GROWING BLACK HOLES: ACCRETION AND MERGERS (Kathmandu, Nepal 2022)

Milli-Hertz break detection in faint hard state of GX339-4, with AstroSat

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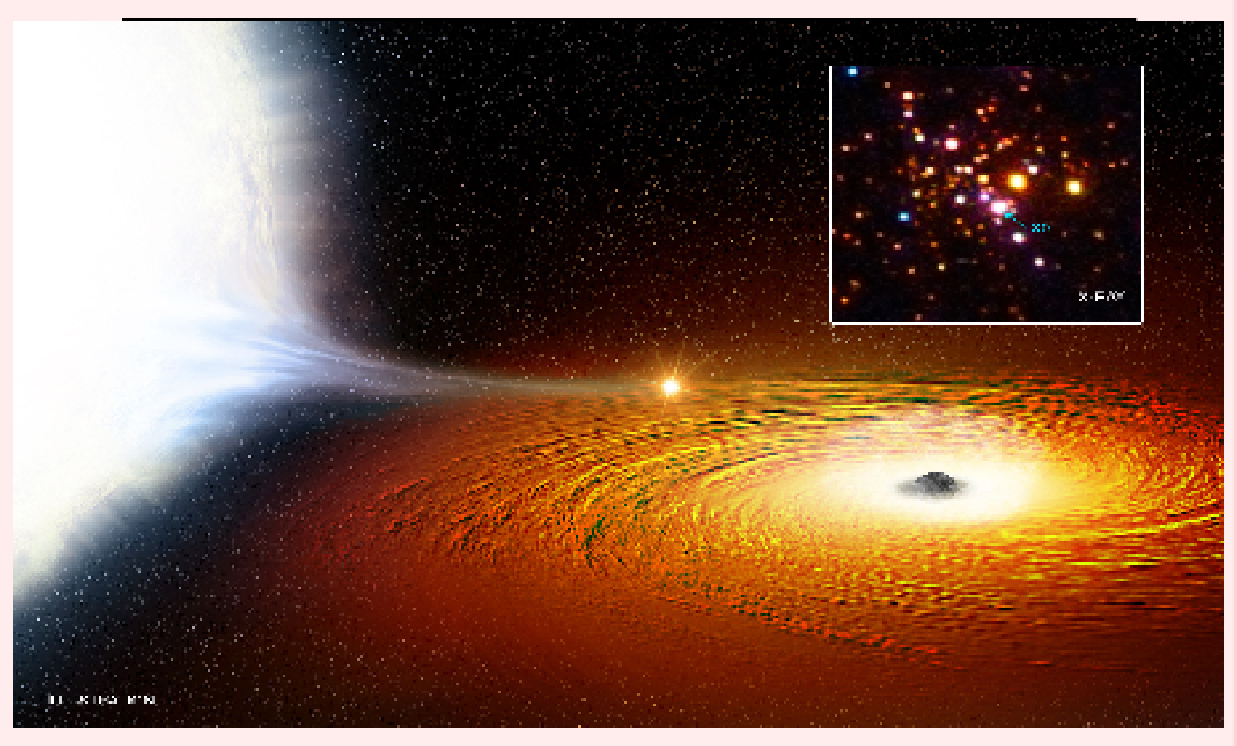
Summary

"We detect mHz breaks in the Power spectrum of GX 339-4, which are amongst the lowest frequency breaks observed for this Blackhole system. We try to put constraint on the geometry of accretion disk using milli-hertz variability. We also find that our detections roughly fit the positive correlation between the mHz break and flux."

Introduction

- BHB: System of a Black hole and a star.
- Accretion disk becomes a tool to study Black hole physics, via
  - Spectral: Modelling the continuum and line features.
  - Timing: Study of variability over different time scales.
- GX339-4 is a transient ($M_{BH} \sim 6M_\odot$ and distance of $> 5kpc$).

Fig:Depiction of Black hole binary



Credit: NASA/CXC/M.Weiss

Geometry and Observations

Fig: Structure of Inner flow (Left Panel) and AstroSat satellite (Right Panel)

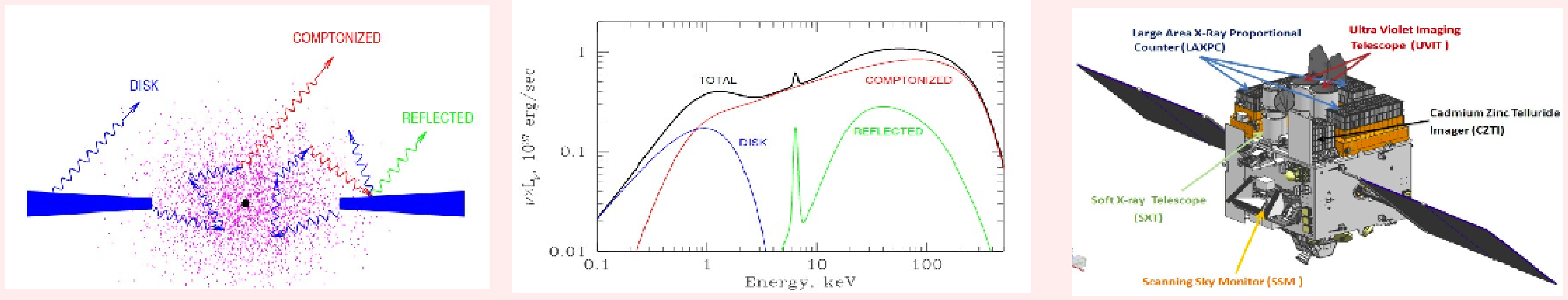
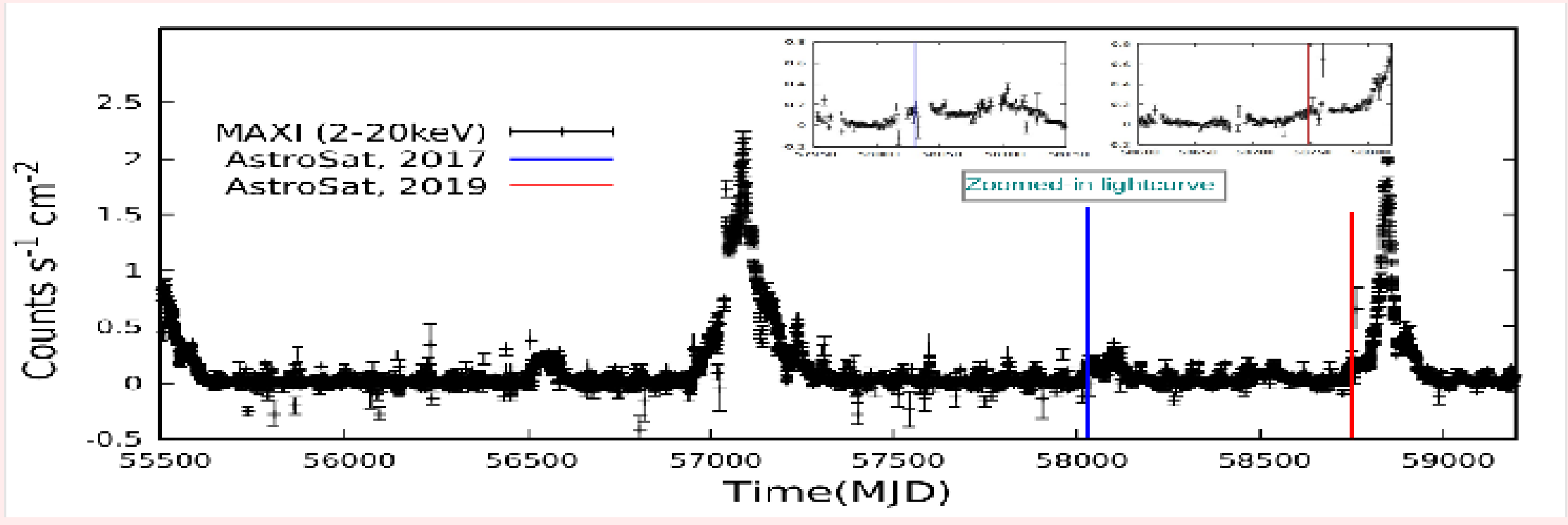
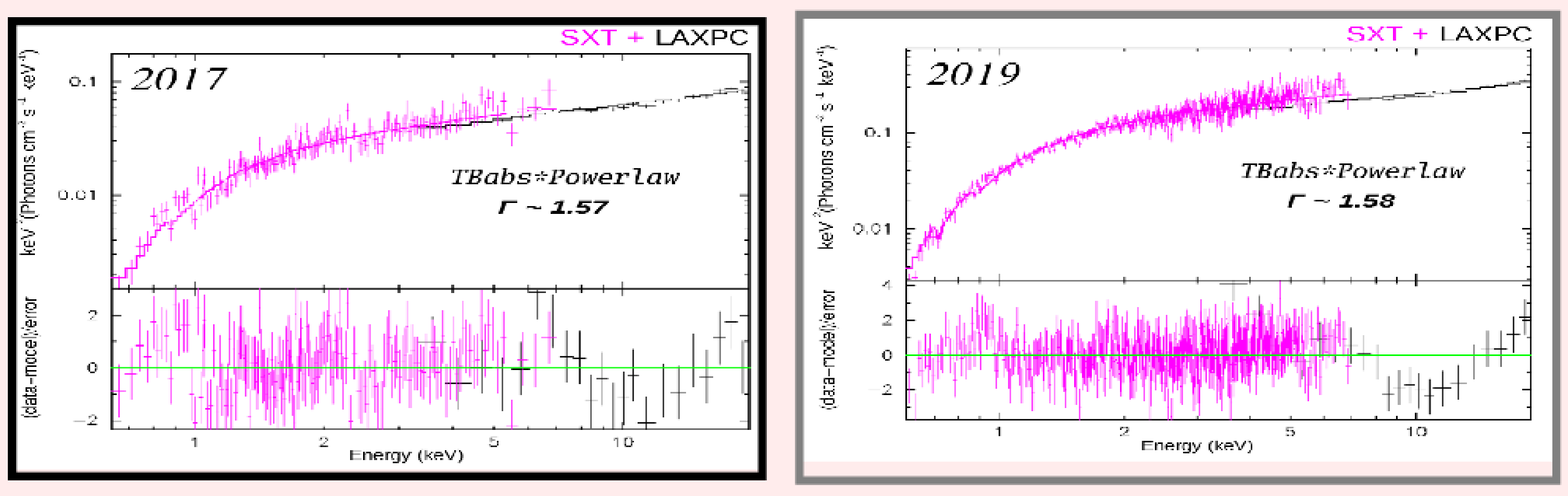


Fig: MAXI lightcurve with simultaneous AstroSat observations



Spectral Study

Fig:Continuum Modelling with TBabs*Powerlaw



Model	Parameter	2017	2019
TBabs	N_H $(10^{22}\ cm^{-2})$	$0.430^{+0.035}_{-0.033}$	$0.440^{+0.014}_{-0.014}$
Powerlaw	Γ	$1.570^{+0.031}_{-0.031}$	$1.583^{+0.020}_{-0.020}$
	N_Γ (10^{-2})	$2.35^{+0.17}_{-0.15}$	$9.73^{+0.45}_{-0.43}$
χ^2/dof		189.61/169.00	531.82/441.00
L/L_{edd}		0.001	0.005

Relline, Ireflect improved the χ^2 fitting → signifying presence of reflection

Discussion and Conclusions

- We confirm mHz detections with independent detectors (LAXPCs and SXT)
- The low count rate hard state allowed us to observe the characteristic mHz break in the PDS.
- Independent estimation of Inner radius is carried out, however the assumed values of α, H/R and M_{BH} might be different.
- The break frequency flux correlation roughly follows the trend of Inner radius moving closer to Blackhole as the flux increases.

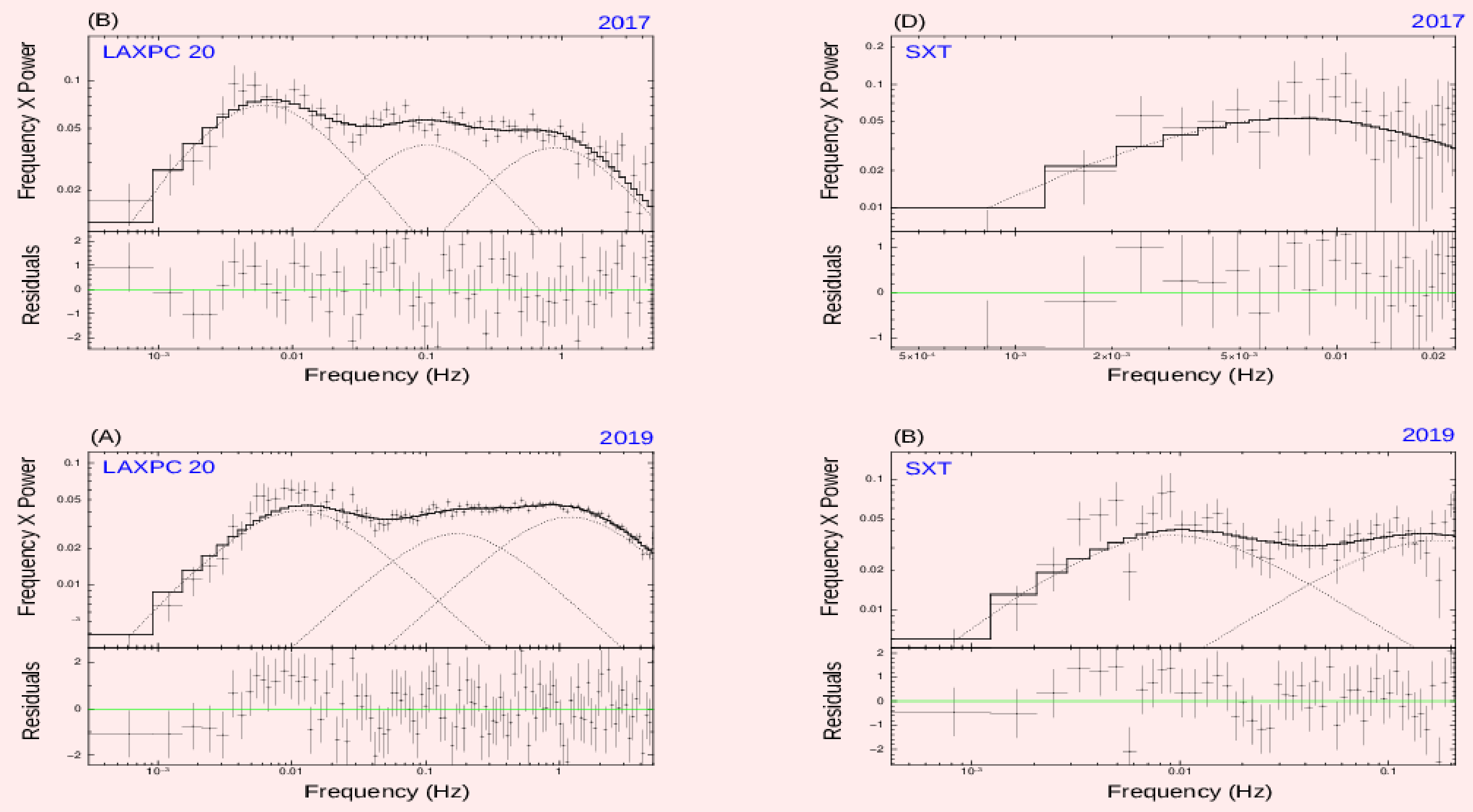
Timing Study

To study variability of source, we made use of Fourier Transform of the lightcurve via Power Density Spectrum.

Characteristic PDS in hard state: Broadband noise + Low Frequency QPOs

$$\boxed{L(\nu) = \frac{N_L \Delta}{\pi}\left(\frac{1}{(\nu-\nu_o)^2+\Delta^2}\right) \quad , \nu_{Brk} = \sqrt{\nu_o^2+\Delta^2}}$$

ν_o , N_L and Δ as centroid frequency, norm and HWHM.



Multiple Lorentzian fitting of PDS

Obs.	Payload	ν_{Brk} (mHz)	ν_2 (Hz)	ν_3 (Hz)	χ^2/dof
2017	LXP10	$6.95^{+1.11}_{-0.93}$	$0.16^{+0.03}_{-0.03}$	$1.75^{+1.16}_{-0.64}$	63.48/63.00
	LXP20	$6.12^{+1.10}_{-0.93}$	$0.196^{+0.054}_{-0.043}$	$0.86^{+0.29}_{-0.19}$	83.67/63.00
	LXP10+20	$6.65^{+1.09}_{-0.92}$	$0.13^{+0.026}_{-0.024}$	$0.98^{+0.28}_{-0.20}$	76.43/63.00
	SXT	$7.34^{+2.03}_{-1.51}$	$0.13(f)$	—	114.32/140.00
2019	LXP20	$11.40^{+1.07}_{-1.08}$	$0.17^{+0.02}_{-0.02}$	$1.19^{+0.12}_{-0.10}$	114.80/99.00
	SXT	$10.95^{+2.56}_{-1.87}$	$0.13^{+0.02}_{-0.02}$	—	44.76/45.00

Break Frequency in Truncated disk geometry

In truncated disk picture, the timescale at break frequency is assumed to be associated with the viscous timescale at the truncation radius of the disk.

$$T_{Brk} = 1/\nu_{Brk} = T_{visc}$$

$$\boxed{T_{\rm visc} = 4.5 \times 10^{-3}\frac{1}{\alpha}\left(\frac{H}{R}\right)^{-2}\left(\frac{R_{in}}{6\ R_g}\right)^{3/2}\left(\frac{M_{BH}}{10\ M_\odot}\right)}$$

- α is the dimensionless viscosity parameter.
- H/R is the semi-thickness.

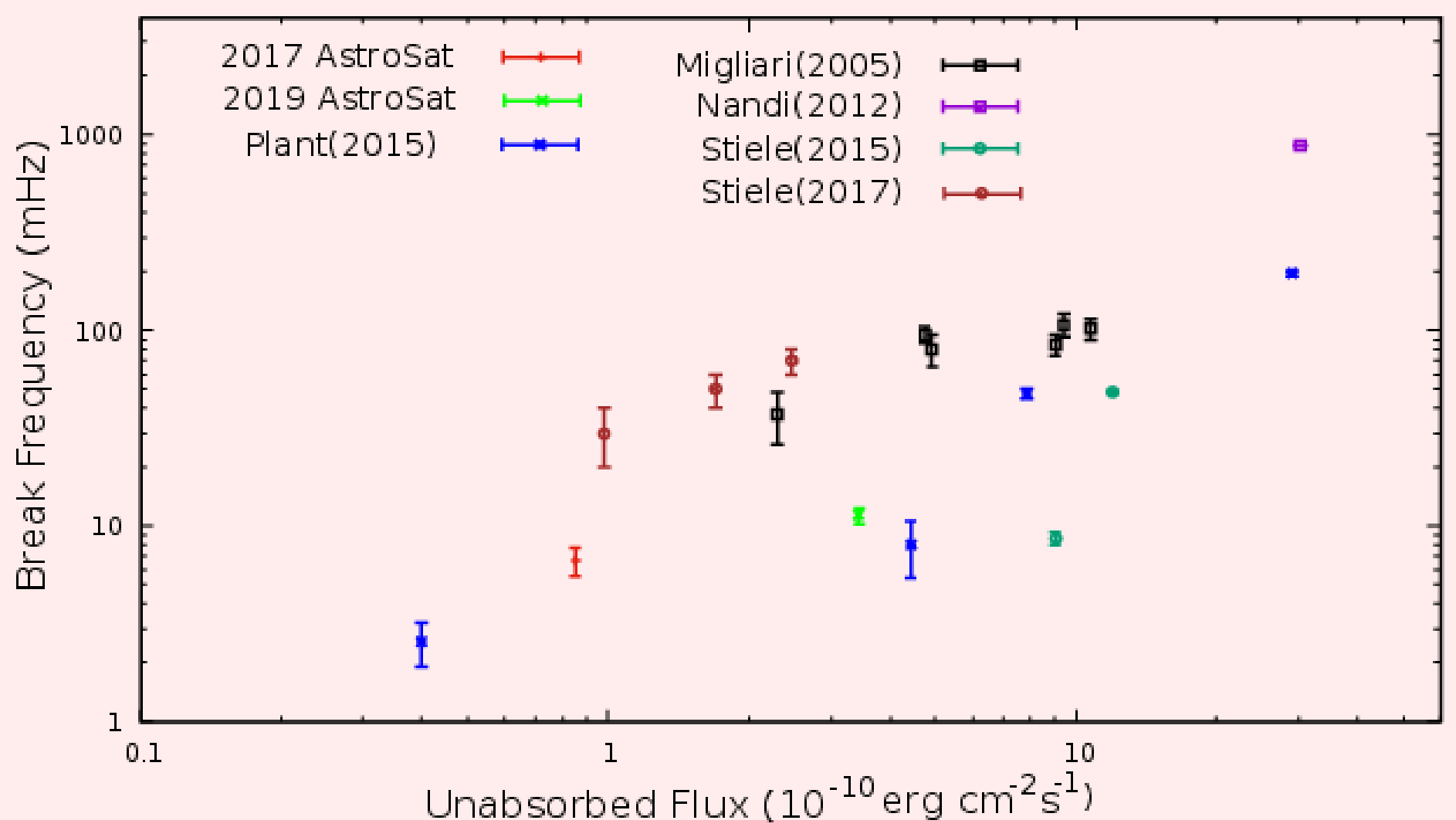
$\boxed{Estimating R_{in}}$

For $\alpha = 0.1$, $H/R = 0.01$ (thin disk parameters) and $M_{BH} = 6M_\odot$

$$R_{in} = \begin{cases} 93 \pm 3.8\ R_g & \text{(2017 Obs.)}, \\ 61 \pm 1.4\ R_g & \text{(2019 Obs.)} \end{cases} \quad R_g = GM/c^2.$$

Correlation of Break frequency with Flux

Break frequency v/s Flux



- All detections were done in hard state..
- The flux was estimated in 3.0-9.0keV
- Shows a positive correlation with flux

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