On the Spectro-Temporal difference in origin of the kHz QPO and noise component in 4U 1702-429 using AstroSat and NICER.

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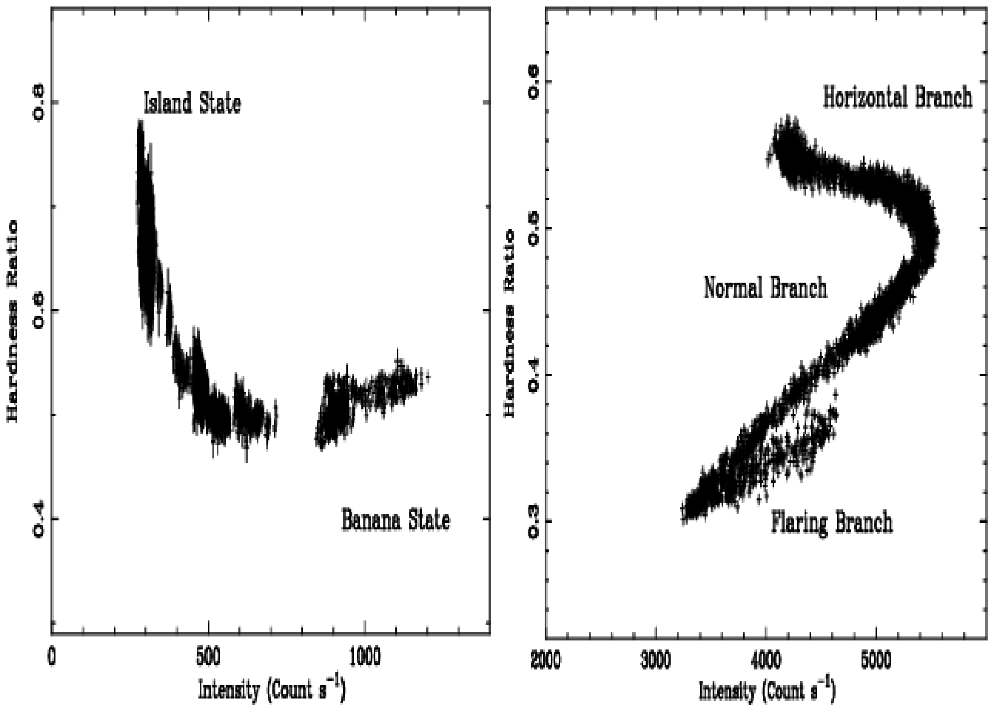
PLAN

- Introduction
- Source studies of 4U 1702-429
- Spectral results
- Temporal behaviours
- Key conclusions

NSLMXBs

- Neutron star Low Mass X ray Binaries (NSLMXBs) contain a neutron star as a central compact object that accretes matter from its companion star.
- For the case of the Low mass scenario, the companion star is of late O, A, B type star with mass comparable to the solar mass.
- These systems are often exhibits a number of different temporal and spectral variability in their Power density spectrum and Energy spectrums.

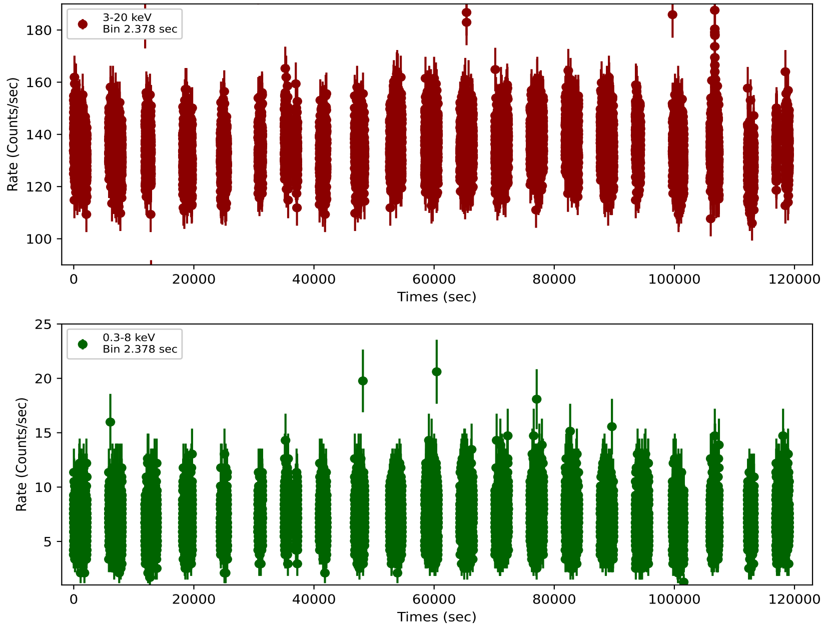


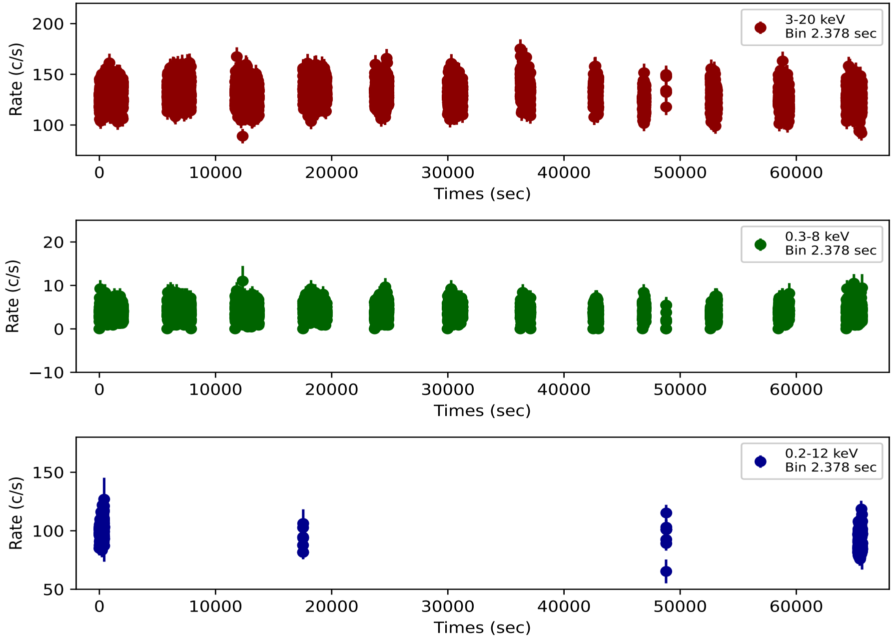
Source 4U 1702-429

- 4U 1702-429 (Ara X-1) is a Neutorn star X-ray binary source. Specifically this is an atoll type source.
- The source was first discovered by OSO8 as a burster in 1971.The source shows Type 1 burst in its lightcurve.
- It is a very bright source with luminosity 10^{37} ergs/sec.
- From the Type 1 burst it produces, the distance has been measured to be 4.19-7 kpc.
- Moreover, kHz oscillations has also been detected at a frequency of 900 Hz by Markwardt et al 1999.

Credit: Google

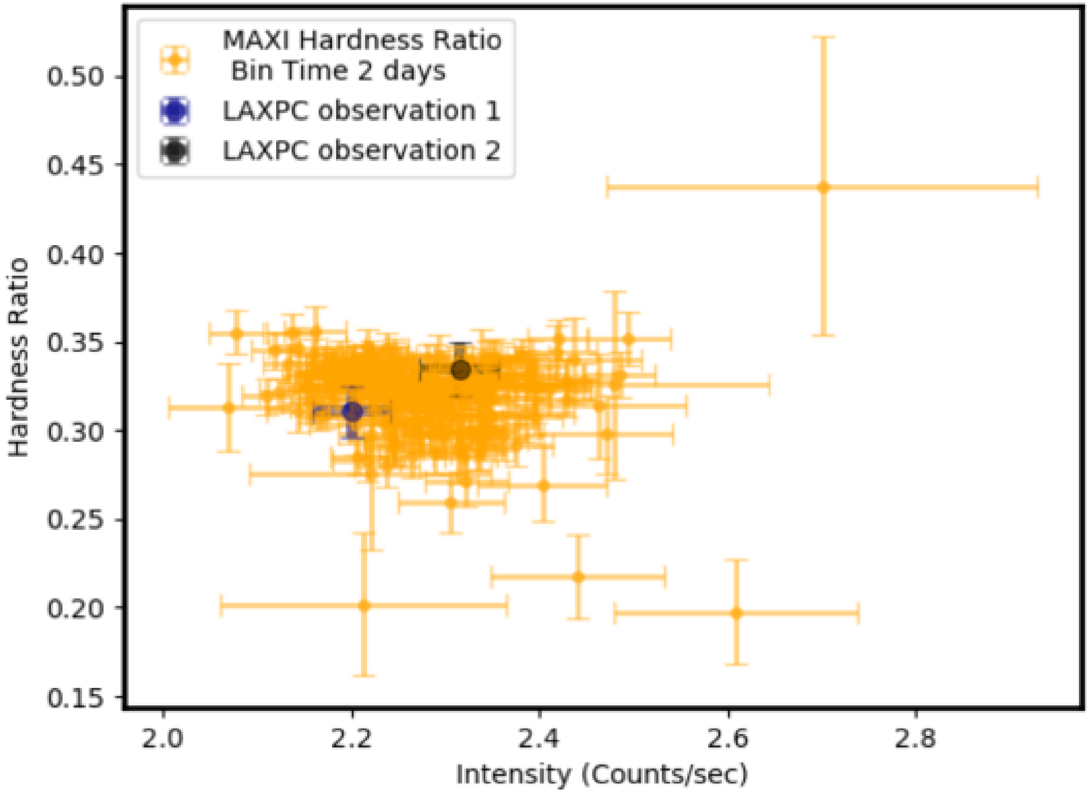
Present Scenario & Observation





We have taken two observations which are one year apart from each other. Left hand side is from 2018 and the right hand side is from 2019.

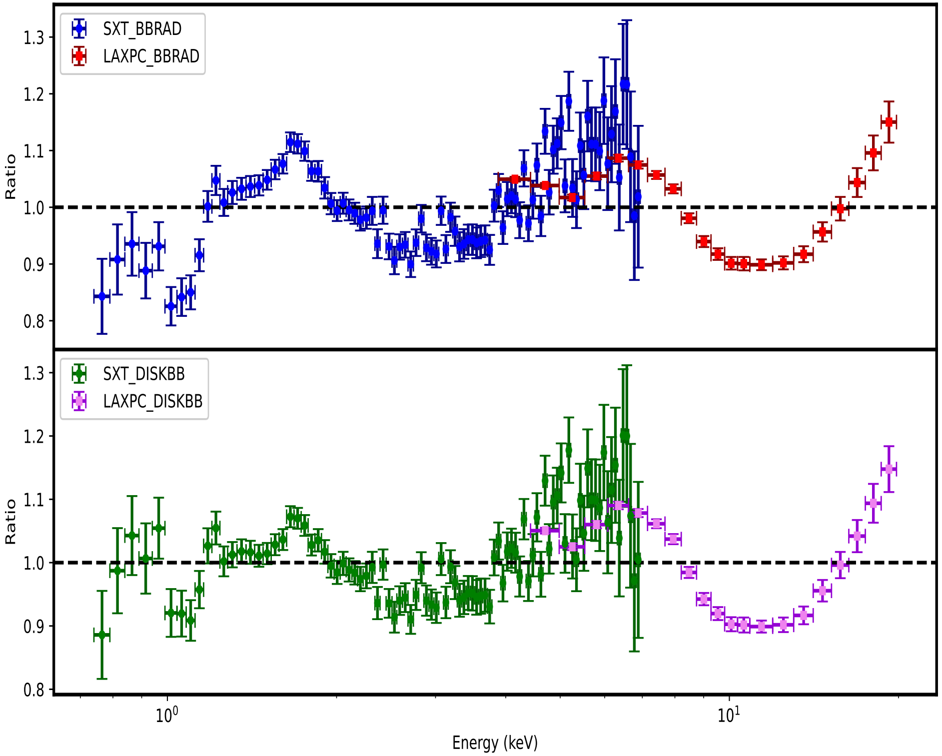
Position in Hardness Ratio



LAXPC observation No 2 coinsides with the NICER Observation.

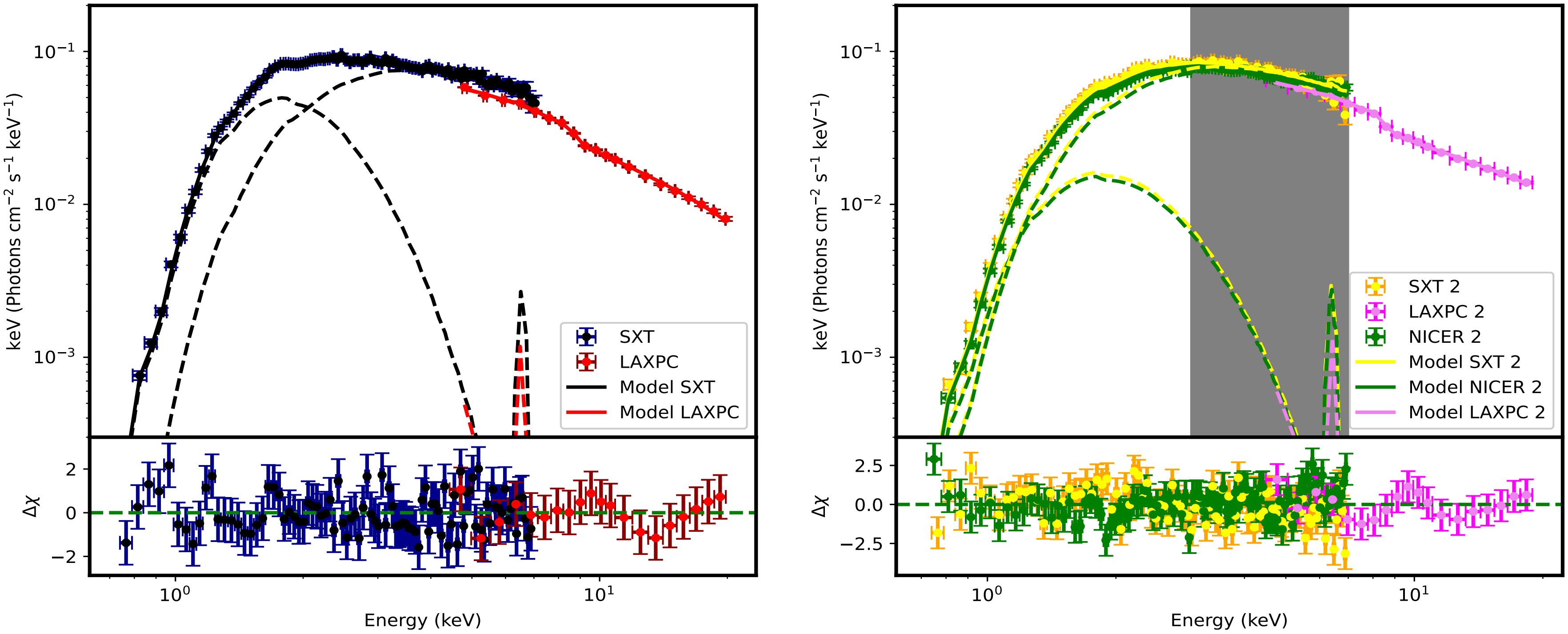
Hardness ratio (8-20 keV Counts / 3-8 keV Counts) using Long term MAXI long lightcurve with 2 days binning (1 year long observation data) shows that the source mostly stays in a particular apex region of so called Banana branch and Observation 1 is in relatively harder region compared to Observation 2.

Spectral Properties



- Simple combination of Tbabs * (Thcomp * Bbodyrad) or Tbabs * (Thcomp * Diskbb) are insufficient.
- Adding a simple Gaussian to take care of the residual in 6-8 keV, ends up giving unphyiscally large width.
- Previous studies (Ludlam et. al. 2019, Mazzola et al. 2019) suggests that the spectra shows a presence of reflection feature in the spectra.

Complex Spectral behaviour

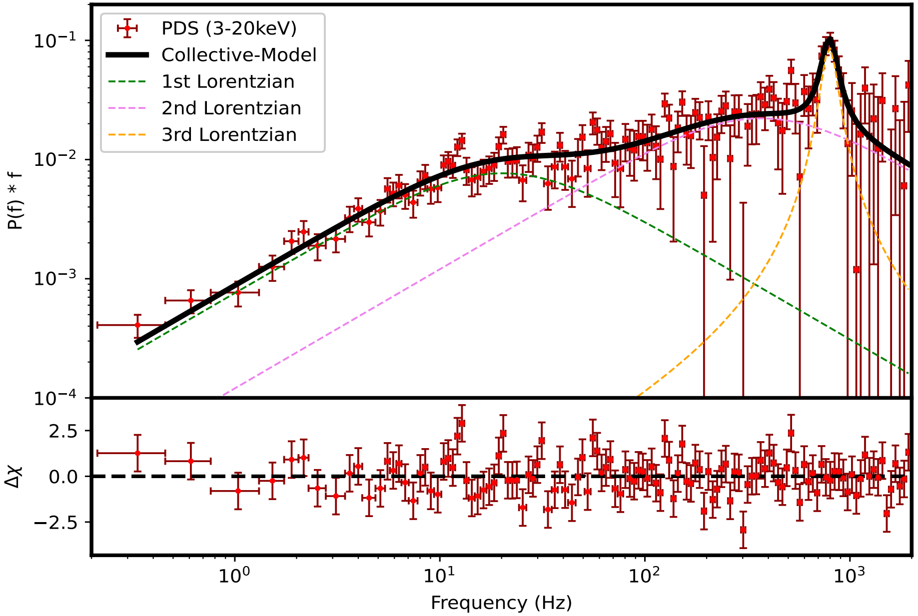


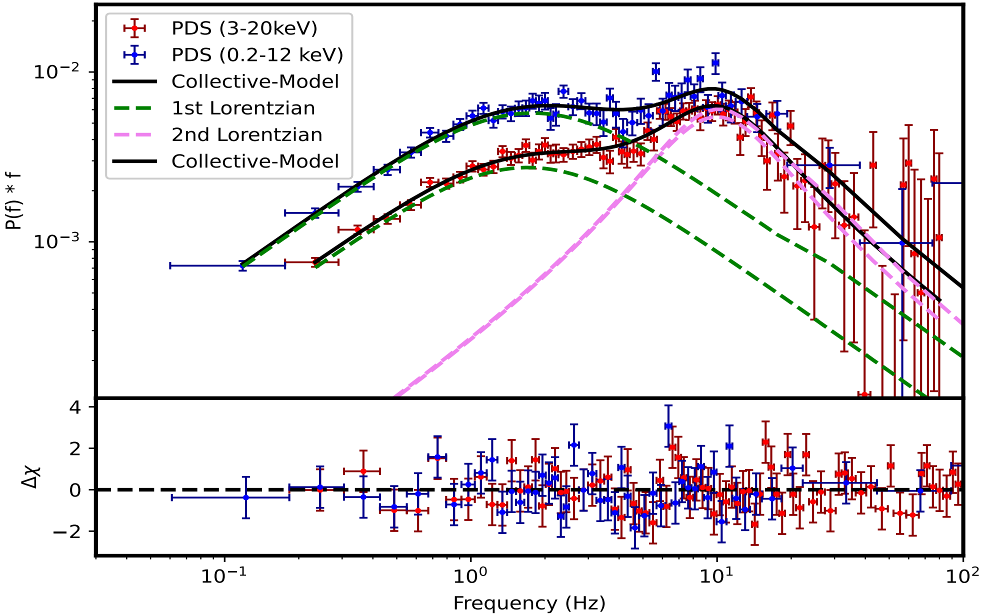
The Best fitted Spectral model is : Tbabs * (Gaussian + Diskbb + Ireflect * Thcomp* Bbodyrad).
The spectra shows a comparatively complicated scenario.

Spectral Analysis Results

Constant	1/0.94	1/0.93/0.85
(nH x 10^{22} atoms/cm^2)	**1.72 +/- 0.04**	**1.49 +/- 0.06**
Gaussian Norm (10^4)	1.31 +/- 1.1	1.41 +/- 1.1
KT_{in} (Inner Disk Temp)	**0.44+/- 0.03**	**0.51 +/- 0.03**
Disk Norm	**1464 +/- 509**	**263.2 +/- 143**
Reflection Fraction	0.63 +/- 0.3	0.61 +/- 0.11
Optical Depth (Tau)	**7.21 +/- 0.52**	**7.83 +/- 0.36**
Kt_e(Electron Temp)	**5.51 +/- 0.25**	**6.47 +/- 0.45**
Kt_{bb}(Blackbody Temp)	0.77 +/- 0.04	0.71 +/- 0.05
Chi^2/Dof	86.45/104	216.1/204

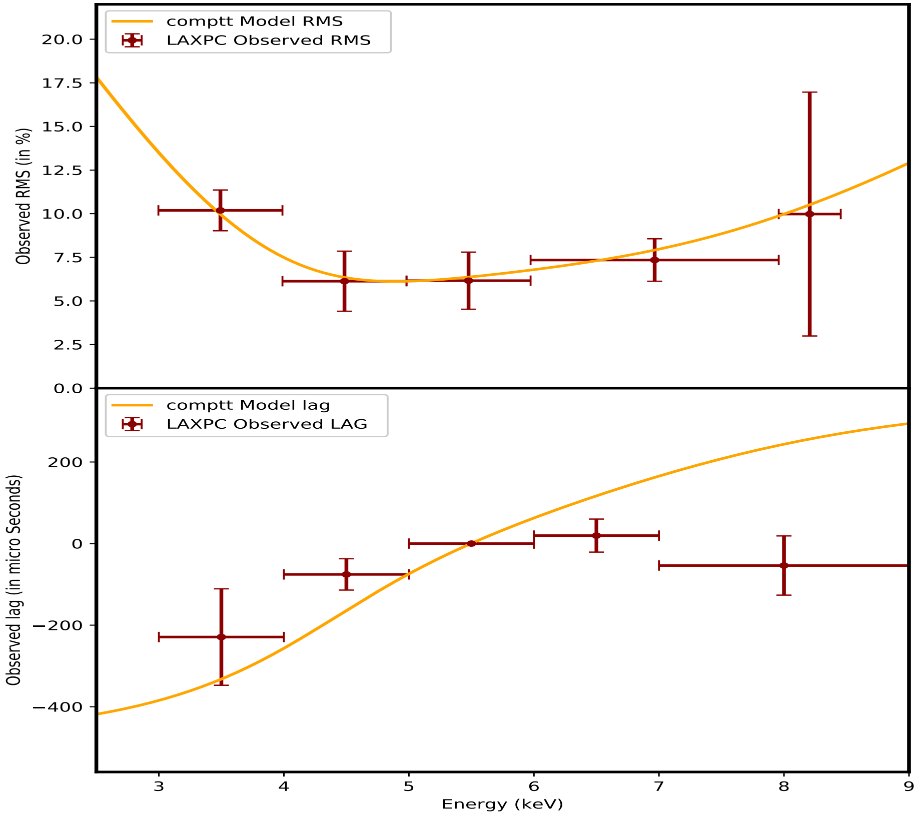
Temporal Features

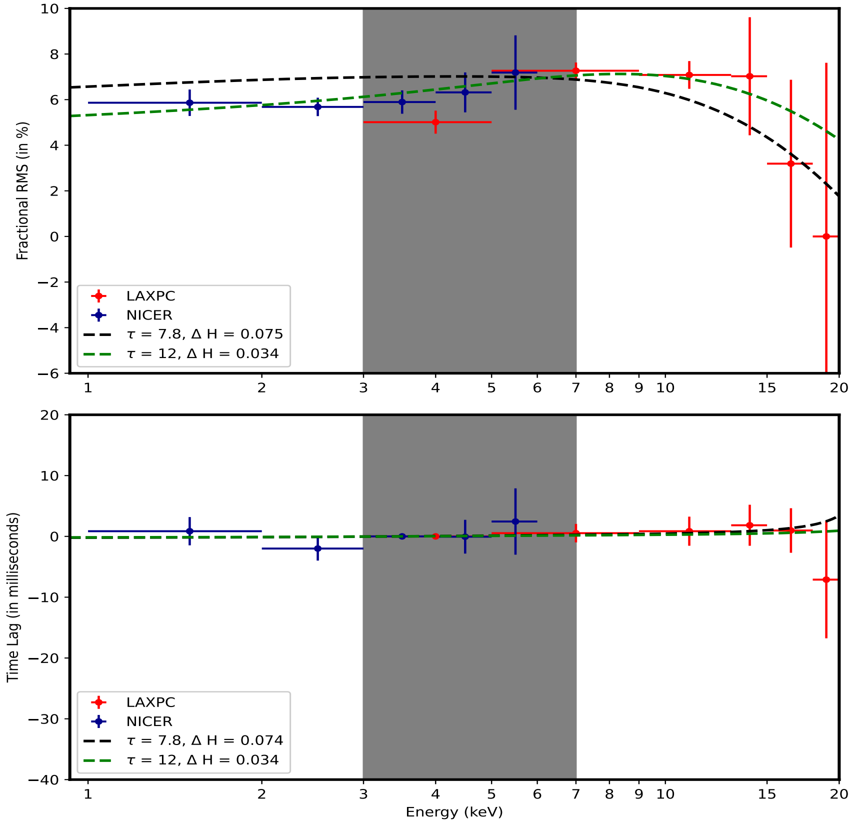




- Observation 1 shows the presence of the kHz QPO at around ~ 790 Hz. No presence of the kHZ QPO has been observed in the PDS of the observation 2. Presence of a double hump (~ 10 Hz) kind of feature is present in the observation 2 which is not seen in 1.

Lag & RMS variation





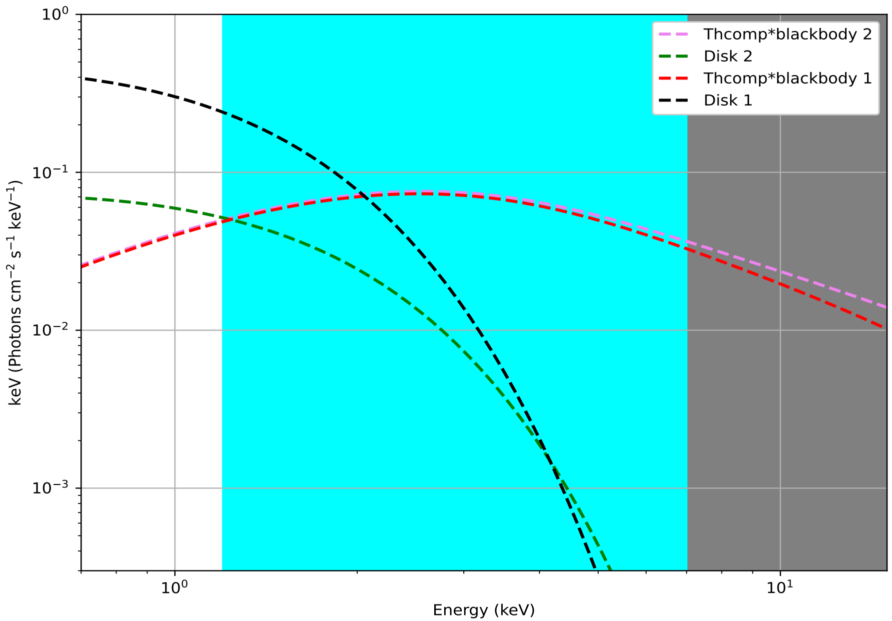
Radiative Origin

$$-\frac{d^2\Delta n_\gamma}{dE^2}+\left(-\frac{1}{kT_{co}}-\frac{2}{n_{\gamma o}}\frac{dn_{\gamma o}}{dE}\right)\frac{d\Delta n_\gamma}{dE}+\frac{m_e c^2(n_{s\dot{\gamma}o}-i\omega n_{\gamma o})}{E^2 n_{\gamma o} kT_{co}}\Delta n_\gamma =$$

$$\left(-\frac{2}{E^2}+\frac{1}{n_{\gamma o}}\frac{d^2 n_{\gamma o}}{dE^2}\right)\Delta T_e+\frac{m_e c^2 t_c n_{s\dot{\gamma}o}}{E^2 n_{\gamma o} kT_{co}}\left(\frac{\frac{E}{kT_{bo}}}{1-\exp\left(\frac{-E}{kT_{bo}}\right)}\right)\Delta T_b$$

Kumar & Misra 2014, 2016 in their series of paper has developed an idea that predicts the plasma response separately due to either variation of input seed photon temprature or variation of coronal heating rate variation. They have solved the linearized Kompaneet's Equation to calculated the plasma response due to the variation of heating rate and input seed photon temperature separately.

Connection to Spectral Contributions



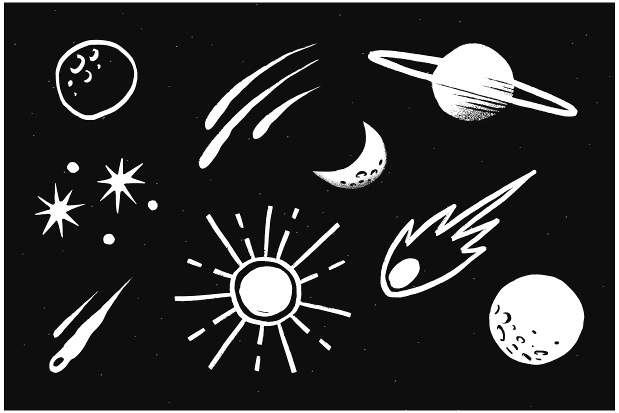
Energy(keV)	Counts 1	Counts 2	Counts 3	Ratio 1 (C1/C2)	Ratio 2 (C2/C3)	Ratio 3 (C1/C3)
1-2 (NICER)	30.33	28.72	18.24	1.05	1.57	1.66
2-3 (NICER)	25.83	24.18	20.06	1.06	1.20	1.28
3-4 (NICER)	17.21	15.53	14.64	1.10	1.06	1.17
4-5 (NICER)	9.02	7.80	7.66	1.16	1.01	1.17
5-6 (NICER)	4.68	3.86	3.84	1.21	1.00	1.21
4-5 (LAXPC)	9.47	8.40	8.16	1.12	1.02	1.16
5-9 (LAXPC)	43.09	34.59	34.51	1.24	1.00	1.24
4-5 (LAXPC)	11.33	10.07	10.07	1.12	1.00	1.12
5-6 (LAXPC)	2.84	2.37	2.37	1.19	1.00	1.19
6-8 (LAXPC)	2.15	1.72	1.72	1.25	1.00	1.25
8-9 (LAXPC)	1.67	1.29	1.29	1.29	1.00	1.29

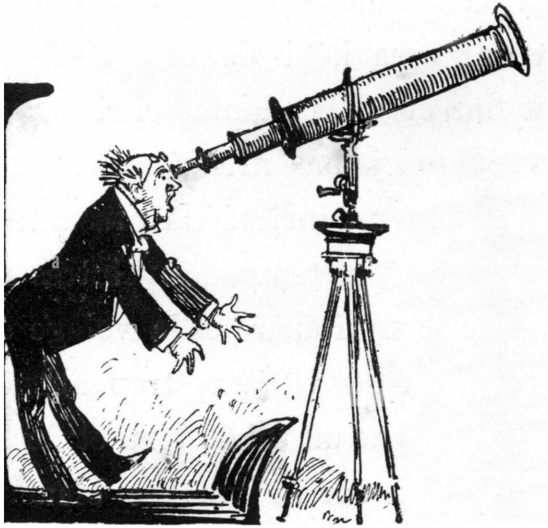
- Thcomp*Blackbody contribution dominates over Disk beyond 3 keV for both of the Observation. Although, the Disk effect should come between 1-3 keV.

- Reflection has no significant effect on the model counts (Ratio 1) but disk has in 1-3 keV , hence we have rescaled the rms by using the Ratio 3 to omit the effect of Disk and reflection.

Key Conclusions

- Spectra has prominent presence of reflection as well as disk.
- Disk has significant dominence below 3 keV.
- As previously reported, we found the disc to be highly ionized, likely due to high temperatures. However, unlike earlier reports, we observed that the Fe abundance matches the solar Fe abundance.
- PDS analysis in the soft state reveals a kHz QPO of 790 Hz, consistent with previous reports. Notably, this QPO appears to occur as the disc recedes. Study of the lag and rms behavior using the source's spectral properties supports this.
- (0.7-20 keV) Broad Noise component and the kHz QPO component (3-10 keV) in the PDS appears to share a similar radiative origin (Variation of Heating rate of Corona) with a feedback factor of 0.1 and corona size of about 30 km.





Thank You.