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# Scientific highlights on accreting black hole X-ray binaries from *insight*-HXMT


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On behalf of Insight-HXMT collaboration team



The 10th FERO meeting, 03/30-04/01, 2022, Toulouse, France



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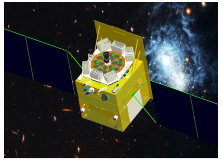
KEY LABORATORY OF PARTICLE ASTROPHYSICS, CAS

慧眼 - HXMT

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# Overview to the *Insight*-Hard X-ray Modulation Telescope (HXMT)

# Science Payload

PI: Shuangnan Zhang

➢ High Energy Telescope (HE )
20-250 keV for pointing; 0.2-3 MeV for Gamma-ray monitoring; Geometrical area of ~5100 cm^2

➢ Medium Energy Telescope (ME )
5-30 keV for pointing; Geometrical area of ~ 952 cm^2

➢ Low Energy Telescope (LE)
1-15 keV for pointing; Geometrical area of ~ 384 cm^2

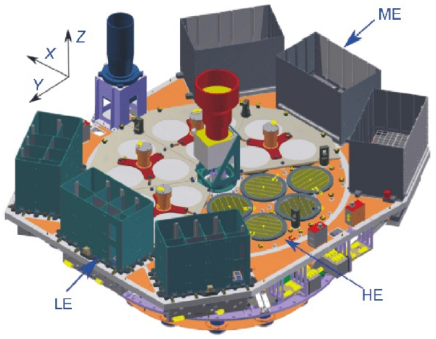


Figure 3 FOVs and their orientations for all telescopes.

**Table 4** The main characteristics of the *Insight*-HXMT payloads

| Detectors | Energy range (keV) | Time resolution | | bility |
|---|---|---|---|---|
| LE : SCD, 384 cm$^2$ | LE: 1-15 | HE: 25 μs | | |
| ME : Si-PIN, 952 cm$^2$ | ME: 5-30 | ME: 280 μs | ME: 14% @ 20 keV | ME: ≤3 Mbps |
| HE : NaI/CsI, 5000 cm$^2$ | HE: 20-250 | LE: 1 ms | HE: 19% @ 60 keV | HE: ≤300 kbps |

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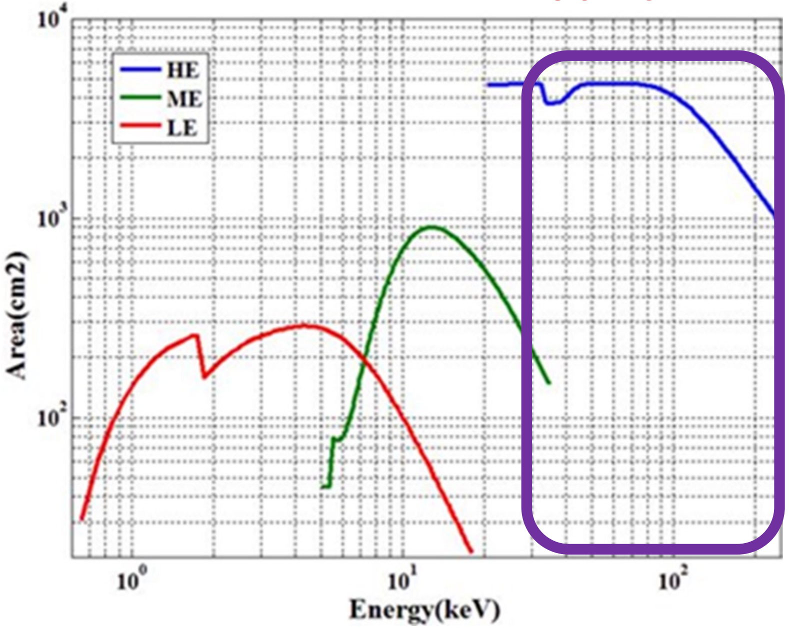
## Core Science

➢ To observe X-ray binaries in broad energy band and study the dynamics and emission mechanism in strong gravitational or magnetic fields;

- **Large Area (5000 $cm^2$)**
- **High time resolution (25us)**
- **Wide energy band :**
  - **Hard X-ray Energy (~250 keV)**
  - **Low Energy (~1keV)**
- **No PileUp**

**HE**

> 30 keV



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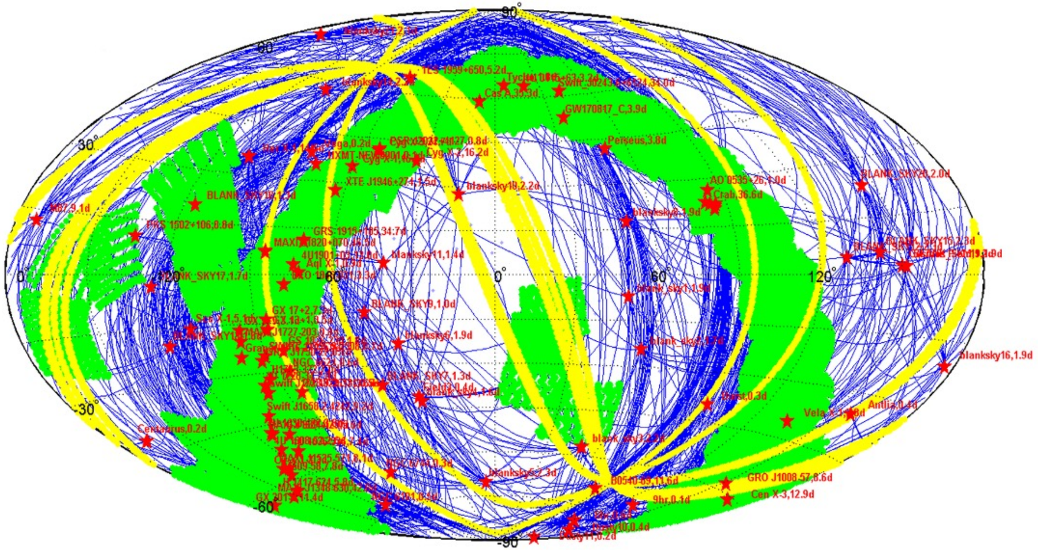
# Total Exposure Map (06/2017 -- 09/2021)




> 80 Ms

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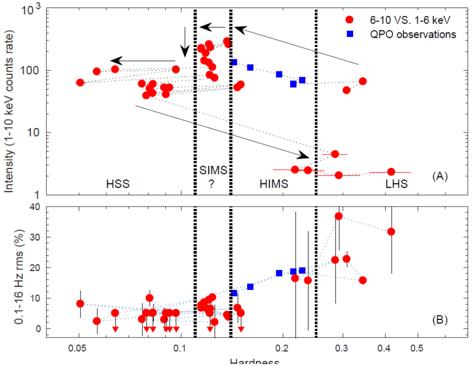
# Summary of the Observations (07/2017 -- 09/2021)

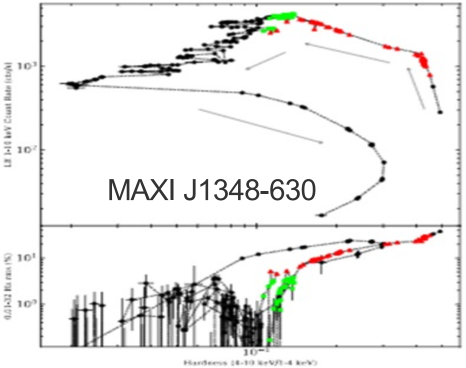
| Obs. Mode | Source Type | No. of sources | No. of the Obs. | Exp. Time (ks) |
|---|---|---|---|---|
| Pointing (> 60 Ms) | SNR | 2 | 48 | 3700 |
| | Isolate pulsar | 4 | 157 | 4240 |
| | Black hole XRB | 15 | 948 | 16070 |
| | neutron star XRB | 47 | 1133 | 24210 |
| | extragalactic objects | 19 | 123 | 1680 |
| | blank sky | 21 | 442 | 4570 |
| | others | 18 | 153 | 4640 |
| Small Sky Survey (>20 Ms) | Crab | 1 | 96 | 2300 |
| | Vela | 1 | 3 | 70 |
| | Cygnus | 1 | 2 | 50 |
| | Galactic Plane | 89 | 2489 | 14760 |

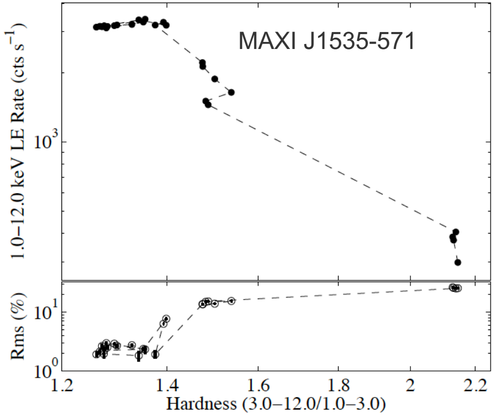
> 20%

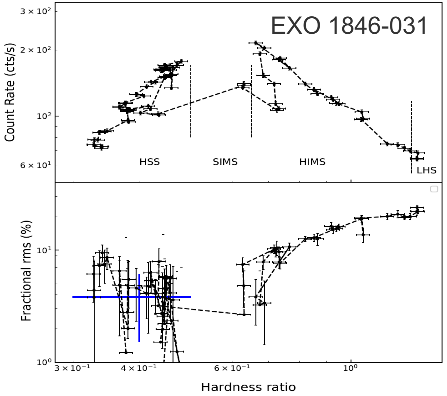
# HXMT observations of bright BH X-ray binaries

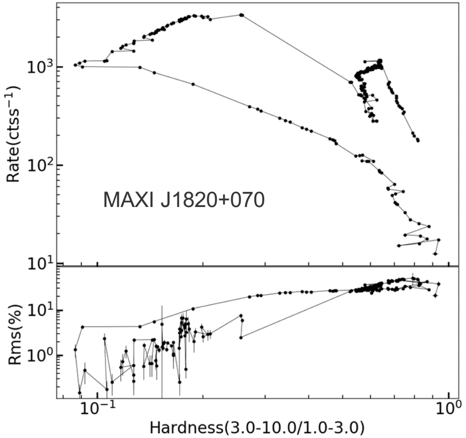
Swift J1658.2-4242

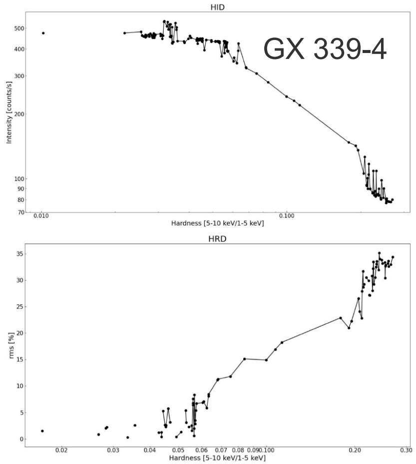


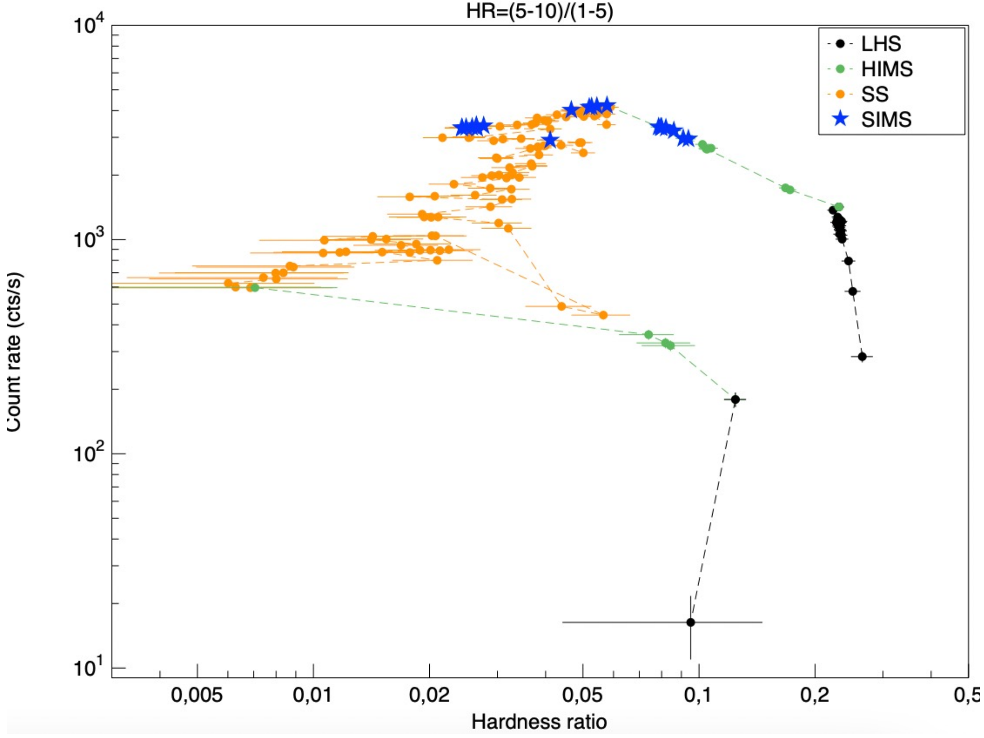



# Scientific highlights from HXMT

MAXI J1820+070

MAXI J1348-630

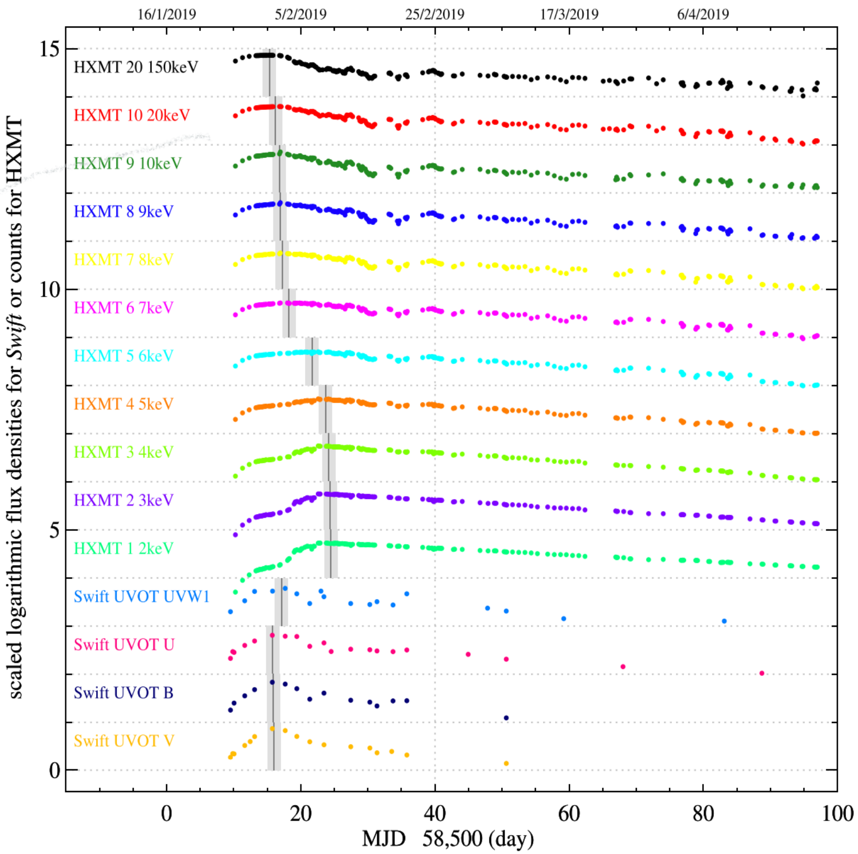
# MAXI J1348-630




What is the quantitative interpretation of HID?

4th polynomial fit for the peak fluxes

$\tau_{\text{fit}}$



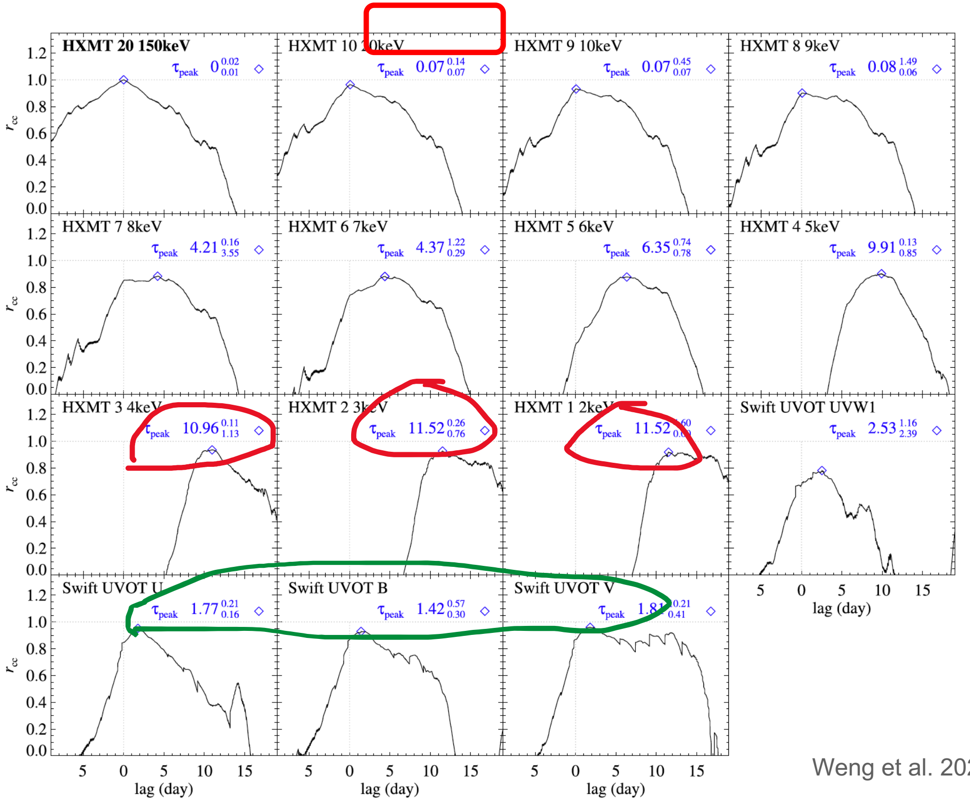

hard X-ray

soft X-ray

UV

Weng et al. 2021, ApJL

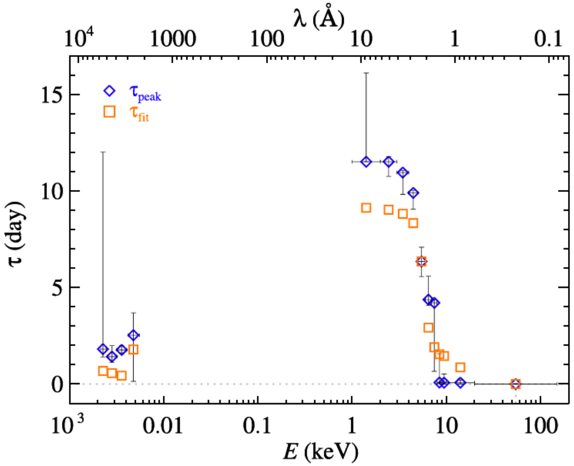
Cross-correlations of the lightcurves

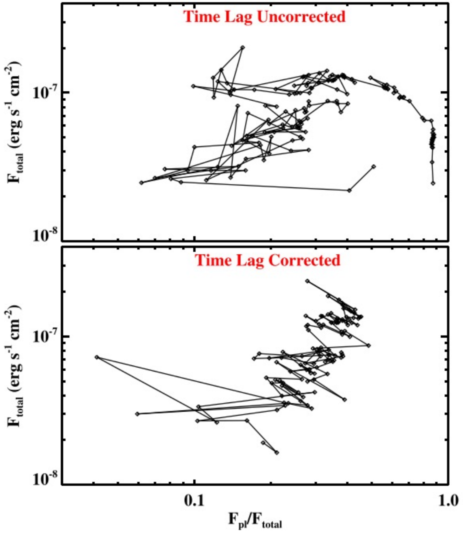


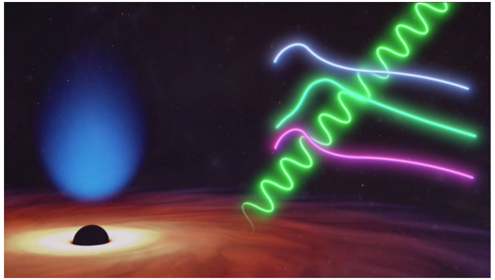

Soft X-ray lags the hard X-ray/UV for ~10 days

Weng et al. 2021, ApJL

# MAXI J1348-630



Weng et al. 2021, ApJL

The “truth” of the HID is the ”time lag” between radiations of the accretion disk and the corona.

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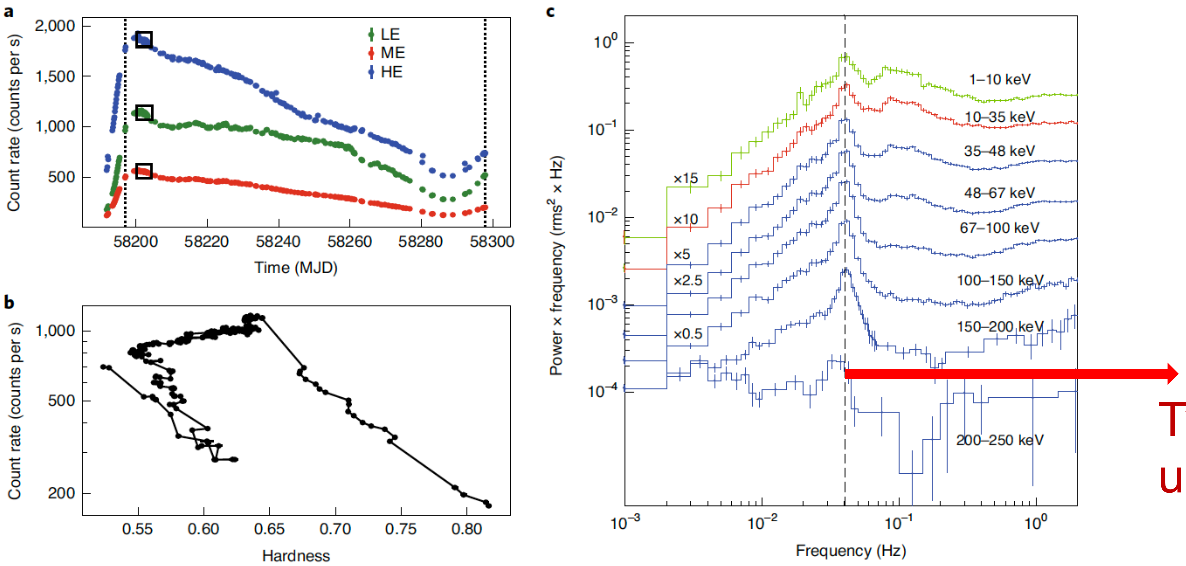
# MAXI J1820+070




Type-C QPO observed up to 250 keV

Ma, X., …, Bu, Q., et al. 2021, Nature Astronomy

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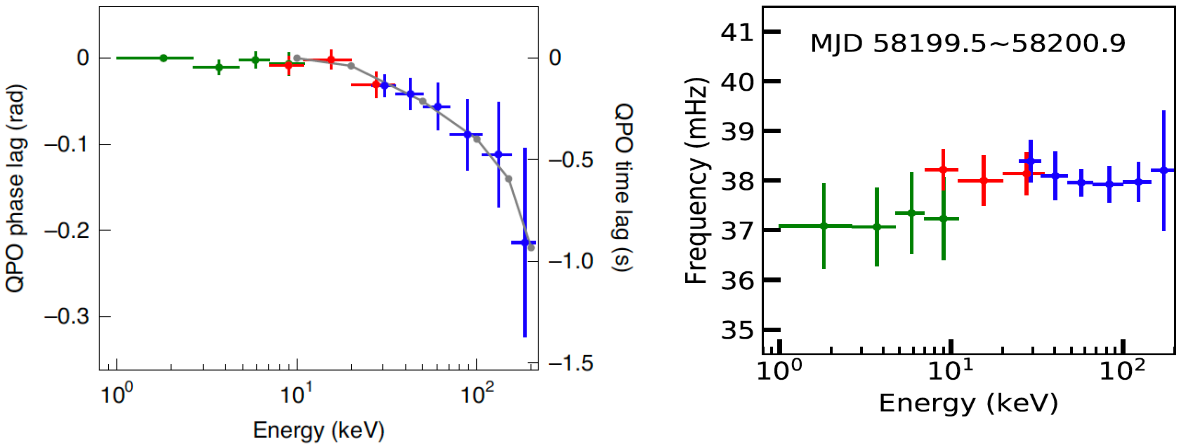
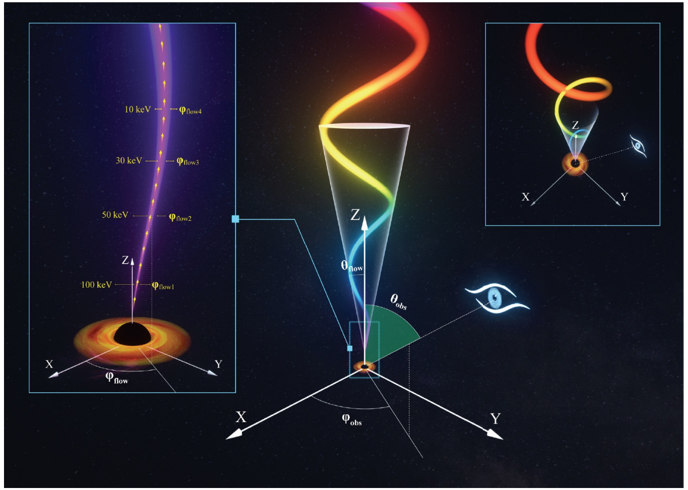
# Challenging the current LFQPO models!!

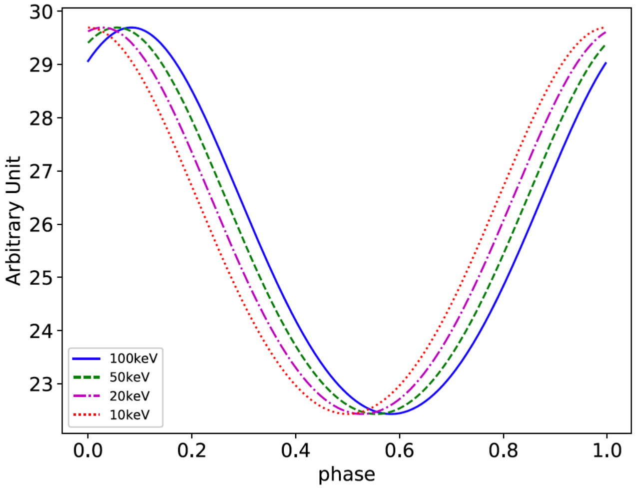



1, Soft lags instead of hard lags
2, A light-travel time lag of ~1 s corresponds to a size of ~10^4 Rg for a 10 solar mass BH
3, QPO frequency is constant at different energies.

Ma, …, Bu, et al. 2021, Nature Astronomy

# LT precession of small-scale jet



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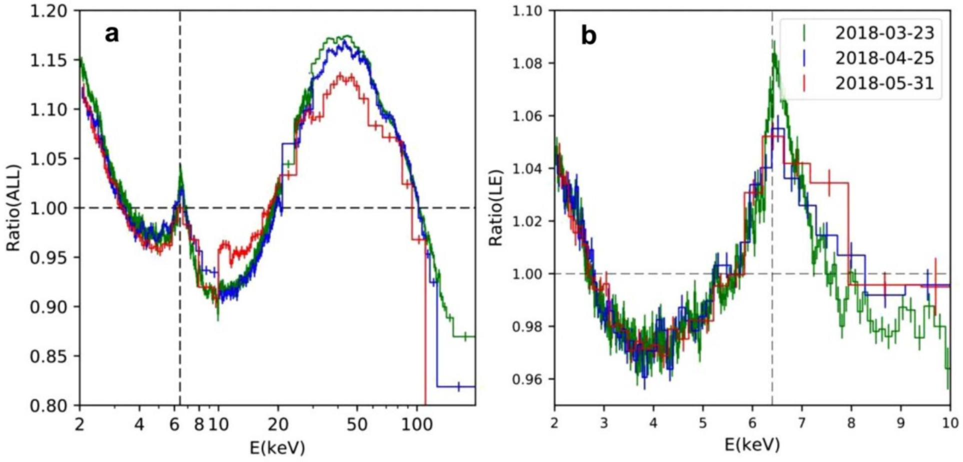
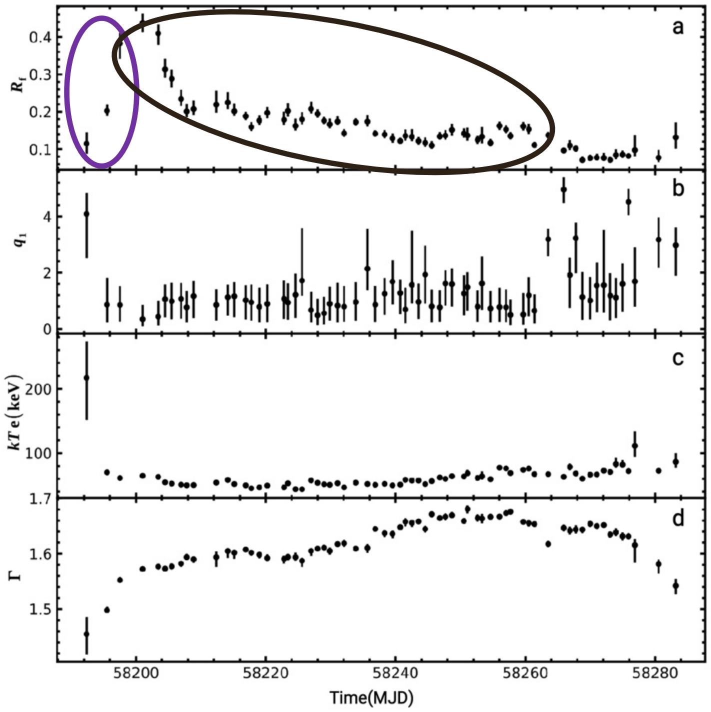



**Hard state**

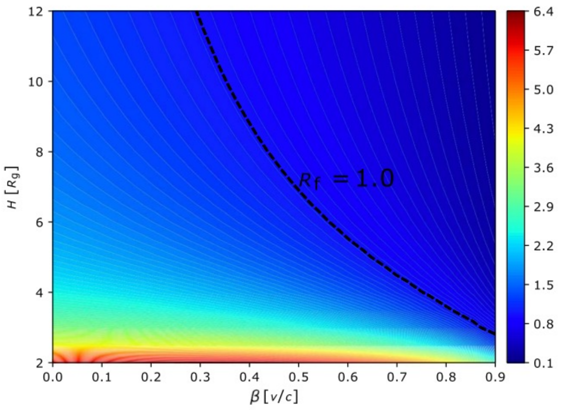
You, ... , Bu, et al. 2021, Nature Communications

Model: tbabs*(diskbb + relxillCp + xillverCp) *constant




You, ... , Bu, et al. 2021, Nature Communications

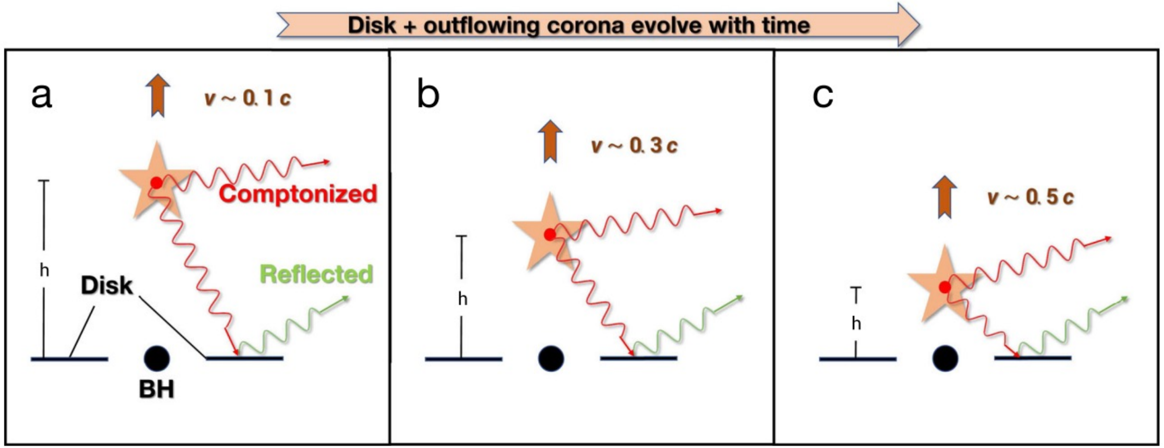
*relxilllpionCp*




In the rise phase, increasing fraction of photons that illuminate the disk;
In the decay phase, decreasing fraction of photons illuminate the.

# Jet-like corona

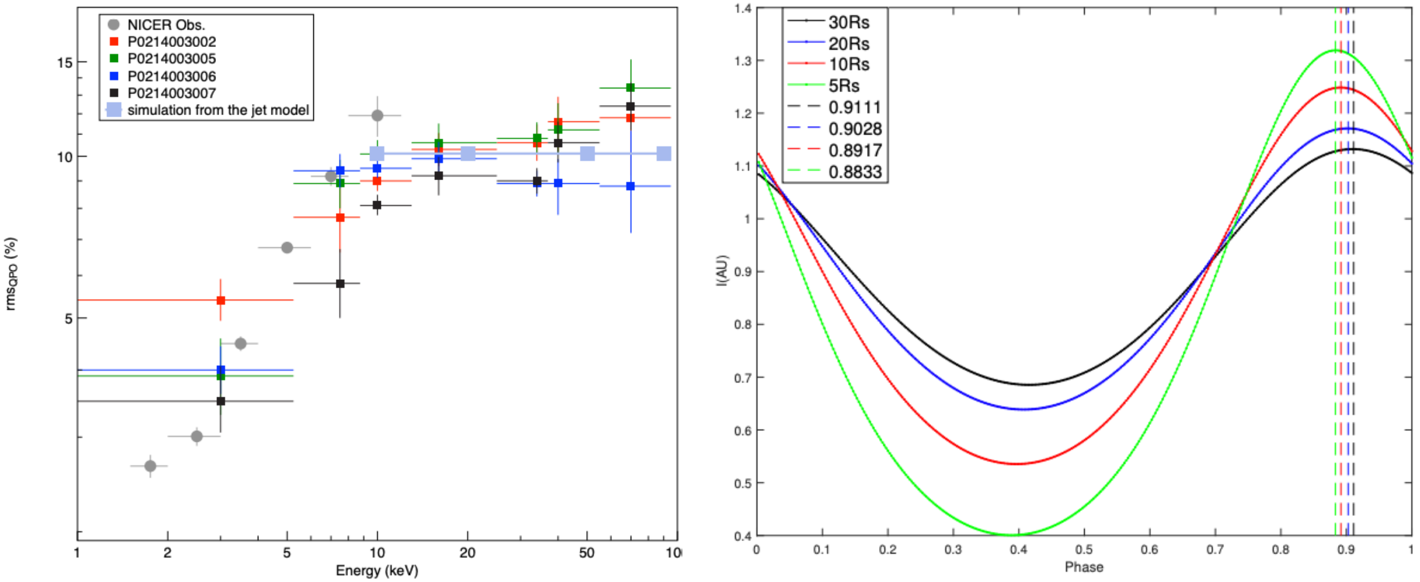
Lamppost geometry




The system is characterized by two parameters: corona position and bulk velocity

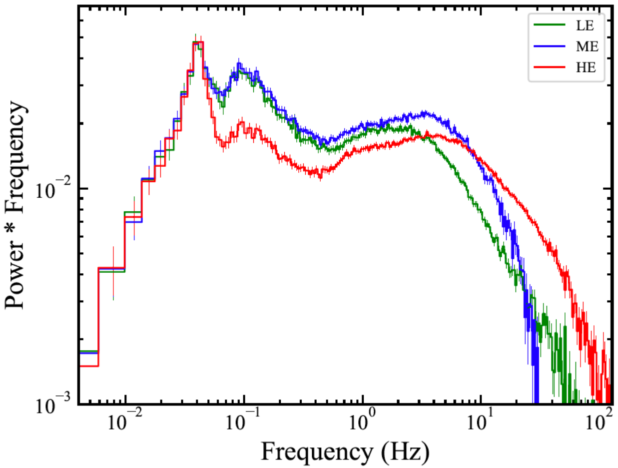
You, ... , Bu, et al. 2021, Nature Communications

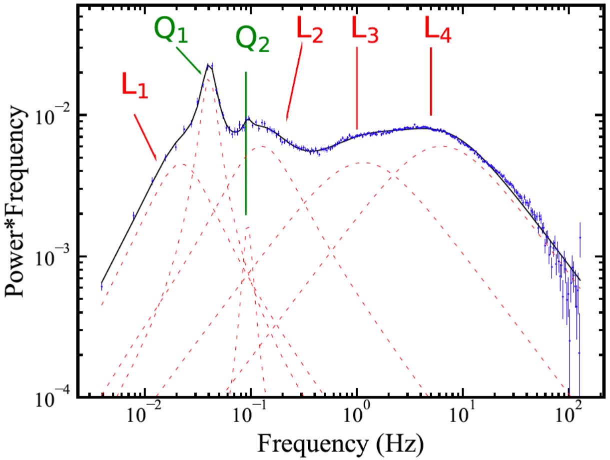
## Application of jet-precession model in MAXI J1631-479




Bu et al. 2021, ApJ

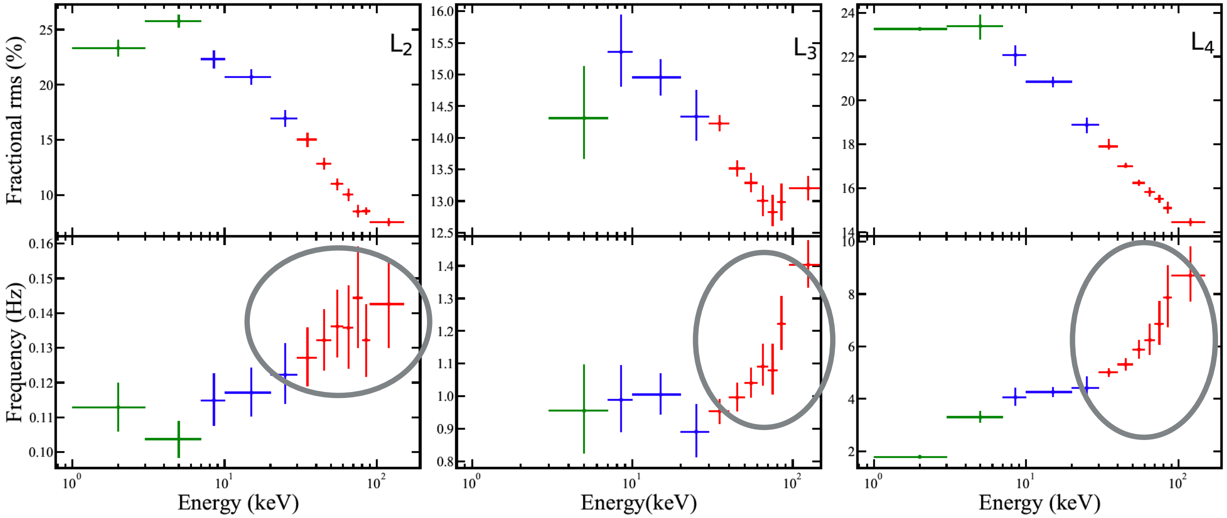
MAXI J1820+070




Yang, Zhang, Bu, et al. 2022, ApJ

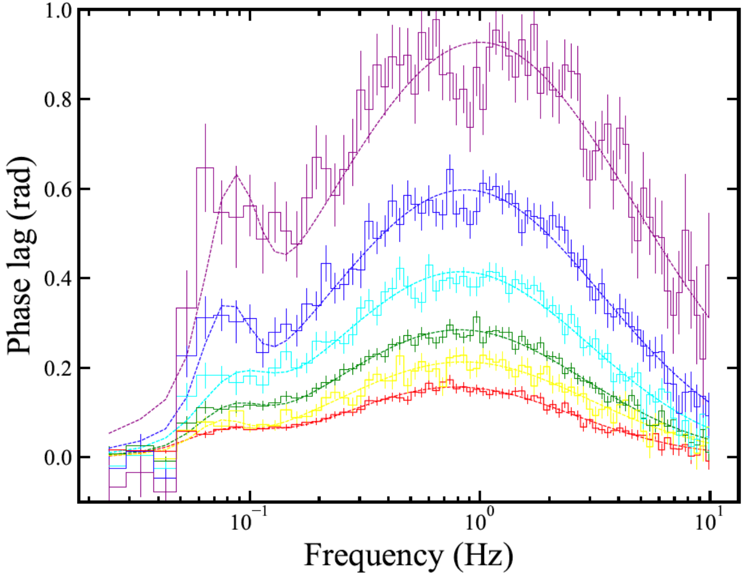
# Broadband variability behaviors in 1-150 keV




High-energy noise (> 30 keV) is more variable on shorter timescales!!

Yang, Zhang, Bu, et al. 2022, ApJ

harder photons from more inner region have larger lags

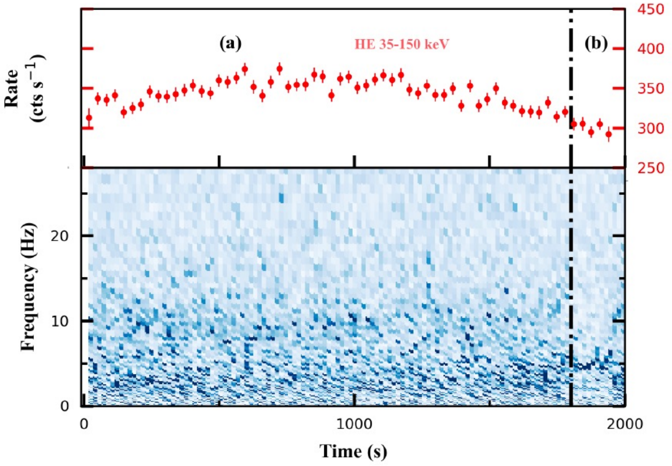


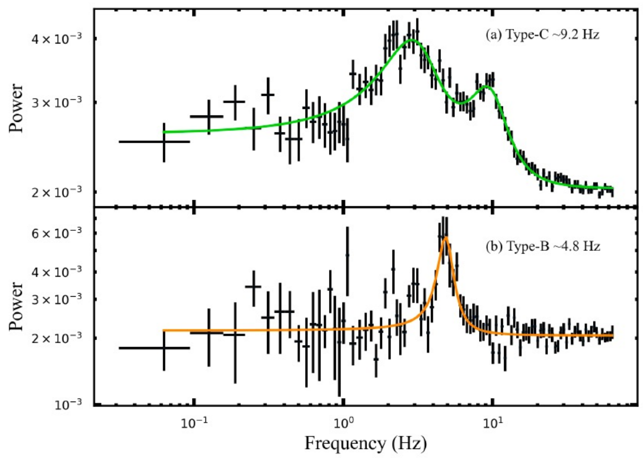

100-150 keV
70-100 keV
50-70 keV
30-50 keV
20-30 keV
10-20 keV

*In-homogeneous hot flow/corona?*

Yang, Zhang, Bu, et al. 2022, ApJ

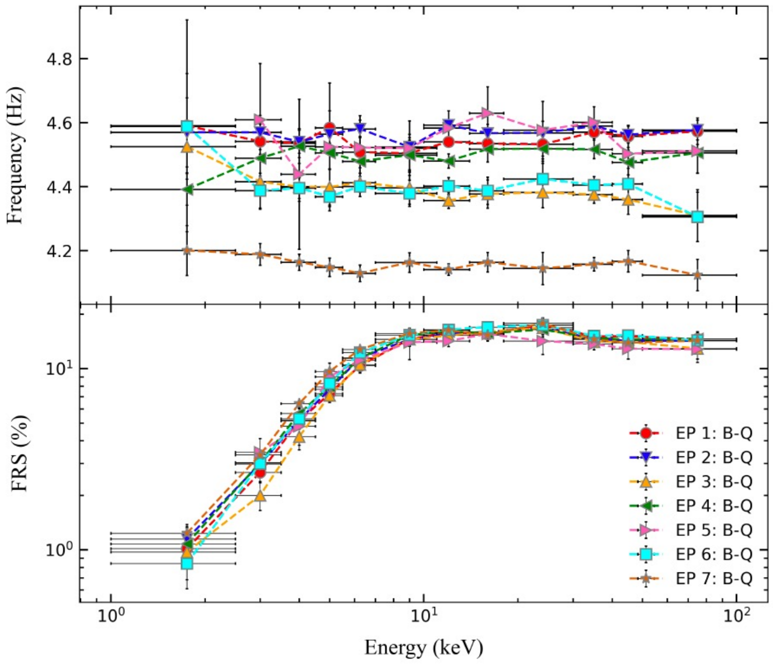
# MAXI J1348-630

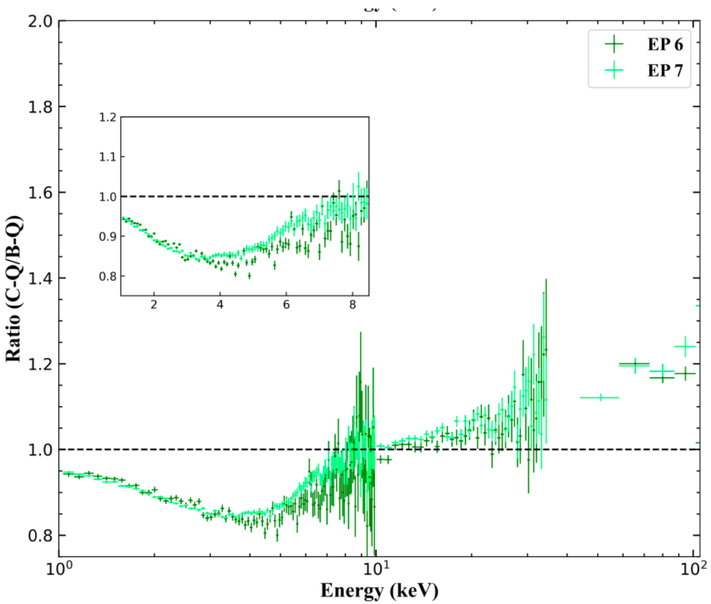



Fast transition between Type-C and -B QPOs in ~10 s

Liu, Huang, Bu, et al. 2022, submitted

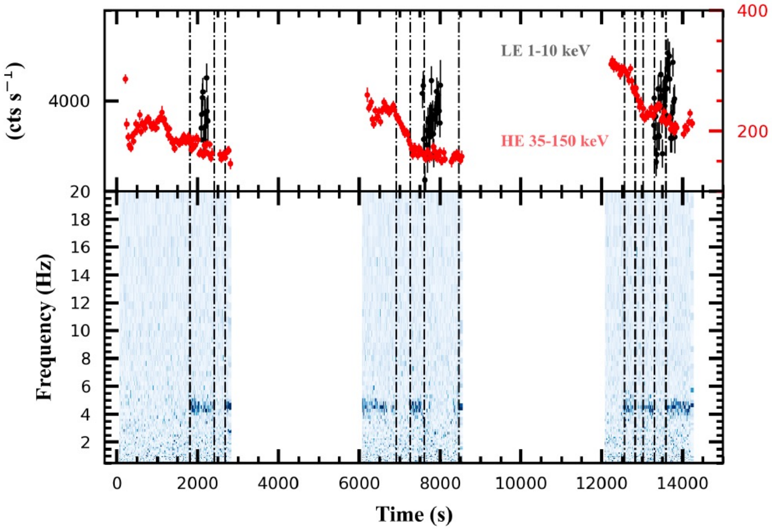


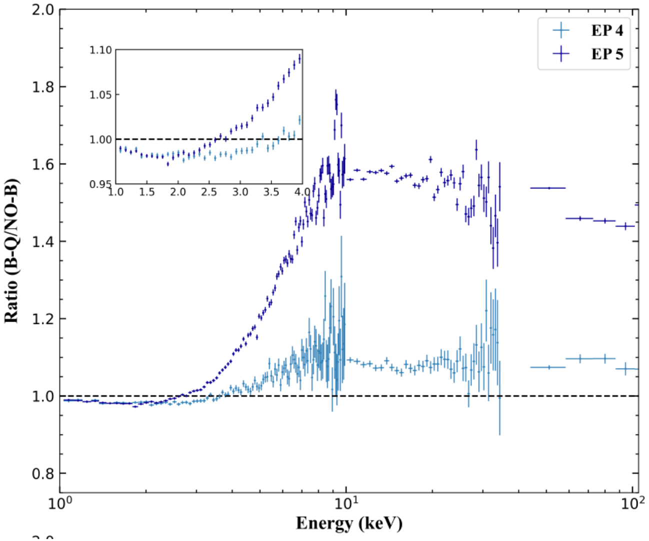




From C to B, soft emission increases, while hard emission decreases

Liu, Huang, Bu, et al. 2022, submitted

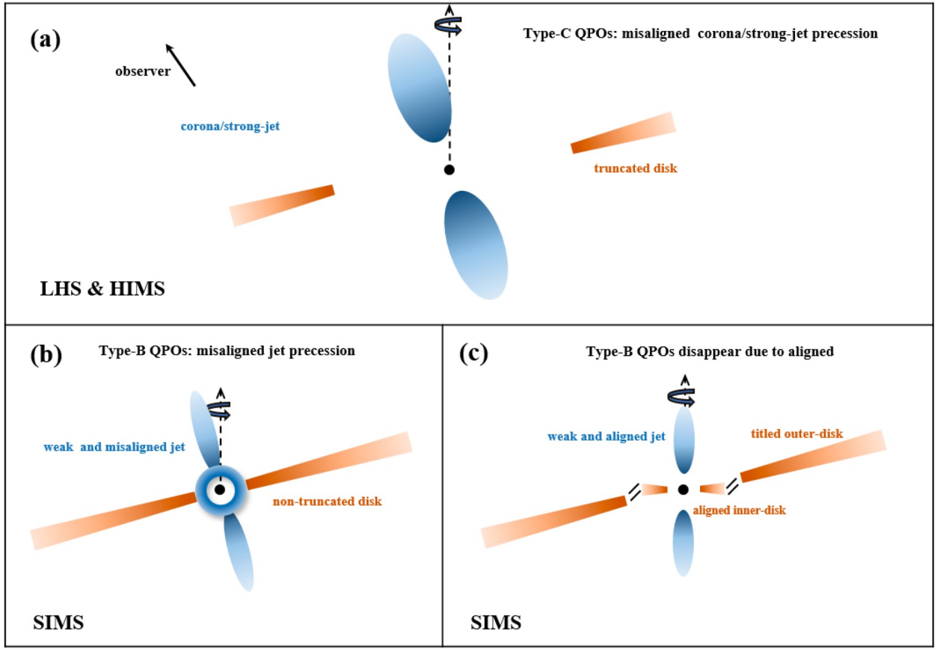
# Fast recurrence of type-B QPOs




From B to no-B, soft X-ray flux decreases, while spectral index remains the same

Could both type-C and -B QPOs be generated by the LT precession of the jet?



# Summary

- Small-scale jet precession model is a promising model in explaining the high energy (> 30 keV) timing properties of type B/C QPOs
- Observed time-lag between radiations of the accretion disk and the corona leads naturally to the hysteresis effect and the "q"-diagram
- HXMT has great advantages in the broadband variability study
- *Everything we are not clear yet, we are counting on eXTP*

Thanks!