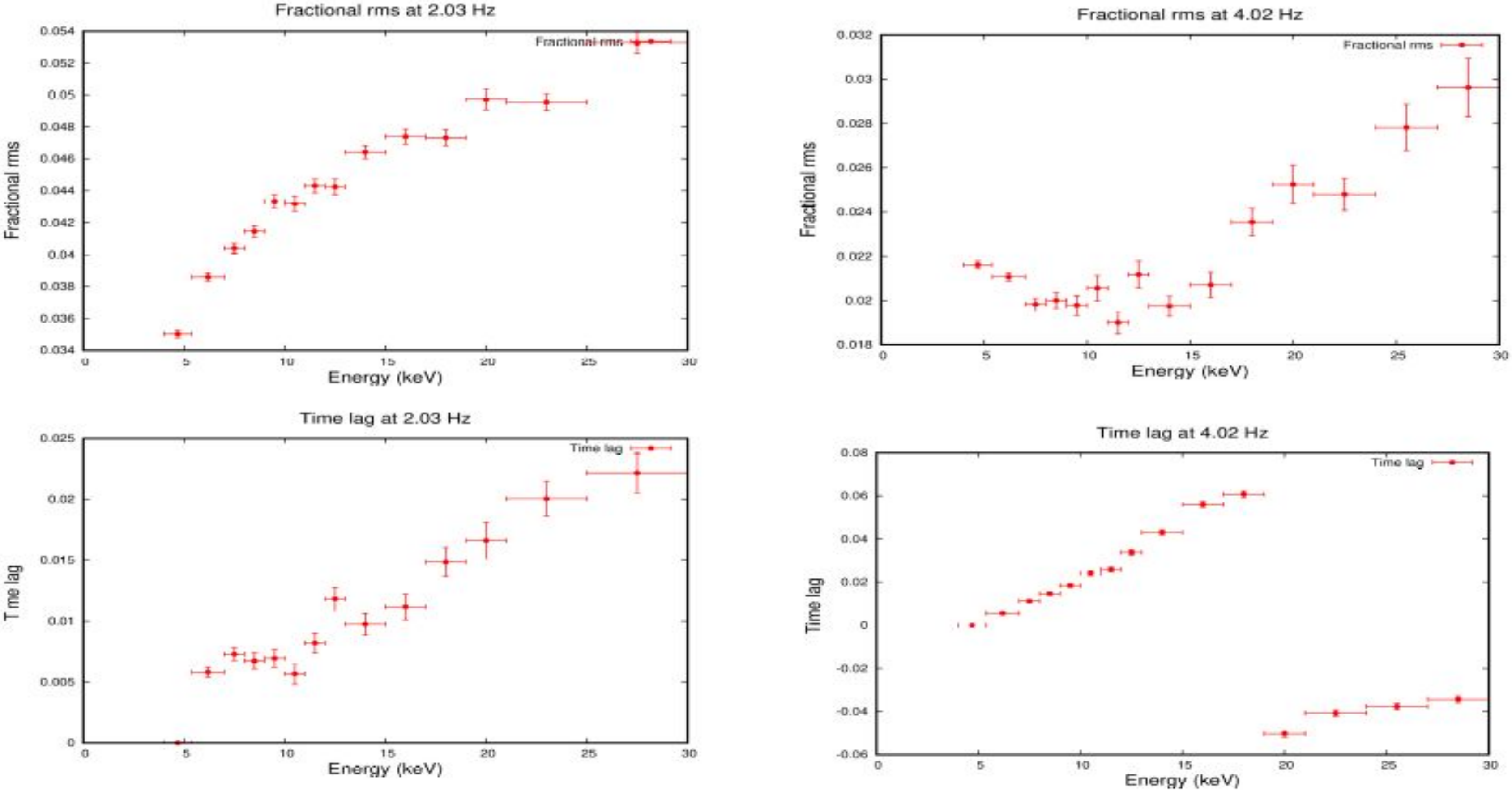
Phase-lag, $\phi =$ Argument of $[\Delta F(E_{ref})^* \Delta F(E)]$

Translation: Spectral to Physical parameters

Original Spectral parameters	Physical parameters
Inner disc temperature (KT_{in})	Accretion rate
Normalization (norm)	Inner disc radius (R_{in})
Photon index	Optical depth
Electron temperature (KT_e)	Heating rate
Scattering fraction	Scattering fraction



Fractional rms at 1.79 Hz
Fractional rms
Energy (keV)
Fractional rms at 3.5 Hz
Fractional rms
Energy (keV)
Time lag at 1.79 Hz
Time lag
Energy (keV)
Time lag at 3.53 Hz
Time lag
Energy (keV)



Fractional rms at 2.03 Hz
Fractional rms
Energy (keV)
Fractional rms at 4.02 Hz
Fractional rms
Energy (keV)
Time lag at 2.03 Hz
T me lag
Time lag
Energy (keV)
Time lag at 4.02 Hz
Time lag
Energy (keV)

Conclusion

- The joint spectral fitting for 62 segments was done for SXT ,LAXPC10 and LAXPC20 and the time evolution of spectral parameters were plotted.
- The correlation between spectral parameters and the harmonic frequency was found.
- The power density spectrum for all the segments was fitted with multiple lorentzians and energy dependent rms variation and time lag were plotted for each segment.
- We have found the heating rate and we will be fitting the rms and time lag of the harmonic using the model described in Garg et. al 2020.

THANK YOU!