Identifying the QPO frequencies of GRS 1915+105 as General Relativistic Dynamic ones

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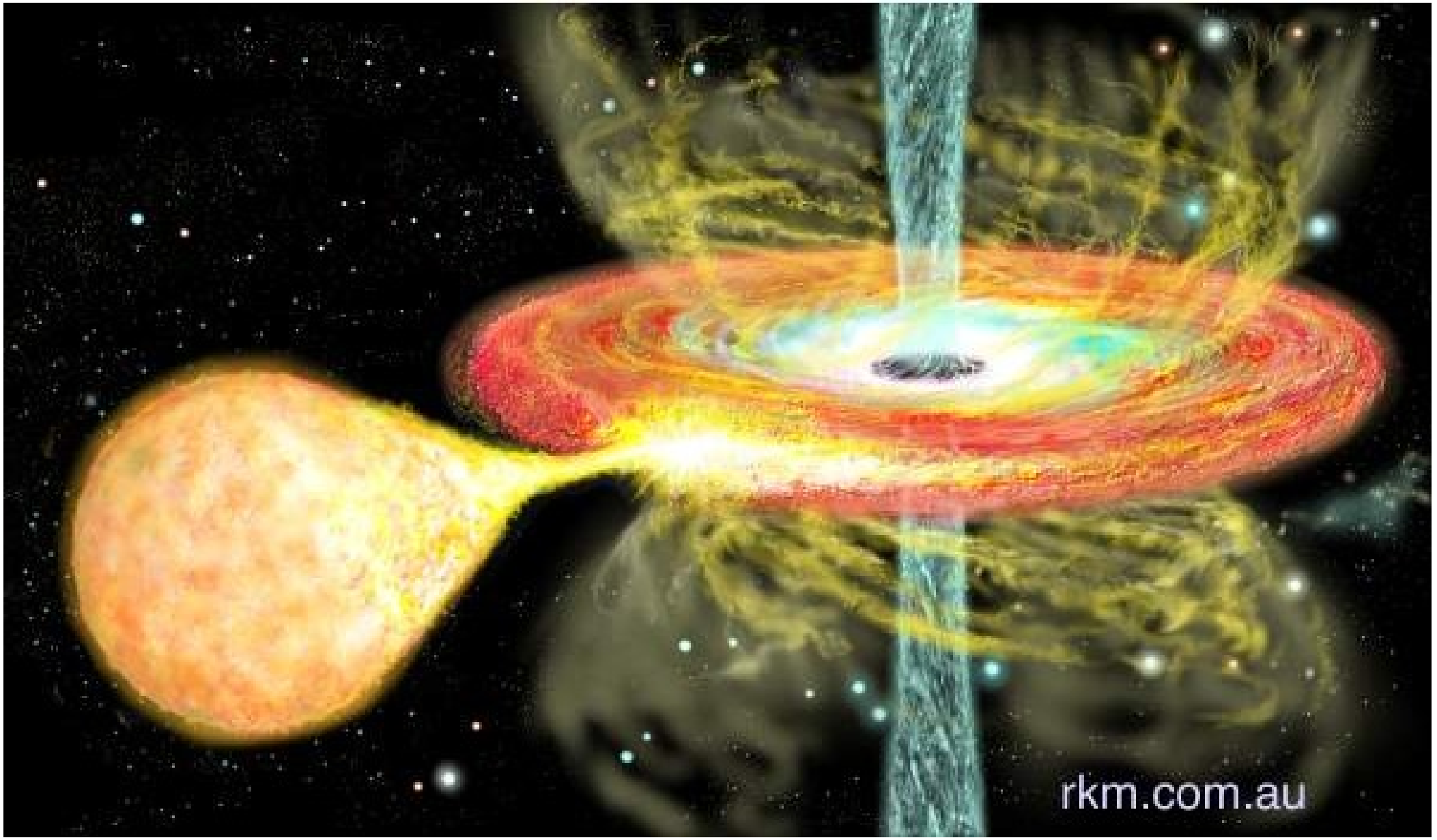
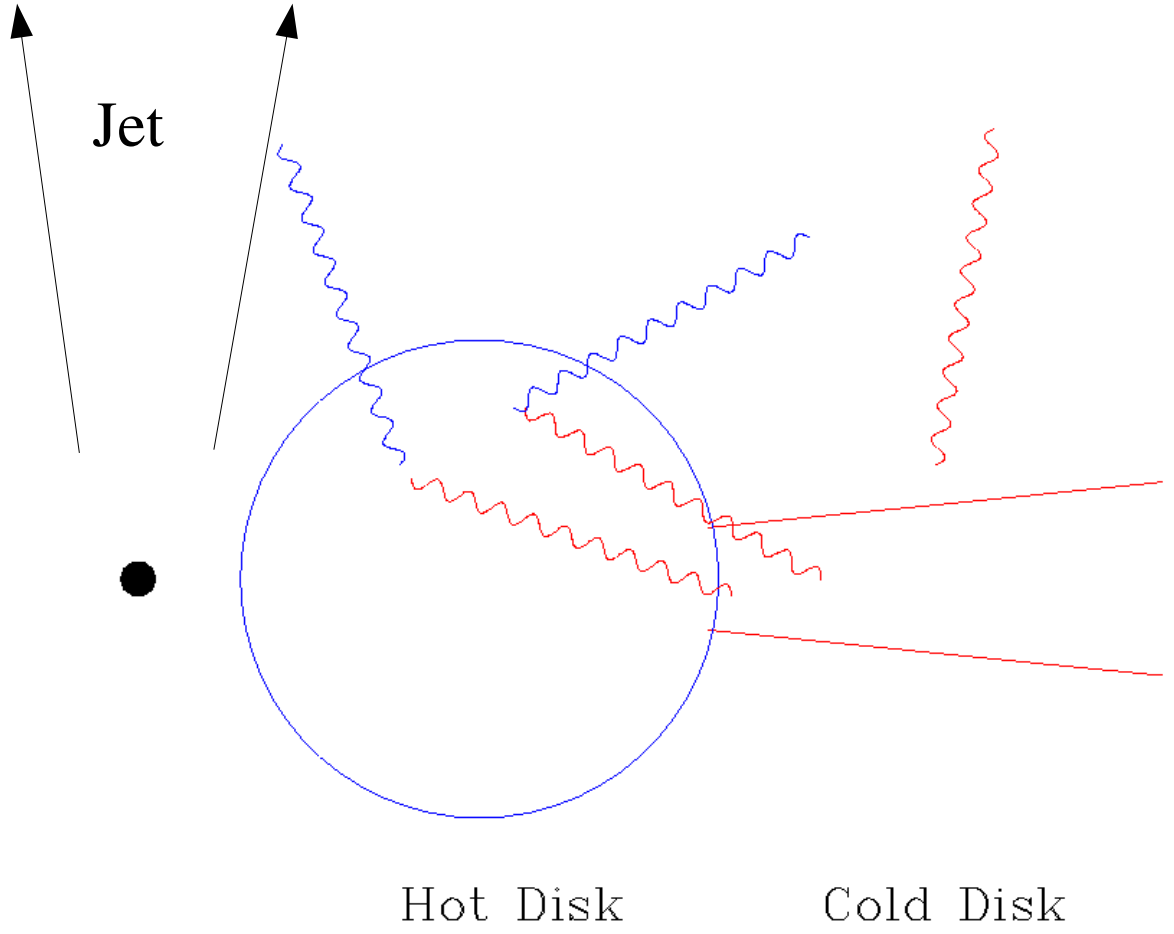
and J.S. Yadav, P. Jain, Ji, Long; C. Bambi, Y. Zhang

Based On: Misra, Rawat et al. 2020, Liu, H. et al. 2020, Dhaka et al. (in preparation) and Rawat et. al. (in preparation)

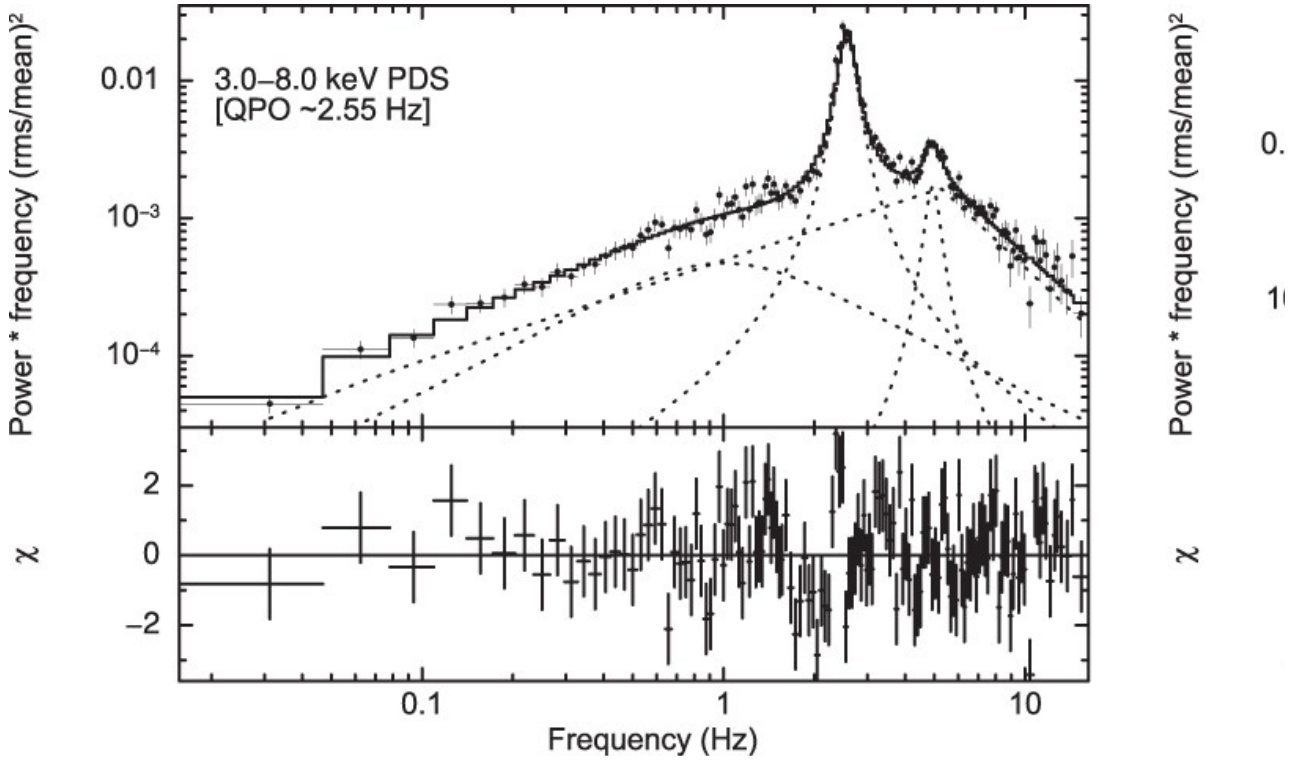
Picture of a Black Hole Binary



What we know about Black Hole Binaries….



AstroSAT/LAXPC: GRS 1915+105, QPO



Quasi Periodic Oscillations (QPO)

Yadav et al. 2016

Origin of QPOs...

- Identification with characteristic frequency of the system...
- Relativistic test particle frequencies
  - Keplerian Frequency
  - Epicyclic Frequency
  - Lenz-Thirring Frequencies

  <u>These frequencies depend only on radii</u>

Origin of QPOs...

- Characteristic time-scales of the accretion disk
  - The sound crossing time, R/c_s
  - The viscous time-scale, R/v_r

<u>These frequencies depend on radius and accretion rate</u>

Standard Accretion Disk Model

- *"Black holes in binary systems: Observational appearance".* ***Shakura, N. I. & Sunyaev, R. A.*** *1973 A&A, 24, 337 - 355* ***(18 Pages)***
- *"Astrophysics of black holes",* ***Novikov, I. D & Thorne, K. S.*** *1974, Black holes (Les astres occlus), p. 343-450* ***(107 pages)***

Origin of QPOs...

Relativistic test particle frequencies

- Keplerian Frequency
- Epicyclic Frequency
- Lenz-Thirring Frequency

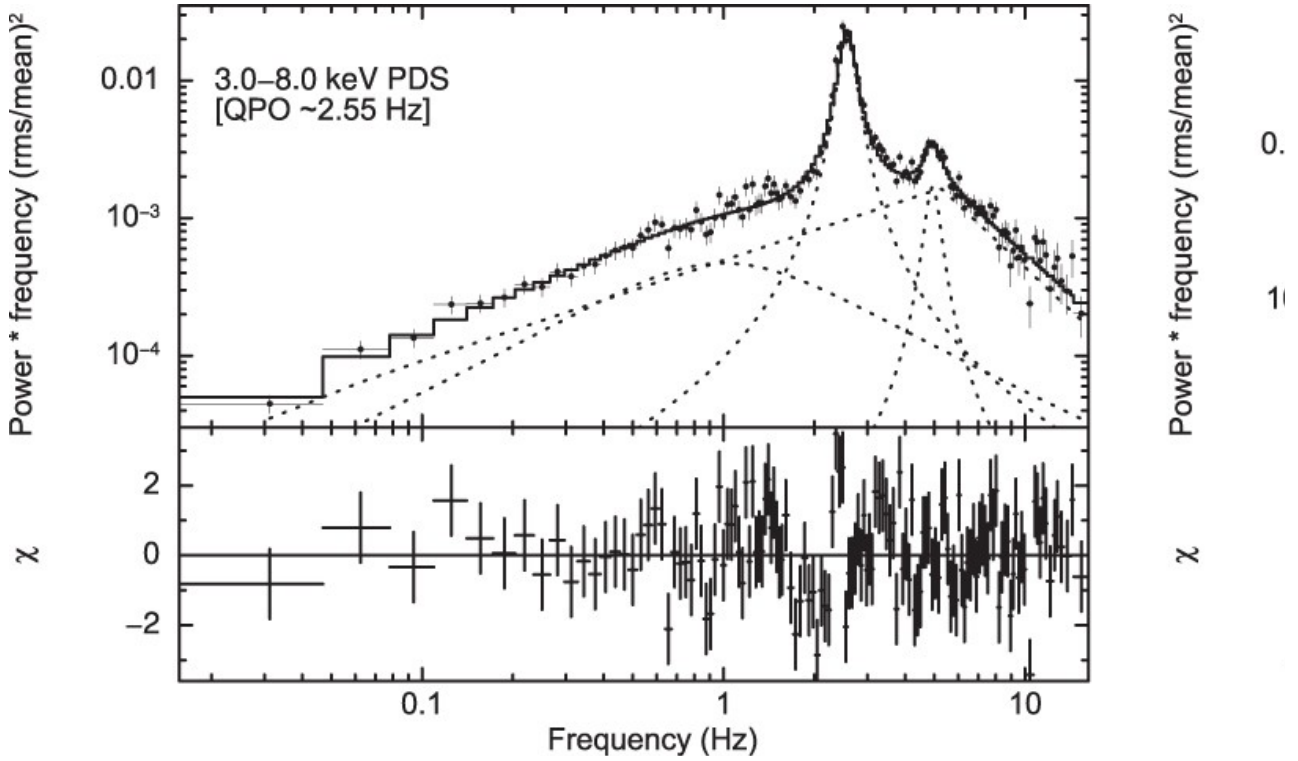
Characteristic time-scales of the accretion disk

- The sound crossing time, R/c_s
- The viscous time-scale, R/v_r

AstroSat


India's first Multiwavelength Space Observatory
ASTROSAT
The 5 telescopes of the Astrosat
1. Large Area X-ray Proportional Counter (LAXPC)
2. Soft X-ray Telecope (SXT)
3. Cadmium-Zinc-Telluride Imager (CZTI)
4. Scanning Sky Monitor (SSM)
5. Ultra Violet Imaging Telescope (UVIT)

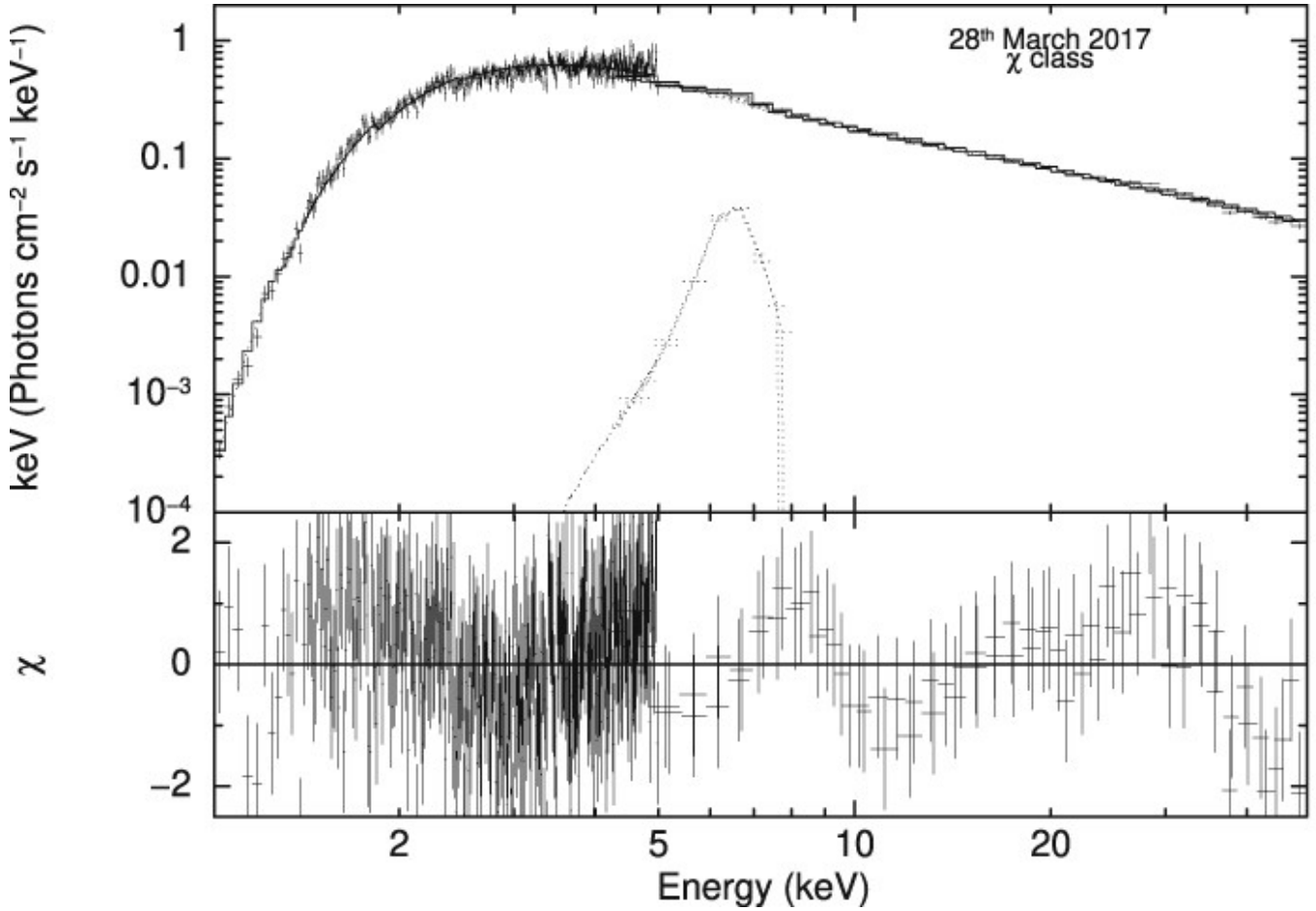
AstroSAT/LAXPC: GRS 1915+105, QPO



Quasi Periodic Oscillations (QPO)

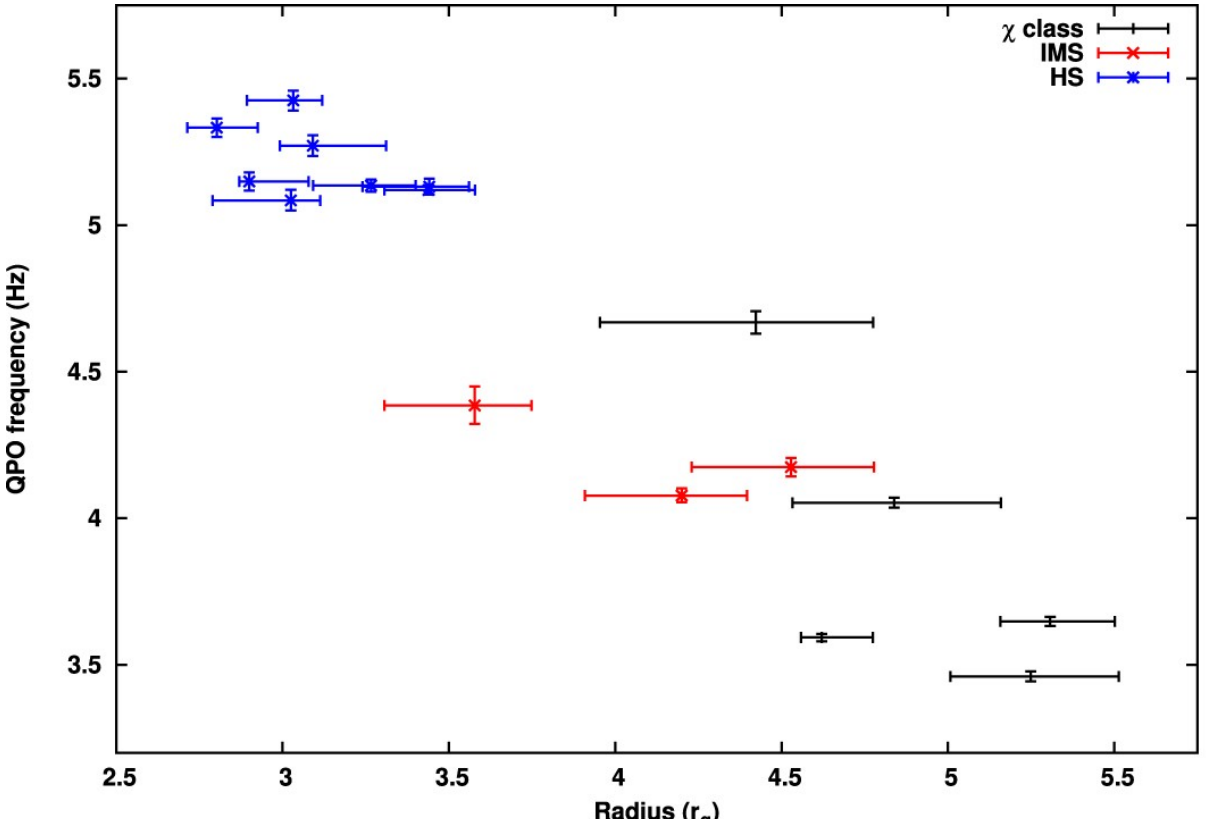
Yadav et al. 2016

AstroSat/LAXPC & SXT Spectra



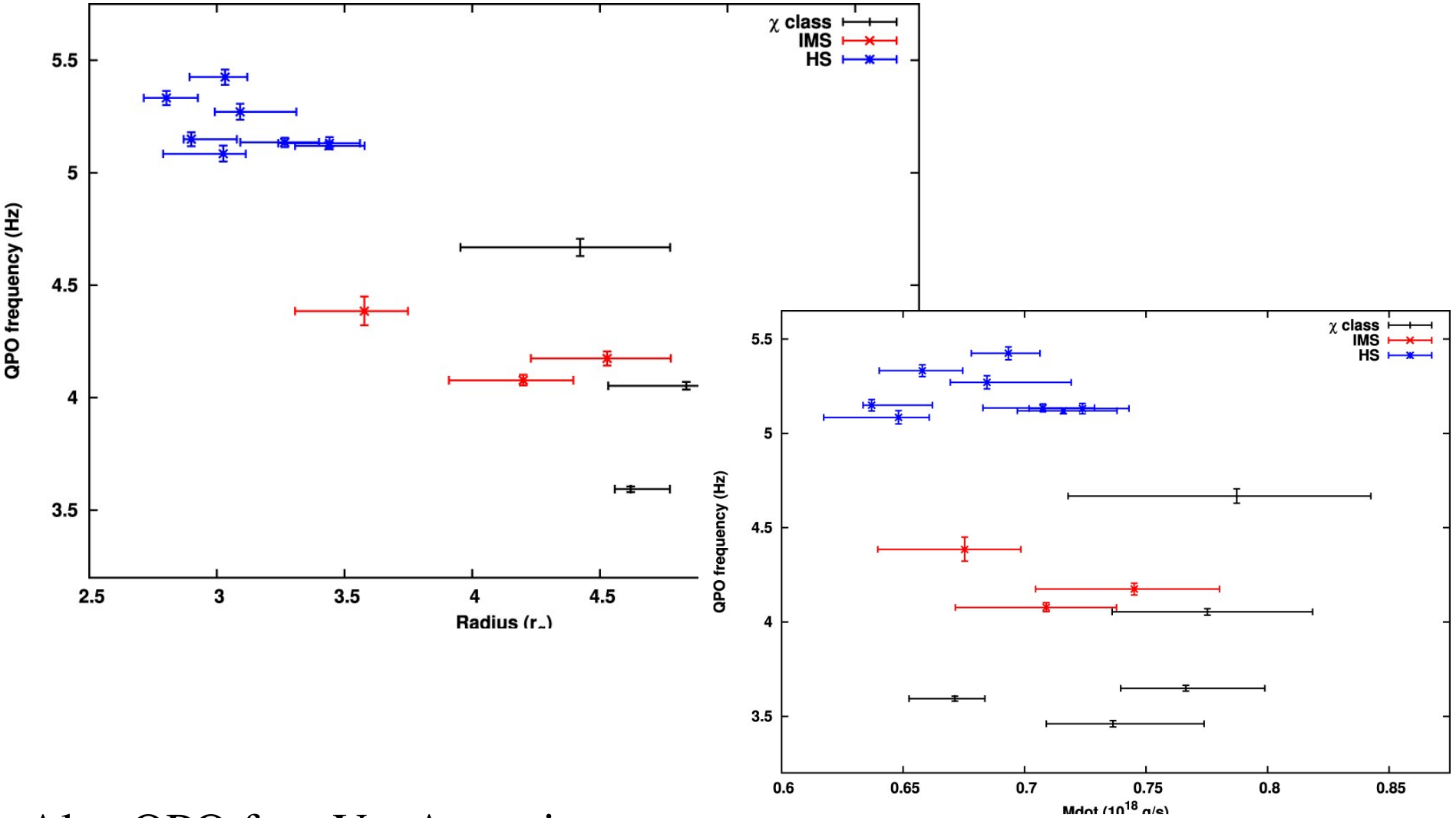
Spectra fitting with AstroSat--→ **Estimate both inner disk radius and Accretion rate**

QPO Frequency and inner disk radius



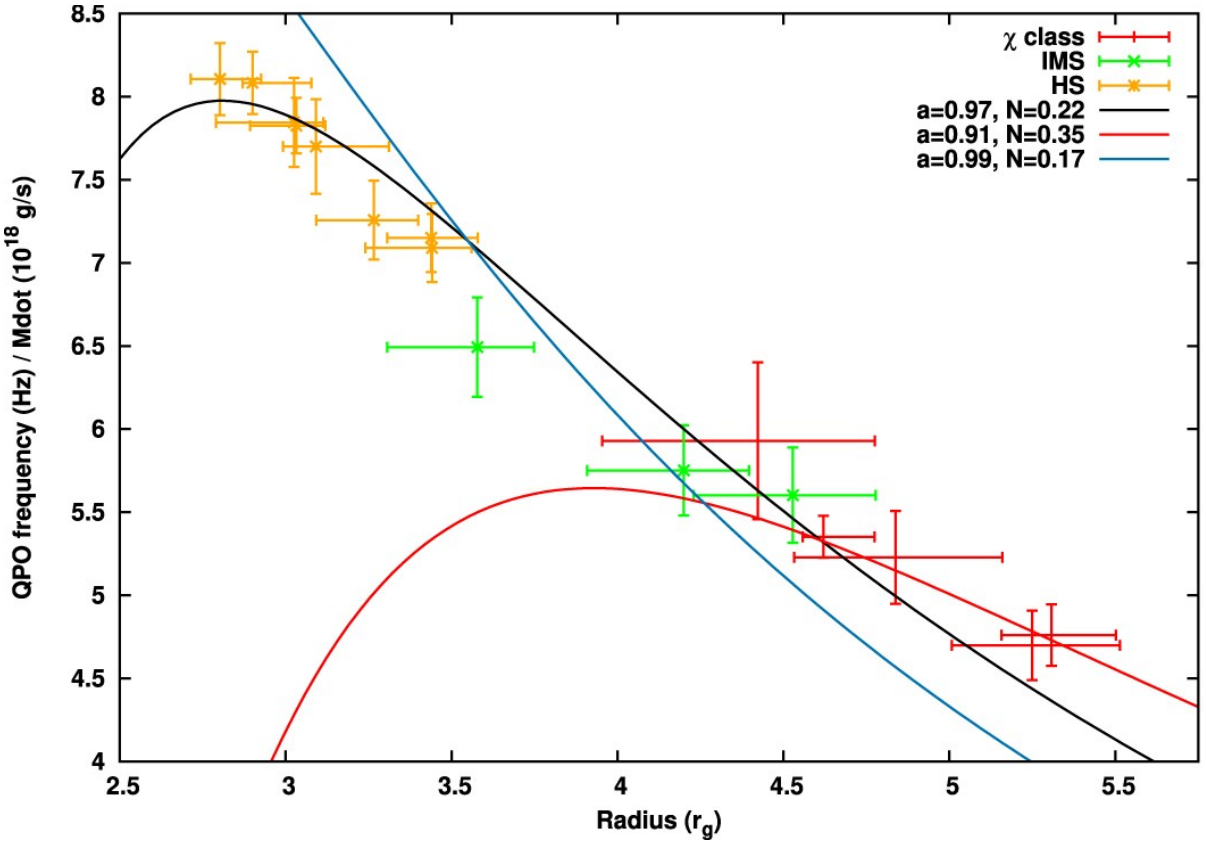
Now we can see how the QPO Frequency varies with inner disk radius

QPO frequency and inner disk radius



Also QPO freq Vs. Accretion rate….

QPO freq and disk radius and accretion rate



QPO Frequency DIVIDED by Accretion rate is much better correlated with inner disk radius...

Misra, Rawat, Yadav & Jain 2020

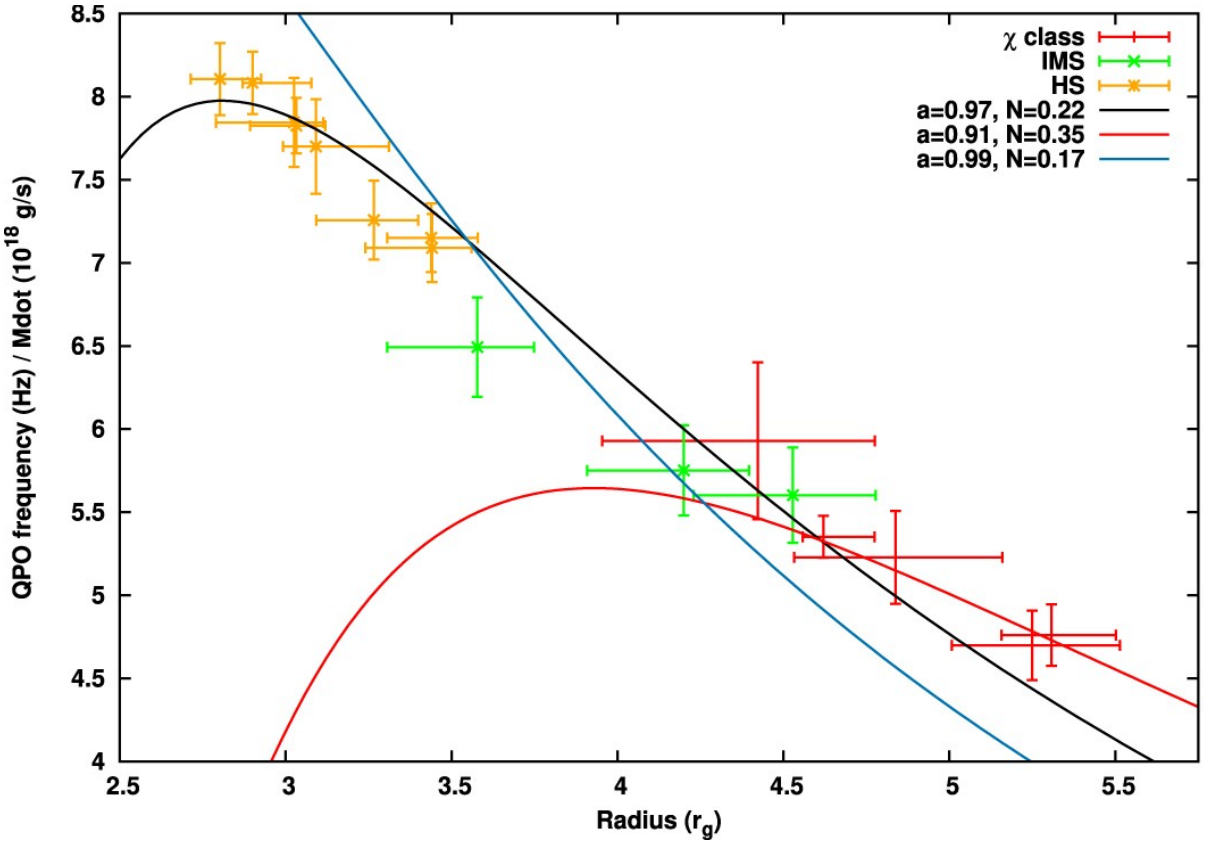
A General Relativity prediction….

Novikov and Thorne derived that the Dynamic frequency (inverse of the sound crossing time) at a radius is given by...

$$\frac{f_{dyn}}{\dot{M}_{18}} = N\ 8979\ \mathrm{Hz}\ (r/r_g)^{-2.5}\ (M/12.4M_\odot)^{-2} \times A^{1}\, B^{-2}\, D^{-0.5}\, E^{-0.5}\, L$$

Frequency divided by the accretion rate is a function of only radius

A General Relativity prediction….

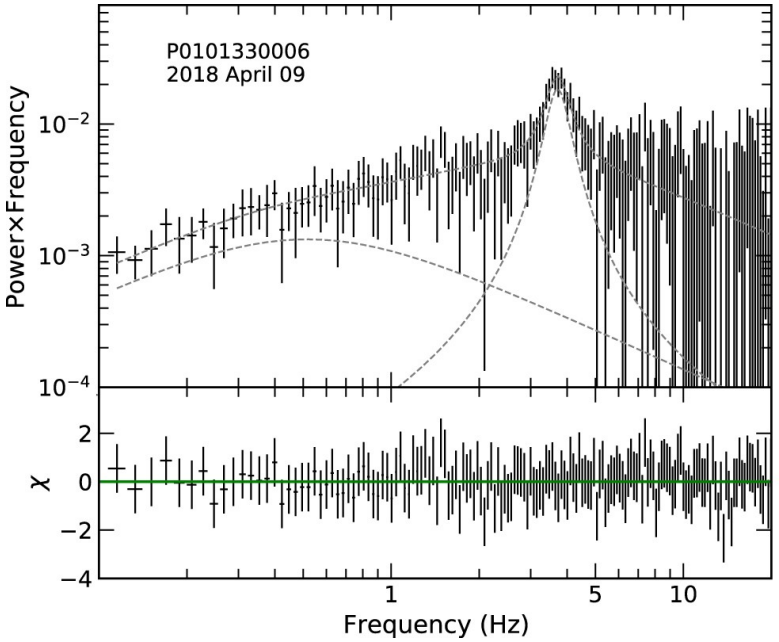


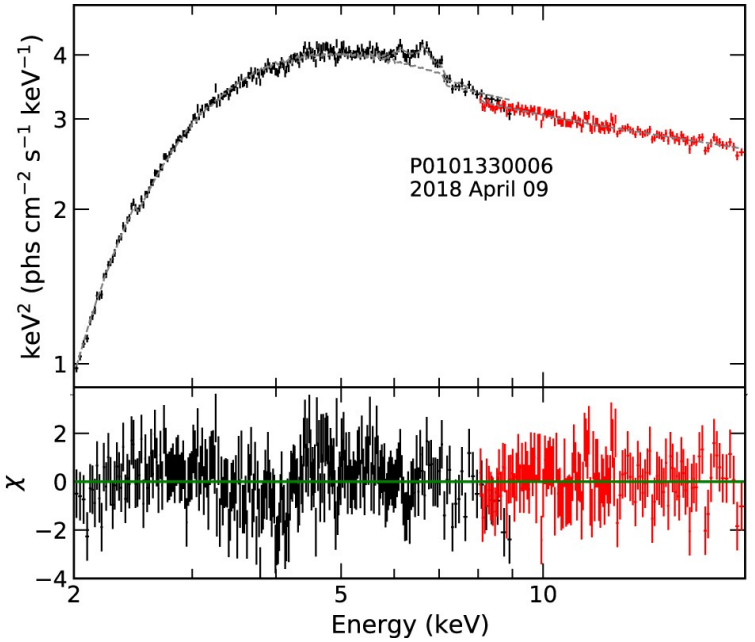
The black line is the predicted behavior for a black hole with Spin parameter = 0.97

Misra, Rawat, Yadav & Jain 2020

Insight HXMT

Insight-HXMT

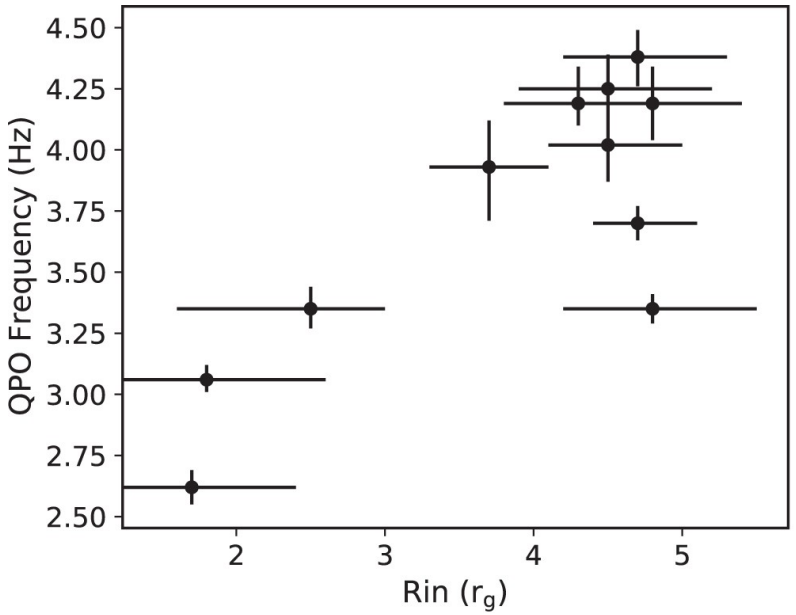


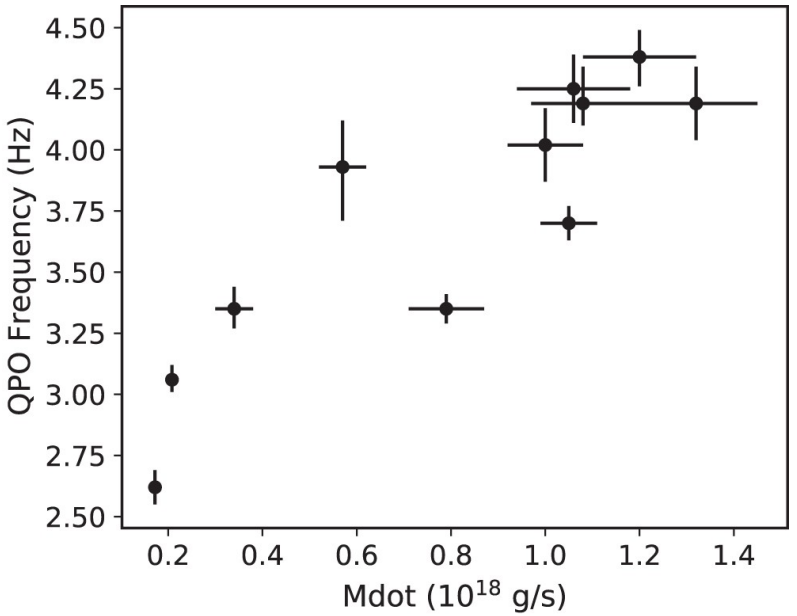


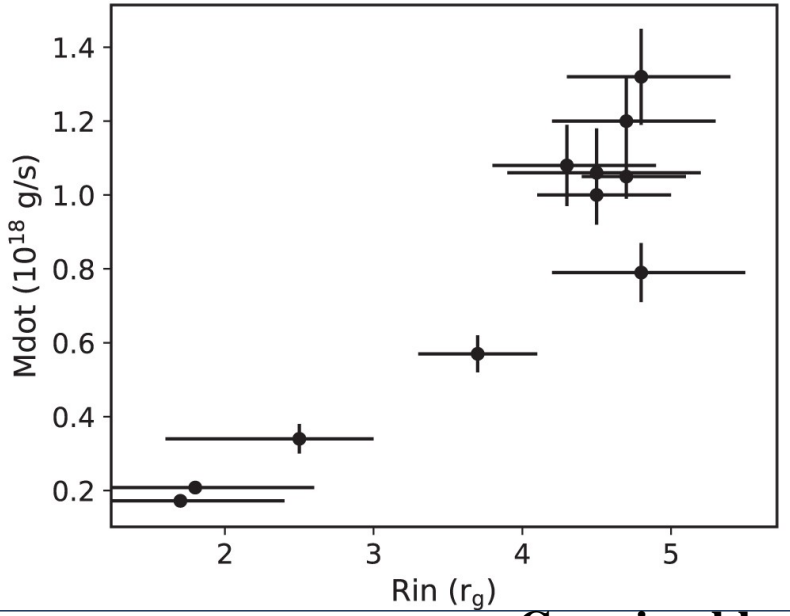
Spectra fitting with Insight-HXMT--

→ **Estimate both inner disk radius and Accretion rate**

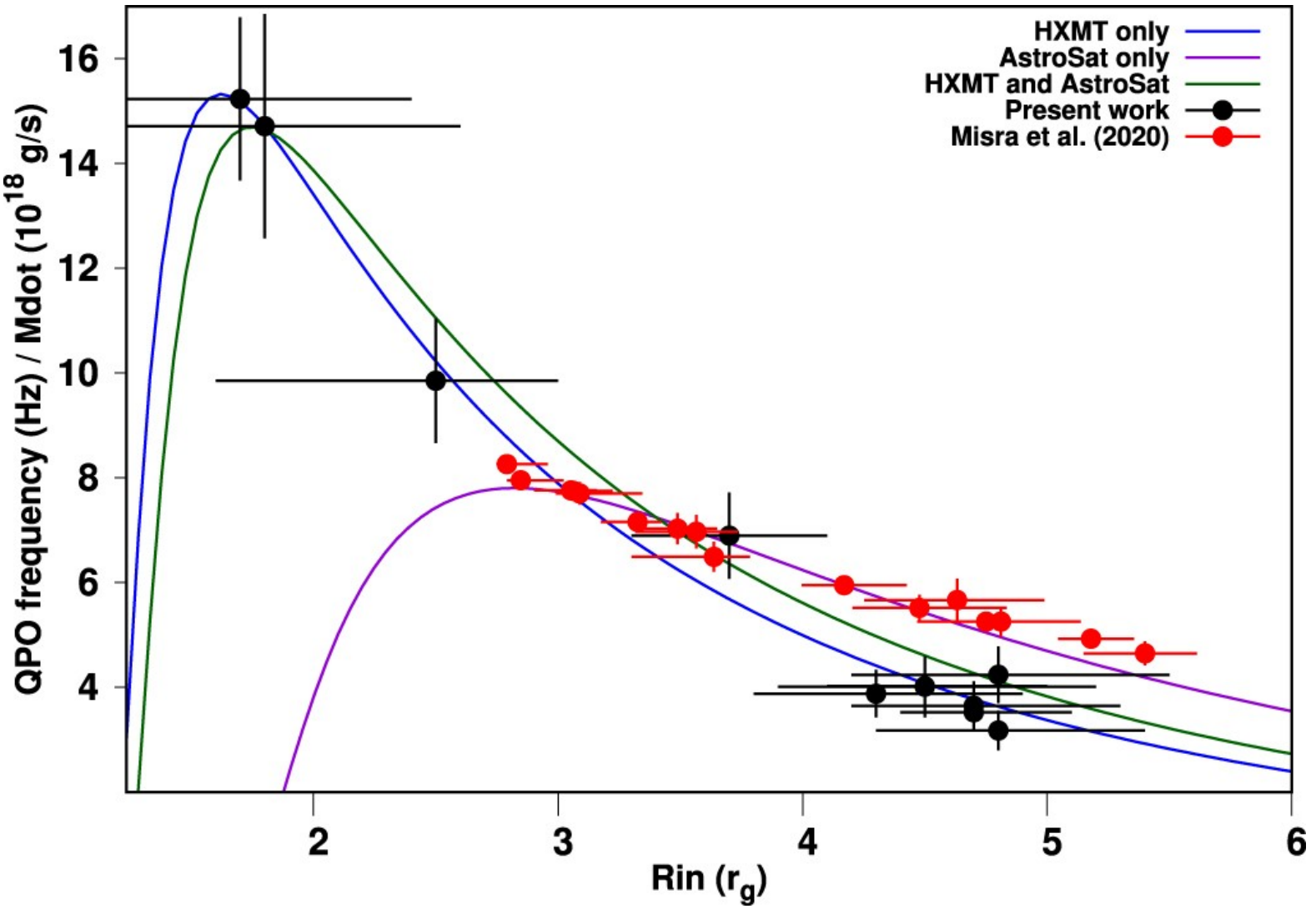
Insight-HXMT



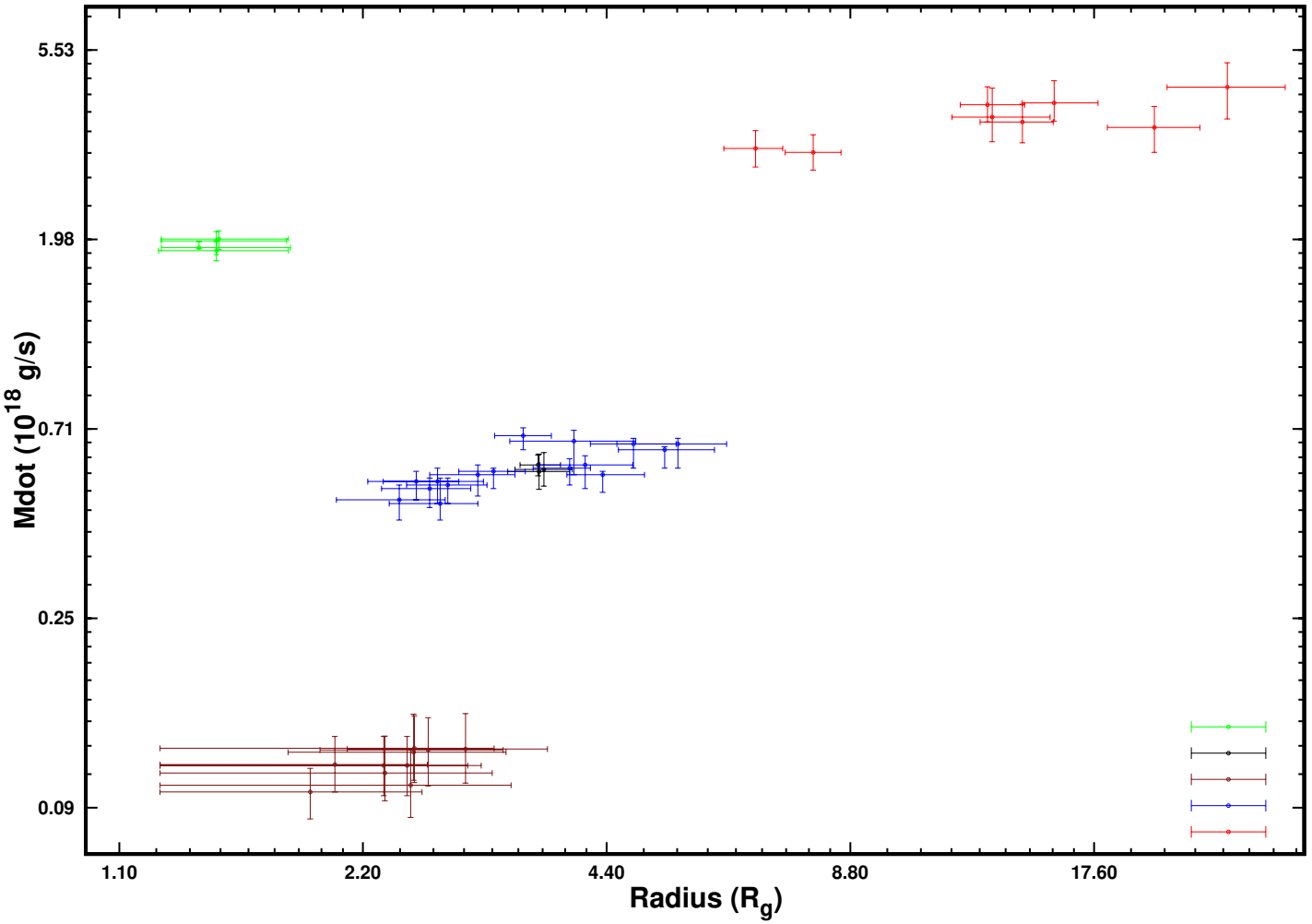




Insight-HXMT



More AstroSat Observations: PRELIMINARY RESULTS



Ruchika Dhaka et. al. in preparation

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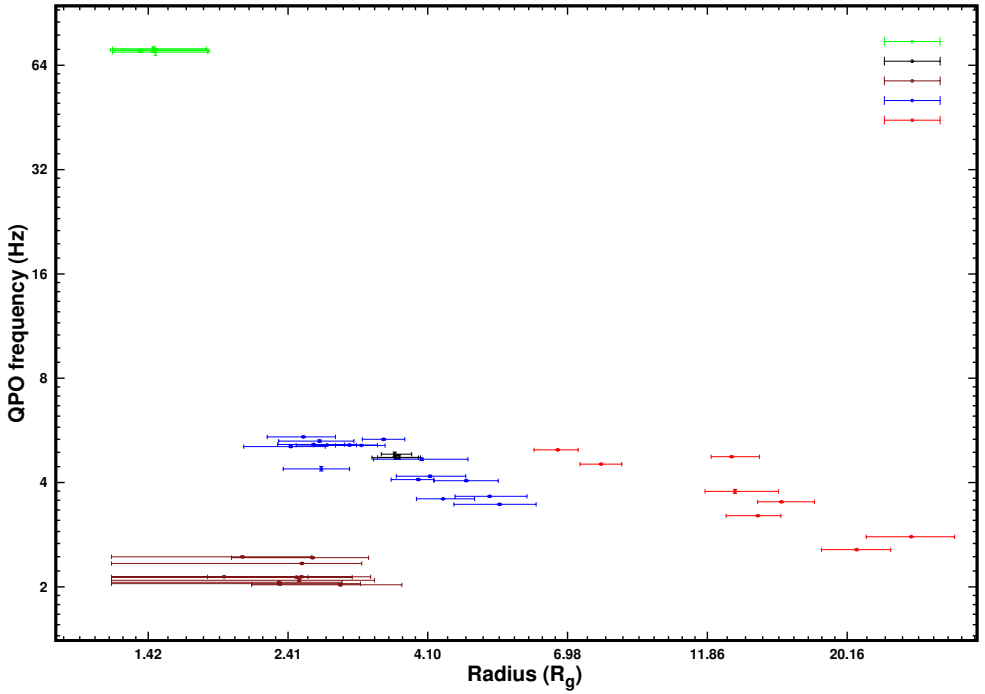

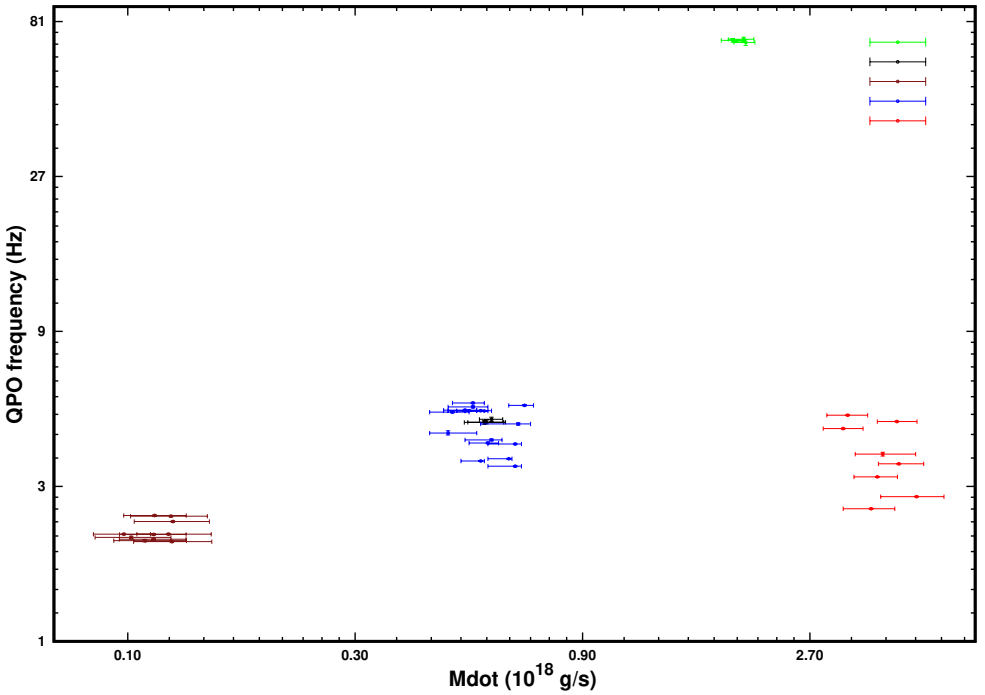

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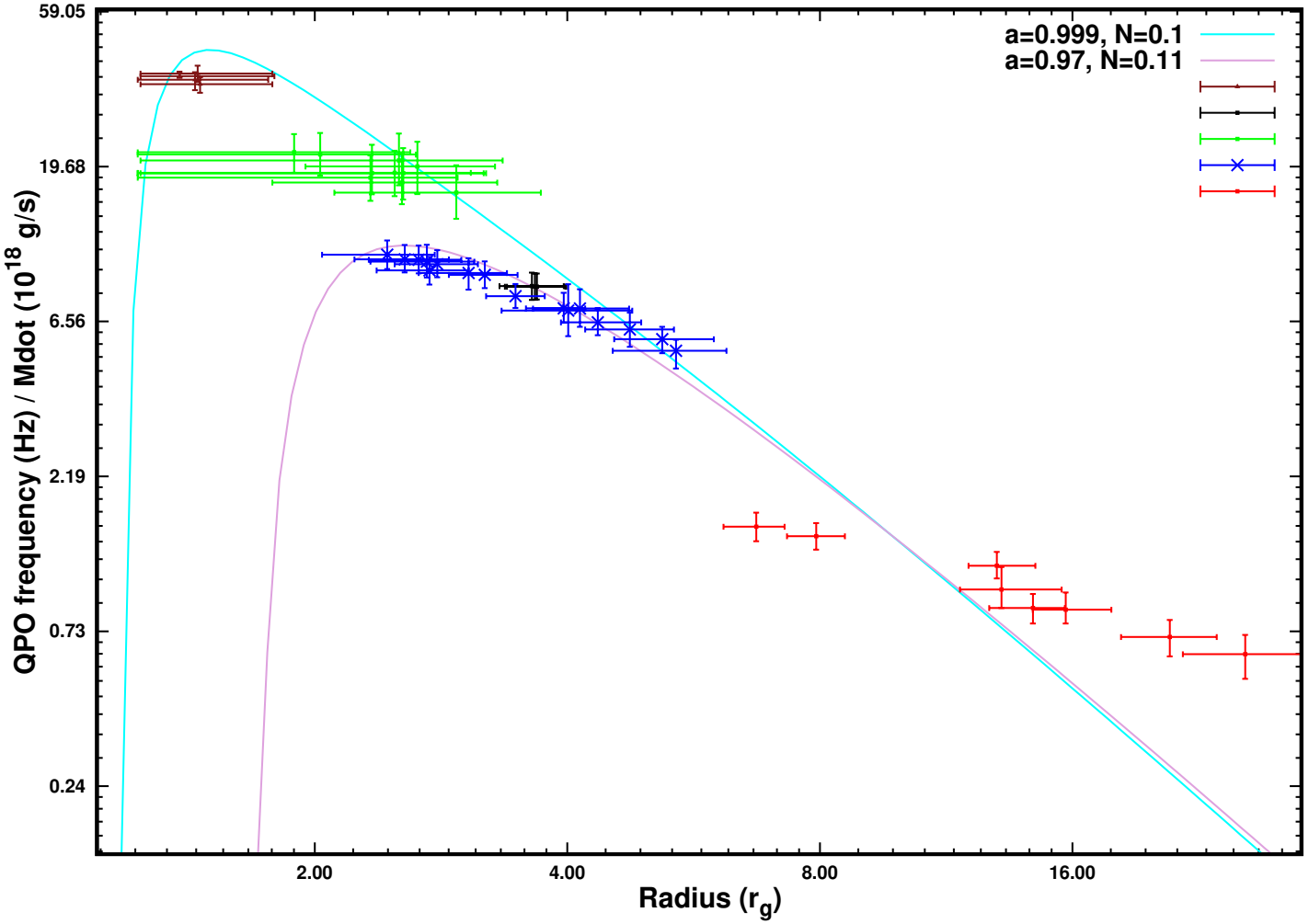

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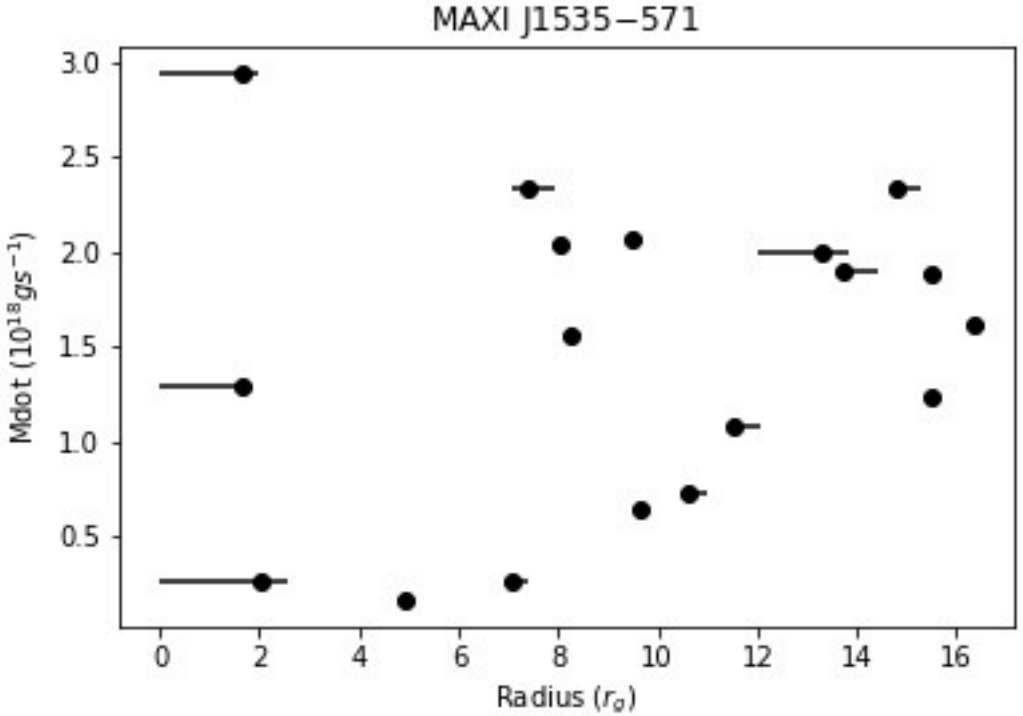
NICER Observations: PRELIMINARY RESULTS



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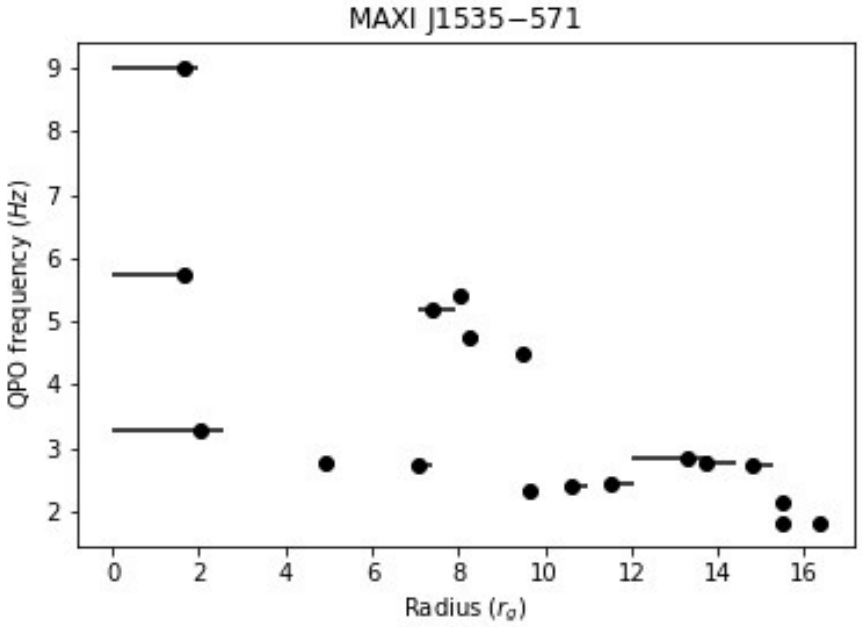
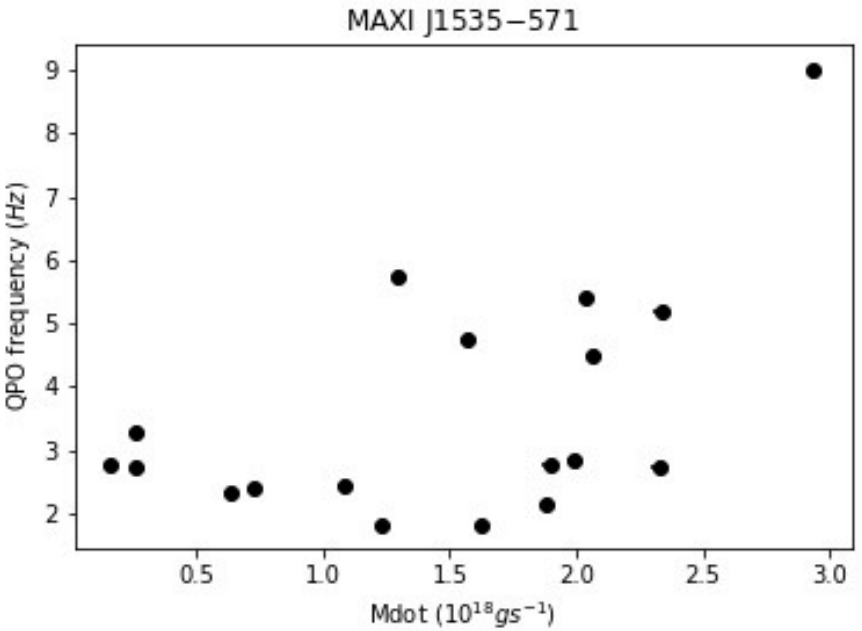
NICER Observations: PRELIMINARY RESULTS





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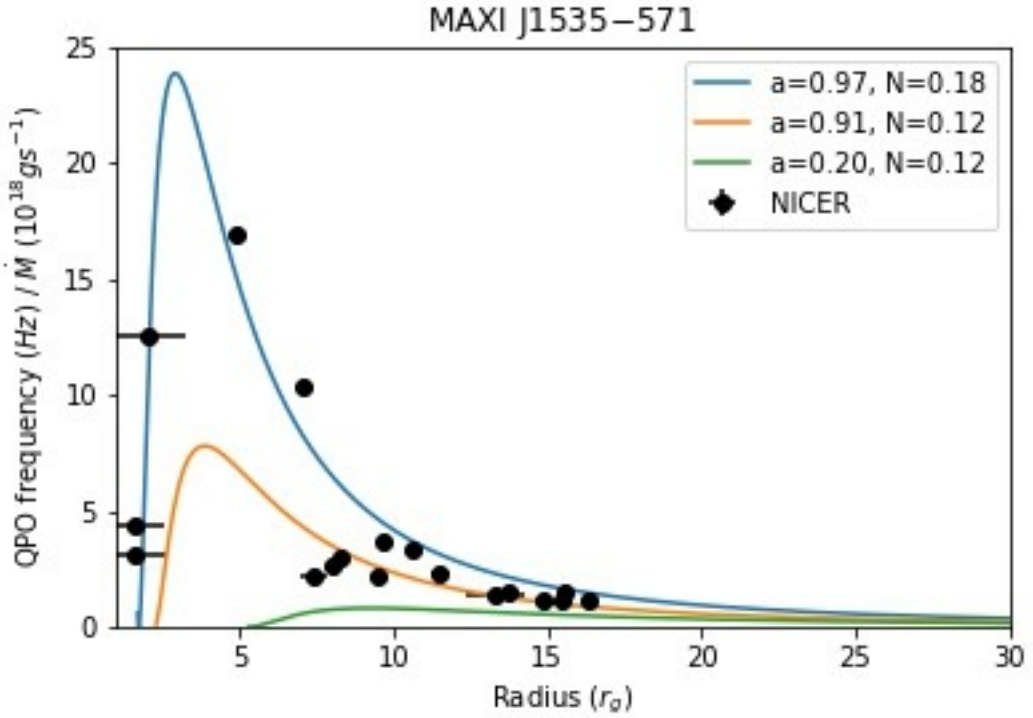

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Summary….

- AstroSat and Insight-HXMT provide wide band spectra and simultaneous rapid timing information
- This allows for correlating QPO frequency with disk parameters (inner radius and accretion rate)

Summary….

- Using BOTH AstroSat and Insight-HXMT, for GRS 1915+105, the C-type QPO frequency is found to be a function of accretion rate and inner radii, thus identifying the frequency as the General Relativistic Dynamic (sound crossing time) one as predicted 49 years ago.
- Need to confirm using other data sets and for other sources..

THANK YOU

Spectral model dependency